SEPTEMBER 2015

GLASTIR MONITORING & EVALUATION PROGRAMME

SECOND YEAR ANNUAL REPORT

Prepared by CEH on behalf of the Glastir Monitoring & Evaluation Programme Team

How to cite this report:

Full version: Emmett, B.E., Abdalla, M., Anthony, S., Astbury, S., August, T., Barrett, G., Beckman, B., Biggs, J., Botham, M., Bradley, D., Chadwick, D., Collier, R., Cooper, D., Cooper, J., Cosby, BJ., Creer, S., Cross, P., Dadam, D., Edwards, F., Edwards, M., Evans, C., Ewald, N., Garbutt, A., Giampieri, C., Goodwin, A., Grebby, S., Greene, S., Halfpenney, I., Hall, J., Harrower, C., Henrys, P., Hobson, R., Hughes, P., Hughes, S., Isaac, N., Jackson, B., Jarvis, S., Jones, D.L., Jones, P., Keith, A., Kelly, M., Kneebone, N., Lallias, D., Lebron, I., Malcolm, H., Maskell, L., MacDonald, J., Maxwell, D., Moxley, J., Norton, L., Oliver, T., Owen, A., Parkhill, K.A., Pereira, M.G., Peyton, J., Powney, G., Prochorskaite, A., Rawlins, B., Reuland, O., Robinson, D.A., Rorke, S., Rowland, C., Roy, D., Scarlett, P., Scholefield, P., Scott, L., Smith, G.R., Siriwardena, G., Smart, S., Smith, P., Swetnam, R., Taft, H., Taylor, R., Tebbs, E., Thomas, A., Tordoff, G., Turner, G., Van Breda, J., Vincent, H., Wagner, M., Waters, E., Walker-Springett, K., Wallace, H., Webb, G., Williams, B., Williams, P., and Wood, C. (2015) Glastir Monitoring & Evaluation Programme. Second Year Annual Report to Welsh Government (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Project: NEC04780),

Short version: Emmett B.E. and the GMEP team (2015) Glastir Monitoring & Evaluation Programme. Second Year Annual Report to Welsh Government (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Project: NEC04780),

Further copies of this report are available from: GMEP Office, Centre for Ecology & Hydrology, Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, LL57 2UW.

Special Thanks to:
Aspey, N., Bamford, R., Barrett, C., Boffey, C., Carter, D., Clarke, S., Cope, S., Ellson, M., Everingham, E., Fitos, E., Green, D., Harvey. A., Haycock, A., Haycock, B., Highfield, C., Jackson, Jenks, P., E., Jones, K., Kelsall, J., Knight, T., Koblizek, E., Meilleur, Norfolk, D., Roberts, M., Salter, A., Sazer, D., Scott, H., Small, J., Smith, A., Stoyanov, J., Tordoff, G., Vaughan, D., Warwick, A. Wilson, P., Wilson, S. and Winder, J.

Crynodeb Dinesydd Blwyddyn 2 Rhaglen Monitro a Gwerthuso Glastir (RhMGG)

Beth yw diben y Rhaglen Monitro a Gwerthuso Glastir?

Glastir yw prif gynllun Llywodraeth Cymru ar gyfer talu am nwyddau a gwasanaethau amgylcheddol ac mae RhMGG yn gwerthuso llwyddiant y cynllun. Mae comisiynu rhaglen fonitro ochr yn ochr â lansio cynllun Glastir yn arwain at adborth buan ac mae'n golygu y gellir diwygio taliadau i gynyddu eu heffeithiolrwydd. Caiff cynllun Glastir ei ariannu ar y cyd gan Lywodraeth Cymru (drwy'r Cynllun Datblygu Gwledig) a'r UE. Bydd RhMGG hefyd yn cefnogi amrywiaeth eang o ofynion adrodd cenedlaethol a rhyngwladol.

Beth yw dull gweithredu RhMGG?

Mae RhMGG yn casglu tystiolaeth ar gyfer y chwe chanlyniad y bwriedir eu cyflawni yn sgil cynllun Glastir, sy'n canolbwyntio ar newid yn yr hinsawdd, ansawdd dŵr a phridd, bioamrywiaeth, tirwedd, mynediad a'r amgylchedd hanesyddol, a chreu a rheoli coedwigoedd. Mae'r gweithgareddau'n cynnwys: rhaglen fonitro genedlaethol barhaus sy'n cynnwys sgwariau 1km; dadansoddiad newydd o ddata hirdymor o gynlluniau eraill sy'n cael eu cyfuno â data RhMGG lle bo hynny'n bosibl; modelu i amcangyfrif canlyniadau yn y dyfodol fel y gellir gwneud diwygiadau i sicrhau bod y taliadau'n cael yr effaith fwyaf; arolygon i asesu buddiannau cymdeithasol-economaidd ehangach; a datblygu technolegau amgen i gynyddu nifer yr asesiadau yn y dyfodol a'u heffeithiolrwydd.

Sut mae RhMGG wedi gwneud cynnydd yn ystod yr ail flwyddyn hon?

Arolygwyd 90 o sgwariau RhMGG ym Mlwyddyn 2, ac arolygwyd 60 ym mlwyddyn 1, sy'n golygu bod 50% o sgwariau arolygu RhMGG bellach wedi'u cwblhau. Bydd y sgwariau'n cael eu harolygu bob 4 blynedd i ganfod pa newidiadau a fu mewn ymateb i Glastir a phwysau arall fel newidiadau yn sefyllfa economaidd busnesau fferm, newid yn yr hinsawdd a llygredd aer. Bydd y cylch arolygu cyntaf hwn yn casglu data sylfaenol ar gyfer asesu unrhyw newidiadau yn y dyfodol yn ei erbyn. Mae hyn yn bwysig gan fod gwaith RhMGG eleni wedi dangos bod y tir sy'n dod o fewn y cynllun yn wahanol mewn rhai ffyrdd i'r tir sydd y tu allan iddo. Felly, bydd unrhyw ddadansoddiad yn y dyfodol o effaith Glastir yn cael ei fesur yn erbyn cefndir cenedlaethol y tir y tu allan i'r cynllun a'r data sylfaenol hwn ar y tir sydd o fewn y cynllun. Cwblhawyd dadansoddiadau o ddata hirdymor ar gyfer holl ganlyniadau Glastir ar wahân i safon y dirwedd a nodweddion hanesyddol, y mae data cyfyngedig ar gael ar eu cyfer. Mae hyn wedi golygu cyfuno data gyda data RhMGG ar gyfer 2013/14, pan fo'r dulliau wedi caniatáu hynny. Mae dadansoddiad cyffredinol o'r data hirdymor yn dangos bod sefydlogrwydd, ond ychydig o dystiolaeth sydd o welliant, ar wahân i'r gwelliant a fu dros yr 20 mlynedd diwethaf mewn perthynas ag ansawdd blaenddyfroedd, allyriadau nwyon tŷ gwydr ac ardaloedd coediog. Mae rhai o'r prif ystadegau'n cynnwys: 51% o nodweddion hanesyddol mewn cyflwr rhagorol neu gadarn; dwy ran o dair o'r hawliau tramwy cyhoeddus ar agor yn gyfan gwbl ac yn hygyrch; gwelliant yn y gwaith o reoli gwrychoedd gydag 85% wedi'u harolygu dros y 3 blynedd diwethaf, ond plannwyd llai na 1% ohonynt yn ddiweddar; roedd 91% o nentydd wedi cael eu haddasu i ryw raddau, ond roedd 60% ohonynt o ansawdd ecolegol da; nid oedd dim newid yn y lefelau carbon mewn uwchbridd dros y 25 mlynedd diwethaf.

Beth oedd yn arloesol?

Mae RhMGG wedi datblygu amryw o fetrigau newydd i alluogi cofnodi symlach yn y dyfodol. Er enghraifft, mae'r mynegai newydd i Gymru ar gyfer rhywogaethau o adar â blaenoriaeth, sy'n cyfuno data o 35 o rywogaethau, yn dangos bod o leiaf hanner ohonynt yn sefydlog neu'n cynyddu. Cafodd Mynegai Ansawdd Gweledol Tirwedd RhMGG ei brofi gan dros 2600 o ymatebwyr. Mae'r canlyniadau wedi dangos ei werth fel dull gwrthrychol y gellir ei ailadrodd o fesur newid yn ansawdd gweledol tirwedd. Mae map unedig newydd i Gymru ar gyfer mawn wedi cael ei ddatblygu, ac mae wedi cael ei drosglwyddo i Reolwyr Cytundebau Glastir er mwyn gwella sut y caiff taliadau eu targedu wrth negodi cytundebau Glastir. Mae amcangyfrif o gyfraniad pridd mawn at allyriadau nwyon tŷ gwydr yn sgil addasiadau dynol wedi cael ei gyfrifo. Mae modelau wedi galluogi i ardaloedd o dir gael eu mesur, sydd wedi helpu i leihau faint o ddŵr glaw sy’n llifo ohono. Rydym yn defnyddio dulliau molecwlaidd newydd i ymchwilio i effeithiau Glastir ar organebau yn y pridd, a thechnolegau lloeren i fesur, er enghraifft, nodweddion coediog bach a newid yn yr hyn sy’n tyfu ar y tir. Yn olaf, rydym yn defnyddio dull gweithredu cymunedol i ddatblygu consensws ynghylch sut i ddiffinio a chofnodi newid mewn Tir Ffermio sydd o Werth Mawr i Natur, a fydd yn cael ei gynnwys yn adroddiad Blwyddyn 3 GMEP.

GMEP Year 2 Citizen Summary

What is the purpose of Glastir Monitoring and Evaluation Programme?

Glastir is the main scheme by which the Welsh Government pays for environmental goods and services whilst the Glastir Monitoring and Evaluation Programme (GMEP) evaluates the scheme's success. Commissioning of the monitoring programme in parallel with the launch of the Glastir scheme provides fast feedback and means payments can be modified to increase effectiveness. The Glastir scheme is jointly funded by the Welsh Government (through the Rural Development Plan) and the EU. GMEP will also support a wide range of other national and international reporting requirements.

What is the GMEP approach?

GMEP collects evidence for the 6 intended outcomes from the Glastir scheme which are focussed on climate change, water and soil quality, biodiversity, landscape, access and historic environment, woodland creation and management. Activities include; a national rolling monitoring programme of 1km squares; new analysis of long term data from other schemes combining with GMEP data where possible; modelling to estimate future outcomes so that adjustments can be made to maximise impact of payments; surveys to assess wider socio-economic benefits; and development of novel technologies to increase detection and efficiency of future assessments.

How has GMEP progressed in this 2nd year?

90 GMEP squares were surveyed in Year 2 to add to the 60 completed in Year 1 resulting in 50% of the 300 GMEP survey squares now being completed. Squares will be revisited on a 4 year cycle providing evidence of change in response to Glastir and other pressures such as changing economics of the farm business, climate change and air pollution. This first survey cycle collects the baseline against which future changes will be assessed. This is important as GMEP work this year has demonstrated land coming into the scheme is different in some respects to land outside the scheme. Therefore, future analysis to detect impact of Glastir will be made both against the national backdrop from land outside the scheme and this baseline data from land in scheme. A wide range of analyses of longterm data has been completed for all Glastir Outcomes with the exception of landscape quality and historic features condition for which limited data is available. This has involved combining data with 2013/14 GMEP data when methods allow. Overall analysis of long term data indicates one of stability but with little evidence of improvement with the exception of headwater quality, greenhouse gas emissions and woodland area for which there has been improvement over the last 20 years. Some headline statistics include: 51% of historic features in excellent or sound condition; two thirds of public rights of way fully open and accessible; improvement in hedgerow management with 85% surveyed cut in the last 3 years but < 1% recently planted; 91% of streams had some level of modification but 60% retained good ecological quality; no change topsoil carbon content over last 25 years.

What is innovative?

GMEP has developed various new metrics to allow for more streamlined reporting in the future. For example a new Priority Bird species Index for Wales which combines data from 35 species indicates at least half have stable or increasing populations. The new GMEP Visual Quality Landscape Index has been tested involving over 2600 respondents. Results have demonstrated its value as an objective and repeatable method for quantifying change in visual landscape quality. A new unified peat map for Wales has been developed which has been passed to Glastir Contract Managers to improve targeting of payments when negotiating Glastir contracts. An estimate of peat soil contribution to current greenhouse gas emissions due to human modification has been calculated. Models have allowed quantification of land area helping to mitigate rainfall runoff. We are using new molecular tools to explore the effects of Glastir on soil organisms and satellite technologies to quantify e.g. small woody features and landcover change. Finally we are using a community approach to develop a consensus on how to define and report change in High Nature Value Farmland which will be reported in the Year 3 GMEP report.

Crynodeb Gweithredol Blwyddyn 2 RhMGG

Mae Rhaglen Monitro a Gwerthuso Glastir (RhMGG) yn darparu rhaglen gynhwysfawr i fonitro effeithiau Glastir a chyfrannu at ddarparu data am dueddiadau cenedlaethol tuag at ystod o dargedau cenedlaethol a rhyngwladol sy'n ymwneud â bioamrywiaeth a'r amgylchedd. Erbyn hyn, mae RhMGG yn ei thrydedd flwyddyn o'r cyfnod asesu llinell sylfaen pedair blynedd cychwynnol. Mae'r adroddiad blynyddol hwn yn cyflwyno canlyniadau ail flwyddyn y rhaglen. Mae RhMGG yn cyflawni ymrwymiad gan Lywodraeth Cymru i sefydlu rhaglen fonitro ar yr un pryd â lansio cynllun Glastir, ac felly mae'n ddatblygiad mawr o'i gymharu â rhaglenni monitro yn y gorffennol, sydd wedi cyflwyno adroddiadau ar ôl i gynlluniau ddod i ben yn unig. Mae'r prosiect yn sicrhau y cydymffurfir â gofynion trylwyr Fframwaith Monitro a Gwerthuso Cyffredin Comisiwn Ewrop (CMEF) drwy gyfrwng y Cynllun Datblygu Gwledig i Gymru. Mae canfyddiadau cynnar RhMGG eisoes wedi darparu adborth cyflym i Lywodraeth Cymru o ran sut i dargedu taliadau'n ofodol i sicrhau'r manteision gorau wrth i'r cynllun fynd yn ei flaen.

Y tu hwnt i'r broses o gyflwyno adroddiadau ar ganlyniadau Glastir, bydd data a modelau RhMGG hefyd yn cyfrannu at ystod o ofynion adrodd eraill, gan gynnwys y Gyfarwyddeb Fframwaith Dŵr, y Gyfarwyddeb Gynefinoedd a'r Rhestr Allyriadau Nwyon Tŷ Gwydr sy'n deillio o Fil yr Amgylchedd, fel yr adroddiad ar Gyflwr Adnoddau Naturiol, y Polisi Adnoddau Naturiol Cenedlaethol a Datganiadau Ardal. Yr hyn sy'n ganolog i Fil yr Amgylchedd yw'r angen i fabwysiadu dull gweithredu newydd, mwy integredig o reoli ein hadnoddau naturiol mewn modd mwy cynaliadwy, gan sicrhau ar yr un pryd ein bod yn diogelu ac yn datblygu cydnerthedd systemau naturiol er mwyn iddynt barhau i ddarparu'r manteision hyn y tymor hir. Ystyrir bod mwy o gydnerthedd pan geir lefel uchel o ran maint, cyflwr, cysylltedd ac amrywiaeth. Gall nifer o fetrigau RhMGG gael eu cysylltu â'r gofynion hyn ac felly gellid manteisio arnynt er mwyn mapio'r 4 nodwedd hyn ar gyfer ardaloedd gwahanol yn y dyfodol. Bydd y manteision hyn yn sail i agweddau penodol ar Fil Llesiant Cenedlaethau'r Dyfodol. Dull arall posibl o ddefnyddio data RhMGG yw i gefnogi gwaith gan Defra a Llywodraeth Cymru o ddatblygu Cyfrifon Cenedlaethol i gynnwys agweddau ar yr adnoddau naturiol (hynny yw, carbon, dŵr, a phridd) a'u gwerth cyfunol ar ffurf ecosystemau cyfan (hynny yw, coedwigoedd, gwlyptiroedd, ac yn y blaen). Gall data RhMGG gyfrannu at ddarparu'r data cadarn, y gellir eu harchwilio, sy'n ofynnol ar gyfer y gweithgaredd hwn.

Bydd RhMGG felly yn gwella'r gronfa dystiolaeth empirig ar gyfer sefyllfa a chyfanrwydd / cyflwr presennol asedau naturiol Cymru (a elwir yn gyfalaf naturiol) a sut y mae'r rhain yn newid mewn ymateb i ysgogwyr fel newid yn yr hinsawdd, arferion rheoli tir a llygredd aer y mae opsiynau Glastir yn cael eu gosod arnynt. Yr her i'r tîm RhMGG yw arwahanu'r newidiadau sy'n gysylltiedig ag opsiynau Glastir eu hunain, sef prif ddiben y rhaglen monitro a gwerthuso. Mae newidiadau i faint a chyfanrwydd y cyfalaf naturiol yn cael effaith yn eu tro o ran pa mor dda y gallant gyflawni'r swyddogaethau a'r gwasanaethau ecosystemau sydd eu hangen arnom, ac a werthfawrogwn. Nid yw'r cyswllt hwn wedi'i feintoli'n dda ar hyn o bryd. Mae'r gwahaniaeth rhwng gwasanaethau a chyfalaf naturiol yn bwysig gan fod cyfalaf yn ased tymor hwy yr ydym am ei ddiogelu ar gyfer y dyfodol, ac mae'n anodd neilltuo gwerth iddo ynddo'i hun, ond y gwasanaethau sy'n deillio o'r cyfalaf hwn yw'r hyn y mae economegwyr a gwyddonwyr cymdeithsol yn gallu neilltuo gwerth iddo, ac sy'n arbennig o berthnasol i Fil Llesiant Cenedlaethau'r Dyfodol. Mae'r cam hwn o neilltuo gwerth yn un hanfodol er mwyn inni ddarparu fframwaith cadarn ar gyfer deall yr opsiynau y mae llywodraeth a chymdeithas yn eu hwynebu. Mae tîm RhMGG yn gweithio ar y materion hyn drwy gyfrwng ei waith ar y canfyddiad a'r defnydd o'r dirwedd, arolygon cymdeithasol, ac arolygon ynghylch arferion ffermwyr. Fodd bynnag, mae hwn yn bwnc mawr y bydd angen gwaith ychwanegol arno y tu hwnt i'r adnoddau sydd ar gael ym mhrosiect RhMGG ar hyn o bryd.

Mae'r tîm RhMGG sy'n cyflawni'r rhaglen gynhwysfawr hon yn cynnwys cymysgedd o sefydliadau sydd ag arbenigaethau gwahanol, sy'n cwmpasu'r gwahanol gynlluniau, gweithgareddau, amcanion a chanlyniadau. Caiff y rhaglen ei harwain gan Ganolfan Ecoleg a Hydroleg Cyngor Ymchwil yr Amgylchedd Naturiol, sef corff ymchwilio cyhoeddus annibynnol. Mae gan y Ganolfan Ecoleg a Hydroleg safle ymchwil ym Mangor sy'n darparu'r arweinyddiaeth a'r gwaith cydgysylltu ar gyfer RhMGG. Mae consortiwm y prosiect yn cynnwys ADAS, APEM, Prifysgol Bangor, *Biomathematics and Statistics Scotland*, Ymgynghorwyr Bowburn, Arolwg Daearegol Prydain, Ymddiriedolaeth Adareg Prydain, *Butterfly Conservation*, ECORYS, Ymgynghorwyr Edwards, Prifysgol Staffordshire, Prifysgol Aberdeen, Prifysgol Southampton, a Phrifysgol Wellington Victoria, Seland Newydd.

Dull gweithredu RhMGG a'r gofynion o ran cyflwyno adroddiadau

Yn gryno, rhaglen ddata a modelu wedi'i chyfuno yw dull gweithredu sylfaenol RhMGG, sy'n defnyddio data presennol sydd wedi'u gwella gan arolwg maes treigl newydd, mawr sy'n darparu data wedi'u cydleoli ynghylch ystod o fetrigau amgylcheddol. Mae gwaith modelu'n darparu dulliau o gyfuno ac uwchraddio data arolygon ar gyfer cyflwyno adroddiadau ar raddfa genedlaethol ac ymchwilio i sefyllfaoedd posibl y dyfodol sy'n gysylltiedig â chanlyniadau posibl y cynllun. Mae data'r arolwg sydd wedi'u cydleoli yn peri bod modd cyflwyno adroddiadau yn ôl y chwe chanlyniad a fwriedir yng nghyswllt Glastir, ac effeithiau gwrthbwyso a chydfyddiannau taliadau Glastir rhwng y canlyniadau hyn. Y chwe chanlyniad yw: Mynd i'r afael â'r newid yn yr hinsawdd; Gwella ansawdd dŵr a rheoli adnoddau dŵr i helpu i leihau'r perygl o lifogydd; Diogelu adnoddau'r pridd a gwella cyflwr y pridd; Cynnal bioamrywiaeth a'i gwella; Rheoli a diogelu tirweddau a'r amgylchedd hanesyddol; Creu cyfleoedd newydd i wella'r mynediad i gefn gwlad a'r ddealltwriaeth ohoni; a Chreu coetiroedd a'u rheoli.

Yn ychwanegol at y Canlyniadau gwreiddiol hyn ar gyfer cynllun Glastir, ym mis Medi 2014 cyhoeddodd Archwilydd Cyffredinol Cymru adroddiad[1] ar Glastir. Roedd yr adroddiad yn cynnwys cyfres o sylwadau ac argymhellion cysylltiedig gan gynnwys nifer a oedd wedi'u cysylltu â phennu targedau'r cynllun a monitro ei effeithiau gwirioneddol yn ôl ei dargedau, sydd wedi effeithio ar ofynion prosiect RhMGG o ran cyflwyno adroddiadau. Nododd chwe Amcan Strategol. Er mwyn ymateb i'r argymhellion hyn, mae RhMGG wedi gweithio gyda Llywodraeth Cymru a Grŵp Cynghori RhMGG i ddatblygu nifer fach o ddangosyddion effaith yng nghyswllt pob Amcan Strategol ar gyfer Glastir.

Mae'r rhain i'w gweld yn y prif Adroddiad Blwyddyn 2 RhMGG ac ar borth data RhMGG: www.rhamagg.wales. Mae'r dagnosydd hwn yn dangos yr ystod eang o fesuriadau a deiliannau amgylcheddol sydd wedi'u hymgorffori yn rhaglen waith RhMGG, sef ystod o fetrigau ynghylch ansawdd pridd a dŵr, y dirwedd a nodweddion hanesyddol, amrywiaeth planhigion a dŵr croyw, nwyon tŷ gwydr, asesu cyflwr nodweddion hanesyddol, pryfed peillio a phedwar arolwg ynghylch adar, arolygon cymdeithasol-economaidd ynghylch manteision i'r diwydiannau ffermio a choedwigaeth a chymuned ehangach Cymru.

Cylch RhMGG

Oherwydd cynhelir ailymweliadau â safleoedd arolygu RhMGG yn ôl cylch treigl pedair blynedd, a'n bod ym Mlwyddyn 3 o'r cylch pedair blynedd cychwynnol hwn, mae canlyniadau presennol Blwyddyn 2 yn cyfrannu at linell sylfaen a fydd yn sail i'r broses o fesur effeithiau taliadau Glastir yn y dyfodol. Fesul Canlyniad Glastir, mae gwaith sydd wedi'i ganolbwyntio ar fioamrywiaeth (gan gynnwys cynefinoedd coetiroedd) yn cyfateb i 42% o gyfanswm cyllideb RhMGG, mae 41% wedi'i ddyrannu ar draws priddoedd, dyfroedd, lliniaru newid yn yr hinsawdd, nodweddion y dirwedd a

[1] http://audit.wales/cy/cyhoeddi/glastir

nodweddion hanesyddol, effeithiau gwrthbwyso a chydfuddiannau, ac mae'r 17% sy'n weddill wedi'i ddyrannu i ategu gweithgareddau fel gwybodeg, y porth data a rheoli prosiectau. Mae'r arolwg maes yn cynnwys dwy ran, sef y cydrannau Cymru Ehangach a'r arolwg wedi'i dargedu. Mae sgwariau arolygu Cymru Ehangach yn cael eu dewis i gynrychioli'r amodau cefndir ledled Cymru ac maent yn cael eu dewis drwy samplu ar hap o fewn dosbarthiadau tir wedi'u neilltuo. Mae hyn yn helpu RhMGG i ddarparu'r data sydd eu hangen ar dueddiadau cenedlaethol. Caiff sgwariau wedi'u targedu eu dewis wedyn i gofnodi'n benodol weithgareddau sy'n gysylltiedig â Glastir.

Crynodeb o'r cynnydd

Blynyddoedd 1 a 2

Ym Mlwyddyn 1, canolbwyntiodd RhMGG ar sefydlu'r rhaglen maes a defnyddio *ensemble* o fodelau i ymchwilio i ddeiliannau posibl o wahanol sefyllfaoedd o ran y defnydd o chwe opsiwn Glastir. Ym mlwyddyn 2, rydym wedi parhau â'r arolwg maes ac wedi canolbwyntio ar ddadansoddi data Blynyddoedd 1 a 2 ynghyd â data o ffynonellau eraill, yn arbennig Cyfoeth Naturiol Cymru, y Rhestr Coedwigaeth Genedlaethol, *Plantlife*, Cynllun Monitro Gloÿnnod Byw y DU, y Cynllun Bridio Adar a'r Arolwg Cefn Gwlad. Mae'r tueddiadau hirdymor a ganfuwyd wedi'u nodi yma (neu yn y porth data). Gwnaethom hefyd ddadansoddi data RhMGG i ganfod a oedd tir sy'n dod i mewn i'r cynllun yn wahanol o ran ansawdd i'r tir y tu allan, ac a oeddem yn gallu canfod effeithiau etifeddol cynlluniau amaeth-amgylcheddol y gorffennol. Canolbwyntiodd y tîm bioamrywiaeth ar ddatblygu technegau ar gyfer cyflwyno adroddiadau ar effeithiau ar gyfer rhywogaethau a chynefinoedd â blaenoriaeth, wrth i waith barhau ar ddatblygu'r offeryn ansawdd / canfyddiad y dirwedd, a'i rhoi ar brawf. Cafodd ymdrechion modelu eu canolbwyntio ar sefydlu'r data llinell sylfaen o ran allyriadau nwyon tŷ gwydr uniongyrchol ac anuniongyrchol mewn ymateb i gyllid Grantiau Effeithlonrwydd Glastir ac asesu effaith ddryslyd bosibl newid yn yr hinsawdd ar allyriadau nwyon tŷ gwydr. Mae gwaith dadansoddi ar bridd a dŵr croyw yn cyflwyno adroddiadau ar ddata Blwyddyn 1 yn unig oherwydd yr amser sy'n ofynnol ar gyfer asesu bioamrywiaeth. Cynhaliwyd dadansoddiad o 7 gwasanaeth ecosystem a'u heffeithiau gwrthbwyso posibl gan gynnwys y broses o ddatblygu metrig i amcangyfrif arwynebedd y tir sy'n lliniaru dŵr ffo/llifogydd. Roedd y gwaith hefyd yn cynnwys darn o waith mawr sydd wedi'i gwblhau a oedd yn ymwneud â datblygu dulliau newydd o fapio ac asesu cyflwr priddoedd mawn yng Nghymru, ynghyd â'u cyfraniad posibl at leihau allyriadau nwyon tŷ gwydr.

Cynlluniau'r dyfodol ar gyfer Blynyddoedd 3 a 4

Blwyddyn 3:

- Mae'r arolwg maes ar gyfer Blwyddyn 3 yn mynd rhagddo eisoes, ac mae 75 o sgwariau wedi'u dewis ar gyfer yr arolwg.
- Byddwn yn ceisio penderfyniad ynghylch cynnwys sgwariau'r Arolwg Cefn Gwlad yn Arolwg Cymru Ehangach RhMGG
- Llunio'r fersiwn derfynol o'r dangosydd newydd ynghylch Tir Fferm o Werth Mawr i Natur.
- Datblygu a lansio Porth Data RhMGG yn Sioe Frenhinol Cymru yn 2015.
- Cyflwyno adroddiadau ar fetrigau sydd eu hangen ar gyfer y 6 Amcan Strategol a Thargedau newydd cytunedig ar gyfer Glastir sy'n cael eu datblygu gan Lywodraeth Cymru. Bydd y metrigau hyn ynghyd â dangosyddion lefel uchel ar gyfer 6 Chanlyniad Glastir yn cael eu defnyddio i ddarparu'r wybodaeth ddiweddaraf yn flynyddol drwy gyfrwng Porth Data GMEP.

Blwyddyn 4:

- Cwblhau'r 75 o sgwariau 1km terfynol yr arolwg maes i gwblhau'r 300 o sgwariau arolygu 1km llinell sylfaen RhMGG.

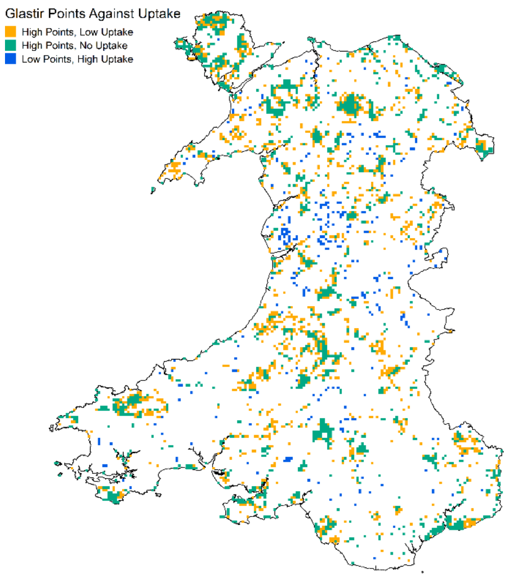
- Ailgynnal yr Arolwg o Arferion Ffermwyr yn haf 2016 i nodi'r newidiadau gwirioneddol ar y fferm ac unrhyw fantais i broffidioldeb a chadernid ffermydd a choedwigaeth.
- Gwaith modelu i ganfod manteision Glastir o ran ansawdd dŵr mewn dalgylchoedd y Gyfarwyddeb Fframwaith Dŵr ar sail newidiadau wedi'u meintoli yn yr Arolwg o Arferion Ffermwyr a gynhelir yn yr haf yn 2016 i'w gyflwyno mewn adroddiad yng ngwanwyn 2017
- Cyfweliadau â ffermwyr wedi'u cyfuno â gwaith modelu i feintoli'r manteision i allyriadau nwyon tŷ gwydr uniongyrchol ac anuniongyrchol fesul math o fferm.

Y canfyddiadau allweddol

Mae'r hyn a ganlyn yn grynodeb lefel uchel o rai o'r prif ganfyddiadau wedi'u strwythuro fesul canlyniad Glastir; mae adrannau ychwanegol wedi'u cynnwys er mwyn dadansoddi'r defnydd o Glastir, priddoedd mawn, tir fferm o Werth Mawr i Natur, ac effeithiau gwrthbwyso a chyfleoedd Ecosystem. Gellir dod o hyd i nifer o ganlyniadau eraill yn yr adroddiad llawn neu ym mhorth data RhMGG https://rhamagg.cymru.

Dadansoddiad o'r defnydd o Glastir

Nodwyd bod 4,911[2] o newydd-ddyfodiad unigryw wedi ymuno â'r cynllun erbyn mis Rhagfyr 2014. Cyfanswm yr arwynebedd a gwmpasir gan opsiynau Glastir yw 3,263 km^2, sef 19% o'r arwynebedd LPIS sydd ar gael, ac 16% o gyfanswm arwynebedd tir Cymru. Roedd y defnydd o Glastir yn ymwneud yn bennaf â bioamrywiaeth a newid yn yr hinsawdd yn dibynnu ar y metrig a ddefnyddiwyd i asesu'r defnydd. Y Canlyniad Coetiroedd a oedd â'r nifer lleiaf o newydd-ddyfodiaid. Os caiff lefelau'r defnydd eu cymharu â symiau'r pwyntiau sydd ar gael, yn amlwg mae pwyntiau wedi ysgogi'r defnydd gan nad oes ond 308km2 (tua 1% o Gymru) lle cafwyd defnydd mawr mewn ardaloedd â phwyntiau isel. Fodd bynnag, roedd 3041km2 (sef tua 15% o Gymru) a oedd â phwyntiau uchel lle na fu fawr o ddefnydd, neu lle na fu dim defnydd. Roedd cynrychiolaeth cynefinoedd yn y categori hwn yn gymesur i'r hyn a welwyd yn y pwyntiau defnydd uchel/isel ac eithrio coetiroedd conifferaidd a oedd wedi'u gorgynrycholi h.y. defnydd anghymesur o isel.

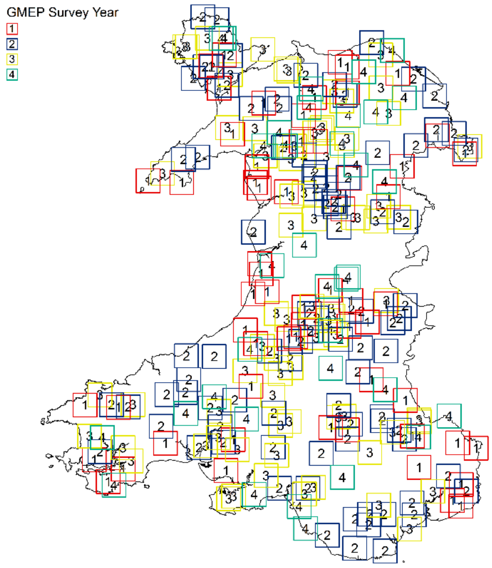


Fifigur 01 Ardaloedd lel ceir defnydd isel/dim defnydd/pwyntau uchel (melyn a gwyrdd) a defnydd uchel / pwyntiau isel (glas)

Cwmpas RhMGG o ran Glastir

[2] Mae'r asesiadau hyn yns eiliedig ar ddyraniad gan dîm y prosiect o ran y canlyniad a fwriadwyd ar gyfer y taliadau gan Swyddog Prosiedct Glastir nad oedd ar gael adeg ysgrifennu'r adroddiad hwn.

Mae cyfanswm o 197 o’r 260 o sgwariau 1km arolwg RhMGG (76%) sydd wedi’u dewis neu eu harolygu ar hyn o bryd yn gorgyffwrdd â rhyw fath o barsel tir a ddefnyddiwyd o dan Glastir.
Fesul Canlyniad, mae’r gorgyffwrdd o fewn sgwariau RhMGG yn debyg i’r defnydd cenedlaethol, a cheir y gorgyffwrdd mwyaf yn achos y Canlyniad Bioamrywiaeth, sef 78% o’r parseli tir. Mae hyn yn cymharu â 62% yn y cynllun. O ran defnydd, coetiroedd a oedd â’r cwmpas lleiaf yn y RhMGG, sef 16%. Mae hyn yn cymharu â 10% yn y cynllun.



Ffigur 02 Dosbarthiad sgwariau 1km RhMGG ond wedi’i ehangu i gwmpasu grid 10km er mwyn diogelu lleoliadau. Mae’r sgwariau’n cynnwys Blynyddoedd 1-3 Arolwg Cymru Ehangach a’r Arolwg wedi’i Dargedu, ond dim ond Arolwg Cymru Ehangach ar gyfer Blwyddyn 4 sydd wedi’i gynnwys oherwydd bydd yr Arolwg wedi’i Dargedu yn cael ei ddewis yn ôl y defnydd yn yr hydref yn 2015.

Y wybodaeth ddiweddaraf am yr arolwg maes

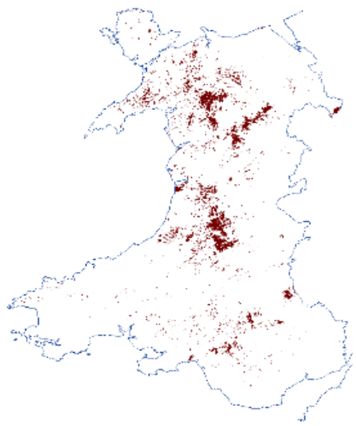
Cynhaliwyd y prif arolwg bioffisegol o 90 o sgwariau 1km er mwyn cyflawni arolwg gwaelodlin Blwyddyn 2 rhwng mis Ebrill a mis Medi 2014. Rhoddodd 68% o’r tirfeddianwyr y cysylltwyd â hwy ac a oedd â thirddaliadau gyda sgwariau arolygu 1km RhMGG ganiatâd ar gyfer yr arolwg; gwrthododd 5% fynediad, ac ni chafwyd ymateb gan y gweddill. Cafodd cyfanswm o 80% o’r tir yn y 90 o sgwariau arolygu 1km ei arolygu yn 2014. Mae’r rhaglen integredig hon o fonitro ac arolygu, sydd wedi’i chydleoli, ac sy’n cynnwys mesur o briddoedd i nwyon tŷ gwyr a dyfroedd, planhigion i adar a phryfed peillio, y dirwedd i nodweddion hanesyddol a chanfyddiad o’r dirwedd yn peri bod mod ymchwilio i’r dibyniaethau rhwng yr elfennau hyn mewn adroddiadau yn y dyfodol. Mae’n cyd-fynd ag amcanion Bil yr Amgylchedd datblygu dulliau gweithredu mwy integredig o reoli ein hadnoddau naturiol yn fwy cynaliadwy.

Priddoedd mawn

Mae Priddoedd Mawn yn gorchuddio 4.3% o Gymru, ac maent yn cynnal cynefinoedd corsydd a mignedd sy’n brin yn genedlaethol ac yn rhyngwladol. Yn ychwanegol at eu pwysigrwydd o safbwynt bioamrywiaeth, priddoedd mawn yw storfa ecosystem diriogaethol fwyaf Cymru, ac os ydynt mewn cyflwr da mae ganddynt botensial i ddylanwadu ar yr hinsawdd drwy ddal a storio CO_2 yn barhaus. Fodd bynnag, mae priddoedd mawn Cymru wedi’u niweidio gan ganrifoedd o weithgarwch dynol, gan gynnwys draenio, gormod o bori, a’u troi’n laswelltir a choedwigoedd. O ganlyniad credir ar hyn o bryd fod priddoedd mawn Cymru yn ffynhonnell allyriadau nwyon tŷ gwydr. Mae mesurau a gefnogir drwy Glastir yn anelu at leihau’r allyriadau hyn, ac i adfer swyddogaeth dal a storio carbon priddoedd mawn Cymru, drwy leihau pwysau o ran defnyddio’r tir ar ystod o gorsydd a mignedd yn yr ucheldir a’r iseldir. Comisiynwyd RhMGG ym mlwyddyn 2 i wneud darn pwysig newydd o waith i ddatblygu gwell metrigau ar gyfer asesu cyflwr priddoedd mawn yng Nghymru.

Y canfyddiadau allweddol:
Mae'r allbynnau'n cynnwys map mawn unedig a ddylai ganiatáu i asesiad mwy dibynadwy gael ei wneud o gyflwr adnodd mawn cyfan Cymru, gyda chynrychiolaeth well o briddoedd tir isel, a thargedu mesurau Glastir sy'n gysylltiedig â phridd mawn yn fwy manwl gywir o ran yr ardaloedd hynny lle mae mawn yn bresennol. Mae'r map hwn bellach wedi'i drosglwyddo I Reolwyr Contract Glastir I'w ddefnyddio wrth negodi Cytundeb newydd Glastir.

O ran cyflwr pridd mawn, mae'r darlun ehangach yn dangos priddoedd mawn sydd wedi'u haddasu'n sylweddol ledled Cymru gyda dim ond 30% mewn cyflwr da. O ganlyniad i'r gweithgareddau hyn, amcangyfrifir bod priddoedd mawn Cymru yn cynhyrchu allyriadau 'anthropogenig' o oddeutu 400 kt CO_2-y flwyddyn (sy'n gyfwerth â thua 7% o'r holl allyriadau sy'n gysylltiedig â thrafnidiaeth yng Nghymru). Mae hyn yn cymharu ag amcangyfrif o gyflwr 'cyfeirio' naturiol (h.y. pe bai'r holl ardal fawn sydd wedi'i mapio ar hyn o bryd yn gors neu'n fignen naturiol) o oddeutu 140 kt CO_2-eq yr^{-1} Yr unig welliannau diweddar yw rhoi'r gorau i echdynnu mawn ac yng nghyflwr y corsydd h.y. defnyddio rhywogaethau planhigion fel procsi ar gyfer cyflwr y gors, rhwng 1990 a 2007 roedd cynnydd bach yn nifer y rhywogaethau corsydd nodweddiadol ('dangosydd cadarnhaol') a thybir bod hynny yn sgil yr ymgyrch ddiweddar i dargedu corsydd i'w hadfer.


Ffigur 03 Map newydd - mawn unedig o Gymru

Manteision cymdeithasol-economaidd

Mae RhMGG yn cynnal ystod o weithgareddau i gofnodi manteision cymdeithasol-economaidd ehangach cynllun Glastir. Gall y manteision hyn ddeillio o ystod o weithgareddau Glastir gan gynnwys taliadau gan ffermwyr i'r gymuned leol am lafur neu wasanaethau i lwybrau mwy anuniongyrchol fel ansawdd gwell y dirwedd weledol, sydd â'r potensial i fod o fudd i gymunedau lleol a'r diwydiant twristiaeth. Yn fwy cyffredinol, y gobaith yw y bydd y diogelwch gwell i'n hadnoddau naturiol a fwriedir o daliadau Glastir yn cyfrannu at Nod 'Cymru Gydnerth' Bil Llesiant a Chenedlaethau'r Dyfodol.

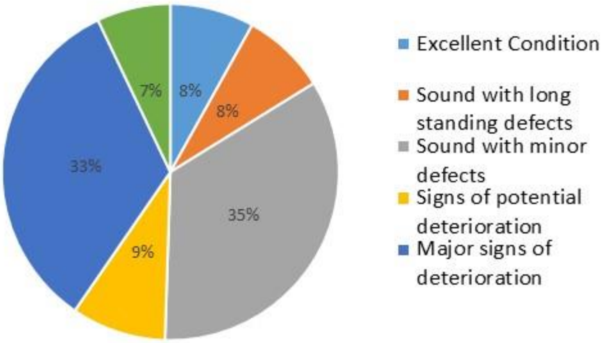
Y canfyddiadau allweddol:

Dywedodd ymatebwyr i arolwg o ffermwyr sy'n cael Grantiau Effeithlonrwydd Glastir fod y grantiau wedi cael effaith ariannol fuddiol ar 44% o gwsmeriaid a chleientiaid sy'n ffermwyr gan gyfeirio at fanteision oddi ar y fferm sy'n ymestyn i'r gymuned ehangach. Cytunodd mwy na 90% o'r ymatebwyr fod Grantiau Effeithlonrwydd Glastir wedi eu hannog i wneud buddsoddiadau cyfalaf newydd. Yn yr un modd, cytunodd mwyafrif y ffermwyr (83%) fod mynediad at Grantiau Effeithlonrwydd Glastir wedi cynyddu maint y buddsoddiad yr oeddent wedi'i gynllunio.

Nododd arolwg RhMGG fod mwy o hyblygrwydd a symleiddio'r broses gwneud cais ynghyd â phroses archwilio lai bygythiol oll yn welliannau posibl er mwyn cynyddu'r defnydd o'r Cynllun Creu Coetiroedd.

Cymerodd mwy na 2600 o ymatebwyr ran yn yr arolwg i brofi mynegai ansawdd tir gweledol a ddatblygwyd gan RhMGG. Ymchwiliwyd i wahaniaeth yn ôl e.e. rhyw, oedran, cenedligrwydd, lleoliad, math o enedigaeth a chartref presennol. Nodwyd nifer rhyfeddol o fach o wahaniaethau. Mae'r mynegai hwn yn cael ei ddefnyddio i asesu effeithiau Glastir ar ansawdd y dirwedd a'r cysylltiadau rhwng ansawdd ecolegol ac ansawdd y dirwedd.

Barnwyd bod hanner y nodweddion hanesyddol a aseswyd mewn cyflwr rhagorol neu gadarn. Llystyfiant oedd y bygythiad amlycaf. Roedd wy ran o dair o hawliau tramwy cyhoeddus ar agor yn llawn, yn hygyrch ac yn hawdd dod o hyd iddynt. Cyflwynir adroddiad ar y newidiadau yn sgil Glastir pan gaiff sgwariau 1k RhMGG eu hailarolygu.



Mae Ffigur 04 yn dangos cyflwr Nodweddion yr Amgylchedd Hanesyddol o sgwariau arolwg 1k RhMGG ym mlynyddoedd 1 a 2.

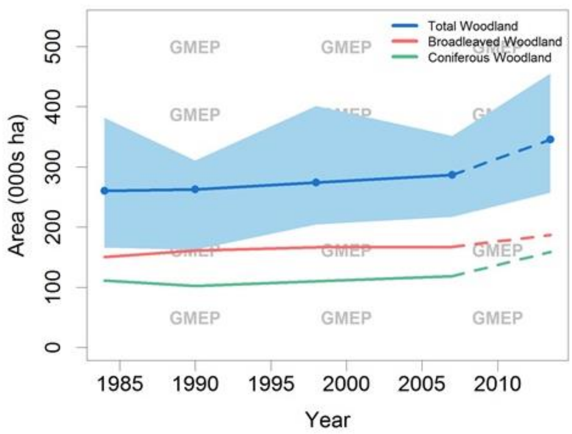
Coetiroedd

Mae coetir yn bwysig ar gyfer darparu nifer o wasanaethau, nwyddau a buddion ecosystem, gan gynnwys pren, diogelu'r pridd, atal llifogydd, hamdden, rheoleiddio'r hinsawdd ac amrywiaeth rhywogaethau gwyllt (i rai cyffredinol a'r rhai sy'n byw mewn coetiroedd yn unig). Mae nifer o'r gwasanaethau hyn yn rhai sy'n ychwanegu at ei gilydd ac mae synergeddau rhwng gwasanaethau yn hytrach nag effeithiau gwrthbwyso; mae coetiroedd yn gynefinoedd sydd â nifer o swyddogaethau. Pennwyd gwerth o £34 miliwn i fanteision amgylcheddol coetiroedd yng Nghymru. Dangosodd arolwg diweddar fod bron 65% o bobl yng Nghymru yn ymweld â choetiroedd Cymru yn rheolaidd ac mae 94% o'r farn eu bod yn darparu budd cadarn i'r gymuned leol.

Y canfyddiadau allweddol:

Mae cyfuno data RhMGG gyda data'r Arolwg Cefn Gwlad yn darparu gwybodaeth hirdymor am duedd. Yn gyffredinol mae'r duedd ar gyfer stoc a chyflwr coetiroedd yn cynyddu o ran ardal ond prin yw'r dystiolaeth o welliant yn y cyflwr. Mae RhMGG yn cofnodi ardaloedd bach o goetir sy'n berthnasol iawn i Glastir ond nad ydynt yn cael eu cofnodi gan y Comisiwn Coedwigaeth.

Ffigur 05 Arwynebedd y coetir yng Nghymru dros amser, a grëwyd ar sail amcangyfrifon cenedlaethol o ddata'r arolwg maes, Arolwg Cefn Gwlad (llinell ddi-dor) a RhMGG (llinell doredig).



Mae data fflora'r tir yn awgrymu y gall y coetiroedd gynnwys llawer o blanhigion sydd wedi tyfu'n wyllt gyda mwy o gysgod, o bosibl oherwydd llai o waith rheoli. Ni nodwyd unrhyw newid cyson yn y Mynegai Coetiroedd Hynafol ers 1990

Nid oes dim newid sylweddol o ran cysylltedd coetiroedd coed ers 1990. Cofnodwyd cynnydd o ran gwrychoedd yn cael eu torri ond hefyd cafwyd gostyngiad mawr o ran plannu, gosod haenau a bondocio newydd ers 1990. Mae cynnydd i hyd gwrychoedd gan beri iddynt ddod yn llinellau o goed yn awgrymu dirywiad o ran rheolaeth yn gyffredinol. Mae gan dir sy'n dod yn rhan o Glastir fwy o gyfoeth o wrychoedd sy'n sylweddol y bydd angen eu hystyried wrth ddadansoddi effaith Glastir yn y dyfodol er mwyn osgoi cambriodoli'r gwahaniaeth cychwynnol hwn i Glastir.

Rydym wedi datblygu Cynnyrch Gorchudd Prennaidd newydd, sy'n mapio gwrychoedd mawr, coed unigol a darnau bach o goetir, yn ogystal â choetiroedd mwy, ar draws Cymru gyfan, a hynny ar raddfa 5m x 5m. Mae'r cynnyrch yn defnyddio cyfuniad o ddata radar a gludir drwy'r awyr (NEXTMap), delweddau optegol o loerennau a data o'r Rhestr Fforestydd Cenedlaethol. Mae gan y cynnyrch hwn nifer o ddefnyddiau posibl, gan gynnwys ymchwiliadau i gysylltedd cynefinoedd, modelu prosesau dŵr ffo dalgylchoedd, a mesur stociau carbon. Pan gafodd ei ddilysu yn ôl ffotograffau o'r awyr yn achos nifer o safleoedd prawf, roedd y cynnyrch yn meddu ar gywirdeb dosbarthu o 88 %.

Bioamrywiaeth

Mae gwarchod bioamrywiaeth yng Nghymru yn cael ei ysgogi gan y gwerth y mae pobl yn ei roi ar dreftadaeth gyfoethog o rywogaethau a chynefinoedd gwyllt. Mae gan gynefinoedd a rhywogaethau penodol gadarnleoedd yng Nghymru ond maent yn brin neu'n absennol mewn rhannau eraill o'r DU ac yn Ewrop, sy'n peri bod gan Gymru gyfrifoldeb penodol am eu monitro a'u gwarchod. Yn 20 amcangyfrifodd Asiantaeth yr Amgylchedd Cymru fod gweithgareddau a oedd yn seiliedig ar fywyd gwyllt wedi cyfrannu cyfanswm o £1.9 biiliwn o ran allbwn bob blwyddyn at economi Cymru, a oedd yn fwy na chyfanswm yr allbwn amaethyddol yn 2011, sef £1.3 biliwn. Felly, ni ddylid tanbrisio cyfraniad bioamrywiaeth at ffyniant, lles a chreu swyddi yng Nghymru. Mae dulliau RhMGG yn gweddu'n arbennig o dda â chofnodi newidiadau mewn bioamrywiaeth yn yr ardal wledig ehangach sy'n amgylchynu ardaloedd dynodedig ac felly'n darparu ardaloedd pwysig i rywogaethau a chynefinoedd gysylltu ac ymateb i newidiadau i amodau amgylcheddol sy'n newid, fel newid yn yr hinsawdd. Yn ychwanegol at hynny, mae RhMGG wedi datblygu dulliau ar gyfer canfod effeithiau Glastir ar rywogaethau a chynefinoedd adran 42, gan ganfod yr achosion hynny o gyd-daro rhwng opsiynau a rhywogaethau a chynefinoedd, a chanfod mynegeion newydd o dueddiadau hirdymor mewn bioamrywiaeth a fydd yn gefndir i RhMGG. Rydym hefyd yn datblygu dulliau o nodweddu tir fferm sydd o Werth Mawr i Natur ac o ymestyn ein hamcangyfrifon o'r newid i fioamrywiaeth ac effeithiau Glastir y tu allan i'r sampl o sgwariau 1km RhMGG ac i Gymru yn ehangach, drwy gyfuno â chynnyrch data a gaiff eu synhwyro o bell a chronfeydd data cofnodion biolegol. Er mwyn bod yn gryno, ni chaiff yr holl ddata am dueddiadau cenedlaethol eu nodi yma ond maent ar gael ym Mhorth Data RhMGG. Nid yw Data am faint a chyflwr Cynefinoedd â Blaenoriaeth ar gael hyd yn hyn.

Y canfyddiadau allweddol:

Dadansoddiad o ddata rhywogaethau hirdymor

Mae'r darlun cyffredinol o dueddiadau hirdymor mewn bioamrywiaeth yn darparu peth tystiolaeth o sefydlogrwydd diweddar ar gyfer rhai elfennau o fioamrywiaeth ond prin yw'r dystiolaeth o welliant. Deillia hyn o ddadansoddiad RhMGG newydd o ddata hirdymor o ffynonellau fel y Cynllun Monitro

Gloÿnnod Byw, data a gedwir gan y Ganolfan Cofnodion Biolegol o ystod eang o raglenni monitro, data Arolwg Adar Magu Ymddiriedolaeth Adareg Prydain/Cyd-bwyllgor Cadwriaeth Natur/RSPB a data o arolygon adar eraill o ystod o ffynonellau a'r Arolwg Cefn Gwlad. Er enghraifft mae Mynegai Rhywogaethau Adar â Blaenoriaeth ar gyfer 35 o rywogaethau lle mae digon o ddata ar dueddiadau ar gael yng Nghymru yn dangos bod o leiaf hanner y rhywogaethau'n cynyddu neu wedi sefydlogi ers 1994 ond nad oes patrwm ar gyfer gwelliant cyffredinol yn iechyd y boblogaeth dros amser.

	1994-1999	2000-2004	2005-2009	2010-2014
Nifer y rhywogaethau â data am dueddiadau	34	35	35	34
Y nifer a oedd yn cynyddu/sefydlog	23	21	17	22
Y ganran a oedd yn cynyddu/sefydlog	67.6	60.0	48.6	64.7

Tabl 01 *Crynodeb o dueddiadau poblogaeth ar draws rhywogaethau adar â blaenoriaeth (Adran 42).*

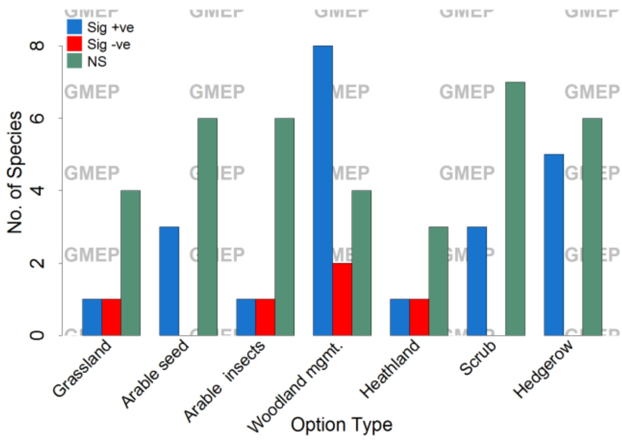
Y Cynefinoedd a'r Rhywogaethau â blaenoriaeth a adroddir yn uniongyrchol arnynt o arolwg RhMGG

O arolwg RhMGG ei hun, disgwylir y bydd digon o bŵer samplu i adrodd ar newid ar gyfer 13 o Gynefinoedd â Blaenoriaeth yn y dyfodol. Mae tueddiadau diweddar a nodwyd yn sgil dadansoddi data hanesyddol yn cael eu trafod gyda Cyfoeth Naturiol Cymru ar hyn o bryd. Efallai y bydd digon o ddata hefyd i adrodd ar ddata tuedd ar gyfer 14 o blith 50 o rywogaethau adar â blaenoriaeth a 7 o blith 15 o rywogaethau gloÿnnod byw â blaenoriaeth. Disgrifir dulliau ar gyfer adrodd ar newid mewn amodau ecolegol y byddai disgwyl iddynt ffafrio rhywogaethau eraill â blaenoriaeth megis y Pathew a'r Ystlum Pedol Lleiaf.

Effaith Glastir a chynlluniau amaeth-amgylchedd blaenorol ar fioamrywaieth

Sefydlu gwelodlin i olrhian newid yn y dyfodol yw un o'r prif resymau dros sefydlu RhMGG i redeg ochr yn ochr â'r Cynllun Glastir o'r cychwyn cyntaf. Dengys dadansoddiadau pa mor hanfodol bwysig fydd hyn er mwyn osgoi manteision cadarnhol ffug. Er enghraifft, canfuwyd cyfraddau ystadegol arwyddocaol uwch o amrywiaeth cynefinoedd a hyd gwrychoedd sy'n rhan o'r cynllun Glastir. Dangosir gwahaniaeth cychwynnol mewn dwyseddau adar mewn tir sy'n rhan o'r cynllun a thir nad yw'n rhan ohono a rhaid ystyried hynny wrth ddadansoddi effaith Glastir yn y dyfodol.

Mae gwaith hefyd wedi'i wneud i asesu effaith cynlluniau amaeth-amgylchedd y gorffennol. Adroddir rhai manteision clir yn sgil cynlluniau opsiynau Tir Gofal ar gyfer rhai newidiadau o flwyddyn i flwyddyn h.y. twf poblogaethau ar gyfer rhywogaethau adran o gymharu â 2 flynedd cyn Tir Gofal hyd 2013 yn enwedig ar gyfer rheoli coetiroedd a gwrychoedd, wedi'i ddilyn gan ddarpariaeth tir âr ar gyfer hadu a rheoli prysgwydd. Nid yw'r manteision gwaddol ar gyfer rhywogaethau planhigion a chyflwr cynefinoedd mor amlwg ond gallant gynyddu wrth i'r arolwg gwaelodlin gael ei chwblhau.



Ffigur 06 Nifer y rhywogaethau adar â chysylltiadau cadarnhaol, negyddol ac anarwyddocaol â grwpiau opsiynau Tir Gofal.

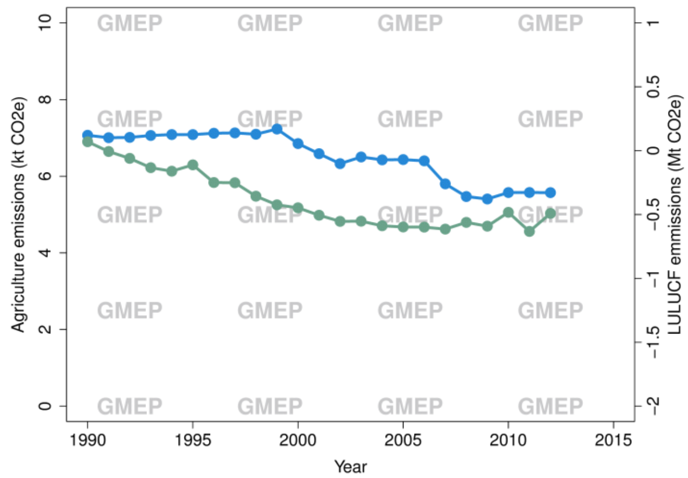
Technolegau newydd ar gyfer mesur Gwasanaeth Ecosystem 'Cefnogol'
Rydym wedi cynhyrchu map rhagfynegol manwl o Gynhyrchiant Sylfaenol Net Blynyddol (h.y. twf planhigion) ar gyfer Cymru gan ddefnyddio cyfuniad o ddata o bell a modelu nodweddion planhigion. Mae cynhyrchiant sylfaenol yn sail i lawer o'r gwasanaethau darparu gyda lefelau canolradd yn gysylltiedig â'r lefelau uchaf o fioamrywiaeth.

Lliniaru newid yn yr hinsawdd

Mae amaethyddiaeth yn parhau'n ffynhonnell sylweddol o lygredd dŵr gwasgaredig ac allyriadau nwyon tŷ gwydr yng Nghymru, er bod rhai arferion amaethyddol hefyd yn gyfrifol am golledion ac enillion o ran carbon yn y pridd. Mae Llywodraeth Cymru wedi pennu targedau cenedlaethol i leihau allyriadau nwyon tŷ gwydr, a disgwylir i'r sector amaethyddol gyfrannu at gyrraedd y targedau hyn.

Tueddiadau nwyon tŷ gwydr o'r rhestrau cenedlaethol
Yn 2012, cyfrannodd amaethyddiaeth 13% o'r allyriadau CO_2e yng Nghymru. Mae allyriadau'r sector amaethyddol o nwyon tŷ gwydr yng Nghymru wedi gostwng >20% ers 1990 (Ffigur 12). Mae'r duedd gyffredinol o ostyngiadau o allyriadau o'r pridd wedi deillio o'r gostyngiadau yn y defnydd o wrtaith nitrogen (yn arbennig ar laswelltir) a niferoedd llai o dda byw. Mae'r ffaith bod niferoedd yr anifeiliaid wedi sefydlogi yn y blynyddoedd diwethaf wedi golygu na chafwyd fawr o newid mewn allyriadau rhwng 2011 a 2012 (cynnydd o 0.2%). Mae Cymru wedi bod yn ddalfa gynyddol ar gyfer nwyon tŷ gwydr yn sgil gweithgareddau LULUCF (Ffigur 12; h.y. mae'r rhifau'n negyddol). Fodd bynnag mae nifer yr allyriadau a'r ddalfa yn wahanol iawn gan olygu mai amaethyddiaeh a defnydd tir yw'r ffynhonnell net.

Ffigur 07 Allyriadau nwyon tŷ gwydr o amaethyddiaeth a'r defnydd o dir, newid yn y defnydd o dir a choedwigaeth (LULUCF). Sylwch ar y gwahaniaethau o ran maint; 0-10 yn achos amaethyddiaeth a -2 i 1 yn achos LULUCF. Mae rhifau negyddol yn dangos defnydd o garbon. Mae'n amlwg nad yw gweithgareddau LULUCF yn gwrthbwyso allyriadau amaethyddiaeth.



Canfod yr Ôl Troed Carbon gan gynnwys allyriadau anuniongyrchol a rhai wedi'u hymgorffori
Mae'r RhMGG wedi astudio'n fanwl set o 16 o ffermydd enghreifftiol yng Nghymru i ymchwilio i effaith 4 opsiwn Glastir. Dangosodd y data effaith amrywiol ond cafodd yr effaith a fwriadwyd o leihau allyriadau nwyon tŷ gwydr ac (ym mwyafrif yr achosion) cynyddu'r broses o ddal a storio carbon mewn biomas a phriddoedd. Yr opsiwn mwyaf effeithiol yr ymchwiliwyd iddo oedd lleihau da byw. Rydym hefyd wedi casglu data gwaelodlin o set o ffermydd er mwyn mesur effeithiau Cynllun Effeithlonrwydd Glastir ar Olion Troed Carbon Ffermydd gan nad oedd digon o amser wedi mynd heibio i ffermwyr weithredu Grantiau Effeithlonrwydd Glastir ar eu ffermydd er mwyn asesu eu heffaith ar olion troed carbon. Yr ôl troed cyfartalog fesul hectar ar bob fferm oedd ca. 10 t CO_2/ha/yr, ac roeddent yn amrywio o 2 - 19 t CO_2e/ha/yr. Roedd yr ôl troed cyfartalog fesul hectar ar ffermydd llaeth bron ddwbl ôl troed ffermydd gwartheg a defaid mewn ardaloedd llai ffafriol ac roedd gan ffermydd llai ôl troed uwch ar gyfartaledd fesul hectar o dri o gymharu â fferm fwy. Yn

seiliedig ar yr astudiaeth hon, mae'r argymhellion yn cynnwys blaenoriaethu rhagor o ddyraniad grant i'r sector llaeth, yn amodol ar ddichonolrwydd.

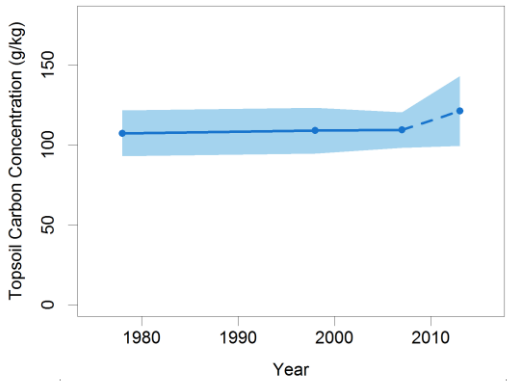
Effeithiau Newid yn yr Hinsawdd ar allyriadau nwyon tŷ gwydr
Defnyddiwyd y model ECOSSE i ymchwilio i effaith ddryslyd newid yn yr hinsawdd ar allyriadau nwyon tŷ gwydr yn sgil defnyddio a rheoli tir. Y casgliad cyffredinol yw na fydd newid yn yr hinsawdd yn cael effaith sylweddol ar fflycsau nwyon tŷ gwydr o briddoedd Cymru na thrwy gynhyrchiant sylfaenol net drwy lystyfiant erbyn 2050. Mae hyn yn deillio'n bennaf o'r gwahaniaethau bach rhwng y llinell sylfaen a senarios hinsawdd 2050 (tua ±2%).

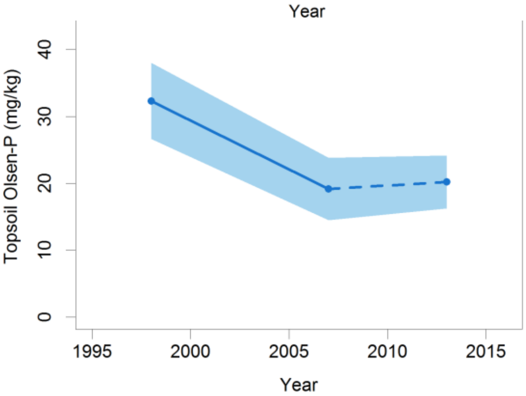
Ansawdd y pridd

Mae priddoedd iach yn creu ein bwyd, ein porthiant a'n ffeibr, gan ddarparu swyddogaethau pwysig eraill fel rheoleiddio'r hinsawdd a dŵr a gwanhau llygryddion. Maent yn system fioamrywiol ynddynt eu hunain, y mae arnynt angen cael eu bwydo a'u dyfrio. Amcangyfrifwyd eu bod yn cynnwys chwarter o fioamrywiaeth y byd, er mai gymharol brin yw'r gwaith ymchwilio a wnaed arnynt hyd yn hyn, gan mai dim ond ~1% o'r rhywogaethau a nodwyd hyd yma. Amrywiaeth y bywyd o dan ein traed yw'r peiriant sy'n ysgogi'r broses o gylchynnu maethynnau, ymddatodiad gwastraff, hidlo dŵr a thwf planhigion, a dyma pam mae priddoedd yn ganolog i'r gwaith o fonitro'r amgylchedd a bioamrywiaeth. Yn RhMGG caiff yr uwchbridd (0-15cm) ei samplo mewn 5 lleoliad ar hap o fewn pob sgwâr gerllaw lleiniau botanegol parhaol.

Y canfyddiadau allweddol:
At ei gilydd mae'r darlun yn dangos bod cyflwr yr uwchbridd yn sefydlog ar gyfer y metrigau sydd ar gael inni. Deillia hyn o ddadansoddiad o'r arolwg Cefn Gwlad ynghyd â data RhMGG. Er enghraifft:

- Ers 1978 prin yw'r newid mewn crynodiad carbon mewn uwchbridd, os o gwbl
- Yn ystod yr un cyfnod mae asidedd yr uwchbridd wedi'i leihau, a hynny yn ôl pob tebyg oherwydd gostyngiad o ran mewnbynnau dyddodiad atmosfferig asidig.
- Nid yw lefelau'r maethynnau ers 1998 pan ddechreuodd y cofnodion yn dangos dim newid i lefelau nitrogen a bod y gostyngiad diweddar mewn lefelau ffosfforws sydd ar gael yn y pridd wedi sefydlogi. Mae'r lefelau'n dal i fod yn dderbyniol ar gyfer cynhyrchu ond byddant wedi lleihau'r perygl o ffosfforws yn trwytholchi i ddyfroedd croyw.
- Ni chanfuwyd unrhyw newid mewn poblogaethau anifeiliaid y pridd ers 1998.
- Mae data gwaelodlin ar gyfer amrywiad microbaidd yn y pridd wedi'u casglu. Mae'r amrywiad pennaf yn gysylltiedig â rheoli tir yn hytrach na'r math o bridd sy'n dangos potensial gwirioneddol i Glastir ddylanwadu ar lefelau amrywiaeth y pridd.





Dylid Nodi y gall yr ystadegau uwchbridd cenedlaethol hyn guddio newidiadau o fewn cynefinoedd y dylid eu hadolygu'n unigol. O bryder penodol mae a yw systemau âr yn cynnal lefelau carbon. Ar lefel y DU mae'n hysbys eu hod yn dirywio ond nid yw niferoedd y samplau ar ôl dim ond 2 flynedd o RhMGG yn ddigonol i ganfod lefel debyg o newid yng Nghymru.

Ffigur 08 Tueddiadau hirdymor ar gyfer crynodiad carbon mewn uwchbridd (uwch) a bioargaeledd ffosfforws (is). Daw'r data o 2013 Llinell las gadarn (data CS); llinell las doredig (RhMGG 2012 Arolwg Cymru Ehangach)

Mae gwaith newydd arloesol wedi manteisio ar dechnegau moleciwlaidd i ymchwilio i amrywiaeth microbaidd yn y pridd. Wedi'i gyfuno â data o mesoffawna o 1998 a 2007, mae'n ymddangos bod uwchbriddoedd yng Nghymru yn anhygoel o amrywiol ac mae'r fioamrywiaeth hon yn ymddangos fel pe bai'n ymateb i system rheoli tir yn hytrach na math o bridd sy'n awgrymu bod gan Glastir botensial gwirioneddol i ddylanwadu ar ansawdd y pridd.

Tystiolaeth brin a geir ar gyfer erydu gan ddŵr a'r gwynt ar raddfeydd cenedlaethol ledled y DU, gan gynnwys Cymru. Nid oes gan RhMGG yr adnoddau i lenwi'r bwlch hwn; fodd bynnag mae angen inni feintoli effeithiau Glastir. Felly, rydym yn defnyddio dull modelu sy'n darparu amcangyfrifon ynghylch erydu ac arwynebedd y tir sy'n debygol o fod mewn perygl o gael ei golli drwy erydu a gwaddodion lliniarol a ddarperir. Gweler adroddiad RhMGG ar gyfer blwyddyn 1 i gael rhagor o wybodaeth.
Ni chafwyd dim tystiolaeth yn samplau cyfyngedig yr arolwg ym Mlwyddyn 1 o unrhyw wahaniaeth yn ansawdd yr uwchbridd ar dir a oedd yn dod yn rhan o gynllun Glastir. Bydd y dadansoddiad hwn yn cael ei ailadrodd pan fydd yr arolwg llawn ar gyfer Blynyddoedd 1 i 4 wedi'i gwblhau.

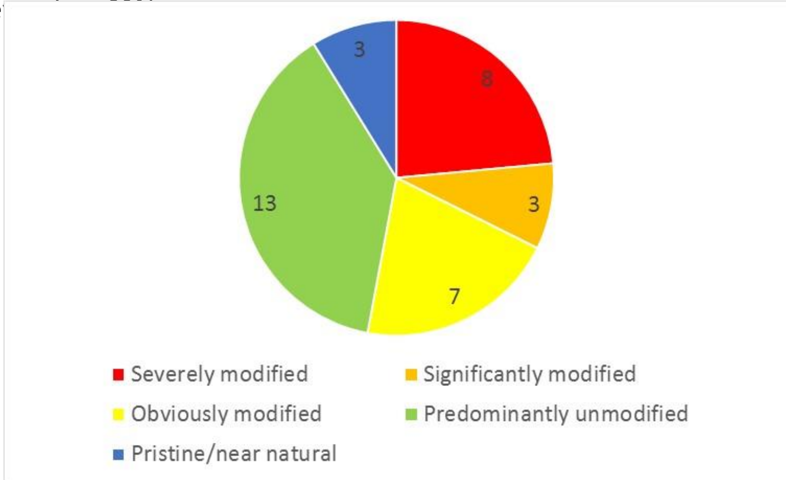
Yn olaf rydym wedi datblygu dull sy'n cyfuno setiau data pridd a gorchudd tir i asesu adnodd pridd mewn gwahanol gynefinoedd eang y gellid eu defnyddio fel sail ar gyfer datblygu Cyfrifon Cyfalaf naturiol ar gyfer priddoedd.

Dŵr croyw

Mae rhagnentydd yn rhan bwysig o'r rhwydwaith afonydd; maent fel rheol yn cyfateb i ran fwyaf hyd afonydd mewn dalgylchoedd (sef 70 i 80%, fel arfer). Mae biota rhagnentydd yn gwneud cyfraniad sylweddol ar lefel genedlaethol wrth i nifer o blanhigion ac anifeiliaid fod wedi'u cyfyngu'n ddaearyddol i'r cynefinoedd nodweddiadol hyn, tra bo rhai'n defnyddio'r cynefinoedd hyn yn dymhorol neu'n ysbeidiol. Mae rhagnentydd wedi'u tangynrychioli ar hyn o bryd yn rhaglenni monitro Cyfoeth Naturiol Cymru, a bwriedir i RhMGG lenwi'r bwlch yn hyn o beth. Bydd effaith Glastir ar afonydd mwy yn destun gwaith ymchwil gan ddefnyddio dull modelu i feintoli'r newid yng nghyfraniad amaethyddiaeth i'r mewnlif o faethynnau ym Mlwyddyn 4; fodd bynnag, bydd asesiad ffurfiol y Gyfarwyddeb Fframwaith Dŵr yn dibynnu ar asesiadau ecolegol Cyfoeth Naturiol Cymru. Nid oes unrhyw fantais yn gysylltiedig â RhMGG yn ailadrodd yr asesiad hwn.

Mae pyllau'n fwy helaeth nag afonydd a llynnoedd, ac maent i'w cael ym mron pob amgylchedd. Caiff pyllau eu cydnabod yn Erthygl 10 o'r Gyfarwyddeb Gynefinoedd am eu rôl o fod yn 'gerrig camu', a hynny rhwng cyrff dŵr eraill a gwlyptiroedd, gan gynyddu cysylltedd cynefinoedd dŵr croyw ar raddfeydd gofodol eang. O fewn RhMGG caiff sgwariau 1km eu sampl ar gyfer 1 rhagnant ac 1 pwll pan fyddant yn bresennol. Mae'r dulliau'n cyd-fynd â'r Gyfarwyddeb Fframwaith Dŵr.

Y canfyddiadau allweddol:
At ei gilydd mae'r darlun ar gyfer afonydd bach yn un o welliant sylweddol dros yr 20 mlynedd diwethaf. O fewn arolwg RhMGG, roedd yr ansawdd ecolegol ar gyfer diatomau ac macroinfertebratau yn dda/uchel me safleoedd rhagnentydd, ac roedd y crynodiadau ffosfforws yn gyson ag ansawdd da yn 85% o'r safleoedd. Fodd bynnag mewn 53% o safleoedd roedd lefelau nitrogen uwch ac mewn 91% roedd rhyw fath o addasiad i gynefin, ac roedd hwnnw'n addasiad helaeth mewn 32% o safleoedd. Mewn safleoedd Tir Isel gwelwyd cyfoethogiad o ran maeth a lefel uwch o addasu o gymharu a thir uchel, yn ôl y disgwyl



Ffigur 09: Nifer y safleoedd rhagnentydd yn y 5 dosbarth addasiadau I gynefinoedd yn arolwg RhMGG blwyddyn 1

Dim ond 8% o byllau y barnwyd bod eu hansawdd yn dda yn ecolegol, ac roedd y rhan fwyaf o'r lleill yn y categori ansawdd cymedrol (Ffigur 16). Nid yw'r asesiad hwn yn gysylltiedig â'r Fframwaith Ansawdd Dŵr, gan nad oes unrhyw brotocol asesu na dosbarthu ar gael ar gyfer pyllau ar hyn o bryd. Prif ysgogwyr y gymuned macroinfertebratau oedd ffactorau naturiol (alcalinedd, uchder) ond roedd crynodiadau ffosfforws hefyd yn ysgogydd pwysig ac roeddent yn debygol o gael eu dylanwadu gan weithgaredd dynol.

Nid oes dim tystiolaeth o wahaniaethau wedi'u harsylwi hyd yma yn achos blaenddyfroedd na phyllau yn dod yn rhan o Glastir o'u cymharu â'r rhai y tu allan i'r cynllun. Dylid nodi y bydd effeithiau Glastir ar lefelau cyfoethogi maethynnau mewn dyfroedd croyw yn fwy cyffredinol yn cael eu mesur gan ddefnyddio gwaith modelu, fel y disgrifir yn adroddiad Blwyddyn 1 RhMGG.

Tir Fferm sydd o Werth Mawr i Natur

Mae tir fferm sydd o Werth Mawr i Natur wedi'i ddiffinio'n ardaloedd yn Ewrop lle y mae amaethyddiaeth yn ddull pwysig o ddefnyddio'r tir (ac fel arfer y prif ddefnydd) a lle y bo'r amaethyddiaeth honno'n cynnal neu'n gysylltiedig naill ai ag amrywiaeth fawr o ran rhywogaethau a chynefinoedd neu bresenoldeb rhywogaethau sy'n peri pryder o safbwynt Ewropeaidd, neu'r ddau. Mae'n ddangosydd cytunedig o un o Chwe Amcan Strategol Glastir, ond mae angen ymgymryd â gwaith datblygu arno er mwyn cael consensws ynghylch bod yn fetrig dilys y gellir ei gyflwyno i'r UE. Cytunwyd yn gyffredinol y gellid r hannu tir fferm sydd o Werth Mawr i Natur yn 3 math:

- Math 1: Tir fferm sydd â chyfran uchel o lystyfiant lled-naturiol
- Math 2: Tir fferm sydd â mosäig o gynefinoedd a/neu o ddulliau o ddefnyddio'r tir
- Math 3: Tir fferm sy'n cynnal rhywogaethau prin neu gyfran uchel o boblogaethau Ewropeaidd neu'r byd

Yn yr UE, mae Aelod-wladwriaethau wedi ymrwymo i ganfod a chynnal ffermio sydd o Werth Mawr i Natur; fodd bynnag nid oes dim rheolau penodol na meini prawf a metrigau generig wedi'u pennu ar lefel yr UE i ganfod tir fferm sydd o Werth Mawr i Natur. O ganlyniad, mae pob aelod-wladwriaeth yn dehongli'r cysyniad ac yn penderfynu ar y modd gorau o'i gymhwyso i'r wladwriaeth honno.

Rhoddodd Llywodraeth Cymru y dasg i'r tîmRhMGGo ymchwilio i'r cysyniadau hyn a chynnig syniadau, meini prawf a metrigau newydd y gellid eu cymhwyso i'r broses o ddiffinio tir sydd o 'Werth Mawr i Natur', ynghyd â llunio dangosydd i bennu maint llinell sylfaen a mesur newidiadau o ran maint ac ansawdd. Rydym yn cynnal y gwaith hwn drwy ymgynghori ag ystod o bartneriaid a rhanddeiliaid sydd hefyd â diddordeb yng ngwerth posibl y metrig hwn gan gynnwys Cyfoeth Naturiol Cymru, Ymddiriedolaeth Adareg Prydian ac RSPB. Mynegwyd ystod eang o safbwyntiau sy'n amrywio o "mae hwn yn fetrig nad oes ganddo fawr o werth ac a allai beri dryswch yn hytrach na thaflu goleuni" i "metrig a all fod yn ddefnyddiol i gyfleu tueddiadau cyffredinol o ran bioamrywiaeth".

Mae RhMGG wedi casglu tabl o fetrigau a setiau data posibl i gyfrifo a phrofi tir fferm sydd o Werth Mawr i Natur. Yn bwysig mae'n rhaid i ddata fod ar gael ar raddfa genedalethol, ar ffurf sy'n berthnasol ac yn ddefnyddiol ar lawr gwlad ac y mae modd ei ailadrodd er mwyn caniatau am newid mewn trefniadau adrodd. Ar sail y gwaith a wnaed hyd yma, mae'r metrigau a ganlyn yn cael eu harchwilio ar gyfer tir fferm o Werth Mawr i Natur ym Mlwyddyn 3:

Math 1 Tir fferm sydd â chyfran uchel o lystyfiant lled-naturiol:

- Ardaloedd o bob parsel tir lled-naturiol
- % y cynefin lled-naturiol a diffinio trothwy – e.e. > 20 % - yn achos tir fferm o Werth Mawr i Fyd Natur

Math 2 Tir fferm sydd â mosäig o gynefinoedd a/neu ddulliau o ddefnyddio'r tir:

- Defnyddio'r chwartel uwch o amrywiaeth gynefinoedd (Mynegai Shannon)
- Ymgorffori cysylltedd coetir a / neu ffiniau caeau yn rhan o'r metrig
- Ymgorffori cyfoeth rhywogaethau neu bresenoldeb/helaethrwydd y rhywogaethau a ddetholwyd, yn arbennig rhywogaethau sy'n nodweddiadol o fosäig o gynefinoedd gan gynnwys tir fferm â dwysedd isel

Math 3 Tir fferm sy'n cynnal rhywogaethau prin neu gyfran uchel o boblogaethau Ewropeaidd neu'r byd:

- Ymgorffori data ar safleoedd gwarchodedig: Safleoedd Gwarchod Arbennig, Safleoedd Cadwraeth Arbennig, Safleoedd o Ddiddordeb Gwyddonol Arbennig, neu eu defnyddio ar ffurf set ddata ar wahân i'w gymharu â'r metrig ynghylch Gwerth Mawr i Natur.
- Mabwysiadu haenau targed Glastir a pharthau gwarchodedig i ganfod ardaloedd o Werth Mawr i Natur neu eu defnyddio ar ffurf set ddata i'w chymharu â metrig Gwerth Mawr i Natur
- Datblygu dangosydd ar sail data rhywogaethau, yn arbennig rhywogaethau sy'n brin neu rywogaethau y canfyddir cyfran uchel o boblogaethau Ewrop a'r byd yn y DU.

Rydym yn cyflwyno sawl dull posibl o asesu cyfraniad y pridd at dir o Werth Mawr i Natur, a hynny pe bai'r gweithgor yn penderfynu ei fod yn adnodd naturiol y dylid ei gynnwys yn y metrig hwn. Rydym yn nodi bod hyd yn oed priddoedd cyffredin Cymru yn gymharol anarferol yng nghyd-destun y byd, yn arbennig y priddoedd clai glas dŵr wyneb ac, i raddau llai, y podsolau. Gwnaethom ganfod bod pob un o'r priddoedd prin neu achlysurol wedi'i gwmpasu gan Safleoedd o Ddiddordeb Gwyddonol Arbennig, ac eithrio 1, sy'n pwysleisio'r cyswllt agos rhwng nodweddion y pridd a nodweddion ecolegol.

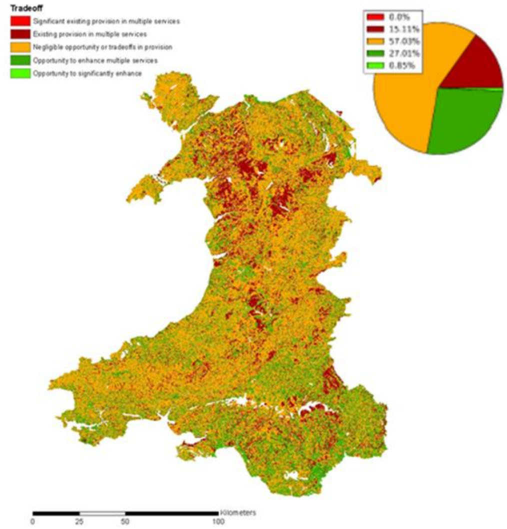
Bydd y camau nesaf yn cynnwys dull cyfranogi amser real gan Grŵp Cynghori RhMGG, a fydd yn cymharu canlyniadau o gyfuniad gwahanol o fetrigau gan ddefnyddio dull ar y we o fapio y mae'r Ganolfan Ecoleg a Hydroleg yn ei ddatblygu; bydd ar gael ym mis Ionawr 2016. Bydd canlyniadau gwahanol gyfuniadau o ddata yn cael eu cymharu ag ardaloedd gwarchodedig, haenau Glastir wedi'u targedu a metrigau eraill o ran cyfalaf naturiol a gwasanaethau ecosystem er mwyn asesu eu perthynas.

Mapio effeithiau cyfaddawd a chyfleoedd gwasanaethau'r ecosystem

Mae angen darparu offeryn cymorth ar gyfer gwneud penderfyniadau sy'n gallu helpu'r rhai sy'n llunio polisïau a rheolwyr tir i dargedu ardaloedd penodol yn nhirwedd Cymru lle y ceir y cyfleoedd mwyaf i gynyddu'r ddarpariaeth o wasanaethau ecosystem gan achosi'r effeithiau gwrthbwyso lleiaf. Rydym wedi manteisio ar ddull modelu LUCI a ddisgrifiwyd yn adroddiad Blwyddyn 1 RhMGG i gychwyn y broses hon. Dyma'r gwaith cyntaf erioed i ddefnyddio model gwasanaethau ecosystem â chymaint o fanylder gofodol a oedd yn briodol ar gyfer yr opsiynau ar raddfa gymharol fân y tu mewn i Glastir ar raddfa genedlaethol ar gyfer 7 gwasanaeth. Ym Mlwyddyn 2, rydym eto wedi defnyddio model LUCI i ganfod ymhle y ceir cyfle i wella pob gwasanaeth a phan allai'r cyfleoedd hyn wrthdaro. Dylid nodi bod model LUCI yn ystyried nid yn unig yr ardal a newidwyd ond yr ardal yr effeithir arni i lawr y llethr gan y broses o reoli tir, gan fod ganddo ddull llwybrau topograffig o ystyried llif dŵr a'r broses o gludo maethynnau/gwaddodion, hynny yw, cyfres o haenau o fapiau System Gwybodaeth Ddaearyddol yw. Yn olaf, rhaid pwysleisio bod LUCI yn darparu dull sgrinio cychwynnol defnyddiol i nodi'r ardaloedd i'w targedu ar gyfer asesiad ar lawr gwlad a darparu metrigau ar lefel genedlaethol. Argymhellir yn gryf y dylid ailedrych ar ardaloedd y nodwyd bod ganddynt botensial mawr ar gyfer gwella gwasanaethau, a hynny gyda'r model (neu ddull modelu gwasanaethau ecosystem arall) er mwyn sôn am opsiynau wrth randdeiliaid lleol gan ymgorffori'r data lleol gorau sydd ar gael. Defnyddiwyd LUCI ac yn wir cafodd ei ddatblygu i ddechrau ar gyfer y math hwn o waith ymgysylltu a thrafod lleol ar gyfer datblygu cynllunio cymunedol sy'n amlwg yn ofodol.

Canfyddiadau allweddol:
Mae gan ardaloedd sylweddol gyfle i wella statws carbon (C) (10508km^2); fodd bynnag, yn achos mwyafrif llethol y safleoedd hyn, mae gwasanaethau eraill sydd mewn cyflwr da, ac felly rhaid cymryd gofal i osgoi effeithiau niweidiol os caiff effeithiau eu targedu at wella statws C. Cynhyrchwyd metrigau a mapiau tebyg ar gyfer 6 gwasanaeth arall. Gwnaed cyfrifiadau ynghylch pob allbwn i ganfod ymhle y ceir effeithiau gwrthbwyso ac enillion cyffredinol ym mhob un o'r 7 gwasanaeth ecosystem a ystyrir. Mae'r canlyniadau'n nodi bod gan ardaloedd mawr fwy o gyfleoedd i wella gwasanaethau ecosystem gyda statws da presennol. Mae'r rhain yn cyfrif am 67% o Gymru. Mae gan bron 28% o Gymru o leiaf 2 gyfle i wella gwasanaethau uwchlaw'r gwasanaethau sydd i'w cadw.

Ymchwiliwyd i ystod o briodweddau pridd, hinsawdd a thopograffi y dirwedd i weld pa mor dda y gallent bennu darpariaeth gwasanaeth yr ecosystem. Nododd y dadansoddiad mai dim ond 3% o amyrwiad gofodol y gellid ei esbonio tra bod defnydd tir, mewn gwrthgyferbyniad, yn esbonio 40%. Mae hyn yn pwysleisio faint sy'n cael ei benderfynu nid yn unig gan ein defyndd o dir ond hefyd gan ffufwedd gofodol a thopograffi penodol a chysylltedd priodweddau'r dirwedd. Gall cyfuniad o ddata pwynt gofodol e.e. mewn haenau GIS danamcangyfrif y gwasanaeth a ddarperir mewn nifer o achosion.



Ffigur 10 Canlyniadau ar gyfer cyfaddawd rhwng statws defnydd amaethyddol, statws carbon, statws nitrogen a ffosfforws, statws erdyn, cysylltedd coetir llydanddail, a gwasanaethau lliniaru ecosystem

Cafodd asesiad o swm y tir y tu mewn i'r cynllun a'r tu allan iddo a oedd naill ai'n lliniaru dŵr ffo o law / llifogydd, neu a liniarwyd yn hynny o beth, ei gyfrifo. Mae'r canlyniadau'n awgrymu nad oes fawr o wahaniaeth rhwng y tir y tu mewn i gynllun Glastir a'r tu allan iddo, o ran nodweddion sy'n lliniaru neu a liniarwyd. Y gwerthoedd yw 19% a 21% yn achos tir sydd y tu mewn i'r cynllun ar gyfer nodweddion lliniaru, a 19% a 17% yn achos nodweddion a liniarwyd, yn y drefn honno. Bydd asesiadau pellach i asesu'r gwahaniaethau rhwng tir sy'n dod yn rhan o'r cynllun yn cael eu cynnal ym Mlwyddyn 3.

Ymysg y datblygiadau eraill mae cynnydd sylweddol o ran defnyddio gwasanaeth mapio ar y we ar gyfer LUCI sy'n briodol i ddalgylchoedd Cymru, a sefydlu dull adrodd gan LUCI sy'n fwy amserol/sy'n ymwneud â digwyddiadau, dros Gymru.

Rhagor o wybodaeth

Mae adroddiad llawn RhMGG ar gyfer Blwyddyn 2 yn amlinellu'n fwy manwl yr holl waith sy'n cael ei ddisgrifio yn y crynodeb uchod, a darperir fersiwn lawnach yn y Crynodeb o Adroddiad RhMGG, a chrynodeb mwy hygyrch a byrrach yng Nghrynodeb RhMGG ar gyfer y Dinesydd. Mae adroddiad Blwyddyn 1 RhMGG a llawer mwy o'i ganfyddiadau RhMGG ar gael ar borth data RhMGG, a lansiwyd yn ddiweddar: www.rhamagg.cymru.

GMEP Year 2 Executive Summary

The Glastir Monitoring and Evaluation Programme (GMEP) provides a comprehensive programme to monitor the effects of Glastir and contribute towards providing national trend data towards a range of national and international biodiversity and environmental targets. GMEP is now in its third year of the initial four year baseline assessment period. This annual report presents results from the second year of the programme. GMEP fulfils a commitment by the Welsh Government to establish a monitoring programme concurrently with the launch of the Glastir scheme and as such is a major development from past monitoring programmes which have only reported after schemes have been closed. The project ensures compliance with the rigorous requirements of the European Commission's Common Monitoring and Evaluation Framework (CMEF) through the Rural Development Plan (RDP) for Wales. The early findings from GMEP has already provided fast feedback to Welsh Government as to how to spatially target payments to maximise benefits as the scheme progresses.

Beyond Glastir outcome reporting, GMEP data and models may also contribute to a range of other reporting requirements including the Water Framework Directive, Habitats Directive and the Greenhouse Gas Emission Inventory and actions which arise from the Environment Bill such as the State of Nature Resources report, National Natural Resources Policy and Area Statements. Central to the Environment Bill is the need to adopt a new, more integrated, approach to managing our natural resources in a more sustainable way while safeguarding and building the resilience of natural systems to continue to provide these benefits in the long term. Resilience is considered to be greater where extent, condition, connectivity and diversity are high. Many GMEP metrics can be mapped onto these requirements and thus could be exploited to map these 4 properties for different areas in the future. These benefits will underpin certain aspects of the Well-being and Future Generations Bill. Another potential use of the GMEP data is in support of work by Defra and Welsh Government in their development of National Accounts to include aspects of the natural resources (i.e. carbon, water and soil) and their combined value as whole ecosystems (i.e. forests, wetlands etc). GMEP data can contribute to the provision of the underpinning robust and auditable data required for this activity.

GMEP will therefore improve the empirical evidence base for the current state and integrity / condition of Wales's natural assets (termed natural capital) and how these are changing in response to drivers such as climate change, land management practices and air pollution onto which Glastir options are superimposed. The challenge to the GMEP team is to isolate the changes connected to Glastir options itself which is the primary purpose of the monitoring and evaluation programme. Changes in the extent and integrity of the natural capital in turn impacts on how well they can deliver the ecosystem functions and services we need and value. This link is currently not well quantified. The distinction between natural capital and services is important as capital is a longer term asset which we want to protect for the future and is hard to value in itself, whereas the services which flow from this capital are what economists and social scientists are able to value and which have particular relevance for the Well-being of Future Generations Bill. This valuation step is an essential one if we are to provide a grounded framework for understanding the choices government and society face. The GMEP team is working on these issues through its work on landscape perception and use, social surveys and farmer practice surveys. However, there is a large topic which will need additional work beyond what resources are currently available within the GMEP project.

The GMEP team which is delivering this comprehensive programme compromises a mix of organisations with different specialisations covering the different schemes activities, objectives and outcomes. The programme is led by the Natural Environment Research Councils' Centre for Ecology

& Hydrology (CEH), an independent public research body. CEH has a research station in Bangor which provides the leadership and coordination of GMEP. The project consortium includes ADAS, APEM, Bangor University, Biomathematics and Statistics Scotland, Bowburn Consultants, British Geological Survey, British Trust for Ornithology, Butterfly Conservation, ECORYS, Edwards Consultants, Staffordshire University, University of Aberdeen, University of Southampton, and Victoria University of Wellington, New Zealand.

The GMEP approach and reporting requirements

In summary, the basic approach of GMEP is a combined data and modelling programme which utilises existing data enhanced by a major new rolling field survey which provides co-located data for a range of environmental metrics. Modelling work provides methods for integrating and upscaling survey data for national scale reporting and exploring possible future scenarios of possible outcomes of the scheme. The co-located survey data allows reporting against the six intended outcomes of Glastir and the trade-offs and co-benefits of Glastir payments between these outcomes. The six outcomes are: Combating climate change; Improving water quality and managing water resources to help reduce flood risks; Protect soil resources and improve soil condition; Maintaining and enhancing biodiversity; Managing and protecting landscapes and the historic environment; Creating new opportunities to improve access and understanding of the countryside; and Woodland creation and management.

In addition to these original Glastir Outcomes, in September 2014 the Auditor General for Wales published his report[1] on Glastir. The report contained a series of observations and related recommendations including a number associated with the setting of scheme targets and monitoring actual scheme impact against scheme targets which has had an impact on the reporting requirements of the GMEP project. He identified six Strategic Objectives. To respond to these recommendations, GMEP has worked with the Welsh Government and the GMEP Advisory Group to develop a small number of impact indicators for each Glastir Strategic Objective. These are available to view in the main GMEP Year 2 Report and on the GMEP data portal: www.gmep.wales. This indicator exploit the wide range of environmental outcomes and measurements embedded within the GMEP programme of work i.e. a range of soil and water quality metrics, landscape and historic features, plant and freshwater diversity, greenhouse gas emissions, condition assessment of historic features, pollinator and four bird surveys, socio-economic surveys of benefits to the farming and forestry industries and the wider Wales community.

The GMEP cycle

As GMEP survey sites are revisited on a 4-year rolling cycle and we are currently in Year 3 of this initial 4 year cycle, the current Year 2 results contribute towards a baseline against which the future impacts of Glastir payments will be assessed. By Glastir Outcome, work focussed on biodiversity (including woodland habitats) accounts for 42% of the total GMEP budget, 41% is allocated across soils, waters, climate change mitigation, landscape and historic features, trade-offs and co-benefits, and the remaining 17% allocated to underpinning activities such as informatics, the data portal and project management. The field survey involves two parts namely the Wider Wales and Targeted components. The Wider Wales survey squares are chosen to represent the background conditions across Wales and are chosen by randomly sampling within assigned land classes. This helps GMEP to deliver the required data on national trends. Targeted squares are then chosen to specifically capture Glastir related activity.

[1] http://audit.wales/publication/glastir

Summary of progress

Years 1 and 2

Within Year 1, GMEP focussed on establishing the field programme and using an ensemble of models to explore potential outcomes from different scenarios of uptake of 6 Glastir options. In Year 2, we have continued with the field survey and focussed on analysis of Years 1 & 2 data together with data from other sources notably Natural Resources Wales, the National Forestry Inventory, Plantlife, UK Butterfly Monitoring Scheme, the Breeding Bird Scheme and Countryside Survey. Long term trends identified are reported here (or in the data portal). We also analysed the GMEP data to identify if land coming into the scheme was different in quality to that outside, and if we could detect the legacy effects of past agri-environment schemes. The biodiversity team focussed on developing techniques for reporting on impacts for Priority species and habitats with work continuing on the development and testing of the landscape quality/perception tool. Modelling efforts were focussed on establishing the baseline data for direct and indirect greenhouse gas emissions in response to Glastir Efficiency Grants funding and assessing possible confounding effect of climate change on greenhouse gas emissions. Soil and freshwater analysis reports on Year 1 data only due to the time required for biodiversity assessment. An analysis of 7 ecosystem services and their potential trade-offs was carried out including the development of a metric to estimate area of land mitigating runoff/flood. Work also included a major new and completed piece of work involved developing new methods for mapping and assessing the condition of peat soils of Wales and their potential contribution to reducing greenhouse gas emissions.

Future plans for Years 3 and 4

Year 3:

- The field survey for Year 3 is already underway with 75 squares selected for survey.
- A decision regarding the inclusion of Countryside Survey squares into the Wider Wales Survey of GMEP will be sought
- Finalisation of the new High Nature Value (HNV) Farmland indicator.
- Development and launch of the GMEP Data Portal at the Royal Welsh Show 2015.
- Reporting of metrics needed for the new agreed 6 Strategic Objectives and Targets for Glastir under development by the Welsh Government. These metrics together with high level indicators for the 6 Glastir Outcomes will be used to provide annual updates through the GMEP Data Portal.

Year 4:

- Completion of the final 75 1km field survey squares to complete the 300 GMEP baseline 1km survey squares will be undertaken.
- Repeat of the Farmer Practice Survey in the summer of 2016 to identify actual changes on the farm and any benefit to farm and forestry profitability and resilience.
- Modelling work to identify benefits of Glastir for water quality in Water framework Directive catchments based on changes quantified in the Farmer Practice Survey of summer 2016 for reporting in Spring 2017
- Farmer interviews combined with modelling to quantify benefits to direct and indirect greenhouse emissions by farm type.

Key findings

The following represents a high level summary of some of the key findings structured by Glastir outcome with additional sections added for analysis of Glastir uptake, peat soils, High Nature Value farmland and Ecosystem trade-offs and opportunities. Many others results can be found in the full report or in the GMEP Data Portal www.gmep.wales.

Analysis of Glastir Uptake

[2]4,911 unique entrants were identified as having joined the scheme by Dec 2014. The total area covered by Glastir options is 3,263 km^2, 19% of the available LPIS area and 16% of the total Wales land area. Uptake of Glastir applied most to biodiversity and climate change depending on the metric used to assess uptake. The Woodlands Outcome had the fewest entrants. If the levels of uptake are compared to amounts of points available, clearly points have driven uptake with only 308km^2 (ca. 1% of Wales) where there was high uptake in areas with low points. However, there was 3041km^2 (ca. 15% of Wales) with high points where there was little or no uptake. Habitat representation in this category was proportional to that observed in the high uptake /low points with the exception of coniferous woodland which appears to be overly represented i.e. it has had disproportionally low uptake.

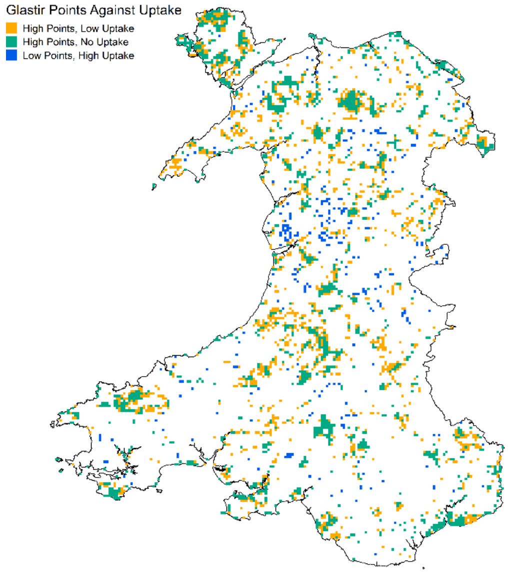


Figure 01 Areas of low or no uptake / high points (yellow and green) and high uptake / low points (blue)

Coverage by GMEP of Glastir

In total, 197 of the 260 GMEP 1 km survey squares (76%) currently selected or surveyed overlap with some form of Glastir uptake parcel. By Outcome, the overlap within GMEP squares indicates a similar distribution to uptake numbers with the majority capturing biodiversity options with 78% of land parcels with biodiversity options. This compares to 62% in the scheme. As for uptake, Woodlands had the lowest coverage in GMEP at 16%. This compares to 10% in the scheme.

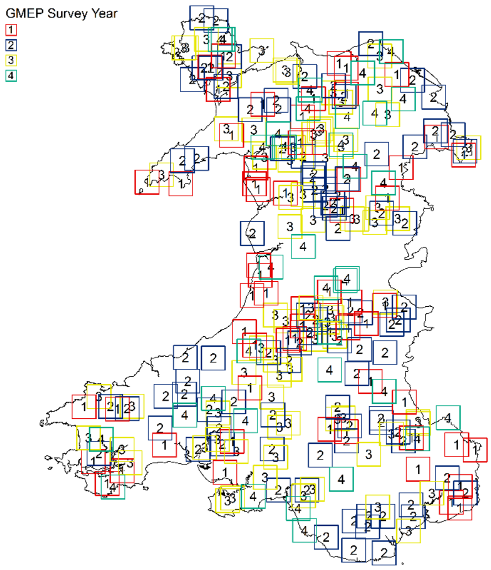


Figure 02 Distribution of GMEP 1km survey squares but enlarged to cover 10km grid to protect locations. Squares include Years 1-3 Wider Wales Survey and Targeted Survey but only Wider Wales Survey for Year 4 as Targeted Survey will be selected according to uptake in autumn 2015.

Field survey update

The main biophysical survey of 90 1km squares to deliver the Year 2 baseline survey was delivered from April to Sept 2014. 68% of landowners contacted who had landholdings with the GMEP 1km survey squares gave permission to survey, 5% refused access, with the remainder providing no response. In total 80% of land within the 90 1km survey squares was surveyed in 2014. This co-located integrated programme of monitoring and survey which includes measurement from soils to greenhouse gases and waters, plants to birds and pollinators, landscape to historic features and

[2] These assessments are based on allocation by the project team as the actual intended outcome of the payments intended by the Glastir Project Officer was not available at the time of writing this report.

landscape perception enables the inter-dependencies between these elements to be explored in future reports. It is consistent with the aims of the Environment Bill to develop more integrated approaches to managing our natural resources in a more sustainable way.

Peat soils

Peat soils cover 4.3% of Wales, and support nationally and internationally rare bog and fen habitats. In addition to their importance for biodiversity, peat soils act as Wales' largest terrestrial ecosystem store of carbon, and in good condition have the potential to contribute to climate regulation through ongoing CO_2 sequestration. However, Welsh peat soils have been detrimentally impacted by centuries of human activity including drainage, over-grazing and conversion to grassland and forestry. As a result Welsh peat soils are currently thought to act as a source of greenhouse gas (GHG) emissions. Measures supported through Glastir aim to reduce these emissions, and to restore the carbon sequestration function of Welsh peat soils, through a reduction in land-use pressures on a range of both upland and lowland bogs and fens. GMEP was commissioned in year 2 to do a major piece of new work to develop improved metrics for assessing the condition of peat soils in Wales.

Key findings:

Outputs include a new unified peat map which should allow a more reliable assessment of the state of the Welsh peat resource as a whole, with better representation of lowland peats, and more accurate targeting of Glastir peat soil-related measures on those areas where peats are present. This map has now been passed to Glastir Contract Managers to use when negotiating new Glastir Agreements.

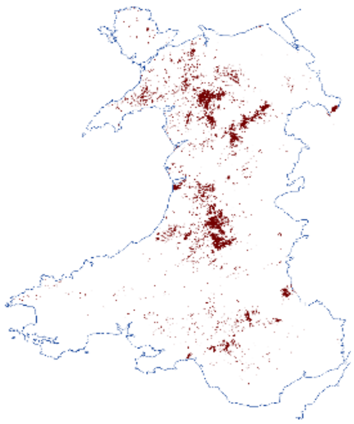


Figure 03 A new unified peat map of Wales

With respect to peat soil condition, overall the picture is one of highly modified peat soils across Wales with only 30% in good condition. As a result of these activities, Welsh peat soils are currently estimated to be generating 'anthropogenic' emissions of around 400 kt CO_2-equivalents per year (equating to around 7% of all Welsh transport-related emissions). This compares to an estimated natural 'reference' condition (i.e. if all the currently mapped peat area was natural bog or fen) of approximately 140 kt CO_2-eq yr^{-1} The only recent improvements are in the cessation of peat extraction and in the condition of bogs i.e. using plant species as a proxy for bog condition, between 1990 and 2007 there was a slight increase in the number of characteristic ('positive indicator') bog species presumably due to recent targeting of bogs for restoration.

Socio-economic benefits

GMEP undertakes a range of activities to capture the wider socio-economic benefits of the Glastir scheme. These benefits may arise from a range of Glastir activities including payments from farmers into the local community for labour or services to more indirect pathways such as an improved visual landscape quality which has the potential to benefit both local communities and the tourism industry. More generally it is hoped the greater protection of our natural resources intended from Glastir payments will contribute to the 'Resilient Wales' Goal of the Well-being and Future Generations Bill.

Key findings:
Respondents to a survey of farmers receiving Glastir Efficiency Grants reported 44% farm customers and clients had experienced beneficial financial effects from the grants indicating off-farm benefits into the wider community. More than 90% of respondents agreed that Glastir Efficiency Grants (GEGs) had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GEGs increased their scale of planned investment.

A GMEP survey identified greater flexibility and simplicity of the application process with less threatening audit process were all potential improvements to make to increase uptake of the Woodland Creation Scheme.

More than 2600 respondents have taken part in a survey to test a visual landscape quality (VQI) index developed by GMEP. Differences in landscape preferences by e.g. gender, age, nationality, location type of birth and current home were all explored. Surprisingly few differences were identified. This index is being used to assess impacts of Glastir on landscape quality and the links between ecological and landscape quality.

Half of historic features assessed were found to be in excellent or sound condition. Vegetation was the most prevalent threat. Two thirds of public rights of way fully open, physically accessible and easy to find. Changes in both due to Glastir will be reported when GMEP 1km squares are resurveyed.

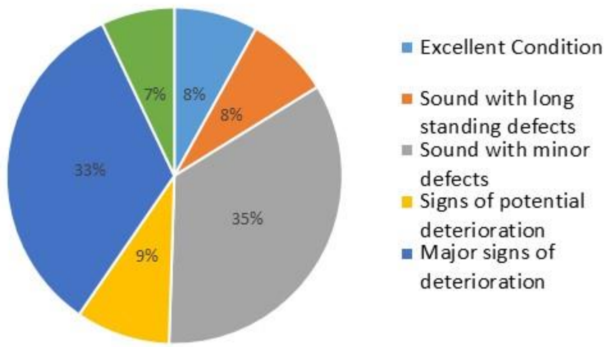


Figure 04 shows condition of Historic Environment Features (HEF's) from years 1 and 2 of GMEP 1km survey squares.

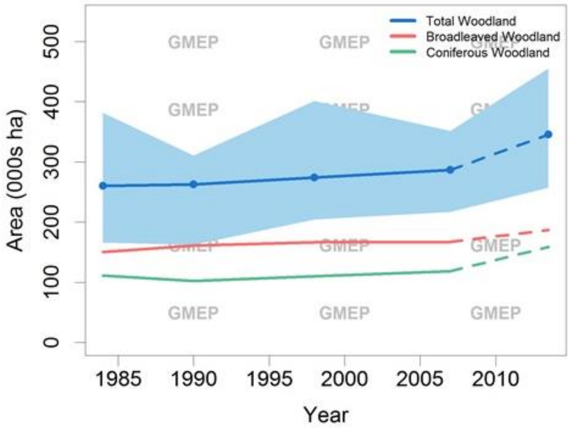
Woodlands

Woodlands are important for the provision of multiple Ecosystem Services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million. A recent survey demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community.

Key findings:

Combining data from GMEP with Countryside Survey provides long term trend information. Overall the trend for woodland stock and condition is one of increased area but little evidence of improved condition. GMEP captures small areas of woodland which are very relevant to Glastir but are not captured by the Forestry Commission.

Figure 05 The area of woodland in Wales over time, created by national estimates from field survey from Countryside Survey (solid line) and GMEP (dotted line) data.



Groundflora data suggests woodlands may be more overgrown with increased shading, possibly due to less management. No consistent change in the Ancient Woodland Index was noted since 1990

There is no evidence of increased connectivity of woodland since 1990. An increase in cutting of hedgerows has been recorded but also large declines in new planting, layering and coppicing since 1990. An increase in the length of hedgerows becoming lines of trees suggests a decline in management overall. Land coming into Glastir is notably more rich in hedgerow length which will need to be taken into consideration in future analyses of Glastir impact to avoid false attribution of this initial difference to Glastir.

We have developed a new Woody Cover Product (WCP), which maps large hedgerows, individual trees and small patches of woodland, as well as larger woodland, across the whole of Wales at a 5m x 5m scale. The product uses a combination of airborne radar data (NEXTMap®), optical imagery from satellites and data from the National Forest Inventory. This has numerous potential applications, including investigations of habitat connectivity, modelling catchment run-off processes and quantification of carbon stocks. When validated against aerial photography for several test sites the product had a classification accuracy of 88 %.

Biodiversity

The conservation of biodiversity in Wales is motivated by the value people place on a rich heritage of wild species and habitats. Particular habitats and species have a stronghold in Wales whilst being rare or absent elsewhere in the UK and Europe so that Wales has a particular responsibility for their monitoring and conservation. In 2007 the Environment Agency Wales estimated that "wildlife-based activity" contributed a total output of £1.9 billion per year to the Welsh economy which exceeded the total agricultural output in 2011 of 1.3 billion. Therefore the contribution of biodiversity to prosperity, well-being and job creation in Wales should not be underestimated.
GMEP methods are particularly well suited to reporting change changes in biodiversity in the wider countryside which surround designated areas and thus provide important areas for species and habitats to connect and respond to changing environmental conditions such as climate change. In addition, GMEP has developed methods for detecting Glastir impacts on section 42 species and habitats determining the coincidence of options with species and habitats and deriving new indices of long term trends in biodiversity as the backdrop to GMEP. We are also developing methods to characterise High Nature Value farmland and to extend our estimates of biodiversity change and impacts of Glastir outside of the sample of GMEP 1 km survey squares and into wider Wales by integration with remotely sensed data products and biological records databases. For brevity not all national trend data are reported here but are available within the GMEP Data Portal. Data on Priority Habitats extent and condition are not yet available.

Key findings:

Analysis of long term species data

The overall picture for long term trends in biodiversity is some evidence of recent stability for some elements of biodiversity but little evidence currently of improvement. This emerges from new GMEP analysis of long term data from sources such as the UK Butterfly Monitoring Scheme, data held by the Biological Record Centre from a wide range of monitoring programme, the BTO/JNCC/RSPB Breeding Bird Survey and other bird survey data from a range of sources and Countryside Survey. For example. A newly constructed Priority Bird Species Index for 35 species with sufficient trend data available in Wales indicates at least half as increasing or stable since 1994 but with no pattern for an overall improvement in population health over time.

	1994-1999	**2000-2004**	**2005-2009**	**2010-2014**
Number of species with trend data	34	35	35	34
Number increasing/stable	23	21	17	22
Percentage increasing/stable	67.6	60.0	48.6	64.7

Table 01 Summary of population trends across priority (Section 42) bird species.

Priority Habitats and Species reporting direct from the GMEP survey

From the GMEP survey itself, it is expected there will be sufficient sampling power to report on change in extent for 13 Priority Habitats in the future. Recent trends identified from analysis of historical data are currently being discussed with NRW. There may also be sufficient data for reporting on trend data for 14 of 50 priority bird species and 7 of 15 priority butterfly species. Methods for reporting change in ecological conditions that would be expected to favour other priority species such as the Dormouse and the Lesser Horseshoe Bat are described.

Impact of Glastir and past agri-environment schemes on biodiversity

Establishing a baseline to track future change is one of the main reasons for establishing GMEP to run alongside the Glastir Scheme from its inception. Analyses indicate how critical this will be if false positives benefits are to be avoided. For example, statistically significant higher habitat diversity of land and length of hedgerows entering the Glastir scheme have been detected. Initial difference in baseline bird densities of land in and out of scheme are indicated which must also be taken into consideration in future analyses of Glastir impact.

Work has also been undertaken to assess the impact of past agri-environment schemes. Some clear benefits of Tir Gofal options for some year to year changes i.e. population growth for bird species from 2 years before TIr Gofal to 2013 are reported particularly for woodland and hedgerow management, followed by arable seed provision and scrub management. Legacy benefits for plant species and habitat condition are less clear but may increase as the baseline survey is completed.

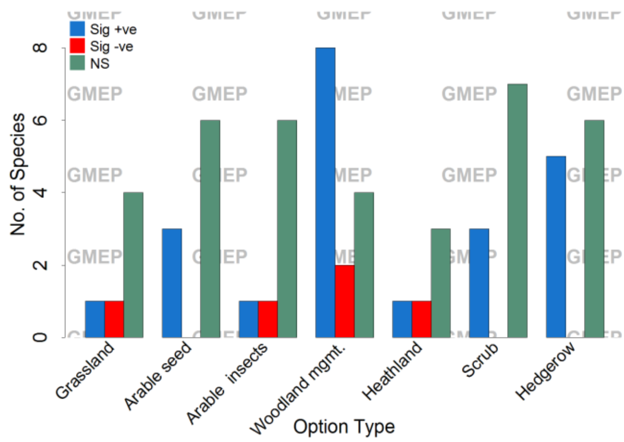


Figure 06 Numbers of bird species with positive, negative and non-significant associations with TG option groups.

New technologies for quantifying a 'Supporting' Ecosystem Service

We have produced a finely resolved predictive map of Annual Net Primary Productivity (i.e. plant growth) for Wales using a combination of remotely sensed data and plant trait modelling. Primary productivity underpins many of the provisioning services with intermediate levels related to highest levels of biodiversity.

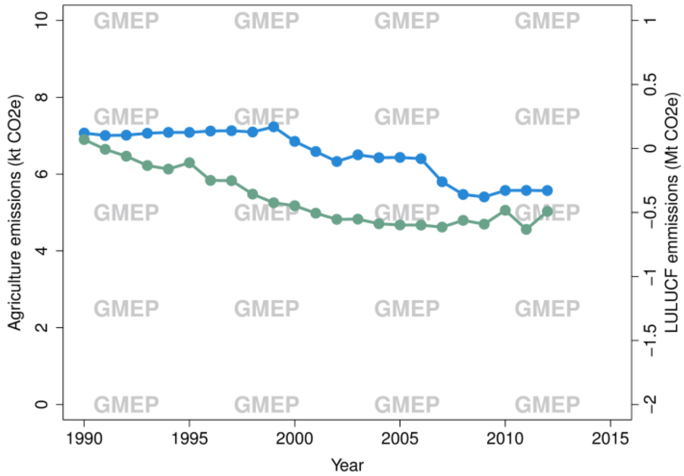
Climate change mitigation

Agriculture continues to be a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets.

Greenhouse gas emission trends from the national inventories

In 2012, Agriculture contributed 13% of CO_2e emissions in Wales. Agricultural sector GHG emissions in Wales have decreased by >20% since 1990 (Figure 12). The overall trend in reductions of emissions from soil have been the result of reductions in fertiliser nitrogen use (particularly in grasslands) and reduced numbers of livestock. The stabilisation of animal numbers in recent years means that there has been little change in emissions between 2011 and 2012 (0.2% increase). Wales has been an increasing net sink of greenhouse gases from LULUCF activities (Figure 12; i.e. numbers are negative). However the scale of emissions and sink is very difference resulting in agriculture and land use being a net source.

Figure 07 Greenhouse gas emissions from agriculture and land use, land use change and forestry (LULUCF). Note the differences in scale; 0-10 for agriculture and -2 to 1 for LULUCF. Negative numbers indicate an uptake of carbon. LULUCF activities are clearly not compensating for emissions from agriculture.



Carbon Footprinting including indirect and embedded emissions

GMEP has studies in depth a set of 16 Welsh model farms to explore the impact of 4 Glastir options. The data indicated a variable impact but did have the intended effect of reducing GHG emissions and (in most cases) increasing C-sequestration in biomass and soils. The most effective option explored was reductions in livestock. We have also collected baseline data from a set of farms to quantify the effects of the Glastir Efficiency Scheme of Farm Carbon footprints as insufficient time had passed for farmers to implement GEGs grants on their farms to assess their effect on carbon footprints. The average estimated footprint per hectare across all farms was ca. 10 t CO_2/ha/yr, and ranged from 2 – 19 t CO_2e/ha/yr. The average footprint per hectare on dairy farms was almost double that of LFA cattle and sheep farms with smaller farms averaging a higher footprint per ha of land than larger farm. Based on this study recommendations include prioritisation of further grant allocation to the dairy sector, subject to feasibility.

Effects of Climate Change on Greenhouse gas emissions

The ECOSSE model was used to explore the potential confounding impact of climate change on greenhouse gas emissions from land use and management. The overall conclusion is that climate change will not significantly affect net GHG fluxes from Welsh soils or by net primary productivity by vegetation by 2050. This is primarily a result of the small differences between the baseline and 2050 climate scenarios (about ±2%).

Soil quality

Healthy soils produce our food, feed and fibre, whilst providing other important functions such as regulating climate and water and attenuating pollutants. They are a biodiverse ecosystem in themselves needing to be fed and watered, and contain an estimated quarter of global biodiversity, whilst remaining relatively unexplored with only ~1% of species as yet identified. It is the diversity of life below our feet that provides the engine fuelling nutrient cycling, breakdown of waste, water filtration and plant growth which is why soils are central to environmental and biodiversity monitoring. Within GMEP topsoil (0-15cm) is sampled in 5 random locations within each square alongside permanent botanical plots.

Key findings:

Overall the picture is one of stability in topsoil condition for the metrics we have available to us. This emerges from analysis of Countryside survey together with the 2013 GMEP data. For example:

- There has been no over little change in topsoil carbon concentration in Wales since 1978.
- During the same period soil acidity was reduced probably due to decreased inputs of acidic atmospheric deposition.
- Nutrient levels since 1998 when records started indicate no change in nitrogen levels and a stabilisation of a recent decline in soil available phosphorus levels. Levels are still acceptable for production but will have reduced the risk of phosphorus leaching to freshwaters.
- No change in soil animal populations were found since 1998.
- Baseline data for soil microbial diversity have been collected. Variation is found to be predominanatly linked to land management rather than soil type which indicates real potential for Glastir to influence levels of soil diversity.

It should be noted these national topsoil statistics may mask changes within habitat types which should be reviewed individually. Of particular concern is whether arable systems are maintaining carbon levels. At the UK scale they are known to be in decline but sample numbers after only 2 years of GMEP are currently not sufficient to detect a similar level of change within Wales.

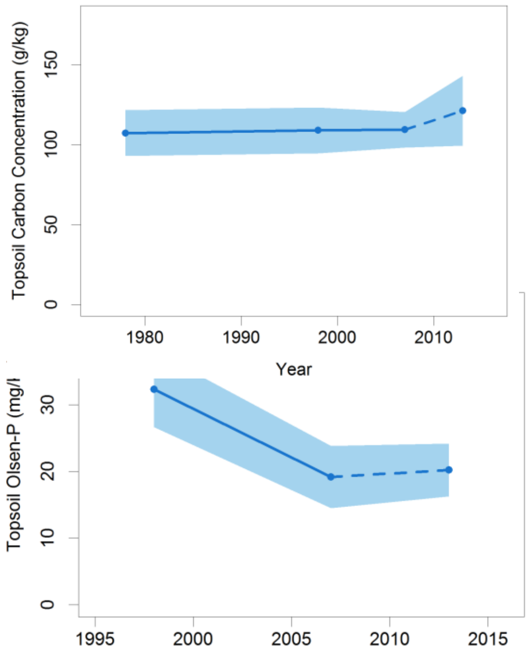


Figure 08 Long term trend data for topsoil carbon concentration (upper) bio-available phosphorus (lower). Data are 2013 Solid blue line (CS data); dashed blue line (GMEP 2013 Wider Wales Survey).

Innovative new work has exploiting new molecular techniques to explore soil microbial diversity. Combined with data from mesofauna from 1998 and 2007, it appears top soils in Wales are incredibly diverse and this biodiversity appears most responsive to land management regime rather than soil type indicating Glastir has real potential to influence soil quality.

Evidence for water and wind erosion is sparse at national scales across the UK including Wales. GMEP does not have the resources to fill this gap however we need to quantify the impacts of Glastir. We are therefore using a modelling approach which provides both erosion estimates and area of land likely to be at risk of erosion loss and mitigating sediment delivery. See the GMEP year 1 report for more information.

No evidence of the limited samples in the Year 1 survey of any difference in topsoil quality of land coming into the Glastir scheme. This analysis will be repeated when the full Year 1-4 survey is complete.

Finally, we have developed a method which combines soil and land cover data sets to assess soil resource areas under different broad habitats which could be used as the basis for developing Natural Capital Accounts for soils.

Freshwater

Headwater streams are an important part of the river network, they typically account for most of river length in catchments (typically 70 to 80 %). The biota of headwater streams makes a significant contribution to biodiversity at a national level with many plants and animals geographically restricted to these characteristic habitats, while some use these habitats seasonally or intermittently. Headwater streams are currently under-represented in NRW monitoring programmes which GMEP is intended to fill. The impact of Glastir on larger rivers will be explored using a modelling approach to quantify change in the contribution of agriculture to nutrient inflow in Year 4 however formal WFD assessment will rely on NRW ecological assessments. There is no benefit of GMEP repeating this assessment. Ponds are more abundant than rivers and lakes, and are found in virtually all environments. Ponds, are recognised in Article 10 of the EU Habitats Directive for their role as 'stepping stones', between other waterbodies and wetlands, increasing freshwater habitat connectivity at wide spatial scales. Within the GMEP, 1 km survey squares are sampled for 1 headwater stream and 1 pond when present. Approaches are WFD compliant.

Key findings:

Overall the picture for small rivers is one of recent significant improvement over the last 20 years. Within the GMEP survey, ecological quality for diatoms and macroinvertebrates was good/high in over 60% of headwater stream sites, and phosphorous concentrations were consistent with good quality at 85% of the sites. However 53% of sites had elevated nitrogen levels and 91% had some form of habitat modification, which was extensive in 32% of sites Lowland sites demonstrated nutrient enrichment and higher levels of habitat modification than uplands, as expected.

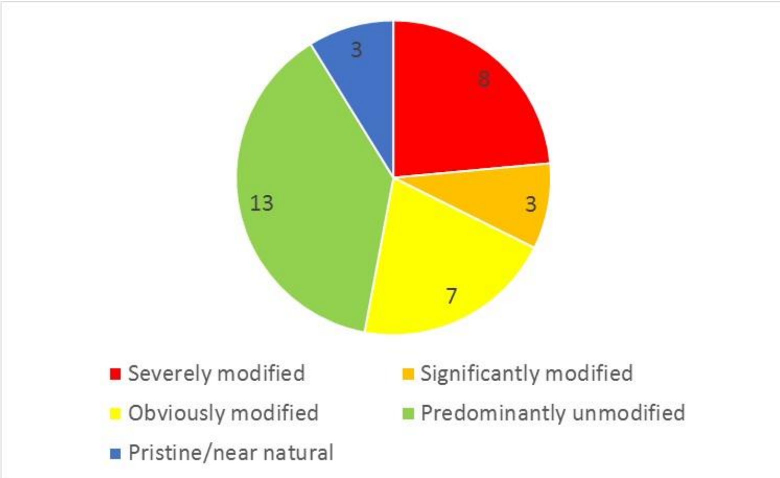


Figure 09: Number of headwater sites falling in the 5 habitat modification classes in GMEP survey from year 1

Only 8% of ponds were judged to be in good ecological quality, most others fell under moderate quality (Figure 16). This assessment is not related to WFD, as no assessment and classification protocol currently exists for ponds. The main drivers of the macro-invertebrate community were natural (alkalinity, altitude) but phosphorous concentrations were also an important driver and are likely to be influenced by human activity.

No evidence of differences to date have been observed for headwaters or ponds coming into Glastir compared to that outside of the scheme. It should be noted, impacts of Glastir on nutrient enrichment levels in freshwaters more generally will be quantified using a modelling work as described in the GMEP Year 1 report.

High Nature Value Farmland (HNV)

HNV farmland has been defined as 'areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European concern or both'. It is an agreed indicator of one of the six Strategic Objectives of Glastir but requires development work to gain consensus as a valid metric which can be reported to the EU. It has been generally agreed that HNV farmland can be broken down into 3 types:

- Type 1: Farmland with a high proportion of semi-natural vegetation
- Type 2: Farmland with a mosaic of habitats and/or land uses
- Type 3: Farmland supporting rare species or a high proportion of European or world populations

Within the EU, Member States are committed to identifying and maintaining HNV farming; however, there are no specific rules or generic metrics and criteria established at EU level to determine HNV farmland. Each member state therefore interprets the concept and decides how best to apply it to their state. The GMEP team have been tasked by WG to explore these concepts and propose new ideas, criteria and metrics that might be applied to define land of 'High Nature Value' and form an indicator to create a baseline extent and measure changes in extent and quality. We are conducting this work in consultation with a range of partners and stakeholders who are also interested in the potential value of this metric including NRW, BTO and RSPB. A wide range of views were expressed which range from this "is a metric of little value which could confuse rather than illuminate" to "a potentially useful metric to communicate overall trends in biodiversity".

GMEP has collated a table of possible metrics and datasets to calculate and test HNV. Critically data has to be available at a national scale, at a resolution which is applicable and useful on the ground and repeatable to allow for change reporting. We have tested for four case study areas and based on the work undertaken so far the following metrics are being explored for HNV farmland in Year 3:

Type 1 Farmland with a high proportion of semi-natural vegetation:

- Areas of all semi-natural land parcels
- % semi-natural habitat and define a threshold – e.g. > 20 % - for HNV farmland

Type 2 Farmland with a mosaic of habitats and/or land uses:

- Use upper quartile of habitat diversity (Shannon's Index)
- Incorporate woodland connectivity and / or field boundaries into the metric
- Incorporate species richness or presence/abundance of selected species, particularly species which are characteristic of a mosaic of habitats including low intensity farmland

Type 3 Farmland supporting rare species or a high proportion of European or world populations:

- Incorporate data on protected areas SPAs, SACs, SSSIs or use as a separate dataset to compare HNV metric to.
- Adopt Glastir target layers and protected zones to identify HNV areas or use as a dataset for comparison with an HNV metric
- Develop an indicator based on species data, particularly species which are rare or species for which a high proportion of European or world populations are found in the UK.

We present several methods of potentially assessing the contribution of soil to High Nature Value land should the working group decide it is a natural resource which should be included in the HNV metric. We report that even common Welsh soils are relatively unusual in the global context, especially the surface-water-gley soils and to a lesser extent the podzols. We found that all of the rare or occasional soils are covered by SSSI's bar 1 emphasising the close link between soil and ecological properties.

Next steps will include a real-time participatory approach by the GMEP Advisory Group comparing outcomes from different combination of metrics using a web based data mapping tool CEH is developing which will be available in January 2016. Outcomes of different data combinations will be compared to protected areas, Glastir target layers and other metrics of natural capital and ecosystem services to assess their relationship.

Ecosystem Service Trade-off and opportunity mapping

There is a need to provide a decision-support tool which can help policy makers and land managers target specific areas in the Welsh landscape where opportunities are greatest to increase ecosystem service provision with minimal trade-offs. We have exploited the LUCI modelling tool described in the GMEP Year 1 report to start this process. This work was the first ever deployment of an ecosystem service model with such fine spatial resolution appropriate for the relatively fine scale options within Glastir at a national scale for 7 services. In Year 2, we have again used the LUCI model to identify where there is an opportunity to improve each service and where these opportunities may conflict. It should be noted that the LUCI model takes into account not just the area modified but the area affected downslope by land management as it has a topographical routing approach to water flow and nutrient/sediment transport i.e. it is not a suite of GIS map overlays. Finally it must be emphasised, LUCI provides a useful initial screening tool to identify areas to target for a ground-based assessment and provide national based metrics. It is strongly recommended that areas identified as having high potential for service improvement be re-visited with the model (or another ecosystem service modelling tool) to iterate options with local stakeholders incorporating best available local data. LUCI has been used, and indeed was initially developed, for this type of local engagement and negotiation approach to development of spatially explicit community planning.

Key findings:
Significant areas have opportunity to improve carbon (C) status (10508km^2), however for the vast majority of these sites, there are other services in good condition, so care must be taken to avoid detrimental effects if options are targeted at improving C status. Similar metrics and maps have been produced for the 6 other services. Calculations have been performed on all outputs to identify where there are trade-offs and win-wins across all 7 ecosystem services considered. Results indicate large areas have more opportunities to improve than services with existing good status. These "win-wins" account for 67% of Wales. Almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.

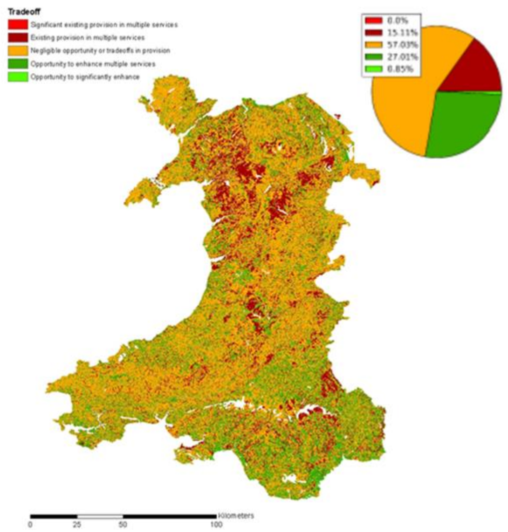


Figure 10 Outcomes for trade-offs between agricultural utilisation status, carbon status, nitrogen and phosphorus status, erosion status, broadleaved woodland connectivity and flood mitigation ecosystem services

We explored a range of soil, climatic and topographical properties of the landscape to see when combined how well they could determine ecosystem service provision. The analysis identified only 3% of the spatial variation could be explained whilst land use in contrast explained 40%. This emphasises how much is determined not only but our use of the land but also the specific spatial and topographical configuration and connectivity of landscape properties. Combination of spatial point data e.g. in GIS overlays may underestimate service provision in many cases.

An assessment of the amount of land inside and outside of the scheme which was either mitigating or mitigated for rainfall runoff / flood mitigation was calculated. The results suggests there is little difference between the land inside and outside of the Glastir scheme currently with respect to either mitigating or mitigated features. The values are 19% and 21% for land in and out of scheme for mitigating features and 19% and 17% for mitigated features respectively. Further assessments to assess differences between land coming into the scheme will be undertaken in Year 3. Other developments includes significant progress on deploying a web-mapping service for LUCI appropriate for Welsh catchments, and setting up for more temporal /event reporting from LUCI over Wales.

Further information

The complete Year 2 GMEP report outlines in more detail all the work described in summary above with a fuller summary provided in the 'GMEP Report Summary' and a more easily accessible and shorter summary in the 'GMEP Citizen Summary'. The GMEP Year 1 report and many other GMEP findings can be found on the recently launched GMEP data portal www.gmep.wales.

Crynodeb o Adroddiad Blwyddyn 2 RhMGG

Mae Rhaglen Monitro a Gwerthuso Glastir (RhMGG) yn darparu rhaglen gynhwysfawr i fonitro effeithiau Glastir a chyfrannu at ddarparu data am dueddiadau cenedlaethol tuag at ystod o dargedau cenedlaethol a rhyngwladol sy'n ymwneud â bioamrywiaeth a'r amgylchedd. Erbyn hyn, mae RhMGG yn ei thrydedd flwyddyn o'r cyfnod asesu llinell sylfaen pedair blynedd cychwynnol. Mae'r adroddiad blynyddol hwn yn cyflwyno canlyniadau ail flwyddyn y rhaglen. Mae RhMGG yn cyflawni ymrwymiad gan Lywodraeth Cymru i sefydlu rhaglen fonitro ar yr un pryd â lansio cynllun Glastir, ac felly mae'n ddatblygiad mawr o'i gymharu â rhaglenni monitro yn y gorffennol, sydd wedi cyflwyno adroddiadau ar ôl i gynlluniau ddod i ben yn unig. Mae'r prosiect yn sicrhau y cydymffurfir â gofynion trylwyr Fframwaith Monitro a Gwerthuso Cyffredin Comisiwn Ewrop (CMEF) drwy gyfrwng y Cynllun Datblygu Gwledig i Gymru. Mae canfyddiadau cynnar RhMGG eisoes wedi darparu adborth cyflym i Lywodraeth Cymru o ran sut i dargedu taliadau'n ofodol i sicrhau'r manteision gorau wrth i'r cynllun fynd yn ei flaen.

Y tu hwnt i'r broses o gyflwyno adroddiadau ar ganlyniadau Glastir, bydd data a modelau RhMGG hefyd yn cyfrannu at ystod o ofynion adrodd eraill, gan gynnwys y Gyfarwyddeb Fframwaith Dŵr, y Gyfarwyddeb Gynefinoedd a'r Rhestr Allyriadau Nwyon Tŷ Gwydr sy'n deillio o Fil yr Amgylchedd, fel yr adroddiad ar Gyflwr Adnoddau Naturiol, y Polisi Adnoddau Naturiol Cenedlaethol a Datganiadau Ardal. Yr hyn sy'n ganolog i Fil yr Amgylchedd yw'r angen i fabwysiadu dull gweithredu newydd, mwy integredig o reoli ein hadnoddau naturiol mewn modd mwy cynaliadwy, gan sicrhau ar yr un pryd ein bod yn diogelu ac yn datblygu cydnerthedd systemau naturiol er mwyn iddynt barhau i ddarparu'r manteision hyn y tymor hir. Ystyrir bod mwy o gydnerthedd pan geir lefel uchel o ran maint, cyflwr, cysylltedd ac amrywiaeth. Gall nifer o fetrigau RhMGG gael eu cysylltu â'r gofynion hyn ac felly gellid manteisio arnynt er mwyn mapio'r 4 nodwedd hyn ar gyfer ardaloedd gwahanol yn y dyfodol. Bydd y manteision hyn yn sail i agweddau penodol ar Fil Llesiant Cenedlaethau'r Dyfodol. Dull arall posibl o ddefnyddio data RhMGG yw i gefnogi gwaith gan Defra a Llywodraeth Cymru o ddatblygu Cyfrifon Cenedlaethol i gynnwys agweddau ar yr adnoddau naturiol (hynny yw, carbon, dŵr, a phridd) a'u gwerth cyfunol ar ffurf ecosystemau cyfan (hynny yw, coedwigoedd, gwlyptiroedd, ac yn y blaen). Gall data RhMGG gyfrannu at ddarparu'r data cadarn, y gellir eu harchwilio, sy'n ofynnol ar gyfer y gweithgaredd hwn.

Bydd RhMGG felly yn gwella'r gronfa dystiolaeth empirig ar gyfer sefyllfa a chyfanrwydd / cyflwr presennol asedau naturiol Cymru (a elwir yn gyfalaf naturiol) a sut y mae'r rhain yn newid mewn ymateb i ysgogwyr fel newid yn yr hinsawdd, arferion rheoli tir a llygredd aer y mae opsiynau Glastir yn cael eu gosod arnynt. Yr her i'r tîm RhMGG yw arwahanu'r newidiadau sy'n gysylltiedig ag opsiynau Glastir eu hunain, sef prif ddiben y rhaglen monitro a gwerthuso. Mae newidiadau i faint a chyfanrwydd y cyfalaf naturiol yn cael effaith yn eu tro o ran pa mor dda y gallant gyflawni'r swyddogaethau a'r gwasanaethau ecosystemau sydd eu hangen arnom, ac a werthfawrogwn. Nid yw'r cyswllt hwn wedi'i feintoli'n dda ar hyn o bryd. Mae'r gwahaniaeth rhwng gwasanaethau a chyfalaf naturiol yn bwysig gan fod cyfalaf yn ased tymor hwy yr ydym am ei ddiogelu ar gyfer y dyfodol, ac mae'n anodd neilltuo gwerth iddo ynddo'i hun, ond y gwasanaethau sy'n deillio o'r cyfalaf hwn yw'r hyn y mae economegwyr a gwyddonwyr cymdeithsol yn gallu neilltuo gwerth iddo, ac sy'n arbennig o berthnasol i Fil Llesiant Cenedlaethau'r Dyfodol. Mae'r cam hwn o neilltuo gwerth yn un hanfodol er mwyn inni ddarparu fframwaith cadarn ar gyfer deall yr opsiynau y mae llywodraeth a chymdeithas yn eu hwynebu. Mae tîm RhMGG yn gweithio ar y materion hyn drwy gyfrwng ei waith ar y canfyddiad a'r defnydd o'r dirwedd, arolygon cymdeithasol, ac arolygon ynghylch arferion ffermwyr. Fodd bynnag, mae hwn yn bwnc mawr y bydd angen gwaith ychwanegol arno y tu hwnt i'r adnoddau sydd ar gael ym mhrosiect RhMGG ar hyn o bryd.

Mae'r tîm RhMGG sy'n cyflawni'r rhaglen gynhwysfawr hon yn cynnwys cymysgedd o sefydliadau sydd ag arbenigaethau gwahanol, sy'n cwmpasu'r gwahanol gynlluniau, gweithgareddau, amcanion a chanlyniadau. Caiff y rhaglen ei harwain gan Ganolfan Ecoleg a Hydroleg Cyngor Ymchwil yr Amgylchedd Naturiol, sef corff ymchwilio cyhoeddus annibynnol. Mae gan y Ganolfan Ecoleg a Hydroleg safle ymchwil ym Mangor sy'n darparu'r arweinyddiaeth a'r gwaith cydgysylltu ar gyfer RhMGG. Mae consortiwm y prosiect yn cynnwys ADAS, APEM, Prifysgol Bangor, *Biomathematics and Statistics Scotland*, Ymgynghoriaeth Bowburn, Arolwg Daearegol Prydain, Ymddiriedolaeth Adareg Prydain, *Butterfly Conservation*, ECORYS, Ymgynghorwyr Edwards, Prifysgol Staffordshire, Prifysgol Aberdeen, Prifysgol Southampton, a Phrifysgol Wellington Victoria, Seland Newydd.

Dull gweithredu RhMGG a'r gofynion o ran cyflwyno adroddiadau

Yn gryno, rhaglen ddata a modelu wedi'i chyfuno yw dull gweithredu sylfaenol RhMGG, sy'n defnyddio data presennol sydd wedi'u gwella gan arolwg maes treigl newydd, mawr sy'n darparu data wedi'u cydleoli ynghylch ystod o fetrigau amgylcheddol. Mae gwaith modelu'n darparu dulliau o gyfuno ac uwchraddio data arolygon ar gyfer cyflwyno adroddiadau ar raddfa genedlaethol ac ymchwilio i sefyllfaoedd posibl y dyfodol sy'n gysylltiedig â chanlyniadau posibl y cynllun. Mae data'r arolwg sydd wedi'u cydleoli yn peri bod modd cyflwyno adroddiadau yn ôl y chwe chanlyniad a fwriedir yng nghyswllt Glastir, ac effeithiau cyfaddawd a chydfanteision taliadau Glastir rhwng y canlyniadau hyn. Y chwe chanlyniad yw: Mynd i'r afael â'r newid yn yr hinsawdd; Gwella ansawdd dŵr a rheoli adnoddau dŵr i helpu i leihau'r perygl o lifogydd; Diogelu adnoddau'r pridd a gwella cyflwr y pridd; Cynnal bioamrywiaeth a'i gwella; Rheoli a diogelu tirweddau a'r amgylchedd hanesyddol; Creu cyfleoedd newydd i wella'r mynediad i gefn gwlad a'r ddealltwriaeth ohoni; a Chreu coetiroedd a'u rheoli. Yn ychwanegol at y canlyniadau gwreiddiol hyn ar gyfer cynllun Glastir, ym mis Medi 2014 cyhoeddodd Archwilydd Cyffredinol Cymru adroddiad[1] ar Glastir. Roedd yr adroddiad yn cynnwys cyfres o sylwadau ac argymhellion cysylltiedig gan gynnwys nifer a oedd wedi'u cysylltu â phennu targedau'r cynllun a monitro ei effeithiau gwirioneddol yn ôl ei dargedau, sydd wedi effeithio ar ofynion prosiect RhMGG o ran cyflwyno adroddiadau. Nododd chwe Amcan Strategol. Er mwyn ymateb i'r argymhellion hyn, mae RhMGG wedi gweithio gyda Llywodraeth Cymru a Grŵp Cynghori RhMGG i ddatblygu nifer fach o ddangosyddion effaith yng nghyswllt pob Amcan Strategol ar gyfer Glastir. Dyma'r metrigau sy'n cael eu hystyried:

[1] http://audit.wales/cy/cyhoeddi/glastir

Amcan Strategol	Dangosydd y gellir adrodd amdano
1.Sicrhau mwy o fuddsoddi mewn mesurau i liniaru allyriadau nwyon tŷ gwydr er mwyn cyfrannu at leihau'r allyriadau net gan sector diwydiannau'r tir yn unol â'n rhwymedigaethau rhyngwladol	Cyfraniad yn ôl y defnydd o dir a newid mewn defnydd ($ktCO_2eq$ y flwyddyn^{-1}) (nid yw'n cynnwys priddoedd mawn)
	Allyriadau Amaethyddiaeth[6] (CO_2eq (kt $N_2O + CH_4$))
	Allyriadau amaethyddiaeth gan gynnwys allyriadau wedi'u hymgorffori (data fferm gyfartalog nodweddiadol yn unig, tCO_2eq/ha) Cig eidion Llaeth Cymysg Defaid
2.Sicrhau mwy o fuddsoddi mewn mesurau i addasu i'r newid yn yr hinsawdd er mwyn cyd-nerthu busnesau ffermydd a choedwigoedd ac economi ac amgylchedd Cymru yn gyffredinol rhag y newid yn yr hinsawdd	Arolwg Arferion Ffermwyr i roi syniad o'r busnes fferm wedi'i rannu yn ôl llaeth, gwartheg, cymysg a defaid a choedwigaeth
	Cyfoethogrwydd / amrywiaeth rhywogaethau cefn gwlad ehangach, wedi'u rhannu yn ôl planhigion, adar a phryfed peillio ar dir âr, tir wedi'i wella, tir cynefin a choetir
	Dangosydd adar tir fferm
	Amrywiaeth cynefinoedd
	Maint cymedrig darn o dir (yn achos coetir cynefin a choed llydanddail yn unig)
3.Sicrhau mwy o fuddsoddi mewn mesurau i reoli ein hadnoddau dŵr yn effeithiol er mwyn cyfrannu at wella ansawdd dŵr yng Nghymru ac at gyflawni ein rhwymedigaethau o dan y Gyfarwyddeb Fframwaith Dŵr	Dosbarthiad safle rhagnant sy'n cydymffurfio â'r Gyfarwyddeb Fframwaith Dŵr (mae'n defnyddio cyfres eang o ddangosyddion o ran cyflwr ecolegol ar sail macroinfertebratau, diatomau, newidiadau i'r cynefin, maethynnau) (% mewn cyflwr da iawn neu dda)
	Ardal o dir wedi'i modelu sy'n lliniaru dŵr ffo /llifogydd (%)[1]
4.Neilltuo mwy o adnoddau at rywogaethau a chynefinoedd penodedig sydd â blaenoriaeth er mwyn cyfrannu at wrth-droi'r dirywiad mewn bioamrywiaeth frodorol yng Nghymru ac at gyflawni ein rhwymedigaethau o dan agenda Bioamrywiaeth 2020 yr UE	12-15 Maint a chyflwr Cynefinoedd â Blaenoriaeth (Dim ond pan ellir cyflwyno adroddiadau am y ddau gyda'i gilydd)
	Niferoedd rhywogaethau â blaenoriaeth (adar (17 o'r 51 o rywogaethau adran 42), gloÿnnod byw (6 o'r 15 o rywogaethau gloÿnnod byw adran 42))
	Cyflwr procsi cynefin wedi'i deilwra ar gyfer anghenion penodol rhywogaethau â blaenoriaeth (metrig wedi'i agregu ar draws yr holl rywogaethau) y tu mewn i'r cynllun a'r tu allan iddo
5. Trefnu mesurau a buddsoddi sy'n cynnal ac yn gwella'r elfennau nodweddiadol yn nhirwedd ac amgylchedd hanesyddol Cymru wledig a hybu gwerthfawrogiad y cyhoedd a mynediad i gefn gwlad	Ansawdd y dirwedd – Mynegai Ansawdd Gweledol Cymedrig (mynegai 0 – 1.0) y tu mewn i'r cynllun a'r tu allan iddo i gychwyn (ac yna'r newid dros amser)
	Cyflwr Nodwedd o'r Amgylchedd Hanesyddol (% mewn cyflwr Cadarn neu Ragorol)[2]
	Hawliau Tramwy Cyhoeddus (% ar agor ac yn hygyrch).
	Metrig arolwg o ddefnydd hamdden yn yr awyr agored
6.Defnyddio buddsoddiadau mewn mesurau amaeth-amgylcheddol mewn ffordd sy'n hybu canlyniadau amgylcheddol cadarnhaol ac sydd hefyd yn cyfrannu at broffidioldeb busnesau ffermydd a choedwigoedd ac at gynaliadwyedd yr economi wledig yn gyffredinol	Arolwg Arferion Ffermwyr – gyda chwestiwn yn gofyn a yw'r busnes wedi cael budd o gynllun Glastir. Wedi'i rannu fesul coedwig, llaeth, gwartheg, defaid a menter gymysg.
	Ardal o dir fferm o Werth Mawr i Natur (metrig cyfanredol sy'n cael ei ddatblygu)

Tabl 01 *Dangosyddion effaith ar gyfer cyflwyno adroddiadau yn ôl chwe Amcan Strategol Glastir*

Mae Tabl 01 yn dangos yr ystod eang o fesuriadau a deiliannau amgylcheddol sydd wedi'u hymgorffori yn rhaglen waith RhMGG, sef ystod o fetrigau ynghylch ansawdd pridd a dŵr, y dirwedd a nodweddion hanesyddol, amrywiaeth planhigion a dŵr croyw, nwyon tŷ gwydr, asesu cyflwr nodweddion hanesyddol, pryfed peillio a phedwar arolwg ynghylch adar, arolygon cymdeithasol-economaidd ynghylch manteision i’r diwydiannau ffermio a choedwigaeth a chymuned ehangach Cymru.

Cylch RhMGG

Oherwydd cynhelir ailymweliadau â safleoedd arolygu RhMGG yn ôl cylch treigl pedair blynedd, a'n bod ym Mlwyddyn 3 o'r cylch pedair blynedd cychwynnol hwn, mae canlyniadau presennol Blwyddyn 2 yn cyfrannu at linell sylfaen a fydd yn sail i'r broses o fesur effeithiau taliadau Glastir yn y dyfodol. Fesul Canlyniad Glastir, mae gwaith sydd wedi'i ganolbwyntio ar fioamrywiaeth (gan gynnwys cynefinoedd coetiroedd) yn cyfateb i 42% o gyfanswm cyllideb RhMGG, mae 41% wedi'i ddyrannu ar draws priddoedd, dyfroedd, lliniaru newid yn yr hinsawdd, nodweddion y dirwedd a nodweddion hanesyddol, effeithiau cyfaddawd a chydfanteison, ac mae'r 17% sy'n weddill wedi'i ddyrannu i ategu gweithgareddau fel gwybodeg, y porth data a rheoli prosiectau. Mae'r arolwg maes yn cynnwys dwy ran, sef y cydrannau Cymru Ehangach a'r arolwg wedi'i dargedu. Mae sgwariau arolygu Cymru Ehangach yn cael eu dewis i gynrychioli'r amodau cefndir ledled Cymru ac maent yn cael eu dewis drwy samplu ar hap o fewn dosbarthiadau tir wedi'u neilltuo. Mae hyn yn helpu RhMGG i ddarparu'r data sydd eu hangen ar dueddiadau cenedlaethol. Caiff sgwariau wedi'u targedu eu dewis wedyn i gofnodi'n benodol weithgareddau sy'n gysylltiedig â Glastir.

Crynodeb o'r cynnydd

Blynyddoedd 1 a 2

Ym Mlwyddyn 1, canolbwyntiodd RhMGG ar sefydlu'r rhaglen maes a defnyddio *ensemble* o fodelau i ymchwilio i ddeiliannau posibl o wahanol sefyllfaoedd o ran y defnydd o chwe opsiwn Glastir. Ym mlwyddyn 2, rydym wedi parhau â'r arolwg maes ac wedi canolbwyntio ar ddadansoddi data Blynyddoedd 1 a 2 ynghyd â data o ffynonellau eraill, yn arbennig Cyfoeth Naturiol Cymru, y Rhestr Coedwigaeth Genedlaethol, *Plantlife*, Cynllun Monitro Gloÿnnod Byw y DU, y Cynllun Bridio Adar a'r Arolwg Cefn Gwlad. Mae'r tueddiadau hirdymor a ganfuwyd wedi'u nodi yma (neu yn y porth data). Gwnaethom hefyd ddadansoddi data RhMGG i ganfod a oedd tir sy'n dod i mewn i'r cynllun yn wahanol o ran ansawdd i'r tir y tu allan, ac a oeddem yn gallu canfod effeithiau etifeddol cynlluniau amaeth-amgylcheddol y gorffennol. Canolbwyntiodd y tîm bioamrywiaeth ar ddatblygu technegau ar gyfer cyflwyno adroddiadau ar effeithiau ar gyfer rhywogaethau a chynefinoedd â blaenoriaeth, wrth i waith barhau ar ddatblygu'r offeryn ansawdd / canfyddiad y dirwedd, a'i rhoi ar brawf. Cafodd ymdrechion modelu eu canolbwyntio ar sefydlu'r data llinell sylfaen o ran allyriadau nwyon tŷ gwydr uniongyrchol ac anuniongyrchol mewn ymateb i gyllid Grantiau Effeithlonrwydd Glastir ac asesu effaith ddryslyd bosibl newid yn yr hinsawdd ar allyriadau nwyon tŷ gwydr. Mae gwaith dadansoddi ar bridd a dŵr croyw yn cyflwyno adroddiadau ar ddata Blwyddyn 1 yn unig oherwydd yr amser sy'n ofynnol ar gyfer asesu bioamrywiaeth. Cynhaliwyd dadansoddiad o 7 gwasanaeth ecosystem a'u heffeithiau gwrthbwyso posibl gan gynnwys y broses o ddatblygu metrig i amcangyfrif arwynebedd y tir sy'n lliniaru dŵr ffo/llifogydd. Roedd y gwaith hefyd yn cynnwys darn o waith mawr sydd wedi'i gwblhau a oedd yn ymwneud â datblygu dulliau newydd o fapio ac asesu cyflwr priddoedd mawn yng Nghymru, ynghyd â'u cyfraniad posibl at leihau allyriadau nwyon tŷ gwydr.

Cynlluniau'r dyfodol ar gyfer Blynyddoedd 3 a 4

Blwyddyn 3:

- Mae'r arolwg maes ar gyfer Blwyddyn 3 yn mynd rhagddo eisoes, ac mae 75 o sgwariau wedi'u dewis ar gyfer yr arolwg.
- Byddwn yn ceisio penderfyniad ynghylch cynnwys sgwariau'r Arolwg Cefn Gwlad yn Arolwg Cymru Ehangach RhMGG
- Llunio'r fersiwn derfynol o'r dangosydd newydd ynghylch Tir Fferm o Werth Mawr i Natur.
- Datblygu a lansio Porth Data RhMGG yn Sioe Frenhinol Cymru yn 2015.
- Cyflwyno adroddiadau ar fetrigau sydd eu hangen ar gyfer y 6 Amcan Strategol a Thargedau newydd cytunedig ar gyfer Glastir sy'n cael eu datblygu gan Lywodraeth Cymru. Bydd y metrigau hyn ynghyd â dangosyddion lefel uchel ar gyfer 6 Chanlyniad Glastir yn cael eu

defnyddio i ddarparu'r wybodaeth ddiweddaraf yn flynyddol drwy gyfrwng Porth Data RhMGG.

Blwyddyn 4:

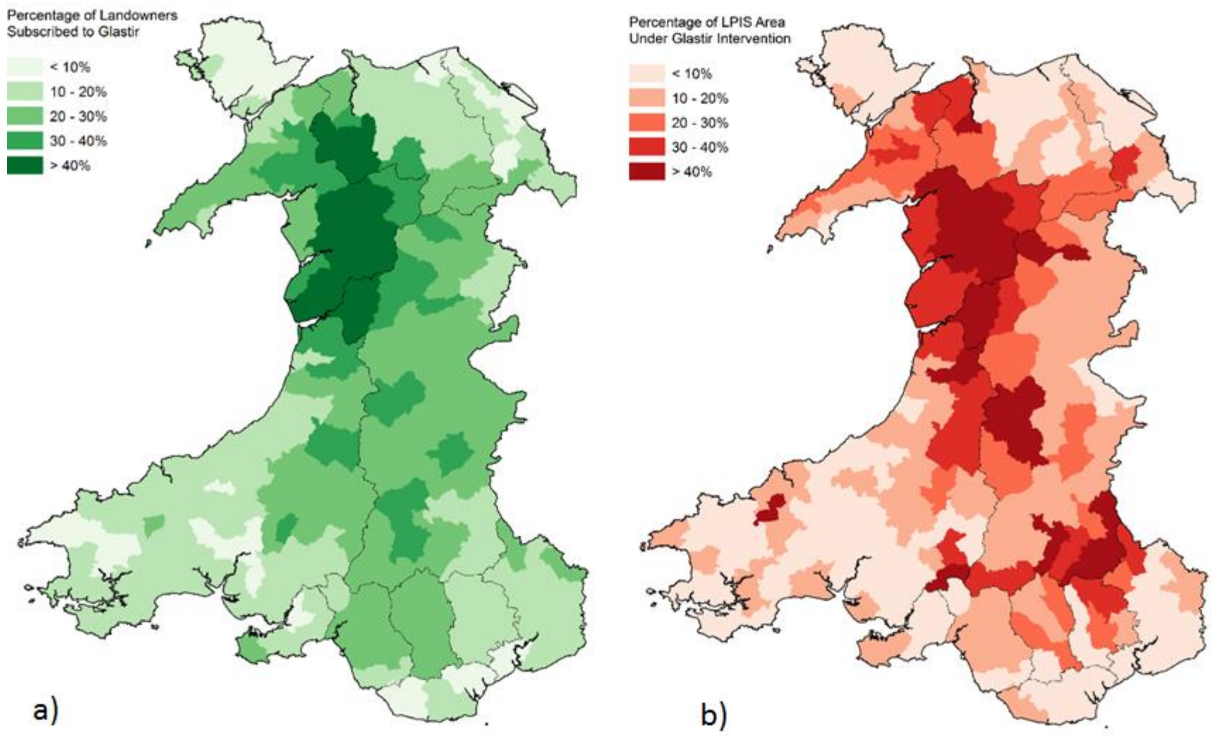
- Cwblhau'r 75 o sgwariau 1km terfynol yr arolwg maes i gwblhau'r 300 o sgwariau arolygu 1km llinell sylfaen RhMGG.
- Ailgynnal yr Arolwg o Arferion Ffermwyr yn haf 2016 i nodi'r newidiadau gwirioneddol ar y fferm ac unrhyw fantais i broffidioldeb a chadernid ffermydd a choedwigaeth.
- Gwaith modelu i ganfod manteision Glastir o ran ansawdd dŵr mewn dalgylchoedd y Gyfarwyddeb Fframwaith Dŵr ar sail newidiadau wedi'u meintoli yn yr Arolwg o Arferion Ffermwyr a gynhelir yn yr haf yn 2016 i'w gyflwyno mewn adroddiad yng ngwanwyn 2017
- Cyfweliadau â ffermwyr wedi'u cyfuno â gwaith modelu i feintoli'r manteision i allyriadau nwyon tŷ gwydr uniongyrchol ac anuniongyrchol fesul math o fferm.

Uchafbwyntiau Blwyddyn 2

Mae'r hyn a ganlyn yn grynodeb lefel uchel o rai o'r prif ganfyddiadau wedi'u strwythuro fesul canlyniad Glastir; mae adrannau ychwanegol wedi'u cynnwys er mwyn dadansoddi'r defnydd o Glastir, priddoedd mawn, tir fferm o Werth Mawr i Natur, ac effeithiau gwrthbwyso a chyfleoedd Ecosystem. Gellir dod o hyd i nifer o ganlyniadau eraill yn yr adroddiad llawn neu ym mhorth data RhMGG https://rhamagg.cymru.

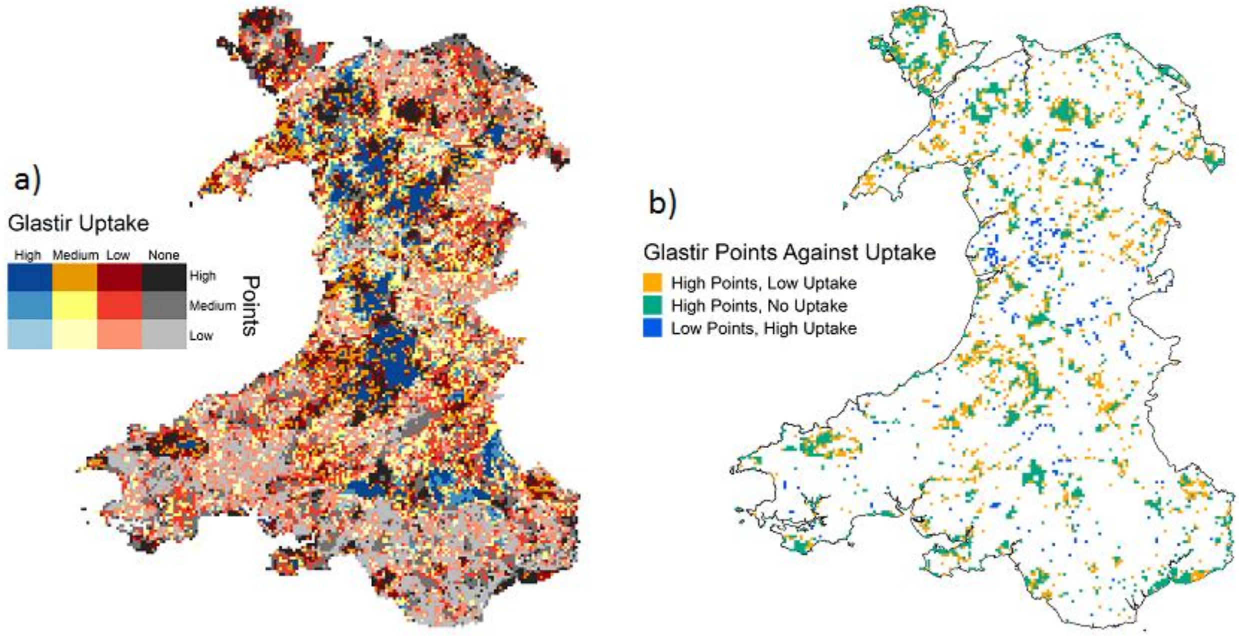
Dadansoddiad o'r defnydd o Glastir

Nodwyd bod 4,911 o newydd-ddyfodiad unigryw wedi ymuno â'r cynllun erbyn mis Rhagfyr 2014, sef 22% o'r holl dirfeddiannwyr sydd wedi'u cofrestru gyda'r System Adnabod Parseli Tir (LPIS) yng Nghymru. Wedi'u grwpio fesul ardal fach amaethyddol, roedd canran y tirfeddiannwyr LPIS sydd wedi tanysgrifio i Glastir yn amrywio o 4% i 51%, gyda'r cyfrannau uchaf yn Eryri (Ffigur 01). Cyfanswm yr arwynebedd a gwmpasir gan opsiynau Glastir yw 3,263 km^2, sef 19% o'r arwynebedd LPIS sydd ar gael, ac 16% o gyfanswm arwynebedd tir Cymru. O'r 4109 o newydd-ddyfodiaid i Glastir, tanysgrifiodd 84% i'r opsiynau o dan lefel Mynediad, Uwch, neu Reoli Coetiroedd. Ledled Cymru, mae 190 o godau opsiynau Glastir unigryw wedi'u defnyddio, gan gynnwys 3,050 km o opsiynau llinol.
Roedd y defnydd o Glastir yn ymwneud yn bennaf â bioamrywiaeth, a hynny oedd â'r gwerthoedd mwyaf ymhlith yr holl fetrigau, ac eithrio ardal parseli tir (a oedd a 62% o gyfrifiadau'r parseli tir), lle lliniaru'r newid yn yr hinsawdd oedd y Canlyniad â'r ardal fwyaf o dan opsiynau (80% o'r parseli tir a gafodd eu cyfrif). Y Canlyniad Coetiroedd a oedd â'r nifer lleiaf o newydd-ddyfodiaid, parseli tir, a chyfanswm yr arwynebedd, er bod ganddo werthoedd cyfartalog o ran nifer y codau opsiynau a hyd yr opsiynau. Mae'r asesiadau hyn wedi'u seilio ar ddyraniad gan y tîm prosiect gan nad oedd y canlyniad gwirioneddol yr oedd y Swyddog Prosiect Glastir yn bwriadu ei greu yn sgil y taliad ar gael ar adeg ysgrifennu'r adroddiad hwn.



Ffigur 01 *a) Y ganran o dirfeddiannwyr LPIS sydd wedi tanysgrifio i Glastir, wedi'i hagregu fesul ardal fach amaethyddol; b) Canran arwynebedd y tirfeddiannwyr LPIS sy'n gorgyffwrdd â lleiniau o ran y defnydd o Glastir, wedi'i hagregu fesul ardal fach amaethyddol.*

Os caiff lefelau'r defnydd eu cymharu â symiau'r pwyntiau sydd ar gael, yn amlwg mae pwyntiau wedi ysgogi'r defnydd gan nad oes ond 308km2 (tua 1% o Gymru) lle cafwyd defnydd mawr mewn ardaloedd â phwyntiau isel. Fodd bynnag, roedd 3041km2 (sef tua 15% o Gymru) a oedd â phwyntiau uchel lle na fu fawr o ddefnydd, neu lle na fu dim defnydd (Ffigur 02). Er mwyn ceisio canfod a oedd unrhyw batrwm cyson o ran tir yn peidio â dod yn rhan o'r cynllun, bu inni ddadansoddi'r tir yn ôl ei fath o gynefin. Yn gyffredinol, cafwyd swm cyfrannol tebyg yn gyffredinol o'r tir Cynefin Eang a geir gan mwyaf yn rhannau eithaf yr asesiad hwn, hynny yw, defnydd uchel / pwyntiau isel yn erbyn defnydd isel / pwyntiau uchel. Felly, roedd y ddau ddosbarth wedi'u cysylltu'n llinol sy'n awgrymu nad oedd dim tuedd cyson o dir yn dod i mewn, neu'n peidio â dod i mewn, i'r cynllun. Yr unig eithriad oedd coedwigoedd conwydd, a oedd yn allanolyn. Roedd arwynebedd mwy yn gyfrannol heb fawr o ddefnydd er gwaethaf pwyntiau uchel ac arwynebedd llai o dir yn gyfrannol a oedd â defnydd uchel a phwyntiau isel o'i gymharu â'r 7 prif fath arall o gynefin. Mae mater y defnydd gwael o'r cynllun Creu Coetir y byddai'r data hyn yn ei gefnogi yn cael sylw pellach yn yr adran ynghylch Manteision Cymdeithasol-economaidd.



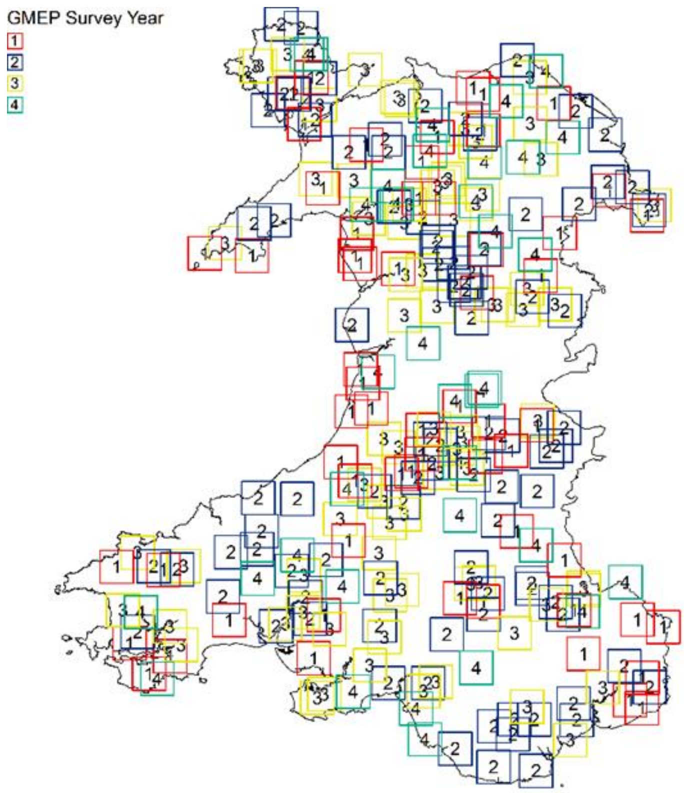
Ffigur 02a *Cymhariaeth o'r defnydd gan ffermwyr o'i gymharu â chyfanswm y pwyntiau sydd ar gael ar draws pob canlyniad;* **Ffigur 02b** *Ffigur wedi'i symleiddio sy'n dangos pwyntiau eithaf Ffigur 02a.*

Cwmpas RhMGG o ran Glastir

Mae cyfanswm o 197 o'r 260 o sgwariau RhMGG (76%) sydd wedi'u dewis neu eu harolygu ar hyn o bryd (Blynyddoedd 1-3 ac elfen Cymru Ehangach o Flwyddyn 4) yn gorgyffwrdd â rhyw fath o barsel tir a ddefnyddiwyd o dan Glastir. Dangosir dosbarthiad y sgwariau yn Ffigur 03. Mae hyn yn cynnwys 1,609 o leiniau unigol sy'n perthyn i 321 o newydd-ddyfodiaid i Glastir ac mae'n cwmpasu ardal o 63 km^2. O blith y 171 o sgwariau sy'n gorgyffwrdd â lleiniau opsiynau, mae cyfanswm o 88 o wahanol opsiynau wedi'u harolygu, gan gynnwys 38km o opsiynau llinol.

Wedi'i rannu fesul Elfen, mae cofnod arolwg maes RhMGG o'r defnydd o Glastir yn dilyn y duedd genedlaethol; dod yn rhan o Glastir yw'r Elfen a arolygwyd fwyaf yn achos mwyafrif y metrigau; yr agwedd Organig oedd yn yr ail safle. Mae'r Elfennau defnydd is o Grantiau Effeithlonrwydd Glastir ar yn achos Coetiroedd yn gorgyffwrdd â'r nifer lleiaf o sgwariau. Mae rhagor o leiniau Glastir Uwch wedi'u harolygu na'r rhai Cyffredin, er bod y lleiniau mawr o dir cyffredin yn golygu bod cyfanswm yr arwynebedd a arolygwyd yn fwy.

Fesul Canlyniad, mae'r gorgyffwrdd y tu mewn i sgwariau RhMGG yn debyg i'r defnydd cenedlaethol, a cheir y gorgyffwrdd mwyaf yn achos y Canlyniad Bioamrywiaeth, sef 78% o'r parseli tir (62% yn y cynllun). Fodd bynnag, coetiroedd a oedd â'r cwmpas lleiaf, sef 16% (10% yn y cynllun). Bydd angen ailadrodd y dadansoddiad hwn gan fod y data wedi'u cyflwyno erbyn hyn, sy'n cynnwys y canlyniad a fwriedir ar gyfer yr opsiynau yng nghontractau Glastir. Roedd yr asesiad presennol wedi'i seilio ar ganlyniad tebygol y targed gan y tîm RhMGG.



Ffigur 03 *Dosbarthiad sgwariau 1km RhMGG ond wedi'i ehangu i gwmpasu grid 10km er mwyn diogelu lleoliadau. Mae'r sgwariau'n cynnwys Blynyddoedd 1-3 Arolwg Cymru Ehangach a'r Arolwg wedi'i Dargedu, ond dim ond Arolwg Cymru Ehangach ar gyfer Blwyddyn 4 sydd wedi'i gynnwys oherwydd bydd yr Arolwg wedi'i Dargedu yn cael ei ddewis yn ôl y defnydd yn yr hydref yn 2015.*

Ar wahân i ddata'r arolwg maes, a data deilliedig a gynhyrchwyd yn fewnol, mae ystod o ddata allanol wedi'i chasglu o Lywodraeth Cymru a ffynonellau eraill ar gyfer y prosiect, sydd ar hyn o bryd yn cynnwys dros 700 o ffeiliau unigol a fydd yn helpu'r broses o ddadansoddi yn y dyfodol.

Y wybodaeth ddiweddaraf am yr arolwg maes

Cafodd ail flwyddyn y rhaglen fonitro goruchwyliaeth genedlaethol i feintoli'r newid parhaus yng nghefn gwlad Cymru ac effeithiau opsiynau Glastir ei gweithredu o fis Ebrill hyd at fis Medi 2014. Cafodd y prif arolwg bioffisegol o 90 o sgwariau 1km ei reoli gan y Ganolfan Ecoleg a Hydroleg; cafodd arolygon o bryfed peillio (gloÿnnod byw, gwenyn a phryfed hofran) eu rheoli gan *Butterfly Conservation*; a chafodd arolygon ynghylch adar eu rheoli gan Ymddiriedolaeth Adareg Prydain. Swyddog Cyswllt â Ffermwyr a gyflogir yn llawn-amser gan y Ganolfan Ecoleg a Hydroleg fu'n cydlynu symudiadau'r holl dimau maes ac yn trefnu caniatâd i gael mynediad i dir. Rhoddodd 68% o'r tirfeddiannwyr y cysylltwyd â hwy ac a oedd â thirddaliadau gyda sgwariau arolygu 1km RhMGG ganiatâd i'r arolwg; gwrthododd 5% fynediad, ac ni chafwyd ymateb gan y gweddill. Cafodd cyfanswm o 80% o'r tir yn y 90 o sgwariau arolygu 1km ei arolygu yn 2014. Mae'r rhaglen integredig hon o fonitro ac arolygu, sydd wedi'i chydleoli, ac sy'n cynnwys mesur o briddoedd i nwyon tŷ gwyr a dyfroedd, planhigion i adar a phryfed peillio, y dirwedd i nodweddion hanesyddol a chanfyddiad o'r dirwedd yn peri bod mod ymchwilio i'r dibyniaethau rhwng yr elfennau hyn mewn adroddiadau yn y dyfodol. Mae'n cyd-fynd ag amcanion Bil yr Amgylchedd datblygu dulliau gweithredu mwy integredig reoli ein hadnoddau naturiol yn fwy cynaliadwy. O ran Blwyddyn 1, roedd mesuriadau'r arolwg yn cynnwys mapio cynefinoedd, nodweddion llinol ac o ran pwyntiau, cofnodi rhywogaethau planhigion mewn lleiniau botanegol llystyfiant parhaol, samplu'r uwchbridd, arolygu a samplu blaenddyfroedd a phyllau, arolygon o adar a phryfed peillio, ffotograffiaeth o'r dirwedd, ac asesiadau o nodweddion hanesyddol a chyflwr llwybrau cerdded. Caiff yr holl ddata eu cadw yng nghronfa ddata ofodol a sicr

Oracle RhMGG. Er gwaethaf pob ymdrech i sicrhau cysondeb rhwng arolygwyr y tir drwy gyfrwng hyfforddiant trylwyr, methodolegau manwl wedi'u hamlinellu yn y llawlyfrau maes, proses rheoli ansawdd a chyfathrebu'n aml, mae'n anochel y bydd rhywfaint o amrywiad. Felly, mae'n bwysig cynhyrchu mesur meintiol o gysondeb a dibynadwyedd y data. O ganlyniad, cynhaliwyd ymarfer Sicrhau Ansawdd i gofnodi a deall yr amrywiad hwn ac i sicrhau nad oedd dim tuedd sylweddol yn y data a gasglwyd. Mae'r manylion llawn i'w gweld yn adroddiad Blwyddyn 1 (Emmett et al. 2014). Cafodd chwe sgwâr RhMGG eu hailarolygu ar gyfer Sicrhau Ansawdd ym Mlwyddyn 2 (2014). Mae'r adroddiad llawn ar Sicrhau Ansawdd i'w weld yn Atodiad 1.1.

Priddoedd mawn

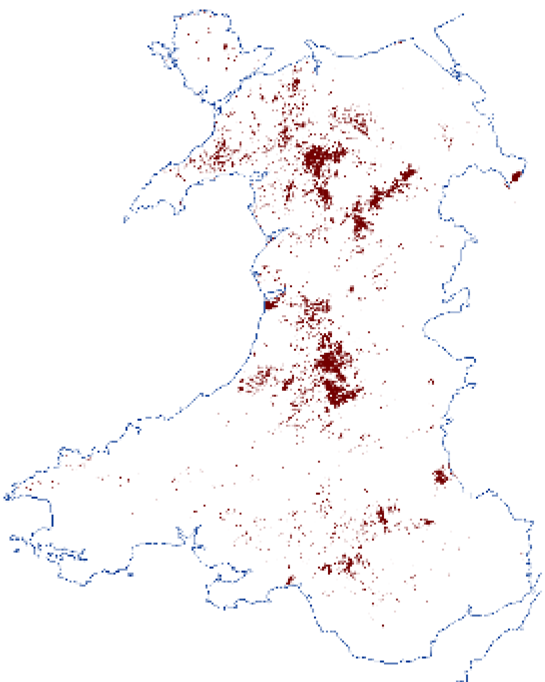
Mae Priddoedd Mawn yn gorchuddio 4.3% o Gymru, ac maent yn cynnal cynefinoedd corsydd a mignedd sy'n brin yn genedlaethol ac yn rhyngwladol. Yn yr ucheldiroedd, mae gorgorsydd yn ffurfio mewn tir llawn dŵr, ac maent yn cynnwys rhywogaethau planhigion sy'n creu mawn, fel migwyn, yn ogystal â rhywogaethau nodweddiadol fel grug a phlu'r gweunydd, a rhywogaethau prin fel gwlith yr haul a mwyar y Berwyn. Yn ychwanegol at eu pwysigrwydd o safbwynt bioamrywiaeth, priddoedd mawn yw storfa ecosystem diriogaethol fwyaf Cymru, ac os ydynt mewn cyflwr da mae ganddynt botensial i ddylanwadu ar yr hinsawdd drwy ddal a storio CO_2 yn barhaus. Fodd bynnag, mae priddoedd mawn Cymru wedi'u niweidio gan ganrifoedd o weithgarwch dynol, gan gynnwys draenio, gormod o bori, a'u troi'n laswelltir a choedwigoedd. O ganlyniad credir ar hyn o bryd fod priddoedd mawn Cymru yn ffynhonnell allyriadau nwyon tŷ gwydr. Mae mesurau a gefnogir drwy Glastir yn anelu at leihau'r allyriadau hyn, ac i adfer swyddogaeth dal a storio carbon priddoedd mawn Cymru, drwy leihau pwysau o ran defnyddio'r tir ar ystod o gorsydd a mignedd yn yr ucheldir a'r iseldir.

Uchafbwyntiau Blwyddyn 2

Ym mlwyddyn 1 RhMGG, yn ychwanegol at weithgareddau craidd yr arolwg, roedd y gwaith a wnaed yn cynnwys mapio graddau'r erydu o fawn ledled Cymru o ffotograffau o'r awyr, ac asesiad i ganfod a ellid defnyddio data lloerenni i fonitro newidiadau i uchder wyneb priddoedd mawn a fyddai'n dangos a oeddent yn cronni carbon neu'n ei golli. Ym Mlwyddyn 2, rydym wedi cynnal asesiad newydd manwl o faint a chyflwr holl adnodd priddoedd mawn Cymru, a hynny ar sail dadansoddiad integredig o ddata mapio priddoedd, data ynghylch gorchudd y tir a'r defnydd o ffotograffau o'r awyr i ganfod ffosydd draenio a'u mapio. Rydym hefyd wedi casglu nifer fawr o greiddiau mawn, sy'n cael eu defnyddio i fesur cyfraddau cronni mawn dros y ganrif ddiwethaf o ran ei berthynas â'r defnydd o dir.

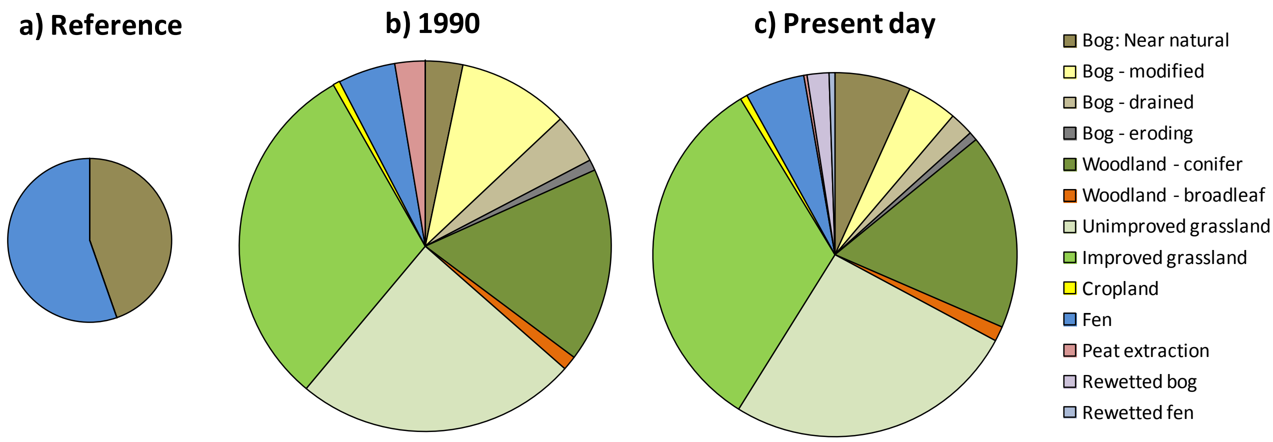
Y prif ganfyddiadau

- Mae map mawn unedig newydd wedi'i ddiffinio ar gyfer prosiect RhMGG, a ddylai beri bod modd cynnal asesiad mwy dibynadwy o gyflwr adnodd mawn Cymru yn ei gyfanrwydd, ynghyd â chynrychiolaeth well o fawn yr iseldir, a thargedu'n fwy cywir fesurau Glastir sy'n gysylltiedig â phridd mawn at y meysydd hynny lle ceir mawn (Ffigur 04).
- Mae'r map hwn bellach wedi'i gyflwyno i Reolwyr Contractau Glastir i'w ddefnyddio wrth drafod Cytundebau newydd Glastir.



Ffigur 04 *Map mawn unedig i Gymru, yn seiliedig ar ddata cyfunol Arolwg Daearegol Prydain a Chyfoeth Naturiol Cymru*

- Ar sail y map mawn 'unedig' hwn o Gymru sydd wedi'i ddatblygu, amcangyfrifir bod priddoedd mawn yn gorchuddio dros 90,000 ha o Gymru (4.3% o gyfanswm yr arwynebedd tir) y mae 75% ohonynt yn yr ucheldir, a 25% yn yr iseldir
- Mae prosesu digidol o ffotograffau o'r awyr yn awgrymu bod o leiaf 3000 km o ffosydd draenio ar bridd mawn yng Nghymru
- Yn gyffredinol, credir yr effeithiwyd ar dri chwarter o arwynebedd pridd mawn Cymru gan un gweithgaredd defnydd tir neu ragor, gan gynnwys draenio, gormod o bori, troi tir yn laswelltir neu greu coedwigoedd, gyda 30% yn unig mewn 'cyflwr da' a 25% wedi'i 'newid' yn laswelltir a 10% yn goetir.
- O ganlyniad i'r gweithgareddau hyn, amcangyfrifir bod priddoedd mawn Cymru yn cynhyrchu allyriadau 'anthropogenig' o tua 400 kt o nwyon sy'n cyfateb i CO_2 y flwyddyn (sy'n cyfateb i tua 7% o'r holl allyriadau o Gymru sy'n gysylltiedig â thrafnidiaeth). Mae hyn yn cymharu â chyflwr 'cyfeirio' naturiol wedi'i amcangyfrif (hynny yw, pe bai'r holl ardal fawn sydd wedi'i mapio yn gors neu'n fign naturiol) o tua 140 kt o nwyon sy'n cyfateb i CO_2 y flwyddyn^{-1} (Ffigur 05). Mae hyn yn dangos bod priddoedd mawn naturiol yn allyrwyr net o nwyon sy'n cyfateb i nwyon tŷ gwydr, a hynny'n bennaf oherwydd pŵer ymbelydrol methan. Maent yn storio carbon yn gyffredinol os ydynt mewn cyflwr da (neu ni fyddai mawn yn cronni) a diogelu'r storfa garbon hon ac osgoi allyriadau yw'r amcan y gall Glastir gyfrannu ato. Gan fod taliadau Glastir yn cael eu targedu at fawn sydd wedi'u lled-wella yn unig, amcangyfrifir mai'r gostyngiadau posibl mewn allyriadau y gellid eu cyflawni pe bai modd dychwelyd yr holl briddoedd mawn sydd wedi'u lled-wella i'r cyflwr cyfeirio yw 150 kt o nwyon sy'n cyfateb i CO_2 y flwyddyn^{-1}.
- Rhwng 1990 a 2007 cafwyd gostyngiad o ran cyfoeth rhywogaethau mewn gorgorsydd, ond cynnydd bach yn nifer y rhywogaethau (dangosyddion Monitro Safonau Cyffredin (CSM) cadarnhaol) mawn nodweddiadol ('dangosydd cadarnhaol')
- Mae pum deg o greiddiau mawn wedi'u casglu o bob rhan o Gymru erbyn hyn er mwyn mesur faint o CO_2 yr oedd mawn Cymru'n gallu ei ddal a'i storio yn y gorffennol, a'r graddau yr effeithiwyd ar hyn gan goedwigaeth a rheolaeth amaethyddol ddiweddar.
- Ein hargymhelliad yw y dylid defnyddio'r canfyddiadau newydd hyn i ddiwygio'r cynllun wrth iddo fynd yn ei flaen er mwyn sicrhau'r manteision gorau o daliadau Glastir o ran lleihau allyriadau o briddoedd mawn.



Ffigur 05 *Cyfraniad amcangyfrifedig gwahanol gategorïau o ran cyflwr/defnydd tir mawn at gyfanswm yr allyriadau nwyon tŷ gwydr o fawn yng Nghymru, a hynny mewn cyflwr 'cyfeirio' naturiol, yn 1990, a heddiw. Mae maint pob siart cylch yn dangos lefel gyffredinol yr allyriadau.*

Yn gyffredinol, gwelir bod priddoedd mawn wedi'u newid i raddau mawr ledled Cymru, gan gyfateb i tua 75%. Mae'r unig welliannau diweddar yn ymwneud â rhoi terfyn ar echdynnu mawn (Ffigur XX) ac yng nghyflwr corsydd, hynny yw, gan ddefnyddio rhywogaethau planhigion yn ddull procsi o ganfod cyflwr cors, rhwng 1990 a 2007 cafwyd cynnydd bach yn nifer y rhywogaethau nodweddiadol mewn corsydd ('dangosydd cadarnhaol'), a hynny yn ôl pob tebyg oherwydd targedu corsydd yn ddiweddar i gael eu hadfer.

Manteision Cymdeithasol-economaidd

Mae RhMGG yn cynnal ystod o weithgareddau i gofnodi manteision cymdeithasol-economaidd ehangach cynllun Glastir. Gall y manteision hyn ddeillio o ystod o weithgareddau Glastir gan gynnwys taliadau gan ffermwyr i'r gymuned leol am lafur neu wasanaethau i lwybrau mwy anuniongyrchol fel ansawdd gwell y dirwedd weledol, sydd â'r potensial i fod o fudd i gymunedau lleol a'r diwydiant twristiaeth. Yn fwy cyffredinol, y gobaith yw y bydd y diogelwch gwell i'n hadnoddau naturiol a fwriedir o daliadau Glastir yn cyfrannu at Nod 'Cymru Gydnerth' Bil Llesiant a Chenedlaethau'r Dyfodol.

Mae gweithgareddau yn y maes hwn ym Mlwyddyn 2 wedi cynnwys:

- Asesiad o fanteision Grantiau Effeithlonrwydd Glastir i'r gymuned ehangach a'r effeithiau posibl ar ôl-troed carbon ffermydd;
- Deall y rhwystrau i'r defnydd o'r Cynllun Creu Coetir
- Datblygu mesurau gwrthrychol, tryloyw ac y gellir eu hailadrodd ar gyfer asesu ansawdd y dirwedd weledol i beri bod modd asesu effaith Glastir yn y dyfodol
- Meintoli hygyrchedd y dirwedd o ran hygyrchedd ffisegol drwy'r rhwydwaith Hawliau Tramwy Cyhoeddus a mesur deilliedig o hygyrchedd gweledol sy'n ystyried yr olygfa fel y'i profir gan y cyhoedd yn y dirwedd.
- Asesiad sy'n parhau o gyflwr yr asedau hanesyddol a geir fel y gellir asesu effeithiau Glastir yn y dyfodol.

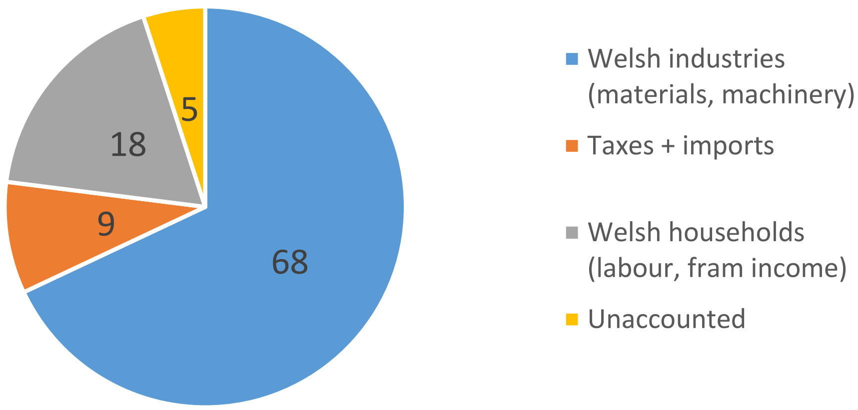
Mae uchafbwyntiau Blwyddyn 2 yn cynnwys:

Effeithiau cymdeithasol-economaidd ehangach Grantiau Cynllun Effeithlonrwydd Glastir

- Ceir diddordeb o fewn Llywodraeth Cymru i ganfod manteision ehangach Glastir y tu hwnt i'r tirfeddiannwr sy'n cael y taliad. Cynhaliwyd arolwg i ymchwilio i fanteision ehangach Grantiau Effeithlonrwydd Glastir ar ffurf astudiaeth achos i ymchwilio i'r mater.
- Cafodd cyfanswm o 305 o grantiau eu cymeradwyo ar gyfer ffermydd yn yr arolwg (mis Gorffennaf 2014). Roedd grantiau Effeithlonrwydd Ynni yn cyfrif am 9.2% o gyfanswm y

grantiau a gymeradwywyd, roedd 7.9% wedi'u neilltuo i ffermydd llaeth, 1.3% i ffermydd 'eraill' ac nid oedd dim wedi'u neilltuo i ffermydd gwartheg a defaid mewn ardaloedd llai ffafriol. Roedd y grantiau a ddyfarnwyd i ffermydd gwartheg a defaid mewn ardaloedd llai ffafriol bron i gyd ar gyfer Effeithlonrwydd Slyri a Thail (174 o'r 179 o'r grantiau a gymeradwywyd).

- Cyfanswm gwerth ariannol y grantiau a dalwyd oedd £1,006,490. Nid oedd dim grantiau Effeithlonrwydd Dŵr yn mynd drwy'r broses erbyn mis Gorffennaf 2014. Roedd grantiau Effeithlonrwydd Slyri a Thail yn cyfateb i £883,000, ac roedd grantiau Effeithlonrwydd Ynni'n cyfateb i £123,490.
- Ffermydd llaeth yr iseldir a gafodd y grant mwyaf fesul fferm ar gyfartaledd (£16,102), o gymharu â £9,855 ar gyfer ffermydd gwartheg a defaid mewn ardaloedd llai ffafriol a £8,732 ar gyfer ffermydd llaeth mewn ardaloedd llai ffafriol. Y ffermydd yn y categori maint lleiaf (0-19.9 ha) a gafodd y grant cyfartalog lleiaf, sef £8,370.
- Cytunodd mwy na 90% o'r ymatebwyr fod Grantiau Effeithlonrwydd Glastir wedi eu hannog i ymgymryd â buddsoddiadau cyfalaf newydd. Yn yr un modd, cytunodd mwyafrif y ffermwyr (83%) fod mynediad at GEG wedi cynyddu maint y buddsoddiad yr oeddent wedi'i gynllunio. Cytunodd dros 87% o'r ffermwyr na fyddai eu prosiect a ariannwyd wedi mynd yn ei flaen heb y grant, gan awgrymu bod GEG wedi bod yn ddull defnyddiol o gyflawni datblygiad economaidd ac annog mentrau newydd ar ffermydd.
- O ganlyniad i'r Grantiau Effeithlonrwydd Glastir, nododd dros chwarter (28%) o fusnesau fferm gynnydd cyffredinol mewn gwerthiannau, wrth i 51% nodi cynnydd mewn gwerthiannau o ffermio'n benodol.
- Cafodd mwy o wariant ffermydd ei wario yn niwydiannau Cymru(68%), aelwydydd Cymru (18%) a threthi (8%); nid oedd cofnod o ran y 6% sy'n weddill oherwydd camgymeriadau ymatebwyr i'r arolwg (Ffigur 06).
- O'r gwariant y gwnaeth ymatebwyr ei dyrannu i ddeunyddiau sy'n cael eu mewnforio, roedd y rhan fwyaf ar gyfer deunyddiau adeiladu (49%), a pheirianwaith ac offer (32%). O'r mewnforion hyn, roedd 57% o'r gwariant yn y DU ac Iwerddon; roedd 8% wedi nodi cymysgedd o wario ledled y DU a gwledydd Ewrop, ac roedd 13% yn mewnforio cynnyrch o wledydd Ewrop.
- Yn ôl 71% o'r ymatebwyr, mae Grantiau Effeithlonrwydd Glastir wedi hyrwyddo effaith fuddiol ar gyflenwyr ffermydd ar draws pob math o fferm. Yn yr un modd, gwnaeth 44% o'r ymatebwyr ddatgan bod cwsmeriaid a chleientiaid ffermydd wedi bod yn destun effeithiau ariannol buddiol o'r grantiau.



Ffigur 06 *Dyraniad gwariant uwch ar ôl cael grantiau Cynllun Effeithlonrwydd Glastir.*

Deall yr Hyn sy'n Rhwystro'r Defnydd o Gynlluniau Creu Coetir

- Mae creu coetir yn weithgaredd y mae Glastir yn ei hyrwyddo i sicrhau bod mwy o garbon yn cael ei ddal a'i storio, ac felly i leihau allyriadau cyffredinol nwyon tŷ gwydr o'r sector tir. Fodd bynnag, ni chafwyd llawer o ddefnydd o'r cynllun ac mae arolwg RhMGG wedi'i gynllunio i nodi'r rhwystrau i'r defnydd.
- Dangosodd y canlyniadau bod canfyddiad bod y broses yn tanseilio amcanion y cynllun ac yn anghymhelliad i ddarpar aelodau'r cynllun, a hynny o'r gymuned ffermio a'r Awdurdodau Lleol.
- Mae argymhellion i wella'r defnydd yn cynnwys:
    - I sicrhau defnydd uwch o'r cynllun dylid symleiddio'r broses ymgeisio.
    - Mae angen i'r cynllun fod yn fwy hyblyg er mwyn ystyried dylanwadau allanol.
    - Rhaid i'r broses archwilio fod yn llai bygythiol, a rhaid cyfleu cosbau'n glir er mwyn annog mwy o ddefnydd.
    - Rhaid sicrhau darlun cliriach o ran cyfraddau talu er mwyn annog darpar-aelodau i fabwysiadu'r cynllun.

Y dirwedd a'r amgylchedd hanesyddol
O ystyried mai cenedl gymharol fach yw Cymru, mae'n cynnwys ystod arbennig o amrywiol o dirweddau; o arfordiroedd i'r gweundiroedd, y tir sy'n cael ei ffermio i'r tir diwydiannol. Mae nodweddion diriaethol unigryw y dirwedd sy'n deillio o'i dopograffi, daeareg, pridd a hinsawdd amrywiol i gyd wedi helpu i greu tirwedd ddiwylliannol a hanesyddol unigryw a werthfawrogir sy'n cwmpasu ffermio, adeiladau gwledig, trefi yn ogystal â safleoedd hanesyddol unigryw ac archaeoleg ddiwydiannol. Mae'r 3.1 miliwn o breswylwyr, y mae'r mwyafrif ohonynt yn byw yng nghytrefi de Cymru (Caerdydd, Abertawe) ac ar hyd arfordir y gogledd ac ymylon aber afon Dyfrdwy yn nifer bach o'i gymharu â'r 100 miliwn o ymweliadau diwrnod a'r 6 miliwn o deithiau dros nos a wnaed i Gymru gan ymwelwyr hamdden yn 2013.

Mae gan Gymru hefyd amgylchedd hanesyddol gyfoethog a gwahanol. Ar hyn o bryd mae 3 Safle Treftadaeth y Byd UNESCO, 30,000 o adeiladau rhestredig a dros 4,000 o Henebion Rhestredig yng Nghymru sy'n cael eu diogelu gan y gyfraith. Amcangyfrifwyd bod yr amgylched hanesyddol yn cynnal dros 30,000 o swyddi ac yn 2009 roedd yn cyfrannu tua £840 miliwn i'r economi ehangach. Mae'r amgylchedd hanesyddol hefyd yn creu manteision cymdeithasol i breswylwyr Cymru, gan gynnwys cyfleoedd ar gyfer hamdden, gwirfoddoli a dysgu. Mae'r set ddata ynghylch nodweddion yr amgylchedd hanesyddol yn cofnodi'r lleoliad a'r wybodaeth sy'n hysbys am y nodweddion hanesyddol hyn nas dynodwyd. Ynghyd â'r safleoedd a ddynodwyd fel yr Henebion Rhestredig a'r adeiladau rhestredig, mae'r nodweddion llai hyn yn cyfrannu at werth hanesyddol a diwylliannol cyffredinol tirwedd. Mae nodweddion hanesyddol nas dynodwyd yn gyffredin ledled tirweddau Cymru. Ar y cyfan, mae'r nodweddion hyn i'w cael ar dir preifat, felly mae'r gwaith hirdymor o ofalu am yr asedau diwylliannol hyn yn cael ei roi yng ngofal tirfeddiannwyr unigol. Weithiau mae'r nodweddion hyn yn wynebu sefyllfa o gael eu hesgeuluso neu'n cael eu difrodi drwy ddiffyg gwybodaeth a rheolaeth briodol. Mae Glastir yn darparu cyllid i dirfeddiannwyr i ddiogelu nodweddion hanesyddol drwy reoli'r defnydd o'r tir fel newid o gnydau âr i borfeydd gwair neu reoli erydu drwy reoli stoc yn well â ffensys. Yn ychwanegol at hynny, mae taliadau ar gael i helpu i reoli prysgwydd sy'n broblem benodol ar rai safleoedd hanesyddol. Mae effeithiau cadarnhaol posibl ar ansawdd y dirwedd weledol yn gysylltiedig â'r math hwn o reolaeth weithredol, gan beri y gellir gweld y dirwedd yn glir, a bod y cyhoedd yn gweld nodweddion hanesyddol ac yn eu hadnabod.

Mae Glastir yn cydnabod yn amlwg bwysigrwydd tirwedd Cymru; un o bum nod datganiedig y cynllun yw rheoli a diogelu tirwedd Cymru a'r amgylchedd hanesyddol ynddi, gan sicrhau ar yr un pryd fod y cyhoedd yn gallu mynd at y dirwedd, a bod hynny'n cael ei hyrwyddo. Mae pedwar targed penodol ynglŷn â'r dirwedd wedi'u hamlinellu yn y rhaglen, gan gynnwys: tirwedd ffos; nodweddion a thirweddau hanesyddol; tirwedd pwll a thirweddau gwarchodedig. Mae gan bum targed ychwanegol elfennau sylweddol o ran ansawdd y dirwedd ac maent yn cynnwys y rhai sy'n gysylltiedig â pherllannau; tir parciau a phorfeydd coed; parciau a gerddi; mynediad caniataol a choetir. Ym mhob un o'r targedau hyn ceir opsiynau rheoli penodol sy'n cael effeithiau uniongyrchol ar ansawdd posibl yr olygfa o'r dirwedd. Er bod setiau data presennol yn darparu gwybodaeth am leoliad nodweddion hanesyddol yng Nghymru, mae RhMGG yn darparu cipolwg ar y nodweddion hynny yn sgwariau 1km arolwg RhMGG, a'r pwysau y maent yn eu hwynebu ar hyn o bryd, ac yn y pen draw bydd yn dangos sut y mae hyn yn newid dros amser.

Newidiadau mawr ym Mlwyddyn 2

- Mae Mynegai Ansawdd Gweledol RhMGG wedi'i gynnal yn llwyddiannus ar 150 o sgwariau arolygu 1km RhMGG y flwyddyn 1af a'r 2il flwyddyn. Mae hyn wedi cynhyrchu data sy'n rhestru pob un o'r 23 o baramedrau mewnbynnu fesul sgwâr a gwerthoedd mynegai wedi'u pwysoli ar gyfer pob un. Mae pob un o sgwariau'r arolwg wedi'u gosod mewn trefn erbyn hyn, o 1 (mynegai o'r ansawdd uchaf) i 150(mynegai o'r ansawdd isaf).
- Cwblhawyd dadansoddiad Viewshed ar 3 raddfa ar gyfer 150 o sgwariau arolygu 1km y flwyddyn 1af a'r 2il flwyddyn, a hynny gan ddefnyddio 4 categori gwahanol o ddefnyddwyr (cerddwyr, seiclwyr, defnyddwyr cerbydau bach, defnyddwyr y rheilffordd), ar 3 gwahanol raddfa: gan edrych y tu mewn i'r sgwâr 1km, edrych i'r tu allan i'r 3 x 3 km amgylchynol, ac edrych i mewn o'r sgwâr 3 x 3 km amgylchynol. Mae hyn yn cyfateb i 1800 o setiau data viewshed ar wahân ar gyfer y ddwy flynedd.
- Mae data asesu cyflwr wedi'u casglu a'u dadansoddi ar gyfer nodweddion amgylchedd hanesyddol y 150 o safleoedd arolygu 1km RhMGG y flwyddyn 1af a'r 2il flwyddyn.
- Mae nifer a chyflwr yr Hawliau Tramwy Cyhoeddus yn sgwariau RhMGG Blwyddyn 2 wedi'u hasesu.
- Cynhaliwyd arolwg ffotograffig o'r hyn a ffefrir yn gynnar yn y gwanwyn yn 2014, a hynny ar ffurf cynllun peilot; cafodd yr arolwg ar-lein ei fireinio wedyn a'i lansio yn yr haf yn 2014 â fersiynau Cymraeg a Saesneg ar gael. Mae'r arolwg hwn wedi dilysu proses y Mynegai Ansawdd Gweledol o osod opsiynau mewn trefn ac mae wedi darparu rhagor o wybodaeth am effeithiau cadarnhaol a negyddol rhannau penodol o'r Mynegai. Ein targed cychwynnol oedd cael 500 o arolygon wedi'u cwblhau, felly mae hyn wedi rhagori ar ein disgwyliadau'n sylweddol ac mae wedi creu set ddata â phwysigrwydd a gwerth ehangach.

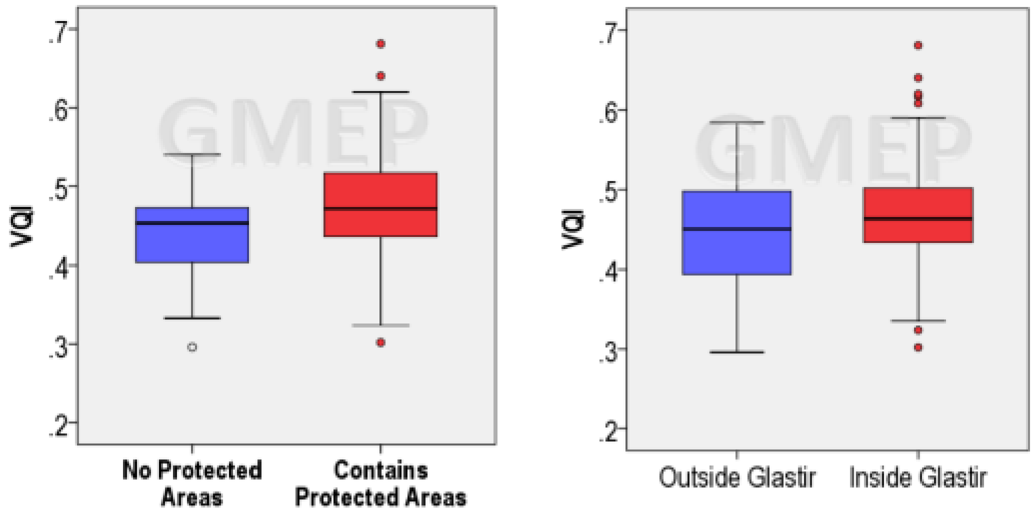
Y prif ganfyddiadau

Ystod y Mynegai Ansawdd Gweledol ar draws tirwedd Cymru

- Cafodd Mynegai Ansawdd Gweledol y dirwedd ei ddatblygu gan RhMGG ym mlwyddyn 1 i geisio cofnodi'n wrthrychol ansawdd tirwedd Cymru gan ddefnyddio dull y gellid ei ailadrodd a'i ddadansoddi'n gadarn ochr yn ochr â'r nifer o fetrigau adnoddau naturiol eraill yn yr arolwg. Ym mlwyddyn 2, rydym wedi dechrau ymchwilio i sut y mae'r mynegai hwn yn amrywio ar draws tirwedd Cymru i ddarparu llinell sylfaen ar gyfer asesiadau'r dyfodol o effeithiau taliadau Glastir.
- Nid oes dim gwahaniaeth sylweddol o ran y Mynegai Ansawdd Gweledol rhwng safleoedd yr ucheldir a safleoedd yr iseldir. Fodd bynnag, mae gan dirweddau'r ucheldir ystod lai o werthoedd o ran y Mynegai a gwerth cymedrig cyffredinol uwch, sy'n dangos eu bod yn tueddu i beidio â chynnwys y tirweddau o'r ansawdd isaf. Dim ond pan fo ystod o werthoedd cadarnhaol yn cyd-daro y bydd sgoriau uchel iawn o ran ansawdd y dirwedd yn goruchafu.
- Nid oes dim gwahaniaeth ystadegol rhwng y sgoriau ansawdd cymedrig a neilltuwyd i'r safleoedd 1km sy'n dod o fewn / y tu allan i ardal warchodedig. Fodd bynnag, mae gwahaniaethau clir yn ystod y gwerthoedd, ac mae'r gwerthoedd uwch i gyd i'w cael mewn ardaloedd gwarchodedig (Ffigur 07).
- Cafodd sgwariau sy'n cynnwys ardaloedd o dir Glastir eu cymharu â'r rhai nad oes ganddynt ddim tir Glastir. Er bod rhywfaint o arwydd bod y safleoedd hynny sydd â gwerthoedd Mynegai Ansawdd Gweledol uwch i'w cael yng nghynllun rheoledig Glastir, nid yw'r

canlyniadau'n sylweddol hyd yma. Wrth i ragor o sgwariau gael eu harolygu gall y duedd hon ddod yn gliriach (Ffigur 07).

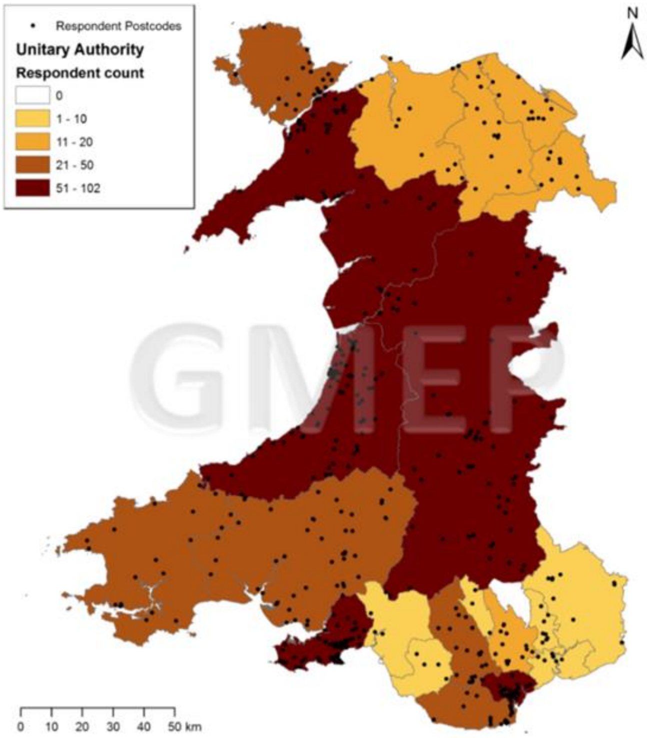
- Ar hyn o bryd, ni chanfyddir dim perthynas rhwng y sgôr o ran ansawdd y dirwedd a nifer y rhywogaethau planhigion, adar, gloÿnnod byw neu wenyn yn sgwariau arolygu 1km Blwyddyn 1 a 2 RhMGG, sy'n awgrymu nad oes dim perthynas uniongyrchol rhwng ansawdd ecolegol a thirwedd fel y dangosir gan y metrigau prawf cychwynnol hyn. Fodd bynnag, bydd dull mwy systematig ac integredig, e.e. gan ddefnyddio'r mynegai Tir Fferm o Werth Mawr i Natur sy'n cael ei ddatblygu ar hyn o bryd, yn cael ei asesu yn y blynyddoedd i ddod, a bydd hwn hefyd yn elwa ar sampl fwy.



Ffigur 07: *Mynegai Ansawdd Gweledol safleoedd arolygu 1km RhMGG yn y flwyddyn 1af a'r 2il flwyddyn (n= 150) gan gymharu a) y tu mewn i'r ardaloedd gwarchodedig, a'r tu allan iddynt a b) sgwariau sydd â rhywfaint o dir a reolir gan Glastir o'u cymharu â'r rhai nad oes ganddynt ddim.*

Arferion ymweld â chefn gwlad a'i bwysigrwydd

- Roedd mwyafrif y 1,360 o ymatebwyr i arolwg ffotograffig RhMGG o'r hyn a ffefrir wedi'u gwasgaru'n dda ledled Cymru (cafwyd ymatebion ychwanegol o rannau eraill y DU) (Ffigur 08).
- Ymwelodd yr ymatebwyr â chefn gwlad naill ai bob dydd neu ddwy neu dair gwaith bob wythnos.
- Y pum prif reswm dros ymweld â chefn gwlad oedd: *ymlacio*, *hamdden egnïol*, *rhesymau iechyd*, *llonyddwch a thawelwch*, a: *crwydro a darganfod mannau newydd*.
- Teithio mewn car preifat oedd y dull mwyaf cyffredin o gyrraedd cefn gwlad; roedd cerdded yn yr ail safle.
- Roedd mwyafrif llethol yr ymatebwyr yn ystyried bod cefn gwlad Cymru naill ai'n 'bwysig' neu'n 'bwysig iawn' iddynt.



Ffigur 08 *Dosbarthiad yr ymatebwyr i'r arolwg o Gymru. O'r 976 o arolygon a gwblhawyd, nododd 758 eu bod yn Gymry (78%)*

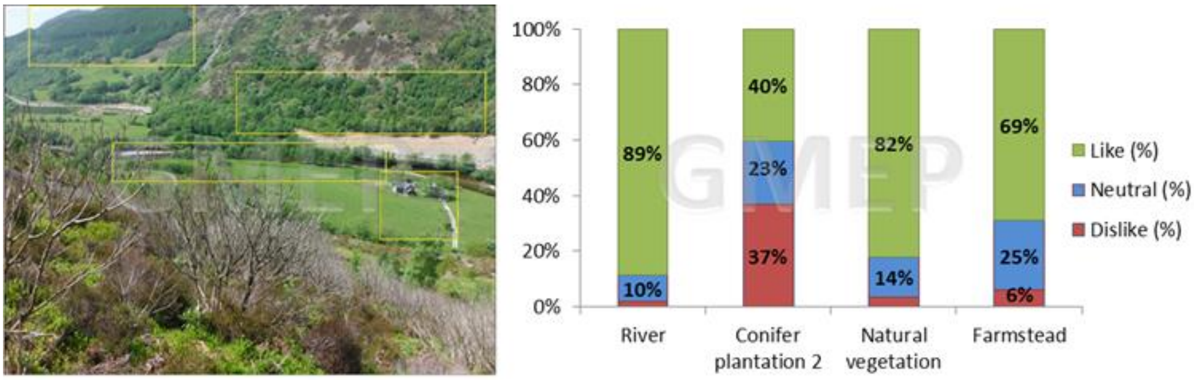
Atyniad cyffredinol ar sail yr arolwg ffotograffig o'r hyn a ffefrir

- Mae trefn gyffredinol atyniad y dirwedd a nododd yr ymatebwyr yn debyg yn fras i'r drefn a ddangosir gan y Mynegai Ansawdd Tirwedd.
- Roedd trefn y tirweddau a nodwyd gan ymatebwyr benywaidd a gwrywaidd yn debyg yn gyffredinol.
- Ni ellid canfod dim gwahaniaethau mawr o ran trefn y dirwedd a nodwyd gan y gwahanol grwpiau oedran: nododd yr holl grwpiau oedran (ac eithrio'r rhai rhwng 30 a 44) yr un drefn ar gyfer y pum tirwedd. Fodd bynnag, nododd ymatebwyr iau sgoriau is yn gyffredinol nag a wnaeth y grwpiau hŷn.
- Dangosodd y sgoriau cymedrig o ran y drefn fod ymatebwyr a oedd yn ystyried eu hunain yn Gymry, yn Saeson, yn Brydeinwyr ac yn Wyddelod o Ogledd Iwerddon yn nodi'r un drefn ar gyfer y tirweddau. Fodd bynnag, cafwyd gwahaniaeth bach ond o bwys yn ystadegol yn y sgoriau ar gyfer un math o dirwedd rhwng ymatebwyr a oedd yn ystyried eu hunain yn Gymry o'u cymharu â'r rhai a oedd yn eu hystyried eu hunain yn Brydeinwyr, yn Saeson neu o genedligrwydd arall.
- Cafodd y math o leoliadau lle y magwyd ymatebwyr effaith fach ond o bwys yn ystadegol ar y drefn a nodwyd ar gyfer y mathau o dirwedd. Roedd ymatebwyr a gafodd eu magu mewn pentref yn tueddu i nodi trefn wahanol o ran rhai tirweddau o'u cymharu â'r rhai a gafodd eu magu mewn tref fach neu dref (ar gyfer E). Ni chanfuwyd dim effaith o ran cartref bresennol yr ymatebwyr.

Gwerthfawrogi nodweddion penodol y dirwedd

- Mewn rhai tirweddau, roedd nodweddion unigol yn cael y dylanwad mwyaf ar yr asesiadau e.e. glan y môr neu rug yn blodeuo. Yn achos tirweddau eraill, roedd nifer o ardaloedd yn cael eu ffafrio, yn enwedig coetir/coed collddaill, gwrychoedd, afonydd a dyffrynnoedd yn y pellter.
- Roedd mwyafrif yr ymatebwyr yn hoffi nodweddion 'naturiol' fel dolydd, coed collddail, coetir a nodweddion dyfrol, fel yr oedd da byw ac elfennau artiffisial llai 'ymwthiol' fel wal gerrig a fferm fach.

- Roedd safbwyntiau llai terfynol ynghylch y nodweddion artiffisial mwy amlwg fel planhigfeydd conwydd, ffyrdd ac adeiladau mawr ar ffermydd. Er bod cyfran sylweddol o ymatebwyr yn mynegi nad oeddent yn eu hoffi, nid oedd y rhain byth yn fwyafrif llethol gan fod cyfran nodedig o'r ymatebwyr hefyd yn hoffi'r nodweddion hyn neu wedi nodi eu bod yn 'niwtral' e.e. Ffigur 09.



Ffigur 09 *Un o'r ffotograffau o'r dirwedd a ddefnyddiwyd yn yr arolwg ynghylch tirwedd a ffefrir, gyda'r hoff dirweddau wedi'u nodi.*

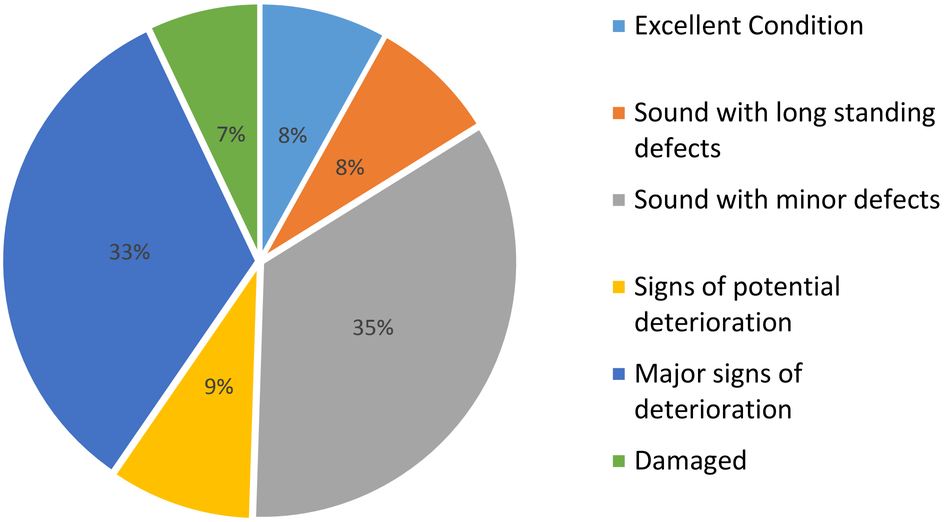
Gweld y dirwedd a'i defnyddio

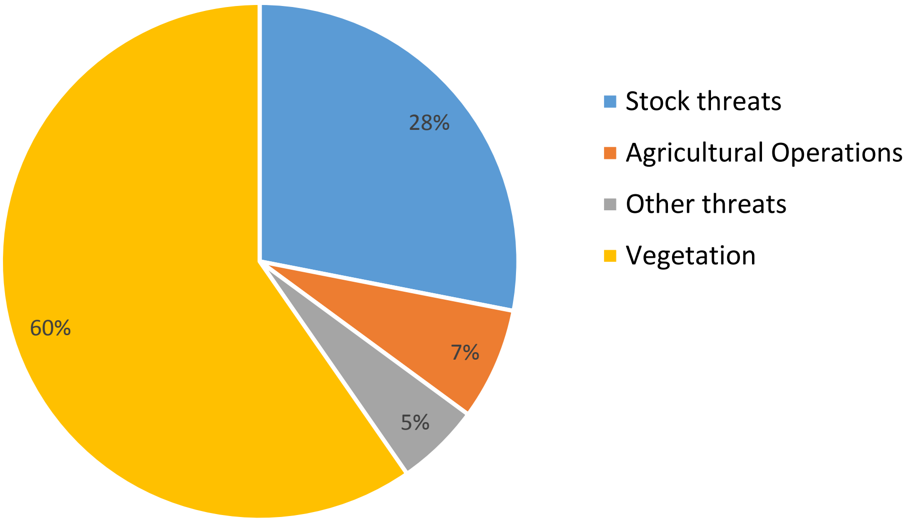
- Mae cerddwyr a seiclwyr ar gyfartaledd yn mwynhau golygfa sydd 45% o'r sgwâr 1km o'u cymharu â 36% o'r bobl sydd wedi'u cyfyngu i gar.
- Ar raddfa ehangach y dirwedd 3 x 3km amgylchynol o'r tu mewn i'r sgwâr 1km eto, cerddwyr sy'n gallu gweld y golygfeydd ehangach hyn, wrth i tua 40% o'r rhanbarth amgylchynol fod i'w weld.
- O'r tu allan i'r sgwâr 1km, mae sgwariau arolygu 1km RhMGG hefyd yn cyfrannu at y dirwedd y maent wedi'u lleoli ynddo. Gallai 81% o'r grŵp o gerddwyr weld y sgwariau, sy'n adlewyrchu dwysedd cyffredinol ffyrdd a llwybrau yng Nghymru.
- O blith y safleoedd blwyddyn gyntaf ac ail flwyddyn, mae'r data digidol yn dangos bod 133 o'r 150 yn cynnwys rhai Hawliau Tramwy Cyhoeddus; roedd y 17 sy'n weddill i gyd yn safleoedd anghysbell, yn yr ucheldir. Roedd dosbarthiad y llwybrau'n amrywio'n sylweddol, ond mewn mannau roedd y rhwydwaith yn ddwys wrth i un safle feddu ar bron 6km o lwybrau yn y 1km^2, er ei bod yn fwy arferol i'r ffigur hwn fod rhwng 1.5 a 3km.
- Canfu arolygon cyflwr fod 57 o'r 90 o safleoedd Blwyddyn 2 â rhai Hawliau Tramwy Cyhoeddus, ac o blith y rheini dim ond 20 a oedd â llwybrau a oedd yn gwbl agored, gan gynnwys arwyddion a llwybrau y gellid teithio arnynt. Mewn sgwar 1km arferol, dim ond dwy ran o dair o'r llwybrau ar safle 1km oedd yn gwbl agored, yn hygyrch ac yn hawdd eu canfod. Cafwyd arwyddion gwael yn aml ac roedd nifer o lwybrau nad oeddent yn cael eu defnyddio'n aml o ganlyniad i hynny, a oedd yn arwain felly at ddirywiad a gwaith cynnal a chadw gwael.

Cyflwr nodweddion hanesyddol

- Dengys asesiad o gyflwr fod 8% wedi'u barnu i fod mewn cyflwr rhagorol ar adeg cynnal yr arolwg ac y gwelwyd bod 35% yn gadarn â mân ddiffygion. Fodd bynnag, aseswyd bod 33% yn dangos arwyddion mawr o ddirywiad tra gwelwyd bod 7% arall â niwed sylweddol.(Ffigur 10)
- Llystyfiant oedd y bygythiad mwyaf (gan gynnwys prysgwydd, rhedyn, mieri a brwyn), gan fod â'r potensial nid yn unig i guddio nodweddion hanesyddol ond i'w niweidio hefyd. Cafwyd bygythiadau'n gymharol aml hefyd i stoc (gan gynnwys herwhela, erydu a thraul stoc) tra bo bygythiadau amaethyddol (er enghraifft olion teiars wyneb, gollwng, draenio a gwella porfeydd) a bygythiadau cyffredinol eraill (gan gynnwys dirywiad naturiol, fandaliaeth, datblygiad, tipio anghyfreithlon) yn llai cyffredin. (Ffigur 11)

Mae **Ffigur10** *yn dangos cyflwr Nodweddion yr Amgylchedd Hanesyddol ar gyfer blynyddoedd 1 a 2 sgwariau arolygu 1km RhMGG.*





Mae **Ffigur 11** *yn dangos bygythiadau i Nodweddion yr Amgylchedd Hanesyddol ar gyfer blynyddoedd 1 a 2 sgwariau arolygu 1km RhMGG.*

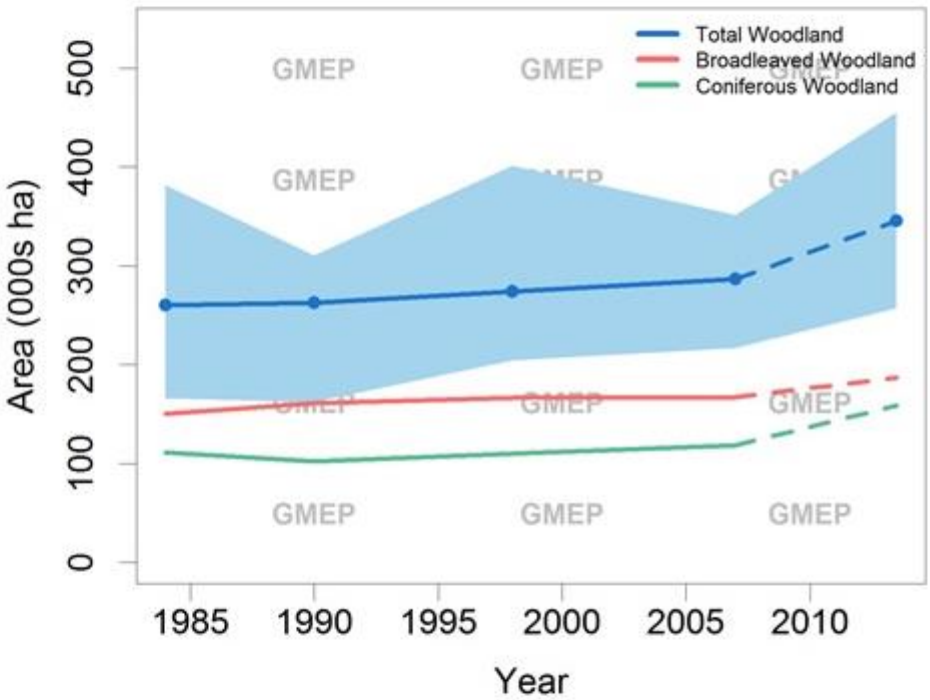
Coetiroedd

Mae coetir yn bwysig ar gyfer darparu nifer o wasanaethau, nwyddau a buddion ecosystem, gan gynnwys pren, diogelu'r pridd, atal llifogydd, hamdden, rheoleiddio'r hinsawdd ac amrywiaeth rhywogaethau gwyllt (i rai cyffredinol a'r rhai sy'n byw mewn coetiroedd yn unig). Mae nifer o'r gwasanaethau hyn yn rhai sy'n ychwanegu at ei gilydd ac mae synergeddau rhwng gwasanaethau yn hytrach nag effeithiau gwrthbwyso; mae coetiroedd yn gynefinoedd sydd â nifer o swyddogaethau. Pennwyd gwerth o £34 miliwn i fanteision amgylcheddol coetiroedd yng Nghymru. Dangosodd arolwg diweddar fod bron 65% o bobl yng Nghymru yn ymweld â choetiroedd Cymru yn rheolaidd ac mae 94% o'r farn eu bod yn darparu budd cadarn i'r gymuned leol. O blith gwledydd y DU, Cymru sydd â'r ganran uchaf o orchudd gan goetiroedd coed llydanddail, cymysg a choed yw, er bod y ganran yn isel o'i chymharu â safonau Ewropeaidd; dim ond yr Alban sydd wedi'i gorchuddio gan ganran uwch. Fodd bynnag, canlyniad yw hyn i'r ganran lawer uwch o orchudd gan goetiroedd conwydd yno nag a geir mewn mannau eraill. Mae tua 210 (39%) a rhywogaethau Adran 42 o'r pwysigrwydd pennaf o safbwynt gwarchod amrywiaeth fiolegol yng Nghymru naill ai'n dibynnu ar gynefinoedd coetir, neu y gellid effeithio arnynt o bosibl gan weithrediadau coedamaeth. Cyhoeddwyd strategaeth Llywodraeth Cymru 'Coetiroedd i Gymru' yn 2001 a chafodd ei diwygio yn 2012. Mae'n hyrwyddo'r broses o gynllunio a rheoli coetiroedd i ddarparu ystod eang a chytbwys o wasanaethau ecosystem. Mae cyfres o 23 o ddangosyddion wedi'u datblygu i fesur y cynnydd tuag at gyflawni'r 20 o ganlyniadau lefel uchel a amlinellir yn strategaeth Coetiroedd i Gymru. Yng Nghymru, mae cynllun Glastir yn rhan sylweddol o'r Rhaglen Datblygu Gwledig ac felly mae'n cyfrannu at gyflawni nifer o rwymedigaethau statudol a thargedau sy'n berthnasol i fioamrywiaeth sy'n deillio o gytundebau ar lefelau byd eang (targedau Aichi), Ewropeaidd (Strategaeth Bioamrywiaeth yr Undeb Ewropeaidd ynghyd â'r Cyfarwyddebau Cynefinoedd ac Adar) a'r DU (y Ddeddf Bywyd Gwyllt a Chefn Gwlad a'r Ddeddf Amgylchedd Naturiol a Chymunedau Gwledig) a fydd yn gymwys i gynefinoedd coetir. Mae gan Glastir elfen goetiroedd benodol sy'n cynnwys opsiynau ynghylch creu a rheoli coetiroedd. Mae RhMGG hefyd wedi cynnal arolwg o dirfeddiannwyr er mwyn canfod y rhwystrau i'r defnydd o gynllun Creu Coetiroedd Glastir.

Y prif ganfyddiadau

Maint y coetir

- Roedd prif ganfyddiad Blwyddyn 2 yn cynnwys cynnydd i arwynebedd coetiroedd Cymru dros y 30 mlynedd diwethaf, gyda chynnydd hyd at 2014 (a gofnodwyd gan RhMGG a'r Rhestr Goedwigaeth Genedlaethol). Mae'r mathau o goetiroedd coed llydanddail a chonwydd wedi cynyddu yn yr ardal (Ffigur 12). Sylwch nad yw RhMGG na'r Rhestr Goedwigaeth Genedlaethol yn darparu darlun cyflawn o dueddiadau hanesyddol neu bresennol ond dylid eu dewis gan ddibynnu ar y cwestiwn a ofynnir gan fod eu dulliau'n fwy perthnasol i rai cwestiynau nag eraill e.e. yr ardal sy'n cael ei hailstocio (y Rhestr), ardal o goetir bach (RhMGG) ac yn y blaen.
- Mae RhMGG yn amcangyfrif mai cyfanswm arwynebedd coetiroedd yng Nghymru yw 346 000ha (187000ha yn goetiroedd coed llydanddail a 159 000ha yn goetiroedd conwydd); mae hyn y cyfateb i 16.3% o Gymru yn 2013/14. Mae hyn yn cymharu â 10% yn Lloegr ac oddeutu 15-18% yn yr Alban.
- Mae'r Rhestr Goedwigaeth Genedlaethol yn amcangyfrif mai cyfanswm arwynebedd coetir Cymru yn 2014 oedd 306 000 ha, sef 14.8% o Gymru, y mae 156 000ha ohono'n goetir coed llydanddail a 151 000 ha yn rhai conwydd.
- Mae cyfanswm arwynebedd coetir Cymru yn gyson yn yr Arolwg Cefn Gwlad/RhMGG a'r Rhestr Goedwigaeth Genedlaethol (yn arbennig o ystyried y cyfyngau hyder mawr a geir yng nghyswllt yr amcangyfrifon); mae'r ffigur ar gyfer coetir coed conwydd yn debyg iawn (RhMGG 159 000ha, Rhestr Goedwigaeth Genedlaethol 151 000 ha) mae'r Arolwg Cefn Gwlad yn cofnodi bod swm uwch o goetir yn goetir coed llydanddail, cymysg a choed yw, o'i gymharu â Choetir Coed Conwydd.
- Amcangyfrifodd y Rhestr Goedwigaeth Genedlaethol fod plannu newydd ac ailstocio yng Nghymru yn cyfateb i 3 100 ha rhwng y ddau gyfnod 2009-2010 a 2013-2014. Mae hyn yn llai nag a gafwyd mewn blynyddoedd blaenorol a chyfran fach yw o'r plannu newydd yn y DU (50 900 ha), y cafwyd y mwyafrif ohono yn yr Alban.

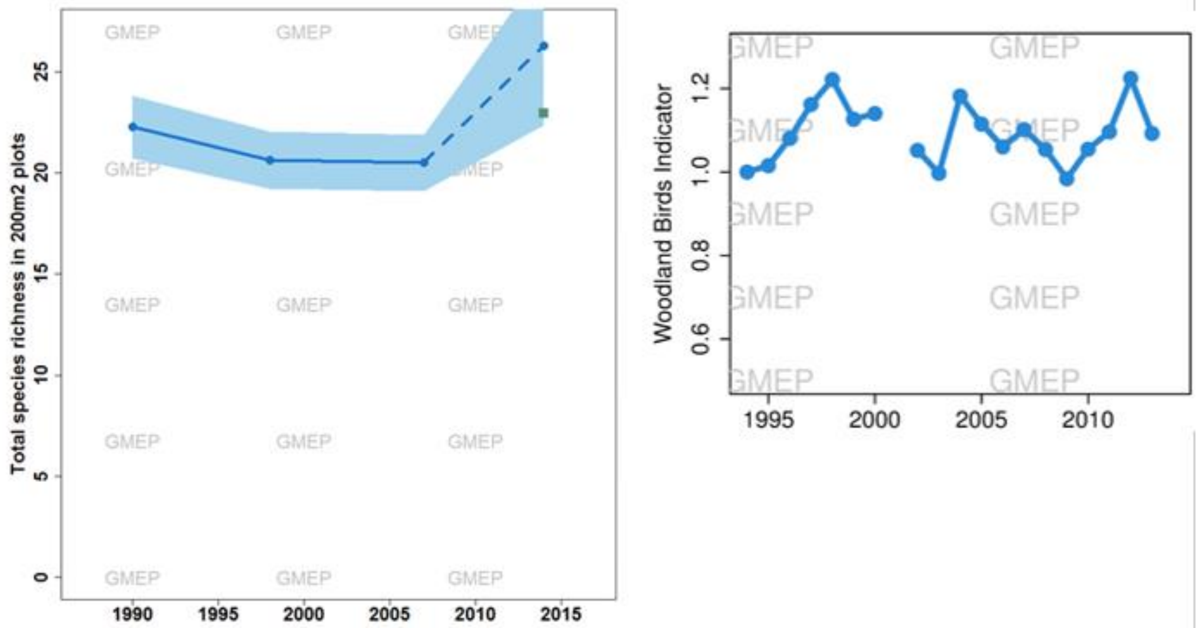


Ffigur 12 *Arwynebedd y coetir yng Nghymru dros amser, a grëwyd ar sail amcangyfrifon cenedlaethol o ddata'r arolwg maes, Arolwg Cefn Gwlad (llinell ddi-dor) a RhMGG (llinell doredig).* Cyflwr Coetir

- Mae cyfanswm arwynebedd y coetir y gwyddys ei fod yn cael ei reoli i Safon Goedwigaeth y DU wedi cynyddu o 123,000 ha yn 2001 i o leiaf 203,000 ha yn 2014.
- Ers 2010, cafwyd dau achos o glefydau cwarantin yn effeithio ar rywogaethau coed yng Nghymru (*Phytophthora ramorum* a *Chalara fraxinea*). Lansiwyd proses benodol i Gymru ar gyfer rheoli clefyd *Phytophthora ramorum* ym mis Rhagfyr 2013 sy'n pennu parthau rheoli. Mae yna hefyd nifer fach o blâu a chlefydau nad ydynt yn rhai cwarantin y gwyddys eu bod yn effeithio ar rywogaethau coed yng Nghymru.
- Ceir amrywiad rhyng-flynyddol yn y dangosydd adar coetir ond ymddengys na chafwyd newid cyfeiriadol sylweddol o ran helaethrwydd rhywogaethau adar coetir. Mae'n gymharol sefydlog mewn cyferbyniad â'r dangosydd adar tir fferm (Ffigur 13)
- Amcangyfrifir mai'r carbon sy'n cael ei ddal a'i storio o goetiroedd Cymru ar hyn o bryd yw tua 1,419 gigagram (1,419,000 o dunelli) bob blwyddyn. Rhagamcenir y bydd coedwigaeth yn parhau'n ddalfa net ar gyfer carbon atmosfferig.
- Rhwng 1990 a 2007, cafwyd tuedd ostyngol gyffredinol nad oedd o sylwedd yn achos rhywogaethau'r dangosydd Coetir Hynafol mewn lleiniau llystyfiant coetir mawr, sef 200m^2; fodd bynnag, cynyddodd nifer rhywogaethau'r dangosydd Coetir Hynafol yn sylweddol yn sampl RhMGG ar gyfer 2013/14.
- Gwelwyd tuedd debyg yn achos cyfanswm cyfoeth rhywogaethau planhigion mewn lleiniau mawr o lystyfiant (Ffigur 03).
- Caiff sgoriau ar gyfer rhywogaethau planhigion sy'n ffafrio golau eu cyfrifo ar ffurf gwerth cyfartalog fesul llain, hynny yw, mae sgôr uwch yn golygu bod y planhigion a geir yno'n ffafrio amodau â mwy o olau. Cafwyd gostyngiad bach rhwng 1990 a 2013/14 i'r sgôr o ran amodau â golau; mae hyn yn dangos bod lleiniau'n dod yn fwy gwyllt a'u bod â mwy o gysgod, a hynny o bosibl oherwydd eu bod yn cael eu rheoli llai.
- Ni chafwyd dim newid sylweddol o ran cysylltedd coetiroedd coed llydanddail rhwng 1990 a 2013/14.
- Ni chafodd dim newid sylweddol ei arsylwi o ran amrywiaeth rhywogaethau prennaidd mewn gwrychoedd dros y 10-20 mlynedd diwethaf. Cofnodwyd cynnydd o ran gwrychoedd

yn cael eu torri ond cafwyd gostyngiad mawr o ran plannu, gosod haenau a bondocio newydd ers 1990. Mae cynnydd i hyd gwrychoedd gan beri iddynt ddod yn llinellau o goed yn awgrymu dirywiad o ran rheolaeth yn gyffredinol.

- Mae gan dir sy'n dod yn rhan o Glastir wrychoedd sy'n sylweddol hwy na'r rhai a geir y tu allan i'r cynllun, a rhaid ystyried hyn mewn asesiadau yn y dyfodol o effaith Glastir.



Ffigur 13 *Tueddiadau yng nghyfanswm cyfoeth rhywogaethau planhigion mewn coetiroedd (data'r Arolwg Cefn Gwlad/RhMGG) a rhywogaethau adar coetir (data'r Arolwg Adar Bridio).*

- Rydym yn disgrifio datblygiad Cynnyrch Gorchudd Prennaidd newydd, sy'n anelu at fapio gwrychoedd mawr, coed unigol a darnau bach o goetir, yn ogystal â choetiroedd mwy, ar draws Cymru gyfan, a hynny ar raddfa 5m x 5m (Ffigur 16). Mae gan y cynnyrch sy'n deillio o hynny nifer o ddefnyddiau posibl, gan gynnwys ymchwiliadau i gysylltedd cynefinoedd, modelu prosesau dŵr ffo dalgylchoedd, a meintoli stociau carbon. Pan gafodd ei ddilysu yn ôl ffotograffau o'r awyr yn achos nifer o safleoedd prawf, roedd y cynnyrch yn meddu ar gywirdeb dosbarthu o 88 %.

Ffigur 16 *Golygfa a gymerwyd o'r Cynnyrch Gorchudd Prennaidd newydd sy'n dangos yr ardaloedd y nodwyd eu bod yn orchudd prennaidd (ardaloedd coch) wedi'u gosod ar ben y ffotograff o'r awyr.*

Yn gyffredinol, mae'r duedd ar gyfer stoc coetir a'i gyflwr yn dangos bod arwynebedd mwy, ond nad oes fawr o dystiolaeth bod cyflwr wedi gwella.

Bioamrywiaeth

Mae gwarchod bioamrywiaeth yng Nghymru yn cydnabod y gwerth y mae pobl yn ei roi ar dreftadaeth gyfoethog o rywogaethau a chynefinoedd gwyllt. Mae rhai cynefinoedd a rhywogaethau â chadarnleoedd yng Nghymru tra bônt yn brin neu'n absennol mewn mannau eraill yn y DU ac yn Ewrop, sy'n peri bod gan Gymru gyfrifoldeb penodol am eu monitro a'u gwarchod. Er bod pwysigrwydd bioamrywiaeth yn adlewyrchu'r gwerth y mae pobl yn ei roi arno, mae rhai o'r gwerthoedd hyn yn anos i'w meintoli nag y mae rhai eraill. Maent yn bwysig er hynny, ac maent yn cynnwys, er enghraifft, gwarchod rhywogaethau a chynefinoedd gwyllt oherwydd eu pwysigrwydd diwylliannol, ysbrydol, esthetig ac o safbwynt hamdden. Yn 2007 amcangyfrifodd Asiantaeth yr Amgylchedd Cymru fod gweithgareddau a oedd yn seiliedig ar fywyd gwyllt wedi cyfrannu cyfanswm o £1.9 biiliwn o ran allbwn bob blwyddyn at economi Cymru, a oedd yn fwy na chyfanswm yr allbwn amaethyddol yn 2011, sef £1.3 biliwn. Felly, ni ddylid tanbrisio cyfraniad bioamrywiaeth at ffyniant, lles a chreu swyddi yng Nghymru.

Mae dulliau RhMGG yn gweddu'n arbennig o dda â chofnodi newidiadau mewn bioamrywiaeth yn yr ardal wledig ehangach sy'n amgylchynu ardaloedd dynodedig ac felly'n darparu ardaloedd pwysig i rywogaethau a chynefinoedd gysylltu ac ymateb i newidiadau i amodau amgylcheddol sy'n newid, fel newid yn yr hinsawdd. Yn ychwanegol at hynny, mae RhMGG wedi datblygu dulliau ar gyfer canfod effeithiau Glastir ar rywogaethau a chynefinoedd adran 42, gan ganfod yr achosion hynny o gyd-daro rhwng opsiynau a rhywogaethau a chynefinoedd, a chanfod mynegeion newydd o dueddiadau hirdymor mewn bioamrywiaeth a fydd yn gefndir i RhMGG. Rydym hefyd yn datblygu dulliau o nodweddu tir fferm sydd o Werth Mawr i Natur (gweler yr adran 'Tir Fferm sydd o Werth Mawr i Natur') ac o ymestyn ein hamcangyfrifon o'r newid mewn bioamrywiaeth ac effeithiau Glastir y tu allan i'r sampl o sgwariau RhMGG ac i Gymru yn ehangach, drwy gyfuno â chynnyrch data a gaiff eu synhwyro o bell a chronfeydd data cofnodion biolegol. Er mwyn bod yn gryno, ni chaiff yr holl ddata am dueddiadau cenedlaethol eu nodi yma ond maent ar gael ym Mhorth Data RhMGG. Nid yw Data am faint a chyflwr Cynefinoedd â Blaenoriaeth ar gael hyd yn hyn.

Uchafbwyntiau Blwyddyn 2

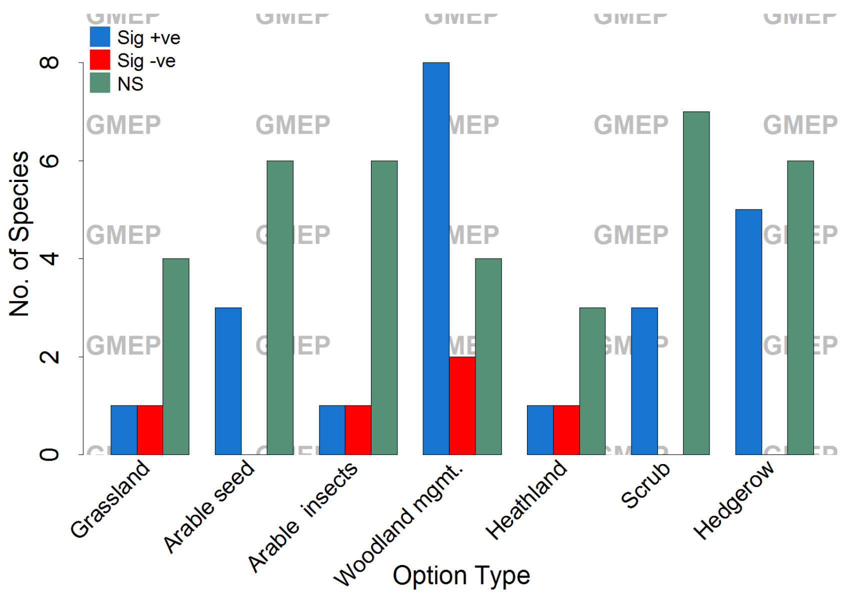
- Mae data Cynllun Monitro Gloÿnnod Byw y DU (UKBMS) sydd ar gael ers 1976 wedi'u casglu ar gyfer 324 o'r sgwariau 1km ac mae'r llinellau tueddiadau wedi'u cyfrifo. Mae'r canlyniadau'n dangos y cafwyd gostyngiad hanesyddol mewn rhywogaethau gloÿnnod byw arbenigol ac y bu'r sefyllfa'n sefydlog yn ddiweddar, gan na chafwyd dim gostyngiad pellach dros y 10 mlynedd diwethaf. Ceir tueddiadau mwy sefydlog yn achos rhywogaethau gloÿnnod byw mwy cyffredinol.
- Mae dangosyddion adar tir fferm Cymru Ymddiriedaeth Adareg Prydain/Cyd-bwyllgor Cadwraeth Natur/Arolwg Adar Bridio'r RSPB yn dangos tueddiad i ostwng ers tua 2000, tra bo'r mynegai ynghylch coetir wedi parhau'n gymharol sefydlog. Mae hyn yn adlewyrchu'r tueddiadau sy'n parhau o ran gostyngiad mewn nifer o rywogaethau adar tir fferm, fel y bras melyn a'r ehedydd. Fel yn achos pob mynegai ynghylch nifer o rywogaethau, mae'n werth nodi ei bod yn debygol, yng nghyswllt dangosydd sy'n gostwng, na fydd angen camau gwarchod ar rai rhywogaethau sy'n rhan ohono, ond gall rhywogaethau sy'n dirywio gael eu cynnwys mewn tuedd gynyddol ac felly dod yn flaenoriaethau o ran cael eu gwarchod.
- Canfuwyd bod y metrigau newydd a ddatblygwyd gan RhMGG ynghylch cyfanswm helaethrwydd ac amrywiaeth rhywogaethau adar targed gan ddefnyddio data'r Arolwg o Adar Bridio yn eithaf sefydlog dros yr 20 mlynedd diwethaf. Fodd bynnag, fel yn achos dangosyddion eraill, bydd y broses o grynhoi wedi cuddio rhai patrymau o gynnydd cymharol ar gyfer rhywogaethau unigol, tra byddant yn cuddio patrymau eraill o ddirywiad cymharol yn achos rhywogaethau eraill.
- Cafodd data'r Arolwg Adar Bridio eu cyfrifo ar gyfer 35 o'r rhywogaethau a dargedwyd a'u hagregu yn 'fynegai rhywogaethau adar a dargedir' newydd. Cafodd o leiaf hanner y 35 o rywogaethau adar â blaenoriaeth yr oedd digon o ddata ar gael mewn cysylltiad â hwy (mae 50 i gyd) sgôr a nododd eu bod yn cynyddu neu'n sefydlog ym mhob un o'r cyfnodau a ystyriwyd o 1994 i 2014, ond cafwyd amrywiad sylweddol o ran cyfeiriad tueddiadau o fewn rhywogaethau a rhyngddynt, gan arwain at amrywiad sylweddol yn y mynegai cyffredinol o iechyd y duedd o ran y boblogaeth. Yn benodol, roedd cryn dipyn yn fwy o dueddiadau poblogaeth yn rhai negyddol rhwng 2000 a 2009 nag a gafwyd yn y naill ben neu'r llall o'r gyfres amser a ystyriwyd, ac nid oedd dim patrwm o ran gwelliant cyffredinol i iechyd poblogaeth dros amser (Tabl 02).

	1994-1999	2000-2004	2005-2009	2010-2014
Nifer y rhywogaethau â data am dueddiadau	34	35	35	34
Y nifer a oedd yn cynyddu/sefydlog	23	21	17	22
Y ganran a oedd yn cynyddu/sefydlog	67.6	60.0	48.6	64.7

Tabl 02 *Crynodeb o dueddiadau poblogaeth ar draws rhywogaethau adar â blaenoriaeth (Adran 42).*

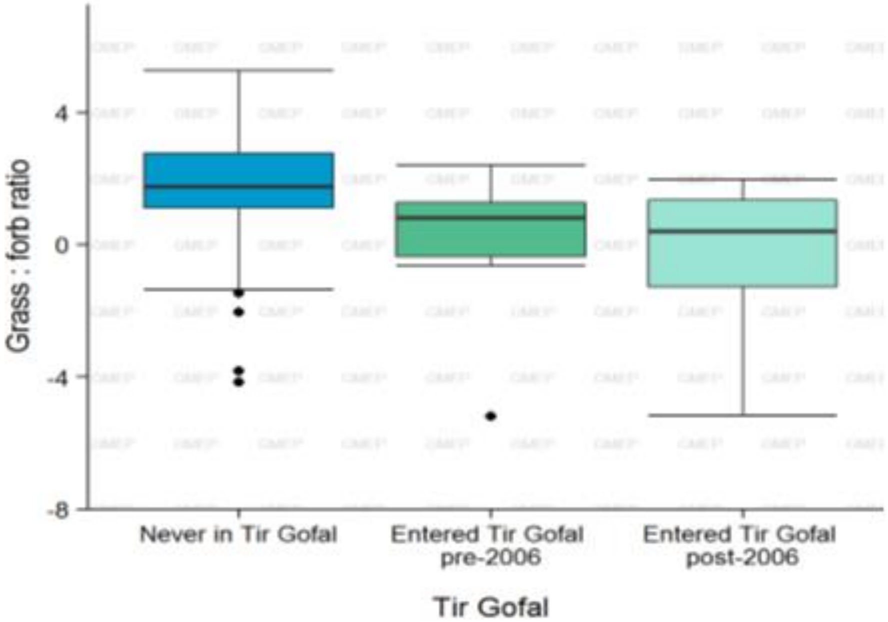
- Yn y dyfodol, mae posibilrwydd da y gellid monitro'r newid mewn maint yn achos 13 o Gynefinoedd â Blaenoriaeth. Mae tueddiadau diweddar o ddadansoddi'r data hanesyddol yn cael eu trafod ar hyn o bryd â Chyfoeth Naturiol Cymru. Yn achos rhywogaethau adar â blaenoriaeth, mae'n debyg y bydd RhMGG yn gallu cyflwyno adroddiadau am 14 o rywogaethau (o'r 50 a restrwyd) yn uniongyrchol o ddata'r arolwg RhMGG. Mae nifer o rai eraill wedi diflannu o ran bod yn rhywogaethau bridio yng Nghymru, yn rhywogaethau nosol (neu gyfnosol), neu'n ymwelwyr yn ystod y gaeaf yn unig sy'n cael eu cofnodi gan arolygon eraill. Yn bwysicach, mae cynnwys monitro adar yn yr un sgwariau â phob un o'r mesuriadau RhMGG eraill yn peri bod modd ymchwilio i'r dibyniaethau rhwng metrigau ynghyd ag ysgogwyr newid yn y RhMGG, nad yw bob amser yn bosibl yn achos yr arolygon sydd wedi'u targedu fwy, gan nad yw'r data ategol yn cael eu casglu. Mae posibilrwydd y gellid cyflwyno adroddiadau ar 7 o'r 15 o rywogaethau gloÿnnod byw â blaenoriaeth.

- Yn achos rhywogaethau eraill â blaenoriaeth, rydym wedi datblygu'r gronfa dystiolaeth sydd ei hangen i ganfod setiau o newidion dangosyddion a fydd yn ddull procsi ar gyfer rhywogaethau adran 42, ac sy'n ymwneud â deillio'r dangosyddion hyn o ddata arolygon RhMGG. Mae hyn yn cynnwys adolygiadau cynhwysfawr o ecoleg rhywogaethau a phennu sut mae opsiynau rhywogaethau'n cael eu trosi'n ddangosyddion sy'n cael eu tynnu o briodoleddau arolygon maes. Mae'r dangosyddion hyn yn mesur a yw opsiynau Glastir wedi arwain at newidiadau ecolegol y cymerir eu bod o fudd i boblogaethau rhywogaethau adran 42. Dewiswyd sampl gychwynnol o 6 o rywogaethau sy'n cynrychioli infertebratau adran 42, mamaliaid, adar a phlanhigion gan ganolbwyntio ar y rhai sydd wedi'u dosbarthu'n fwy eang yng Nghymru; pathewod, planhigion âr prin, gylfinirod, cornchwiglod, britheg y gors a'r ystlum pedol lleiaf.
- Cafodd effaith cynlluniau amaeth-amgylcheddol y gorffennol ar adar ei hasesu gan ddefnyddio cyfraddau twf poblogaethau adar (newidiadau o un flwyddyn i'r llall), gan ddefnyddio gwahanol feintiau o ran rheolaeth cynlluniau amaeth-amgylcheddol berthnasol mewn sgwariau 1km Ymddiriedaeth Adareg Prydain/Cyd-bwyllgor Cadwraeth Natur/Arolwg Bridio'r RSPB a'r tu allan i'r sgwariau hyn. Roedd cysylltiadau cadarnhaol ag opsiynau Tir Gofal lawer yn fwy cyffredin na rhai negyddol, yn enwedig yn achos rheoli coetir a gwrychoedd; yn yr ail safle yn hyn o beth oedd darparu hadau âr a rheoli prysgwydd. Mae'r dystiolaeth felly yn ategu effeithiau cadarnhaol cyffredinol yn sgil Tir Gofal, yn arbennig yn cynnwys rheoli coetir, prysgwydd, gwrychoedd, a chynefinoedd yn darparu hadau'r gaeaf ar dir fferm âr (Ffigur 14).



Ffigur 14 *Nifer y rhywogaethau adar â chysylltiadau cadarnhaol, negyddol ac nad ydynt yn sylweddol â grwpiau opsiynau Tir Gofal.*

- Cafodd effaith etifeddol Tir Gofal ar dir sy'n dod yn rhan o gynllun Glastir ei hasesu o safbwynt rhywogaethau planhigion. Yn achos mwyafrif llethol y dangosyddion (42 o 45) ni chafwyd dim tystiolaeth fod lleiniau a oedd ar dir a oedd yn destun amodau Tir Gofal o'r blaen â gwerthoedd gwahanol i leiniau na fu erioed yn rhan o gynllun Tir Gofal. Roedd maint y samplau'n fach, er hynny, a bydd y gallu i ganfod unrhyw etifeddiaeth yn cynyddu wrth i arolwg RhMGG barhau. Er gwaethaf maint cyfyngedig y sampl, yn achos dau opsiwn cafwyd gwahaniaethau sylweddol o ran; a) cyfoeth rhywogaethau mewn coetiroedd coed llydanddail nad ydynt yn cael eu pori (opsiwn 1A) mewn lleiniau a oedd wedi yn dod yn rhan o gynllun Tir Gofal cyn 2006 a b) ar gyfer y gyfradd gwair:fforb (sef dangosydd negyddol) yn achos rhos yr ucheldir (Ffigur 15)



Ffigur 15 *Gostyngiad sylweddol i'r gyfradd gwair: fforb yn rhostir yr ucheldir ar dir a ddaeth yn rhan o gynllun Tir Gofal o fewn y sampl RhMGG bresennol.*

- Rydym wedi llunio map rhagfynegol manwl o Gynhyrchiant Sylfaenol Net Blynyddol i Gymru – yn ei hanfod, dyma swm y twf gan blanhigion ac felly mae'n sail i gynhyrchiant amaethyddiaeth a choedwigaeth. Mae'r dull yn defnyddio cyfuniad o ddata a gaiff eu synhwyro o bell a phroses o fodelu nodweddion planhigion. Mae Cynhyrchu Sylfaenol yn fesuriad sylfaenol o swyddogaeth ecosystem, a bydd rhagor o waith yn bwrw ymlaen â'r broses o ddilysu ein model cychwynnol, ac yn ymchwilio ymhellach i berthnasau â phriodoleddau ecolegol a chyfalaf naturiol ledled Cymru, ac y tu mewn i sgwariau arolygu.

Y darlun cyffredinol yng nghyswllt bioamrywiaeth yw bod rhywfaint o dystiolaeth o sefydlogrwydd diweddar yn achos rhai elfennau o fioamrywiaeth ond prin yw'r dystiolaeth o welliannau, ar hyn o bryd. Mae gwahaniaethau llinell sylfaen o ran bioamrywiaeth tir sy'n dod yn rhan o gynllun Glastir wedi'u nodi y bydd y rhaid eu cynnwys mewn dadansoddiadau'r dyfodol i osgoi priodoli effeithiau cadarnhaol ffug i Glastir.

Lliniaru newid yn yr hinsawdd

Mae amaethyddiaeth yn parhau'n ffynhonnell sylweddol o lygredd dŵr gwasgaredig ac allyriadau nwyon tŷ gwydr yng Nghymru, er bod rhai ymarferion amaethyddol hefyd yn gyfrifol am golledion ac enillion o ran carbon y pridd. Mae Llywodraeth Cymru wedi pennu targedau cenedlaethol i wella ansawdd dŵr a lleihau allyriadau nwyon tŷ gwydr, a disgwylir i'r sector amaethyddol gyfrannu at gyrraedd y targedau hyn. O ganlyniad i hynny, mae cynllun Glastir wedi'i ddatblygu â digon o hyblygrwydd i dargedu themâu â blaenoriaeth (fel carbon y pridd) mewn cyd-destun gofodol, a chyflwyno mesurau ar ffermydd er mwyn, er enghraifft, wella'r broses o ddal a storio carbon, lleihau allyriadau nwyon tŷ gwydr a llygredd dŵr gwasgaredig o'r sector amaethyddol. Mae Llywodraeth Cymru wedi blaenoriaethu cyllid ar gyfer opsiynau sy'n canolbwyntio ar liniaru'r newid yn yr hinsawdd a llygredd dŵr gwasgaredig ar gyfer Blynyddoedd 1 a 2 y cynllun.

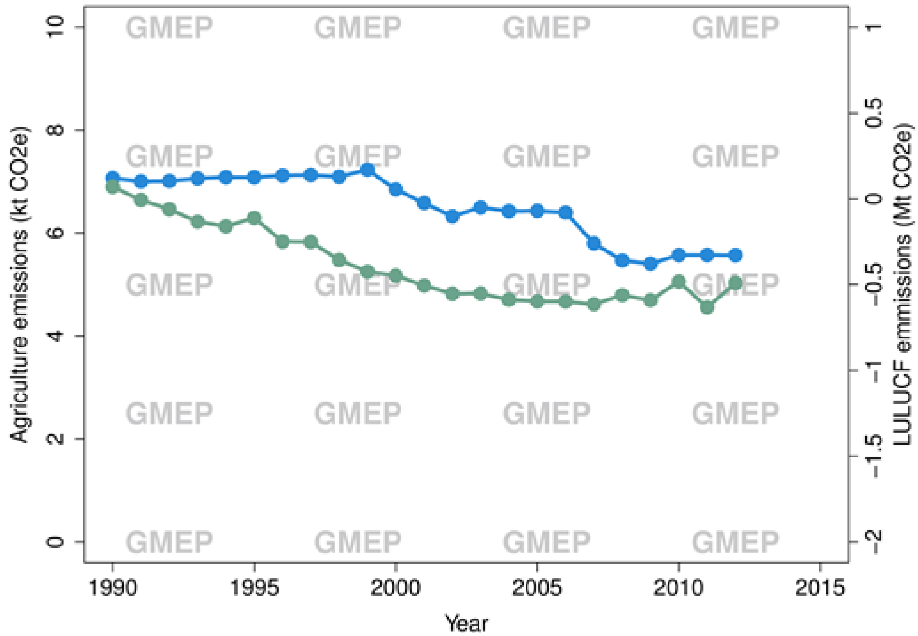
Gan gymryd y cam cyntaf yn y broses o ganfod effeithiau posibl Glastir ar allyriadau nwyon tŷ gwydr a llygredd gwasgaredig, ac o ran dal a storio carbon, gosododd Llywodraeth Cymru y dasg i Raglen Monitro a Gwerthuso Glastir o asesu effaith bosibl opsiynau Glastir ar y meysydd blaenoriaeth hyn drwy gyfrwng modelu (gan gynnwys ffynhonnell yr allyriad nad yw'n cael ei gynnwys yn y rhestrau nwyon tŷ gwydr), gwaith i ganfod manteision ehangach Grantiau Effeithlonrwydd Glastir ac astudiaeth gwmpasu i ganfod y rhwystrau i'r defnydd o'r Cynllun Creu Coetir. Creu Coetir yw un o'r gweithgareddau lliniaru prin sy'n gallu dal carbon yn uniongyrchol. Mae mwyafrif y mesurau eraill yn gallu lleihau allyriadau yn unig.

Darparodd adroddiad RhMGG ar gyfer Blwyddyn 1 ddisgrifiad cychwynnol o'r dull gweithredu sy'n cynnwys *ensemble* o fodelau y gwnaethom ei ddefnyddio. Ym Mlwyddyn 2 rydym wedi parhau i fonitro tueddiadau cenedlaethol parhaus o ran allyriadau nwyon tŷ gwydr, ond rydym yn gwella'r rhain i gynnwys allyriadau wedi'u hymgorffori a rhai anuniongyrchol; ac rydym wedi cymhwyso model proses i ymchwilio i newidiadau posibl oherwydd newid yn yr hinsawdd, a fydd yn cael ei osod ar ben canlyniadau hirdymor Glastir.

Uchafbwyntiau Blwyddyn 2

Tueddiadau nwyon tŷ gwydr o'r rhestrau cenedlaethol

- Yn 2012, cyfrannodd amaethyddiaeth 13% o'r allyriadau CO_2e yng Nghymru; roedd methan(CH_4) ac ocsid nitraidd (N_2O) yn cyfateb i 64% a 79% o gyfanswm allyriadau Cymru o'r ddau nwy hyn, yn y drefn honno (Ffigur 17). Cafodd cyfanswm o 6,142 CO_2e ei allyrru gan amaethyddiaeth yng Nghymru yn 2012; roedd hyn yn cynnwys 47% ar ffurf CH_4 (2,864 kt CO_2e), 44% ar ffurf N_2O (2,707 kt CO_2e), ac roedd y gweddill yn gysylltiedig â thrafnidiaeth.
- Cyfrannodd eplesiad enterig >80% o gyfanswm y CH_4 amaethyddol yng Nghymru (2,294 kt CO_2e); rheoli tail oedd gweddill yr allyriad CH_4. Roedd gwartheg llaeth ac eidion yn gyfrifol am 63%, a defaid yn gyfrifol am 34%, o allyriadau amaethyddol CH_4.
- Amaethyddiaeth yw'r brif ffynhonnell o N_2O yng Nghymru, ac mae >90% (2,491 ktCO_2e) o hyn yn deillio o briddoedd amaethyddol. Y prif ffynonellau o N_2O o briddoedd amaethyddol yw: nitrogen gwrtaith, tail yn sgil pori a thaenu tail.
- Mae allyriadau'r sector amaethyddol o nwyon tŷ gwydr yng Nghymru wedi gostwng >20% ers 1990 (Ffigur 17). Cafwyd cynnydd bach o lai na 1% mewn allyriadau rhwng 2011 a 2012, a hynny'n bennaf oherwydd gostyngiad o 1% yn nifer y gwartheg wedi'i gydbwyso gan gynnydd o 3% yn nifer y defaid. Mae'r duedd gyffredinol o ostyngiadau o allyriadau (N_2O) o'r pridd wedi bod yn ganlyniad i'r gostyngiadau yn y defnydd o wrtaith nitrogen (yn arbennig ar laswelltir) a niferoedd llai o dda byw (gadael wrin a thail) dros y degawd diwethaf. Yr allyriadau blynyddol presennol (2012) o N_2O yng Nghymru yw 2707 kt CO_2e (8.73 kt N_2O). Mae'r duedd o ran gostwng nifer y da byw wedi arwain hefyd at lai o allyriadau CH_4. Mae'r broses o niferoedd yn sefydlogi yn y blynyddoedd diwethaf wedi golygu na chafwyd fawr o newid mewn allyriadau rhwng 2011 a 2012 (cynnydd o 0.2%).



Ffigur 17 *Allyriadau nwyon tŷ gwydr o amaethyddiaeth a'r defnydd o dir, newid mewn defnydd tir a choedwigaeth (LULUCF). Sylwch ar y gwahaniaethau o ran maint; 0-10 yn achos amaethyddiaeth a -2 i 1 yn achos LULUCF. Mae rhifau negyddol yn dangos defnydd o garbon. Mae'n amlwg nad yw gweithgareddau LULUCF yn gwrthbwyso allyriadau amaethyddiaeth.*

- Mae Cymru'n ddalfa net fach o nwyon tŷ gwydr o weithgareddau LULUCF (Ffigur 17). Rhwng 1990 a 2012, cynyddodd dalfa garbon yng nglaswelltir Cymru ychydig (mae allyriadau wedi dod yn fwy negyddol), tra bo allyriadau o dir cnydau wedi gostwng. Mae'r tueddiadau hyn yn adlewyrchu'r broses o newid tir cnydau'n laswelltir sy'n dyddio yn ôl nifer ddegawdau, gan ei bod yn cymryd sawl blwyddyn i swm y carbon sydd wedi'i storio mewn priddoedd sefydlogi ar ôl newid o un ffordd o ddefnyddio tir i un arall.

Canfod yr Ôl Troed Carbon gan gynnwys allyriadau anuniongyrchol a rhai wedi'u hymgorffori

- Ar y set hon o 16 o ffermydd enghreifftiol yng Nghymru, mae disgwyl i'r 4 opsiwn Glastir yr ymchwiliwyd iddynt gael yr effaith a fwriedir o leihau allyriadau nwyon tŷ gwydr ac (ym mwyafrif yr achosion) cynyddu'r broses o ddal a storio carbon mewn biomas a phriddoedd.
- Roedd effeithiolrwydd y gwahanol opsiynau ar gyfer lleihau nwyon tŷ gwydr a chynyddu'r broses o ddal a storio carbon yn amrywio yn ôl y math o fferm.
- Dangosodd yr offeryn fod gostyngiadau i nwyon tŷ gwydr yn cael eu creu'n bennaf drwy ostyngiadau mewn da byw, gyda gostyngiadau ychwanegol bach yn gysylltiedig â gofynion is ar gyfer mewnbynnau fferm a oedd yn gysylltiedig â rheoli stoc. Mae'r gostyngiadau hyn i'r mewnbynnau'n ymestyn effaith yr opsiwn yn y cynllun y tu hwnt i ffiniau'r fferm sy'n cymryd rhan, a hynny i'r gadwyn gyflenwi amaethyddol ddilynol.
- Gall gostyngiadau mewn niferoedd da byw arwain, neu efallai na fydd yn arwain, at ostyngiadau o ran cynhyrchiant ffermydd ac felly perfformiad economaidd y fferm, a'i pherfformiad o ran cyflenwi, er ei bod yn anodd bod yn hyderus wrth ragfynegi hyn.
- Dangosodd yr offeryn fod newid glaswelltir yn goetir yn arwain at gynnydd net o ran y broses o ddal a storio carbon, ond cyfyngir ar effeithiolrwydd yr opsiynau "ymestyn ymyl coetir" a'r "creu coridor – ar ddwy lan nant" gan y nifer fach o ffermydd sydd â thir cymwys.

Effeithiau posibl Grantiau Cynllun Effeithlonrwydd Glastir ar Olion Traed Carbon

- Nid oedd digion o amser wedi mynd heibio er mwyn i ffermwyr weithredu Grantiau Effeithlonrwydd Glastir ar eu ffermydd i asesu eu heffaith ar olion traed carbon. Yn lle hynny, defnyddiwyd yr arolwg cychwynnol hwn i bennu blwyddyn llinell sylfaen ar gyfer cymharu olion traed carbon ar ôl cwblhau Grantiau Effeithlonrwydd Glastir.

- Yr ôl troed cyfartalog a amcangyfrifwyd fesul hectar ar draws yr holl ffermydd oedd 10,236.0 kg CO_2/ha/y flwyddyn, ac roedd hyn yn amrywio o 2,385.1 kg CO_2/ha/y flwyddyn i 18,987.2 kg CO_2e/ha/y flwyddyn.
- Roedd yr ôl-troed cyfartalog fesul hectar ar ffermydd llaeth (14,032.9 kg CO_2e/ha/y flwyddyn) bron ddwywaith ôl-troed ffermydd gwartheg a defaid ardaloedd llai ffafriol (7,704.8 kg CO_2/ha/y flwyddyn).
- Roedd gan ffermydd llai (11,654.3 kg CO_2e/ha/y flwyddyn) ôl-troed uwch ar gyfartaledd fesul hectar o dir na ffermydd mwy (7,602.0 kg CO_2/ha/y flwyddyn).
- Ar sail yr astudiaeth hon mae'r argymhellion yn cynnwys:
    - Ailadrodd y broses o ganfod ôl troed carbon y sampl bresennol o ffermydd, a hynny ar adeg briodol ar ôl adeiladu a defnyddio eitemau cyfalaf a ariannir gan Gynllun Effeithlonrwydd Glastir. Bydd hyn yn peri bod modd cymharu rhwng allyriadau llinell sylfaen ac allyriadau wedi gweithredu; bydd felly'n ddangosydd o effaith y cynllun.
    - Blaenoriaethu dyraniad pellach o'r grant i'r sector llaeth, yn ddarostyngedig i ddichonadwyedd.
    - Blaenoriaethu dyraniad pellach o'r grant yn y categori busnesau bach a chanolig.
    - Osgoi dyrannu grantiau awyru pridd i ffermydd lle byddai awyru'n mynd rhagddo ar briddoedd mawn.
    - Asesu effaith Cynllun Effeithlonrwydd Glastir ar y broses anweddu amonia, gan fod hyn yn debyg o fod o fudd pwysig o safbwynt yr amgylchedd ac iechyd dynol sy'n deillio o weithredu rhai technolegau busnesau bach a chanolig.
    - Dylid bod yn ofalus wrth ddehongli tueddiadau ystadegol mewn data a ddangosir yn yr adroddiad hwn, oherwydd roedd nifer y ffermydd a gafodd eu samplu ym mhob categori yn rhy fach i fod yn sail i unrhyw gasgliadau cadarn.

Effeithiau Defnyddio Llai o Wrtaith N a Newid yn yr Hinsawdd ar Allyriadau Nwyon tŷ Gwydr Gofodol

- Mae'r model ECOSSE yn wahanol i'r modelau a ddefnyddiwyd yng ngwaith senario Blwyddyn 1 RhMGG gan ei fod yn fodel sy'n seiliedig ar broses ac felly mae'n gallu meintoli newidiadau i allyriadau nwyon tŷ gwydr yn y tymor hwy pan allai ffactorau allyriadau sy'n sail i fodelau eraill newid e.e. mewn ymateb i newid yn yr hinsawdd. Y modelau hyn sy'n ddelfrydol ond mae angen llawer iawn o ddata arnynt. Mae materion ansicr yn parhau o ran y wyddoniaeth ac mae graddfa'r canlyniadau wedi'i lleihau'n sylweddol o'i chymharu â'r modelau eraill.
- Amcangyfrifodd ECOSSE fod y cyfrif nwyon tŷ gwydr net blynyddol cymedrig ar linell sylfaen yr hinsawdd sef 0.2 t CO_2e /ha/y flwyddyn, sy'n cyfateb i golled net o garbon o 54 kg C /ha/y flwyddyn.
- Gallai mesur Glastir o leihau gwrtaith N i leihau fflycsau nwyon tŷ gwydr a charbon organig y pridd leihau'r cyfrif nwyon tŷ gwydr net blynyddol o 0.20 i 0.17 (i beri gostyngiad o 20% o N), ac i 0.15 (i beri gostyngiad o 40% o N) t CO_2e /ha/y flwyddyn, yn y drefn honno.
- Y casgliad cyffredinol yw bod y model wedi dangos na fydd newid yn yr hinsawdd yn cael effaith sylweddol ar fflycsau nwyon tŷ gwydr priddoedd Cymru na Chynhyrchiant Sylfaenol Net fesul llystyfiant erbyn 2050. Mae hyn yn deillio'n bennaf o'r gwahaniaethau bach rhwng y llinell sylfaen a senarios hinsawdd 2050 (tua ±2%).

Yn gyffredinol, mae'r darlun o ran cyfraniad amaethyddiaeth a'r defnydd o dir at allyriadau nwyon tŷ gwydr yn dangos gwelliant mawr rhwng 1990 a 2010, sef 20%, ond daeth y duedd honno i ben yn ddiweddar ac ni chafwyd dim gostyngiad diweddar dros y 5 mlynedd diwethaf. Bydd gwelliannau pellach yn cyflwyno her gan fod Glastir yn ystyried y broses o stoc coedwigoedd yn heneiddio, defnydd cyfyngedig o'r cynllun creu coetir a'r effaith gyfyngedig y disgwylir y bydd Glastir yn ei chael ar niferoedd stoc.

Ansawdd y pridd

Mae priddoedd iach yn creu ein bwyd, ein porthiant a'n ffeibr, gan ddarparu swyddogaethau pwysig eraill fel rheoleiddio'r hinsawdd a dŵr a gwanhau llygryddion. Maent yn system fioamrywiol ynddynt eu hunain, y mae arnynt angen cael eu bwydo a'u dyfrio. Amcangyfrifwyd eu bod yn cynnwys chwarter o fioamrywiaeth y byd, er mai gymharol brin yw'r gwaith ymchwilio a wnaed arnynt hyd yn hyn, gan mai dim ond ~1% o'r rhywogaethau a nodwyd hyd yma. Amrywiaeth y bywyd o dan ein traed yw'r peiriant sy'n ysgogi'r broses o gylchynnu maethynnau, ymddatodiad gwastraff, hidlo dŵr a thwf planhigion, a dyma pam mae priddoedd yn ganolog i'r gwaith o fonitro'r amgylchedd a bioamrywiaeth.

Mae'r statws a'r duedd o ran newid yn yr uwchbridd (0-15cm) ledled Cymru wedi'u cofnodi gan yr Arolwg Cefn Gwlad ers 1978. Cyflwynodd yr arolwg diwethaf yn 2007 newidiadau i ystod eang o nodweddion ffisegol, cemegol a biolegol ar bridd. Yn gyffredinol, cafwyd darlun o ansawdd sefydlog neu a oedd yn gwella yng nghyswllt uwchbridd, ac eithrio priddoedd âr. Dylid nodi y cydnabyddir bod y dulliau a ddefnyddiwyd yn yr Arolwg Cefn Gwlad (a rhaglenni eraill ar gyfer monitro'r pridd, fel y Rhestr Bridd Genedlaethol) yn annigonnol ar gyfer monitro pridd mawn, ac felly mae dulliau newydd wedi'u comisiynu o fewn RhMGG i fynd i'r afael â hyn. Gweler Pennod 2.

Yng Nghymru, bu cyllid gan gynlluniau amaeth-amgylcheddol ar gael ers dechrau'r 90au, ac mae hyn yn cynnwys Ardaloedd Amgylcheddol Sensitif, y Cynllun Cynefinoedd, Cynllun Grantiau Coetiroedd, cynllun grantiau Ffermydd a Chadwraeth, Tir Cymen, Tir Cynnal, Tir Gofal ac, erbyn hyn, Glastir. Nododd y gwaith o fonitro ffermydd o dan Tir Gofal (Llywodraeth Cymru, 2013) ei bod wedi'i arsylwi bod lefelau pH y pridd a ffosfforws y gellir ei echdynnu yn is ar ffermydd Tir Gofal o'u cymharu â ffermydd nad oeddent yn rhan o'r cynllun. Nododd yr adroddiad ei bod yn bosibl, er hynny, nad oedd y gwahaniaeth hwn yn deillio o reolaeth Tir Gofal, a'i bod yn fwy tebygol y gellid ei briodoli i opsiynau rheoli Tir Gofal yn cael eu cymhwyso i ardaloedd o dir mwy ymylol. Nododd yr adroddiad, ar draws yr holl ddangosyddion eraill ynghylch ansawdd y pridd (dwysedd swmp, bod yn fregus o safbwynt erydu, dyfnder deunydd mawn, carbon organig a'r gyfradd carbon i nitrogen), na chofnodwyd dim gwahaniaethau cadarnhaol rhwng ffermydd Tir Gofal a ffermydd nad oeddent yn rhan o'r cynllun. Er na ddatgelodd yr adroddiad fawr ddim o fanteision cadarnhaol i ansawdd y pridd o gymharu â ffermydd nad oeddent wedi dod yn rhan o'r cynllun, gallai'r canfyddiad hwn ddeillio o sawl ffactor. Yn gyntaf, gallai'r cyfnodau monitro (< 3 blynedd) fod yn rhy fyr i ganfod newid sylweddol; yn ail, mae'n bosibl mai'r dull o gymharu ffermydd fesul parau y tu mewn i'r cynllun a'r tu allan oedd y dull anghywir o samplu (hynny yw, dim digon o samplau, parau anghywir); ac, yn drydydd, efallai nad oedd dim mantais sylweddol yn deillio o'r cynllun mewn gwirionedd. Gan ei fod yn amhosibl canfod pa un o'r tri rheswm hyn sy'n ddilys, y gobaith yw y bydd cynllun ystadegol presennol gwaith monitro Glastir yn helpu i ddatrys y materion hyn.

Nod proses Glastir o fonitro ansawdd y pridd yw casglu tystiolaeth am effeithiolrwydd casgliadau o opsiynau rheolaeth yn y broses o helpu i ddarparu pridd o ansawdd gwell, a fydd yn mynd i'r afael â chanlyniadau o ddiddordeb sy'n gysylltiedig â newid yn yr hinsawdd, bioamrywiaeth, ansawdd pridd a dŵr, ac ehangu coetir. Mae'r graddau y mae'r broses fonitro bresennol yn cydweddu â'r Arolwg Cefn Gwlad yn golygu y gall ddefnyddio'r cofnod data hwn i ddeall a gwahanu newidiadau mewn tueddiadau cenedlaethol o effaith benodol casgliadau o opsiynau. Mae'n ofynnol hefyd i'r broses fonitro gasglu tystiolaeth i fesur statws a thuedd ansawdd dŵr a phridd yn gyffredinol ar gyfer gofynion adrodd eraill, a bydd y gwaith hwn yn darparu cronfa dystiolaeth gwrth-ffeithiol bwysig. Bydd gwaith cyfuno a dadansoddi'r data hyn yn ceisio canfod sut yr effeithir ar amgylchedd Cymru gan yr hyn sy'n ysgogi newid, fel y defnydd o dir, yr hinsawdd, a llygredd, yn annibynnol ar opsiynau Glastir. Mae llawer o'r data o'r gwaith yng nghyswllt priddoedd yn darparu tystiolaeth ar gyfer y dadansoddiad integredig, ac mae hefyd yn helpu i ategu astudiaethau modelu.

Wrth ddisgwyl gweld effaith opsiynau, mae'n bwysig ystyried, ar sail canfyddiadau'r gwaith o fonitro ansawdd y pridd a wnaed o dan Glastir, ochr yn ochr ag arolygon cenedlaethol blaenorol, (e.e. yr Arolwg Cefn Gwlad), y gellir disgwyl na fydd newidiadau mawr i ansawdd y pridd ar lefel genedlaethol yn cael eu datgelu yn y tymor byr. Er enghraifft, mae angen 10 mlynedd o waith monitro fel arfer i ddatgelu newidiadau mawr i rai o nodweddion pridd (e.e. statws carbon) tra nad yw deinameg nodweddion eraill fel bioamrywiaeth yn hysbys. Er bod gan y rhaglen fonitro dreigl a weithredir o dan Glastir fwy o rym ystadegol nag arolygon blaenorol, mae'n dal yn annhebyg y bydd tueddiadau o ran carbon y pridd i'w gweld am o leiaf 5 mlynedd, neu'n hwy, o bosibl, er bod iddo'r fantais o gysylltu â set ddata 30 blynedd yr Arolwg Cefn Gwlad, sy'n darparu mwy o rym ystadegol. Hefyd, dylid cofio ei bod yn hanfodol cynnwys nodweddion y pridd wrth ddehongli ymatebion eraill mewn llystyfiant, allyriadau nwyon tŷ gwydr, ac ansawdd dŵr.

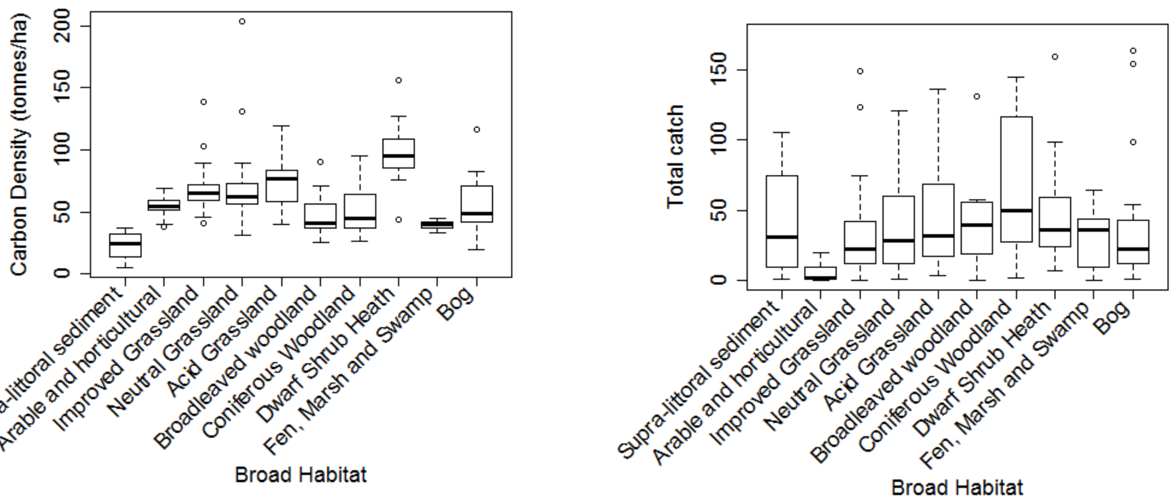
Llwyddiannau mawr ym Mlwyddyn 2.

- Prif arolwg 2014
  - Deuddeg o syrfëwyr wedi'u hyfforddi mewn dulliau o samplu pridd.
  - Syrfëwyr wedi samplu ~450 o leiniau ac wedi casglu 4 o samplau pridd o bob un (~1800 o samplau i gyd).
  - Mesurodd labordai'r Ganolfan Ecoleg a Hydroleg greiddiau o 435 o leiniau i ganfod 45 o baramedrau ar gyfer gwaith dadansoddi ffisegol, o ran microbau, cemegol, ac o ran carbon ac infertebratau. Mae'r data hyn yn ategu'r dadansoddiad o ganlyniadau ym mhob categori.
  - Protocolau labordy newydd wedi'u gweithredu i wella effeithlonrwydd gan gynnwys dulliau ar gyfer nodwedd wrthyrru dŵr pridd gan ddefnyddio fideo i ganfod y swyddogaeth hydrolig.
  - Dadansoddwyd holl ddata 2013 ac fe'u cyflwynwyd i borth data RhMGG.

- Cyfrifyddu Cyfalaf Naturiol Pridd
  - Ymgymerwyd â phrawf o gysyniad gan gyfuno setiau data ynghylch pridd a gorchudd y tir i asesu ardaloedd adnoddau pridd o dan wahanol Gynefinoedd Eang

Y prif ganfyddiadau

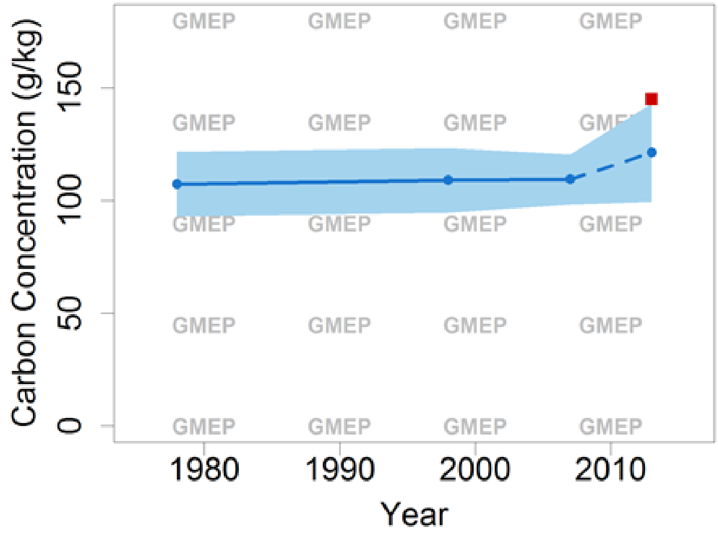
- Mae ansawdd yr uwchbridd ar gyfer ystod o fetrigau wedi'i nodweddu ar gyfer Cynefinoedd Eang Cymru (Ffigur 18)



Ffigur 18 *Uwchbridd (0-15 cm) a) dwysedd carbon a b) mesoffawna'r pridd o fewn gwahanol Gynefinoedd Eang ledled Cymru yn 2013. Nodwch mai cyfanswm y stoc carbon i ddyfnder llawn y proffil mawn mewn corsydd yw'r mwyaf o blith unrhyw gynefin. Fodd bynnag, mae 15cm uchaf y mawn, er ei fod yn llawn o garbon, â dwysedd llawer llai na phriddoedd mwynau, a dyma pham y ceir*

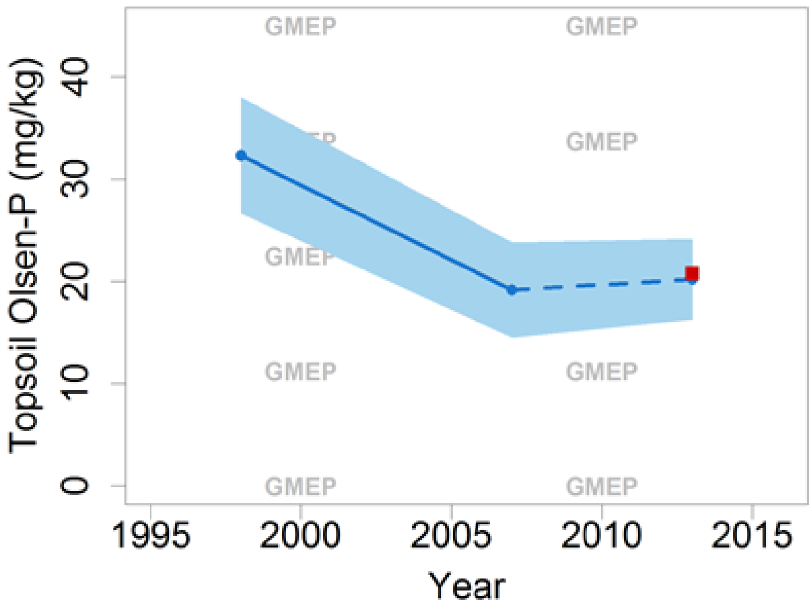
gwertheodd gymharol isel. Dim ond yr uwchbridd (0-15cm) a gafodd ei samplu, a hynny oherwydd y costau sydd ynghlwm wrth samplu i ddyfnder. Ystyrir hefyd mai dyma'r gorwel pridd yr effeithir arno fwyaf gan faterion rheoli tir.

- Nid yw dadansoddiad o dueddiadau hirdymor wedi canfod unrhyw newid cyffredinol o ran crynodiad y carbon mewn pridd (Ffigur 19)



Ffigur 19 *Data RhMGG ynghylch crynodiad y carbon yn yr uwchbridd ar gyfer 2013 o'i gymharu â data a gasglwyd ers 1978 gan yr Arolwg Cefn Gwlad. Llinell las ddi-dor (data'r Arolwg Cefn Gwlad); llinell las doredig (Arolwg Cymru Ehangach RhMGG 2013); dot sgwâr coch (Arolwg RhMGG wedi'i dargedu)*

- Ers 1978 mae asidedd yr uwchbridd wedi'i leihau, a hynny yn ôl pob tebyg oherwydd gostyngiad i fewnbynnau gan ddyddodiad atmosfferig asidig. Nid yw lefelau'r maethynnau ers 1998 pan ddechreuodd y cofnodion yn dangos dim newid yn lefelau nitrogen a bod y gostyngiad diweddar mewn lefelau ffosfforws sydd ar gael yn y pridd wedi sefydlogi (Ffigur 20). Mae'r lefelau'n dal i fod yn dderbyniol ar gyfer cynhyrchu ond byddant wedi lleihau'r perygl o ffosfforws yn trwytholchi i ddyfroedd croyw. Ni chanfuwyd dim newid ym mhoblogaethau anifeiliaid yr uwchbridd ers 1998.



Ffigur 20 *Tueddiadau hirdymor o ran argaeledd ffosfforws yr uwchbridd (Olsen-P) gan ddefnyddio data'r Arolwg Cefn Gwlad (llinell las); llinell ddotiog – Arolwg Cymru Ehangach RhMGG; a'r sgwâr coch - Arolwg RhMGG wedi'i Dargedu.*

- Tystiolaeth brin a geir ar gyfer erydu gan ddŵr a'r gwynt ar raddfeydd cenedlaethol ledled y DU, gan gynnwys Cymru. Nid oes gan RhMGG yr adnoddau i lenwi'r bwlch hwn; fodd bynnag mae angen inni feintoli effeithiau Glastir. Felly, rydym yn defnyddio dull modelu sy'n darparu amcangyfrifon ynghylch erydu ac arwynebedd y tir sy'n debygol o fod mewn perygl o gael ei golli drwy erydu a gwaddodion lliniarol a ddarperir. Gweler adroddiad RhMGG ar gyfer blwyddyn 1 i gael rhagor o wybodaeth.
- Ni chafwyd dim tystiolaeth yn samplau cyfyngedig yr arolwg ym Mlwyddyn 1 o unrhyw wahaniaeth yn ansawdd yr uwchbridd ar dir a oedd yn dod yn rhan o gynllun Glastir. Bydd y dadansoddiad hwn yn cael ei ailadrodd pan fydd yr arolwg llawn ar gyfer Blynyddoedd 1 i 4 wedi'i gwblhau.
- Mae gwaith o ymchwilio i effeithiau rheoli gan ddefnyddio gwahaniaethau o dan ddulliau rheoli tir presennol yn awgrymu y bydd rheoli'r tir yn newid cyflwr y pridd
- Mae uwchbriddoedd yng Nghymru'n hynod amrywiol ac mae'n ymddangos mai nhw sy'n ymateb fwyaf i'r drefn o reoli'r tir o ystyried y math o bridd, gan ddangos bod gan Glastir botensial gwirioneddol i ddylanwadu ar ansawdd y pridd.
- Mae nifer o fentrau'n mynd rhagddynt i gydnabod y gwerth y mae adnoddau naturiol yn ei ddarparu i'r economi. Ym mwyafrif y gwledydd, cedwir cyfrifon cenedlaethol o weithgarwch economaidd, ac mae dangosyddion fel cynnyrch domestig gros yn cael eu defnyddio'n eang yn y llywodraeth ac mewn polisïau er mwyn asesu cynnydd a gweithgarwch economaidd. Fodd bynnag, mae dangosyddion fel cynnyrch domestig gros yn mesur trafodion y farchnad yn bennaf ac nid ydynt yn ddangosyddion da o les; mae cynnyrch domestig gros yn anwybyddu costau cymdeithasol, effeithiau amgylcheddol ac anghydraddoldeb o ran incwm. Nid yw cynnyrch domestig gros ychwaith yn tynnu'r gost uniongyrchol o ddisbyddu adnoddau naturiol i incwm cenedlaethol ac nid yw'n ystyried yr effaith y mae ein prosesau o echdynnu a defnyddio byd natur yn ei chael ar barhad system y ddaear o gynnal bywyd. Gan ddefnyddio data sydd ar gael i GEMP rydym yn cyflwyno dull profi cysyniad i ganfod arwynebedd y priddoedd at ddibenion cyfrifyddu. Gan ddefnyddio'r priddoedd prin ac achlysurol a nodwyd o'r blaen yn y gwaith o ran Gwerth Mawr i Natur, gwnaethom groes-ddadansoddi'r rhain â data ynghylch y gorchudd o dir o 2007. Mae hyn yn ein galluogi i ganfod canran pob math o bridd o dan math penodol o Gynefin Eang.

Yn gyffredinol, ceir darlun o sefydlogrwydd yng nghyflwr yr uwchbridd dros y 2 neu 3 degawd diwethaf yn achos y metrigau sydd ar gael inni. Erydu yw'r prif mater nad yw'n cael ei gwmpasu gan RhMGG ac mae data eraill yn ei gylch yn brin iawn.

Dŵr croyw

Mae rhagnentydd yn rhan bwysig o'r rhwydwaith afonydd; maent fel rheol yn cyfateb i ran fwyaf hyd afonydd mewn dalgylchoedd (sef 70 i 80%, fel arfer). Mae biota rhagnentydd yn gwneud cyfraniad sylweddol ar lefel genedlaethol wrth i nifer o blanhigion ac anifeiliaid fod wedi'u cyfyngu'n ddaearyddol i'r cynefinoedd nodweddiadol hyn, tra bo rhai'n defnyddio'r cynefinoedd hyn yn dymhorol neu'n ysbeidiol. Mae deddfwriaeth yr UE yn anelu at ddiogelu rhagnentydd drwy gyfrwng y Gyfarwyddeb Fframwaith Dŵr, sy'n peri bod disgwyl i'r holl gyrff dŵr gyrraedd statws da neu uchel yn ecolegol, y Gyfarwyddeb Gynefinoedd, a Chynllun Gweithredu Bioamrywiaeth y DU, sy'n ystyried bod rhagnentydd yn 'gynefin â blaenoriaeth' ac felly'n fater i ganolbwyntio arno at ddibenion cadwraeth. Mae blaenddyfroedd hefyd yn gartref i rywogaethau gwarchodedig o dan Ddeddf Bywyd Gwyllt a Chefn Gwlad 1981 a'i gwelliannau (e.e. cimwch afon crafanc wen), rhywogaethau o bysgod sy'n bwysig yn genedlaethol fel eog yr Iwerydd, lamprai'r nant, a phennau lletwad, a gallant gynnal rhywogaethau o famaliaid ac adar gwarchodedig (e.e. dyfrgwn, glas y dorlan).

Gall arferion amaethyddol fel pori gan dda byw a throi tir arwain at erydu pridd a mân waddodion, maethynnau a phlaladdwyr yn llifo mewn dŵr ffo i ragnentydd. Mae hyn yn cael effeithiau uniongyrchol ar y biota a natur gyfannol cynefinoedd, er enghraifft drwy leihau bioamrywiaeth ac achosi i ffawna sensitif gael eu disodli gan fathau sy'n goddef llygredd. Caiff effeithiau cronnus ar draws blaenddyfroedd eu hadlewyrchu ymhellach ar hyd rhwydaith yr afonydd, gan leihau ansawdd dŵr cyrff dŵr mwy, a pheri goblygiadau negyddol ar gyfer eu biota, ac ar gyfer gwasanaethau ecosystemau fel darparu dŵr glan i'w ddefnyddio gan bobl, ac at ddibenion ffermio pysgod a hamdden. Felly, nid yw'n syndod bod ansawdd dŵr yn darged allweddol i nifer o gynlluniau amaeth-amgylcheddol, gan gynnwys Glastir, sy'n cynnwys mesurau sy'n anelu at leihau'r dŵr ffo a chynyddu'r clustogi ecolegol ar hyd nentydd ac afonydd.

Mae rhagnentydd wedi'u tangynrychioli ar hyn o bryd yn rhaglenni monitro Cyfoeth Naturiol Cymru, a bwriedir i RhMGG lenwi'r bwlch yn hyn o beth. Targed Cyfoeth Naturiol Cymru yn y pen draw yw i'r holl ddyfroedd wyneb gyrraedd statws ecolegol da fel sy'n ofynnol yn ôl deddfwriaeth yr UE. Fodd bynnag, mae maint a niferoedd uchel iawn y blaenddyfroedd yn golygu ei bod yn bosibl na fydd dull llym y Gyfarwyddeb Fframwaith Dŵr yn ymarferol. Gan fod angen hefyd i ragnentydd gael eu nodi o dan y gyfarwyddeb gynefinoedd gan eu bod yn 'gynefinoedd â blaenoriaeth', gall fod yn fwy priodol cyflwyno adroddiadau am ganlyniadau effeithiau yn achos blaenddyfroedd o dan y cynefinoedd â Blaenoriaeth yn hytrach na chydymffurfiaeth â'r Gyfarwyddeb Fframwaith Dŵr. Bydd RhMGG a Chyfoeth Naturiol Cymru yn cydweithio i lunio, erbyn diwedd y cyfnod llinell sylfaen, ddull o asesu statws ecolegol a fydd wedi'i seilio ar yr arolwg maes sy'n cyd-fynd â phroses adrodd y Gyfarwyddeb Fframwaith Dŵr. Fodd bynnag, yn yr adroddiad hwn gwnawn sylwadau ar ansawdd ecolegol heb eu trosi'n oblygiadau o dan y Gyfarwyddeb Fframwaith Dŵr. Bydd effaith Glastir ar afonydd mwy yn destun gwaith ymchwil gan ddefnyddio dull modelu i feintoli'r newid yng nghyfraniad amaethyddiaeth i'r mewnlif o faethynnau ym Mlwyddyn 4; fodd bynnag, bydd asesiad ffurfiol y Gyfarwyddeb Fframwaith Dŵr yn dibynnu ar asesiadau ecolegol Cyfoeth Naturiol Cymru. Nid oes unrhyw fantais yn gysylltiedig â RhMGG yn ailadrodd yr asesiad hwn.

Mae pyllau'n fwy helaeth nag afonydd a llynnoedd, ac maent i'w cael ym mron pob amgylchedd. Er y bydd amrywiaeth pwll unigol yn llai yn gyffredinol na'r amrywiaeth a geir mewn afon neu lyn, mae eu gwerth bioamrywiaeth i'w gael ar raddfeydd gofodol ehangach. Mae pyllau'n gynefin arbennig o bwysig ar gyfer rhai rhywogaethau prin a gwarchodedig. Yng Nghymru, mae hyn yn cynnwys nifer o rywogaethau sy'n gostwng yn rhyngwladol fel canrhi felen eiddil a'r grafanc deiran, yn ogystal â rhywogaethau sydd wedi'u gwarchod yn Ewropeaidd, gan gynnwys y fadfall ddŵr gribog a llyriad y dŵr. Yn ychwanegol at hynny, mae pyllau'n darparu cynefin a bwyd i fywyd gwyllt daearol fel adar, ystlumod, mamaliaid, ymlusgiaid, a phryfed peillio, gan olygu eu bod yn bwysig mewn tirweddau amaethyddol a threfol sydd ag ychydig yn unig o lochesi naturiol. Caiff pyllau eu cydnabod yn Erthygl 10 o'r Gyfarwyddeb Gynefinoedd am eu rôl o fod yn 'gerrig camu', a hynny rhwng cyrff dŵr eraill a gwlyptiroedd, gan gynyddu cysylltedd cynefinoedd dŵr croyw ar raddfeydd gofodol eang. Mae pyllau hefyd yn gronfeydd bach gan eu bod yn casglu ac yn arafu llif dŵr oddi ar gaeau ac ardaloedd eraill, gan gadw ac ailgylchu maethynnau a gwaddodion cyn iddynt allu mynd i grynofa ddŵr sy'n llifo. Oherwydd eu maint bach, o'u cymharu ag afon neu lyn, maent yn arbennig o sensitif i lygredd ac maent â gallu cyfyngedig i glustogi. Mewn tirweddau amaethyddol mae pyllau'n derbyn gwaddodion, maethynnau a phlaladdwyr sy'n cael effeithiau uniongyrchol ar gyfanrwydd cynefinoedd a biota, er enghraifft drwy leihau bioamrywiaeth ac achosi i ffawna sensitif gael eu disodli gan fathau sy'n goddef llygredd.

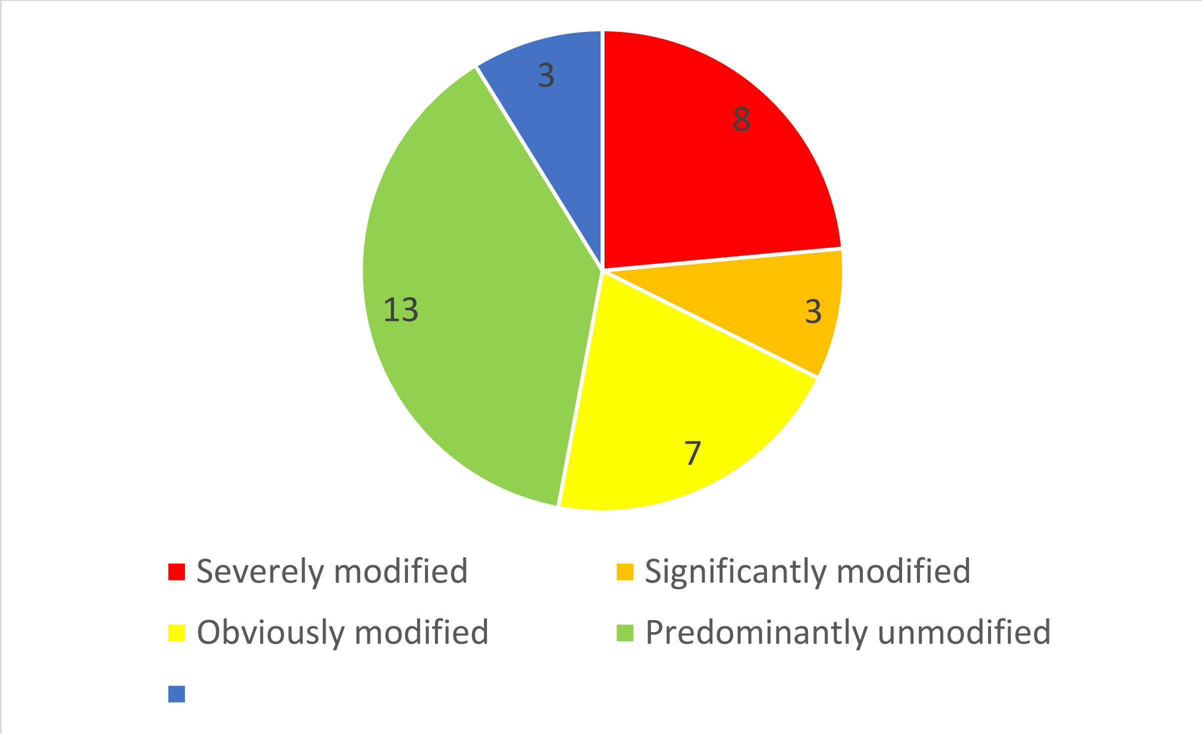
O fewn y RhMGG, caiff sgwariau arolygu eu samplu ar gyfer 1 rhagnant ac 1 pwll pan fyddant yn bresennol. Nid yw'r adnoddau'n peri bod modd samplu rhagor hyd yn oed os ydynt yn bresennol. Caiff y technegau a ddefnyddir mewn rhagnentydd i gyd yn ddulliau bio-monitro sy'n cael eu cydnabod. Ar hyn o bryd, nid yw asesiad RhMGG yn asesiad Cyfarwyddeb Fframwaith Dŵr, er y nod yw sefydlu fframwaith erbyn diwedd yr arolwg llinell sylfaen. Gan ei fod wedi'i seilio ar un arolwg yn yr haf, mae'n debyg bod y gwaith samplu yn amcangyfrif yn rhy isel ansawdd ecolegol ychydig o'i gymharu â'r gwanwyn neu'r hydref, ond nid ecoleg yw'r prif ffactor sy'n gostwng ansawdd nant, yn wir newid cynefinoedd ac ansawdd dŵr sy'n gwneud hyn (gweler isod). Mae'n bosibl felly na fydd gwelliannau mewn ansawdd dŵr oherwydd Glastir yn trosi i gydymffurfiaeth â'r Gyfarwyddeb Fframwaith Dŵr heb waith gweithredol i adfer cynefinoedd.

Mewn pyllau, defnyddiwyd y technegau a ddefnyddir yn fwyaf eang, ac sy'n cael eu hargymell gan yr Ymddiriedolaeth Cynefinoedd Dŵr Croyw (nid oes dim techneg safonol gydnabyddedig naill ai ar lefel y DU na'r UE), er mwyn monitro macroinfertebratau, macroffytau a chynefinoedd. Mae'r technegau hyn yn caniatáu inni ganfod ansawdd cemegol dŵr yn ogystal â'i ansawdd ecolegol. Oherwydd yr amser sydd ei angen i nodi'r nifer o samplau diatomau ac infertebratau, nid yw'r data ar gyfer Blwyddyn 2 (2014) yn barod eto i gyflwyno adroddiad arno.

Y prif ganfyddiadau:

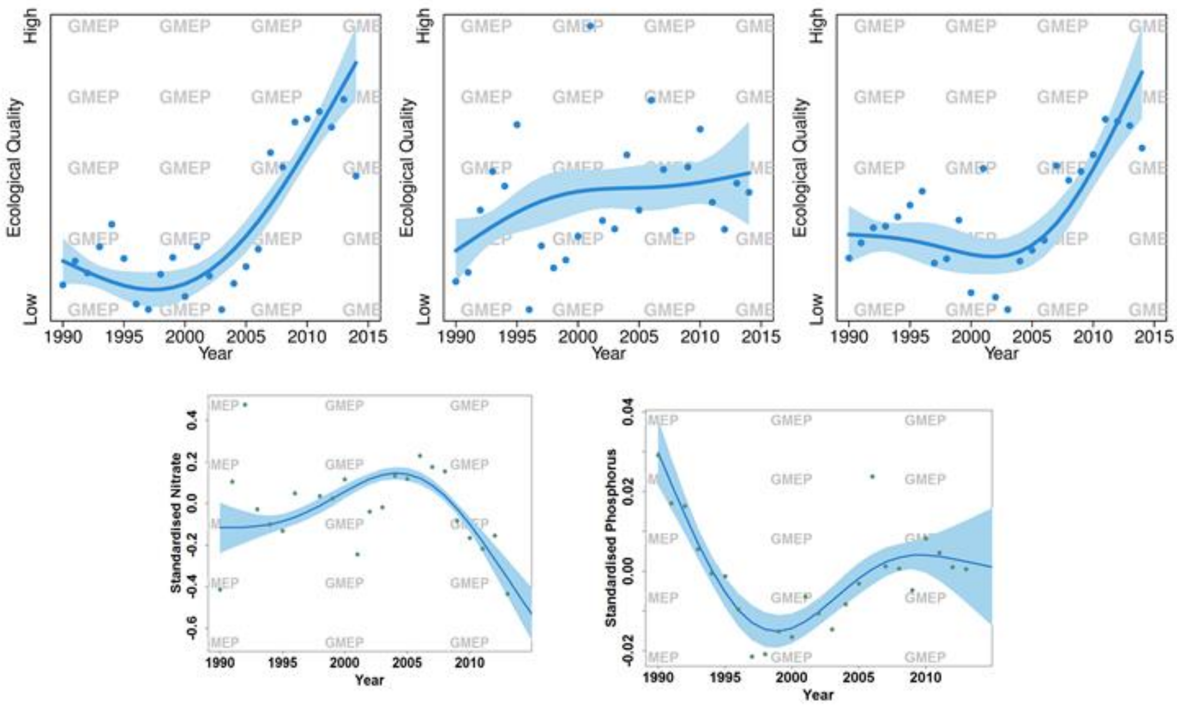
Rhagnentydd

- Roedd gan 57% o'r sgwariau arolygu o leiaf un rhagnant
- Dangosodd safleoedd yr iseldir faethynnau'n cael eu cyfoethogi o'u cymharu â safleoedd yr ucheldir
- Roedd gan 85% o'r safleoedd grynodiadau ffosfforws sy'n cyd-fynd â'r broses o gynnal ansawdd ecolegol da; roedd gweddill y safleoedd i gyd yn yr iseldir, ac eithrio un
- Roedd gan 53% o'r safleoedd grynodiadau nitrogen a oedd yn uwch na'r ystod sy'n gysylltiedig ag afonydd Ewropeaidd nad effeithir arnynt. Nid oedd yr un safle yn uwch na safon dŵr yfed y DU.
- Cafwyd lefelau uwch o gynefinoedd yn newid ar safleoedd yr iseldir
- Yn gyffredinol, roedd gan 91% o safleoedd blaenddŵr gynefinoedd a oedd wedi newid, ac roedd 32% yn dangos lefelau uchel o newid (Ffigur 21)
- Roedd prif ysgogwyr cymunedau macroinfertebratau yn rhai bioddaeryddol (uchder, alcalinedd, dargludedd) ond roedd newid cynefinoedd dynol hefyd yn ffactor ysgogi
- Roedd diatomau (cyfraniad grŵp sylweddol at gynhyrchiant sylfaenol) yn fwy ymatebol i raddiant uchder, a chafwyd ansawdd ecolegol gwell yn yr ucheldir (roedd hyn i'w ddisgwyl oherwydd mae dangosyddion diatomau'n ymateb yn bennaf i staws maethynnau) ond ceir mwy o amrywiaeth yn yr iseldir, fel y disgwyliwyd
- Amlygodd y dangosyddion ynghylch macroffytau fod gan fwyafrif y safleoedd lefelau canolig o gyfoethogi; dim ond yn achos 1 safle yn yr iseldir y gellid gwneud diagnosis ei fod ag effeithiau clir o ran ewtroffigedd, ac yn achos 12 safle (roedd 9 o'r rhain yn yr ucheldir) gellid gwneud diagnosis ei bod yn annhebyg y byddai ewtroffigedd neu lygredd organig yn effeithio arnynt
- Amlygodd dangosyddion macroinfertebratau fod gan 62% o safleoedd gymunedau o facroinfertebratau a oedd yn gydnaws g ansawdd ecolegol da. Roedd y sgôr bennaf sy'n seiliedig ar ddiatomau'n llai gofalus, gan ddangos bod gan 91% o safleoedd gymunedau diatomau y barnwyd eu bod o ansawdd ecolegol da.



Ffigur 21: *Nifer y safleoedd blaenddŵr sy'n perthyn i'r 5 dosbarth newid cynefinoedd yn arolwg RhMGG o flwyddyn 1*

- Mae tueddiadau hirdymor gan ddefnyddio data Cyfoeth Naturiol Cymru, pan wnaethom allgáu afonydd mwy, yn cynnwys llawer mwy na blaenddyfroedd sydd wedi'u cyfyngu i 2.5km o'r ffynhonnell, y mae data yn eu cylch yn brin, ond efallai fod hyn yn darparu rhywfaint o wybodaeth am dueddiadau afonydd bach yng Nghymru yn y gorffennol. Mae'r data'n dangos gwelliant mewn ansawdd ecolegol nentydd llai dros y ddau ddegawd diwethaf, sydd wedi'u cysylltu â gwelliannau i ansawdd dŵr. Mae hyn yn cyd-fynd â'r patrwm a geir ledled y DU (Ffigur 22).



Ffigur 22 *Brig: sgôr BMWP (ar y chwith; mynegai o ewtroffigedd a dirywiad cyffredinol), Ntaxa (canol; nifer y tacsa sy'n sensitif i ansawdd dŵr sy'n cyfrannu at y sgôr WHPT), ac ASPT (ar y dde; sensitifrwydd y tacsa i ansawdd dŵr sy'n cyfrannu at y sgôr WHPT). Gwaelod: Cyfres amser o ffosfforws adweithiol toddadwy (mg/L), ac ar y dde: cyfres amser cyfanswm y nitrogen toddedig (rhannau fesul miliwn), sy'n deillio o waith monitro Cyfoeth Naturiol Cymru, nad yw'n cynnwys afonydd mawr. Sylwch fod hyn yn cynnwys llawer o nentydd llai nad ydynt yn rhagnentydd, ond mae'n rhoi rhywfaint o'r cyd-destun hanesyddol.*

- Cafwyd tuedd (nad yw'n sylweddol ar hyn o bryd ond sy'n debygol o ddod yn sylweddol wrth i fwy o samplau llinell sylfaen gael eu cymryd) o weld rhagnentydd o ansawdd uwch ar dir yng nghynllun Glastir. Mae angen ystyried y duedd hon wrth wneud gwaith dadansoddi ynghylch manteision Glastir yn y dyfodol.
- Ni chanfuwyd unrhyw effaith etifeddol sylweddol o gynlluniau amaeth-amgylcheddol blaenorol, er bod tuedd o ran effaith gadarnharol ar ansawdd ecolegol ac roedd maint y sampl yn isel gan fod hyn yn cynrychioli Blwyddyn 1 yn unig o hyfnod samplu 4 blynedd cyflawn RhMGG (Tabl 03). Bydd ein gallu i ganfod newidiadau yn cynyddu gyda'r boblogaeth 4 blynedd.

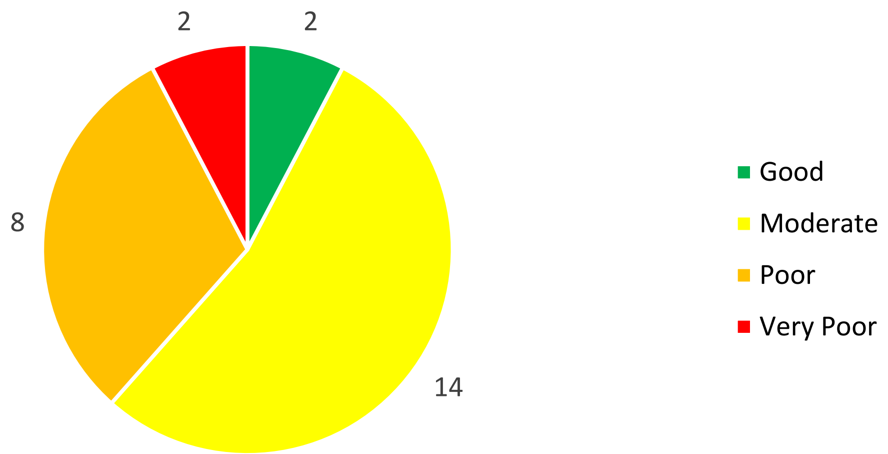
	Statws	Cymedr	Cyfeiliornad safonol
Ntaxa	Y tu allan GAA y gorffennol	16.44	2.06
	Y tu mewn i GAA y gorffennol	19.19	0.98
ASPT	Y tu allan i GAA y gorffennol	5.66	0.28
	Y tu mewn i GAA y gorffennol	5.83	0.14
BMWP	Y tu allan i GAA y gorffennol	93.44	11.69
	Y tu mewn i GAA y gorffennol	110.12	7.17

Tabl 03 *Gwerth cymedrig y tri phrif ddangosydd ynghylch macroinfertebratau o ansawdd ecolegol mewn safleoedd arolygu sy'n perthyn i gynlluniau amaeth-amgylcheddol (GAA) blaenorol neu nad ydynt yn perthyn iddynt.*

- Targed priodol ar gyfer Glastir fyddai cynyddu nifer y safleoedd o ansawdd 'da' o dan y Gyfarwyddeb Fframwaith Dŵr (ac felly targed i RhMGG yw llunio asesiad sy'n cydymffurfio â'r Gyfarwyddeb Fframwaith Dŵr ac y gellir ei ddefnyddio i gyflwyno adroddiad am nifer y safleoedd yn ôl dosbarthiadau statws y Gyfarwyddeb Fframwaith Dŵr (uchel, da, canolig, gwael, drwg)). Er bod profiad yn dangos, os caiff mewnbynnau maethynnau yn y ffynhonnell eu rheoli, y gellir cyflawni newid cyflym o ran crynodiadau maethynnau mewnffrwd, mae angen i'r gymuned fiolegol ymateb i'r newid hwnnw cyn bod newid mewn statws. O ganlyniad, efallai na fydd y systemau hyn yn cael eu hadfer drwy gael gwared ar yr hyn sy'n achosi'r straen yn unig os yw'r casgliad ffynhonnell o rywogaethau a ddymunir o safbwynt ailgytrefu wedi'i ddisbyddu i'r fath raddau na all y fioleg ymateb (mater tebyg i'r hyn a ganfuwyd yn adroddiad blwyddyn 1 RhMGG yn achos adferiad rhywogaethau planhigion). Mae'r mater hwn yn hysbys iawn ledled yr UE. O ganlyniad, argymhelliad y Ganolfan Ecoleg a Hydroleg yw cael fframwaith rheoli ymatebol sy'n gallu diwygio'i strategaeth wrth i ragor o wybodaeth ddod ar gael ac sydd hefyd yn caniatáu hyblygrwydd o ran y prif ganolbwynt, hynny yw, a ddylai Cymru flaenoriaethu mwy o safleoedd da, llai o safleoedd gwael, neu'r ddau?

Pyllau

- Roedd gan 48% o'r sgwariau arolygu o leiaf un pwll
- Roedd tueddiad i faethynnau gael eu cyfoethogi yn yr iseldir, ond nid oedd yn dueddiad sylweddol
- Adlewyrchodd dangosyddion macroffytau gyflyrau'r maethynnau fel y disgwyliwyd, er bod rhywogaethau mwy anghyffredin i'w cael yn yr ucheldir
- Roedd prif ysgogwyr y gymuned macroinfertebratau'n rhai naturiol (alcalinedd, uchder), ond roedd crynodidau ffosfforws hefyd yn ysgogwr pwysig, ac mae'n debygol bod gweithgareddau dynol yn effeithio arnynt
- Dim ond 8% o'r pyllau a gafodd eu barnu i fod o ansawdd ecolegol da, tra bo mwyafrif y rhai eraill ag ansawdd canolig (Ffigur 23) (Sylwch nad yw pyllau'n cael eu monitro o dan y Gyfarwyddeb Fframwaith Dŵr ac felly nid yw'r termau da a chanolig yn perthyn i derminoleg y Gyfarwyddeb Fframwaith Dŵr)
- Yn achos nentydd, ni chanfuwyd dim gwahaniaeth sylweddol rhwng ansawdd pyllau y tu mewn i'r cynllun a'r tu allan iddo, ond gwelwyd tuedd i Glastir gael effaith gadarnhaol ar ansawdd ecolegol y bydd angen ei ystyried pan fydd effaith Glastir yn cael ei asesu. Bydd data pellach o arolygon yn creu darlun cliriach yn hyn o beth.



Ffigur 23 *Ansawdd ecolegol pyllau yn arolwg RhMGG o ddata Blwyddyn 1*

Yn gyffredinol, mae'r darlun o ran blaenddyfroedd yn dangos gwelliant sylweddol diweddar dros yr 20 mlynedd diwethaf. Mae crynodiadau ffosfforws yn dangos bod 89% yn gydnaws â statws ecolegol da, a chafwyd gwerth tebyg yn achos diatomau, sef 91%, a oedd yn dangos ansawdd ecolegol da. Fodd bynnag, mae cymunedau macroinfertebratau yn dangos mai dim ond 62% sy'n gydnaws ag ansawdd ecolegol da, a dangosir lefelau canolig o gyfoethogi hefyd gan gymunedau macroffytau. Mae 91% o'r safleoedd yn parhau i fod wedi'u newid mewn rhyw ffordd wrth i 32% o safleoedd ddangos lefelau uchel o ran bod wedi'u newid. Yn achos pyllau, dim ond yn achos 8% y barnwyd eu bod o ansawdd ecolegol da, tra bo mwyafrif y rhai eraill o ansawdd ecolegol canolig. Nid oes dim tystiolaeth o wahaniaethau wedi'u harsylwi hyd yma yn achos blaenddyfroedd na phyllau yn dod yn rhan o Glastir o'u cymharu â'r rhai y tu allan i'r cynllun. Dylid nodi y bydd effeithiau Glastir ar lefelau cyfoethogi maethynnau mewn dyfroedd croyw yn fwy cyffredinol yn cael eu mesur gan ddefnyddio gwaith modelu, fel y disgrifir yn adroddiad Blwyddyn 1 RhMGG.

Tir Fferm sydd o Werth Mawr i Natur

Mae tir fferm sydd o Werth Mawr i Natur wedi'i ddiffinio'n ardaloedd yn Ewrop lle y mae amaethyddiaeth yn ddull pwysig o ddefnyddio'r tir (ac fel arfer y prif ddefnydd) a lle y bo'r amaethyddiaeth honno'n cynnal neu'n gysylltiedig naill ai ag amrywiaeth fawr o ran rhywogaethau a chynefinoedd neu bresenoldeb rhywogaethau sy'n peri pryder o safbwynt Ewropeaidd, neu'r ddau. Mae'n ddangosydd cytunedig o un o Chwe Amcan Strategol Glastir, ond mae angen ymgymryd â gwaith datblygu arno er mwyn ennill consensws ynghylch bod yn fetrig dilys y gellir ei gyflwyno i'r UE.

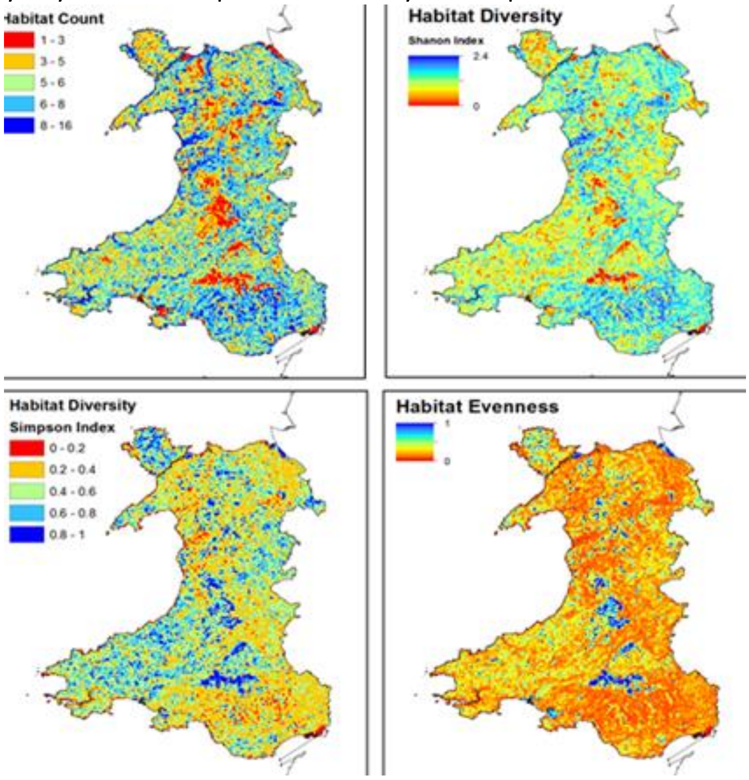
Edrychodd gwaith blaenorol a wnaed ar lefel Ewropeaidd ac yng Nghymru ar y cysyniad o dir fferm o werth Mawr i Natur a sut y gellid ei ddiffinio a'i gymhwyso. Gall arferion amaethyddol dwysedd isel fod yn bwysig o ran cynnal yr ardaloedd hyn lle y ceir amrywiaeth fawr neu gallant fodoli er gwaethaf y gweithgareddau ffermio. Mae heterogenedd gofodol yn bwysig yng nghyswllt mosaigiau cynefinoedd ac elfennau strwythurol gwahanol e.e. prysgwydd a nodweddion llinol. Nid yw tir sydd o 'Werth Mawr i Natur' yn hawdd ei ddiffinio; gall fod yn ymarfer goddrychol a dadleuol dewis pa elfennau sy'n cynrychioli 'gwerth mawr' yn y modd gorau. Cytunwyd yn gyffredinol y gellid dadansoddi tir fferm o Werth Mawr i Fyd Natur yn 3 math:
Math 1: Tir fferm sydd â chyfran uchel o lystyfiant lled-naturiol
Math 2: Tir fferm sydd â mosäig o gynefinoedd a/neu o ddulliau o ddefnyddio'r tir
Math 3: Tir fferm sy'n cynnal rhywogaethau prin neu gyfran uchel o boblogaethau Ewropeaidd neu'r byd
Yn yr EU, mae Aelod-wladwriaethau wedi ymrwymo i ganfod a chynnal ffermio sydd o Werth Mawr i Natur; fodd bynnag nid oes dim rheolau penodol na meini prawf a metrigau generig wedi'u pennu ar lefel yr UE i ganfod tir fferm sydd o Werth Mawr i Natur. O ganlyniad, mae pob aelod-wladwriaeth yn dehongli'r cysyniad ac yn penderfynu ar y modd gorau o'i gymhwyso i'r wladwriaeth honno. Mae'n anochel y bydd amrywiad o ran diffiniadau tir fferm o Werth Mawr i Natur, a bydd gan wledydd unigol ddangosyddion gwahanol (yn arbennig yn achos rhywogaethau dangosydd Math 3) neu wahanol nodweddion ar y dirwedd; fodd bynnag, mae arnom angen hefyd ddull mwy cyfannol ar draws gwledydd Ewrop, ynghyd â safonau a diffiniadau cyffredin.

Rhoddodd Llywodraeth Cymru y dasg i'r tîmRhMGGo ymchwilio i'r cysyniadau hyn a chynnig syniadau, meini prawf a metrigau newydd y gellid eu cymhwyso i'r broses o ddiffinio tir sydd o 'Werth Mawr i Natur', ynghyd â llunio dangosydd i bennu maint llinell sylfaen a mesur newidiadau o ran maint ac ansawdd. Rydym yn cynnal y gwaith hwn drwy ymgynghori ag ystod o bartneriaid a rhanddeiliaid sydd hefyd â diddordeb yng ngwerth posibl y metrig hwn. Yn benodol, mae hyn wedi cynnwys gweithgor bach sy'n cynnwys y Ganolfan Ecoleg a Hydroleg, Ymddiriedaeth Adareg Prydain, RSPB a Llywodraeth Cymru, a gyfarfu am y tro cyntaf ym mis Ebrill 2013; gweithdy RSPB ag ystod eang o gyfranogwyr o bob rhan o'r adran ffermio a chadwraeth ym mis Mai 2013; Grŵp Cynghori RhMGG ym mis Mehefin 2013 â chynrychiolwyr o'r gymuned ffermio, Llywodraeth Cymru, Cyfoeth Naturiol Cymru a sefydliadau anllywodaethol, a nifer o gyfarfodydd gweithgor dilynol yn 2013/2014. Mynegwyd ystod eang o safbwyntiau sy'n amrywio o "mae hwn yn fetrig nad oes ganddo fawr o werth ac a allai beri dryswch yn hytrach na thaflu goleuni" i "metrig a all fod yn ddefnyddiol i gyfleu tueddiadau cyffredinol o ran bioamrywiaeth".

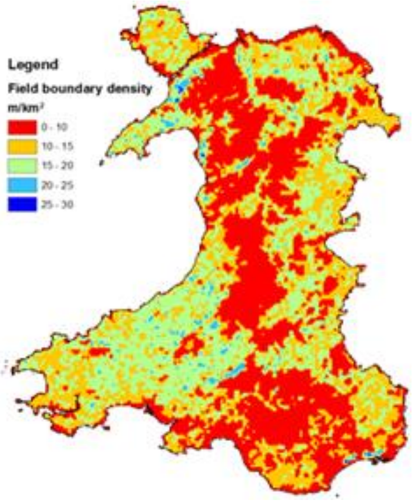
Y Prif Lwyddiannau ym Mlynyddoedd 1 a 2

- Wedi ymgynnull ac wedi cwrdd ag ystod o randdeiliaid i drafod dulliau gweithredu posibl a chytuno ar ffordd ymlaen
- Wedi casglu tabl o fetrigau posibl ynghylch Gwerth Mawr i Natur
- Wedi casglu setiau data posibl y gellid cyfrifo metrigau ohonynt
- Datblygu a chyfrifo metrigau e.e. cysylltedd, amrywiaeth cynefinoedd, rhywogaethau prin, priddoedd prin ac yn y blaen (Ffigurau 24 & 25)

- Dadansoddiad a thrafodaeth ynghylch y posibilrwydd o israddio o setiau data sy'n cofnodi cydraniad bras – set ddata ar gyfer rhywogaethau planhigion wedi'i llunio
- Wedi cyfrifo metrigau ar gyfer pedair ardal astudiaeth achos a chynigion wedi'u cyflwyno ar gyfer y camau nesaf (Ffigur 26)
- Rydym yn cyflwyno sawl dull posibl o asesu cyfraniad pridd at dir o Werth Mawr i Natur.

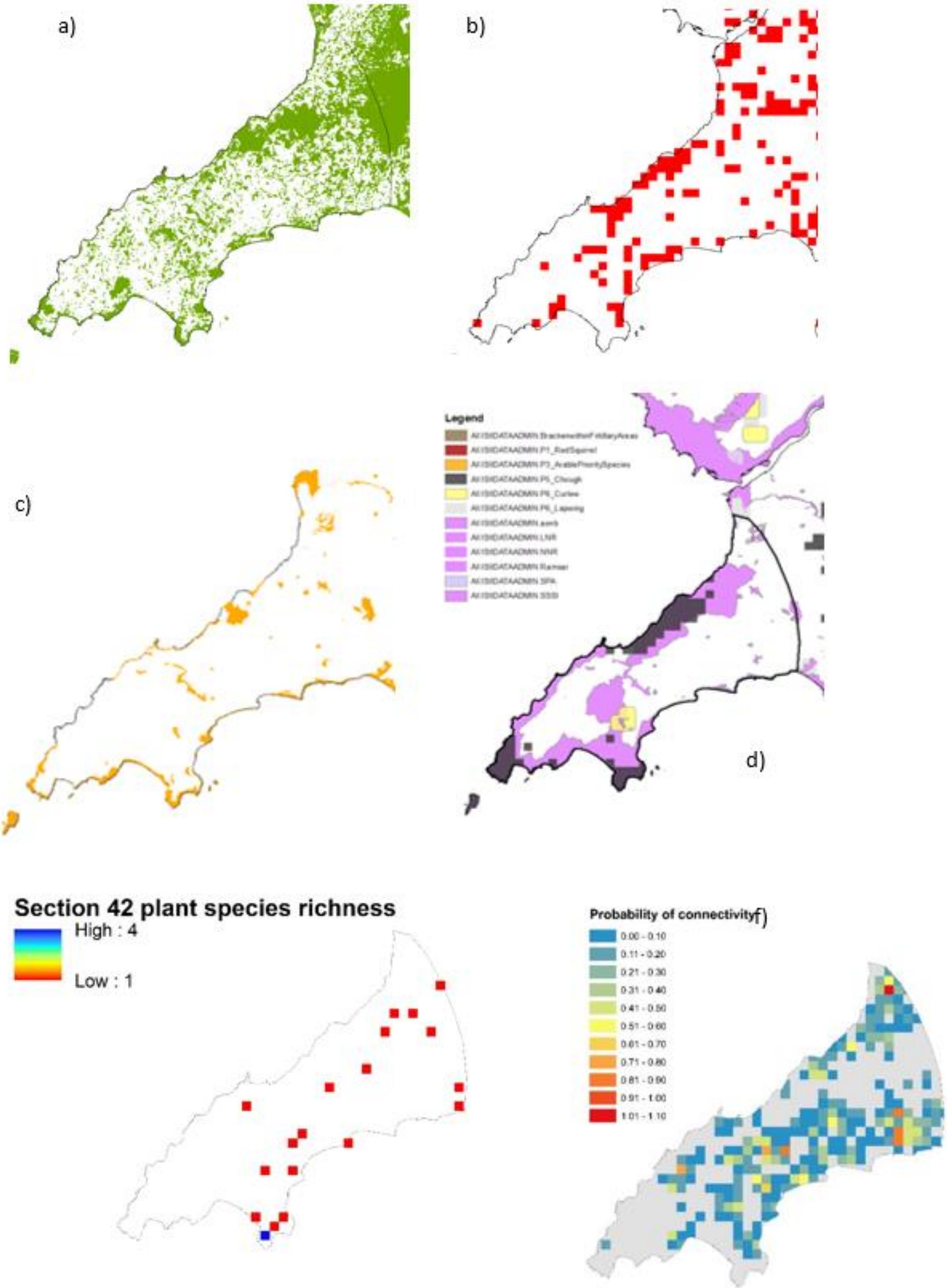


Ffigur 24 *a) Dulliau gwahanol o asesu amrywiaeth cynefinoedd ar gyfer pob 1km² ledled Cymru, ar sail LCM2007;*



Ffigur 24 *b) Map o ddwysedd ffiniau caeau ledled Cymru, wedi'i seilio ar ddata ar gyfer y System Wybodaeth Parseli Tir*

Ffigur 25 *Mapiau enghreifftiol o gyfoeth rhywogaethau ym mhob cell grid 10km x 10km ledled Cymru yn achos gwahanol grwpiau o rywogaethau, ar sail data'r Ganolfan Cofnodion Biolegol.*



Ffigur 25. *Mapiau o ddangosyddion posibl ynghylch Gwerth Mawr i Natur ar gyfer Pen Llŷn, gan gynnwys; a) Math 1 - llecynnau cynefinoedd lled-naturiol; b) Math 2 – Chwartel uwch o ran amrywiaeth cynefinoedd (Mynegai Shannon; nid yw'r data am rywogaethau wedi'u hymgorffori eto); c) Math 3 – Ardaloedd Gwarchodaeth Arbennig, Ardaloedd Cadwraeth Arbennig a Safleoedd o*

Ddiddordeb Gwyddonol Arbennig (nid yw'r data am rywogaethau wedi'u cynnwys eto); d) map sy'n dangos ardaloedd gwarchodedig a pharthau gwarchodedig; e) map sy'n dangos dosbarthiad y rhywogaethau planhigion prin ((adran 42); f) a metrigau cysylltedd cynefinoedd coetir coed llydanddail ar gyfer pob cell grid 1 km

Ar sail y gwaith a wnaed hyd yma, mae'r metrigau a ganlyn yn cael eu harchwilio ar gyfer tir fferm o Werth Mawr i Natur ym Mlwyddyn 3:

Math 1 Tir fferm sydd â chyfran uchel o lystyfiant lled-naturiol:

- Ardaloedd o bob parsel tir lled-naturiol
- % y cynefin lled-naturiol a diffinio trothwy – e.e. > 20 % - yn achos tir fferm o Werth Mawr i Fyd Natur

Math 2 Tir fferm sydd â mosäig o gynefinoedd a/neu ddulliau o ddefnyddio'r tir:

- Defnyddio'r chwartel uwch o amrywiaeth gynefinoedd (Mynegai Shannon)
- Ymgorffori cysylltedd coetir a / neu ffiniau caeau yn rhan o'r metrig
- Ymgorffori cyfoeth rhywogaethau neu bresenoldeb/helaethrwydd y rhywogaethau a ddetholwyd, yn arbennig rhywogaethau sy'n nodweddiadol o fosäig o gynefinoedd gan gynnwys tir fferm â dwysedd isel

Math 3 Tir fferm sy'n cynnal rhywogaethau prin neu gyfran uchel o boblogaethau Ewropeaidd neu'r byd:

- Ymgorffori data ar safleoedd gwarchodedig: Safleoedd Gwarchod Arbennig, Safleoedd Cadwraeth Arbennig, Safleoedd o Ddiddordeb Gwyddonol Arbennig, neu eu defnyddio ar ffurf set ddata ar wahân i'w gymharu â'r metrig ynghylch Gwerth Mawr i Natur.
- Mabwysiadu haenau targed Glastir a pharthau gwarchodedig i ganfod ardaloedd o Werth Mawr i Natur neu eu defnyddio ar ffurf set ddata i'w chymharu â metrig Gwerth Mawr i Natur
- Datblygu dangosydd ar sail data rhywogaethau, yn arbennig rhywogaethau sy'n brin neu rywogaethau y canfyddir cyfran uchel o boblogaethau Ewrop a'r byd yn y DU.

Rydym yn cyflwyno sawl dull posibl o asesu cyfraniad y pridd at dir o Werth Mawr i Natur, a hynny pe bai'r gweithgor yn penderfynu ei fod yn adnodd naturiol y dylid ei gynnwys yn y metrig hwn. Rydym yn nodi bod hyd yn oed priddoedd cyffredin Cymru yn gymharol anarferol yng nghyd-destun y byd, yn arbennig y priddoedd clai glas dŵr wyneb ac, i raddau llai, y podsolau. Gwnaethom ganfod bod pob un o'r priddoedd prin neu achlysurol wedi'i gwmpasu gan Safleoedd o Ddiddordeb Gwyddonol Arbennig, ac eithrio 1, sy'n pwysleisio'r cyswllt agos rhwng nodweddion y pridd a nodweddion ecolegol.

Bydd y camau nesaf yn cynnwys dull cyfranogi amser real gan Grŵp Cynghori RhMGG, a fydd yn cymharu canlyniadau o gyfuniad gwahanol o fetrigau gan ddefnyddio dull ar y we o fapio y mae'r Ganolfan Ecoleg a Hydroleg yn ei ddatblygu; bydd ar gael ym mis Ionawr 2016. Bydd canlyniadau gwahanol gyfuniadau o ddata yn cael eu cymharu ag ardaloedd gwarchodedig, haenau Glastir wedi'u targedu a metrigau eraill o ran cyfalaf naturiol a gwasanaethau ecosystem er mwyn asesu eu perthynas.

Mapio effeithiau gwrthbwyso a chyfleoedd gwasanaethau ecosystem

Mae cyfyngiadau ecolegol ac amgylcheddol gwaelodol ar wasanaethau ecosystem wedi arwain at greu'r dosbarthiad gofodol cymhleth a welir yn achos y rhain yn nhirwedd Cymru ar hyn o bryd. Yn aml, mae rhai gwasanaethau i'w cael gyda'i gilydd gan fod angen amodau amgylcheddol tebyg arnynt e.e. storio carbon a rheoleiddio dŵr tra bo gwasanaethau eraill yn cael eu cysylltu'n negyddol yn aml (cynhyrchu amaethyddiaeth ac ansawdd dŵr). Nododd adroddiad Blwyddyn 1 RhMGG am ddadansoddiad cychwynnol o'r data a ddangosodd y modd y gellid defnyddio data RhMGG i feintoli'r effeithiau cyfaddawd hyn a'r cydfanteision. Nodwyd bod cynhyrchiant amaethyddol a storio carbon ar wahanol begynnau ar raddiant, o lefel uchel i lefel isel o ran dwysáu tir; yn aml roedd bioamrywiaeth ar ei lefel fwyaf gyfoethog o ran rhywogaethau ar lefelau canolig (Emmett et al.

2014). Yn y dyfodol, bydd data RhMGG yn cael eu defnyddio i ymchwilio i'r perthnasau hyn ar wahanol raddfeydd ac ar gyfer gwahanol ranbarthau. Fodd bynnag, mae angen yn awr ddarparu dull sy'n gallu helpu'r rhai sy'n llunio polisi a rheolwyr tir i dargedu ardaloedd penodol yn nhirwedd Cymru lle y ceir y cyfleoedd mwyaf i gynyddu'r ddarpariaeth o wasanaethau ecosystem gan achosi'r effeithiau gwrthbwyso lleiaf. Rydym wedi manteisio ar ddull modelu LUCI a ddisgrifiwyd yn adroddiad Blwyddyn 1 RhMGG i gychwyn y broses hon (Emmett et al. 2014). Dyma'r tro cyntaf erioed i fodel gwasanaethau ecosystem gael ei ddefnyddio â chymaint o fanylder gofodol a oedd yn briodol ar gyfer yr opsiynau ar raddfa gymharol fân y tu mewn i Glastir ar raddfa genedlaethol ar gyfer 7 gwasanaeth. Ym Mlwyddyn 2, rydym eto wedi defnyddio model LUCI i ganfod ymhle y ceir cyfle i wella pob gwasanaeth a phan allai'r cyfleoedd hyn wrthdaro. Dylid nodi bod model LUCI yn ystyried nid yn unig yr ardal a newidwyd ond yr ardal yr effeithir arni i lawr y llethr gan y broses o reoli tir, gan fod ganddo ddull llwybrau topograffig o ystyried llif dŵr a'r broses o gludo maethynnau/gwaddodion, hynny yw, cyfres o haenau o fapiau System Gwybodaeth Ddaearyddol yw. Yn olaf, rhaid pwysleisio bod LUCI yn darparu dull sgrinio cychwynnol defnyddiol i nodi'r ardaloedd i'w targedu ar gyfer asesiad ar lawr gwlad a darparu metrigau ar lefel genedlaethol. Argymhellir yn gryf y dylid ailedrych ar ardaloedd y nodwyd bod ganddynt botensial mawr ar gyfer gwella gwasanaethau, a hynny gyda'r model (neu ddull modelu gwasanaethau ecosystem arall) er mwyn sôn am opsiynau wrth randdeiliaid lleol gan ymgorffori'r data lleol gorau sydd ar gael. Defnyddiwyd LUCI ac yn wir cafodd ei ddatblygu i ddechrau ar gyfer y math hwn o waith ymgysylltu a thrafod lleol ar gyfer datblygu cynllunio cymunedol sy'n amlwg yn ofodol.

Llwyddiannau a'r prif ganfyddiadau

Cafodd cyflwr gwasanaethau ecosystem, y cyfleoedd i wella, ac effeithiau cyfaddawd neu gydfanteision rhwng 7 gwasanaeth eu nodi gan ddefnyddio model LUCI. Mae cyfrifiadau wedi'u gwneud ar y data gofodol i ganfod ar gyfer pob gwasanaeth ecosystem gyfanswm yr arwynebedd sydd â darpariaeth dda, cyfanswm yr arwynebedd sydd â chyfle i wella, a'r arwynebedd sydd â chyfle i wella heb greu perygl i wasanaethau presennol sydd mewn cyflwr da. Ymgymerwyd wedyn â chyfrifiadau pellach ar gyfer pob gwasanaeth ecosystem i ganfod ymhle y mae cyfleoedd ar gyfer gwella gwasanaethau ecosystem yn cyd-daro'n ofodol â chyflwr da presennol yng nghyswllt pob gwasanaeth ecosystem arall. Yn olaf, gwnaed cyfrifiadau ar gyfer pob pâr o wasanaethau ecosystem i ganfod ymhle y mae gan y ddau gyfleoedd i wella. Mae'r canfyddiadau'n cynnwys yr hyn a ganlyn:

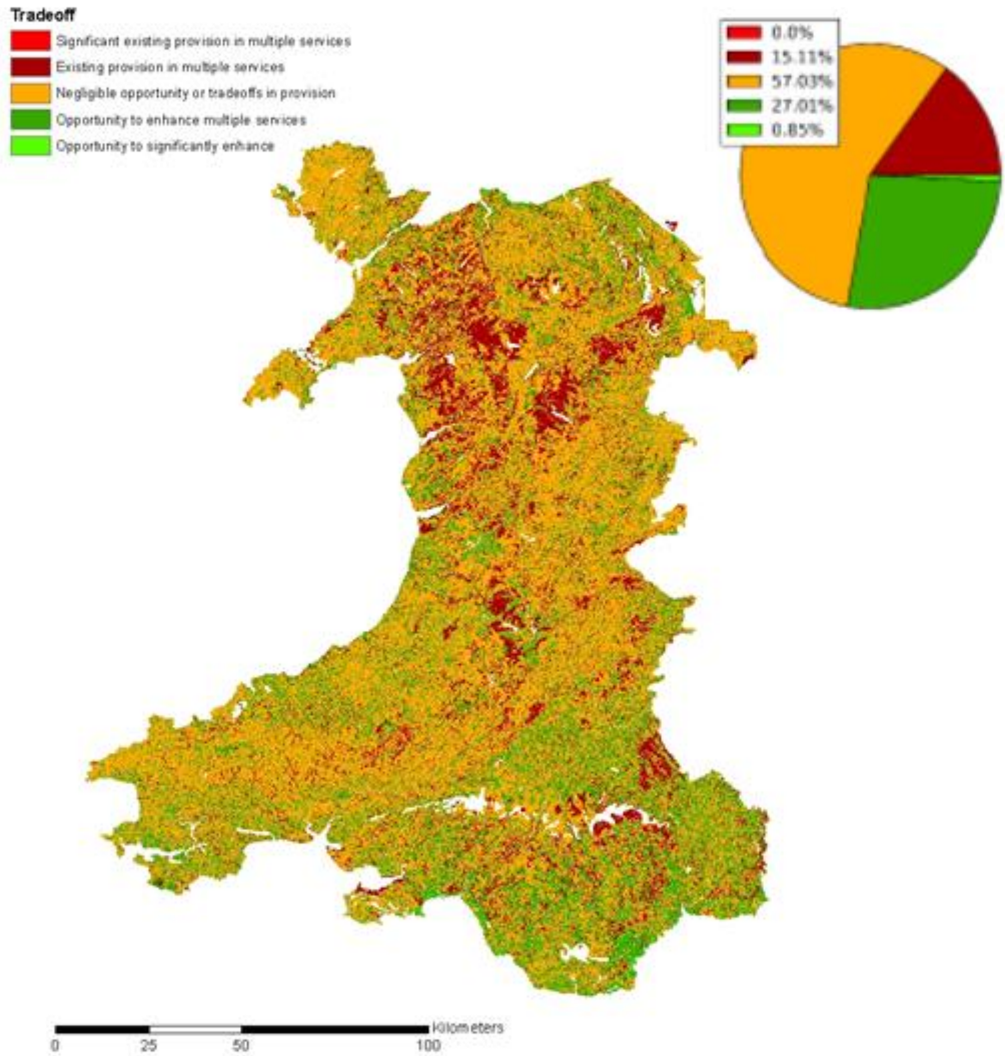
Cyfleoedd i wella gwasanaethau:

- Mae gan ardaloedd sylweddol gyfle i wella statws carbon (C) (10508km^2); fodd bynnag, yn achos mwyafrif llethol y safleoedd hyn, mae gwasanaethau eraill sydd mewn cyflwr da, ac felly rhaid cymryd gofal i osgoi effeithiau niweidiol os caiff effeithiau eu targedu at wella statws C. Mae nifer o'r effeithiau gwrthbwyso hyn yn ymwneud â chynefinoedd â blaenoriaeth (7488 km^2) (gan amlaf glaswelltir lle y ceir grug yn bennaf), defnydd amaethyddol (5424 km^2) ardaloedd sy'n lleihau'r perygl o erydu (9693 km^2), a cholled bosibl o nitrogen (N) (7731 km^2) a ffosfforws (Ff) (9834 km^2) i ddyfroedd croyw . Mae'n debyg na fyddai newidiadau i wella statws C yn cynyddu'r perygl o ran erydu, na'r golled bosibl o N a Ff i ddyfroedd croyw. Fodd bynnag, gall yr angen i warchod cynefinoedd â blaenoriaeth, a gwerth cymdeithasol-economaidd cynhyrchu amaethyddol leihau'r potensial i gyflawni gwelliannau o ran statws carbon.
- Mae cyfleoedd rhesymol i wella (lleihau) y posibilrwydd o golli N i ddyfroedd croyw (104 km^2), a hynny heb berygl o niweidio gwasanaethau ecosystem eraill na chynhyrchiant amaethyddol. Mae cyfrannau sylweddol o'r 5231 km^2 o safleoedd sydd â chyfle i wella (lleihau) y golled bosibl o N i ddyfroedd croyw hefyd â chyfleoedd i wella (lleihau) y golled bosibl o Ff i ddyfroedd croyw (1228 km^2), statws C (2777 km^2), cysylltedd cynefinoedd coetir coed llydanddail (1038 km^2), a'r broses o liniaru llif dros y tir, a all gyfrannu at liniaru llifogydd (3955 km^2).
- Cafodd dros 321km^2 ei ddosbarthu'n dir nas lliniarwyd o ran dŵr ffo, ac nad oedd â dim gwasanaethau ecosystem eraill mewn cyflwr da, a all ddangos posibilrwydd sylweddol i

ymyriadau leihau'r perygl o lifogydd, a hynny heb niweidio ar wasanaethau ecosystem eraill na chynhyrchiant amaethyddol. Fodd bynnag, ymchwilir ar hyn o bryd i ddata ychwanegol i wella'r dull o gynrychioli draenio pridd, a chan ddibynnu ar drefnau llifo nid yw pob nodwedd nas lliniarwyd yn creu perygl o lifogydd ar hyn o bryd, ac felly mae angen cynnal gwaith dadansoddi pellach ar y cyfleoedd hyn.

- Cafodd lleoliadau sydd â chynhyrchiant amaethyddol isel nad ydynt mewn cyflwr da o ran gwasanaethau ecosystem eraill eu mapio, a chanfuwyd eu bod yn cyfateb i dros 97 km^2. Er y gall fod potensial i gynyddu cynhyrchiant amaethyddol yn y lleoliadau hyn, gall tir fod yn llai addas ar gyfer amaethyddiaeth, a gall ymyriadau i wella gwasanaethau ecosystem eraill fod yn fwy addas.

Gwnaed cyfrifiadau ynghylch pob allbwn i ganfod ymhle y ceir effeithiau gwrthbwyso ac enillion cyffredinol ym mhob un o'r 7 gwasanaeth ecosystem a ystyrir. Mae ystyried cydleoli'r cyfleoedd i wella gwasanaethau ecosystem yn achos pob un o'r 7 gwasanaeth yn dangos bod tua 15% â darpariaeth o nifer o wasanaethau ar hyn o bryd tra bo gan bron 28% o Gymru o leiaf 2 gyfle i wella gwasanaethau uwchlaw'r gwasanaethau sydd i'w cadw.



Ffigur 26 *Canlyniadau effeithiau gwrthbwyso'r gwasanaethau ecosystem a ganlyn: statws defnydd amaethyddol, statws carbon, statws nitrogen a ffosfforws, statws erydu, cysylltedd coetiroedd o goed llydanddail, a lliniaru llifogydd; mae gan bron 28% o Gymru o leiaf 2 gyfle i wella gwasanaethau uwchlaw'r gwasanaethau i'w cadw.*

Cafodd asesiad o swm y tir y tu mewn i'r cynllun a'r tu allan iddo a oedd naill ai'n lliniaru dŵr ffo o law / llifogydd, neu a liniarwyd yn hynny o beth, ei gyfrifo. Mae'r canlyniadau'n awgrymu nad oes fawr o wahaniaeth rhwng y tir y tu mewn i gynllun Glastir a'r tu allan iddo, o ran nodweddion sy'n lliniaru neu a liniarwyd. Y gwerthoedd yw 19% a 21% yn achos tir sydd y tu mewn i'r cynllun ar gyfer nodweddion lliniaru, a 19% a 17% yn achos nodweddion a liniarwyd, yn y drefn honno. Bydd asesiadau pellach i asesu'r gwahaniaethau rhwng tir sy'n dod yn rhan o'r cynllun yn cael eu cynnal ym Mlwyddyn 3. Mae'r gwerthoedd hyn yn darparu amcangyfrif pwyllog, a disgwylir i werthoedd gynyddu ychydig drwy gynnwys set ddata HOST i roi cyfrif am liniaru o briddoedd sy'n cael eu draenio'n dda.

Gwnaeth y broses o roi cyfyngiadau amgylcheddol amrywiad gofodol mewn trefn benodol ddangos mai dim ond 3% o'r amrywiad gofodol mewn statws gwasanaeth ecosystem cyfunol sy'n deillio o ddyddodiad, trefn tymheredd, uchder, y llethr, a draenio'r pridd a'i asidedd. Mae hyn yn dangos pwysigrwydd efelychu topoleg a thopograffi wrth asesu cyflwr y gwasanaethau ecosystem perthnasol gan nad yw'r broses o ddarparu gwasanaeth wedi'i chysylltu'n uniongyrchol â'r amodau yn y lleoliad; am y rheswm hwn mae gan fodelu sy'n amlwg yn ofodol fel y'i cymhwysir yn LUCI fanteision sylweddol o'i gymharu â dull gor-syml o gyfuno data gofodol drwy gyfrwng pwyntiau.

Mae'r gwaith o roi allbynnau LUCI ar brawf wedi parhau ac mae'n awgrymu bod canfyddiadau'n gadarn ar gyfer llif dŵr, potensial amaethyddiaeth a'r defnydd presennol o ran amaethyddiaeth, a'r nitrad sy'n mynd i afonydd. Gan nad yw LUCI yn cynnwys ffynonellau pwynt ffosfforws fel gwaith trin carthion, mae angen cynnal gwaith pellach naill ai i gynnwys y rhain neu eu hallgáu o asesiadau LUCI o ffosfforws yn y dyfodol. Mae diffyg data am waddodiad at ddibenion cynnal profion, ond mae'n debyg hefyd fod angen i fodel LUCI gael ei fireinio ar gyfer y gwasanaeth hwn er mwyn cynnwys dulliau rheoli'r tir, fel troi tir. Mae'r asesiadau presennol yn cynnwys dim ond strwythur cynhenid y dirwedd fel llethr a llif dŵr.

Ymysg y datblygiadau eraill mae cynnydd sylweddol o ran defnyddio gwasanaeth mapio ar y we ar gyfer LUCI sy'n briodol i ddalgylchoedd Cymru, a sefydlu dull adrodd gan LUCI sy'n fwy amserol/sy'n ymwneud â digwyddiadau, dros Gymru. Mae cyllid newydd wedi'i ennill yn ddiweddar gan NERC i sicrhau tryloywder o ran lefel y dystiolaeth sy'n sail i'r gwahanol allbynnau a ddaw o LUCI, a fydd â chyswllt â'r gwasanaeth mapio ar y we.

Rhagor o wybodaeth

Mae adroddiad llawn RhMGG ar gyfer Blwyddyn 2 yn amlinellu'n fwy manwl yr holl waith sy'n cael ei ddisgrifio yn y crynodeb uchod, a darperir fersiwn lawnach yn y Crynodeb o Adroddiad RhMGG, a chrynodeb mwy hygyrch a byrrach yng Nghrynodeb RhMGG ar gyfer y Dinesydd. Mae adroddiad Blwyddyn 1 RhMGG a llawer mwy o'i ganfyddiadau RhMGG ar gael ar borth data RhMGG, a lansiwyd yn ddiweddar: https://rhamagg.cymru.

GMEP Year 2 Report Summary

The Glastir Monitoring and Evaluation Programme (GMEP) provides a comprehensive programme to monitor the effects of Glastir and contribute towards providing national trend data towards a range of national and international biodiversity and environmental targets. GMEP is now in its third year of the initial four year baseline assessment period. This annual report presents results from the second year of the programme. GMEP fulfils a commitment by the Welsh Government to establish a monitoring programme concurrently with the launch of the Glastir scheme and as such is a major development from past monitoring programmes which have only reported after schemes have been closed. The project ensures compliance with the rigorous requirements of the European Commission's Common Monitoring and Evaluation Framework (CMEF) through the Rural Development Plan (RDP) for Wales. The early findings from GMEP has already provided fast feedback to Welsh Government as to how to spatially target payments to maximise benefits as the scheme progresses.

Beyond Glastir outcome reporting, GMEP data and models will also contribute to a range of other reporting requirements including the Water Framework Directive, Habitats Directive and the Greenhouse Gas Emission Inventory and actions which arise from the Environment Bill such as the State of Nature Resources report, National Natural Resources Policy and Area Statements. Central to the Environment Bill is the need to adopt a new, more integrated, approach to managing our natural resources in a more sustainable way while safeguarding and building the resilience of natural systems to continue to provide these benefits in the long term. Resilience is considered to be greater where extent, condition, connectivity and diversity are high. Many GMEP metrics can be mapped onto these requirements and thus could be exploited to map these 4 properties for different areas in the future. These benefits will underpin certain aspects of the Well-being and Future Generations Bill. Another potential use of the GMEP data is in support of work by Defra and Welsh Government in their development of National Accounts to include aspects of the natural resources (i.e. carbon, water and soil) and their combined value as whole ecosystems (i.e. forests, wetlands etc.). GMEP data can contribute to the provision of the underpinning robust and auditable data required for this activity.

GMEP will therefore improve the empirical evidence base for the current state and integrity / condition of Wales's natural assets (termed natural capital) and how these are changing in response to drivers such as climate change, land management practices and air pollution onto which Glastir options are superimposed. The challenge to the GMEP team is to isolate the changes connected to Glastir options=s itself which is the primary purpose of the monitoring and evaluation programme. Changes in the extent and integrity of the natural capital in turn impacts on how well they can deliver the ecosystem functions and services we need and value. This link is currently not well quantified. The distinction between natural capital and services is important as capital is a longer term asset which we want to protect for the future and is hard to value in itself, whereas the services which flow from this capital are what economists and social scientists are able to value and which have particular relevance for the Well-being of Future Generations Bill. This valuation step is an essential one if we are to provide a grounded framework for understanding the choices government and society face. The GMEP team is working on these issues through its work on landscape perception and use, social surveys and farmer practice surveys. However, there is a large topic which will need additional work beyond what resources are currently available within the GMEP project.

The GMEP team which is delivering this comprehensive programme compromises a mix of organisations with different specialisations covering the different schemes activities, objectives and outcomes. The programme is led by the Natural Environment Research Councils' Centre for Ecology & Hydrology (CEH), an independent public research body. CEH has a research station in Bangor which provides the leadership and coordination of GMEP. The project consortium includes ADAS, APEM, Bangor University, Biomathematics and Statistics Scotland, Bowburn Consultanty, British Geological Survey, British Trust for Ornithology, Butterfly Conservation, ECORYS, Edwards Consultants, Staffordshire University, University of Aberdeen, University of Southampton, and Victoria University of Wellington, New Zealand.

The GMEP approach and reporting requirements

In summary, the basic approach of GMEP is a combined data and modelling programme which utilises existing data enhanced by a major new rolling field survey which provides co-located data for a range of environmental metrics. Modelling work provides methods for integrating and upscaling survey data for national scale reporting and exploring possible future scenarios of possible outcomes of the scheme. The co-located survey data allows reporting against the six intended outcomes of Glastir and the trade-offs and co-benefits of Glastir payments between these outcomes. The six outcomes are: Combating climate change; Improving water quality and managing water resources to help reduce flood risks; Protect soil resources and improve soil condition; Maintaining and enhancing biodiversity; Managing and protecting landscapes and the historic environment; and Creating new opportunities to improve access and understanding of the countryside; and Woodland creation and management. In addition to these original Glastir Outcomes, in September 2014 the Auditor General for Wales published his report[1] on Glastir. The report contained a series of observations and related recommendations including a number associated with the setting of scheme targets and monitoring actual scheme impact against scheme targets which has had an impact on the reporting requirements of the GMEP project. He identified six Strategic Objectives. To respond to these recommendations, GMEP has worked with the Welsh Government and the GMEP Advisory Group to develop a small number of impact indicators for each Glastir Strategic Objective. Metrics under consideration are:

[1] http://audit.wales/publication/glastir

Strategic Objective	Reportable Indicator
1.To increase the level of investment into measures to mitigate greenhouse gas emissions with the aim of contributing towards a reduction of net emissions from the land based sector in line with our international obligations	Contribution by land use and land use change ($ktCO_2eq\ yr^{-1}$) (excludes peat soils)
	Agriculture Emissions[6] (CO_2eq (kt N_2O + CH_4))
	Agriculture emissions including embodied emissions (typical average farm data only tCO_2eq/ha) Beef Dairy Mixed Sheep
2.To increase the level of investment into measures for climate change adaptation with the aim of building greater resilience into both farm and forest businesses and the wider Welsh economy and environment to ongoing climate change	Farmer Practice Survey to give an indication of farm business split by dairy, cattle, mixed and sheep and forestry
	Species richness / diversity of the wider countryside split by plants, birds and pollinators on arable land, improved land, habitat land and woodland
	Farmland bird indicator
	Habitat diversity
	Mean patch size (for habitat and Broadleaved woodland only)
3.To increase the level of investment into measures to manage our water resources effectively with the aim of contributing towards an improvement in water quality in Wales and to meeting our obligations under the Water Framework Directive	WFD compliant headwater stream site classification (uses a broad set of indicator of ecological condition based on macroinvertebrates, diatoms, habitat modification, nutrients) (% in high or good condition)
	Modelled area of land mitigating runoff /flood (%)[1]
4.To focus increased resources on an identified list of priority species and habitats with the aim of contributing towards a reversal in the decline of Wales's native biodiversity and to meeting our obligations under the EU Biodiversity 2020 agenda	12-15 Priority Habitat extent and condition (Only where both are reportable together)
	Priority species numbers (birds (17 of the 51 section 42 species), butterflies (6 of the 15 Section 42 butterfly species))
	Proxy habitat condition bespoked for particular needs of priority species (aggregated metric across all specie) in and out of scheme
5.To put in place measures and investment which maintain and enhance the characteristic components of the landscape and historic environment of rural Wales and to encourage increased public appreciation and access to the countryside	Landscape quality - Median Visual Quality Index (index from 0 – 1.0) in and out of scheme initially (then change over time)
	Historic Environment Feature Condition (% in 'Sound' or 'Excellent' condition)[2]
	Public Rights of Way (% open and accessible).
	Outdoor recreation use survey metric
6.To use agri-environment investment in way that encourages positive environmental outcomes but also contributes towards farm and forest business profitability and the wider sustainability of the rural economy	Farmer Practice Survey – with a question asking whether the business has benefitted from the Glastir scheme. Split by forest, dairy, cattle, sheep and mixed enterprise.
	HNV Farmland area (aggregate metric under development)

Table 01 *Impact Indicators for reporting against the six Strategic Objectives of Glastir*

Table 01 illustrates the wide range of environmental outcomes and measurements embedded within the GMEP programme of work i.e. a range of soil and water quality metrics, landscape and historic features, plant and freshwater diversity, greenhouse gas emissions, condition assessment of historic features, pollinator and four bird surveys, socio-economic surveys of benefits to the farming and forestry industries and the wider Wales community.

The GMEP cycle

As GMEP survey sites are revisited on a 4-year rolling cycle and we are currently in Year 3 of this initial 4 year cycle, the current Year 2 results contribute towards a baseline against which the future impacts of Glastir payments will be assessed. By Glastir Outcome, work focussed on biodiversity (including woodland habitats) accounts for 42% of the total GMEP budget, 41% is allocated across soils, waters, climate change mitigation, landscape and historic features, trade-offs and co-benefits, and the remaining 17% allocated to underpinning activities such as informatics, the data portal and project management. The field survey involves two parts namely the Wider Wales and Targeted components. The Wider Wales survey squares are chosen to represent the background conditions across Wales and are chosen by randomly sampling within assigned land classes. This helps GMEP to deliver the required data on national trends. Targeted squares are then chosen to specifically capture Glastir related activity.

Summary of progress

Years 1 and 2

Within Year 1, GMEP focussed on establishing the field programme and using an ensemble of models to explore potential outcomes from different scenarios of uptake of 6 Glastir options. In Year 2, we have continued with the field survey and focussed on analysis of Years 1 & 2 data together with data from other sources notably Natural resources Wales, the National Forestry Inventory, Plantlife, UK Butterfly Monitoring Scheme, the Breeding Bird Scheme and Countryside Survey. Long term trends identified are reported here (or in the data portal). We also analysed the GMEP data to identify if land coming into the scheme was different in quality to that outside, and if we could detect the legacy effects of past agri-environment schemes. The biodiversity team focussed on developing techniques for reporting on impacts for Priority species and habitats with work continuing on the development and testing of the landscape quality / perception tool. Modelling efforts were focussed on establishing the baseline data for direct and indirect greenhouse gas emissions in response to Glastir Efficiency Grants funding and assessing possible confounding effect of climate change on greenhouse gas emissions. Soil and freshwater analysis reports on Year 1 data only due to the time required for biodiversity assessment. An analysis of 7 ecosystem services and their potential trade-offs was carried out including the development of a metric to estimate area of land mitigating runoff/flood. Work also included a major new and completed piece of work involved developing new methods for mapping and assessing the condition of peat soils of Wales and their potential contribution to reducing greenhouse gas emissions.

Future plans for Years 3 and 4

Year 3:

- The field survey for Year 3 is already underway with 75 squares selected for survey.
- A decision regarding the inclusion of Countryside Survey squares into the Wider Wales Survey of GMEP will be sought
- Finalisation of the new High Nature Value (HNV) Farmland indicator.
- Development and launch of the GMEP Data Portal at the Royal Welsh Show 2015.
- Reporting of metrics needed for the new agreed 6 Strategic Objectives and Targets for Glastir under development by the Welsh Government. These metrics together with high level indicators for the 6 Glastir Outcomes will be used to provide annual updates through the GMEP Data Portal.

Year 4:

- Completion of the final 75 1km field survey squares to complete the 300 GMEP baseline 1km survey squares will be undertaken.

- Repeat of the Farmer Practice Survey in the summer of 2016 to identify actual changes on the farm and any benefit to farm and forestry profitability and resilience.
- Modelling work to identify benefits of Glastir for water quality in Water framework Directive catchments based on changes quantified in the Farmer Practice Survey of summer 2016 for reporting in Spring 2017
- Farmer interviews combined with modelling to quantify benefits to direct and indirect greenhouse emissions by farm type.

Highlights from Year 2

The following represents a high level summary of some of the key findings structured by Glastir outcome with additional sections added for analysis of Glastir uptake, peat soils, High Nature Value farmland and Ecosystem trade-offs and opportunities. Many others results can be found in the full report or in the GMEP Data Portal www.gmep.wales.

Analysis of Glastir Uptake

4,911 unique entrants were identified as having joined the scheme by Dec 2014, 22% of all landowners registered with LPIS in Wales. Grouped by agricultural small area, the percentage of LPIS landowners subscribed to Glastir varied from 4% to 51%, with the highest proportions present in Snowdonia (Figure 01). The total area covered by Glastir options is 3,263 km^2, 19% of the available LPIS area and 16% of the total Wales land area. Of the 4109 Glastir entrants, 84% subscribed to options under Entry Level, Advanced, or Woodland Management. Across Wales, 190 unique Glastir options codes have been taken up, including 3,050 km of linear options.
Uptake of Glastir applied most to biodiversity, which had the greatest values for all metrics except parcel area with (62% of land parcel counts), where climate change mitigation was the Outcome with most area under options (80% of land parcel counts). The Woodlands Outcome had the fewest entrants, parcels, and total area, although with average values for the number of option codes and option length. These assessments are based on allocation by the project team as the actual intended outcome of the payments intended by the Glastir Project Officer was not available at the time of writing this report.

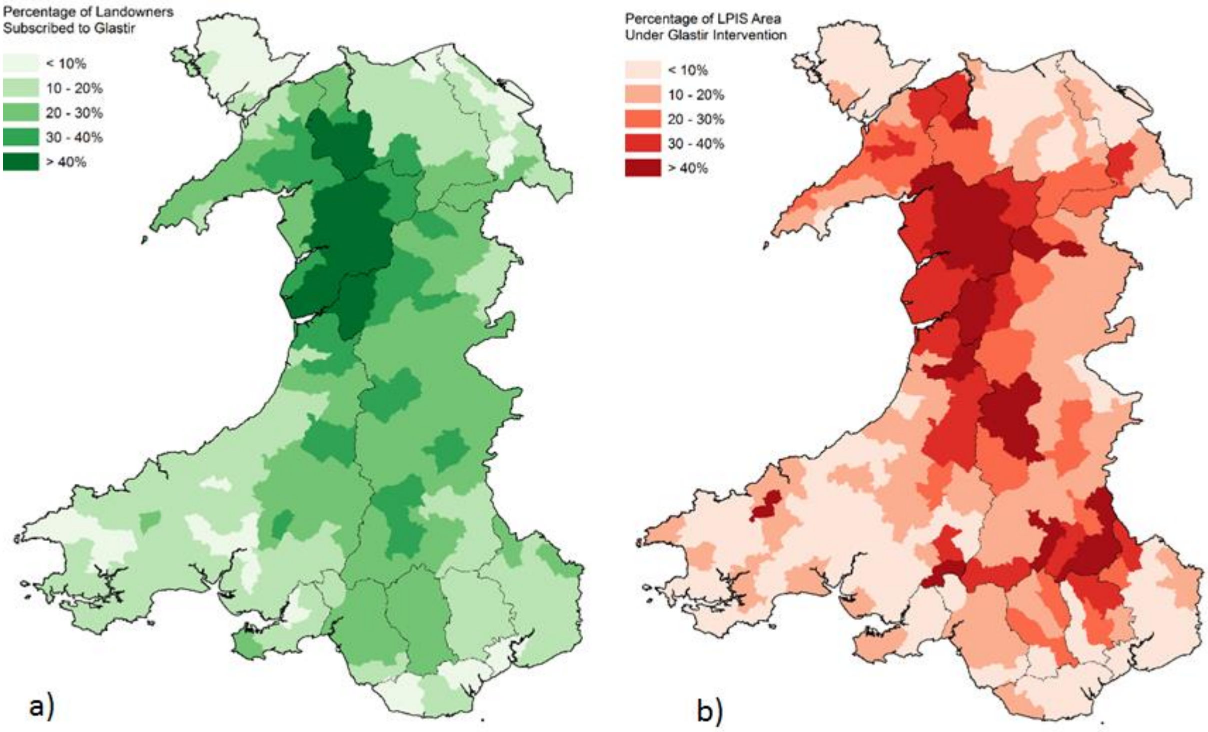


Figure 01 *a) Percentage of LPIS landowners that have subscribed to Glastir, aggregated by agricultural small area; b) Percentage of LPIS landowner area that overlaps with Glastir uptake parcels, aggregated by agricultural small area.*

If the levels of uptake are compared to amounts of points available, clearly points have driven uptake with only 308km2 (ca. 1% of Wales) where there was high uptake in areas with low points. However, there was 3041km2 (ca. 15% of Wales) with high points where there was little or no uptake (Figure 02). To try and identify if there was any consistent pattern of land not coming into scheme, we analysed the land according to its habitat type. Broadly similar proportional amount of the dominant Broad Habitat land was present occurred in the extremes of this assessment i.e. high uptake / low points versus low uptake / high points i.e. the two classes were linearly related suggesting there was no consistent bias of land coming in, or not coming in, to the scheme. The one exception was coniferous forest which was an outlier. There was proportionally a larger area with little uptake despite high points and proportionally lower area of land with high uptake and low points relative to the other 7 major habitat types. The issue of poor uptake of the Woodland Creation scheme which this data would support is further addressed in the Socio-economic Benefits section.

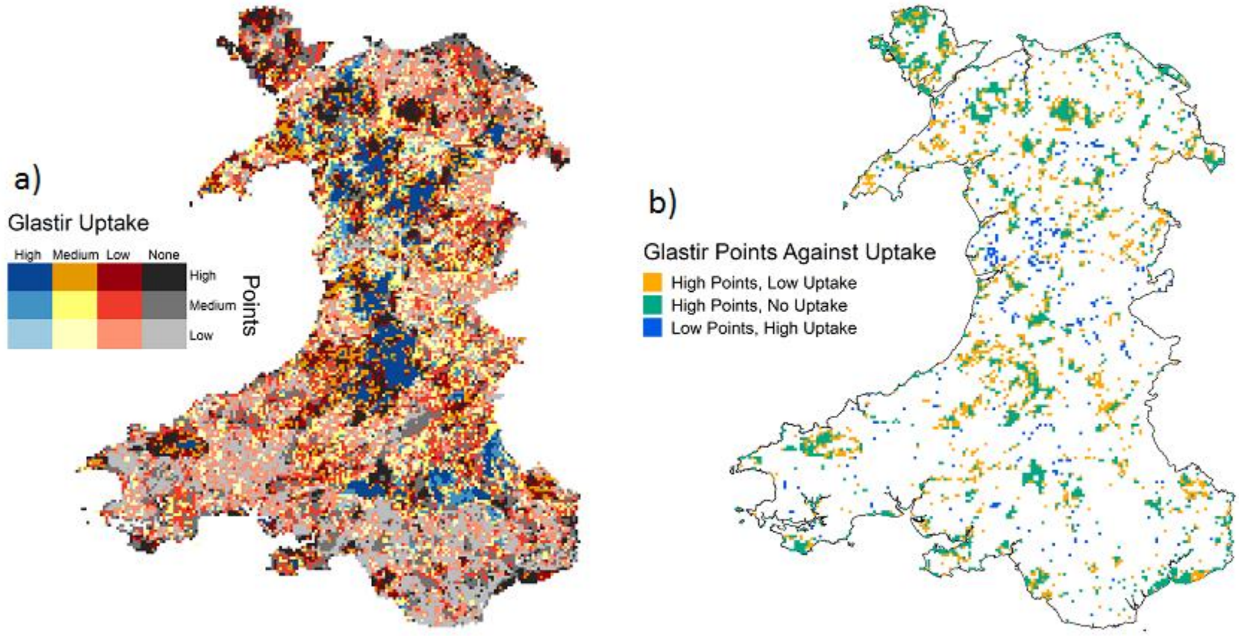


Figure 02a *Comparison of uptake by farmers compared to total points available across all outcomes;* **Figure 02b** *Simplified figure highlighting the extremes of Figure 02a.*

Coverage by GMEP of Glastir

In total, 197 of the 260 GMEP squares (76%) currently selected or surveyed (Years 1-3 and Wider Wales element of Year 4) overlap with some form of Glastir uptake parcel. Squares distribution is shown in Figure 03. This includes 1,609 individual parcels belonging to 321 Glastir entrants and covering an area of 63 km^2. From the 171 squares that overlap with options parcels, a total of 88 different options have been surveyed, including 38 km of linear options.

Split by Element, the GMEP field survey capture of Glastir uptake follows the national trend, with Glastir Entry being the most surveyed Element for most metrics, followed by Organic. The lower uptake Elements of Woodland GEG overlap with the fewest squares. More Glastir Advanced parcels have been surveyed than those of Commons, although the large parcels of the common land mean the total area surveyed is larger.

By Outcome, the overlap within GMEP squares indicates a similar skewed distribution compared to uptake numbers with the majority capturing biodiversity options with 78% of land parcels with biodiversity options (62% in the scheme). Woodlands did however have the lowest coverage at 16% (10% in the scheme). This analysis will need repeating now the data has come through which includes the intended outcome for the options within the Glastir contracts. Current assessment was based on likely target outcome by the GMEP team.

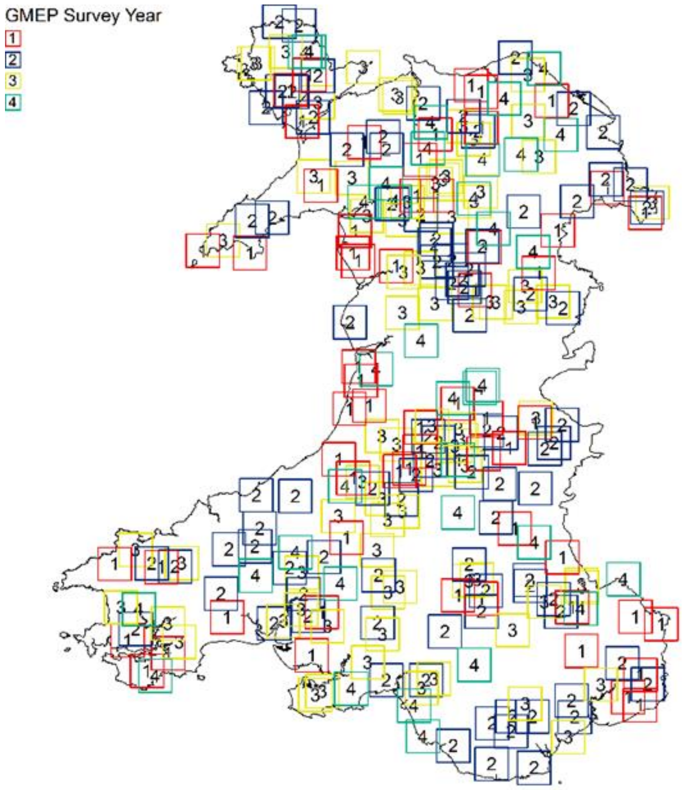


Figure 03 *Distribution of GMEP 1km survey squares but enlarged to cover 10km grid to protect locations. Squares include Years 1-3 Wider Wales Survey and Targeted Survey but only Wider Wales Survey for Year 4 as Targeted Survey will be selected according to uptake in autumn 2015.*

Aside from the field survey data, and internally-generated derived data, a range of third party data has been acquired from the Welsh Government and other sources for the project, currently including over 700 individual files which will help with future analysis.

Field survey update

The 2nd year of the rolling national surveillance monitoring programme to quantify on-going change in the Welsh countryside and impacts of Glastir options was implemented from April through to September 2014. The main biophysical survey of 90 1km squares was managed by CEH; pollinator surveys (butterflies, bees and hoverflies) were managed by Butterfly Conservation (BC); and bird surveys were managed by the British Trust for Ornithology (BTO). A full time Farmer Liaison Officer employed by CEH coordinated the movements of all field teams and arrange land access permissions. 68% of landowners contacted who had landholdings with the GMEP 1km survey squares gave permission to survey, 5% refused access, with the remainder providing no response. In total 80% of land within the 90 1km survey squares was surveyed in 2014. This co-located integrated programme of monitoring and survey which includes measurement from soils to greenhouse gases and waters, plants to birds and pollinators, landscape to historic features and landscape perception enables the inter-dependencies between these elements to be explored in future reports. It is consistent with the aims of the Environment Bill to develop more integrated approaches to managing our natural resources in a more sustainable way. As for Year 1, survey measurements included mapping of habitats, linear and point features, recording of plant species within permanent vegetation botanical plots, topsoil sampling, headwater and pond survey and sampling, bird and pollinator surveys, landscape photography, historic feature and footpath condition assessments. All data is held within the GMEP secure Oracle spatial database. Despite every effort to ensure consistency between field surveyors by rigorous training, detailed methodologies outlined in the field handbooks, quality control and frequent communication, there will inevitably be some variation. It is therefore important to produce a quantitative measure of consistency and reliability of the data. As such, a Quality Assurance exercise was carried out to capture and understand this variation and to ensure that there was no significant bias in the data collected. See Year 1 report for full details (Emmett et al. 2014). Six GMEP squares were also re-surveyed for Quality Assurance in Year 2 (2014). See Appendix 1.1 for full Quality Assurance report.

Peat soils

Peat soils cover 4.3% of Wales, and support nationally and internationally rare bog and fen habitats. In the uplands, blanket bogs form in waterlogged conditions, and contain peat-forming plant species such as Sphagnum mosses, as well as characteristic species such as heather and cotton grasses, and rare species such as sundews and cloudberries. In addition to their importance for biodiversity, peat soils act as Wales' largest terrestrial ecosystem store of carbon, and in good condition have the potential to contribute to climate regulation through ongoing CO_2 sequestration. However, Welsh peat soils have been detrimentally impacted by centuries of human activity including drainage, over-grazing and conversion to grassland and forestry. As a result Welsh peat soils are currently thought to act as a source of greenhouse gas (GHG) emissions. Measures supported through Glastir aim to reduce these emissions, and to restore the carbon sequestration function of Welsh peat soils, through a reduction in land-use pressures on a range of both upland and lowland bogs and fens.

Highlights from Year 2

In year 1 of GMEP in addition to the core survey activities, work undertaken included the mapping of the extent of peat erosion across Wales from aerial photographs, and an assessment of whether satellite data could be used to monitor changes in the surface elevation of peat soils that would indicate whether they were accumulating or losing carbon. In Year 2, we have undertaken a detailed new assessment of the extent and condition of the full Welsh peat soil resource, based on an integrated analysis of soil mapping data, land-cover data and the use of aerial photographs to identify and map drainage ditches. We have also collected a large number of peat cores, which are being used to measure rates of peat accumulation over the last century as a function of land-use.

Main Findings

- A new unified peat map has been defined for the GMEP project which should allow a more reliable assessment of the state of the Welsh peat resource as a whole, with better representation of lowland peats, and more accurate targeting of Glastir peat soil-related measures on those areas where peats are present (Figure 04).
- This map has now been passed to Glastir Contract Managers to use when negotiating new Glastir Agreements.

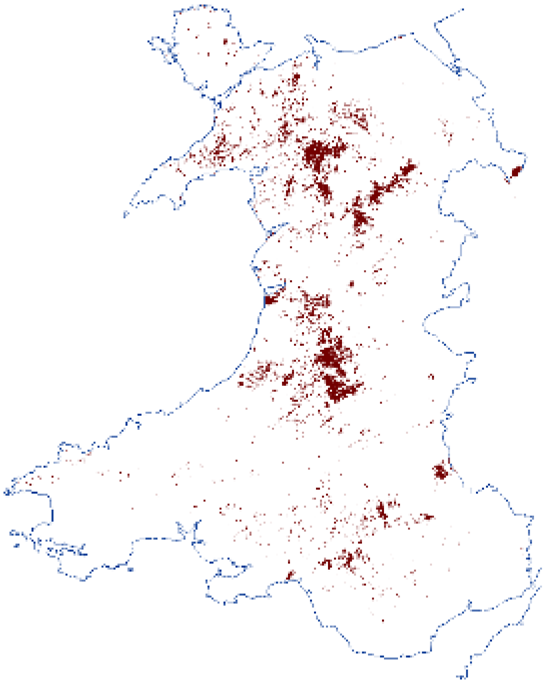


Figure 04 *A unified peat map for Wales, based on combined BGS and NRW data*

- Based on this new 'unified' Welsh peat map developed, peat soils are estimated to cover over 90,000 ha of Wales (4.3% of the total land area) of which 75% is in upland areas, and 25% in lowland areas
- Digital processing of aerial photographs suggests that there are at least 3000 km of drainage ditches on peat soil in Wales
- Overall, around three quarters of the Welsh peat soil area is thought to have been impacted by one or more land-use activity, including drainage, overgrazing, conversion to grassland and afforestation with only 30% in 'good condition' with 25% 'modified' into grassland and 10% into woodland.
- As a result of these activities, Welsh peat soils are currently estimated to be generating 'anthropogenic' emissions of around 400 kt CO_2-equivalents per year (equating to around 7% of all Welsh transport-related emissions). This compares to an estimated natural 'reference' condition (i.e. if all the currently mapped peat area was natural bog or fen) of approximately 140 kt CO_2-eq yr^{-1} (Figure 05).This indicates that natural peat soils are net emitters of greenhouse gas equivalents primarily due to the radiative power of methane. They store carbon overall if in good condition (or peat would not accumulate) and it is the protection of this carbon store and avoidance of emissions which is the objective Glastir can contribute to. As Glastir payments are targeted on semi-improved peats only, the potential emission reductions which could be achieved if all semi-improved peat soils could be returned to the reference state is estimated at 150 kt CO_2-eq yr^{-1}.
- Between 1990 and 2007 there was a decline in species richness in blanket bogs, but a slight increase in the number of characteristic ('positive indicator') bog species (positive CSM indicators).
- Fifty peat cores have now been collected from around Wales in order to measure how much CO_2 Welsh peats were able to sequester in the past, and how much this has been affected by recent agricultural management and forestry.
- Our recommendation is that these new findings should be used to revise the scheme as it goes forward to maximise benefits of Glastir payments for emission reduction from peat soils.

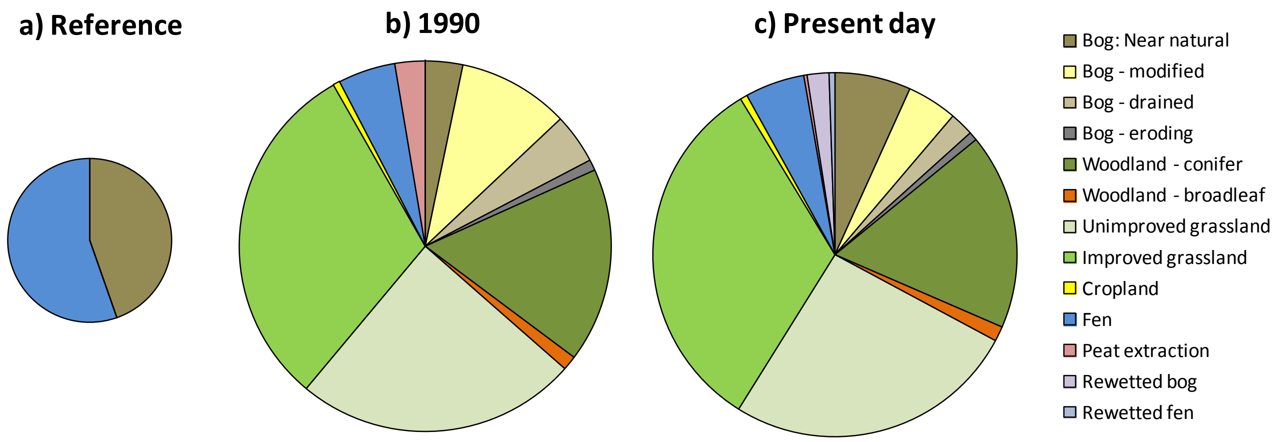


Figure 05 *The estimated contribution of different peat land-use/condition categories to total greenhouse gas emissions from Welsh peats under a natural 'reference' condition, in 1990, and at present day. The size of each pie chart is illustrative of the overall level of emissions.*

Overall the picture is one of highly modified peat soils across Wales ca. 75% .The only recent improvements are in the cessation of peat extraction (Figure XX) and in the condition of bogs i.e. using plant species as a proxy for bog condition, between 1990 and 2007 there was a slight increase in the number of characteristic ('positive indicator') bog species presumably due to recent targeting of bogs for restoration.

Socio-economic Benefits

GMEP undertakes a range of activities to capture the wider socio-economic benefits of the Glastir scheme. These benefits may arise from a range of Glastir activities including payments from farmers into the local community for labour or services to more indirect pathways such as an improved visual landscape quality which has the potential to benefit both local communities and the tourism industry. More generally it is hoped the greater protection of our natural resources intended from Glastir payments will contribute to the 'Resilient Wales' Goal of the Well-being and Future Generations Bill.

Activities in this area in Year 2 have included:

- An assessment of the benefits of the Glastir Efficiency Grants to the wider community and the potential impacts on farm carbon footprints;
- Understanding the barriers to uptake of the Woodland Creation Scheme
- Developing objective, transparent and repeatable measures for assessing the visual landscape quality to enable the impact of Glastir to be assessed in the future
- Quantifying accessibility the landscape both in terms of physical accessibility through the Public Rights of Way network (PROW) and a derived measure of visual accessibility which takes account of the view as experienced by the public within the landscape.
- Continued assessment of the condition of the historic assets present such that future **i**mpacts of Glastir can be assessed.

Highlights from Year 2 include:

Wider Socio-Economic Effects of Glastir Efficiency Scheme Grants

- There is interest within the Welsh Government to identify the wider benefits of Glastir beyond the landowner is receipt of the payment. A survey was carried out to explore the wider benefits of the Glastir Efficiency Grants as a case study to explore this issue.
- A total of 305 grants were approved for farms in the survey (July 2014). Energy Efficiency grants accounted for 9.2% of total approved grants, 7.9% were assigned to dairy farms, 1.3%

to 'other' farms and none to LFA cattle and sheep. Grants awarded to LFA cattle and sheep farms were nearly all for Slurry and Manure Efficiency (174 of the 179 approved grants).

- The total monetary value of the paid grants amounted to £1,006,490. No Water Efficiency grants were in progress by July 2014. Slurry and Manure Efficiency grants accounted for £883,000, and Energy Efficiency grants, £123,490.
- Lowland dairy farms received the largest grant per farm on average (£16,102), compared to £9,855 for LFA cattle and sheep farms and £8,732 for LFA dairy farms. The smallest size category of farms (0-19.9 ha) received the smallest average grant of £8,370.
- More than 90% of respondents agreed that Glastir Efficiency Grants (GEGs) had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GEGs increased their scale of planned investment. Over 87% of farmers agreed that their funded project would not have happened without the grant, suggesting that GEGs has provided a useful tool for delivering economic development and encouraging new on-farm initiatives.
- As a consequence of the GEGs grants more than a quarter (28%) of farm businesses reported a general increase in sales with 51% reporting an increase in sales from farming specifically.
- Increased farm expenditure was spent within Welsh industries (68%), Welsh households (18%) and taxes (8%) with the remaining 6% unaccounted for due to respondent survey error (Figure 06).
- Of the expenditure that respondents allocated to imported materials, the majority was for building materials (49%), and machinery and equipment (32%). Of these imports, 57% of spending was within the UK and Ireland; 8% reported a mixture of spending throughout the UK and European countries and 13% imported products from other European countries.
- According to 71% of respondents, GEGs grants have promoted a beneficial effect on farm suppliers across all farm types. Similarly, 44% of respondents stated that farm customers and clients had experienced beneficial financial effects from the grants.

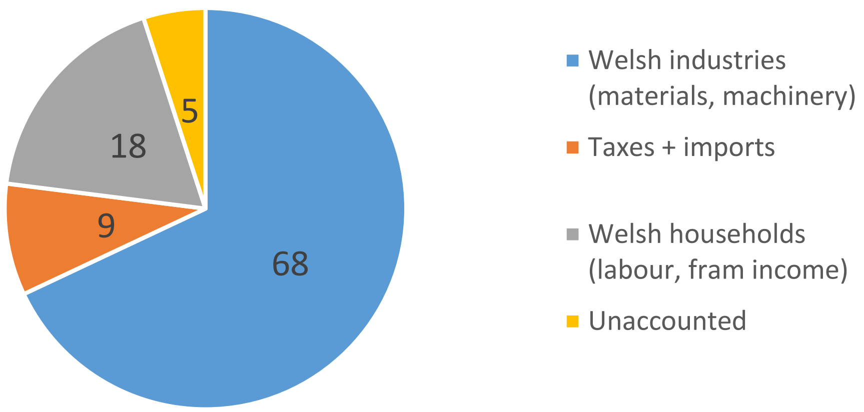


Figure 06 *Allocation of increased expenditure following receipt of GES grants.*

Understanding Barriers to Uptake of Woodland Creation Schemes

- Woodland creation is an activity promoted by Glastir to increase carbon sequestration and thus reduce overall GHG emissions from the land sector. However, uptake of the scheme has been low and a GMEP survey was designed to identify the barriers to uptake.
- The results indicated that the process is perceived to undermine the scheme objectives and acts as a disincentive for potential scheme members from both the farming community and the Local Authorities.
- Recommendations to improve uptake include:
    - To achieve greater scheme uptake the application process should be simplified.

- The scheme needs to be more flexible to account for external influences.
- The auditing process needs to be less threatening, and penalties need to be clearly communicated to encourage greater uptake.
- Payment rates need to be clarified to encourage potential members to adopt the scheme.

Landscape and historic environment

For a relatively small nation, Wales contains a remarkably diverse range of landscapes; from the coasts to the moors, the farmed to the industrialised. The unique physical characteristics of the landscape which derive from its diverse topography, geology, soils and climate have all helped to create a valued cultural and historic landscape which encompasses farming, rural buildings, towns as well as unique historical sites and industrial archaeology. The 3.1 million residents, the majority of whom live within the urban conurbations of south Wales (Cardiff, Swansea) and along the north coast and the fringes of the Dee Estuary are dwarfed by the 100 million day visits and an estimated 6 million overnight trips made to Wales by recreational visitors in 2013.

Wales also has a rich and distinctive historic environment. There are currently 3 UNESCO World Heritage Sites, 30,000 listed buildings and over 4,000 Scheduled Ancient Monuments in Wales which are protected by law. It has been estimated that the historic environment supports over 30,000 jobs and in 2009 contributed approximately £840 million to the wider economy. The historic environment also creates social benefits for residents of Wales, including opportunities for leisure, volunteering and learning. The HEF dataset records the location and known information about these non-designated historic features. Together with the designated sites such as the Scheduled Ancient Monuments and listed buildings, these smaller features contribute to the overall historic and cultural value of a landscape. Non-designated historic features are common throughout all landscapes in Wales. On the whole, these features are found on private land so the long-term care of these cultural assets is frequently entrusted to individual landowners. Sometimes these features face neglect or suffer damage through lack of appropriate knowledge and management. Glastir provides funding to landowners to protect historic features through land use management such as switching from arable cropping to grass pasture or managing erosion by controlling stock better with fencing. In addition, payments are available to help manage scrub which is a particular problem on some historic sites. This type of active management has potentially positive impacts on visual landscape quality, where sightlines are clear, historic features can be seen and recognised as such by the general public.

Glastir explicitly recognises the importance of the Welsh landscape; one of the five stated aims of the programme is to manage and protect the Welsh landscape and the historic environment therein, whilst retaining and promoting public access. Four specific landscape targets are outlined in the programme including: ditch landscapes; historic features and landscapes; pond landscapes and protected landscapes. An additional five targets have significant landscape quality components and include those relating to orchards; parkland and wood pastures; parks and gardens; permissive access and woodland. Within each of these targets are specific management options which have direct impacts on the potential quality of the landscape view. Whilst existing datasets provide information on the location of historic features present within Wales, GMEP is providing an insight into the condition of those features within the GMEP 1km survey squares, the pressures they currently face and eventually will indicate how this changes over time.

Major achievements in Year 2

- A GMEP Visual Quality Index (VQI) has now been successfully run on the 150 1st and 2nd year GMEP 1km survey squares. This has generated a data listing all of the 23 input parameters by square and weighted index values for each. Each of the survey squares has now been ranked from 1 (highest quality index) to 150 (lowest quality index).

- Viewshed analysis has been completed at 3 scales for 150 1st and 2nd year 1km survey squares using 4 different categories of users (pedestrians, cyclists, small vehicle users, rail users) for 3 different scales: looking within the 1km square, looking out to the surrounding 3 x 3 km, looking in from the surrounding 3 x 3 km square. This equates to 1800 separate viewshed datasets for the two years.
- Condition assessment data has been collected and analysed for the historic environment features of the 150 1st and 2nd year GMEP 1km survey sites.
- Number and condition of Public Rights of Ways in the Year 2 GMEP squares have been assessed.
- Photographic preference survey pilot undertaken early spring 2014, the online survey was then refined and launched summer 2014 with both English and Welsh versions available. Currently, over 1360 surveys have been completed online with approximately 10% of these completed in Welsh. The PPS has validated the VQI ranking process and has provided further information about the positive and negative impacts of specific components of the VQI. Our initial target was 500 completed surveys, so this has exceeded our expectations significantly and has generated a dataset of wider significance and value.

Main findings

The range of VQI across the Welsh landscape

- A new Visual Quality Index (VQI) of landscape was developed by GMEP in year 1 to try and capture objectively Welsh landscape quality using a method which could be repeated and analysed robustly alongside the many other natural resource metrics within the survey. In year 2, we have started to explore how this index varies across the Welsh landscape to provide a baseline for future assessments of the effect of Glastir payments.
- There is no significant difference in VQI between upland and lowland sites. However, the upland landscapes have a smaller range of VQI values and a higher overall median value which indicates that they tend not to include the lowest quality landscapes. It is only where a range of positive values coincide that very high landscape quality scores prevail.
- There is no statistical difference between the mean quality ratings assigned to the 1km sites which fall within / without of a protected area. However, there are clear differences in the range of values, with all the highest values falling into protected areas (Figure 07).
- Squares which contained areas of Glastir land were compared against those with none. Although there was some indication that those sites with higher VQI values were found within the Glastir managed scheme, the results were not significant to date. As more squares are surveyed this trend may become clearer (Figure 07).
- Currently, no relationship is found between the landscape quality rating and the number of plant, bird, butterfly or bee species in the GMEP Year 1 and 2 1km survey squares suggesting there is no direct relationship between ecological and landscape quality as indicated by these initial test metrics. However, a more systematic and integrated approach, e.g. using the High Nature Value Farmland index currently under development, will be assessed in future years which will also benefit from a greater sample size.

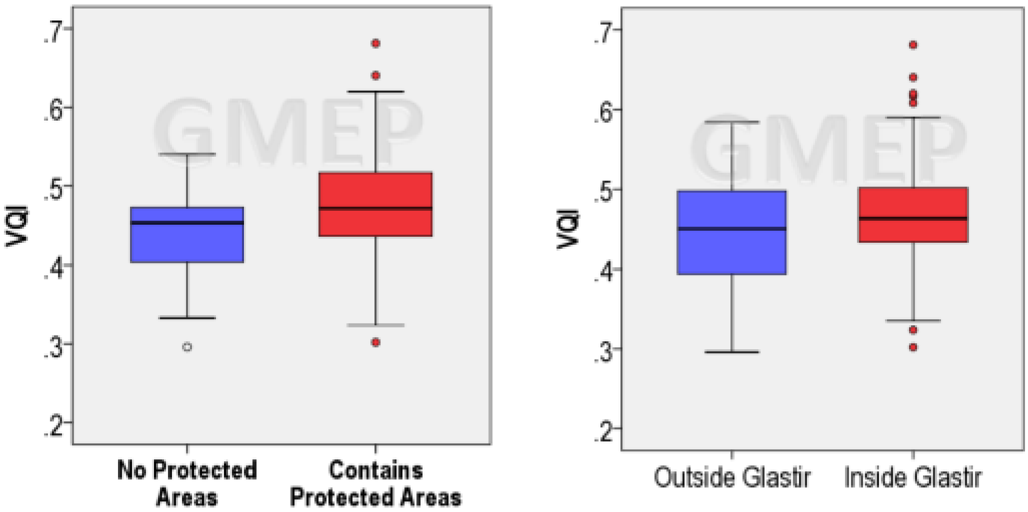


Figure 07: *The VQI of the 1st and 2nd year GMEP 1km survey sites (n= 150) comparing a) inside and outside of protected areas and b) squares with some Glastir managed land as compared against those within none.*

Countryside visiting habits and its importance

- The majority of the 1,360 respondents to the GMEP photo preference survey were well spread across Wales (with additional responses from other parts of the UK) (Figure 08).
- Respondents visited the countryside either daily or two to three times per week.
- The top five reasons for visiting the countryside were: '*relaxation*', '*active recreation'*, '*health reasons*', '*peace and quiet*', and '*to explore and discover new places*'.
- Private car was the most common way of getting to the countryside, followed by walking.
- The vast majority of respondents considered the Welsh countryside to be either 'important' or 'very important' to them.

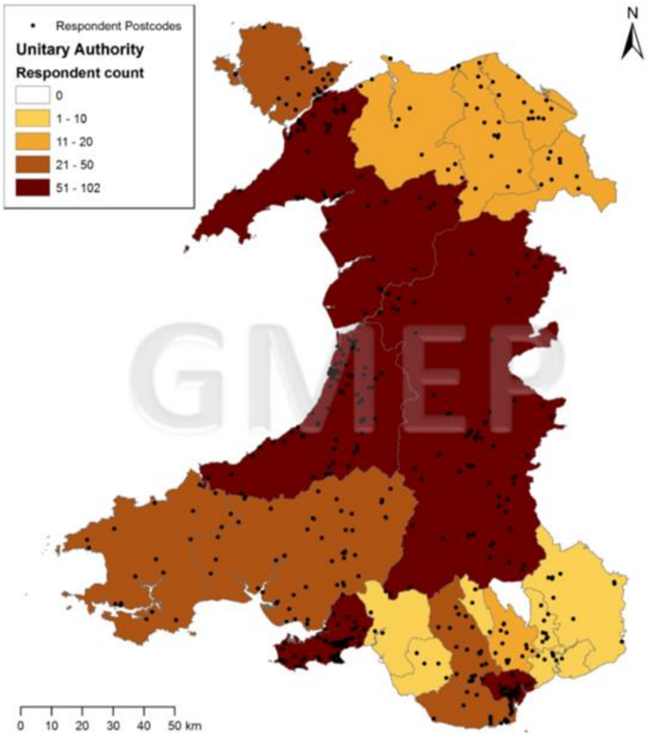


Figure 08 *Distribution of survey respondents from within Wales. Of the 976 completed surveys, 758 described themselves as Welsh (78%)*

Overall attractiveness from the photographic preference survey

- The overall order of landscape attractiveness indicated by the respondents is largely similar to the order indicated by the VQI.
- The ranking of landscapes by females and males were generally similar.
- No major differences could be found in landscape rankings by the different age groups: all age groups (except those between 30 and 44) ranked the five landscaped in the same order. However, younger respondents gave lower overall ratings than the older groups.
- The mean rating scores indicated that respondents who considered themselves Welsh, English, British and Northern Irish ranked the landscapes in the same order. However there was a small but statistically significant difference in the ratings for one type of landscapes between respondents who considered themselves Welsh relative to those considering themselves British, English or other nationality.
- The type of locations where respondents grew up in had a small but statistically significant impact on ranking of landscape types. Respondents who grew up in a village tended to differ in some ranking some landscapes relative to those who grew up in a small town or a town (for E). No effect of current home was found.

Appreciation of specific landscape features

- In some landscapes, single features dominated assessments e.g. the sea shore or flowering heather. For other landscapes, multiple areas were favoured particularly deciduous trees/woodland, hedgerows, river and valley in the distance.
- 'Natural' features such as meadows, deciduous trees, woodland and water features were liked by the majority of respondents, as were livestock and less 'intrusive' man-made elements such as stone wall and small farmstead.
- Less conclusive were opinions towards the more prominent man-made features such as conifer plantations, road and large farm buildings. While a substantial proportion of respondents disliked them, these were never an overwhelming majority as notable proportion of respondents also liked these features or marked them as 'neutral' e.g. Figure 09.

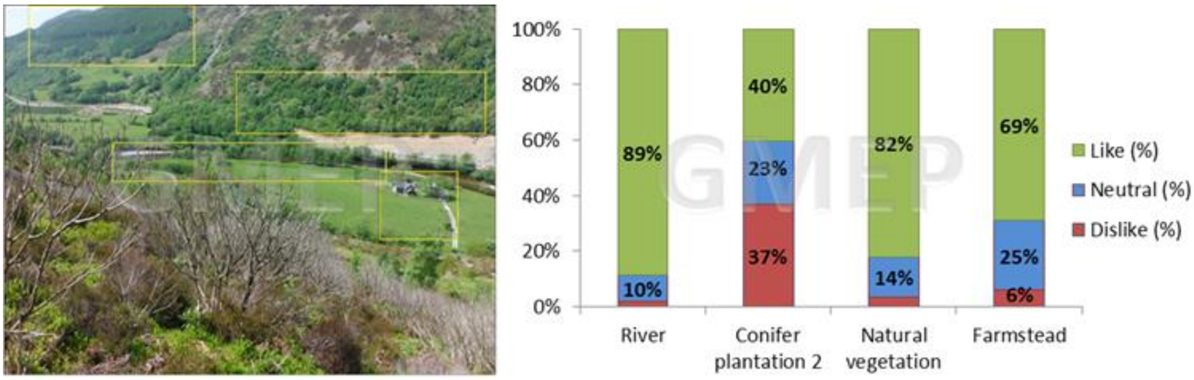


Figure 09 *One of the landscape photos used in the landscape preference survey with the preferences indicated.*

Visual and physical access of the landscape

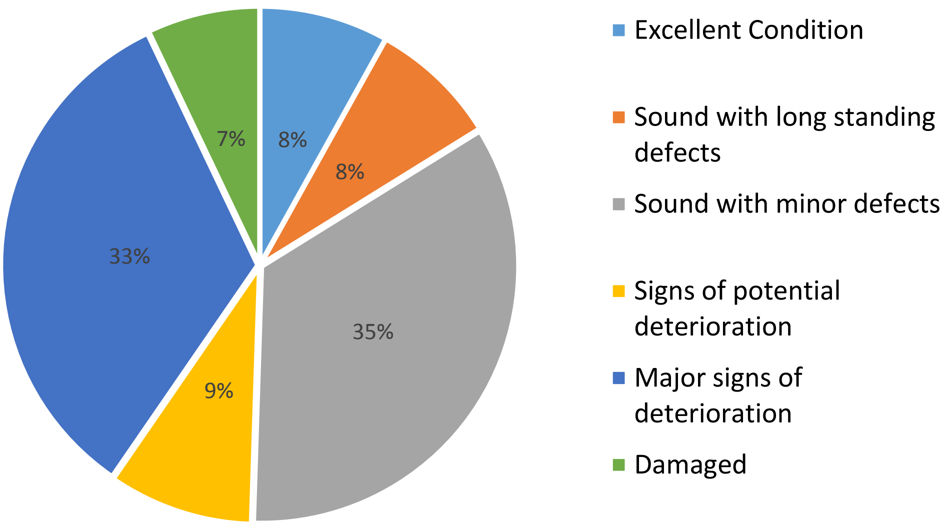
- Walkers and cyclists enjoy on average a view of 45% of the 1km square compared against 36% of people confined to a car.
- At the wider scale of the surrounding 3 x 3km landscape from within the 1km square again, pedestrians have most access to these wider views with on average 40% of the surrounding region being visible.
- From outside of the 1km square, the GMEP 1km survey squares also contribute to the landscape in which they are sited. 81% of the pedestrian group could view the squares which reflects the overall density of roads and footpaths in Wales.

- Of the first and second year sites, the digital data show that 133 of the 150 contained some Public Rights of Way (PROW); the remaining 17 sites were all remote, upland sites. The distribution of paths varied significantly, but in places the network was dense with one site having nearly 6km of footpaths within the 1km^2, though more typically this figure was between 1.5 –3km.
- Condition surveys found that 57 of the 90 Year 2 sites had some PROW of which only 20 had fully open, signed and navigable paths. In a typical 1km square, only two-thirds of the paths on a 1km site were fully open, physically accessible and easy to find. Poor signage was common and many footpaths were infrequently used as a consequence which led to degradation and poor maintenance.

Condition of historic features

- An assessment of condition shows that 8% were judged to be in excellent condition at the time of survey and 35% were seen to be sound with minor defects. However, 33% were assessed to be showing major signs of deterioration while a further 7% were seen to have significant damage.(Figure 10)
- Vegetation was the most prevalent threat (including scrub, bracken, brambles and rushes), with potential to not only visually obscure but also physically damage historic features Stock threats were also relatively frequent (including poaching, erosion and stock wear) while agricultural (for example surface tyre tracks, dumping, ploughing, drainage and pasture improvement) and other general threats (including natural decay, vandalism, development, flytipping) were less common. (Figure 11)

Figure10 *shows condition of Historic Environment Features (HEF's) from years 1 and 2 of GMEP 1kmsurvey squares.*



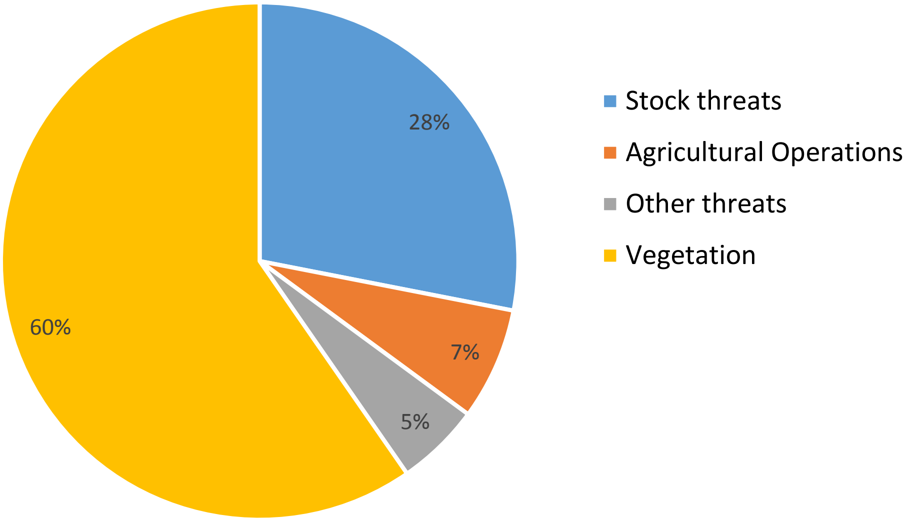


Figure 11 *shows threats to Historic Environment Features (HEF's) or years1 1 and 2 of GMEP 1km survey squares.*

Woodlands

Woodlands are important for the provision of multiple Ecosystem Services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million. A recent survey demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community. Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland although this is low by European standards, only Scotland has a higher total woodland cover however this is a consequence of the much higher percentage cover of Coniferous Woodland there than elsewhere. About 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations. The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy. In Wales, the Glastir scheme is a significant component of the Rural Development Program and therefore contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act) which will apply to woodland habitats. Glastir has a specific woodlands element which includes options on creating and managing woodland. GMEP has also undertaken a survey of landowners intended to identify barriers to the uptake of the Glastir Woodland Creation scheme.

Main findings

Woodland extent

- The main finding of Year 2 included an increase in the area of woodland in Wales over the past thirty years with an increase to 2014 (recorded by both GMEP and the National Forest Inventory). Both Broadleaved and coniferous woodland types have increased in area (Figure 12). Note that neither GMEP nor NFI provides a complete picture of historical or current trends but should be selected depending on the question being asked as their methods are more relevant to some questions than others e.g. area of restocking (NFI), area of small woodland (GMEP) etc.

- GMEP estimates the total area of all woodland in Wales to be 346 000ha (187000ha Broadleaved and 159 000ha coniferous woodland), this is 16.3% of Wales in 2013/14. This compares to 10% in England and approximately 15-18% in Scotland.
- The National Forest Inventory estimate the total area of all woodland in Wales in 2014 to be 306 000 ha, 14.8% of Wales, 156 000ha of which is Broadleaved woodland and 151 000ha is coniferous.
- The total area of woodland in Wales is consistent between Countryside Survey/GMEP and National Forest Inventory (particularly considering the large confidence intervals for the estimates), the figure for coniferous woodland is very similar (GMEP 159 000ha, NFI 151 000ha) Countryside Survey records a greater amount of woodland as Broadleaved, Mixed & Yew Woodland relative to Coniferous Woodland.
- The National Forest Inventory estimated new planting and restocking in Wales to be 3 100 ha between the two periods 2009-2010 and 2013-2014. This is less than in previous years and a small proportion of the UK new planting (50 900 ha) the majority of which was in Scotland.

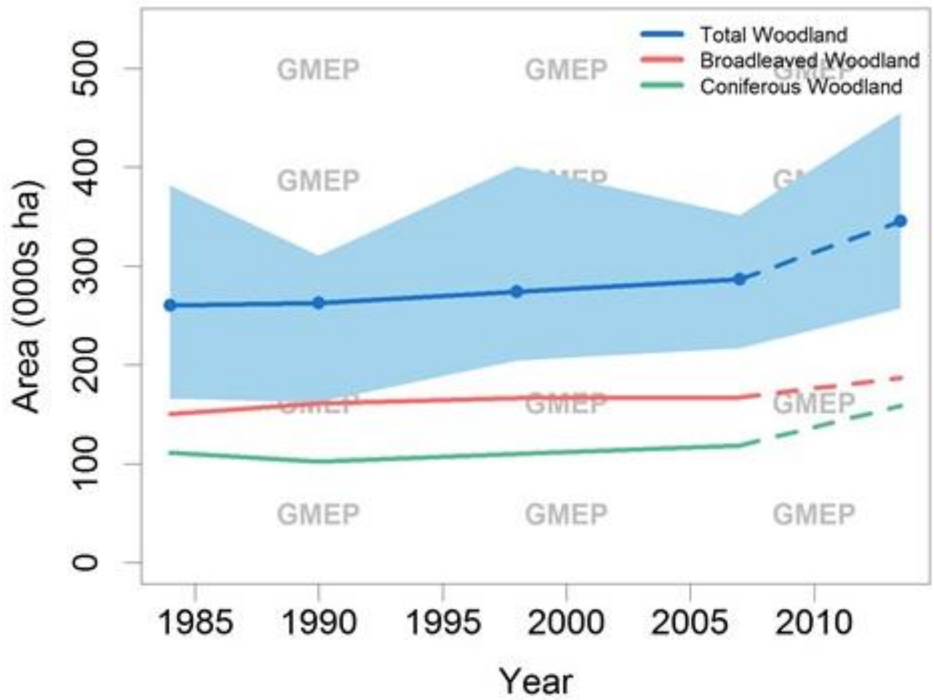


Figure 12 *The area of woodland in Wales over time, created by national estimates from field survey from Countryside Survey (solid line) and GMEP (dotted line) data.*

Woodland condition

- The total area of woodland known to be managed to the UK Forestry Standard has increased from 123,000 ha in 2001 to at least 203,000 ha in 2014.
- Since 2010, there have been outbreaks of two quarantine diseases affecting tree species in Wales (*Phytophthora ramorum* and *Chalara fraxinea*). A Wales specific *Phytophthora ramorum* disease management was launched in December 2013 which establishes management zones. There are also a small number of non-quarantine pests and diseases known to be affecting tree species in Wales.
- There is inter-annual variation in the woodland bird indicator but there does not appear to have been a significant directional change in woodland bird species abundance. It is relatively stable in contrast to the farmland bird indicator (Figure 13)

- Current sequestration from Welsh woodlands is estimated to be about 1,419 gigagrams (1,419,000 tonnes) annually. Forestry is predicted to remain a net sink for atmospheric carbon.
- There was a general non-significant downward trend in Ancient Woodland indicator (AWI) species in large 200m^2 woodland vegetation plots between 1990 and 2007 however the number of AWI species increased significantly in the 2013/14 GMEP sample.
- A similar trend was seen for total plant species richness in large vegetation plots (Figure 03).
- Scores for plant species preference for light are calculated as an average value per plot i.e. higher score= plants present prefer lighter conditions. There has been a decline in light score between 1990 and 2013/14 this indicates that plots are becoming more overgrown with increased shading, possibly due to less management.
- There has been no significant change in connectivity of broadleaf woorland between 1990 and 2013/14.
- No significant change in woody species diversity in hedgerows over the last 10-20 years has been observed. An increase in cutting of hedgerows has been recorded but large decline in new planting, layering and coppicing since 1990. An increase in the length of hedgerows becoming lines of trees also increased suggests a decline in management overall.
- Land coming into Glastir has a significantly higher length of hedgerows than that outside which needs to be taken into consideration in future assessments of Glastir impact.

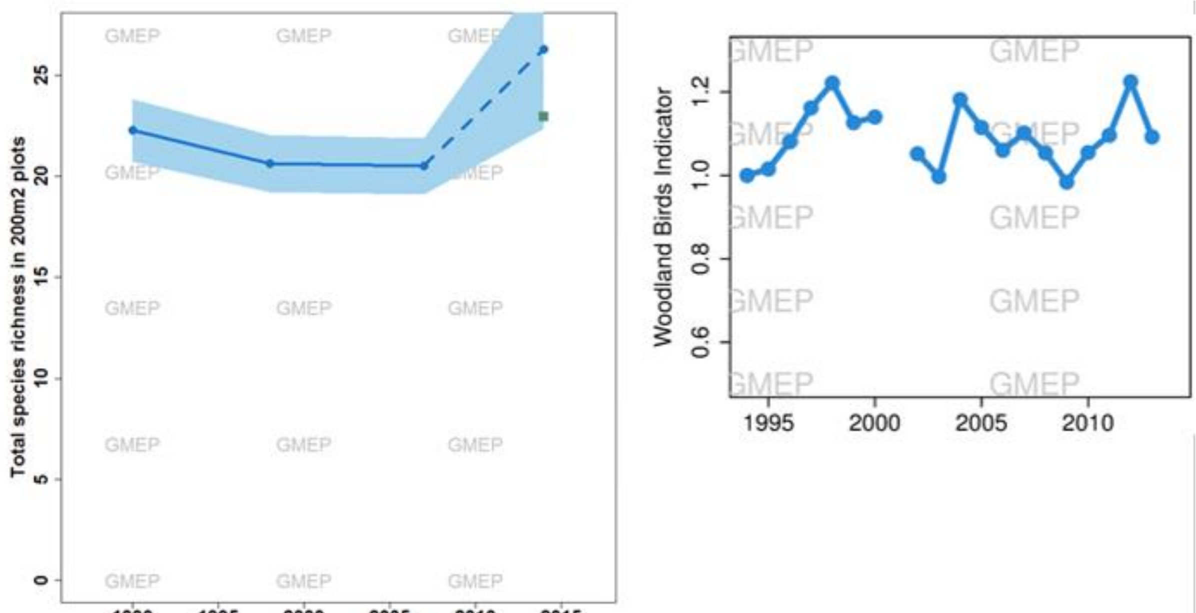


Figure 13 *Trends in mean total plant species richness in woodlands (CS/GMEP data) and woodland bird species (BBS data).*

- We describe the development of a new Woody Cover Product (WCP), which aims to map large hedgerows, individual trees and small patches of woodland, as well as larger woodland, across the whole of Wales at a 5m x 5m scale (Figure 16). The resulting product has numerous potential applications, including investigations of habitat connectivity, modelling catchment run-off processes and quantification of carbon stocks. When validated against aerial photography for several test sites the product had a classification accuracy of 88 %.

Figure 16 *A scene from the new Woody Cover Product showing the areas identified as woody cover (red areas) overlaid onto aerial photography.*

Overall the trend for woodland stock and condition indicate one of increased area but little evidence of improved condition.

Biodiversity

The conservation of biodiversity in Wales recognizes the value people place on a rich heritage of wild species and habitats. Some habitats and species have a stronghold in Wales whilst being rare or absent elsewhere in the UK and Europe so that Wales has a particular responsibility for their monitoring and conservation. While the importance of biodiversity reflects the values placed on it by people, some of these values are harder to quantify than others. They are nonetheless important, including for example conservation of wild species and habitats for their cultural, spiritual, aesthetic and recreational importance. In 2007 the Environment Agency Wales estimated that "wildlife-based activity" contributed a total output of £1.9 billion per year to the Welsh economy which exceeded the total agricultural output in 2011 of 1.3 billion. Therefore the contribution of biodiversity to prosperity, well-being and job creation in Wales should not be underestimated.
GMEP methods are particularly well suited to reporting change changes in biodiversity in the wider countryside which surround designated areas and thus provide important areas for species and habitats to connect and respond to changing environmental conditions such as climate change. In addition, GMEP has developed methods for detecting Glastir impacts on section 42 species and habitats determining the coincidence of options with species and habitats and deriving new indices of long term trends in biodiversity as the backdrop to GMEP. We are also developing methods to characterise High Nature Value farmland (see HNV Section) and to extend our estimates of biodiversity change and impacts of Glastir outside of the sample of GMEP squares and into wider Wales by integration with remotely sensed data products and biological records databases. For brevity not all national trend data are reported here but are available within the GMEP Data Portal. Data on Priority Habitats extent and condition are not yet available.

Highlights from Year 2

- The UK Butterfly Monitoring Scheme (UKBMS) data for Wales going back to 1976 has been collated for 324 1km squares and trend lines calculated. Results indicate a historic decline in specialist butterfly species with recent stability with no further decline over the last 10 years whilst there are more stable trends for more generalist butterfly species.
- The BTO/JNCC/RSPB Breeding Bird Survey (BBS) Welsh farmland bird indices from the show a tendency to declines from around 2000, while the woodland index has remained relatively stable. This reflects the continuing downward trends in a number of farmland bird species, such as Yellowhammer and Skylark. As with all multi-species indices it is worth noting within a declining indicator, it is likely that some component species will need no conservation action, but declining species may feature within an increasing trend and thus be conservation priorities.
- New metrics developed by GMEP for total abundance and diversity of target bird species exploiting the BBS data were found to be rather stable over the last 20 years. As with other indicators, however, the process of summarization will have masked some patterns of relative increase for individual species, while masking others of relative decline for other species.
- The Breeding Bird Survey (BBS) trend data were calculated for 35 of the target species and aggregated into a new 'target bird species index'. At least half of the 35 priority bird species for which there was sufficient data (there are 50 in total) were scored as increasing or stable in each of the periods considered from 1994 - 2014, but there was considerable variation in trend direction within and between species, leading to considerable variation in the overall index of population trend health. Specifically, rather more population trends were negative during 2000-2009 than at either end of the time series considered and there was no pattern for an overall improvement in population health over time (Table 02).

	1994-1999	2000-2004	2005-2009	2010-2014
Number of species with trend data	34	35	35	34
Number increasing/stable	23	21	17	22
Percentage increasing/stable	67.6	60.0	48.6	64.7

Table 02 *Summary of population trends across priority (Section 42) bird species.*

- In the future, there is good potential to monitor for change in extent for 13 Priority Habitats. Recent trends from analysis of historical data are currently being discussed with NRW. For priority bird species it is likely GMEP will be able to report on 14 species (out of 50 listed) directly from the GMEP survey data. Many others are extinct as breeding species in Wales, are nocturnal (or crepuscular) species, or are only winter visitors which are captured by other surveys. More importantly, the inclusion of bird monitoring within the same squares as all the other GMEP measurements enable the inter-dependencies between metrics plus drivers of change to be explored within GMEP which is not always possible within the more targeted surveys as the supporting data is not gathered. There may be potential for reporting on 7 of the 15 priority butterfly species.
- For other Priority species, we have developed the knowledge base required to identify sets of proxy indicator variables for section 42 species and on the derivation of these indicators from GMEP survey data. This comprises comprehensive reviews of species' ecology and establishing how species options are translated into indicators drawn from field survey attributes. These indicators measure whether Glastir options have resulted in ecological changes assumed favourable to section 42 species populations. An initial sample of 6 species were selected representing section 42 invertebrates, mammals, birds and plants focusing on

those that are more widely distributed in Wales; Dormouse, Rare Arable Plants, Curlew, Lapwing, Marsh Fritillary and the Lesser Horseshoe Bat.

- The impact of past agri-environment schemes on birds was assessed using bird population growth rates (changes from year to year) using different quantities of relevant AES management in and around BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1km squares. Positive associations with Tir Gofal options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management. The evidence therefore supports broadly positive effects of Tir Gofal, notably involving management of woodland, scrub, hedgerows and habitats providing winter seed in arable farmland (Figure 14).

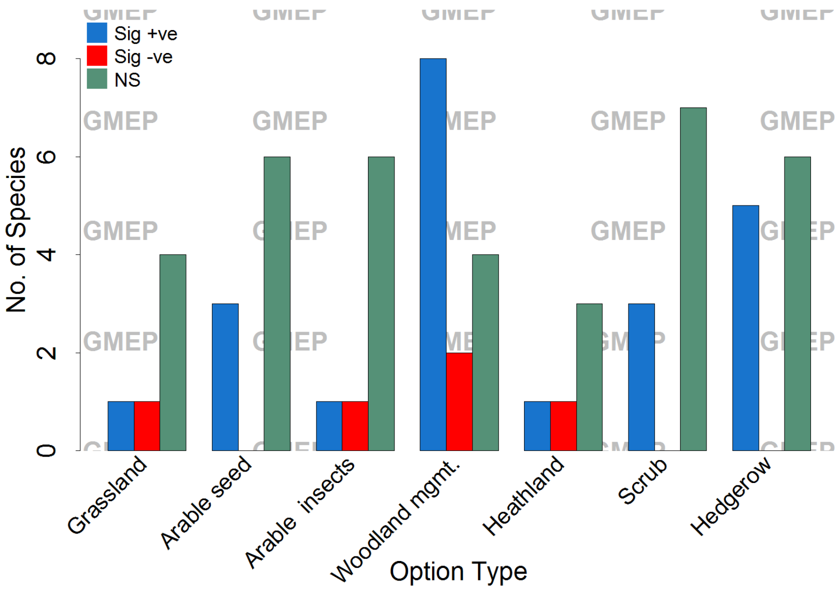


Figure 14 *Numbers of bird species with positive, negative and non-significant associations with TG option groups.*

- The legacy effect of Tir Gofal on land coming into the Glastir scheme was assessed for plant species. For the vast majority of indicators (42 out of 45) there was no evidence that plots occurring on land previously subjected to Tir Gofal prescriptions had different values to plots on land which had never been under Tir Gofal. Sample sizes were small however and the power to detect any legacy will increase as the GMEP survey continues. Despite this limited sample size, for two options there were significant differences of; a) terms of species richness in ungrazed Broadleaves woodlands (option 1A) in plots that had entered Tir Gofal before 2006 and b) for the grass:forb ratio (a negative indicator) for upland heath (Figure 15)

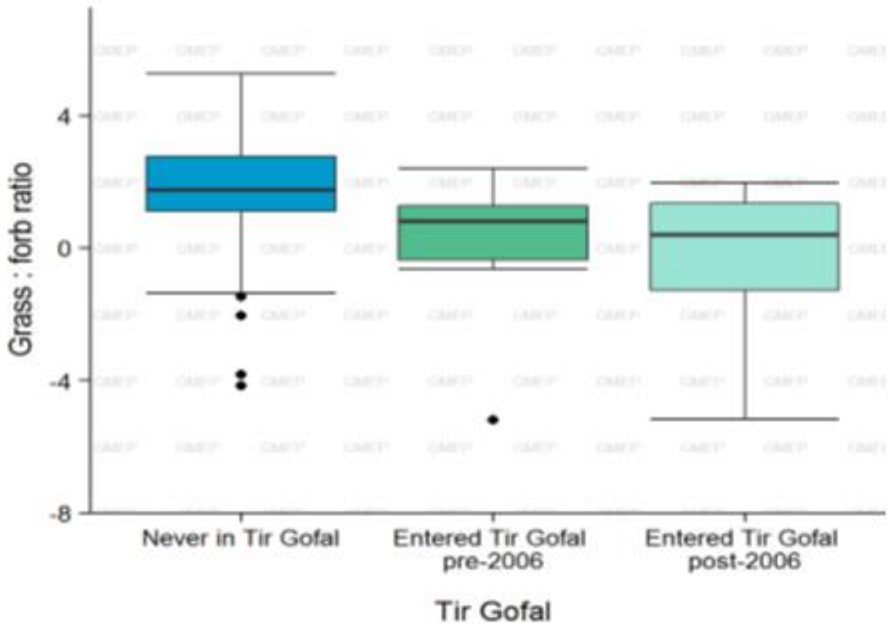


Figure 15 *Significant reduction in the grass:forb ratio in upland heath in land that entered Tir Gofal within the current GMEP sample.*

- We have produced a finely resolved predictive map of Annual Net Primary Productivity for Wales – this essentially is the amount of plant growth and thus underpins agriculture and forestry productivity. The methods uses combination of remotely sensed data and plant trait modelling. Primary Production is a fundamental measurement of ecosystem function and further work will progress the validation of our initial model and explore further relationships with ecological attributes and natural capital across Wales and within survey squares.

The overall picture for biodiversity is some evidence of recent stability for some elements of biodiversity but little evidence currently of improvement. Baseline differences in biodiversity of land coming into the Glastir scheme have been identified which will need to be included in future analyses to avoid false positive impacts being attributed to Glastir.

Climate change mitigation

Agriculture continues to be a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to improve water quality and reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets. In consequence, the Glastir scheme has been developed with sufficient flexibility to target priority themes (such as soil carbon) in a spatial context, and introduce measures on farms to e.g. enhance carbon sequestration, reduce greenhouse gas emissions and diffuse water pollution from the agricultural sector. The Welsh Government has prioritised funding for options focussed on climate change mitigation and diffuse water pollution for Years 1 and 2 of the scheme.

As a first step to determine the potential impacts of Glastir on greenhouse gas and diffuse pollution emissions and carbon sequestration, the Welsh Government tasked the Glastir Monitoring and Evaluation Programme to assess the potential impact of Glastir options on these priority areas through modelling (including emission source not included in the greenhouse gas inventories), work to identify the wider benefits of the Glastir Efficiency Grants and a scoping study to identify barriers for uptake of the Woodland Creation Scheme. Woodland creation is one of the few mitigation activities which can directly capture carbon. Most other measures are only able to reduce emissions. The Year 1 GMEP Report provided an initial description of the modelling ensemble approach we used. In Year 2 we have continued to monitor ongoing national trends of greenhouse gas emissions but enhance these to include embedded and indirect emissions and applied a process model to explore potential changes due to climate change which will be superimposed on the long term outcomes of Glastir.

Highlights from Year 2

Greenhouse gas emission trends from the national inventories

- In 2012, Agriculture contributed 13% of CO_2e emissions in Wales, with methane (CH_4) and nitrous oxide (N_2O) representing 64% and 79% of total Welsh emissions of these two gases, respectively (Figure 17). In total, 6,142 CO_2e were emitted by agriculture in Wales in 2012; comprising 47% as CH_4 (2,864 kt CO_2e), 44% as N_2O (2,707 kt CO_2e), and the remainder associated with transport.
- Enteric fermentation contributed >80% of total agricultural CH_4 in Wales (2,294 kt CO_2e), manure management representing the remaining CH_4 emission. Dairy and beef cattle were responsible for 63%, and sheep 34% of agricultural CH_4 emissions.
- Agriculture is the dominant source of N_2O in Wales, with >90% (2,491 ktCO_2e) of this arising from agricultural soils. The key sources of N_2O from agricultural soils are: fertiliser nitrogen, grazing returns and manure applications.
- Agricultural sector GHG emissions in Wales have decreased by >20% since 1990 (Figure 17). There was a small increase of less than 1% in emissions from 2011 to 2012 mainly due to a 1% reduction in cattle numbers balanced by an increase of 3% in sheep numbers. The overall trend in reductions of (N_2O) emissions from soil have been the result of reductions in fertiliser nitrogen use (particularly in grasslands) and reduced numbers of livestock (manures and urine deposition) over the past decade. Current (2012) annual emissions of N_2O for Wales are 2707 kt CO_2e (8.73 kt N_2O). The trend in the reduction of livestock numbers has also resulted in lower CH_4 emissions. The stabilisation of numbers in recent years means that there has been little change in emissions between 2011 and 2012 (0.2% increase).

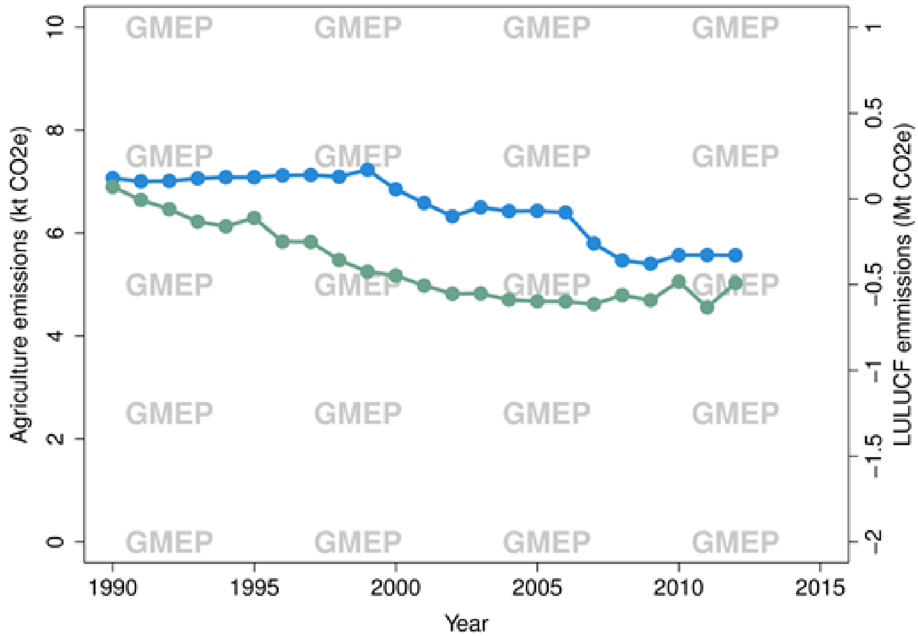


Figure 17 *Greenhouse gas emissions from agriculture and land use, land use change and forestry (LULUCF). Note the differences in scale; 0-10 for agriculture and -2 to 1 for LULUCF. Negative numbers indicate an uptake of carbon. LULUCF activities are clearly not compensating for emissions from agriculture.*

- Wales is a small net sink of greenhouse gases from LULUCF activities (Figure 17). Between 1990 and 2012, the carbon sink in Welsh grassland increased slightly (emissions have become more negative), while emissions from cropland have decreased. These trends reflect conversion of cropland to grassland dating back several decades, as it takes many years for the amount of carbon stored in soils to stabilise after conversion between one land use and another.

Carbon Footprinting including indirect and embedded emissions

- On this set of 16 Welsh model farms, the 4 Glastir options explored is projected to have had the intended effect of reducing GHG emissions and (in most cases) increasing C-sequestration in biomass and soils.
- The effectiveness of the different options in reducing GHG and increasing C sequestration varied between farm types.
- The tool indicated the GHG reductions were mediated primarily through reductions in livestock, with small additional reductions associated with lower requirements for farm inputs associated with stock management. These reductions to inputs extend the impact of the scheme option beyond the boundaries of the participating farm, and into the upstream agricultural supply chain.
- Reductions in livestock numbers may or may not lead to reductions in farm productivity and hence the economic and supply performance of the farm, although this is difficult to predict with confidence.
- The tool indicated the conversion of grassland to woodland resulted in a net increase in carbon sequestration but the effectiveness of the "woodland margin extension" and "streamside corridor" options is limited by the small number of farms with applicable land.

Potential Effects of Glastir Efficiency Scheme Grants on Farm Carbon Footprints

- Insufficient time had passed for farmers to implement GEGs grants on their farms to assess their effect on carbon footprints. Instead, this initial survey was used to establish a baseline year from which to compare carbon footprints after GEGs grants have been completed,

- The average estimated footprint per hectare across all farms was 10,236.0 kg CO_2/ha/yr, and ranged from 2,385.1 kg CO_2/ha/yr to 18,987.2 kg CO_2e/ha/yr.
- The average footprint per hectare on dairy farms (14,032.9 kg CO_2e/ha/yr) was almost double that of LFA cattle and sheep farms (7,704.8 kg CO_2/ha/yr).
- Smaller farms (11,654.3 kg CO_2e/ha/yr) averaged a higher footprint per ha of land than larger farms (7,602.0 kg CO_2/ha/yr).
- Based on this study recommendations include:
    - Carbon footprinting to be repeated on the current sample of farms, at an appropriate point in time after construction and use of GES-funded capital items. This will allow a comparison between baseline emissions and emissions post-implementation, acting as an impact indicator of the scheme.
    - Prioritisation of further grant allocation to the dairy sector, subject to feasibility.
    - Prioritisation of further grant allocation in the SME category.
    - Avoid allocating soil aeration grants to farms where aeration would be conducted on peat soils.
    - Assessment of the impact of GES on ammonia volatilisation, as this is likely to be an important environmental and human health benefit of implementing some SME technologies.
    - The statistical trends in data illustrated in this report should be interpreted with caution, as the number of farms sampled within each category were too small to draw any robust conclusions from.

Effects of Reduced Fertiliser N Use and Climate Change on Spatial GHG Emissions

- The ECOSSE model differs with respect to the models used in the GMEP Year 1 scenario work in that is a process-based model so is capable of quantify changes to GHG emissions in the longer term when emission factors which underpin other models may change e.g. in response to climate change. These models are the ideal but require a great deal of data and there remain uncertainties in the science and the scale of results is significantly reduced compared to the other models.
- ECOSSE estimated mean annual net GHG balance at baseline climate of 0.2 t CO_2e /ha/y, which is equivalent to a net C loss of 54 kg C /ha/y.
- The Glastir measure of reducing N fertilizer to reduce GHG and SOC fluxes could reduce the annual net GHG balance from 0.20 to 0.17 (for a 20% N reduction), and to 0.15 (for a 40% N reduction) t CO_2e /ha/y, respectively.
- The overall conclusion is that the model indicated climate change will not significantly affect net GHG fluxes from Welsh soils or Net Primary Productivity by vegetation by 2050. This is primarily a result of the small differences between the baseline and 2050 climate scenarios (about ±2%).

Overall the picture for the contribution of agriculture and land use to greenhouse gas emissions is one of major improvement from 1990 – 2010 by ca. 20% but with recent cessation of that trend with no recent reduction over the last 5 years. Further improvements are going to be challenging as a result of Glastir considering the aging of the forest stock, limited uptake of the woodland creation scheme and the anticipated limited effect of Glastir on stock numbers.

Soil quality

Healthy soils produce our food, feed and fibre, whilst providing other important functions such as regulating climate and water and attenuating pollutants. They are a biodiverse ecosystem in themselves needing to be fed and watered, and contain an estimated quarter of global biodiversity, whilst remaining relatively unexplored with only ~1% of species as yet identified. It is the diversity of life below our feet that provides the engine fuelling nutrient cycling, breakdown of waste, water filtration and plant growth which is why soils are central to environmental and biodiversity monitoring.

The status and trend of topsoil (0-15cm) change across Wales has been captured by the Countryside Survey since 1978. The last survey in 2007 presented changes for a wide range of physical, chemical and biological properties of soil. Overall, the picture was one of stable or improving topsoil quality with the exception of arable soils. It should be noted the methods used in CS (and other soil monitoring programmes such as the National Soil Inventory) are recognised as being inadequate for peat soil monitoring and thus new approaches have been commissioned within GMEP to tackle this. See Chapter 2.

In Wales, funding from agri-environment schemes (AES) has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal and now Glastir. Monitoring of farms under Tir Gofal (Welsh Government, 2013) reported that, 'Soil pH and extractable phosphorus levels were observed to be lower on Tir Gofal farms compared to non- scheme farms. However, this difference may not be due to Tir Gofal management, and was thought instead more likely to be attributable to Tir Gofal management options being applied to areas of more marginal land. Across all the remaining soil quality indicators (bulk density, erosion vulnerability, depth of peat material, organic carbon and carbon to nitrogen ratio) no positive differences were recorded between Tir Gofal and non-scheme farms.' Although the report revealed few positive benefits to soil quality in comparison to farms that had not entered the scheme, this finding could be due to several factors. Firstly, the monitoring timescales (< 3 years) may have been too short to determine significant change, secondly the pair-wise comparison of farms in and out of the scheme may have been the wrong sampling approach (i.e. not enough samples, incorrect pairing), and thirdly there may actually have been no significant benefit from the scheme. As it is impossible to resolve which of these three are valid, it is hoped that the current Glastir monitoring statistical design will help resolve these issues.

The aim of the Glastir monitoring of soil quality is to collect evidence for the effectiveness of bundles of management options in helping to deliver improved soil quality that will address the outcomes of interest related to climate change, biodiversity, soil and water quality and woodland expansion. The compatibility of the current monitoring with Countryside Survey means it can draw on this data record to understand and disentangle changes in national trends from the specific impact of option bundles. The monitoring is also required to collect evidence to quantify the status and trend of water and soil quality in general for other reporting requirements and this work will provide an important counterfactual evidence base. Synthesis and analysis of this data will seek to identify how the Welsh environment is being impacted by drivers of change, such as landuse, climate and pollution over and above Glastir options. Much of the data from the soils work provides evidence for the integrated analysis, and also helps support modelling studies.

When expecting to see the impact of options it is important to consider that based on the findings of the soil quality monitoring performed under Glastir, alongside previous national surveys (e.g. Countryside Survey), it can be expected that major changes in soil quality at the national level will not be revealed in the short-term. For example, 10 years of monitoring are typically required to reveal significant changes in some soil attributes (e.g. carbon status) whilst the dynamics of other attributes such as biodiversity are unknown. Although the rolling monitoring programme implemented under Glastir has greater statistical power than previous surveys, it is still unlikely that trends in soil carbon will become apparent for at least 5 years or possibly longer, though it has the advantage of linking to the 30 year Countryside Survey data set which provides greater statistical power. Also, it should be remembered, the inclusion of soil attributes is essential in the interpretation of other responses in vegetation, GHG emissions and water quality.

Major achievements in Year 2.

- Main 2014 survey
    - Trained 12 surveyors in soil sampling methods.
    - Surveyors sampled ~450 plots and collected 4 soil samples from each (~1800 samples in total).
    - CEH Labs measured cores from 435 plots to determine 45 parameters for physical, microbial, chemical, carbon and invertebrate analysis. This data supports the outcome analysis in all categories.
    - Implemented new lab protocols to improve efficiency including methods for soil water repellency using video to determine hydraulic function.
    - Analysed all 2013 data and submitted to the GMEP data portal.

- Soil Natural Capital Accounting
    - Proof of concept conducted combining soil and land cover data sets to assess soil resource areas under different Broad Habitats

Main findings

- Topsoil quality for a range of metrics has been characterised for Welsh Broad Habitats (Figure 18)

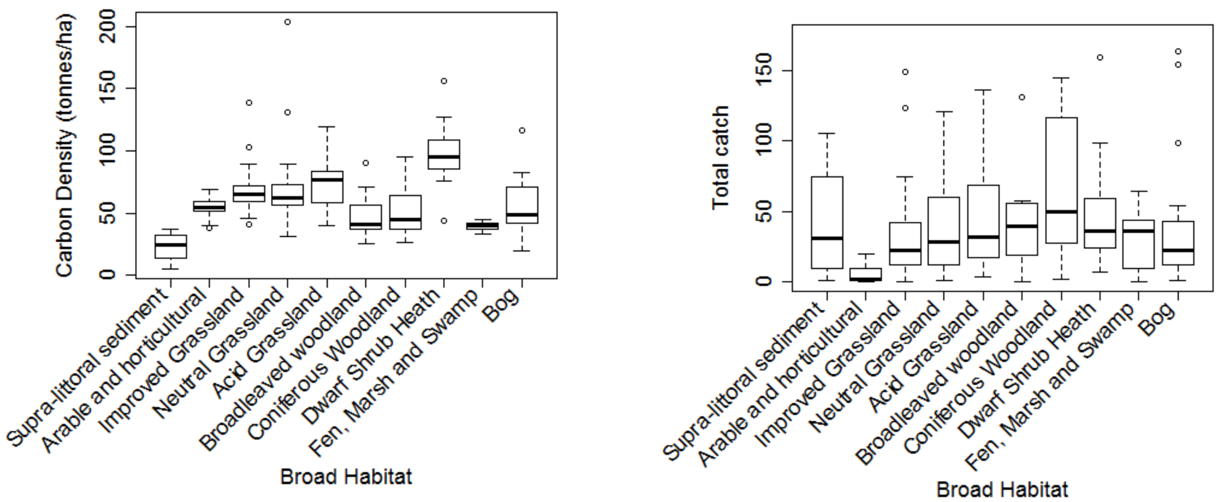
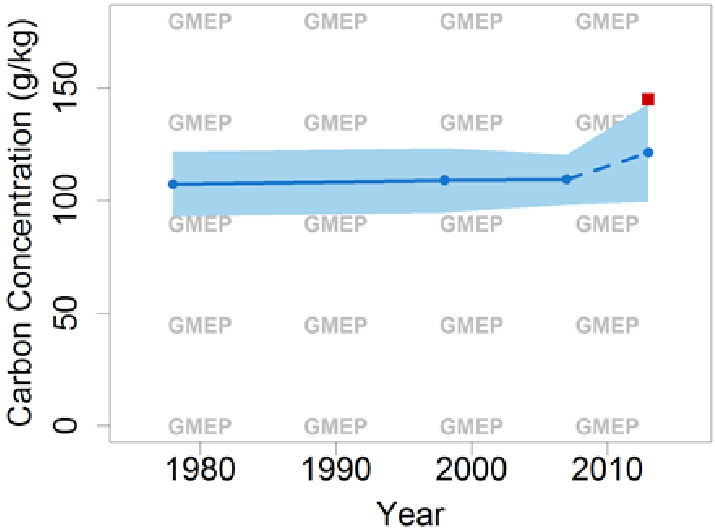


Figure 18 *Topsoil (0-15 cm) a) carbon density and b) soil mesofauna within different Broad Habitats across Wales in 2013. Note total carbon stock to the full depth of the peat profile in bogs is the largest of any habitat. However, the top 15cm of peat whilst carbon rich has a much lower density than mineral soils thus the relatively low values. Top soil (0-15cm) only sampled due to costs involved sampling to depth and it is considered to be the soil horizon most impacted by land management issues.*

- Long term trend analysis has identified no overall change in soil carbon concentration (Figure



19)

Figure 19 *GMEP data for topsoil carbon concentration for 2013 compared with data collected since 1978 by the Countryside Survey. Solid blue line (CS data); dashed blue line (GMEP 2013 Wider Wales Survey); Red square dot (GMEP Targeted survey)*

- Since 1978 topsoil acidity was reduced probably due to decreased inputs of acidic atmospheric deposition. Nutrient levels since 1998 when records started indicate no change in nitrogen levels and a stabilisation of a recent decline in soil available phosphorus levels (Figure 20). Levels are still acceptable for production but will have reduced the risk of phosphorus leaching to freshwaters. No change in topsoil animal populations were found since 1998.

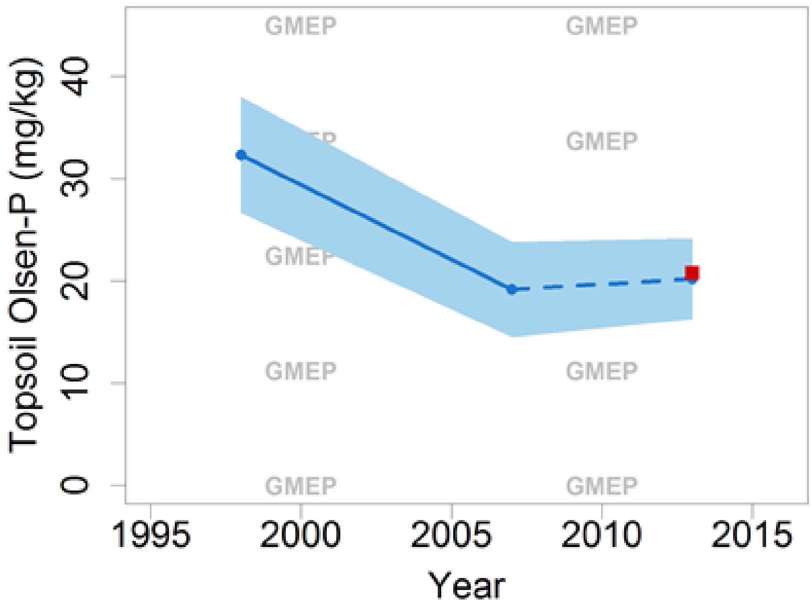


Figure 20 *Long term trends in topsoil phosphorus availability (Olsen-P) using CS data (blue line); dotted line GMEP Wider Wales Survey; and re square (GMEP Targeted survey).*

- Evidence for water and wind erosion is sparse at national scales across the UK including Wales. GMEP does not have the resources to fill this gap however we need to quantify the impacts of Glastir. We are therefore using a modelling approach which provides both erosion estimates and area of land likely to be at risk of erosion loss and mitigating sediment delivery. See the GMEP year 1 report for more information.

- No evidence of the limited samples in the Year 1 survey of any difference in topsoil quality of land coming into the Glastir scheme. This analysis will be repeated when the full Year 1-4 survey is complete.
- Exploration of the impacts of management using differences under existing land management suggests land management will change soil condition
- Topsoils in Wales are incredibly diverse and appears most responsive to land management regime compared to soil type indicating Glastir has real potential to influence soil quality.
- A number of initiatives are underway to recognise the value that natural resources provide to the economy. In most countries, national accounts of economic activity are recorded, and indicators such as gross domestic product (GDP) are widely used in government and policy to assess economic activity and progress. However, indicators such as GDP measure mainly market based transactions and are not good indicators of welfare; GDP ignores social costs, environmental impacts and income inequality. GDP also does not deduct the direct cost of the depletion of natural resources on national income nor does it take into account the impact that our resource extraction and use of nature has on the continued functioning of the earth system for life support. Using data available to GEMP we present a proof of concept approach for determining the area of soils for accounting. Using the rare and occasional soils previously identified in the HNV work, we cross analysed these with land cover data from 2007. This allows us to identify the percentage of each soil type under a particular Broad Habitat type.

Overall the picture is one of stability in topsoil condition over the last 2 to 3 decades for the metrics we have available. Erosion is the main issue which is not covered by GMEP and for which other data is very sparse.

Freshwater

Headwater streams are an important part of the river network, they typically account for most of river length in catchments (typically 70 to 80 %). The biota of headwater streams makes a significant contribution to biodiversity at a national level with many plants and animals geographically restricted to these characteristic habitats, while some use these habitats seasonally or intermittently. EU legislation aims to protect headwater streams through the Water Framework Directive (WFD), where all water bodies are expected to reach good or high ecological status, the Habitats Directive, and the UK Biodiversity Action Plan where headwater streams are considered ‘priority habitat’ and hence a focus for conservation. Headwaters also harbour species protected under the Wildlife and Countryside Act 1981 and its amendments (e.g. white clawed crayfish), nationally important species of fish such as Atlantic salmon, brook lamprey and bullhead, and can support protected species of mammals and birds (e.g. otters, kingfishers).

Agricultural practices such as livestock grazing and tilling can lead to soil erosion and run-off of fine sediments, nutrients and pesticides into headwater streams. This has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types. Cumulative impacts across headwaters are reflected further down the river network, decreasing the water quality of larger waterbodies, with negative consequences for their biota, and for ecosystem services such as the provision of clean water for human consumption, fish farming and recreation. Hence it is not surprising that water quality is a key target of many agri-environment schemes, including Glastir, with measures that aim to reduce run off and increase ecological buffering along streams and rivers.

Headwater streams are currently under-represented in NRW monitoring programmes which GMEP is intended to fill. The NRW target ultimately is all surface waters to reach good ecological status as required by EU legislation. However, the size and vast numbers of headwaters means that it may be a strict WFD approach may not be practical. As headwater streams also need to be reported under the habitats directive as they are 'priority habitats' is may be more appropriate to report impacts results for headwaters under Priority habitats rather than the WFD compliance. GMEP and NRW will collaborate to produce, by the end of the baseline, an ecological status assessment method based on the field survey that is consistent with WFD reporting, but in this report we comment on ecological quality with no translation to consequences under the WFD. Impact of Glastir on larger rivers will be explored using a modelling approach to quantify change in the contribution of agriculture to nutrient inflow in Year 4 however formal WFD assessment will rely on NRW ecological assessments. There is no benefit of GMEP repeating this assessment.

Ponds are more abundant than rivers and lakes, and are found in virtually all environments. Though the diversity of an individual pond will generally be less than that of a river or lake, their biodiversity value lies at wider spatial scales. are a particularly important habitat for some rare and protected species. In Wales, this includes many species which are declining internationally such as yellow centaury and three-lobed crowfoot, as well as European protected species including great crested newt and floating water-plantain. In addition, ponds provide both habitat and food for terrestrial wildlife such as birds, bats, small mammals, reptiles, and pollinating insects, making them important in agricultural and urban landscapes that have few natural refugia. Ponds, are recognised in Article 10 of the EU Habitats Directive for their role as 'stepping stones', between other waterbodies and wetlands, increasing freshwater habitat connectivity at wide spatial scales. Ponds also act as small reservoirs as they collect and slow the flow of water off fields and other areas, trapping and recycling nutrients and sediments before they can enter a flowing water body. Due to their small size, compared to a river or lake, they are particularly sensitive to pollution and have a limited buffering capacity. In agricultural landscapes ponds receive sediments, nutrients and pesticides which has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types.

Within the GMEP, survey squares are sampled for 1 headwater stream and 1 pond when present. Resources do not allow sampling of more even if present. The techniques deployed in headwater streams are all recognised bio-monitoring approaches. Currently the GMEP assessment is not a WFD assessment though the aim is to establish a framework by the end of the baseline survey. Because it is based on one survey in summer, sampling probably underestimates ecological quality a little compared to spring/autumn, but ecology is not the dominant factor which lowers the quality of a stream rather it is habitat modification and water quality (see below). Improvements in water quality from Glastir may therefore not translate to WFD compliance without active habitat restoration.

In ponds, the techniques most widely used, and recommended by the Freshwater Habitats Trust, were used (there is no recognised standard technique at either the UK or EU level) to monitor macroinvertebrates, macrophytes and habitats. These techniques allow us to determine chemical water quality as well as ecological quality. Due to the time required for identifying the many invertebrate and diatom samples the Year 2 (2014) is not yet ready for reporting.

Main findings:

Headwater streams

- 57% of survey squares had at least one headwater stream
- Lowland sites demonstrated nutrient enrichment vs upland sites
- 85% of sites had phosphorous concentrations consistent with supporting good ecological quality, the remaining sites were all in the lowlands bar one
- 53% of sites had nitrogen concentrations that exceeded the range associated with unimpacted European rivers. No site exceeded the drinking water standard for the UK.

- Lowland sites demonstrated higher levels of habitat modification
- Overall, 91% of headwater sites had modified habitats, with 32% displaying high levels of modification (Figure 21)
- The principal drivers of macroinvertebrate communities were biogeographic (altitude, alkalinity, conductivity) but human habitat modification was also a driving factor
- Diatoms (a major group contribution to primary productivity) were more responsive to the altitude gradient, with better ecological quality in uplands (expected as diatom indicators principally respond to nutrient status) but higher diversity in lowlands, as expected
- Macrophyte indicators showed most sites had intermediate levels of enrichment, only 1 lowland site could be diagnosed with clear eutrophication impacts and 12 sites (9 of which in uplands) could be diagnosed as unlikely to be impacted by eutrophication or organic pollution
- Macroinvertebrate indicators indicated 62% of sites had macroinvertebrate communities consistent with good ecological quality. The principal diatom-based score was less conservative, indicating 91% of sites had diatom communities deemed of good ecological quality.

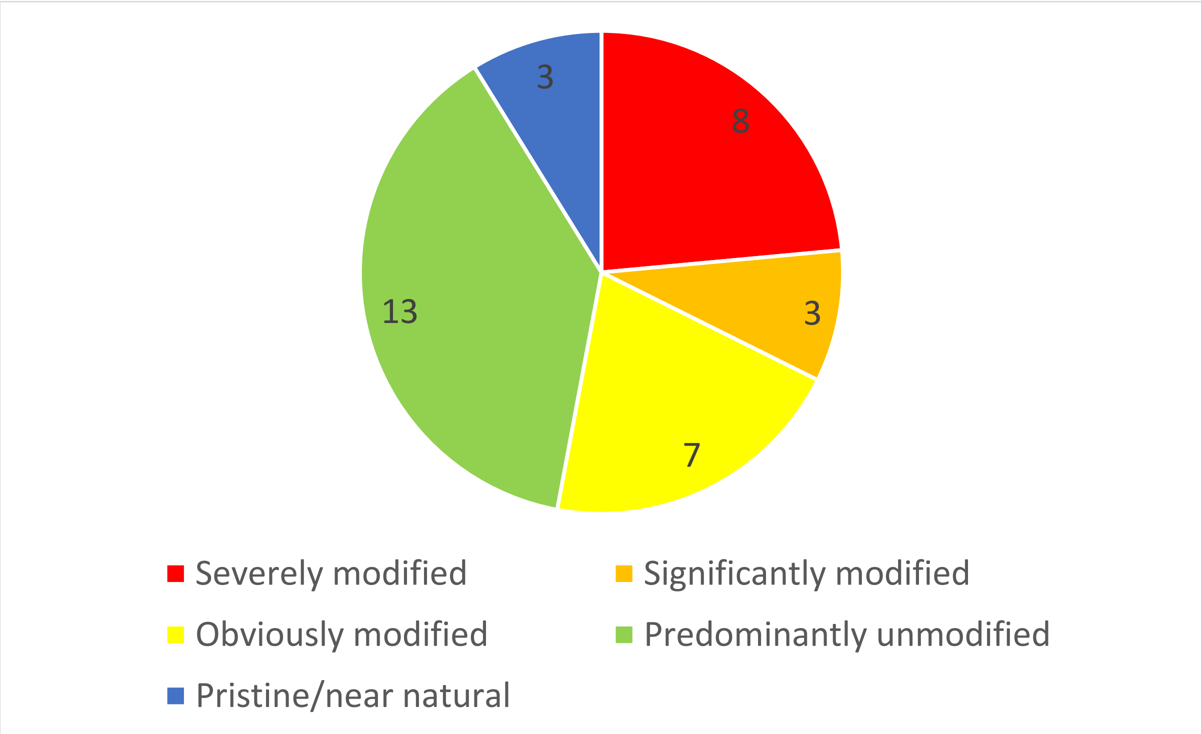


Figure 21: *Number of headwater sites falling in the 5 habitat modification classes in GMEP survey from year 1*

- Long term trends using NRW data where we have screened out larger rivers includes a lot more than headwaters which are limited to 2.5km from source, for which data is sparse but perhaps provides some information on past trends of small rivers in Wales. The data indicates an improvement in ecological quality of smaller streams over the last two decades, linked to improvements in water quality. This is consistent with the UK wide pattern (Figure 22).

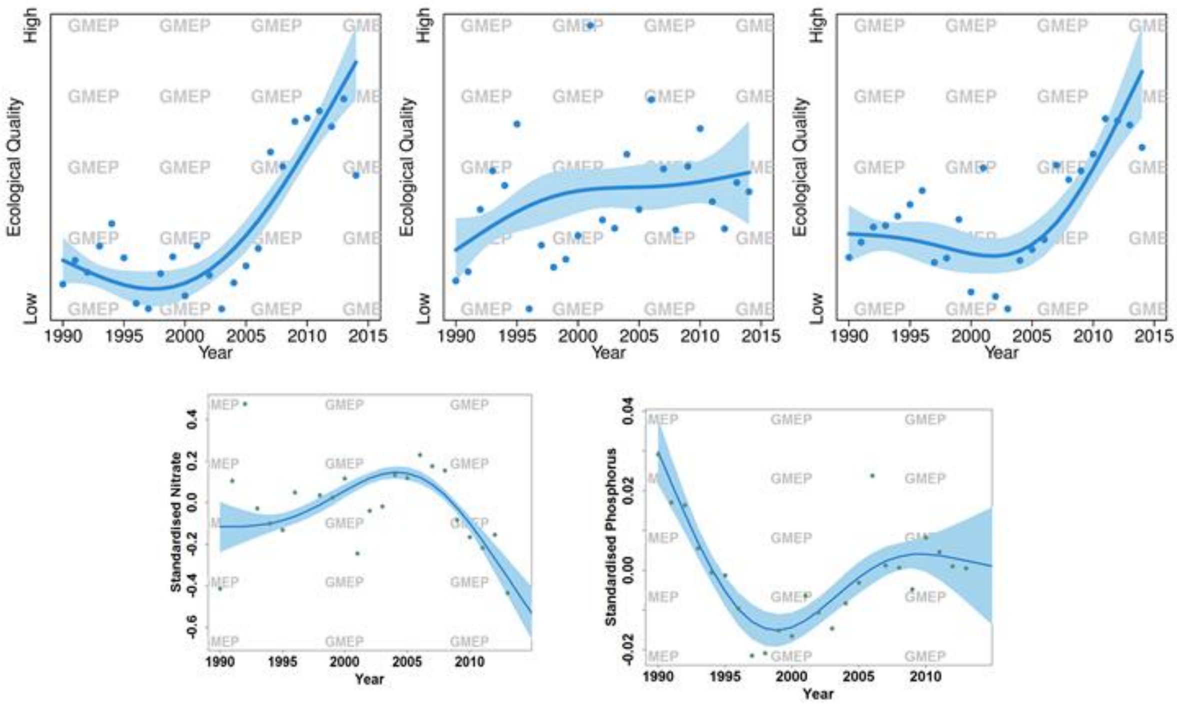


Figure 22 *Top: BMWP score (left; an index of eutrophication and general degradation), Ntaxa (middle; the number of water quality sensitive taxa that contribute to the WHPT score) and ASPT (right; the sensitivity of the taxa to water quality which contribute to the WHPT score). Bottom: Time series of soluble reactive phosphorus (SRP) (mg/L) and right: total dissolved nitrogen (TDN) (ppm) time series derived from NRW monitoring where large rivers have been removed. Note this includes many smaller streams which are not headwater streams but provides some historical context.*

- There was a trend (not significant at present but likely to become so as more baseline samples are taken) of higher quality headwater streams on land within the Glastir scheme which needs to be taken into consideration in future analysis of the benefits of Glastir.
- No significant legacy effect of previous agri-environment schemes was detected though there was a trend for a positive effect on ecological quality and sample size was low as this represents only Year 1 of the full 4 year GMEP sampling period (Table 03). Our power to detect change will increase with the 4 year population.

	Status	Mean	SE
Ntaxa	Outside Past AES	16.44	2.06
	In Past AES	19.19	0.98
ASPT	Outside Past AES	5.66	0.28
	In Past AES	5.83	0.14
BMWP	Outside Past AES	93.44	11.69
	In Past AES	110.12	7.17

Table 03 *Mean values of three main macroinvertebrate indicators of ecological quality in survey sites falling in or out of previous agri-environment schemes.*

- An appropriate target for Glastir would be to increase the number of ‘good’ quality sites under the WFD (hence a target for GMEP is to produce a WFD- compliant assessment that can be used to report the number of sites according to WFD statsus classes (high, good, moderate, poor, bad)Whilst experience indicates if nutrient inputs at source are controlled a rapid change in instream nutrient concentrations can be achieved, the biological community needs to respond to that change before there is a change in status. Thus recovery of these systems may not be achieved by removing the stressor alone if the source pool of recolonizing of desirable species is so depleted that the biology cannot respond (a similar issue to the identified in GMEP year 1 report for plant species recovery). This issue is well known across the EU. Therefore CEH's recommendation is an adaptive management framework which can revise its strategy as more info becomes available and also allows flexibility on the main focus i.e. should Wales prioritise more good sites, less bad sites, or both?

Ponds

- 48% of survey squares had at least one pond
- There was a trend for nutrient enrichment in lowlands which was not significant
- Macrophyte indicators reflected the nutrient conditions as expected, though more uncommon species were found in uplands
- The main drivers of the macroinvertebrate community were natural (alkalinity, altitude) but phosphorous concentrations were also an important driver and are likely to be influenced by human activity
- Only 8% of ponds were judged to be in good ecological quality, most others fell under moderate quality(Figure 23) (Note that ponds are not monitored under the WFD so the terms good and moderate do not relate to WFD terminology)
- As for streams, no significant difference between pond quality in and out of scheme was detected but there was a trend for a positive effect of Glastir on ecological quality which will need to be taken into consideration when the impact of Glastir is assessed. Further survey data will clarify this.

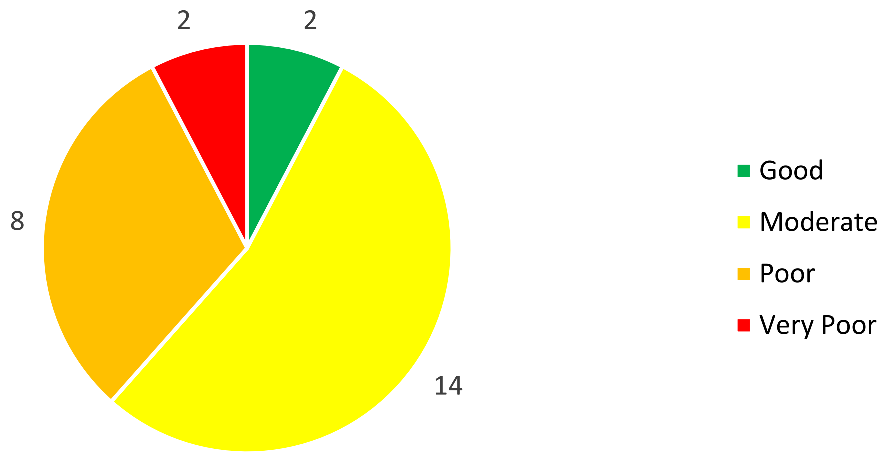


Figure 23 *Ecological quality of ponds in GMEP survey from Year 1 data*

Overall the picture for headwaters is one of recent significant improvement over the last 20 years. Phosphorus concentrations indicate 89% are consistent with good ecological status with similar values for diatoms at 91% indicating good ecological quality. However, macroinvertebrate communities indicate only 62% are consistent with good ecological quality and intermediate levels of enrichment are also indicated by macrophyte communities. 91% of sites remain modified in some way with 32% of sites displaying high levels of modification. For ponds, only 8% were judged to be of good ecological quality, most others were of moderate ecological quality. No evidence of differences to date have been observed for headwaters or ponds coming into Glastir compared to that outside of the scheme. It should be noted, impacts of Glastir on nutrient enrichment levels in freshwaters more generally will be quantified using a modelling work as described in the GMEP Year 1 report.

High Nature Value Farmland (HNV)

HNV farmland has been defined as 'areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European concern or both'. It is an agreed indicator of one of the six Strategic Objectives of Glastir but requires development work to gain consensus as a valid metric which can be reported to the EU.

Previous work carried out at the European scale and within Wales looked at the concept of High Nature Value farmland and how it might be defined and applied. Low intensity agricultural practices may be important in maintaining these areas of high diversity or they may exist despite the farming activities. Spatial heterogeneity is important with habitat mosaics and different structural elements e.g. scrub and linear features. Land which is of 'High Nature Value' is not easily defined, it may be a subjective and contentious exercise choosing which elements best represent 'high value'. It has been generally agreed that HNV farmland can be broken down into 3 types:

Type 1: Farmland with a high proportion of semi-natural vegetation

Type 2: Farmland with a mosaic of habitats and/or land uses

Type 3: Farmland supporting rare species or a high proportion of European or world populations

Within the EU, Member States are committed to identifying and maintaining HNV farming; however, there are no specific rules or generic metrics and criteria established at EU level to determine HNV farmland. Each member state therefore interprets the concept and decides how best to apply it to their state. It is inevitable that there will be variation in HNV farmland definitions, individual countries will have different indicators (particularly for Type 3 indicator species) or landscape features, however, there is also a need for a more integrated approach across European countries with common standards and definitions.

The GMEP team have been tasked by WG to explore these concepts and propose new ideas, criteria and metrics that might be applied to define land of 'High Nature Value' and form an indicator to create a baseline extent and measure changes in extent and quality. We are conducting this work in consultation with a range of partners and stakeholders who are also interested in the potential value of this metric. Specifically this has included a small working group involving CEH, BTO, RSPB and WG who first met in April 2013; a RSPB workshop with a wide range of participants from across the farming and conservation section in May 2013; a GMEP Advisory Group in June 2013 with representative from the farming community, WG, NRW and NGOs and a number of subsequent working group meetings in 2013/2014. A wide range of views were expressed which range from this "is a metric of little value which could confuse rather than illuminate" to "a potentially useful metric to communicate overall trends in biodiversity".

Major Achievements in Years 1 and 2

- Convened and met with a range of stakeholders to discuss possible approaches and agree a way forward
- Collated a table of possible metrics for HNV
- Collation of potential datasets from which to calculate metrics
- Development and calculation of metrics e.g. connectivity, habitat diversity, rare species, rare soils etc. (Figures 24 & 25)
- Analysis and discussion of the potential to downscale from coarse resolution recording datasets- dataset for plant species produced
- Metrics calculated for four case study areas with proposals presented for next steps (Figure 26)
- We present several methods of potentially assessing the contribution of soil to High Nature Value land.

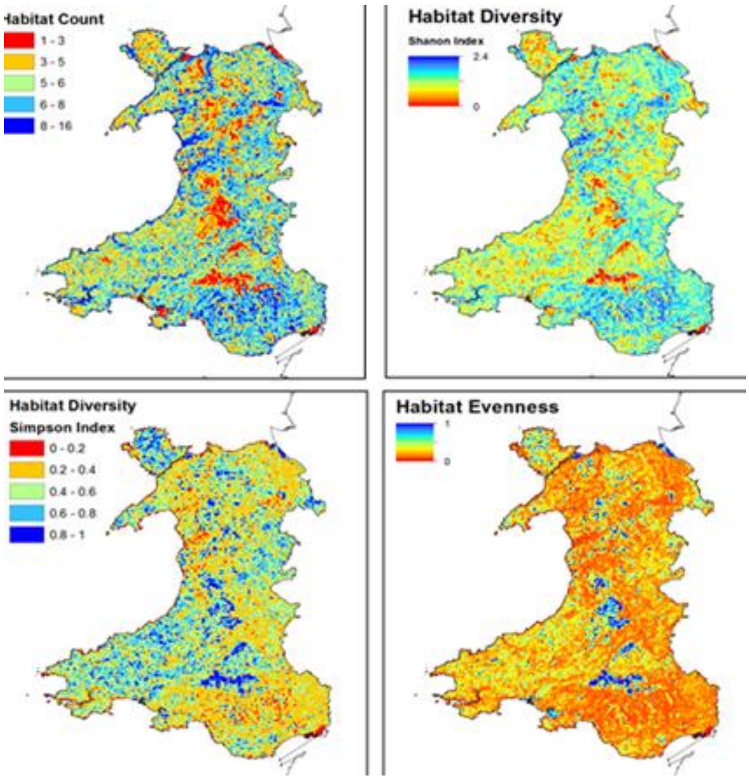


Figure 24 *a) Different approaches to assess habitat diversity for each 1km^2 across Wales based on LCM2007;*

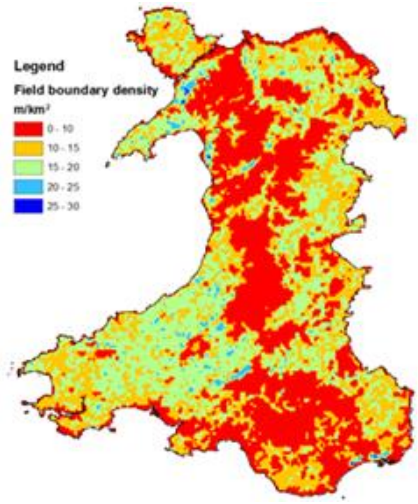


Figure 24 *b) A map of field boundary density across Wales, based on data for the Land Parcel Information System (LPIS)*

Figure 25 *Example maps of species richness within each 10km x 10km grid cell across Wales for different groups of species, based on BRC data.*

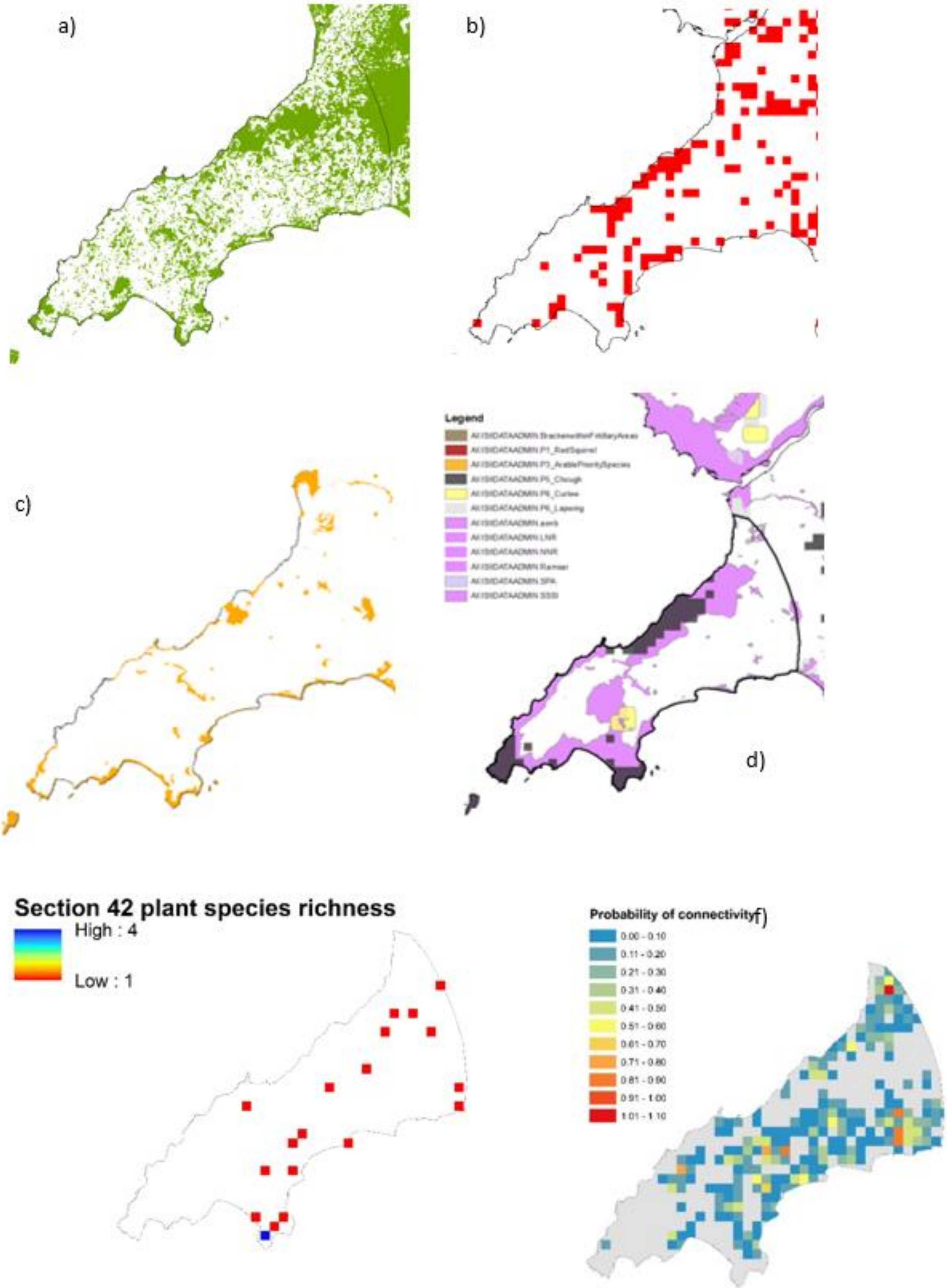


Figure 25. *Maps of potential HNV indicators for Llyn Peninsula, including; a) Type 1 semi-natural habitat patches; b) Type 2 – Upper quartile of habitat diversity (Shannon Index; species data not yet incorporated); c) Type 3 - SPAs, SACs and SSSIs (species data not yet included); d) a map showing*

protected areas and protected zones; e) a map showing the distribution of rare plant species ((section 42); f) and Broadleaf woodland habitat connectivity metrics for each 1 km grid cell
Based on the work undertaken so far the following metrics are being explored for HNV farmland in Year 3:

Type 1 Farmland with a high proportion of semi-natural vegetation:

- Areas of all semi-natural land parcels
- % semi-natural habitat and define a threshold – e.g. > 20 % - for HNV farmland

Type 2 Farmland with a mosaic of habitats and/or land uses:

- Use upper quartile of habitat diversity (Shannon's Index)
- Incorporate woodland connectivity and / or field boundaries into the metric
- Incorporate species richness or presence/abundance of selected species, particularly species which are characteristic of a mosaic of habitats including low intensity farmland

Type 3 Farmland supporting rare species or a high proportion of European or world populations:

- Incorporate data on protected areas SPAs, SACs, SSSIs or use as a separate dataset to compare HNV metric to.
- Adopt Glastir target layers and protected zones to identify HNV areas or use as a dataset for comparison with an HNV metric
- Develop an indicator based on species data, particularly species which are rare or species for which a high proportion of European or world populations are found in the UK.

We present several methods of potentially assessing the contribution of soil to High Nature Value land should the working group decide it is a natural resource which should be included in the HNV metric. We report that even common Welsh soils are relatively unusual in the global context, especially the surface-water-gley soils and to a lesser extent the podzols. We found that all of the rare or occasional soils are covered by SSSI's bar 1 emphasising the close link between soil and ecological properties.
Next steps will include a real-time participatory approach by the GMEP Advisory Group comparing outcomes from different combination of metrics using a web based data mapping tool CEH is developing which will be available in January 2016. Outcomes of different data combinations will be compared to protected areas, Glastir target layers and other metrics of natural capital and ecosystem services to assess their relationship.

Ecosystem Service Trade-off and Opportunity Mapping

Underlying ecological and environmental constraints for ecosystem services have resulted in their current complex spatial distribution in the Welsh landscape. Some services often co-exist as they require similar environmental conditions e.g. carbon storage and water regulation whilst other services are often negatively associated (agriculture production and water quality). The GMEP Year 1 report reported on an initial analysis of the data which highlighted how the GMEP data could be used to quantify these trade-offs and co-benefits. Agricultural productivity and carbon storage were identified to be positioned at different extremes of a gradient from high to low land intensification with biodiversity often at its most species rich at intermediate levels (Emmett et al. 2014). In the future GMEP data will be used to explore these relationships at different scales and for different regions but there is a need now to provide a tool which can help policy makers and land managers target specific areas in the Welsh landscape where opportunities are greatest to increase ecosystem service provision with minimal trade-offs. We have exploited the LUCI modelling tool described in the GMEP Year 1 report to start this process (Emmett et al. 2014). This was the first ever deployment of an ecosystem service model with such fine spatial resolution appropriate for the relatively fine scale options within Glastir at a national scale for 7 services. In Year 2, we have again used the LUCI model to identify where there is an opportunity to improve each service and where these opportunities may conflict. It should be noted that the LUCI model takes into account not just the area modified but the area affected downslope by land management as it has a topographical routing approach to water flow and nutrient/sediment transport i.e. it is not a suite of GIS maps overlays. Finally it must be emphasised, LUCI provides a useful initial screening tool to identify areas to target for a ground-based assessment and provide national based metrics. It is strongly recommended that areas identified as having high potential for service improvement be re-visited with the model (or another ecosystem service modelling tool) to iterate options with local stakeholders incorporating best available local data. LUCI has been used and indeed was initially developed for this type of local engagement and negotiation approach to development of spatially explicit community planning.

Achievements and key findings

Ecosystem services condition, opportunities to improve, and trade-offs or co-benefits between 7 services were identified using the LUCI model. Calculations have been made on the spatial data to identify for each ecosystem service the total area with good provision, total area with opportunity to improve, and area with opportunity to improve without risk to existing services in good condition. Further calculations were then performed for each ecosystem service to identify where opportunities to improve ecosystem services coincide spatially with good existing condition for each other ecosystem service. Finally, calculations were performed for each ecosystem service pair to identify where both have opportunities to improve. The findings include:

Opportunities to improve services:

- Significant areas have opportunity to improve carbon (C) status (10508km^2), however for the vast majority of these sites, there are other services in good condition, so care must be taken to avoid detrimental effects if options are targeted at improving C status. Many of these trade-offs are with priority habitats (7488 km^2) (largely heather dominated grasslands), agricultural utilisation (5424 km^2) areas reducing erosion risk (9693 km^2), and potential nitrogen (N) (7731 km^2) and phosphorus (P) (9834 km^2) loss to freshwaters . It is likely that changes to improve C status would not increase erosion risk, or potential N and P loss to freshwaters, however the need to protect priority habitats, and socioeconomic value of agricultural production may reduce potential to achieve carbon status improvements.
- Potential N loss to freshwaters has reasonable opportunities (104 km^2) to improve (reduce) without risk of damaging other ecosystem services (ES) or agricultural productivity. Significant proportions of the 5231 km^2 of sites with opportunity to improve (reduce) potential N loss to freshwaters also have opportunities to improve (reduce) potential P loss to freshwaters (1228 km^2), C status (2777 km^2), Broadleaved woodland habitat connectivity (1038 km^2) and mitigation of overland flow which may contribute to flood mitigation (3955 km^2).
- Over 321km^2 were classified as non-mitigated land in terms of runoff, and had no other ecosystem services in good condition, which may indicate significant potential for interventions to reduce flood risk, without damaging other ES or agricultural productivity. However, additional data to improve representation of soil drainage is being explored, and depending on flow regimes not all non-mitigated features currently create flood risk, hence further assessment of these opportunities is necessary.
- Locations with low agricultural productivity that are not in good condition for other ES were mapped as over 97 km^2. Whilst there may be potential to increase agricultural productivity in these locations, land may be less suitable for agriculture, and interventions to improve other ES may be more appropriate.

Calculations have been performed on all outputs to identify where there are trade-offs and win-wins across all 7 ecosystem services considered. Looking at co-location of opportunities to improve ecosystem services for all 7 services indicates that ca. 15% has existing multiple service provision whilst almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.

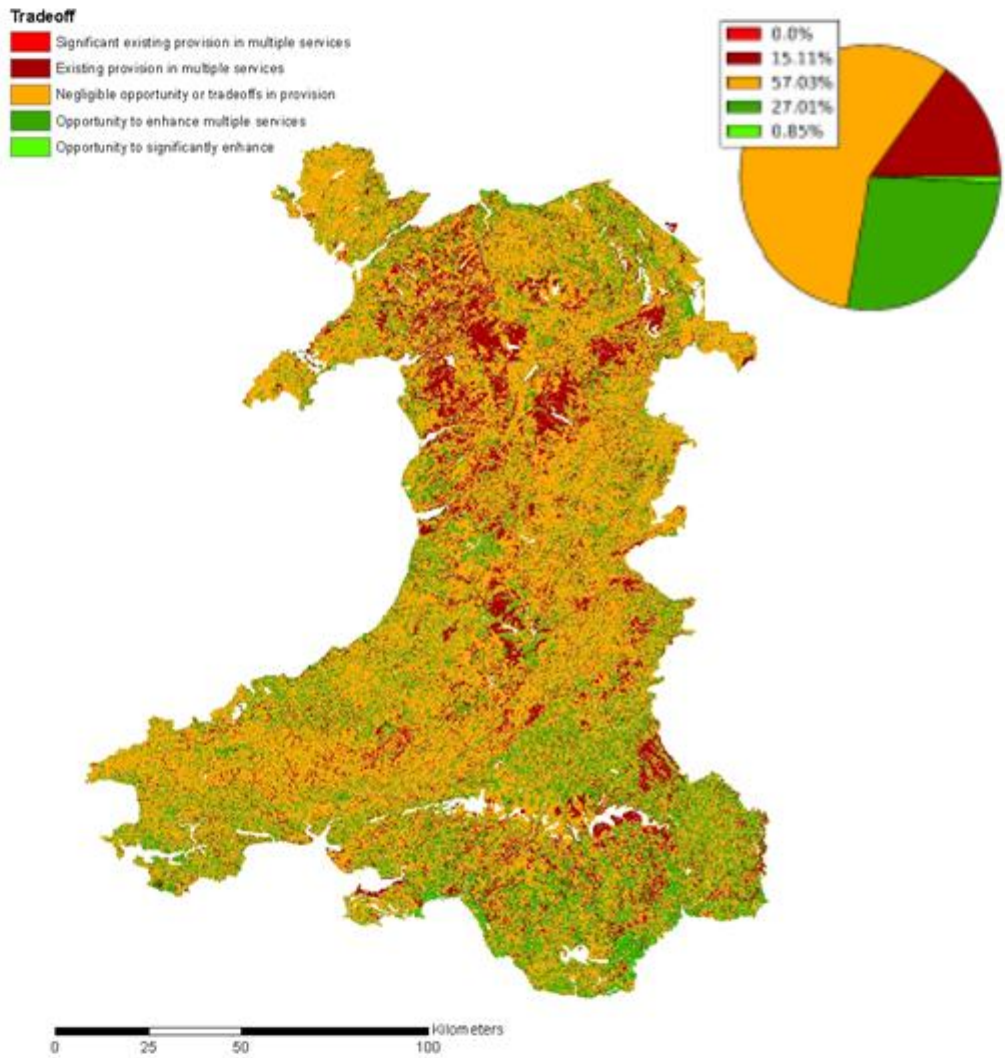


Figure 26 *Outcomes for trade-offs between agricultural utilisation status, carbon status, nitrogen and phosphorus status, erosion status, Broadleaved woodland connectivity and flood mitigation ecosystem services; almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.*

An assessment of the amount of land inside and outside of the scheme which was either mitigating or mitigated for rainfall runoff / flood mitigation was calculated. The results suggests there is little difference between the land inside and outside of the Glastir scheme with respect to either mitigating or mitigated features. The values are 19% and 21% for land in and out of scheme for mitigating features and 19% and 17% for mitigated features respectively. Further assessments to assess differences between land coming into the scheme will be undertaken in Year 3. These values provide a conservative estimate, and values are expected to increase slightly with Inclusion of the HOST dataset to account for mitigation from well drained soils.
Ordination of spatial variation environmental constraints indicated that only 3% of spatial variation in combined ecosystem service status can be explained by precipitation, temperature regime, elevation, slope and soil drainage and acidity. This indicates the importance of simulation of topology and topography when assessing condition of the relevant ecosystem services as the service delivery is not directly related to the conditions at the location; for this reason spatially explicit modelling as applied in LUCI has significant benefits over simplified point combination of spatial data.

Testing of LUCI outputs has continued and suggests findings are robust for water flow, agriculture potential and current agriculture utilisation and nitrate export to rivers. As LUCI does not include point sources of phosphorus such as sewage works, further work is required to include these or mask them out from LUCI assessments for future phosphorus assessments. There is a lack of sediment data for testing but the LUCI model also probably needs refining for this service to include land management such as tillage. Current assessment only include the inherent structure of the landscape such as slope and water flow.
Other developments includes significant progress on deploying a web-mapping service for LUCI appropriate for Welsh catchments, and setting up for more temporal /event reporting from LUCI over Wales. New funding has just been won from NERC to make transparent the level of evidence behind the different outputs from LUCI which will be linked to the web-mapping service.

Further information

The complete Year 2 GMEP report outlines in more detail all the work described in summary above with a fuller summary provided in the 'GMEP Report Summary' and a more easily accessible and shorter summary in the 'GMEP Citizen Summary'. The GMEP Year 1 report and many other GMEP findings can be found on the recently launched GMEP data portal https://gmep.wales.

1 Introduction

Emmett, B[1,] Astbury, S. [1], Garbutt, A.[1], Biggs, J.[2], Edwards, F.[3], Edwards, M.[4], Ewald, N.[2], Halfpenney, I.[5], Maskell, L.[6], Peyton, J.[3], Roy, D.[3] , Scarlett, P.[3], Siriwardena, G.[7], Smart, S. [6], Swetnam, R.[8], Taylor, R.[7], Tordoff, G.[9], Wood, C.[6]

[1]CEH Bangor, [2]Freshwater Habitats Trust, [3] CEH Wallingford, [4]Edwards Ecological Services Ltd, [5]Cadw, [6]CEH Lancaster, [7]BTO, [8]Staffordshire University, [9]Butterfly Conservation

1.1 Introduction

The Glastir Monitoring and Evaluation Programme (GMEP) provides a comprehensive programme to monitor the effects of Glastir and contribute towards providing national trend data towards a range of national and international biodiversity and environmental targets. GMEP is now in its third year of the initial four year baseline assessment period. This annual report presents results from the second year of the programme. GMEP fulfils a commitment by the Welsh Government to establish a monitoring programme concurrently with the launch of the Glastir scheme and as such is a major development from past monitoring programmes which have only reported after schemes have been closed. The project ensures compliance with the rigorous requirements of the European Commission's Common Monitoring and Evaluation Framework (CMEF) through the Rural Development Plan (RDP) for Wales. The early findings from GMEP has already provided fast feedback to the Welsh Government as to how to spatially target payments to maximise benefits as the scheme progresses.

Beyond Glastir outcome reporting, GMEP data and models has potential to contribute to a range of other reporting requirements including the Water Framework Directive, Habitats Directive and the Greenhouse Gas Emission Inventory and actions which arise from the Environment Bill such as the State of Nature Resources report, National Natural Resources Policy and Area Statements. Central to the Environment Bill is the need to adopt a new, more integrated, approach to managing our natural resources in a more sustainable way while safeguarding and building the resilience of natural systems to continue to provide these benefits in the long term. Resilience is considered to be greater where extent, condition, connectivity and diversity are high. Many GMEP metrics can be mapped onto these requirements and thus could be exploited to map these 4 properties for different areas in the future. It is hoped greater resilience of our natural resources will in turn provide social and economic benefits thus helping to underpin the 'A Resilient Wales' Goal of the Well-being and Future Generations Bill. Another potential use of the GMEP data is in the development of National Accounts to include aspects of the natural resources (i.e. carbon, water and soil) and their combined value as whole ecosystems (i.e. forests, wetlands etc.) . Work is currently ongoing in by Defra which includes some test case studies in Wales. GMEP data can contribute to the provision of the underpinning robust and auditable data required for this activity.

GMEP will therefore improve the empirical evidence base for the current state and integrity/condition of Wales's natural assets (termed natural capital) and how these are changing in response to drivers such as climate change, land management practices and air pollution onto which Glastir options are superimposed. The challenge to the GMEP team is to isolate the changes connected to Glastir options itself which is the primary purpose of the monitoring and evaluation programme. Changes in the extent and integrity of the natural capital in turn impacts on how well they can deliver the ecosystem functions and services we need and value. This link is currently not well quantified. The distinction between natural capital and services is important as capital is a longer term asset which we want to protect for the future and is hard to value in itself, whereas the services which flow from this capital are what economists and social scientists are able to value and which have particular relevance for the Well-being of Future Generations Bill. This valuation step is an essential one if we are to provide a grounded framework for understanding the choices government and society face. The GMEP team is working on these issues through its work on landscape perception and use, social surveys and farmer practice surveys. However, this is a large topic which will need additional work beyond what resources are currently available within the GMEP project.

The GMEP team which is delivering this comprehensive programme comprises a mix of organisations with different specialisations covering the different schemes activities, objectives and outcomes. The programme is led by the Natural Environment Research Councils' Centre for Ecology & Hydrology (CEH), an independent public research body. CEH has a research station in Bangor which provides the leadership and coordination of GMEP. The project consortium includes ADAS, APEM, Bangor University, Biomathematics and Statistics Scotland, Bowburn Consultants, British Geological Survey, British Trust for Ornithology, Butterfly Conservation, ECORYS, Edwards Consultants, Freshwater Habitats Trust, St Andrews University, Staffordshire University, University College London, University of Aberdeen, University of Southampton, and Victoria University of Wellington, New Zealand.

1.2 The GMEP approach

In summary, the basic approach of GMEP is a combined data and modelling programme which utilises existing data enhanced by a major new rolling field survey which provides co-located data for a range of environmental metrics. Modelling work provides methods for integrating and upscaling survey data for national scale reporting and exploring possible future scenarios of possible outcomes of the scheme. The co-located survey data allows reporting against the six intended outcomes of Glastir and the trade-offs and co-benefits of Glastir payments between these outcomes. The six outcomes are: Combating climate change; Improving water quality and managing water resources to help reduce flood risks; Protect soil resources and improve soil condition; Maintaining and enhancing biodiversity; Managing and protecting landscapes and the historic environment; and Creating new opportunities to improve access and understanding of the countryside; and Woodland creation and management. In addition to these original Glastir Outcomes, in September 2014 the Auditor General for Wales published his report[1] on Glastir. The report contained a series of observations and related recommendations including a number associated with the setting of scheme targets and monitoring actual scheme impact against scheme targets which has had an impact on the reporting requirements of the GMEP project. He identified six Strategic Objectives. To respond to these recommendations, GMEP has worked with the Welsh Government and the GMEP Advisory Group to develop a small number of impact indicators for each Glastir Strategic Objective. Metrics under consideration are:

[1] http://audit.wales/publication/glastir

Strategic Objective	Reportable Indicator
1.To increase the level of investment into measures to mitigate greenhouse gas emissions with the aim of contributing towards a reduction of net emissions from the land based sector in line with our international obligations	Contribution by land use and land use change ($ktCO_2e\ yr^{-1}$) (excludes Peat Soils)
	Agriculture Emissions[6] (CO_2eq (kt N_2O + CH_4))
	Agriculture emissions including embodied emissions (typical average farm data only tCO2e/ha) Beef Dairy Mixed Sheep
2.To increase the level of investment into measures for climate change adaptation with the aim of building greater resilience into both farm and forest businesses and the wider Welsh economy and environment to ongoing climate change	Farmer Practice Survey to give an indication of farm business split by dairy, cattle, mixed and sheep and forestry
	Species richness / diversity of the wider countryside split by plants, birds and pollinators on arable land, improved land, habitat land and woodland
	Farmland bird indicator
	Habitat diversity
	Mean patch size (for habitat and broadleaved woodland only)
3.To increase the level of investment into measures to manage our water resources effectively with the aim of contributing towards an improvement in water quality in Wales and to meeting our obligations under the Water Framework Directive	WFD compliant headwater stream site classification (uses a broad set of indicator of ecological condition based on macroinvertebrates, diatoms, habitat modification, nutrients) (% in high or good condition)
	Modelled area of land mitigating runoff /flood (%)[1]
4.To focus increased resources on an identified list of priority species and habitats with the aim of contributing towards a reversal in the decline of Wales's native biodiversity and to meeting our obligations under the EU Biodiversity 2020 agenda	12-15 Priority Habitat extent and condition (Only where both are reportable together)
	Priority species numbers (birds (17 of the 51 Section 42 species), butterflies (6 of the 15 Section 42 butterfly species))
	Proxy habitat condition bespoked for particular needs of priority species (aggregated metric across all specie) in and out of scheme
5.To put in place measures and investment which maintain and enhance the characteristic components of the landscape and historic environment of rural Wales and to encourage increased public appreciation and access to the countryside	Landscape quality - Median Visual Quality Index (index from 0 – 1.0) in and out of scheme initially (then change over time)
	Historic Environment Feature Condition (% in 'Sound' or 'Excellent' condition)[2]
	Public Rights of Way (% open and accessible).
	Outdoor recreation use survey metric
6.To use agri-environment investment in way that encourages positive environmental outcomes but also contributes towards farm and forest business profitability and the wider sustainability of the rural economy	Farmer Practice Survey – with a question asking whether the business has benefitted from the Glastir scheme. Split by forest, dairy, cattle, sheep and mixed enterprise.
	HNV Farmland area (aggregate metric under development)

Table 1.2.1 *Impact Indicators for reporting against the six Strategic Objectives of Glastir*

This table illustrates the wide range of environmental outcomes and measurements embedded within the GMEP programme of work i.e. a range of soil and water quality metrics, landscape and historic features, plant and freshwater diversity, greenhouse gas emissions, condition assessment of historic features, pollinator and four bird surveys, socio-economic surveys of benefits to the farming and forestry industries and the wider Wales community.

As GMEP survey sites are revisited on a 4-year rolling cycle and we are currently in Year 3 of this initial 4 year cycle, the current Year 2 results contribute towards a baseline against which the future impacts of Glastir payments will be assessed. To gain an early insight into what changes we may expect in the future, modelling results from the GMEP Year 1 provide a useful insight into the scale, location and timing of potential outcomes. Here we present the highlights from the Year 2 programme.

Much of the Year 2 work focussed on analysis of the data from the rolling field survey which accounts for ca. 55% of the total GMEP budget with the remainder for socio-economic surveys, data analysis, informatics including development of the GMEP Data Portal and project management. By Glastir Outcome, work focussed on biodiversity (including woodland habitats) accounts for 42% of the total GMEP budget with 41% allocated across soils, waters, climate change mitigation, landscape and historics, trade-offs and co-benefits, and the remaining 17% allocated to underpinning activities such as informatics and project management. The field survey involves two parts namely the Wider Wales and Targeted components. Wider Wales squares are chosen to represent the background conditions across Wales and are chosen by randomly sampling within assigned land classes. This helps GMEP to deliver the required data on national trends. Targeted squares are then chosen to specifically capture Glastir related activity.

As priorities for Year 2, GMEP has focussed on analysis of other available data notably Plantlife, UK Butterfly Monitoring Scheme and the Breeding Bird Scheme, and their integration with GMEP data. Analysis of GMEP data was undertaken to identify if land coming into the scheme was different in quality to that outside, and if we could detect the legacy effects of past agri-environment schemes. Approaches to quantify benefits for Priority species and habitats was the focus of the work by the biodiversity team. In Year 1 modelling was focussed on exploring scenarios of possible outcomes from Glastir uptake. For year 2 the work was focussed on identifying opportunities to improve 7 ecosystem services at a national scale and an analysis of their potential trade-offs using the LUCI model, plus reporting of the Bangor footprinting tool to identify direct and indirect greenhouse gas emissions from test farms and the potential benefits of the Glastir Efficiency grants.

1.3 Current Status of Glastir Uptake

This section explores the Glastir uptake data received from the Welsh Government, summarising how uptake varies by Glastir Elements, Glastir Outcomes, and in its geographic distribution across Wales.

1.3.1 Spatial data acquired for analysis

1.3.1.1 Glastir uptake data

Data delineating uptake of the six Glastir Elements was supplied by the Welsh Government in the form of seven spatial layers, which can be visualised and analysed with Geographic Information System (GIS) software to provide a geographic context to uptake (Table 1.3.1.1.1). Each of the spatial layers contain geometry representing either individual Glastir options polygons, or whole land parcel extents (e.g. farm boundaries, commons, woodlands), along with attributes including landowner unique identifiers e.g. Scheme Reference Numbers (SRN), or Client Reference Numbers (CRN), and where applicable, Glastir option codes. To define the magnitude and distribution of uptake, the analysis approach has been to identify where land management options under Glastir will have an active effect. As such, Glastir Entry, Advanced and Woodland Management uptake was analysed at a management option and capital works scale (together referred to as options from now on), rather than as whole farm boundaries. As uptake under Glastir Commons, Woodland Creation, Efficiency Grants, and Organic operates at a whole parcel scale, they have been processed as complete land parcel extents.

Glastir Element Layer	Received	Data Description
Entry	August 2014	Options polygons for Glastir Entry Level uptake.
Advanced	August 2014	Options polygons for Glastir Advanced uptake.
Woodland Management	August 2014	Options polygons for the Woodland Management component of the Woodland Element.
Woodland Creation	February 2015	Whole extents of Woodland Creation operational areas, as received from NRW. A component of the Woodland Element.
Commons	August 2014	Whole extents of registered common land which has entered the Commons Element.
Glastir Efficiency Grants (GEG)	August 2014	Whole extents of farms that have entered the GEG Element, derived from Land Parcel Identification System (LPIS) data and a list of GEG entrants.
Organic	April 2015	Whole extents of fields that have entered the Organic Element, derived from Land Parcel Identification System (LPIS) data and a list of subscribed fields.

Table 1.3.1.1.1 *The Welsh Government Glastir Element uptake layers used to define and analyse uptake.*

1.3.1.2 Land parcels data

Land Parcels Identification System (LPIS) and landowner contact details data are sourced from the Welsh Government annually. Together, these datasets can be used to identify the spatial boundaries and ownership status of most private rural land and registered common land throughout Wales, covering 81% of the country. This dataset is used here as a baseline estimate of rural land that could have been eligible to enter Glastir. A summary of landowners from the latest version received (October 2013) is shown below in Table 1.3.1.3.1, including the number of unique landowners or commons (which may be utilised by multiple landowners, but are only registered under a single identifier), the number of individual land parcels, and the total area covered by the land parcels in kilometres squared (km^2). Parcels that could not be matched to a landowner by a Client Reference Number (CRN), or Common Land Number (CLN), have been excluded. Figure 1.3.1.3.1 shows the spatial distribution of LPIS land parcels across Wales, as landowners, commons, or other land not registered with LPIS (e.g. government owned, urban).

1.3.1.3. Other data

Other data used in analysis were look-up tables to match Glastir Scheme Reference Numbers to the LPIS Client Reference Numbers, and agricultural small areas boundaries, which are used by the Welsh Government for agricultural census reporting. The small areas have been used here to aggregate Glastir uptake metrics to report on the spatial trends in uptake, without disclosing the location of individual entrants. Where data is displayed as maps, NUTS3 (Nomenclature of Territorial Units for Statistics) regions for Wales have been used to outline the country, edited to remove minor islands that are not in Glastir.

Summary Metric	Individual Landowners	Registered Common Land	Total
Total Landowner Count	22,096	327	22,423
Total Land Parcels Count	587,076	3,129	590,205
Total Parcel Area (km^2)	14,869	1,906	16,775

Table 1.3.1.3.1 *Summary of the Land Parcels Identification System (LPIS) data used in analyses.*

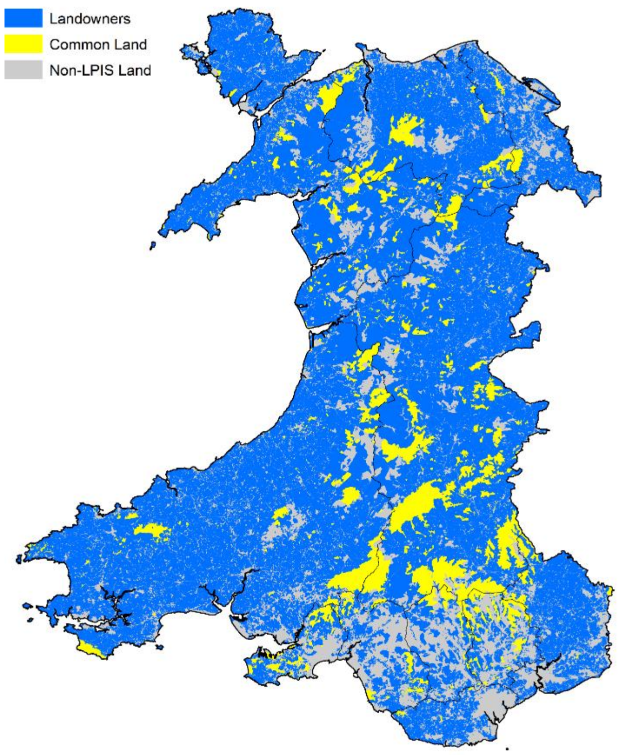


Figure 1.3.1.3.1 *Spatial distribution of the Land Parcels Identification System (LPIS) data used in analyses.*

1.3.2. Glastir uptake analysis methodology

1.3.2.1. Uptake Element spatial layers processing

The Glastir uptake layers in Table 1.3.1.1.1 were processed using Python programs, running ESRI ArcGIS geo-processing tools. The uptake parcels in each of the spatial layers were iterated through, with attributes calculated for the following metrics, split by Element:

- Entrant count: The number of unique Glastir entrants present, preferably identified from SRNs, or if not available, using CRNs.
- Parcel area: The total area covered by all uptake features, in kilometres squared (km^2). Where the extents of parcels overlap, the overlapping area has only been counted once, by using a dissolve geometry procedure. This was done using a separate process, and does not affect the other metrics.
- Parcel count: The number of individual features in the layer, whether option polygons or whole land parcels.
- Number of option codes: The number of unique options codes taken up. Where given as an average per landowner, only the landowners present in the options layers (Entry, Advanced, and Woodland Management) have been counted.

- Linear option length: Where options are present for linear features such as hedgerows and footpaths, and may not be significant when represented as areas, the total length of options has been counted, measured in kilometres (km). Where given as an average per landowner, only the landowners present in the options layers (Entry, Advanced, and Woodland Management) have been counted.

Where total values for all Elements are given, the same metrics as above have been calculated, except that any entrants, options codes, and parcels common to multiple Elements have only been counted once, rather than simply summing the Element-level values.

1.3.2.2. Allocating uptake to Glastir Outcomes

Parcels from the Glastir uptake layers were matched to the six Glastir Outcomes of Biodiversity, Soil, Landscape and Access, Freshwater, Woodlands, and Climate Change Mitigation as follows: Individual option codes for Glastir Entry Level, Advanced, and Woodland Management were allocated to each Outcome, according to guidance in the Welsh Government publications and CEH expert opinion, as the actual outcome as designated by the Glastir Project Officer for the agreement was not available to GMEP at the time of this report. As the Commons, Woodland Creation, Glastir Efficiency Grants, and Organic uptake operates at whole land parcel scales, they were allocated as complete layers, rather than separated by option. In many cases, options or extents apply to multiple Outcomes, and have been processed as belonging to each of those, as the primary objective is not known. The same metrics as above were then calculated, with values aggregated by Outcome rather than by Element.

1.3.2.3. Spatial distribution

To visualise the spatial distribution of Glastir uptake without disclosing locations or precise values of entrants, the same metrics were calculated for each agricultural small area (see section *1.3.1.3*), with the uptake parcels clipped to the boundaries. The results have then been mapped at a small area scale as choropleth maps, where results are converted to ratios and grouped into discrete categories. In the case of Glastir-wide values, results are presented as percentages of the LPIS total, or mean values per Glastir entrant. For Element and Outcome level results, the maps represent the relative proportions of the Glastir total for that small area (e.g. the amount of total Glastir land that is part of the Entry Level Element), displayed using quantiles to equalise the classification range between Elements and Outcomes, to enable comparing relative uptake between the maps.

1.3.3. Glastir uptake analysis results

1.3.3.1. Total Glastir uptake

From all Glastir Elements combined, 4,911 unique entrants were identified as having joined the scheme, 22% of all landowners registered with LPIS in Wales (Table 1.3.3.1.1). Grouped by agricultural small area, the percentage of LPIS landowners subscribed to Glastir varied from 4% to 51%, with the highest proportions present in Snowdonia (Figure 1.3.3.1.1). The total area covered by Glastir options (see definition in section *1.3.1.1*) was 3,263 km^2, 19% of the available LPIS area and 16% of the total Wales land area. This percentage of land under Glastir varies by small area, ranging from less than 1% of the available LPIS parcel area to a maximum of 71% (Figure 1.3.3.1.2). A total of 78,958 individual option polygons or land parcels were present in the layers, with the number of parcels per entrant varying from one Glastir parcel, to a maximum of 317 (Figure 1.3.3.1.3).

4,109 Glastir entrants (84%) subscribed to options under Entry Level, Advanced, or Woodland Management. Across Wales, 190 unique Glastir options codes have been taken up, including 3,050 km of linear options (Table 1.3.3.1.1). The spatial variation in average option codes and linear option lengths is shown in figures 1.3.3.1.4 and 1.3.3.1.5, respectively.

Summary Metric	Uptake Value	Minimum per Entrant	Maximum per Entrant	Average per Entrant
Total Entrant Count	4,911	N/A	N/A	N/A
Total Parcel Count	78,958	1	317	16
Total Parcel Area	3,263 km^2	5 m^2	100 km^2	0.66 km^2
Unique Option Codes Count*	190	1	22	4
Linear Option Length*	3,050 km	<0.01 m	24 km	0.62 km

Table 1.3.3.1.1 *Summary of the Glastir uptake spatial layers. Metrics marked with an asterisk (*) only apply to entrants present in the Entry Level, Advanced, or Woodland Management layers.*

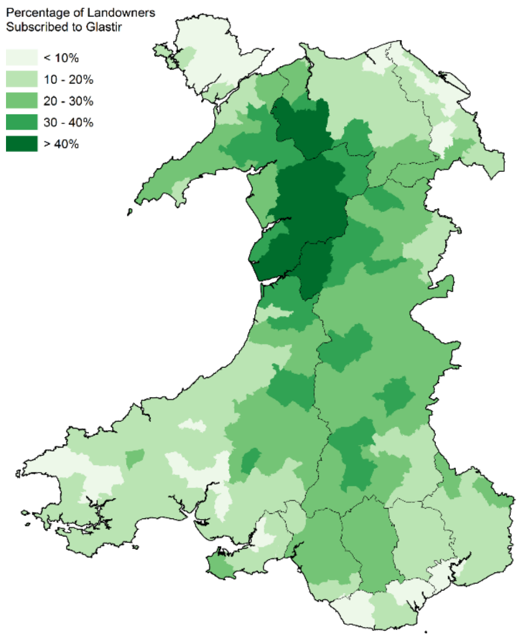


Figure 1.3.3.1.1 *Percentage of LPIS landowners that have subscribed to Glastir, aggregated by agricultural small area.*

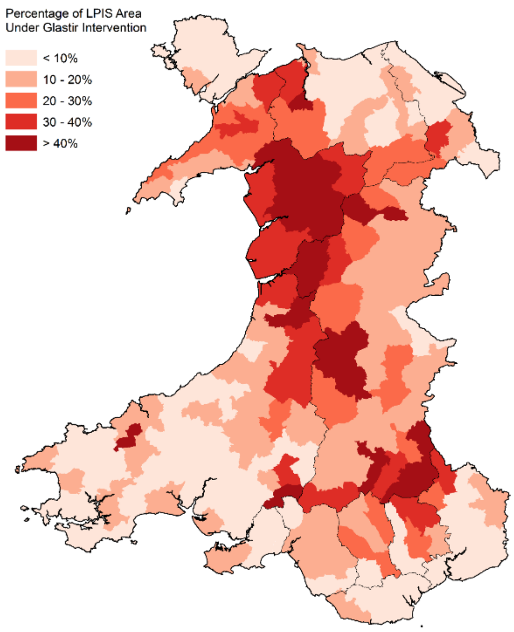


Figure 1.3.3.1.2 *Percentage of LPIS landowner area that overlaps with Glastir uptake parcels, aggregated by agricultural small area.*

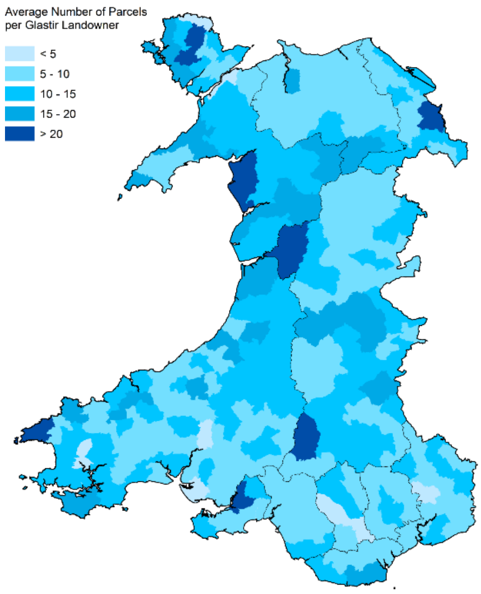


Figure 1.3.3.1.3 *Average (mean) number of uptake parcels per uptake entrant, aggregated by agricultural small area.*

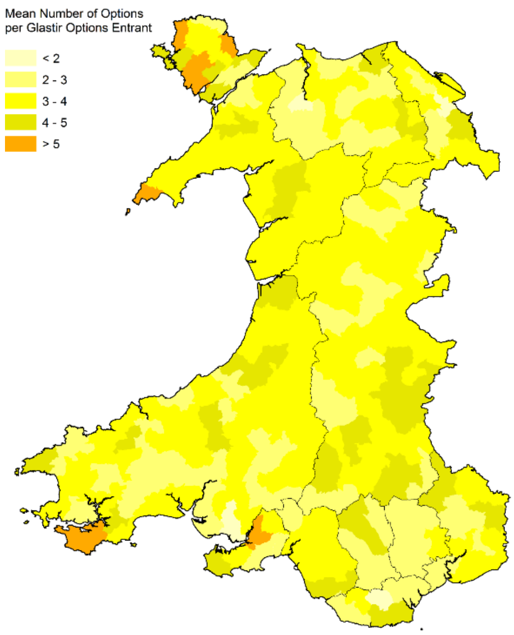


Figure 1.3.3.1.4 *Average (mean) number of uptake options per options entrant, aggregated by agricultural small area.*

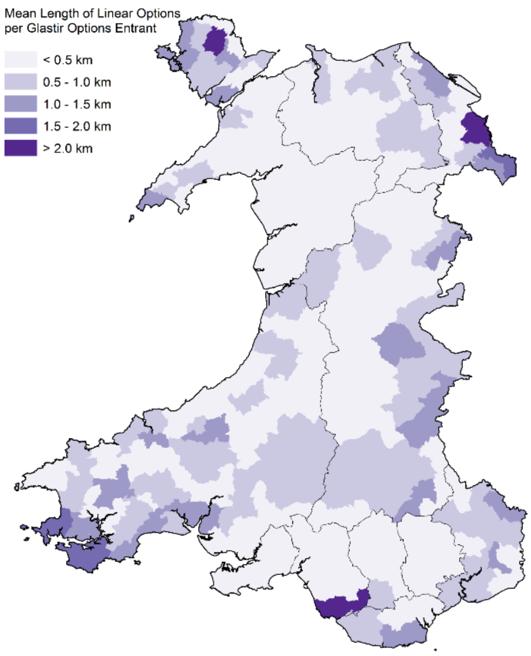


Figure 1.3.3.1.5 *Average (mean) length of uptake linear options per options entrant, aggregated by agricultural small area.*

If the levels of uptake are compared to amounts of points available, clearly points have driven uptake with only 308km2 (ca. 1% of Wales) where there was high uptake in areas with low points. However, there was 3041km2 (ca. 15% of Wales) with high points where there was little or no uptake (Figure 02). To try and identify if there was any consistent pattern of land not coming into scheme, we analysed the land according to its habitat type. Broadly similar proportional amount of the dominant Broad Habitat land was present occurred in the extremes of this assessment i.e. high uptake / low points versus low uptake / high points i.e. the two classes were linearly related suggesting there was no consistent bias of land coming in, or not coming in, to the scheme. The one exception was coniferous forest which was an outlier. There was proportionally a larger area with little uptake despite high points and proportionally lower area of land with high uptake and low points relative to the other 7 major habitat types. The issue of poor uptake of the Woodland Creation scheme which this data would support is further addressed in Chapter 3.

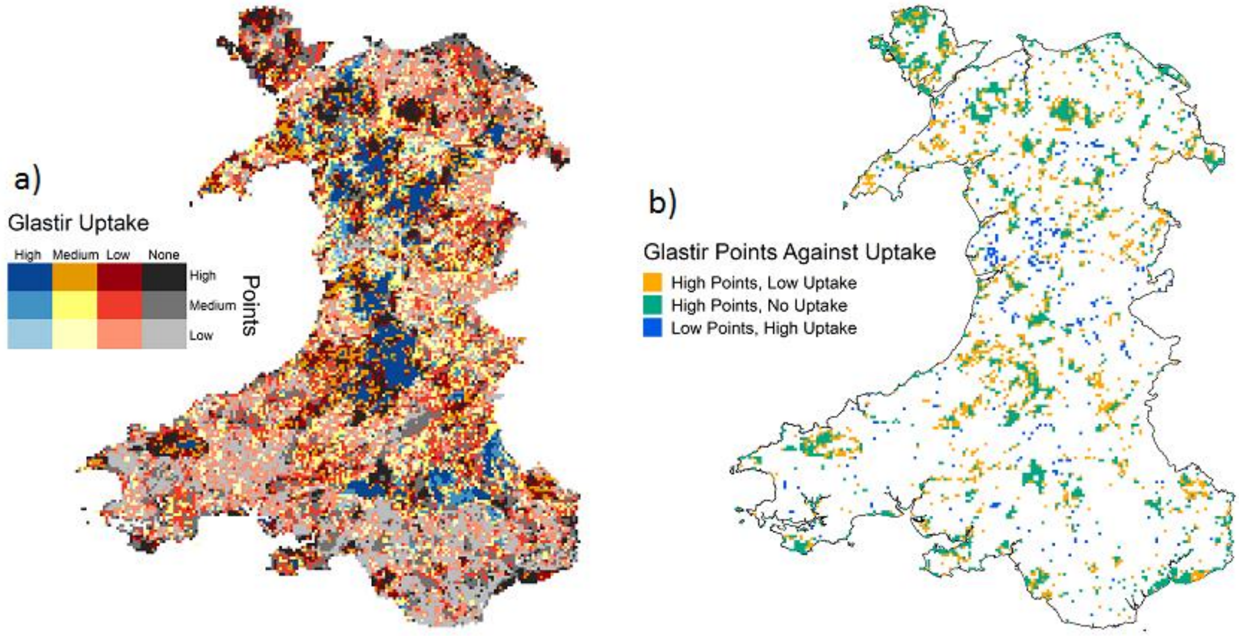


Figure 1.3.3.1.6 a *Comparison of uptake by farmers compared to total points available across all outcomes;*
Figure 1.3.3.1.6 b *Simplified figure highlighting the extremes of Figure 02a.*

1.3.3.2. Glastir uptake by Element

Uptake of Glastir was not equal across Elements, with the Entry level Element having the highest number of entrants, and also the largest total parcel area, the highest number of parcels, and the longest total linear option length (Table 1.3.3.2.1). Options only apply to the Entry and Advanced elements, and the Woodland Management component of the Woodland Element, with Advanced having the highest number of unique options codes. As the Commons, GEG, and Organic Elements are whole extents, the total parcel area is large relative to the number of entrants, with Organic being the second highest uptake Element by entrant, area, and number of uptake parcels.

Small areas maps displaying uptake metric values per Element are shown in Figures 1.3.3.2.1-1.3.3.2.5. For each small area, the proportion of the Elements metric value from the total across all Elements has been calculated for each metric. To allow the individual Element maps to be categorised into equally distributed classes, the results are shown by quantile, where the values are grouped into five classes of roughly equal sizes, with the 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%. This provides a method to spatially compare the relative uptake of each metric between Elements, without disclosing actual uptake values.

Summary Metric	Entry	Advanced	Woodland	Commons	GEG	Organic
Total Entrant Count	3,936	546	732	130	109	578
Total Parcel Area (km^2)	1,554	271	43	733	206	853
Total Parcel Count	46,534	8,736	2,197	359	111	21,021
Unique Option Codes Count*	62	131	51	N/A	N/A	N/A
Linear Option Length (km)*	2,967	60	23	N/A	N/A	N/A

Table 1.3.3.2.1 *Summary of the Glastir uptake spatial layers, split by Element. Metrics marked with an asterisk (*) only apply to entrants present in the Entry Level, Advanced, or Woodland Management layers.*

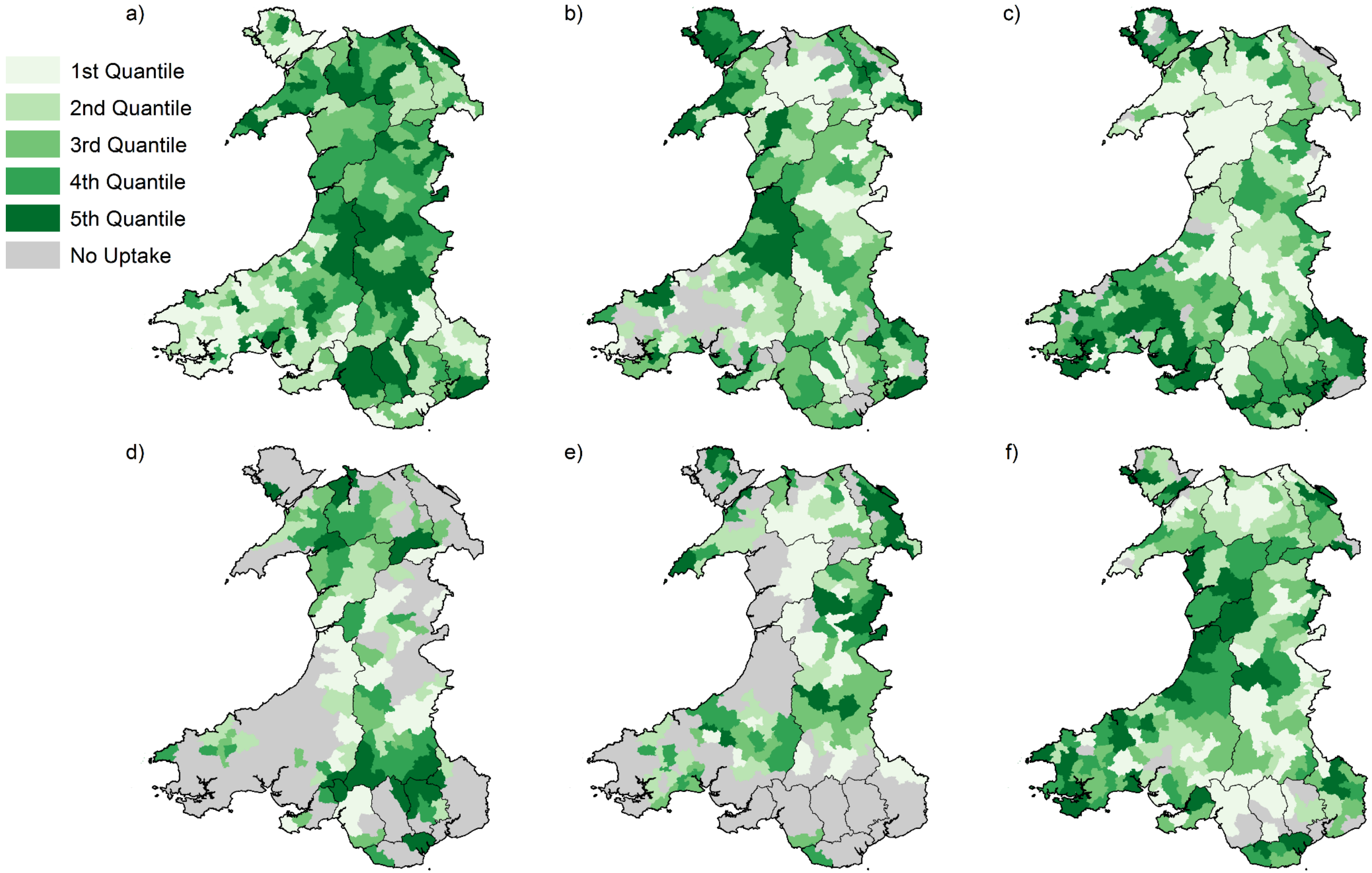


Figure 1.3.3.2.1 *Proportion of entrants to the a) Entry, b) Advanced, c) Woodland, d) Commons, e) GEG, and f) Organic Elements from the total Glastir entrants, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

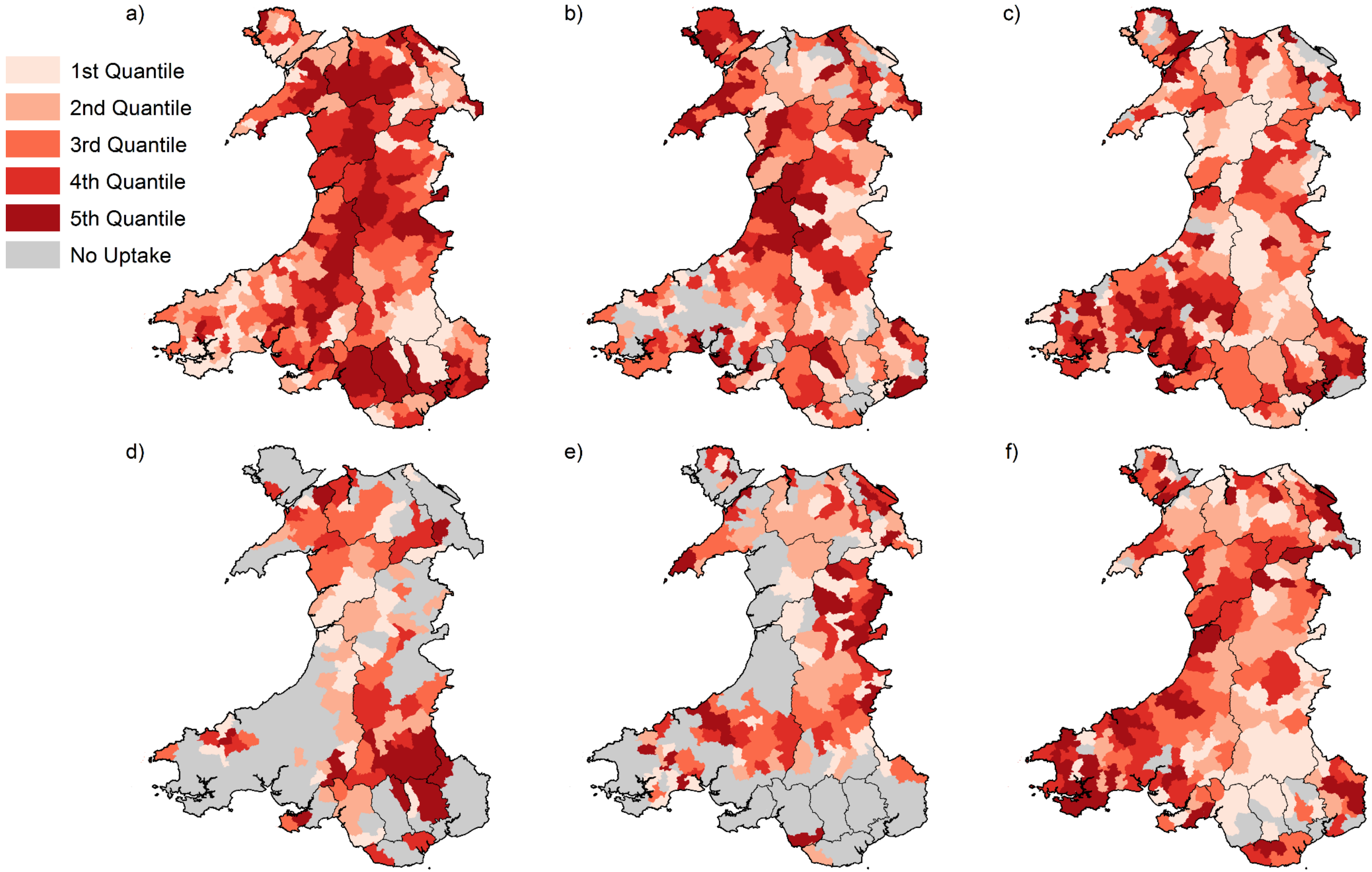


Figure 1.3.3.2.2 *Proportion of uptake parcel area occupied by the a) Entry, b) Advanced, c) Woodland, d) Commons, e) GEG, and f) Organic Elements from the total Glastir uptake area, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

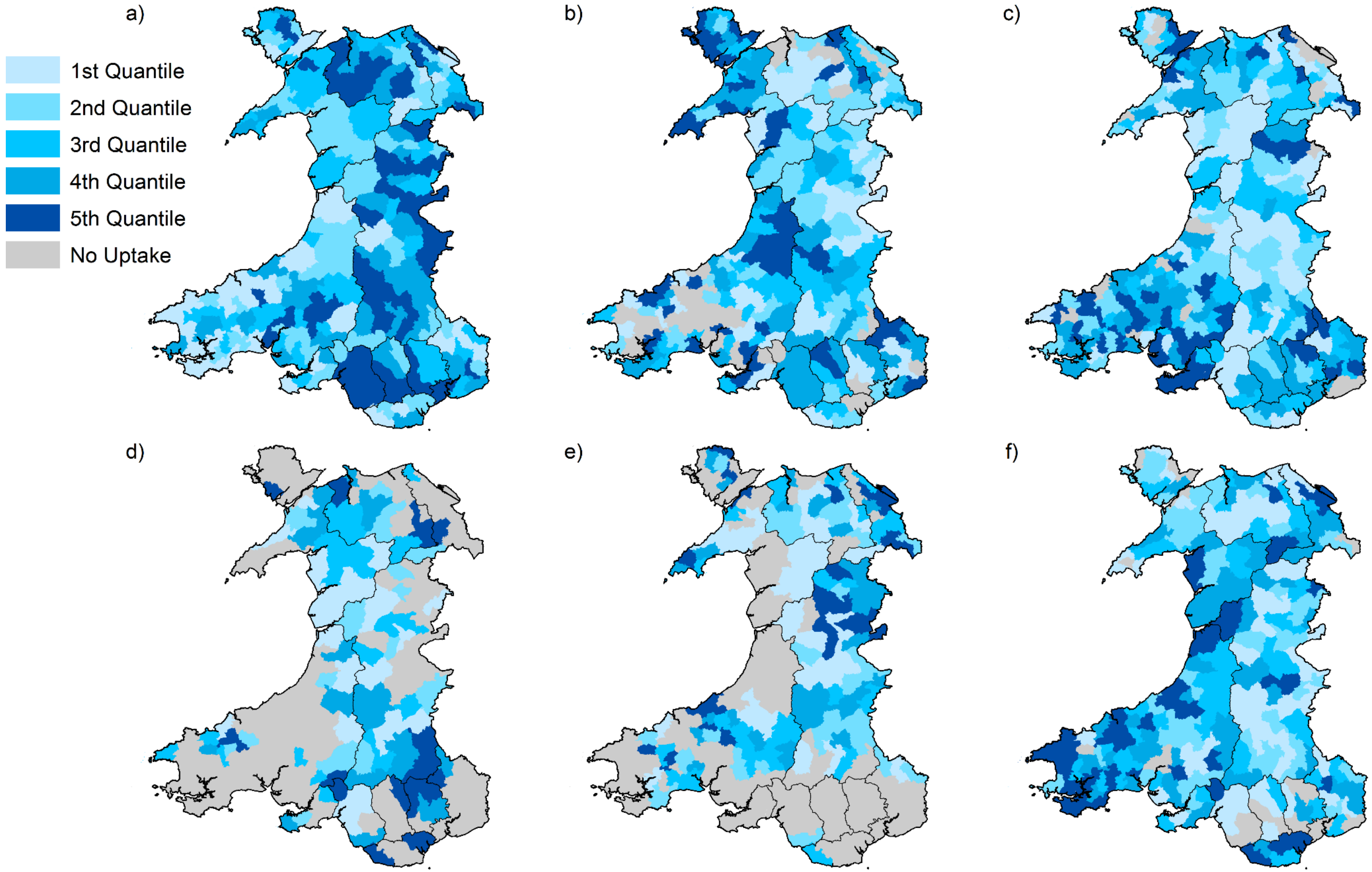


Figure 1.3.3.2.3 *Proportion of uptake parcels of the a) Entry, b) Advanced, c) Woodland, d) Commons, e) GEG, and f) Organic Elements from the total Glastir parcels, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

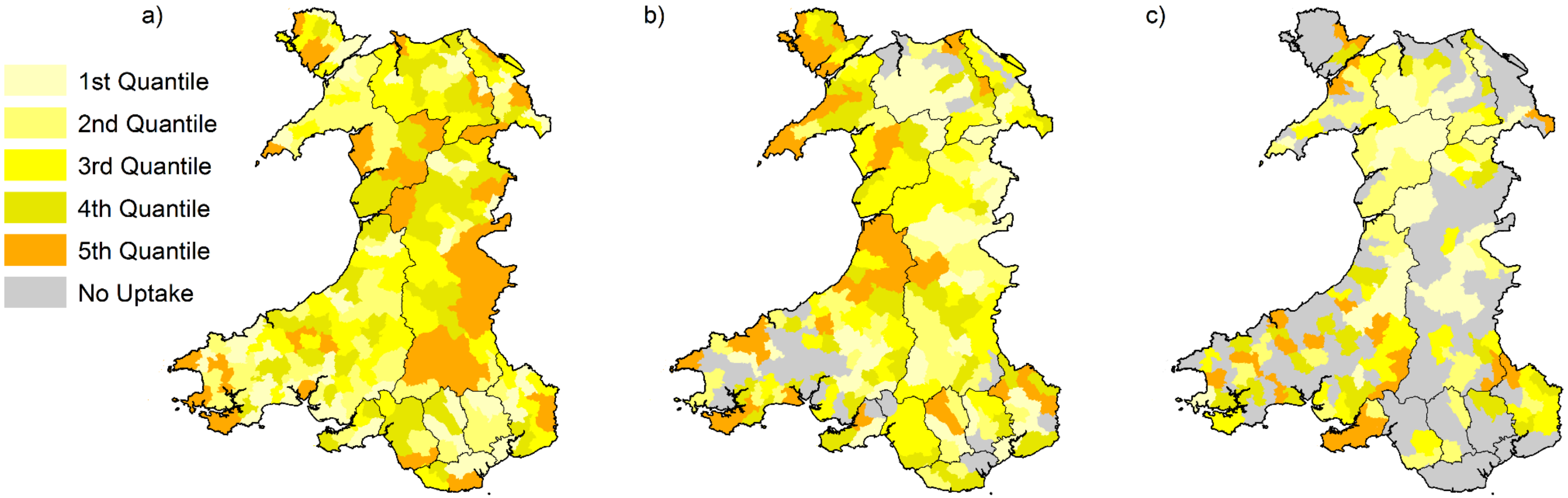


Figure 1.3.3.2.4 *Proportion of options under the a) Entry, b) Advanced, and c) Woodland Elements from the total option uptake, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

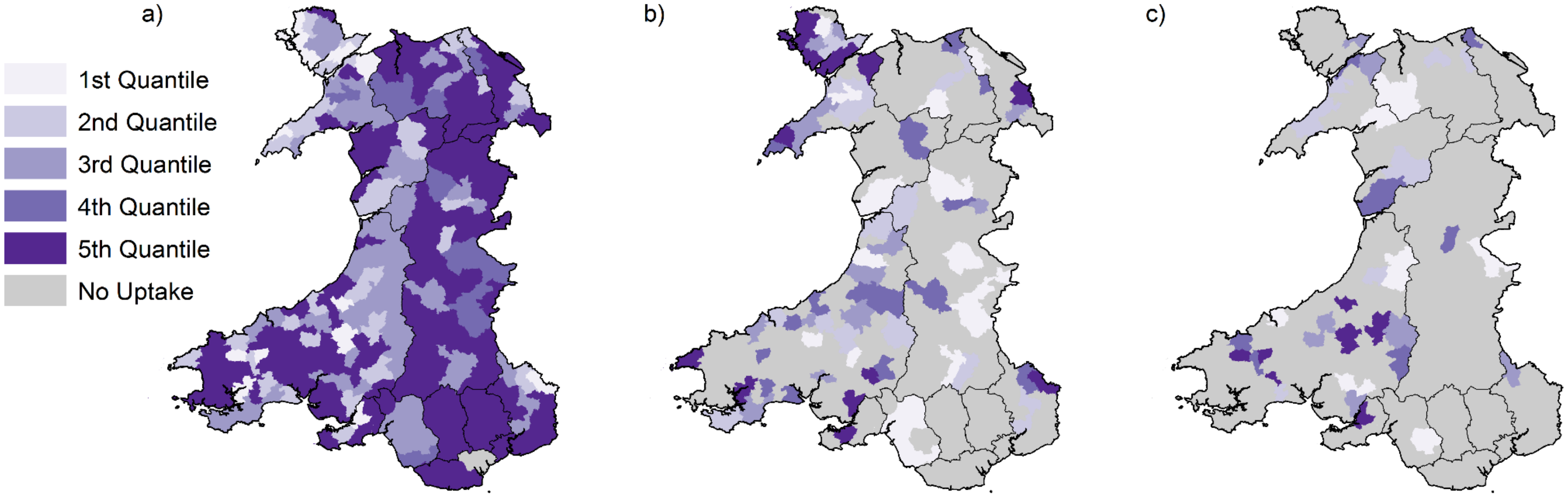


Figure 1.3.3.2.5 *Proportion of linear option lengths of the a) Entry, b) Advanced, and c) Woodland Elements from the total option lengths, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

1.3.3.3. Glastir uptake by Outcome

Uptake of Glastir applied most to biodiversity, which had the greatest values for all metrics except parcel area, where climate change mitigation was the Outcome with most area under options (Table 1.3.3.3.1). The Woodlands Outcome had the fewest entrants, parcels, and total area, although with average values for the number of option codes and option length. No linear options were allocated to the soil or climate change mitigation Outcomes.

Small areas maps displaying uptake metric values per Outcome are shown in Figures 1.3.3.3.1-1.3.3.3.5. For each small area, the proportion of the Outcomes metric value from the total across all Outcomes has been calculated for each metric. To allow the individual Outcome maps to be categorised into equally distributed classes, the results are shown by quantile, where the values are grouped into five classes of roughly equal sizes, with the 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%. This provides a method to spatially compare the relative uptake of each metric between Outcomes.

Summary Metric	**Biodiversity**	**Soil**	**Landscape and Access**	**Freshwater**	**Woodlands**	**Climate Change**
Total Entrant Count	3,959	3,586	3,569	3,599	2,166	3,597
Total Parcel Count	48,516	34,298	38,295	38,638	7,811	34,578
Total Parcel Area (km^2)	2,381	2,025	2,189	2,041	88	2,604
Unique Option Codes Count	107	47	80	68	74	48
Linear Option Length (km)	1,832	N/A	452	421	667	N/A

Table 1.3.3.3.1 *Summary of the Glastir uptake spatial layers, split by Outcome. Metrics can apply to more than one Outcome.*

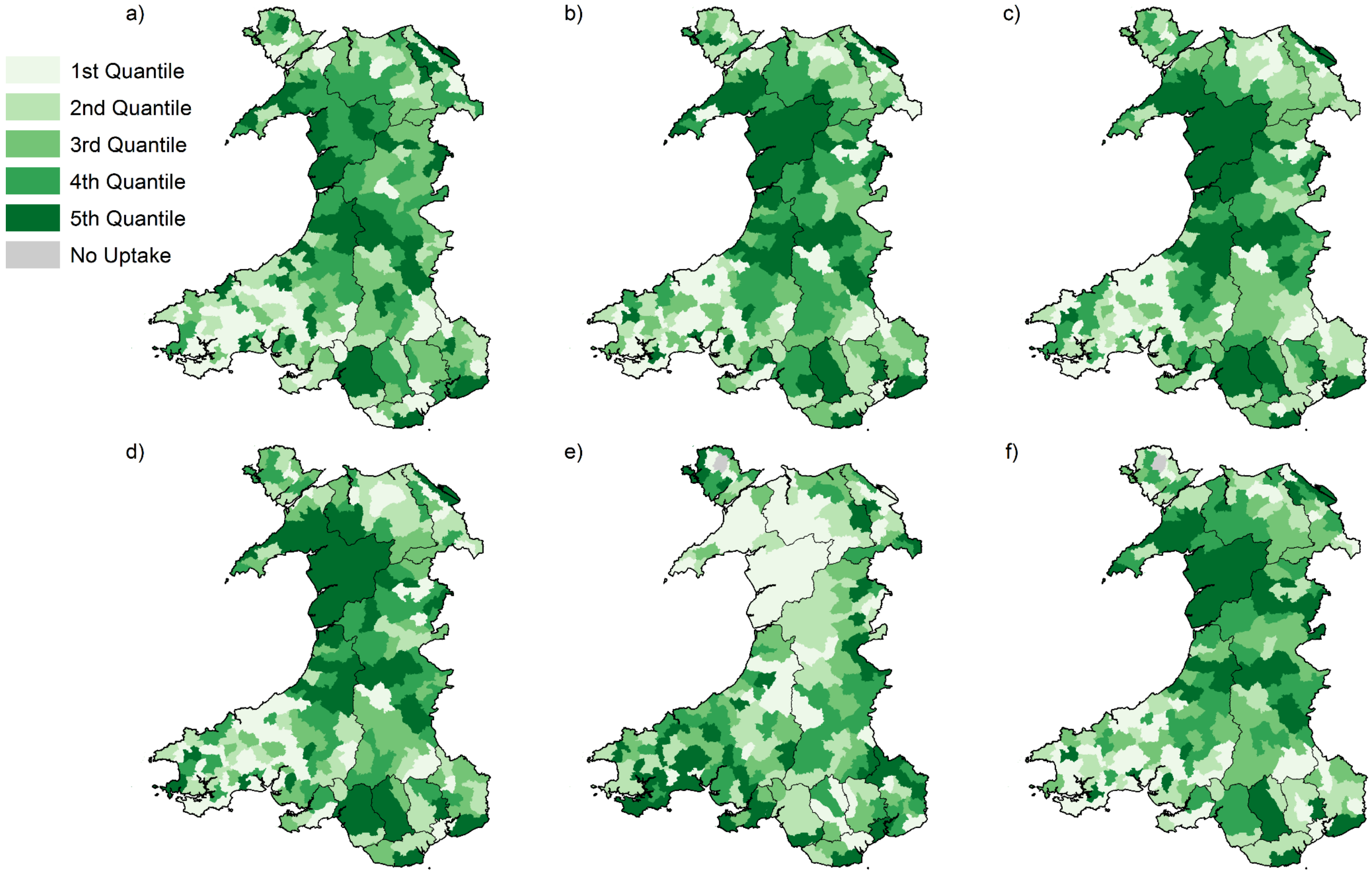


Figure 1.3.3.3.1 *Proportion of entrants who apply to the a) Biodiversity, b) Soil, c) Landscape, d) Freshwater, e) Woodlands, and f) Climate Change Mitigation Outcomes from the total Glastir entrants, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

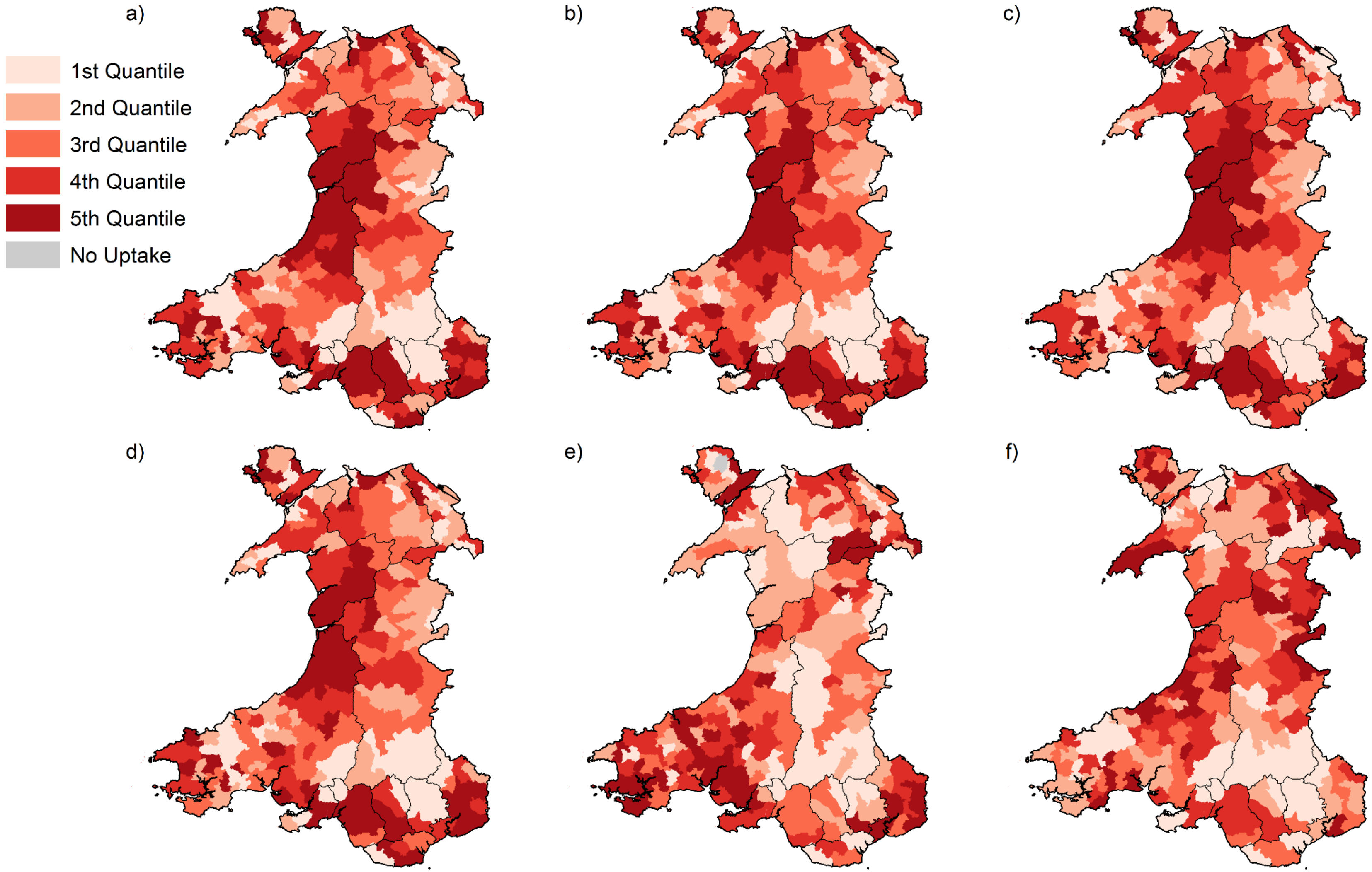


Figure 1.3.3.3.2 *Proportion of uptake parcel area that applies to the a) Biodiversity, b) Soil, c) Landscape, d) Freshwater, e) Woodlands, and f) Climate Change Mitigation Outcomes from the total Glastir uptake area, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

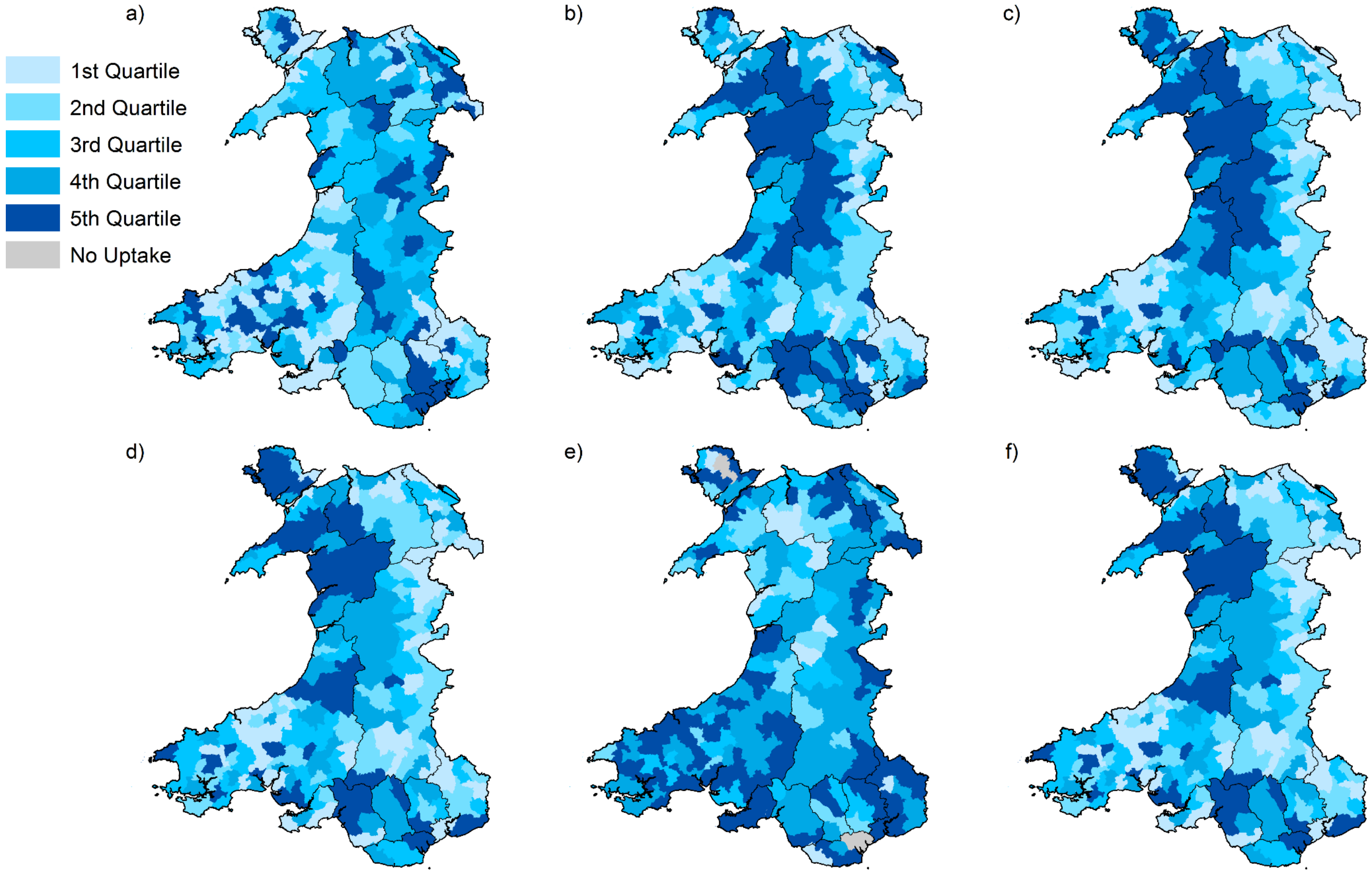


Figure 1.3.3.3.3 *Proportion of uptake parcels that apply to the a) Biodiversity, b) Soil, c) Landscape, d) Freshwater, e) Woodlands, and f) Climate Change Mitigation Outcomes from the total Glastir parcels, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

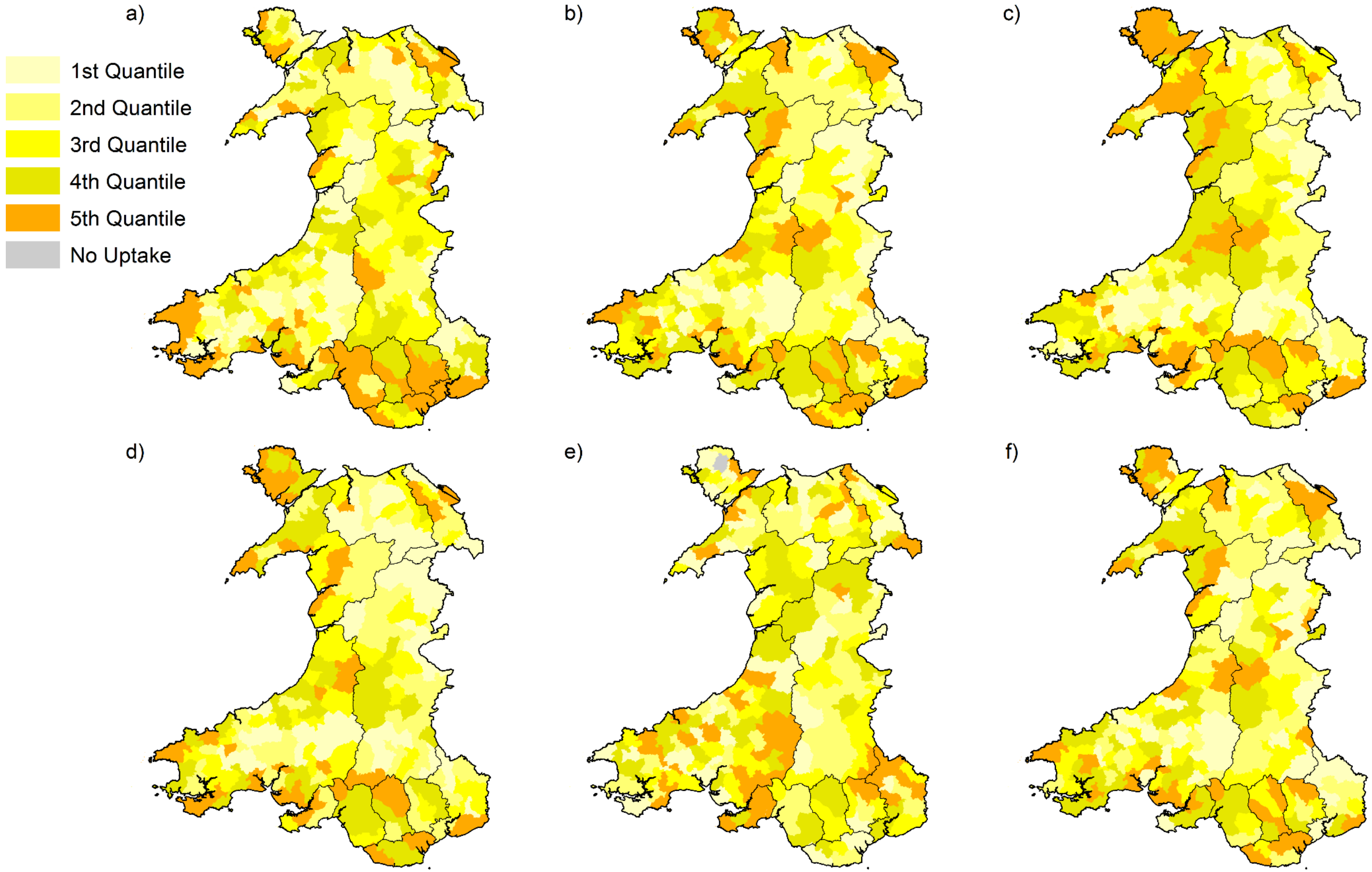


Figure 1.3.3.3.4 *Proportion of options that apply to the a) Biodiversity, b) Soil, c) Landscape, d) Freshwater, e) Woodlands, and f) Climate Change Mitigation Outcomes from the total option uptake, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

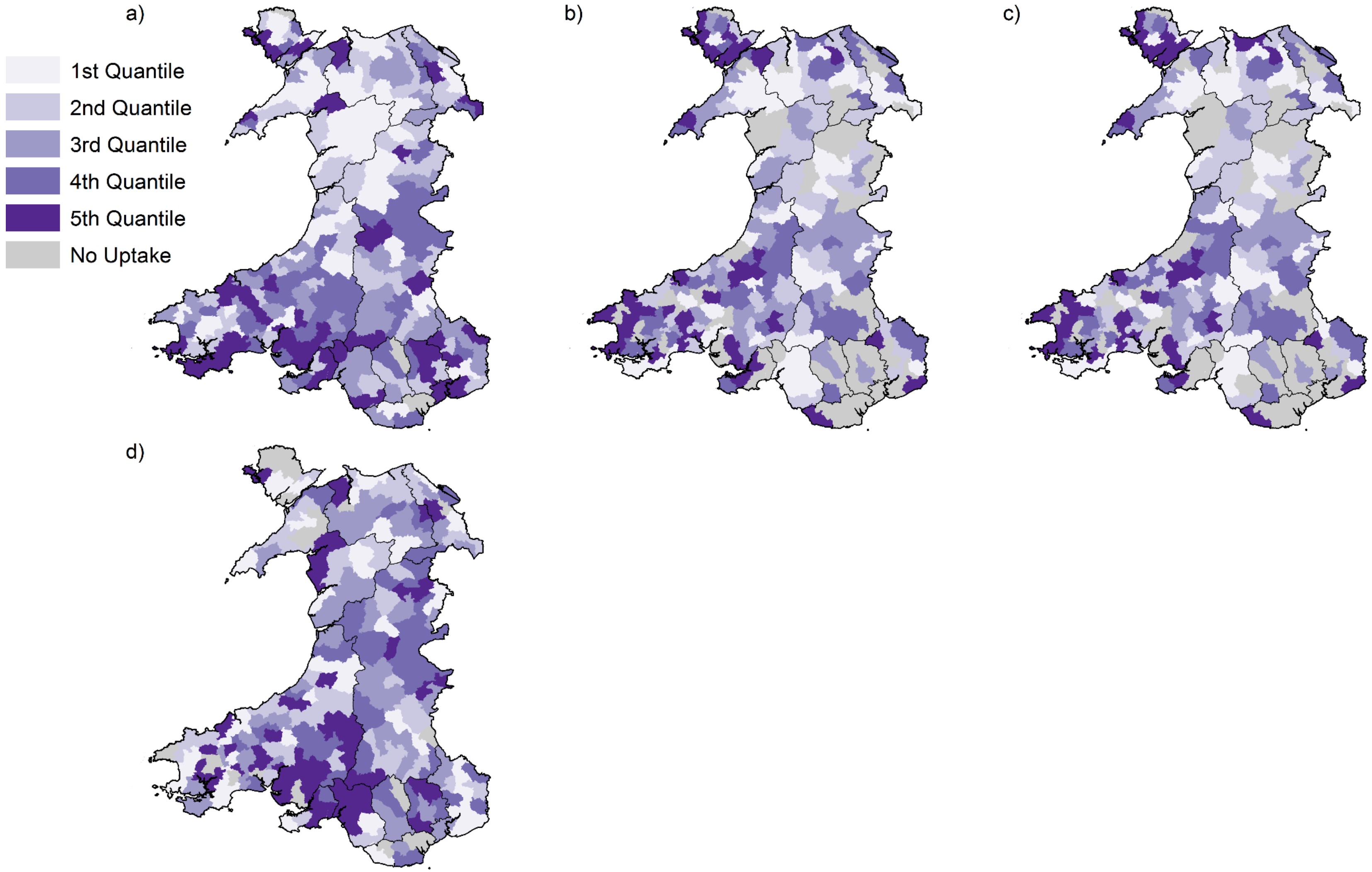


Figure 1.3.3.3.5 *Proportion of linear option lengths that apply to the a) Biodiversity, b) Landscape, c) Freshwater, and d) Woodlands Outcomes from the total option lengths, aggregated by agricultural small area, and with values symbolised by quantile.* The 1st quantile containing the lowest 20% of values, and the 5th quantile the highest 20%.

1.4. Current Status of GMEP Data

1.4.1. Matching GMEP activities to Glastir uptake

Wider Wales Component (WWC) squares in each year, over the four year cycle, were randomly sampled within strata defined according to the Land Classification of Great Britain (Bunce et. al., 2007) – a derived classification of the landscape based on its topography, geology, climate and physical attributes. Environmental heterogeneity is minimized within each stratum of the Land Classification and is maximised between strata. The proportion of the WWC squares randomly sampled from within each stratum was proportional to the size of the stratum in order best to allocate survey effort. Any square randomly selected that contained more than 75% of urban land or that was more than 90% sea (defined by LCM2007 and the UK Census mean high tide data) was excluded. This criteria ensures that we do not remove important coastline squares, which contain a significant number of priority habitats and comprise a high proportion of total land in Wales. The random sampling within these strata for each year of the rolling survey ensures that the square selection is unbiased and representative of the wider environment.

Alongside the randomly sampled WWC component of the monitoring, we also monitored a similar number of 1km squares targeted specifically at Glastir priority areas. This is important because the stratified random sampling for the WWC may not cover the management options prioritised by the Welsh Government to allow inference about changes in relevant metrics. As we wish to compare squares from the targeted monitoring to squares from the WWC monitoring, it was important that we preserved the same spatial scale. These Targeted Component (TC) squares were chosen specifically to map onto areas that the Welsh Government have emphasised as priorities for Glastir Advanced land management scheme delivery (climate change mitigation in Years 1 and 2 of GMEP). The selection of squares was therefore based on the target areas identified by the Welsh Government, using the scoring system that they have adopted in order to combine maps of Glastir priorities. In Years 3 and 4 we will be weighting the way we make the square selection according to actual uptake to provide this more targeted component of the survey as the data is now available. The total numbers of squares will remain at 300 1km squares for the WWC and TC surveys combined.

Due to the way squares are selected, the presence, magnitude, and type of Glastir uptake within and between survey squares will vary. The ability of the GMEP project to accurately monitor change due to Glastir uptake depends on how well the survey captures land representative of the different Glastir options, Elements, and Outcomes. This section summarises the overlap of GMEP survey squares and Glastir uptake data.

1.4.1.1. Methodology

There are currently 260 GMEP 1km survey squares that have been selected for the field survey: 150 that have already been surveyed in years one and two, 75 selected for the year three survey, and 35 Wider Wales squares selected for year four, with the locations of a further 40 Targeted squares for Year 4 still to be decided as more uptake data becomes available. As all Glastir land falling within the 260 squares should be permitted for survey by the landowners, under the terms of entering the scheme, the overlap of all 260 selected squares with Glastir uptake data has been studied.

The same process referred to in section 1.3 has been used to define and quantify Glastir uptake. The uptake layers were clipped to the spatial extents of the GMEP 1km survey squares, and processed in the same way to calculate metrics for entrants, parcel area, parcel count, option count, and linear option length, summarised by Element, and Outcome.

1.4.1.2. Results

In total, 197 of the 260 GMEP 1km survey squares (76%) currently selected or surveyed (Years 1-3 and Wider Wales element of Year 4) spatially overlap with some form of Glastir uptake layer. Squares distribution is shown in Figure 1.4.1.2.1. This includes 1,609 individual parcels belonging to 321 Glastir entrants and covering an area of 63 km^2. From the 171 squares that overlap with options parcels, a total of 88 different options have been surveyed, including 38 km of linear options. Split by Element, the GMEP field survey capture of Glastir uptake follows the national trend, with Glastir Entry being the most surveyed Element for most metrics, followed by Organic. The lower uptake Elements of Woodland GEG overlap with the fewest squares. More Glastir Advanced parcels have been surveyed than those of Commons, although the large parcels of the common land mean the total area surveyed is larger.

By Outcome, the overlap within GMEP 1km survey squares indicates a similar skewed distribution compared to uptake numbers with the majority capturing biodiversity options with 78% of land parcels with biodiversity options (62% in the scheme). Woodlands did however have the lowest coverage at 16% (10% in the scheme). This analysis will need repeating now the data has come through which includes the intended outcome for the options within the Glastir contracts. Current assessment was based on likely target outcome by the GMEP team.

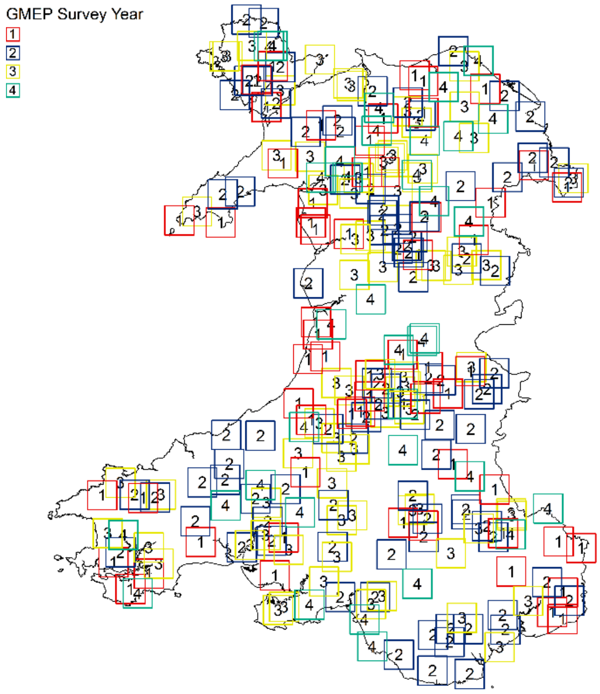


Figure 1.4.1.2.1 *Distribution of GMEP 1km survey squares but enlarged and relocated within a 10km grid to protect locations. Squares include Years 1-3 Wider Wales Survey and Targeted Survey but only Wider Wales Survey for Year 4 as Targeted Survey will be selected according to uptake in autumn 2015.*

1.4.2. Datasets acquired for the GMEP project

Data collected for, or generated by, the GMEP project is stored within a secure Oracle spatial database, managed with the ESRI ArcSDE application. This data is stored under one of a number of schemas – separate spaces within the database structure, designed to hold data in logical groups (Table 1.4.2.1). Project staff can then access the datasets stored under each schema with their own private connection, with read-only access permitted for the required data once the appropriate licensing agreements have been processed.

Aside from the field survey data, and internally-generated derived data, a range of third party data has been acquired from the Welsh Government and other sources for the project, currently including over 700 individual files. A list of all third party data acquired for the project is listed in Table 1.4.2.2.

Database Schema	Description	Number of Files Stored
Third party data	Stores all external data gathered for the project such as Glastir scheme uptake and environmental data (see Table 1.4.2.2), and some key internal data such as GMEP 1km survey square locations.	722
Habitats	The database for the habitats field survey application (CS Surveyor), with the schema structure designed by ESRI. Collected field data is imported to the database using CS Surveyor, which updates the various tables and feature classes, not all of which are relevant to GMEP.	218
Habitats QA	As above, for the quality assurance field survey habitats data.	213
Vegetation	Tables and features from the Vegetation Plots application, containing botanical plots data. Field data is appended to the tables each year.	9
Vegetation QA	As above, for the quality assurance field survey plots data.	6
Freshwater	Tables from the various freshwater applications (RAPID, IRIS etc.), containing field survey data for freshwater. Field data is appended to the tables each year.	26
Soil	Processing results from the soil core samples, such as biological, physical and chemical characteristics. Data is appended to the tables each year.	7
Derived	Internally generated data, produced for use within the project. Includes reprocessed copies of third party data and field data, and intermediate analysis data.	26
Results	Final output analysis results tables generated for the GMEP report and data portal.	5

Table 1.4.2.1 *Schemas present within the GMEP Oracle geodatabase to store data for the project.*

Data Type	Dataset	Description
Agri-environment schemes	Glastir Advanced	Advanced Element uptake extents and options.
	Glastir Commons	Commons Element uptake extents.
	Glastir Efficiency Grants	GEG uptake entrants and field boundaries.
	Glastir Entry	Entry Level uptake extents and options.
	Glastir Organic	Organic uptake entrants and field boundaries.
	Glastir Woodland	Woodland Creation and Woodland Management components of the Woodland Element.
	Organic Farming scheme	OFS entrants (previous scheme).
	Protected Zones	Extents of protected zones for certain species under Glastir.
	Target Areas	Glastir Target Areas from 2013-2015, including: Carbon, Water Quality, Water Quantity, Access, Landscape, Historic Environment, Biodiversity Habitats & Species.
	Tir Cynnal	Tir Cynnal extents and options (previous scheme).
	Tir Gofal	Tir Gofal extents and options (previous scheme).
	Aerial photography	High resolution (25 x 25 cm) Aerial Photography from 2009.

Contextual and basemaps	OS Master Map	Ordnance Survey vector line and polygon features.
	OS Raster	Ordnance Survey raster data at scales of 1:10,000; 1:25,000; 1:50,000; and 1:250,000.
	Public Rights of Way (PROW)	Linear features displaying public footpaths, bridleways etc.
	Stocking boundaries	Open Country and Upland Boundary regions, for calculating livestock stocking values.
	Wales boundaries	Mean high waterline, NUTS 3 regions and agricultural small areas of Wales.
Designated Areas	Areas of Natural Beauty (AONB)	AONB site boundary polygons.
	Biosphere	Biospheric and Biogenetic reserve boundary polygons.
	Heritage	Heritage coastlines polygons.
	National Nature Reserves (NNR)	NNR site boundary polygons.
	Ramsar	Ramsar wetlands boundary polygons.
	Sites of Special Scientific Interest (SSSI)	SSSI site boundary polygons.
	Special Areas of Conservation (SAC)	SAC site boundary polygons.
	Special Protected Areas (SPA)	SPA site boundary polygons.
Farm Holdings	Agricultural Census	Agricultural Survey and lookup tables.
	Land Parcel Identification System (LPIS)	Land parcel boundary polygons and supporting lookup tables to identify the owners of farms and common land.
	Landowner contact details	Contact details for LPIS land parcels.
Habitats and Land Cover	Agricultural Land Classification	ALC regions from 1977 survey.
	BAP Priority Habitats	NRW Biodiversity Action Plan Priority Habitat regions.
	Ffridd 1km	NRW Ffridd habitat 1km^2 locations.
	Habitat Diversity	NRW 1km^2 habitat diversity.
	Land Cover Map 2007	CEH land cover type vector and raster mapping.
	LANDMAP	NRW landscape dataset, including: Geological Landscape, Landscape Habitats, Visual & Sensory, Historic Landscape, Cultural Landscape.
	National Forest Inventory	NFI forest polygons.
	Phase I Habitat Survey	NRW Phase I habitat survey 1km^2 and polygon results.
	Phase II Habitat Survey	NRW Phase II habitat survey polygon features results.
Historic	Designated wrecks	Cadw shipwreck locations.
	Historic Environment Features (HEF)	Archaeological Trust historic features.
	Historic Landscape	Cadw Historic Landscape regions.
	Historic Parks & Gardens	Cadw Parks and Gardens polygons.
	Listed Buildings	Cadw listed buildings point locations.
	Scheduled Ancient Monuments (SAMs)	Cadw SAM polygons.
	World Heritage Sites	Cadw World Heritage Sites and Arcs of View within Wales.
Hydrology and Climate	Detailed River Network (DRN)	Environment Agency/NRW linear rivers features.
	Harmonised Monitoring Scheme	EA/NRW HMS point locations and auxiliary tables.

	Met Office Long Term Averages	Long Term Averages for temperature, precipitation, wind speed etc.
	National River Flow Archive	CEH NRFA catchments and auxiliary tables.
	NextMap Digital Elevation Model (DEM)	Intermap 5 x 5 m elevation raster.
	Water Quality & Biological Monitoring	EA/NRW water monitoring data.
	WFD catchment boundaries	Water Framework Directive.
	WFD water bodies	EA/NRW Water Framework Directive water bodies (rivers, ditches, canals, lakes etc.).
Soils	BGS Soil Parent Material	Soil parent material vector layers.
	Hydrology of Soil Types (HOST)	$1km^2$ soil hydrological properties.
	NRW Soil chemistry	Soil pH, P/K/Mg index values and report.
	NSRI NATMAP	National Soils Resources Institute (Cranfield University) vector and tabular soils data.

Table 1.4.2.2 *Third party datasets acquired for the GMEP project.*

1.5 Current Status of GMEP Survey

1.5.1 Overview of methods

The 2nd year of the rolling national surveillance monitoring programme to quantify on-going change in the Welsh countryside and impacts of Glastir options was implemented from April through to September 2014. The main biophysical survey was managed by CEH; pollinator surveys (butterflies, bees and hoverflies) were managed by Butterfly Conservation (BC); and bird surveys were managed by the British Trust for Ornithology (BTO). A full time Farmer Liaison Officer employed by CEH coordinated the movements of all field teams and arrange land access permissions.

Landownership within each 1km square was identified using the Land Parcel Identification System (LPIS) database provided by the Welsh Government. In total, there were 684 individual land holdings contacted within the 90 1km squares surveyed in 2014. Of these, 629 were obtained directly from the LPIS database, with the remaining 55 identified from a combination of Internet-based research, local authorities, Government agencies, estate management services and Commons associations. Initial contact with landowners was made by letter outlining the objectives and timing of the field survey (see Appendix 1.1 for letter and accompanying GMEP 'flier'). The letter emphasized that the land selected for survey was randomly selected and not related in any way to any compliance inspection process for Glastir, Single Payment Scheme or any other scheme. It was also emphasized that personal data is protected by the Data Protection Act 1998 and information gather through the survey is the property of the Welsh Government, subject to the appropriate data security. Landowners were also asked for information on any animal or plant diseases on their property and bio security measures they would like survey staff to comply with. Bio security measures were put in place for all GMEP surveys following the Welsh Government guidelines. See the GMEP Year 1 report for a full description of methods (Emmett et al 2014).

68% of landowners contacted who had landholdings with the GMEP 1km survey squares gave permission to survey, 5% refused access, with the remainder providing no response. In total 80% of land within the 90 1km squares was surveyed in 2014.

1.5.2 Biophysical survey

Twelve experienced botanists/field surveyors were appointed in April 2014 by CEH to cover the main biophysical survey. A comprehensive, three week training programme was held in to cover all aspects of data collection, Health and Safety, first aid and off-road driving before surveyors started work in the field. The surveyors were split into three teams of three with three part time 'floating' surveyors to cover holiday leave and provide extra support where needed. Each team was allocated 30 1km squares to survey across three regions (north, mid and south Wales). Within each region the 1km squares were visited in order from either east to west or west to east which, along with the north/south division, was designed to avoid longitudinal/latitudinal bias in climate and seasonality. To maximize the efficiency of the field teams, a wide number of ecosystem characteristics were recorded on each visit under seven different activities.

All measurements collected as part of the biophysical survey have been mapped to specific or bundles of options and one of the five Glastir outcomes: climate change mitigation, improving water and soil management, maintaining and enhancing biodiversity, managing and protecting the Welsh landscape including the historic landscape, and creating new opportunities to improve access and increasing the area and management of woodlands. For a full account of field survey methods please refer to the GMEP first year report (Emmett et al 2014).

1.5.2.1 Historic Environment Assets

These measurements will contribute to the Glastir outcome: Managing and protecting the Welsh landscape including the historic landscape.

There were two types of Historic Environment Assets recorded as part of the survey work to provide data in the future on how Glastir options impact our historic landscape (further detail of which is provided in Chapter 2); Scheduled Ancient Monuments (SAMs) – nationally important with statutory protection and Historic Environment Features (HEFs) – regionally important but no statutory protection. A basic condition assessment of SAMs and HEFs were recorded where they occurred within a 1km square.

76 Historic Environment Assets were recorded in 34 of the 90 GMEP 1km survey squares in 2014.

1.5.2.2 Landscape photography

These measurements will contribute to the Glastir outcome: Managing and protecting the Welsh landscape including the historic landscape.

To support the work to be undertaken to quantify the impact of Glastir on landscape quality and how that is linked to ecological quality (further detail of which is provided in Chapter 3), fixed point photographs were taken within each 1km square. These provide repeatable, fixed-point images to monitor landscape change over time and a resource for assessing the planned work to link the perception of landscape quality by the public and ecological quality as assessed through our rolling national survey.

A total of 1,837 landscape photographs were taken across the 90 squares in 2014.

1.5.2.3 Mapping habitats, linear and point features

These measurements will contribute to the Glastir outcomes: Maintaining and enhancing biodiversity; Managing and protecting the Welsh landscape including the historic landscape; creating new opportunities to improve access and increasing the area and management of woodlands.

Collection of detailed spatial data on extent and composition of habitats and features across the entire 1km square was recorded to feed into the assessment of a multitude of Glastir options associated with habitat and to provide underpinning, contextual data for other areas of GMEP. Further details are provided in Chapters 3, 4 and 5. Information on habitat type and landscape features were recorded on a digital map, held on the ruggedized field computers.

Habitat areas (>20m x 20m) were mapped and classified using the Broad and Priority Habitat classification. Additional attributes were recorded using a comprehensive range of pre-determined options which relate directly to Broad and Priority Habitats, vegetation types and landscape features (e.g. Agriculture, Forestry, Buildings and structures); supporting attribute data (e.g. grass ley, burnt vegetation), indicative species presence and cover; and land usage (e.g. stock, cattle, sheep, timber production).

In 2014 the Broad Habitats with the greatest extent were Improved Grassland, Neutral Grassland and Acid Grassland, followed by Coniferous Woodland. The Priority Habitats with the greatest extent were Blanket Bog, Lowland Mixed Deciduous Woodland and Purple Moor-grass Pasture, followed by Wet Woodland (Table 1.5.2.3.1).

Broad Habitat	**Extent (km^2)**	**Priority habitat**	**Extent (km^2)**
Broadleaved Mixed and Yew Woodland	2.24	Lowland Beech and Yew Woodland	0.11
Coniferous Woodland	6.07	Upland Mixed Ashwood	0.02
Boundary and Linear Features	0.07	Wet Woodland	0.88
Arable and Horticulture	2.63	Upland Oakwood	0.25
Improved Grassland	18.11	Lowland Mixed Deciduous Woodland	1.86
Neutral Grassland	11.55	Native Pine Woodland	0
Calcareous Grassland	0	Lowland Hay Meadow	0.26
Acid Grassland	8.17	Upland Hay Meadow	0
Bracken	1.54	Lowland Calcareous Grassland	0
Dwarf Shrub Heath	2.63	Upland Calcareous Grassland	0
Fen, Marsh, Swamp	0.82	Lowland Acid Grassland	<0.01
Bog	1.04	Fen	0.27
Standing Open Waters and Canals	0.87	Purple Moor-grass Rush Pasture	1.77
Rivers and Streams	0.09	Reedbed	0.14
Montane	0	Blanket Bog	3.51
Inland Rock	0.12	Lowland Raised Bog	<0.01
Urban	4.25	Limestone Pavement	0
Supra-littoral Rock	0.04	Maritime Cliffs and Slopes	0.09
Supra-littoral Sediment	0	Sand Dune	0.15
Littoral Rock	0	Strandline/Coastal Vegetated Shingle	<0.01
Littoral Sediment	0.33	Coastal Saltmarsh	0.02
Sea	0.9	Northern Birchwood	0
Mosaic	1.12		

Table 1.5.2.3.1 *Total area of Broad and Priority habitat mapped within the 90 1km squares in the 2014 field survey*

Linear features are landscape elements less than 5m wide that form lines in the landscape and have a minimum length of 20m and may include gaps of up to 20m. Linear features recorded include woody linear features (e.g. managed hedgerows and unmanaged lines of trees), streams and ditches, grass strips, banks, walls, fences and footpaths and tracks. In addition to mapping the length of linear features, a comprehensive condition assessment and secondary attributes are recorded. For example, for hedgerows extra information is recorded on height of base of canopy, management, trees, species composition and gappiness.

In Year 2 there were 1,716 km of linear features recorded within the 90 1km squares in the 2014 field survey (Table 1.5.2.3.2).

Linear feature	Length (m)
Fence	627,407
Inland water	232,930
Bank	230,925
Woody linear feature, natural shape	221,024
Woody linear feature, unnatural shape	185,844
Transport	107,285
Wall	66,560
Agriculture/Natural vegetation	24,115
Forestry	9,187
Grass strip	8,672
Inland physiography	2,049
Structures	631
Historic feature	218

Table 1.5.2.3.2 *Total length of linear features surveyed in the 2014 field survey*

Point features are individual landscape elements that occupy less than an area of 20x20m. They include: forestry features such as individual trees, clumps of trees, patches of scrub, veteran trees; inland water features such as springs and ponds; inland physiography such as cliffs and rocky outcrops and structures such as buildings, quarries and wind turbines

In 2014 there were a total of 2,942 point features recorded. The most frequently recorded features were: Individual trees (1,671), clumps of trees (546), patches of scrub (498), rock outcrops and cliffs (158) and scattered trees (128).

Basic information on the condition of Public Rights of Way was captured by the bird survey teams as they moved around the 1km squares. Rights of way were assessed for quality of signage, accessibility and erosion or other signs of damage and results are presented in Chapter 3.

1.5.2.4 Vegetation Plots

These measurements will contribute to the Glastir outcome: Maintaining and enhancing biodiversity

Plant species presence and abundance was recorded in different sizes and types of vegetation plot allowing vegetation change to be expressed by habitat type, landscape location and whether in or out of the Glastir scheme (further detail of which is provided in Chapter 5). Plots can be located in any semi-natural vegetation; this includes amenity. For each vegetation plot general information was collected including species presence, cover and height. Ten plot types were used to record vegetation.

There were 2,405 vegetation plots recorded in Year 2 (Table 1.5.2.4.1).

Plot type	Number of plots recorded
Nested plots to provide a random sample of common vegetation types	437
Targeted plots to sample Priority Habitats and locations eligible for Glastir	266
Unenclosed plots to sample unenclosed Broad Habitats	300
Boundary plots running adjacent to field boundaries	398
Arable plots on field edges	16
Field margin plots to record new arable field margins that form part of land management agreements	3
Hedgerow plots recording diversity alongside hedgerows	119
Hedgerow diversity plots to record woody linear features and their physical condition	396
Streamside plots to record streamside diversity	235
Stream bank plots to record the upslope habitats	235

Table 1.5.2.4.1 *Numbers of vegetation plots recorded in the 2014 field survey*

1.5.2.5 Soil sampling

These measurements will contribute to the Glastir outcome: Combating climate change through soil carbon storage assessment; improving water and soil management due to the direct link between soil and water quality; and also underpins modelling work to forecast maintaining and enhancing plant biodiversity as soil quality is a key constraint on habitat suitability for a range of plants. In addition, the soil sampling assesses major components of soil natural capital which underpins the delivery of ecosystem services, particularly provisioning and regulating services. In the way that financial capital can be assessed by the quantity of money in the bank, soil natural capital can be assessed by the stocks of nutrients, biomass and organisms etc. in the soil.

Soil samples were collocated from each 1km square to enable changes in several key topsoil characteristics in response to Glastir options to be studied (further detail of which is provided in Chapters 2 and 7). The soil samples were co-located with each of the nested vegetation plots. Four soil samples (for chemical, physical, and soil biological analysis) were collected from the top 15cm of the soil profile and a fifth, for the invertebrate sample from the top 8cm using a corer 5cm in diameter.

There were ca. 1,800 soil samples taken in Year 2

1.5.2.6 Headwater stream survey

These measurements will contribute to the Glastir outcome: Improving water and soil management; Maintaining and enhancing biodiversity.

The physical, biological and chemical condition of headwater streams was recorded to assess the impact of Glastir options on water quality (further detail of which is provided in Chapter 8). Water chemistry, diatom community, macroinvertebrate community, aquatic plant community, hydromorphological and physical characteristics of the watercourse (River Habitat Survey Amended) were recorded. The length of the headwater stream sampling site is 500m of watercourse which defines the limits of the River Habitat Survey area. Other measurements were taken within this same reach.

There were 51 GMEP 1km survey squares where headwater streams were sampled in 2014 out of the total square sample size of 90. Not all squares had headwater streams present.

1.5.2.7 Pond mapping and sampling

These measurements will contribute to the Glastir outcome: Improving water and soil management; Maintaining and enhancing biodiversity.

Two Glastir options relate to pond creation and condition and measures were included in order to assess the success of these options (further detail of which is provided in Chapter 8). A pond was defined as body of standing water 25m^2 to 2ha in area which usually holds water for at least four months of the year. All ponds present within the survey were mapped as part of the habitat mapping exercise from which one was selected for a detailed physical, biological and chemical condition assessment.

One pond was sampled in each of 40 GMEP 1km survey squares in 2014 out of the total square sample size of 90. Not all squares had ponds present.

1.5.2.8 Description of QA activities

Despite every effort to ensure consistency between field surveyors by rigorous training, detailed methodologies outlined in the field handbooks, quality control and frequent communication, there will inevitably be some variation. It is therefore important to produce a quantitative measure of consistency and reliability of the data. As such, a QA exercise was carried out to capture and understand this variation and to ensure that there was no significant bias in the data collected. See Year 1 report for full details. Six GMEP 1km survey squares were re-surveyed for Quality Assurance in 2014. See Appendix 1.2

1.5.2.9 Bird Surveys

These measurements will contribute to the Glastir outcome: Maintaining and enhancing biodiversity

1.5.2.9.1 Breeding bird surveys

The survey protocol described in Emmett et al. 2014 (Section 3.6.5) was followed again in 2014. Surveys were conducted on 90 squares, as used in the rest of the field survey. The bird surveys were the first conducted on each square during the year, so land access to the threshold proportion of each 1km square for surveys to be conducted was not always available at the start of the bird season in April. However, less access was sometimes needed for bird surveys than for the other field surveys because some parts of the square could be covered from public rights of way while access permissions were still pending. This caused a problem in one case only, where access permissions meant that a square was replaced in the GMEP sample after bird surveys had been conducted. This means that this square does not have the spatially matched field data from different protocols intended in the survey design, but the sample size for all protocols relative to the initial stratification remained unaltered.

As many as possible of the surveyors who had been recruited in 2013 were employed again in 2014, but some extra effort was required because the sample size was larger. The extra surveyors again came from the pool of skilled, reliable observers already known to the BTO, so no additional external recruitment was needed.

The field survey process went smoothly and completed field maps have since been processed at the BTO head office, with data from 2013 and 2014 being digitized using ArcGIS 10 for subsequent analysis under Work Package 6. This has entailed the development of efficient procedures for the processing of the data, with some inevitable trial-and-error, but systems are now in place that will facilitate rapid data provision in future years. Data on large mammals recorded during the surveys still remain to be extracted from the field maps; these will provide “added value” from the bird-focused surveys.

1.5.9.2.2 Winter bird surveys

Additional survey work in 2014-2015 has considered birds in winter. This is important in order to assess the performance of Glastir options designed to provide resources for birds during winter and thus to influence breeding populations. In principle, this approach could be used for any management considered likely to influence wintering birds, but to date all options identified as potentially benefiting wintering birds are associated with arable farming. Surveys have, therefore, focused on GMEP survey squares containing more than 20% arable cropping by area, as identified by the field survey, with the addition of any squares with less arable land but in which relevant Glastir options were found. A standard survey protocol (Appendix 1.3) was applied in these squares from the 2013 and 2014 samples, in which, assuming permission had been given by the farmers concerned, a route covering all of the arable fields in the square and a representative selection of the non-arable land within the same farms was followed. This route also took in the arable fields in the focal farms that were outside the strict boundaries of the 1km square, which was important because arable management typically rotates around farms from year to year and birds, of course, will frequently move across square boundaries between seasons. Hence, arable habitats and Glastir management relevant to agreements that overlap GMEP survey squares in some years might not actually be present within the square boundary in all years. The surveys provide data on birds in arable (and adjacent) habitats that are unbiased with respect to the location of Glastir management, thus allowing investigation of the extent to which Glastir option areas are selected by birds, as well as information on use in winter that can be related to changes in breeding abundance of the species concerned between GMEP breeding bird surveys (Siriwardena et al. 2007).

Arable habitats have been rare in the survey squares covered in GMEP to date, but the two-visit winter survey protocol has been followed for the 13 squares that met the inclusion criteria, finishing in February 2015, and data will be processed in due course. Note that any tests of the efficacy of Glastir options cannot yet be conducted because only two squares covered to date included any relevant Glastir management. This reflects the rarity of the options concerned, the rarity of arable management in Wales and the targeting of the TG sample in the first two years of GMEP, which will tend to promote the sampling of habitats other than arable land.

1.5.2.10 Pollinator survey

These measurements will contribute to the Glastir outcome: Maintaining and enhancing biodiversity

Butterfly Conservation subcontracted nine experienced ecologists to survey the 90 1km squares across six regions of Wales. A further region was covered by a BC employee. Pollinator surveys focused on three main pollinator groups: butterflies (*Lepidoptera: Rhopalocera*), bees (*Hymenoptera: Apoidea*) and hoverflies (*Diptera: Syrphidae*). Butterflies were recorded to species level, whilst bees and hoverflies were recorded as groups based on broad differences in morphological features associated with ecological differences. In addition, the abundance of common flowering plant groups (identified at the time of survey) was also recorded. Surveys were split into two independent parts: a standardised 2km transect route through each 1km^2 followed by a timed search in a 150m^2 flower-rich area within the square. In 2014 Year 2 field survey all 90 GMEP 1km survey squares were surveyed in July 2014 and due to access issues with one square, repeat surveys on 89 squares were completed in August 2014.

1.6 Future plans for Years 3 and 4

Year 3:

- The field survey for Year 3 is already underway with 75 squares selected for survey.
- Agreement if Countryside Survey squares should be incorporated with the Wider Wales Survey of GMEP

- Finalisation of the new High Nature Value (HNV) Farmland indicator.
- Development and launch of the GMEP Data Portal at the Royal Welsh Show 2015.
- Reporting of metrics needed for the new agreed 6 Strategic Objectives and Targets for Glastir under development by the Welsh Government. These metrics together with high level indicators for the 6 Glastir Outcomes will be used to provide annual updates through the GMEP Data Portal.

Year 4:

- Completion of the final 75 1km field survey squares to complete the 300 GMEP baseline 1km survey squares will be undertaken.
- Repeat of the Farmer Practice Survey in the summer of 2016 to identify actual changes on the farm and any benefit to farm and forestry profitability and resilience.
- Modelling work to identify benefits of Glastir for water quality in Water framework Directive catchments based on changes quantified in the Farmer Practice Survey of summer 2016 for reporting in Spring 2017
- Modelling work to quantify benefits to direct and indirect greenhouse emissions by farm type.

2 Peat Soils

Evans, C.[1], Rawlins, B.[2], Grebby, S.[2], Collier, R.[3], Hughes, P.[3], Jones, P.[4]

[1]CEH Bangor, [2]BGS, [3]University of Southampton, [4] Natural Resources Wales

2.1 Introduction

Peat Soils cover 4.3% of Wales, and support nationally and internationally rare bog and fen habitats. In the uplands, blanket bogs form in waterlogged conditions, and contain peat-forming plant species such as *Sphagnum* mosses, as well as characteristic species such as heather and cotton grasses, and rare species such as sundews and cloudberries. In addition to their importance for biodiversity, Peat Soils act as Wales' largest terrestrial ecosystem store of carbon, and in good condition have the potential to contribute to climate regulation through ongoing CO_2 sequestration. However, Welsh Peat Soils have been detrimentally impacted by centuries of human activity including drainage, over-grazing and conversion to grassland and forestry. As a result Welsh Peat Soils are currently thought to act as a source of greenhouse gas (GHG) emissions. Options supported through Glastir aim to reduce these emissions, and to restore the carbon sequestration function of Welsh Peat Soils, through a reduction in land-use pressures on a range of both upland and lowland bogs and fens.

In year 2 of the GMEP project we have focused on two main activities. The first of these has involved a major new assessment of the extent and condition of the Welsh peat resource. Identifying the extent and location of peat is important in order to quantify the area of different habitats that Peat Soils support, the amount of carbon they store, and the land-use pressures they are likely to be subject to. An improved knowledge of the condition of this Peat Soil area subsequently enables us to identify the potential effects of land-use on Peat Soil ecosystem functions such as carbon sequestration, greenhouse gas emissions, provision of drinking water and regulation of flooding. From this information, it should be possible to target Glastir options and resources more effectively in order to provide the maximum benefit for Peat Soil habitats, for their climate and water regulation functions, and for the people who benefit from these ecosystem services.

The second task undertaken for Peat Soils during Year 2 of GMEP has involved the measurement of long-term carbon accumulation rates at a range of blanket bogs across Wales, using dated peat cores. This ongoing work aims to quantify how changes in land-management and resulting vegetation have affected rates of historical peat growth, which should provide an improved understanding of how these activities influence the rate of carbon accumulation in blanket bogs today. By quantifying these relationships, the aim of the work is to develop new monitoring methods whereby data collected in the annual GMEP vegetation surveys can be used to provide a 'proxy' measure of carbon accumulation rate, allowing the carbon benefits of Glastir options on blanket bog to be more effectively monitored and evaluated in future.

2.2 Highlights and key findings

In year 1 of GMEP in addition to the core survey activities, work undertaken included the mapping of the extent of peat erosion across Wales from aerial photographs, and an assessment of whether satellite data could be used to monitor changes in the surface elevation of Peat Soils that would indicate whether they were accumulating or losing carbon. In Year 2, we have undertaken a detailed new assessment of the extent and condition of the full Welsh Peat Soil resource, based on an integrated analysis of soil mapping data, land-cover data and the use of aerial photographs to identify and map drainage ditches. We have also collected a large number of peat cores, which are being used to measure rates of peat accumulation over the last century as a function of land-use.

2.2.1 Key results from Year 2 include:

- A new unified peat map has been defined for the GMEP project which should allow a more reliable assessment of the state of the Welsh peat resource as a whole, with better representation of lowland peats, and more accurate targeting of Glastir peat soil-related options on those areas where peats are present (Figure 17).

- This map has now been passed to Glastir Contract Managers to use when negotiating new Glastir Agreements.

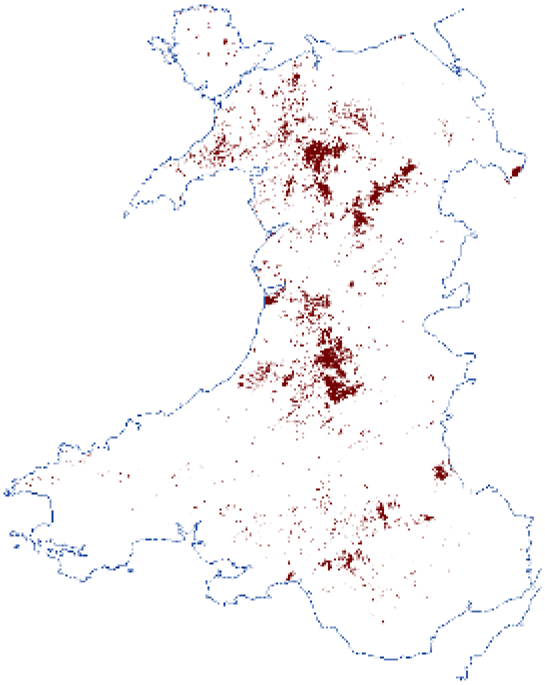


Figure 2.2.1.1 *A unified peat map for Wales, based on combined BGS and NRW data*

- Based on this new 'unified' Welsh peat map developed, peat soils are estimated to cover over 90,000 ha of Wales (4.3% of the total land area) of which 75% is in upland areas, and 25% in lowland areas
- Digital processing of aerial photographs suggests that there are at least 3,000 km of drainage ditches on peat soil in Wales
- Overall, around three quarters of the Welsh peat soil area is thought to have been impacted by one or more land-use activity, including drainage, overgrazing, conversion to grassland and afforestation with only 30% in 'good condition' with 25% 'modified' into grassland and 10% into woodland.
- As a result of these activities, Welsh peat soils are currently estimated to be generating 'anthropogenic' emissions of around 400 kt CO_2-equivalents per year (equating to around 7% of all Welsh transport-related emissions). This compares to an estimated natural 'reference' condition (i.e. if all the currently mapped peat area was natural bog or fen) of approximately 140 kt CO_2-eq yr^{-1} (Figure18).This indicates that natural peat soils are net emitters of greenhouse gas equivalents primarily due to the radiative power of methane. They store carbon overall if in good condition (or peat would not accumulate) and it is the protection of this carbon store and avoidance of emissions which is the objective Glastir can contribute to. As Glastir payments are targeted on semi-improved peats only, the potential emission reductions which could be achieved if all semi-improved peat soils could be returned to the reference state is estimated at 150 kt CO_2-eq yr^{-1}.
- Between 1990 and 2007 there was a decline in species richness in blanket bogs, but a slight increase in the number of characteristic ('positive indicator') bog species (positive CSM indicators).
- Fifty peat cores have now been collected from around Wales in order to measure how much CO_2 Welsh peats were able to sequester in the past, and how much this has been affected by recent agricultural management and forestry.

- Our recommendation is that these new findings should be used to revise the scheme as it goes forward to maximise benefits of Glastir payments for emission reduction from peat soils.

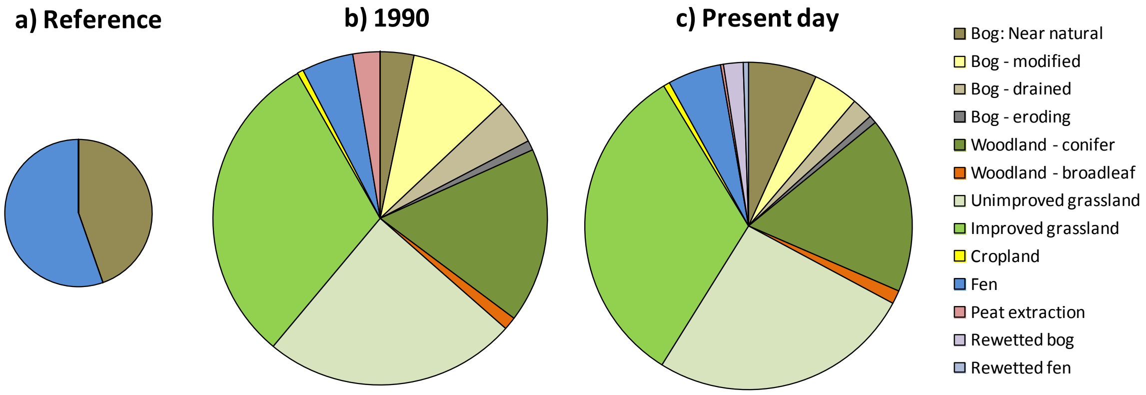


Figure 2.2.1.2 *The estimated contribution of different peat land-use/condition categories to total greenhouse gas emissions from Welsh peats under a natural 'reference' condition, in 1990, and at present day. The size of each pie chart is illustrative of the overall level of emissions.*

2.3 Methods

2.3.1 Peat extent and condition mapping

A new 'unified' peat map for Wales was generated by combining peat extent data from the British Geological Survey superficial geology map, together with Natural Resources Wales (NRW) data from: i) the Phase 1 Habitat Survey, where the vegetation present was strongly indicative of peat occurrence; ii) the Lowland Peat Survey; and iii) soil surveys undertaken by the former Forestry Commission Wales. The four datasets were combined into a single peat layer, with the presence of peat in any one of the four layers taken to indicate the presence of peat at that location. The condition of this peat area was then assessed using data from a number of sources. The NRW Phase 1 dataset provided the base vegetation layer, which was aggregated into a smaller number of broad categories (e.g. near-natural bog, modified bog, unimproved grassland, improved grassland) indicative of peat condition. In addition, aerial photography data (visible and near infra red) were obtained and analysed for a large part of the total peat area (approximately 75% of upland peats and 25% of lowland peats) in order to map the extent of drainage ditches. A linear feature extraction tool (PCI Geomatica LINE function) was used to identify areas containing drainage features, which were then manually digitised. The resulting drainage map was then overlaid on the land-cover map, and buffers were created around the ditches to represent the overall drainage-affected area within each land-use category (varying from 10m in upland blanket bog to 50 m in lowland fens and raised bogs). For peat areas under forestry (where ditches could not be mapped from aerial photography), as well as intensive grassland and arable land, we assumed that 100% of the area under that land-use was drained. For peat areas not covered by the air photos processed we assumed the same ditch density for unmapped areas as for mapped areas in the same land-use category. Finally, we produced initial maps and estimates of GHG emissions associated with each land-use/drainage class using Tier 2 'emission factors' (i.e. net GHG emissions in tonnes CO_2-equivalent per hectare per year) for each land-use class, derived from a combination of the IPCC Wetland Supplement (IPCC, 2013) and ongoing work for the UK Peatland Code (Smyth et al., 2014), following a method recently applied for Peat Soils GHG accounting for the UK Department of Energy and Climate Change (Evans et al., 2014)

2.3.2 Peat core carbon accumulation rates

Fifty peat cores were collected from four of the largest blanket bog areas in Wales; the Migneint and Berwyn areas in North Wales, and the Elenydd and Plynlimon in the Cambrian Mountains, South Wales. Intact 50 cm cores were collected from areas where land-management effects appeared minimal, and additional cores from areas affected by different management activities including drainage, grazing, burning and conifer afforestation. Cores were cut into thin layers, and the carbon content of each layer was measured. The layers were then dated using a combination of methods. For all cores, the number of Spherical Carbonaceous Particles (SCPs) in each layer were recorded; these are produced by coal burning power stations and the appearance and peaks of SCPs in the peat can be linked to fixed dates. A subset of cores were also analysed for levels of the radioactive isotopes of a range of metals including lead (which is produced by natural processes and provides an indication of peat age) and caesium (which peaked following the Chernobyl nuclear accident in 1986, and therefore provides a 'fixed date' in the record). Using these measurements, it was possible to calculate the rate of peat formation, and associated carbon accumulation, over the last century, and to examine who this has changed over time and in response to land-management activities.

2.4 Results

2.4.1 Where does peat occur in Wales?

The new unified peat map of Wales (Figure 2.4.1.1) highlights the geographical spread of Peat Soils across Wales. Although the largest concentrations of peat occur as blanket bog in the uplands of North and Central Wales, substantial areas of peat also occur in the uplands of South Wales, and in many more lowland areas such as Penllŷn, Anglesey, coastal Ceredigion, Pembrokeshire and Carmarthenshire. Overall, the area of peat in Wales is estimated at 90,200 ha, of which around 75% is found in the uplands (defined by NRW's 'Upland Boundary', based on habitat type) and 25% in the lowlands. As illustrated by Figure 2.4.1.1, a large part of the total peat area is located within relatively small units scattered across a wide area. This is significant, because smaller peat areas, particularly in the lowlands, are more susceptible to human modification through drainage and land-use change than larger upland blanket bogs, and are also more challenging to manage and monitor. In addition, previous assessments of peat extent in Wales (as well as the current Glastir target area for peat restoration) have largely been based on the Soil Survey of England and Wales (SSEW) 1:250,000 scale data from Cranfield University, which is at a coarser resolution than the new dataset, more reliant on landscape interpretation rather than ground survey, and which aggregates peat areas into larger aggregated 'soil associations' containing more than one soil type. This approach tends to increase the apparent area of peat in areas where it is the main soil type (e.g. upland blanket bogs containing smaller areas of other soils, which are mapped as a single 'peat' association) whereas it decreases the apparent area of peat in areas where it is a smaller component of the landscape (e.g. lowland areas where small areas of peat occur within larger areas of mineral soil). Whilst this approach provides a pragmatic means to represent heterogeneous soils at a broad spatial scale, it is prone to misinterpretation, and problematic for peat condition assessment because the location of peat units within larger soil associations is unknown, and land-use/condition data cannot therefore be overlaid. The new unified peat map should allow a more reliable assessment of the state of the Welsh peat resource as a whole, with better representation of lowland peats, and more accurate targeting of Glastir Peat Soils related options on those areas where peats are present. We recommend that the unified peat map should be used to derive a new target area for peat restoration, although (as with all maps) allowance should be made for uncertainties, and the presence or absence of peat at a specific location should be confirmed via ground-based survey before options are implemented.

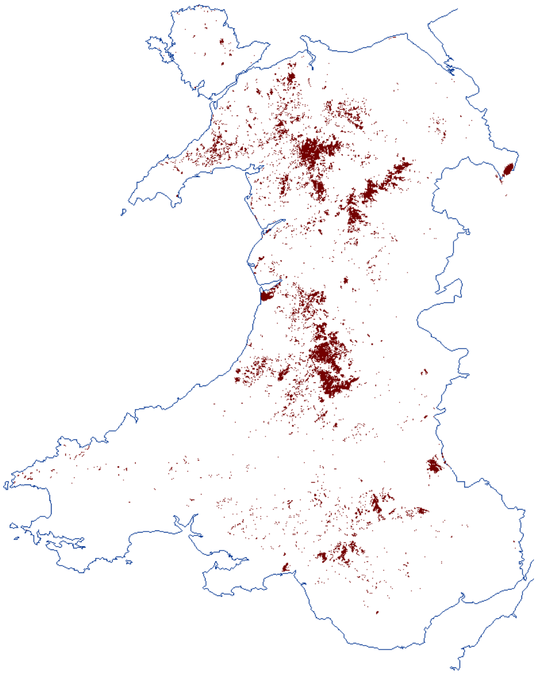


Figure 2.4.1.1 *A unified peat map for Wales, based on combined BGS and NRW data*

2.4.2. What are the current impacts of land-use on Welsh Peat Soils?

An initial classification of Welsh Peat Soils, based on the unified peat map and aggregated data from the NRW Phase 1 Habitat Survey, is shown in Table 2.4.2.1. This suggests that around 30% of the total peat area can be classified as 'good condition', around 90% of which is bog (mainly in the uplands), and the remainder fen (mainly in the lowlands). Although relatively small areas are defined as 'poor condition (e.g. eroding blanket bog), large areas of the total extent of both bog and fen are 'modified' (i.e. subject to vegetation changes such as encroachment of purple moor grass onto blanket bog, which may be linked to over-grazing), and other areas have been subject to conversion to heathland, grassland or woodland. Around a quarter of the overall peat area has been classified as grassland, with unimproved grassland prevalent in the uplands, and more intensive pasture types (improved, semi-improved and marshy grassland) having a disproportionately large impact on lowland peats. Overall, around half of all lowland peats are believed to be under grassland. On the other hand (and in contrast to areas such as East Anglia) the amount of arable land on peat in Wales is minimal. Just over 10% of Welsh Peat Soils are under woodland, of which the vast majority (> 90%) is under conifer, primarily large upland plantations. Scrub and broadleaf woodland on peat occur almost entirely in the lowlands, generally as small areas on the margins of lowland fens and raised bogs.

	Peat areas (ha)			*Area (%)*
Aggregated land cover	Upland	Lowland	Total	
Bog - good condition	22,324	1,683	24,007	*26.6%*
Bog - modified	19,438	2,094	21,532	*23.9%*
Bog - poor condition	221	5	226	*0.3%*
Fen - good condition	1,157	1,835	2,992	*3.3%*
Fen - modified	105	1,288	1,392	*1.5%*
Fen - poor condition	1	1	2	*0.0%*
Wet heath	1,978	391	2,369	*2.6%*
Dry heath	3,855	322	4,177	*4.6%*
Bracken	308	141	449	*0.5%*
Marshy grassland	3,569	3,563	7,132	*7.9%*
Unimproved grassland	6,758	490	7,247	*8.0%*
Semi-improved grassland	216	1,093	1,308	*1.4%*
Improved grassland	306	6,276	6,582	*7.3%*
Arable	1	101	102	*0.1%*
Scrub and broadleaf	26	920	946	*1.0%*
Conifer	6,892	1,682	8,574	*9.5%*
Other	540	658	1,198	*1.3%*
Total	*67,695*	*22,540*	*90,235*	

Table 2.4.2.1 *Aggregated peat land-use and condition classification for Welsh peats, aggregated from NRW Phase 1 data for Wales overlaid on the unified peat map, and subdivided into upland and lowland areas based on the NRW Upland Boundary.*

2.4.3. How much of the Welsh Peat Soils area has been affected by drainage?

Drainage of Peat Soils occurred during the 19th and 20th centuries, with the aim of changing the natural vegetation cover (e.g. to increase grass cover to support grazing in the uplands, or as part of grouse moor management) or as part of land-use changes such as conversion to intensive grassland or forestry plantation. However, draining Peat Soils exposes previously waterlogged peat to oxygen, increasing decomposition rates and potentially causing the Peat Soils to switch from a CO_2 sink to a CO_2 source. Although drainage is known to have been extensive in Wales, until now no detailed, national-scale information has been available. Based on the aerial photograph analysis undertaken for GMEP, we now have detailed maps of drainage extent and intensity for the majority of the Welsh Peat Soils area. Figure 2.4.3.1 shows an example of the extent of drainage ditches at the Cors Fochno raised bog, adjacent to the Dyfi estuary, with a range of buffer distances around each digitised ditch illustrating the potential impact on the overall peat area.

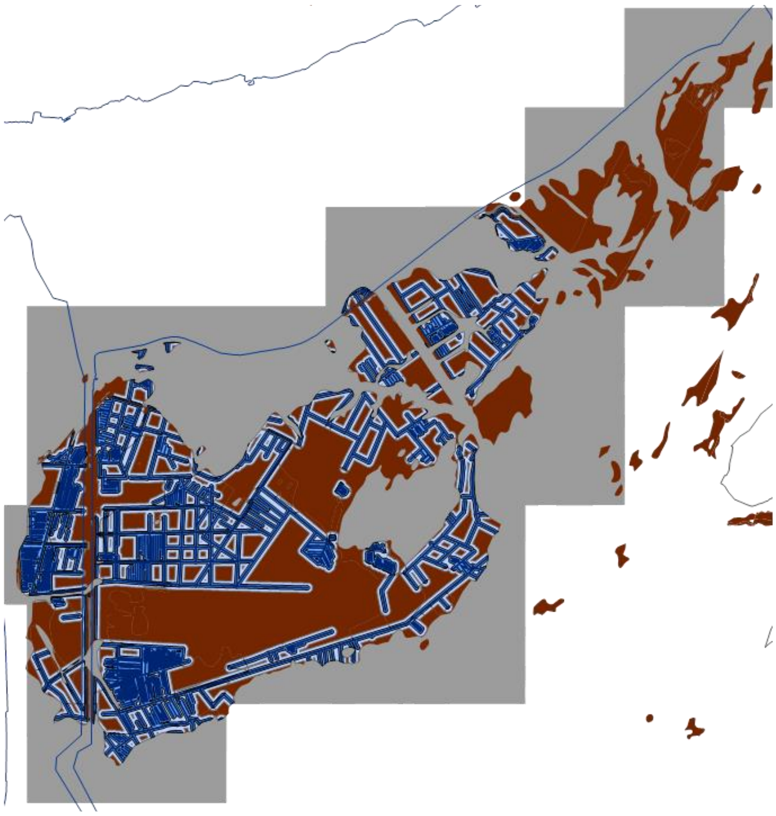


Figure 2.4.3.1 *Example ditch map for the Cors Fochno lowland raised bog complex, Dyfi estuary. The brown area shows the extent of Peat Soils, grey 'tiles' show areas within which ditches have been digitised from aerial photographs, and blue shading shows a range of buffer distances (i.e. assumed drainage impacts) around each ditch, from 10 m (dark blue) to 50 m (light blue).*

Overall, air photos capturing 73% of the upland peat area and 29% of the lowland peat area were processed. Within this area, a total of 1,810 km of ditches were digitised (1,502 km in the uplands and 209 km in the lowlands). It should be noted that the extraction of ditch features from air photos is subject to an inevitable degree of error (e.g. where ditches are not visible below vegetation canopies, or where other linear features such as paths or walls are mis-categorised). However, comparison of digitised ditch layers with NRW ground surveys showed generally good correspondence. It is also worth noting that a considerable length of ditches (1,334) was mapped in areas not classified as peat, indicating that drainage has also significantly affected other soil types, such as peaty gleys.

2.4.4. How much CO_2 can a blanket bog sequester?

In the past, peat formation processes sequestered CO_2 from the atmosphere and locked it up into the soil, which had a cooling effect on the earth's climate. In some areas this process continues, whilst in others it has been reduced or even reversed due to land-management, potentially leading to the emission to the atmosphere of carbon that has been stored for thousands of years. For the range of Welsh blanket bogs over which cores have been collected, the results suggest that in the 19th century these sites were accumulating in the region of 1.5 tonnes of CO_2 per hectare per year through the active formation of new peat. Since that time, many Welsh Peat Soils have been subject to land-use changes such as ditching, afforestation, intensification of grazing and managed burning for red grouse, which have either reduced the cover of peat-forming plant species such as *Sphagnum* mosses, or lowered the water table in the (naturally waterlogged) peat, allowing it to decompose more rapidly.

Preliminary results (Figure 2.4.4.1) suggest that some of these management activities have had a significant effect on rates of peat CO_2 sequestration. In particular, carbon accumulation rates in areas affected by drainage appear to have declined sharply, suggesting that these areas are less able to sequester CO_2 from the atmosphere than before, and could now be sources of CO_2 to the atmosphere. It appears that afforestation may have increased the amount of carbon being added to the peat surface as forest needles, whilst also causing a loss older carbon from the peat itself as drainage ditches have lowered water tables and allowed decomposition rates to increase. Work on these data is ongoing, with the aim of producing new estimates of the overall carbon balance of Welsh blanket bogs under different land-management in order to provide a better understanding of the benefits of Glastir options for soil carbon sequestration, and to improve national-scale greenhouse gas accounting.

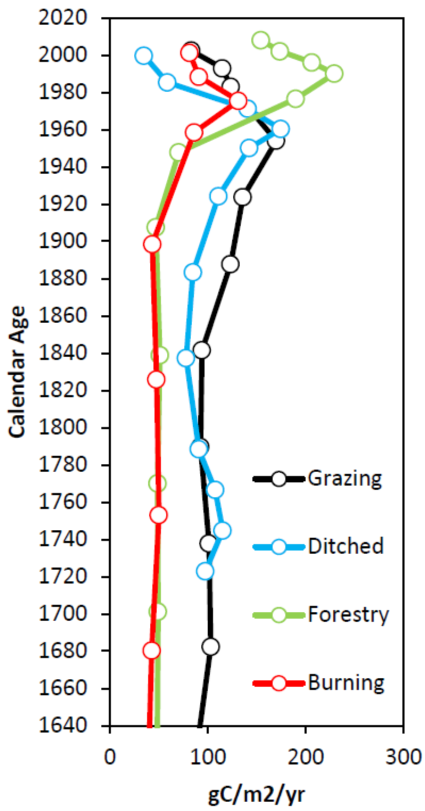


Figure 2.4.4.1 *Average measured rates of carbon accumulation over time for peat cores collected from Welsh blanket bogs under different land-management types. Note that, in a natural system, the 'apparent' rate of carbon accumulation should increase towards the surface, because the recently-formed material near the surface has had less time to decompose than peat which was formed longer ago.*

2.4.5. What is the current contribution of Welsh Peat Soils to greenhouse gas emissions?

Using the spatial data collated for GMEP as described above, together with 'emission factors' developed under other projects, we have been able to generate the first, national-scale maps of greenhouse gas (GHG) emissions from Peat Soils anywhere in the UK. An example emissions map is shown for the Cors Fochno raised bog complex in Figure 2.4.4.1 This shows low emissions from the surviving area of semi-natural bog vegetation in the southwest part of the peat area, with higher emissions where this is intersected by drainage ditches. Wooded areas are associated with higher emissions from the peat (the map does not take account of CO2 uptake into tree biomass), whilst areas of drained and improved grassland around the fringes of the raised bog have high GHG emissions. Note that even areas of intact raised bog are estimated to be small net GHG emissions sources, due to emissions of methane, a powerful greenhouse gas, from the wet peat. However, because these areas of intact Peat Soils vegetation are continuing to sequester CO2 through peat formation they make a make a much smaller contribution to GHG emissions than drained and modified Peat Soils, and will have a net cooling effect on the climate over longer time periods.

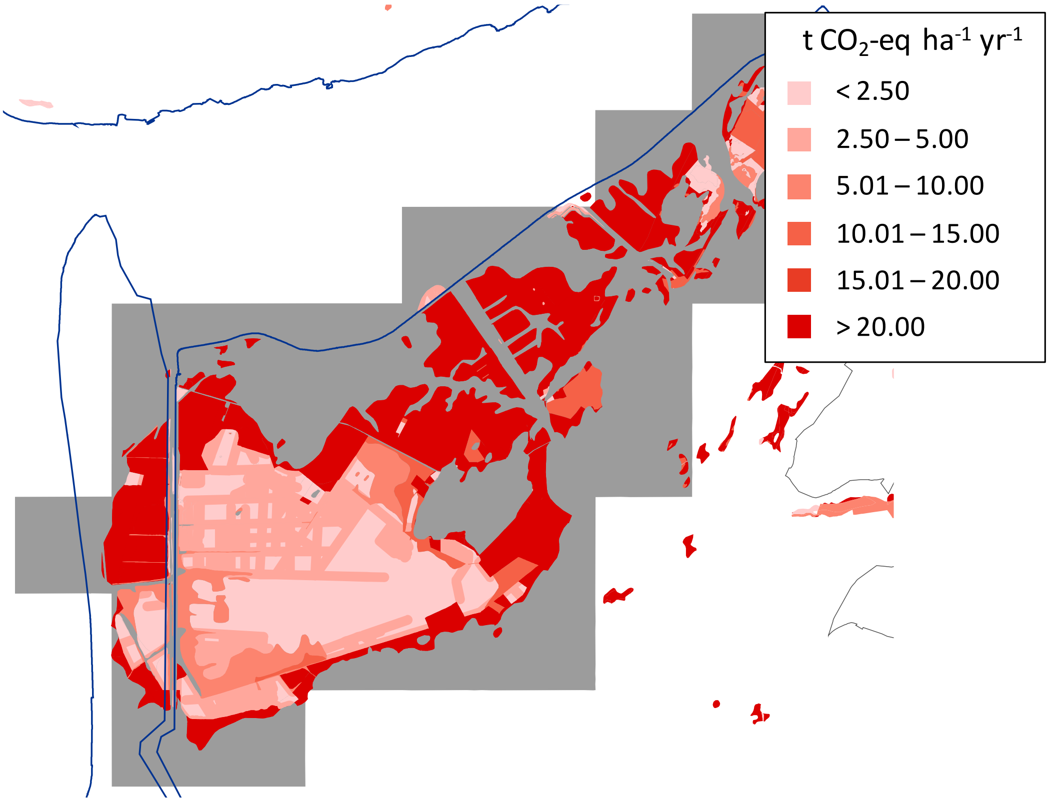


Figure 2.4.5.1 *Example of estimated greenhouse gas emissions for the Cors Fochno, based on the unified peat map, Phase 1 land-cover categories and digitised ditch map. Grey 'tiles' show areas within which ditches have been digitised from aerial photographs.*

Scaling this analysis up to the full Peat Soils area, as defined by the unified peat map, suggests that total GHG emissions from Welsh Peat Soils are currently in the region of 550 kt CO_2-eq yr^{-1}. Of this total emission, 59% is associated with CO_2 emissions (including 'indirect' emissions from dissolved and particulate organic carbon), most of which is derived from drained areas. Around 37% of the total GHG emissions are in the form of CH_4, mainly from undrained and re-wetted bogs and fens (which are therefore mainly of natural rather than anthropogenic origin) with the remaining 4% as N_2O, primarily from improved grasslands. This present-day emission compares to estimated natural emissions from Welsh Peat Soils (i.e. is all the currently mapped peat area was natural bog or fen) of approximately 140 kt CO_2-eq yr^{-1}, which represents the balance of natural CO_2 sequestration and natural CH_4 emissions. The present-day estimate takes account of the estimated changes in emissions that have occurred since 1990 as a result of drain-blocking restoration work that has taken place (primarily on upland blanket bogs) during this time, and of the area of upland bog that was subject to grazing reductions under Tir Gofal. This assessment, which was made as part of an initial assessment of Welsh GHG emissions for the Department of Energy and Climate Change (Evans et al., 2014) assumes that all peat re-wetting projects were effective, and that the grazing options implemented under Tir Gofal were sufficient to convert blanket bog from 'modified' to 'near-natural' status. Based on results from GMEP, it should be possible to test these assumptions in future. Comparing estimated present-day emissions to natural 'reference' emissions suggests a maximum climate mitigation potential (if all Welsh Peat Soils were returned to near-natural condition) of around 300 kt CO_2-eq yr^{-1}.

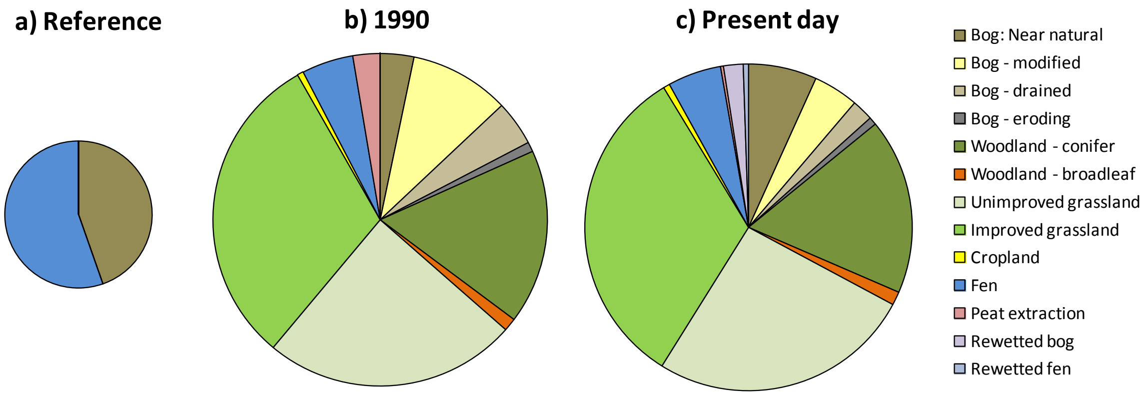


Figure 2.4.5.2 *The estimated contribution of different peat land-use/condition categories to total greenhouse gas emissions from Welsh peats under a natural 'reference' condition, in 1990, and at present day. The size of each pie chart is illustrative of the overall level of emissions.*

Figure 2.4.5.2 illustrates the contribution of different land-use/peat condition categories to total emissions. For Welsh Peat Soils as a whole, the main sources of GHG emissions are believed to be improved and unimproved grassland on peat (58% of all emissions), followed by conifer plantations (17%). Drained, modified and eroding bogs are estimated to have contributed around 15% of GHG emissions in 1990, reducing to around 7% at the present time as a result of restoration and agri-environment options. However it is important to note that the latter figure carries a large uncertainty as it assumes a high success rate for the restoration options undertaken, which may not have been achieved in reality. However, it does make allowance for the likelihood that re-wetted bogs may emit slightly more CH_4 and sequester slightly less CO_2 than natural bogs, at least in the initial post-restoration period. Furthermore, it is worth noting that gains achieved through grazing options may be delayed due to lags in ecosystem recovery, or temporary if grazing controls are not maintained under subsequent agri-environment schemes.

Finally, it is worth noting that the total anthropogenic emissions derived from this assessment (and hence the maximum future climate mitigation potential) are somewhat larger than previous estimates that have been made using a similar methodology, but less detailed spatial data (ADAS, 2014; Evans et al., 2014). The main differences arise from the use of NRW Phase 1 data in this assessment, rather than the CEH Land Cover Map 2007 (which gave a smaller area of grassland on peat) in the previous assessments, and also the absence of detailed data on drainage ditch extent in the previous analyses. Considerable uncertainty still remains in the current assessment, however, particularly in relation to the quantification of emissions from grassland, modified bog and drained fen, which are all currently based on very limited field emissions measurements, in some cases from quite dissimilar habitats such as drained grasslands in the Netherlands and Germany. New data based on UK measurements will be used to revise the current emission factors used in the assessment, and therefore the overall emissions estimates.

2.5 Future plans

The peat condition assessment work for GMEP is ongoing, and should lead to further improvements in the mapping of Welsh Peat Soils in future. Specifically, aerial photographs are currently being used to remotely map peat vegetation, in particular the extent of purple moor grass (*Molinia caerulea*) on blanket bogs, which has a detrimental impact on habitat condition and may contribute to increased GHG emissions. The analysis of peat core data will continue during Year 3 of GMEP, with the aim of quantifying rates of carbon accumulation in blanket bog in relation to its management. By relating historical rates of peat accumulation to the vegetation community, we aim to develop a method that will allow data collected during GMEP vegetation surveys to be used to estimate rates of current carbon accumulation, and therefore to monitor changes in Peat Soils carbon sequestration over time in response to Glastir options. These results should also (along with new flux measurements being made in other ongoing projects) enable us to refine the current emission factors for a range of peat condition categories, and subsequently to refine the emissions maps and national estimates described above.

In addition, the peat condition assessment being undertaken for GMEP is contributing directly to an ongoing UK-wide project, funded by the Department of Energy and Climate Change, to develop methods to account for GHG emissions from Peat Soils and other wetlands across the UK. This should ultimately enable Peat Soils emissions to be included in national greenhouse gas accounts, and in reporting to international frameworks such as the Kyoto Protocol. The work is also supporting the UK Peatland Code, a ‘Payment for Ecosystem Services’ scheme designed to facilitate investment in peat restoration by recognising and quantifying the climate mitigation benefits this delivers. By quantifying these benefits, it should be possible to develop and target future Glastir options in order to optimise the use of resources, and to maximise the climate mitigation benefits that can be delivered through the scheme.

3 Socio-Economic Benefits

Swetnam, R. D.[1], Smith, G. R.[1], Prochorskaite, A.[1], Scott, L.[2]Walker-Springett, K.[3], Parkhill, K.A.[3], Taft, H.[3], Cross, P.[3], Chadwick, D.[3]

[1]Staffordshire University; [2] Ecorys Ltd; [3]Bangor University.

3.1 Introduction

GMEP undertakes a range of activities to capture the wider socio-economic benefits of the Glastir scheme. These benefits may arise from a range of Glastir activities including payments from farmers into the local community for labour or services to more indirect pathways such as an improved visual landscape quality which has the potential to benefit both local communities and the tourism industry. More generally it is hoped the greater protection of our natural resources intended from Glastir payments will contribute to the 'Resilient Wales' Goal of the Well-being and Future Generations Bill.

Activities in this area in Year 2 have included:

- An assessment of the benefits of the Glastir Efficiency Grants to the wider community and the potential impacts on farm carbon footprints;
- Understanding the barriers to uptake of the Woodland Creation Scheme
- Developing objective, transparent and repeatable measures for assessing the visual landscape quality to enable the impact of Glastir to be assessed in the future
- Quantifying accessibility the landscape both in terms of physical accessibility through the Public Rights of Way network (PROW) and a derived measure of visual accessibility which takes account of the view as experienced by the public within the landscape.
- Continued assessment of the condition of the historic assets present such that future impacts of Glastir can be assessed.

3.2 Major achievements in Year 2

- We planned the approach for assessing the impact of Glastir Efficiency grants on i) the carbon footprint of farms which have made use of them, and ii) the wider (off-farm) benefits to the rural economy
- A GMEP Visual Quality Index (VQI) has now been successfully run on the 150 1st and 2nd year GMEP 1km survey squares. This has generated a data listing all of the 23 input parameters by square and weighted index values for each. Each of the survey squares has now been ranked from 1 (highest quality index) to 150 (lowest quality index).
- Viewshed analysis has been completed at 3 scales for 150 1st and 2nd year 1km survey squares using 4 different categories of users (pedestrians, cyclists, small vehicle users, rail users) for 3 different scales: looking within the GMEP 1km survey square, looking out to the surrounding 3 x 3 km, looking in from the surrounding 3 x 3 km square. This equates to 1800 separate viewshed datasets for the two years.
- Condition assessment data collected for the historic environment features of the 150 1st and 2nd year GMEP 1km survey squares.
- Number and condition of Public Rights of Ways in the Year 2 GMEP 1km survey squares have been assessed.
- Photographic preference survey pilot undertaken early spring 2014, the online survey was then refined and launched summer 2014 with both English and Welsh versions available. Currently, over 1360 surveys have been completed online with approximately 10% of these completed in Welsh. The PPS has validated the VQI ranking process and has provided further information about the positive and negative impacts of specific components of the VQI. Our initial target was 500 completed surveys, so this has exceeded our expectations significantly and has generated a dataset of wider significance and value.

3.3 Key Findings in year 2

3.3.1 Wider Socio-Economic Effects of Glastir Efficiency Scheme Grants

More than 90% of respondents agreed that Glastir Efficiency Grants (GEGs) had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GEGs increased their scale of planned investment. Over 87% of farmers agreed that their funded project would not have happened without the grant, suggesting that GEGs has provided a useful tool for delivering economic development and encouraging new on-farm initiatives.

Increased farm expenditure was spent within Welsh industries (68%), Welsh households (18%) and taxes (8%) with the remaining 6% unaccounted for due to respondent survey error. Of the expenditure that respondents allocated to imported materials, the majority was for building materials (49%), and machinery and equipment (32%). Of these imports, 57% of spending was within the UK and Ireland; 8% reported a mixture of spending throughout the UK and European countries and 13% imported products from other European countries.

According to 71% of respondents, GEGs grants have promoted a beneficial effect on farm suppliers across all farm types. Similarly, 44% of respondents stated that farm customers and clients had experienced beneficial financial effects from the grants.

3.3.2 Understanding Barriers to Uptake of Woodland Creation Schemes

Results indicated that the process is perceived to undermine the scheme objectives and acts as a disincentive for potential scheme members from both the farming community and the Local Authorities. Recommendations to improve uptake include:

- To achieve greater scheme uptake the application process should be simplified.
- The scheme needs to be more flexible to account for external influences.
- The auditing process needs to be less threatening, and penalties need to be clearly communicated to encourage greater uptake.
- Payment rates need to be clarified to encourage potential members to adopt the scheme.

3.3.3 The range of VQI across the Welsh landscape

- There is no significant difference in VQI between upland and lowland sites. However, the upland landscapes have a smaller range of VQI values and a higher overall median value which indicates that they tend not to include the lowest quality landscapes. It is only where a range of positive values coincide that very high landscape quality scores prevail.
- There is no statistical difference between the mean quality ratings assigned to the GMEP 1km survey square which fall within / without of a protected area. However, there are clear differences in the range of values, with all the highest values falling into protected areas.
- No relationship is shown between the landscape quality rating and the number of plant, bird, butterfly or bee species was present in the GMEP Year 1 and 2 1km survey squares suggesting there is no direct relationship between ecological and landscape quality as indicated by these initial test metrics. A more systematic and integrated approach, e.g. using the High Nature Value Farmland index currently under development, will be assessed in future years which will also benefit from a greater sample size.
- Sites which contained areas of Glastir land were compared against those with none. Although there was some indication that those sites with higher VQI values were found within the Glastir managed scheme, the results were not significant to date. Again as more squares are surveyed this trend may become clearer. A photographic preference survey undertaken by over 2600 people identified surprisingly few differences between people’s preference for landscapes depending on gender, age, nationality, type of location of birth or current home.

3.3.4 Access

Of the GMEP first and second year sites, the digital data show that 133 of the 150 contained some Public Rights of Way. Two-thirds of the paths on a 1km site were fully open, physically accessible and easy to find. For the remainder, poor signage was common and many footpaths were infrequently used as a consequence which led to degradation and poor maintenance.

3.3.5 Condition of historic features

Within the 150 GMEP 1km survey squares of the first and second year survey, it has been possible to survey around 120 historic features. The most common types of feature were buildings (including houses and cottages), ponds and quarries. An assessment of condition shows that 8% were judged to be in excellent condition at the time of survey and 35% were seen to be sound with minor defects. However, 33% were assessed to be showing major signs of deterioration while a further 7% were seen to have significant damage. Vegetation was the most prevalent threat.
These findings are outlined in more detail below structured by activity.

3.4 Wider Socio-Economic Effects of Glastir Efficiency Scheme Grants

Grants are available to farmers via the Glastir Efficiency Scheme (GES), previously known as the Agricultural Carbon Reduction and Efficiency Scheme (ACRES). The GES provides grants to farmers and land managers to improve farm management, particularly to improve Slurry and Manure Efficiency (SME), Energy Efficiency (EE) and Water Efficiency options (WE). Through these grants, GES aims to reduce greenhouse gas emissions from the agriculture sector, and in particular, the dairy sector. As part of the GMEP project, we have evaluated what grants have been spent on, as well as the socio-economic impact of the scheme at a regional scale. In 2013, a questionnaire was designed and used to collate information from farmers who had been successful with GES applications. There is interest within the Welsh Government to identify the wider benefits of Glastir beyond the landowner in receipt of the payment. A survey was carried out to explore the wider benefits of the Glastir Efficiency Grants as a case study to explore this issue.

3.4.1 Methods

Questionnaires were completed by 120 farmers whose applications for a Glastir Efficiency Scheme grant had been approved. Information was collected about what the grant had been used for, where the money had been spent, the effects the grant had had on labour, as well collecting farm characteristics.

We also evaluated the potential efficacy of the Glastir Efficiency Scheme for reducing carbon emissions across the Welsh livestock sector. The primary aims of this evaluation were to: i) Provide an average baseline carbon footprint for a representative cross-section of GES-participating farms, ii) Evaluate the potential within the Welsh agricultural sector for reducing GHG emissions through application of GES-funded technologies, and iii) Identify key aspects of farm footprints which may facilitate or inhibit the success of the Glastir Efficiency Scheme. To achieve this, twenty farms (of those farms that had been successful with GES applications) were contacted by project officers and interviewed face to face. A questionnaire was used as a script for obtaining the necessary information for input into the Bangor Carbon Footprinting Tool. Since insufficient time had passed for any of the GES grants to have been fully implemented on-farm, farmers were asked to provide information representing one ‘typical’ business year within the period 2011 to 2013, to act as a baseline carbon footprint for future comparison.

3.4.2 Results

3.4.2.1 Grant Allocation (what have grants been spent on)

Of the 120 completed surveys, 59% of respondents farmed on LFA cattle and sheep farms, a further 30% on dairy farms, 7% of farms were described as ‘other’ consisting of various main farm types and

3% of farms did not specify. A total of 305 grants were approved for farms in the survey. Energy efficiency grants accounted for 9.2% of total approved grants, of which 7.9% were assigned to dairy farms, 1.3% to 'other' farms and none to LFA cattle and sheep. Grants awarded to LFA cattle and sheep farms were nearly all for slurry and manure efficiency (174 of the 179 approved grants). The total monetary value of the paid grants amounted to ca. £1 Million by the end of 2013. No water efficiency grants were in progress. Slurry and Manure Efficiency grants accounted for nearly 90% of the spend, with Energy Efficiency grants representing the remainder. Lowland dairy farms received the largest grant per farm (on average ca. £16,000), compared to average grants of between £8000 - £10,000 for LFA farms (cattle and sheep, and dairy).

A wider benefit of some of the Slurry and Manure Efficiency grants is the reduction in ammonia emissions that will result. Livestock manure is a key source of ammonia volatilisation from livestock systems, and represents an agronomic loss of nitrogen that would otherwise be recycled to land for grass and crop growth.

3.4.2.2 Wider Economic Effects of GES Grants

More than half of respondents reported the grants made no impact on all but two sectors of farm expenditure. Fertiliser annual expenditure was positively affected by the grants on 75% of farms (Figure 3.4.2.2.1). Labour expenditure was positively impacted in 50% of cases and contractor expenditure in 40% of cases. Negative impacts were reported by a minority of farmers (2-7%, depending on sector), with the largest negative impacts on contractors and building materials expenditures (6.7% of respondents in both cases), while the least frequently reported negative impact was for veterinary fees (1.7%).

More than 90% of respondents agreed that GES had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GES increased their scale of planned investment. Over 87% of farmers agreed that their funded project would not have happened without the grant. This suggests that GES has provided a useful tool for delivering economic development and encouraging new developments.

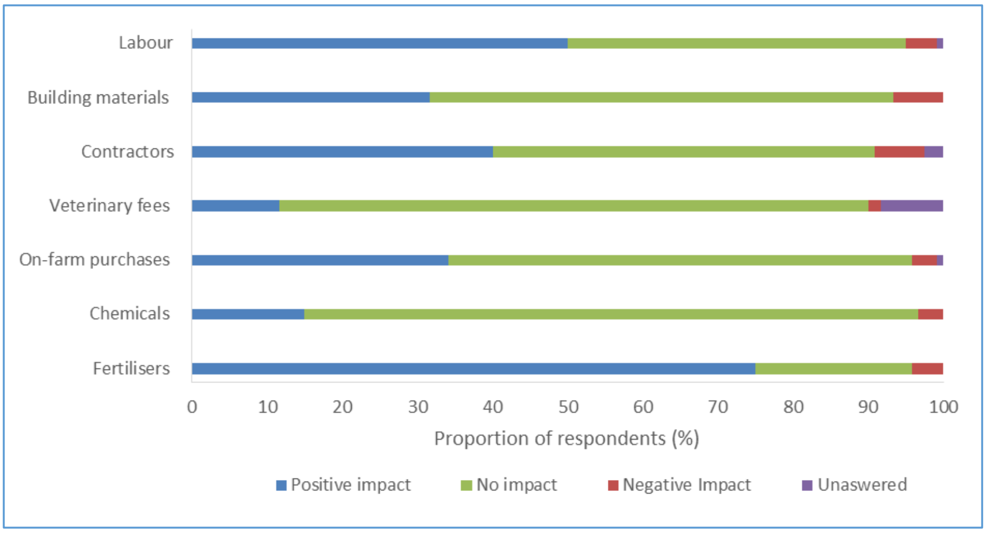


Figure 3.4.2.2.1 *Respondents' perception of grant impact on different sectors of on-farm expenditure.*

3.4.2.3 Where is Glastir Efficiency Scheme Grant Money Spent?

The increased expenditure provided by the grants was distributed primarily to Welsh industries (68%), with smaller quantities of money to Welsh households (18%), taxes and imports (9%; Figure 3.4.2.3.1). The majority of spending allocated to imports was for building materials (49%), and machinery and equipment (32%). Of the expenditure allocated to imports, 57% of farms' spent within the UK and Ireland; 8% reported a mixture of spending throughout the UK and European countries and 13% only imported products from other European countries.

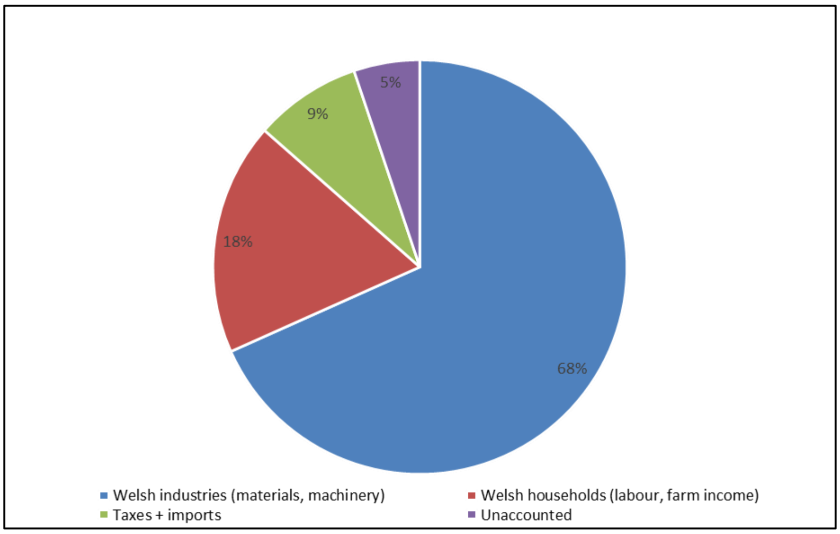


Figure 3.4.2.3.1 *Allocation of increased expenditure following receipt of GES grants.*

It is clear that the majority of the Glastir Efficiency Scheme grant money has been spent in Wales, with Welsh Industries and using Welsh labour, thus benefiting Welsh businesses and rural communities.

A comprehensive report on the wider socio-economic effects of Glastir Efficiency Scheme grants can be found as Appendix 3.3.

3.4.2.4 Effects of Glastir Efficiency Grants on Farm Carbon Footprints

The average estimated PAS-compliant footprint per hectare across all farms was 10,236.0 kg CO_2eq/ha/yr, and ranged from 2,385.1 kg CO_2eq /ha/yr to 18,987.2 kg CO_2eq /ha/yr. The average footprint per hectare on dairy farms (14,032.9 kg CO_2eq /ha/yr) was almost double that of LFA cattle and sheep farms (7,704.8 kg CO_2eq /ha/yr). Smaller farms (11,654.3 kg CO_2eq /ha/yr) averaged a higher footprint per ha of land than larger farms (7,602.0 kg CO_2eq /ha/yr).

The footprint of lamb for slaughter varied from 7.1 kg CO_2eq /kg LW to 29.0 kg CO_2eq /kg LW, and those for wool ranged from 2.8 kg CO_2eq /kg to 21.3 kg CO_2eq /kg. Dairy farms had a lower average footprint per kg lamb and wool than LFA cattle and sheep farms. Footprints for milk production per kg product ranged from 1.0 kg CO_2eq /kg for farms 50 to 199.9 ha in size to 2.2 kg CO_2eq /kg for farms > 200 ha in size.

The largest proportion of total emissions from all farms came from methane (CH_4) accounting for, on average 46.7% of emissions per ha. Methane emission rates correspond to the number of ruminant livestock, and were primarily a function of ruminant livestock enteric (gut) fermentation. Nitrous oxide (N_2O) accounted for, on average 24.5% of emissions. This was largely from direct emissions (from soil management, peaty soils, and manure handling) with the remainder coming from indirect emissions (N deposition, leaching and runoff on soils, and volatilisation from stored manure). Emissions from inputs averaged 27.6% of emissions per ha and were dominated by mineral N fertiliser, feed concentrates, and bought-in stock. The CO_2 footprint from liming was small on all farms, ranging from 0.5 kg C CO_2eq /ha/yr to 3.9 kg CO_2eq /ha/yr.

Very few statistically significant associations were found between footprints of livestock and farm size, stock numbers in winter and summer, or peat soils. Farm types could not be compared statistically due to small farm sample sizes within each typology.

Carbon sequestration ranged from 520.7 to 1,648.4 kg CO_2eq /ha/yr (averaging 1,026.2 kg CO_2eq /ha/yr). Most sequestration (average 80.2%, range 46.6-100%) was in the form of carbon storage in grassland soils. Woodland contributed on average 13.2% (ranging from a net carbon loss of 4.7% to a net carbon gain of 34.4% of whole farm sequestration). Isolated trees sequestered on average 4.8% (range, 0.5% to 21.1%), and hedges 6.6% (range, 0.4 to 25.6%). Farm type and size had a negligible effect on total sequestration per hectare.

The average carbon balance (total footprint minus sequestration) of the twenty farms was 9,209.7 kg CO_2eq ha/yr, varying from 1,102.6 to 17,913.2 kg CO_2eq /ha/yr. Sequestration accounted for an average of 15.1% of the emissions footprint, but this varied widely between 4.4% and 59.9% of farm emissions. None of the farms sequestered more carbon per hectare than their total footprint.

A detailed report of the *Evaluation of the potential efficacy of Glastir Efficiency Scheme for reducing carbon emissions across the Welsh livestock sector* can be found as Appendix 3.2.

3.4.3 Summary

- There is interest within the Welsh Government to identify the wider benefits of Glastir beyond the landowner in receipt of the payment. A survey was carried out to explore the wider benefits of the Glastir Efficiency Grants as a case study to explore this issue.
- A total of 305 grants were approved for farms in the survey (July 2014). Energy Efficiency grants accounted for 9.2% of total approved grants, 7.9% were assigned to dairy farms, 1.3% to 'other' farms and none to LFA cattle and sheep. Grants awarded to LFA cattle and sheep farms were nearly all for Slurry and Manure Efficiency (174 of the 179 approved grants).
- The total monetary value of the paid grants amounted to £1,006,490. No Water Efficiency grants were in progress by July 2014. Slurry and Manure Efficiency grants accounted for £883,000, and Energy Efficiency grants, £123,490.
- Lowland dairy farms received the largest grant per farm on average (£16,102), compared to £9,855 for LFA cattle and sheep farms and £8,732 for LFA dairy farms. The smallest size category of farms (0-19.9 ha) received the smallest average grant of £8,370.
- More than 90% of respondents agreed that Glastir Efficiency Grants (GEGs) had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GEGs increased their scale of planned investment. Over 87% of farmers agreed that their funded project would not have happened without the grant, suggesting that GEGs has provided a useful tool for delivering economic development and encouraging new on-farm initiatives.
- As a consequence of the GEGs grants more than a quarter (28%) of farm businesses reported a general increase in sales with 51% reporting an increase in sales from farming specifically.
- Increased farm expenditure was spent within Welsh industries (68%), Welsh households (18%) and taxes (8%) with the remaining 6% unaccounted for due to respondent survey error (Figure 3.4.3.1).
- Of the expenditure that respondents allocated to imported materials, the majority was for building materials (49%), and machinery and equipment (32%). Of these imports, 57% of spending was within the UK and Ireland; 8% reported a mixture of spending throughout the UK and European countries and 13% imported products from other European countries.

- According to 71% of respondents, GEGs grants have promoted a beneficial effect on farm suppliers across all farm types. Similarly, 44% of respondents stated that farm customers and clients had experienced beneficial financial effects from the grants.

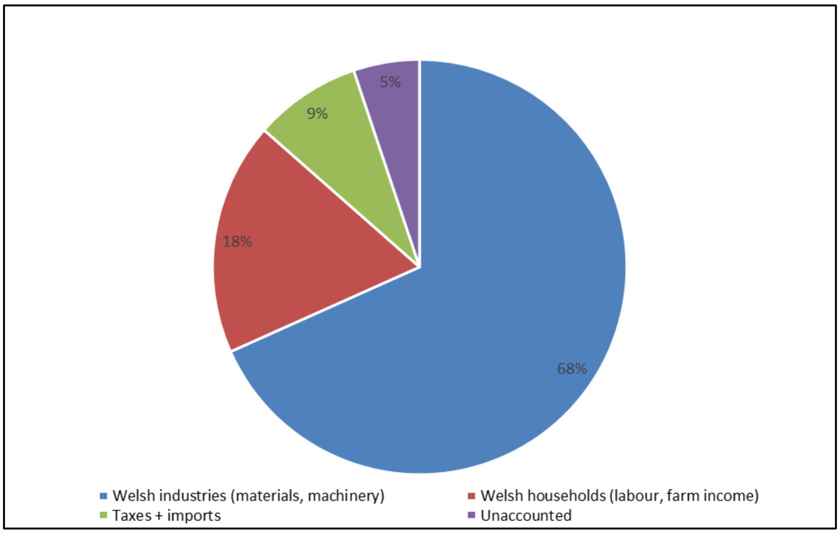


Figure 3.4.3.1 *Allocation of increased expenditure following receipt of GES grants.*

3.4.4 Potential Effects of Glastir Efficiency Scheme Grants on Farm Carbon Footprints

- Insufficient time had passed for farmers to implement GEGs grants on their farms to assess their effect on carbon footprints. Instead, this initial survey was used to establish a baseline year from which to compare carbon footprints after GEGs grants have been completed,
- The average estimated footprint per hectare across all farms was 10,236.0 kg CO_2eq/ha/yr, and ranged from 2,385.1 kg CO_2eq /ha/yr to 18,987.2 kg CO_2eq /ha/yr.
- The average footprint per hectare on dairy farms (14,032.9 kg CO_2eq /ha/yr) was almost double that of LFA cattle and sheep farms (7,704.8 kg CO_2eq /ha/yr).
- Smaller farms (11,654.3 kg CO_2eq /ha/yr) averaged a higher footprint per ha of land than larger farms (7,602.0 kg CO_2eq /ha/yr).
- Based on this study recommendations include:
    - Carbon footprinting to be repeated on the current sample of farms, at an appropriate point in time after construction and use of GES-funded capital items. This will allow a comparison between baseline emissions and emissions post-implementation, acting as an impact indicator of the scheme.
    - Prioritisation of further grant allocation to the dairy sector, subject to feasibility.
    - Prioritisation of further grant allocation in the SME category.
    - Avoid allocating soil aeration grants to farms where aeration would be conducted on peat soils.
    - Assessment of the impact of GES on ammonia volatilisation, as this is likely to be an important environmental and human health benefit of implementing some SME technologies.
    - The statistical trends in data illustrated in this report should be interpreted with caution, as the number of farms sampled within each category was too small to draw robust conclusions.

3.4.5 Recommendations

On the basis of this study's findings, we recommend the following:

- Carbon footprinting to be repeated on the current sample of farms, at an appropriate point in time after construction and use of GES-funded capital items. This will allow a comparison between baseline emissions and emissions post-implementation, acting as an impact indicator of the scheme.
- Prioritisation of further grant allocation to the dairy sector, subject to feasibility.
- Prioritisation of further grant allocation in the SME category.
- Avoid allocating soil aeration grants to farms where aeration would be conducted on peat soils.
- Assessment of the impact of GES on ammonia volatilisation, as this is likely to be an important environmental and human health benefit of implementing some SME technologies.
- The statistical trends in data illustrated in this report should be interpreted with caution, as the number of farms sampled within each category were too small to draw any robust conclusions from.

3.5 Understanding Barriers to Uptake of Woodland Creation Schemes

Woodlands provide a multitude of benefits, so WG wishes to significantly increase the area of woodland (by >30%) by 2030. Hence the Glastir Woodland Creation (WC) scheme and Woodland Management (WM) scheme were introduced to provide financial incentives to encourage more woodland planting by farmers in Wales. Both schemes sit within the wider Glastir Environmental Stewardship scheme, although the WC and WM are available to all farmers, i.e. there is no requirement to be part of the Glastir scheme.
Uptake of the Glastir WC and WM elements has been lower than expected triggering a concern that the ambitious Welsh Government target of increasing the woodland area by >30% by 2030 might not be met. Previous research indicates that there are a number of barriers for farmers (key landowners in Wales) in terms of creating woodlands including: conflict between the land required for food production and that for woodland creation, and a perceived division between the skills and knowledge required to manage agricultural land and forests, as well as economic disincentives.

3.5.1 Methods

As part of the GMEP project we set up four workshops with farmers (in Bangor, Wrexham, Newtown and Abergavenny), and interviewed staff in 14 Local Authorities to better understand the farmers' and Coed Cymru officers in Local Authorities perceptions of the challenges and benefits of the Glastir Woodland Creation and Woodland Management schemes, and identify barriers to help explain the low rate of uptake, as well as explore possible opportunities to encourage greater uptake of the schemes.

3.5.2 Results

The results of this study indicate little evidence of a conflict between land-use for agriculture and forestry. Contrary to previous published reports, famers across Wales appear to be open to woodland creation and appreciate the numerous on and off-site benefits associated with increased tree numbers. However, significant barriers exist in the form of the Glastir scheme process.

The process is perceived to undermine the scheme objectives and acts as a disincentive for potential scheme members from both the farming community and the Local Authorities. We conclude that a number of key elements are explored and adapted to encourage greater scheme uptake:

- The application process should be simplified. The complex nature of the scheme, e.g. operation prescriptions for size and width of woodland, is a barrier.

- The scheme needs to be more flexible to account for external influences. The scheme is perceived to be inflexible, e.g. not allowing postponement of activities due to weather conditions. Its inflexible rules represent a barrier to uptake.
- The auditing process is complex and includes penalties, e.g. withdrawal of Glastir payments, and therefore penalties need to be clearer and the auditing process needs to be less threatening, to encourage greater uptake.
- Payment rates are obscure, e.g. there is confusion about what is covered and rates for contractual labour are not included. These need to be made clearer to encourage potential members to adopt the scheme.

The full report on *Understanding barriers to uptake of Woodland creation schemes* can be found as Appendix 3.1.

3.5.3 Recommendations

- Woodland creation is an activity promoted by Glastir to increase carbon sequestration and thus reduce overall GHG emissions from the land sector. However, uptake of the scheme has been low and a GMEP survey was designed to identify the barriers to uptake.
- The results indicated that the process is perceived to undermine the scheme objectives and acts as a disincentive for potential scheme members from both the farming community and the Local Authorities.
- Recommendations to improve uptake include:
  - To achieve greater scheme uptake the application process should be simplified.
  - The scheme needs to be more flexible to account for external influences.
  - The auditing process needs to be less threatening, and penalties need to be clearly communicated to encourage greater uptake.
  - Payment rates need to be clarified to encourage potential members to adopt the scheme.

3.6 Visual Landscape Quality

For a relatively small nation, Wales contains a remarkably diverse range of landscapes; from the coasts to the moors, the farmed to the industrialised (Figure 3.6.1). It is a mountainous country with significant areas of land above 300m and a diverse range of important habitats including saltmarshes, woodlands, bogs and montane. The unique physical characteristics of the landscape which derive from its diverse topography, geology, soils and climate have all helped to create a valued cultural and historic landscape which encompasses farming, rural buildings, towns as well as unique historical sites and industrial archaeology. Though largely rural and dominated by pastoral farming, the country does have over 3.1 million residents (ONS, 2013), the majority of whom live within the urban conurbations of south Wales (Cardiff, Swansea) and along the north coast and the fringes of the Dee Estuary. These numbers are dwarfed by the 100 million day visits and an estimated 6 million overnight trips made to Wales by recreational visitors in 2013 (VisitBritain, 2015). These visitors are attracted to the country by high quality landscapes, particularly the three national parks of Snowdonia, the Brecon Beacons and the Pembrokeshire Coast.

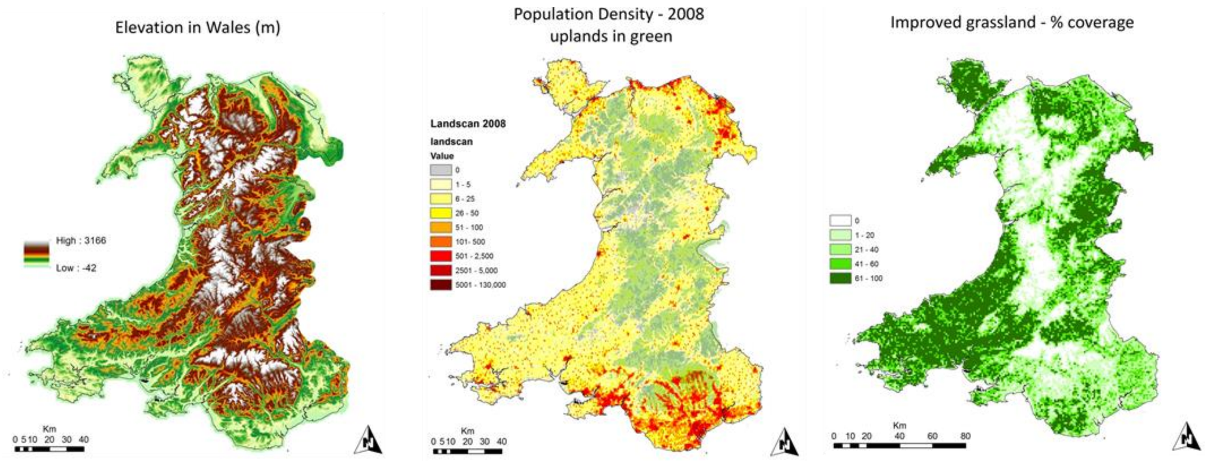


Figure 3.6.1 *Key physical and socio-economic characteristics of Wales which shape landscape character and quality: (L to R) elevation derived from 5m resolution terrain model; population density derived from the Landscan 2008 dataset; percentage coverage of improved grassland in each 1km derived from the CEH 2007 Land Cover Map.*

3.6.1 Landscape and Historic Environment as part of the Ecosystem Services Framework

Cultural ecosystem services include those non-material aspects of the natural environment which support societal needs for recreation and access to green space, alongside spiritual and religious enrichment (MEA, 2005). Indeed, the UK National Ecosystem Assessment of cultural ecosystem services outlines a myriad of contributions that natural landscapes make to our physical and mental well-being (Church *et al*., 2014).The need to both preserve our shared cultural heritage and have access to aesthetically pleasing natural environments is central to this concept and plays an important role in the shaping of GMEP. In Wales, there is a strong sense of “place-based identity” and the connections between the Welsh language, history, culture and physical environment have been enshrined in a number of policy documents, including the Welsh Government’s position statement on the historic environment (Cadw, 2012) and the Wales Landscape Partnership agenda for the protected landscapes of Wales (WLP, 2009).

3.6.2 Current Status and Trends

Overall, when averaged across the whole of the country, the habitats which define the Welsh landscape did not change significantly between 1998 and 2007 (Countryside Survey, 2007). This might imply that the landscape has been static; however in the UK such stability is rare and detailed analysis of the Welsh squares within the survey revealed that there were some important changes in specific components of the landscape. These included an increase in the overall area of built land, which increased by 14,500ha (a rise of 12.5%) and an increase in the area of broad-leaved woodland across lowland Wales (rising by 12%). Woody linear features are important in landscape quality assessments and they make up over half of all boundaries in Wales. Within these boundaries there has been a reduction in the length of managed hedgerow as previously stock-proof hedges have deteriorated into lines of trees. The recently published State of Nature report 2013 and analysis of the species data for Wales in Countryside Survey indicates a decline in overall species diversity. These declines may have cultural significance when considering specific aspects of landscape quality, for example, in Wales 57% of flowering plant species are in decline and this may negatively impact on visitors’ enjoyment of certain landscapes in spring and early summer (Burns et al. 2013).
There is no doubt that high quality landscapes and heritage features are a valued resource in Wales, attracting visitors to the country and generating income across many different sectors. There is clear recognition of the significant contribution of the historic environment to quality of life in Wales. The recent Historic Environment Strategy for Wales (Welsh Government, 2013) is focused on actions to

enable the protection of Wales's heritage while also encouraging public access, enjoyment and participation. The historic environment comprises a diverse set of assets ranging from formally designated sites to locally important landmarks and features. Across Wales there are 3 World Heritage Sites, 428 registered historic landscapes, parks and gardens, 519 conservation areas, 4,000 scheduled ancient monuments and 30,000 listed buildings.

There is evidence that such assets contribute to a range of benefits spanning job creation, tourism, place-making, identity, education and community involvement. Research to assess the value of the historic environment in Wales (ECOTEC, 2010) estimated that the sector supports over 30,000 jobs and contributes around £840 million to national gross value added (GVA). Some of the most popular visitor attractions in Wales are heritage sites, including Conwy Castle which attracted over 160,000 visitors in 2012. The historic environment is widely used in the promotion of Wales as a destination and is one of most popular reasons cited by visitors in Visit Wales research of visitor motivations. However, the strategy identifies a need for action to increase accessibility, understanding and engage under-represented groups. The cost of maintaining and restoring assets is also a significant challenge. The 'Programme for Government', set out in 2011 for the current term, includes an aspiration to enrich the lives of individuals and communities through culture and heritage with a longer-term goal to increase the percentage of historic environment assets in a stable or improved condition. The 2013 update reports that public engagement with heritage is growing and there has been some success in strengthening the place of the Welsh language in everyday life and the percentage of historic environment assets in a stable or improved condition is estimated at just over 78%[1].

Public Rights of Way (PROW) are common throughout the managed landscapes of Wales, often linking farms and settlements together as well as providing routes across mountains and across open land. They are an important resource, particularly for tourists to Wales many of whom come specifically to walk.

3.6.3 Aims of Glastir with respect to landscape & historic environment

Glastir explicitly recognises the importance of the Welsh landscape; one of the six stated aims of the programme is to manage and protect the Welsh landscape and the historic environment therein, whilst retaining and promoting public access. Four specific landscape targets are outlined in the programme including: ditch landscapes; historic features and landscapes; pond landscapes and protected landscapes. An additional five targets have significant landscape quality components and include those relating to orchards; parkland and wood pastures; parks and gardens; permissive access and woodland. Within each of these targets are specific management options which have direct impacts on the potential quality of the landscape view. Notable amongst these are options for the management of woodland, hedgerows, native trees, water features such as ponds and reedbeds as well as stock management around water features and on archaeological sites. These landscape management options are detailed in Appendix 6.5 of the GMEP first year report (Emmett et al. 2014:175).

[1] This figure is based on an assessment of listed buildings and scheduled ancient monuments. The corresponding figure in 2008 was 75% which suggests that progress has been made; however, it is noted that prior to 2012 the percentage of listed buildings deemed to be not at risk was used to represent those in a stable or improved condition but in 2012 a more accurate assessment of those in a stable or improved condition has been used. Cadw is now looking at ways to extent this evaluation to a wider group of historic environment assets.

Within the ecosystem services approach taken by GMEP, the work of the landscape and historic work package contributes specifically to the measurement of the cultural ecosystem services provided by the Welsh landscape. The aims of the landscape component of GMEP are fourfold:

- To assess visual landscape quality using measures which are objective, transparent and repeatable.
- To quantify the accessibility of the GMEP 1km survey squares both in terms of physical accessibility through the Public Rights of Way network (PROW) and a derived measure of visual accessibility which takes account of the view as experienced by the public within the landscape.
- To quantify the condition of the historic assets present.
- To assess the impact of change on the visual quality of these landscapes through landscape changes implemented through the Glastir programme.

3.6.4 Benefits of past schemes

In Wales, Glastir has replaced a number of agri-environment schemes including Tir Gofal, the entry-level scheme of Tir Cynnal and the Tir Mynydd scheme which provided specific support payments to hill-farmers in the Less Favoured Areas.

Under Tir Gofal many of the land management options were designed to protect and enhance components of the natural and cultural heritage of Wales whilst increasing permissive access. In addition, there were capital grants to support specific activities. A review found that 93% of Tir Gofal applicants in 2003 received a capital grant from a total budget of £7.15 million. Of these payments, a significant proportion was spent on activities which have a direct impact on the quality of the landscape and the maintenance of its historic context including: dry stone walling (15.3%), repair of the unique Welsh slate fencing (0.2%), hedgerow management (9.2%) and traditional farm building repair (7.4%). With respect to the creation of new ponds (1.3%) and the planting of new trees (0.5%) overall capital spend was much lower. A further 5.6% of the capital grants budget was spent on improving access through the creation of new permissive paths and improvements to existing access infrastructure (Agra, 2005: Table 3.8).

The mid-term evaluation of the Wales Rural Development Plan for the period 2007-13 (ADAS, 2010) found that in general terms, the area under agri-environment options was likely to at least maintain landscapes and features; and, in particular, Tir Gofal has resulted in a number of specific actions which will have contributed to maintaining and improving landscapes and features. It was also noted that the schemes have also played a role in decisions to remain in farming, usually as one of a number of factors, which will contributed to maintaining the structure of farming in Wales and, in turn, may have helped to maintain existing farm sizes and boundary features. A survey of participants in Tir Gofal, undertaken by the evaluators, asked whether beneficiaries had maintained or improved a range of landscape features since joining the scheme. The most frequently cited response was hedgerows (85%), followed by management of individual trees or orchards (50%) and public rights of way (44%). In terms of historic features, it was reported that work had been done to maintain or improve traditional buildings (37%), other historic features (including mines, ponds, cairns, ruined buildings and features associated with farming or mining) (28%) and scheduled ancient monuments (14%).

A more recent review of the impact of agri-environment schemes undertaken for the UK Government found that the entry level schemes that had operated in England and Wales since 2000 had positive impacts on maintaining landscape character and quality. There was significant uptake of landscape / historic options including the management of archaeological features under grassland; buffer strips in open landscapes; the maintenance of a pastoral character through the

support of low input grazing and mixed stocking, as well as through hedgerow management (FERA, 2013). These landscape impacts were most highly rated by those land managers in the Less Favoured Areas which in the Welsh context is significant as over 80% of the agricultural land in the country falls into an LFA, with 56% of it in severely disadvantaged areas.
Although there have been significant benefits accrued with respect to landscape quality under pre-existing agri-environment schemes, a note of caution must be sounded with respect to the historic and archaeological components of landscapes. A review undertaken by ADAS of the conservation of the historic environment in the English uplands highlighted that there was still a lack of information about this important resource and that this has been exacerbated by a focus on individual sites and features in existing agri-environment schemes rather than considering the historic landscape as a whole (ADAS, 2011).

3.6.5 Methods

The approach taken by the GMEP landscape team has been a sequential one, whereby the methods developed in year 1 have been tested through consultation with the general public in year 2 (Figure 3.6.5.1). Overall, the public have validated the approach taken in the VQI with the positive and negative weightings given to the landscape options that are incorporated within the metric being confirmed as correct.

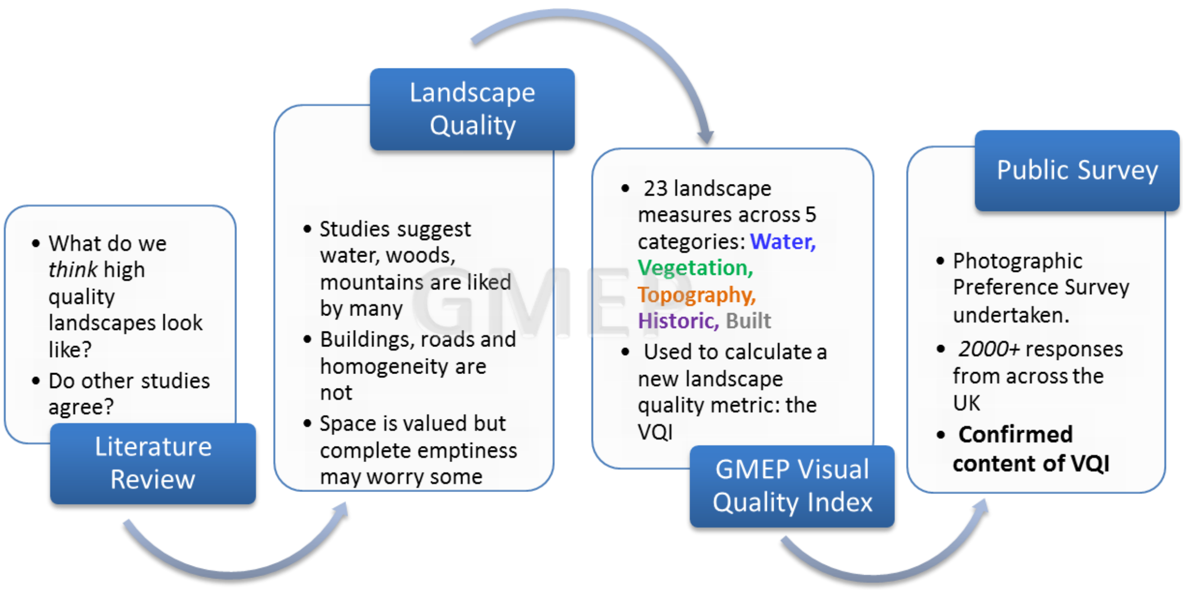


Figure 3.6.5.1 *A summary of the GMEP landscape approach.*

3.6.5.1 Visual Quality Index (VQI)

The VQI methodology is outlined in detail in the first year report (GMEP, 2013: 146-148). In brief, the GMEP Visual Quality Index (VQI) is a new measure of landscape quality with possible values ranging from 0 (worst) to 1 (best). It has five components: physical, blue-space, green-space, historic and built/unnatural.

Blue-space focuses on water and measures area (e.g. ponds), length (e.g. streams) and points (e.g. waterfalls) and contributes positively to the VQI. Green-space focuses on vegetation and measures area (e.g. woodlands), length (e.g. hedgerow length) and points (e.g. number of single large trees) and contributes positively to the VQI. Physical components of the VQI include a terrain roughness index (TRI) which has been adapted from an established geomorphological model originally published by Riley et al., in 1999. It uses a detailed 3D model of the land surface which splits the entire land area of Wales into 5 metre cells, each having one value representing the elevation of that cell above sea-level. By calculating the difference between each cell and the average value of the nearest 8 cell neighbours an index is derived called the Terrain Ruggedness Index (TRI). This value gives an indication of the relative change in height and is more useful than a simple elevation or slope dataset as it considers the context of each cell. Combined with geological information extracted from the Welsh LANDMAP database which defines those areas of high geological landscape value the physical component contributes positively to the overall VQI. The presence of historic / cultural features such as mottes, stone crosses, standing stones, listed buildings, scheduled ancient monuments are all included within the VQI as positive components of landscape quality. Finally the VQI calculates the length and area of roads, buildings, utilities and heavily managed or altered habitats such as monoculture arable and coniferous plantations and rates these negatively within the index.

The totals for each of these five component groups were collated, scaled between 0 and 1, and then the five groups were weighted equally to derive the final VQI.

3.6.5.2 Viewshed Analysis

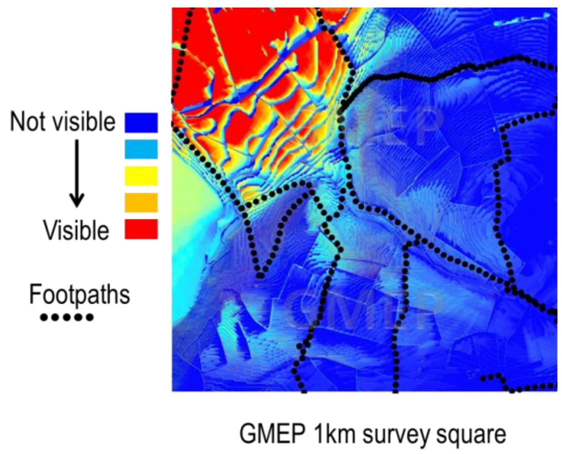


Figure 3.6.5.2.1 *An example pedestrian viewshed calculated for a 1km GMEP survey square. The footpaths from which the view is calculated are shown in black. For each 5x5m cell on the output, a value is derived showing the number of times that cell is seen from the observer points within the square. In this example the land rises steeply towards the north-west of the site and this part of the square is very visible to pedestrians within it.*

For a high quality landscape to be enjoyed, it must be physically accessible but also visible. Aside from designated open-access areas, the public can only physically move through a landscape using either the Public Rights of Way network (PROW) or the existing public highways. What can be seen depends strongly on topography but also vertical structures in a landscape - buildings, trees and high hedges will all obstruct views. By calculating the available view from a human perspective, a measure of the visual accessibility of a known location can be derived called a 'viewshed'. Calculating the viewshed of a landscape is computationally demanding and requires three key inputs: a 3D representation of the land surface; the location and height of all physical barriers such as tall buildings, hedges, woodlands and finally, observer locations from which to calculate the view (Figure 3.6.5.2.1). For each of our study sites four different categories of user were considered: pedestrians, cyclists, small vehicles such as cars and finally rail passengers. A 5m scale digital terrain model provided the base onto which physical barriers were added. This information came from the GMEP field survey which captured information describing the vegetation type, the height of linear features such as hedges. Standard building heights were assigned to structures where these were not directly measured. Known observer locations were taken 20m apart along all the PROW in the square and these were complemented by random sampling within open access areas and on public beaches.

High quality landscapes have an important existence value; although an individual may never visit Snowdonia or the Welsh coast; they may feel strongly that the beauty of the Welsh landscape should be protected so that those members of the public that wish to explore and enjoy it can continue to do so. For visitors to derive a benefit from looking upon, or being within a high quality natural environment it must be both physically and visually accessible. The maintenance of views is therefore, important and studies from across the world show that even fleeting contact with green space improves human health and well-being. Knowing where access is limited may identify areas of high quality landscape that are currently hidden from many people and Glastir has the funding mechanisms in place to promote access into some of these lesser-known rural landscapes.

3.6.5.3 GMEP Photographic Preference Survey (PPS)

The GMEP photographic preference survey (PPS) was delivered online and had two main aims. Firstly, to validate the Visual Quality Index (VQI) by ascertaining whether the ranking assigned to landscapes using the VQI match the ranking of landscapes assigned by the public. In other words, are landscapes with higher VQI scores regarded by people as more 'attractive' than those with lower VQI? What particular landscape features are liked and disliked? Secondly, the questionnaire sought to investigate whether different demographic groups value the landscape in similar ways. Specifically, survey results were interrogated to determine whether the following groups rank landscape 'attractiveness' in the same or different way (and if different, how different their views were?):

i) Gender (male vs female)
ii) Age groups (youth vs middle-aged vs elderly)
iii) 'Perception of nationality' (Welsh vs British vs English)
iv) Welsh speaking vs English speaking
v) Urban vs rural dwellers:
vi) Location of childhood home
vii) Location of current home

3.6.5.4 PPS Survey Design and Distribution

An online questionnaire was prepared using Qualtrics® survey software and consisted of three sections. The first two sections aimed to collect relevant background information of the respondents, including their demographic data and their country-side visiting habits. The third (and main) part of the questionnaire focused on respondents' preferences towards the different types of landscape photographs (selected from the Year 1 field survey photographic archive) using three different forms of questions: a landscape rating; a hotspot choice and a feature response. In the first respondents were asked to rate how attractive they found each of the five presented landscape photographs. The rating was measured using an 11-point numerical scale ranging from 0 for 'Not at all Attractive' to 10 being 'Very Attractive'. Secondly, using the same five landscape images, respondents were then asked to select (by clicking their mouse cursor) one spot in the area they liked the most. This exercise developed a 'heat map' showing areas of preference. Lastly, various landscape features in six different photographs were marked by a surrounding rectangular frame, and respondents were asked to click once if they liked the feature (which turned the frame green), and twice to indicate dislike (turning the frame red), while clicking three times reset the frames to 'neutral' (Figure 3.6.5.4.1) .

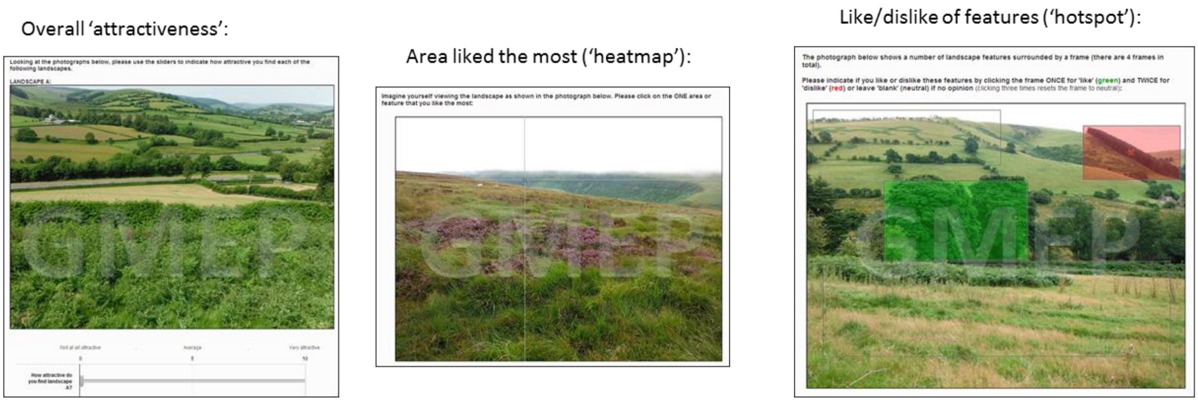


Figure 3.6.5.4.1 *The three types of question asked during the photographic preference survey. (L to R) Sliding scale of attractiveness from 0 to 10; choosing one location on the landscape that is liked the most – data are collected to produce a heatmap of all responses; feature response where individual components of the photograph are highlighted in boxes which the user can either choose to like (green), dislike(red) or leave neutral.*

The survey was piloted and also translated into Welsh. To aid the dissemination of the questionnaire, a dedicated webpage (http://www.glastir-mep-surveys.org.uk/) was created to host the surveys. A 'snowball' sampling technique was employed utilising two sources for respondents:
a. **Public group database.** A database of groups and organisations was created to capture the opinions of various demographic groups. This included residents associations, community groups, elderly (OAP) groups, youth groups, women's institutes and Welsh societies.
b. **GMEP network.** The survey webpage link was circulated to 78 individuals in the GMEP network, which included all GMEP partners (67) as well as a number of the Welsh Government employees (approx. 9) who in particular work and have links with community groups in Wales.
The survey was initiated in September 2014 and closed at the end of June 2015, responses now number over 2600, with respondents across the UK. However the results presented in this report are based on the responses collected between September 2014 and January 2015, the full dataset will be re-analysed in year 3 but it is not envisaged that the larger sample will change the key findings presented here

3.6.5.5 Historic Environment Features

The GMEP survey team undertook a condition assessment of selected historic features identified within each of the survey squares following training from Cadw staff. Once the feature had been identified in the field, photographs were taken. The condition of the feature was assessed as either: excellent; sound with long standing defects; sound with minor defects; signs of potential deterioration; major signs of deterioration; or damaged. Current challenges to the site were also then identified including problems being caused by stock (such as stockwear poaching, erosion and burrowing animals), agricultural operations (such as ploughing, dumping and pasture improvement), vegetation (such as bracken or gorse) as well as a range of other more general issues (such as vandalism, quarrying, stone removal). Surveyed features were primarily undesignated sites which have been documented in the HEF dataset, but the sample also included a number of designated sites, including 5 SAMs.

3.6.6 Results

3.6.6.1 Visual Quality Index: Year 1 and 2 Summary Statistics

The distribution of the VQI values ranges from a low value of 0.30 to a maximum of 0.68 for the 150 1st and 2nd year sites (Figure 3.6.6.1.1) and show a normal distribution (Figure 3.6.6.1.2). The VQI is made up of five components which are all scaled between 0 and 1 before combining them to derive the final score. This means that these five components are weighted equally in the overall VQI even though they have varying numbers of parameters feeding in to their calculation (see GMEP 1st year report for further details on the VQI derivation). It can be seen from the individual statistics (Table 3.6.6.1.1) and from the boxplots representing these distributions that the water components of the square (blue space) have a much smaller range (so typically there is usually some water in the GMEP 1km survey squares somewhere) but there can be extremes where the site can be dominated by water. This is most notable with the coastal sites. Again, the historic features are often completely absent from the sites, accounting for the low tail on the bar chart describing the range (Figure 3.6.6.1.3).

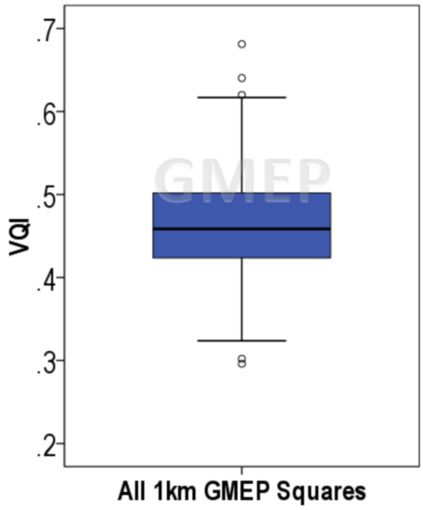


Figure 3.6.6.1.1 *The statistical distribution of the VQI for all 150 1st and 2nd year GMEP 1km survey sites. See* **Table 3.6.6.1.1** *for values associated with these data.*

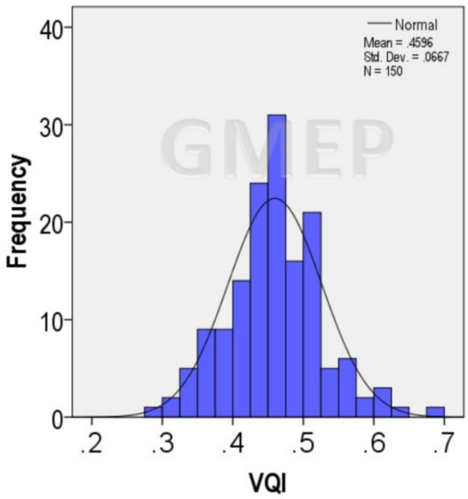


Figure 3.6.6.1.2 *The VQI data exhibit a normal distribution across the 150 1st and 2nd year GMEP 1km survey squares.*

Component	Min	Max	Mean	Std. Deviation	1st Quartile	Median	3rd Quartile
Physical Landscape	0.14	0.86	0.57	0.17	0.43	0.57	0.71
Blue Space	0	0.93	0.31	0.14	0.27	0.30	0.33
Green Space	0.16	0.94	0.58	0.19	0.44	0.63	0.72
Human Influence	0.20	1.00	0.67	0.17	0.57	0.70	0.77
Historic / Cultural	0	0.80	0.18	0.18	0	0.20	0.24
VQI	**0.30**	**0.68**	**0.46**	**0.07**	**0.42**	**0.46**	**0.50**

Table 3.6.6.1.1 *The statistical description of the five components of the Visual Quality Index*

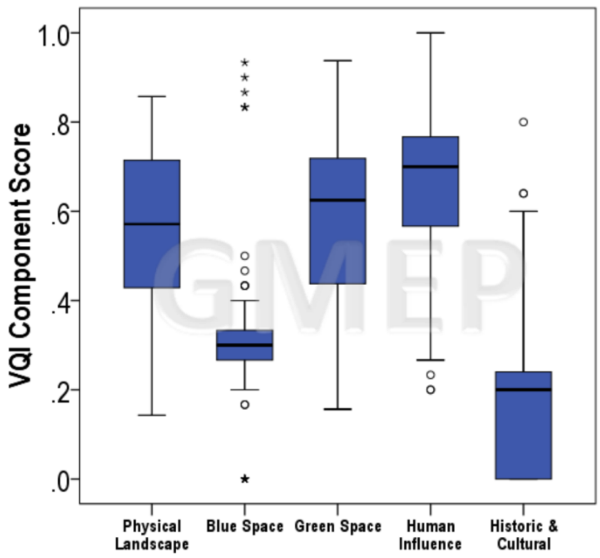


Figure 3.6.6.1.3 *The five components of the VQI (all weighted equally), showing the variation in the range of values present.*

3.6.6.2 What contribution does terrain make to the perceived quality of the Welsh landscape?

Wales is a mountainous country and the varied terrain defines its landscape character. Elevation (or height) is not the sole factor of importance; rather relative differences in height provide interest. Landscape preference surveys from across Europe indicate that rugged, mountainous landscapes are valued by people. Mountains give a sense of scale to a landscape, affording the viewer the opportunity to see across long distances when at height. They can also enclose landscapes and define valleys. Mountainous landscapes often have geological interest and provide opportunities for the geological characteristics of a location to be easily spotted.

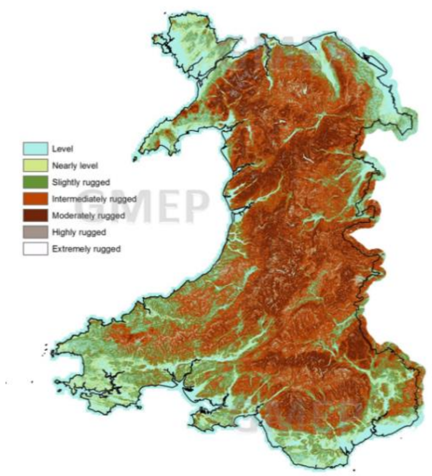


Figure 3.6.6.2.1*The Terrain Ruggedness Index used in the GMEP VQI, adapted from Riley et al.,1999.*

At a European scale, the mountain peaks of Wales are not high in comparison with the Swiss Alps or the Sierra Nevada in Spain but the majority of the country is rugged which contributes to high landscape quality ratings.

The terrain roughness index has been adapted from an established geomorphological model originally published by Riley et al., in 1999. It uses a detailed 3D model of the land surface which splits the entire land area of Wales into 5 metre cells, each having one value representing the elevation of that cell above sea-level. By calculating the difference between each cell and the average value of the nearest 8 cell neighbours an index is derived called the Terrain Ruggedness Index (TRI). This value gives an indication of the relative change in height and is more useful than a simple elevation or slope dataset as it considers the context of each cell (Figure 3.6.6.2.1). The model was applied to the whole of Wales and a ruggedness value was calculated which classified the cells into one of seven classes: level(27.92%), nearly level (4.38%), slightly rugged (15.82%), intermediately rugged (35.81%), moderately rugged (15.80%), highly rugged (0.25%) or extremely rugged (<0.01%).

These values indicate that only one-third of the country (32.3%) is classed as relatively flat (Level and Nearly Level classes combined) and it can be seen that these areas are largely confined to Anglesey, Pembrokeshire and the main river valleys. The complexity of the Welsh topography is clearly shown with high values correctly coinciding with the upland areas of Snowdonia, the Brecon Beacons, the Rhinogs and Berwyn Mountains amongst others.

3.6.6.3 Does the VQI differ between upland and lowland areas?

There is no significant relationship between elevation and the overall quality rating for the first year study sites. When the overall Visual Quality Index for sites with a median elevation of below 200m is compared to those over 200m it can be seen that the range of VQI values for the lowland sites is large and includes both the highest VQI rating (so the best quality landscape) and the lowest VQI values. The upland landscapes have a smaller range of VQI values and a higher overall median value which indicates that they tend not to include the lowest quality landscapes (Figure 3.6.6.3.1). Although rugged terrain and a varied topography contribute positively to the overall VQI, they are only one part of the measure. As elevation increases, the overall tree cover and plant species diversity will tend to decline, so higher elevation alone will not lead to high VQI scores. It is only where a range of positive values coincide that very high landscape quality scores will prevail.

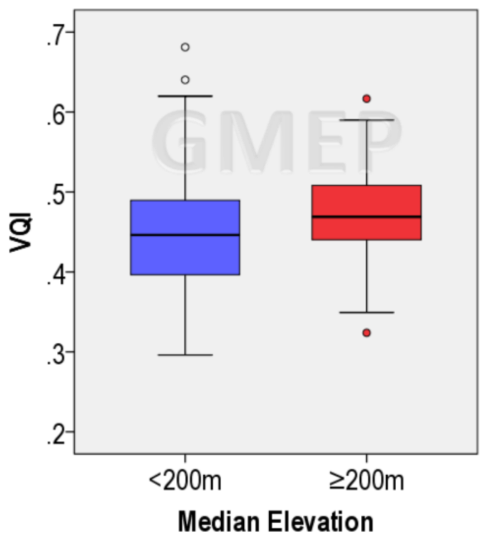


Figure 3.6.3.3.1 *The VQI for areas below 200m and those above.*

3.6.6.4 Does the VQI differ inside and outside protected areas?

There are many different categories of landscape designation in Wales, reflecting local, national and international priorities and these protected areas cover nearly 30% of the total land surface of the country (JNCC, 2014). Many of these sites are designated for nature a conservation purpose which often does contribute to overall visual quality, though the link is not always direct. Some SSSI's for example, are specifically designated for a single species or rare habitat which would not be discernible when viewed by the public reacting to the wider landscape scale.

The location of all known protected areas has been mapped and is available as a spatial dataset. The location of the 150 1st and 2nd year GMEP 1km survey squares was overlaid on this protected area map and used to classify each square either into or outside of a protected area. These two groups of squares were then compared to assess whether there were significant differences between the landscape components of the squares, using the GMEP Visual Quality Index (VQI). The VQI is a new measure of landscape quality with values from 0 (worst) to 1 (best). It has five components: physical, blue-space (water), green-space (vegetation), historic and unnatural (built, roads, utilities).

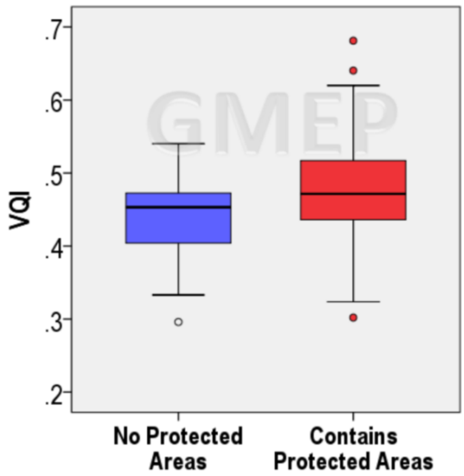


Figure 3.6.6.4.1 *The VQI of the 1st and 2nd year GMEP 1km survey squares (n= 150) compared inside and outside of protected areas.*

Results indicate that there is no statistical difference between the mean quality ratings assigned to the GMEP 1km survey squares which fall within / without of a protected area. However, Figure 3.6.6.4.1 shows that there are clear differences in the range of values, with all the highest values falling into protected areas. The first two years of data revealed that 84 / 150 of the GMEP 1km survey squares were within or partly within a protected area (defined as National Parks, Area of Outstanding Natural Beauty, Sites of Special Scientific Interest, and National Nature Reserves). When these data are split into the components of the VQI (Figure3.6.6.4.2) two things are immediately apparent. Firstly, it is clear that the physical landscape components inside protected areas have significantly higher values than outside. This reflects the dominance of mountain regions in the protected areas of Wales (most notably Snowdonia National Park and the Brecon Beacons). Secondly, the greenspace components are significantly lower inside the protected areas. The greenspace component is heavily dependent on vegetation including parameters describing the area of woodland, hedgerows and a habitat diversity scoring. In many of the valued upland landscapes of Wales, these measures will be lower because the bogs, upland habitats and montane regions do not have high scores.

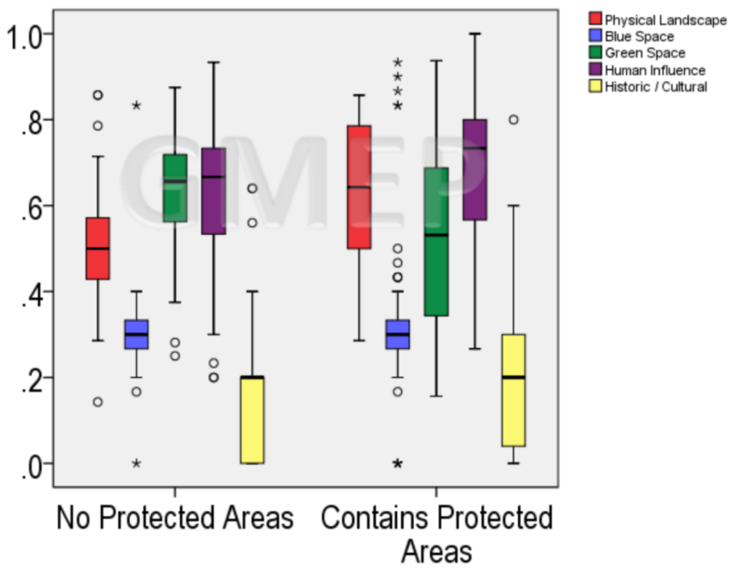


Figure 3.6.6.4.2 *The VQI of the 1st and 2nd year GMEP 1km survey squares (n= 150) compared inside and outside of protected areas, broken down by VQI category.*

3.6.6.5 Do landscapes with a high VQI have greater plant diversity?

The link between species rich locations and peoples' preferences for a landscape is not well understood. Ecological surveys of birds, plants or insects are often designed to work out what components of a habitat (such as presence of a particular nectar species or specific type of land management) are present where numbers are high. Rarely, are these detailed field surveys set within a survey framework as comprehensive at a landscape scale as GMEP. Here we are measuring many ecological indicators of habitat quality at the same locations as landscape quality is being assessed. Within GMEP we have the opportunity to evaluate these potential links with a large dataset and one where the landscape quality indicators are derived from the same field survey data used for the species and augmented by a wide range of landscape measurements.

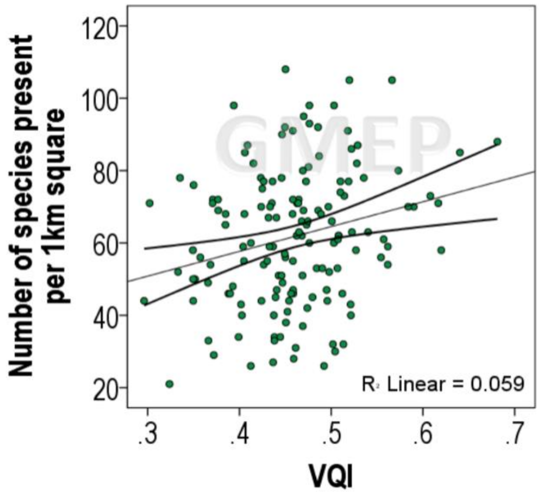


Figure 3.6.6.5.1 *The overall VQI (landscape quality index) compared against the total number of species present in the 150 1st and 2nd year 1km GMEP survey squares.*

The relationship shown in Figure 3.6.6.5.1 is not significant .The lack of a strong overall trend here is perhaps unsurprising as many species-rich habitats tend to occur in the lowlands and may be associated with an increased variety of habitat rather than necessarily higher quality habitat. The valued scenic upland landscapes are often dominated by larger blocks of single habitat types, which may be in themselves relatively poor in overall number of species (such as the montane habitats of Snowdonia) when compared against lowland heaths or woodlands but their component species may be rare and of international significance.

3.6.6.6 Do landscapes with a high VQI have greater bird diversity?

Data from bird surveys conducted in 2013 and 2014 on 150 GMEP 1km survey squares was collected by BTO surveyors during the 3 month breeding season, April – June. These data have been collated and compared against the overall VQI (Figure 3.6.6.6.1). At this summary level, no relationship is shown between the landscape quality rating and the number of bird species present in a 1km survey square.

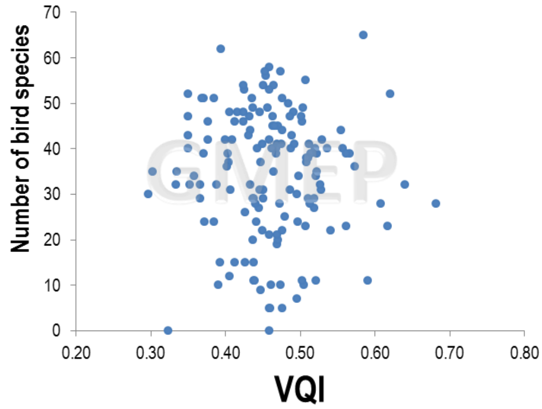


Figure 3.6.6.6.1 *The overall VQI (landscape quality index) compared against the total number of bird species present in the 150 1st and 2nd year 1km GMEP survey squares.*

However, for the individual components of the VQI a number of trends were revealed of interest. As the area of built and human-influenced landscape features increases, the number of bird species declined which would be expected. This negative relationship was also observed when the physical landscape components of the VQI are mapped against bird species diversity which implies that as the landscape become more rugged, the number of bird species declines. Finally, the green-space component of the VQI, which measures a range of parameters to do with woodland, hedgerow length, plant species and habitat diversity, shows the expected positive response to the number of bird species. These trends helpfully provide further validation for the general VQI approach (Figure 3.6.6.6.2).

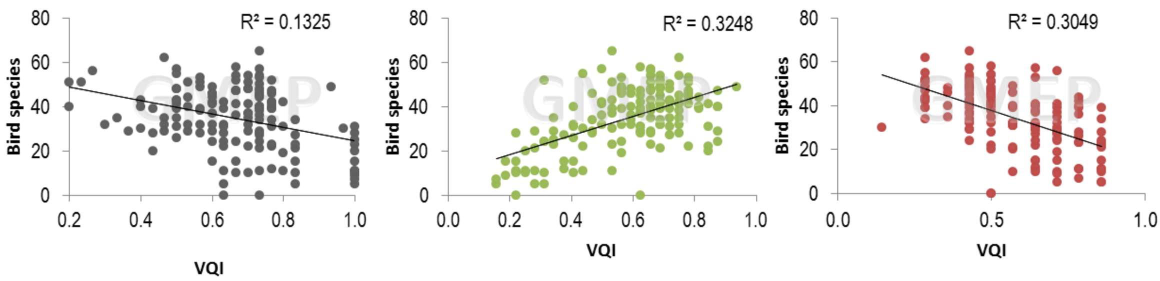


Figure 3.6.6.6.2 *Left = Built component of the overall VQI, Middle = Greenspace (vegetation) component of the overall VQI and Right = Physical component of the VQI compared against the total number of bird species present in the 150 1st and 2nd year 1km GMEP survey squares.*

3.6.6.7 Do landscapes with a high VQI have greater butterfly diversity?

n = 150	Min	Median	Mean	Max
Number of individual Butterflies averaged across 2 surveys	0	25	40.23	270
Butterfly species diversity (Shannon Diversity Index)	0	0.37	0.38	1.23

Table 3.6.6.7.1 *Butterfly data for the 1st and 2nd year survey squares*

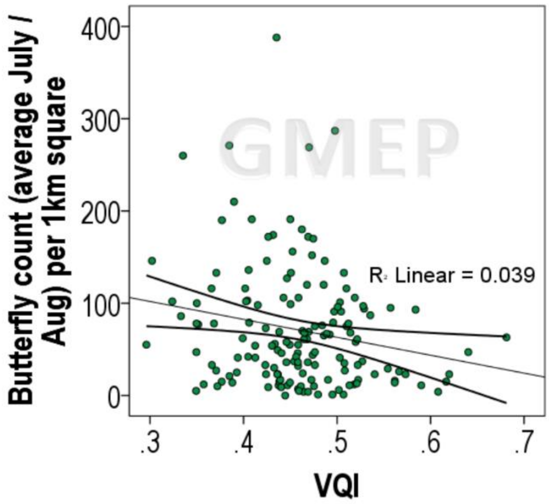


Figure 3.6.6.7.1 *The overall VQI (landscape quality index) compared against the total number of butterflies present in the 150 1st and 2nd year 1km GMEP survey squares.*

When the total number of butterflies observed during the 1st and 2nd year field survey visits is compared to the GMEP landscape VQI, a very weak negative relationship is indicated but this is not significant. The slope of the fitted line implies that the lowest rated landscapes actually have more butterflies but it is clear that there is a great deal of scatter (variation) around this indicating that the relationship is not explained by the measures captured in the landscape VQI (Figure 3.6.6.7.1, Table 3.6.6.7.1). This may be due to scale issues as the landscape VQI is working at a 1 – 3km scale, whereas insect diversity will probably be responding to intricate variations in habitat and plant species diversity that are masked when considered at the whole square scale.

3.6.6.8 Do landscapes with a high VQI have greater bee diversity?

Pollinators like bees are important to the health of the countryside; it is thought that nearly 80% of the flowering plants in temperate areas are reliant on insects for their reproduction. In addition, at least 35% of global food production is dependent on pollination – many of our key combinable crops such as oil seed rape require insect pollination. As recently as 2010, the UK Parliament estimated that this “service” that is provided for free by bees and other insects is worth at least £400 million per year to the UK economy. Bees in particular, seem to provoke a positive response in many people, as their pollinating work on our behalf, is very visible. They obviously require nectar-rich plants to feed upon, so flowers are critical to their survival. Flowers are also valued visual components of a landscape and colour rich meadows and flower-filled hedgerows and field ditches are often highlighted in preference surveys by the general public. Certain flowering events (such as the bluebells opening in spring or the heather flowering in the early autumn) are sensory delights to most visitors and highly valued.

Bees along with butterflies and hoverflies were surveyed twice during the GMEP field season, once in July and once in August. Surveyors walked a 2km route in each GMEP 1km survey square and recorded both presence as well as conducting timed observations in 150m areas. Pollinator surveys were only conducted between 10:00 and 16:00, or between 09:30 and 16:30 if >75% of the survey area was un-shaded and weather conditions were suitable for insect activity. Temperature had to be between 11 and 17°C with at least 60% sunshine or above 17°C regardless of sunshine, and with a wind speed below 5 on the Beaufort scale (small trees in leaf sway).

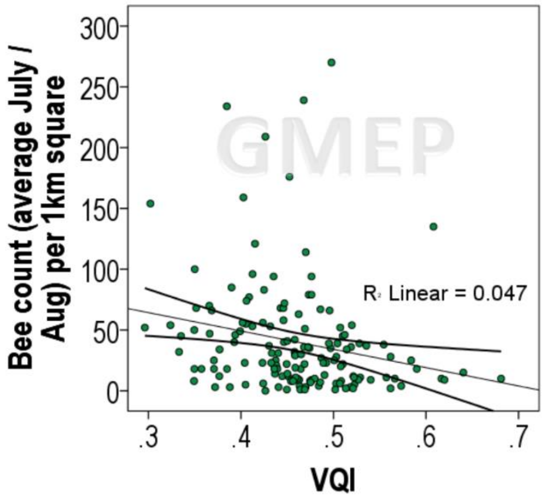


Figure 3.6.6.8.1 *The overall VQI (landscape quality index) compared against the total number of bees present in the 150 1st and 2nd year 1km GMEP survey square.*

When the total number of bees observed during the 1st and 2nd year field survey visits is compared to the GMEP landscape VQI, a very weak negative relationship is indicated but this is not significant. The slope of the fitted line implies that the lowest rated landscapes actually have more bees but it is clear that there is a great deal of scatter (variation) around this indicating that the relationship is not explained by the measures captured in the landscape VQI (Figure 3.6.6.8.1, Table 3.6.6.8.1). This may be due to scale issues as the landscape VQI is working at a 1 – 3km scale, whereas insect diversity will probably be responding to intricate variations in habitat and plant species diversity that are masked when considered at the whole square scale.

n = 150	Min	Median	Mean	Max
Number of individual Bees averaged across 2 surveys	0	25	40.23	270
Bee group diversity (Shannon Diversity Index)	0	0.37	0.38	1.23

Table 3.6.6.8.1 *Bee data for the 1st and 2nd year survey squares*

3.6.6.9 Do landscapes with a high VQI have greater functional connectivity?

Mixed landscapes offer opportunities for increased biodiversity, both in terms of habitat and species. Landscape preference surveys indicate that humans also value variety in their view and respond positively to small-scale landscapes with a mixture of woodlands, wetlands, fields and settlements. When ancient woodlands, wetlands and heathlands become isolated through encroachment of farming, settlements or infrastructure their ecological value diminishes. Species may no longer be able to move freely across a landscape and overall ecological resilience can suffer. A connected landscape functions better – so a well-managed set of hedgerows, grass margins or ditches will allow animals and plants to thrive. Such management also contributes positively to landscape appearance. The link between ecological connectivity and landscape quality can be explored within GMEP by combining the VQI with landscape metrics in order to evaluate whether bio-diverse landscapes are attractive to people.

Mapped habitat data for each GMEP 1km survey square was analysed using robust landscape metrics to assess fragmentation, complexity and connectivity. These mathematical descriptions of landscape include measurements of broadleaved woodland landscape connectivity, habitat diversity, habitat fragmentation, mean patch size (so how big do the bits of similar habitat tend to be?) and shape. Such functional landscape analysis is a well-accepted method of describing the complexity and structure of the land cover of an area and has the advantage that it is objective, quantifiable and repeatable. These data were then compared against the calculated GMEP Visual Quality Index for each site to explore possible relationships between ecological value and landscape value (Figure 3.6.6.9.1). Results were non-significant and showed a wide range of values for the two key connectivity indices.

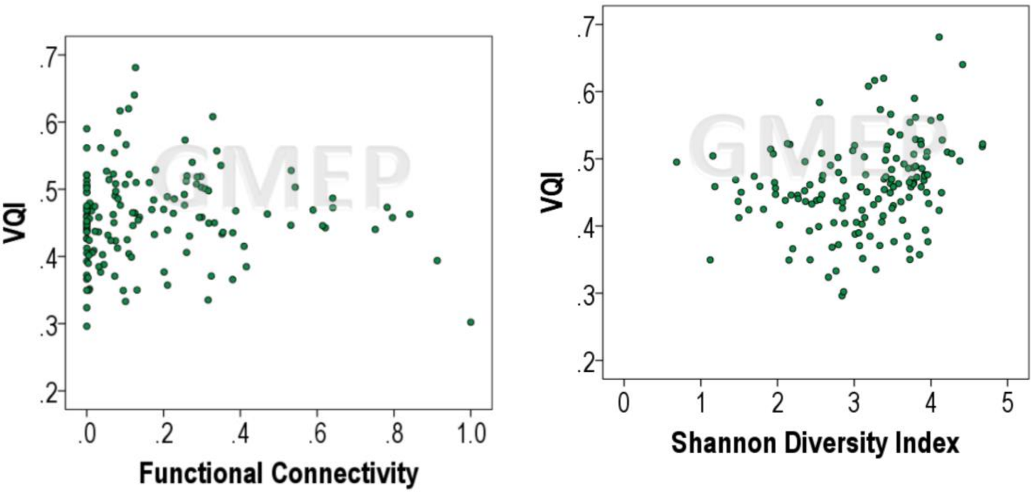


Figure 3.6.6.9.1 *Functional connectivity index for broadleaved woods and the Shannon's Diversity Index calculated for the habitats within the 150 1st and 2nd year GMEP survey squares compared against the overall landscape VQI. No statistically significant trends are revealed.*

3.6.6.10 Do landscapes inside Glastir have higher VQI values than those outside Glastir?

The Glastir scheme has nine target objectives with explicit landscape links including: ditch landscapes; historic features and landscapes; orchards; parkland and wood pastures; parks and gardens; permissive access; pond landscapes; protected landscapes and woodland. Within each of these targets are specific management options which have direct impacts on the potential quality of the landscape view and the subsequent VQI assigned to the site. Notable amongst these are options for the management of woodland, hedgerows, native trees, water features such as ponds and reedbeds as well as stock management around water features and on archaeological sites.
Areas of Glastir managed land were mapped for the GMEP survey squares. Those sites which contained areas of Glastir land were compared against those with none. Although there was some indication that those sites with higher VQI values were found within the Glastir managed scheme, the results were not significant at this scale (Figure 3.6.6.10.1)

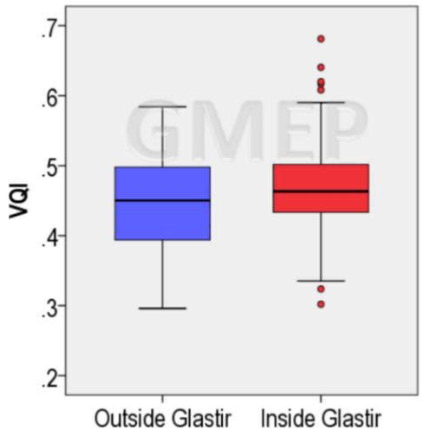


Figure 3.6.6.10.1 *Overall VQI values compared in sites with some Glastir managed land as compared against those within none.*

3.6.7 Viewshed Analysis Results

3.6.7.1 How visually accessible are the GMEP survey squares?

Visual accessibility is of course, strongly associated with physical accessibility which in turn is determined by the density of the PROW / Road network as well as the nature of that access. Pedestrians have the most access as they can use all types of PROW except for motorways. This is shown clearly within the results for the GMEP 1km survey squares where walkers and cyclists enjoy on average a view of 45% of the 1km square compared against 36% of people confined to a car (Table 3.6.7.1.1). In addition to the immediate viewshed of a 1km square, those visitors are also scanning further to take in wider landscape views and this is captured in the statistic which tells us how much of the surrounding 3 x 3km landscape of that square can also be seen from the 1km square. Again, pedestrians have most access to these wider views with on average 40% of the surrounding region being visible. The GMEP 1km survey squares also contribute to the landscape in which they are sited. The final statistic generated shows what proportion of the GMEP 1km survey squares can be seen from the surrounding 3 x 3km landscape. Here the figures are much higher, reaching 81% on average for the pedestrian group which reflects the overall density of roads and footpaths in Wales.

CATEGORIES OF USER	**% of 1km study sites which are visible from WITHIN the square**			**% of the surrounding 3 x 3 km area which is visible from WITHIN the 1km study square**			**% of 1km study sites which are visible from the surrounding 3 x 3 km area.**		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Pedestrians	0	44.6	96.7	0	40.3	78.3	0	80.8	98.7
Cyclists / Horse riders	0	45.0	96.7	0	37.3	77.7	0	77.6	98.6
Small Vehicles	0	35.8	93.8	0	30.9	77.0	0	68.0	97.3
Railway	0	1.1	64.0	0	1.1	39.9	0	2.8	53.7

Table 3.6.7.1.1 *Calculated visibility for the four main categories of user at three different spatial scales generated from 1800 viewsheds for the 150 1st and 2nd year GMEP sites.*

3.6.7.2 How physically accessible are the GMEP survey squares?

People visit the countryside for a range of reasons from the purely recreational such as walking, climbing or bird-watching, to the less tangible such as finding some peace and quiet and mental relief from the pace of modern life. The health benefits derived from outdoor exercise and recreation can only be provided if the general public can physically access landscapes via the Public Rights of Way network (PROW). This defined network of roads, footpaths, bridle paths and open-access land provide the routes that people are legally allowed to use in order to explore the Welsh landscape. It is therefore, important to understand the distribution and the quality of this network. The length of each different type of transport route was calculated from the digital survey data collated for each site (Table 3.6.7.2.1). Additional information on the quality of this network has been collated through incidental surveys undertaken by the GMEP bird surveyors (from BTO) who made notes when they visited the survey sites in the spring of 2014. Surveys found that 57 of the 90, 2nd year sites had some PROW of which only 20 had fully open, signed and navigable paths. In a typical GMEP 1km square, only two-thirds of the paths on a 1km square were fully open, physically accessible and easy to find. Poor signage was common and many footpaths were infrequently used as a consequence which led to degradation and poor maintenance.

	Min	Mean	Max
Open Access Land (*including beaches*) (km^2)	0	0.107	1
Public Rights of Way (km)	0	1.495	5.724
Accessible Roads (km)	0.014	1.777	6.355
Public Rights of Way or Accessible Roads (km)	0	2.826	9.675

Table 3.6.7.2.1 *Calculated lengths of the Public Rights of Way network within the 150 1st and 2nd year GMEP 1km survey squares.*

PROW are common throughout the managed landscapes of Wales, often linking farms and settlements together as well as providing routes across mountains and across open land (Table 3.6.7.2.2). They are an important resource, particularly for tourists to Wales many of whom come specifically to walk. Of the first and second year sites, the digital data show that 133 of the 150 contained some PROW; the remaining 17 sites were all remote, upland sites. The distribution of paths varied significantly, but in places the network was dense with one site having nearly 6km of footpaths within the GMEP 1km survey square, though more typically this figure was between 1.5 – 3km. Roads are included here as a separate value, because in rural areas, these unclassified routes provide pedestrian access in addition to motor access and together with the footpaths can form a dense network of routes.

	Open Access Land (including beaches)		**Public Rights of Way**		**Accessible Roads**		**Public Rights of Way or Accessible Roads**	
	Count	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
No	109	72.7	29	19.3	39	26.0	17	11.3
Yes	41	27.3	121	80.7	111	74.0	133	88.7

Table 3.6.7.2.2 *Counts of different classes of rights of way within the 150 1st and 2nd year GMEP sites.*

3.6.8 GMEP Photographic Preference Survey Results

By January 8th 2015, 1001 people participated in the survey, and of these, 976 completed the survey (97.5% completion rate). The majority of respondents, 874 (89.5%), chose to complete the survey in English, with 102 (10.5%) completing the Welsh version.

3.6.8.1 Demographics

3.6.8.1.1 Gender and Age

The sample is balanced between the genders, 48.5% of the respondents were female and 51.5% were male. While there was a relatively even distribution of respondents aged between 35 and 64, the proportion (18.2%) aged 65+ appears relatively large as it includes all 5 year cohorts up to 100 and although it looks anomalous it compares to an England and Wales average of 16% for the 65+ category (ONS 2011 Census data) and a figure of 18% for Wales (Baxter & Boyce, 2011). Only 0.3% of respondents were children (under 18) and 12.1% aged between 18 and 29 (Figure 3.6.8.1.1.1).

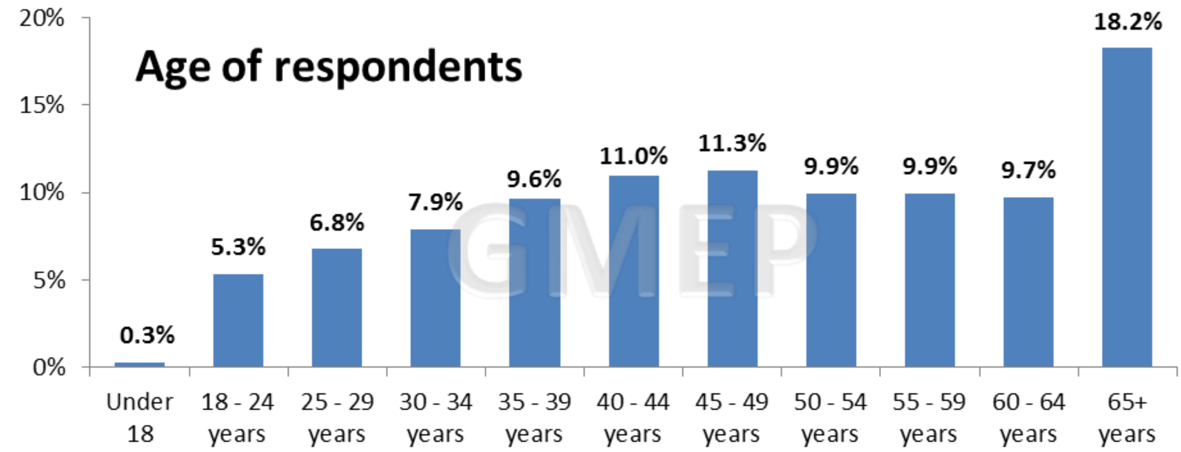


Figure 3.6.8.1.1.1 *Profile of the GMEP Photographic Preference Survey respondents, n = 976*

This distribution is perhaps unsurprising, considering the informal non-stratified approach that was taken to sampling in which it is difficult to control the distribution of the respondents. Accessing children's views is difficult online and will require targeted activity to address if deemed particularly important – for GMEP, this is not deemed to be a particular problem.

3.6.8.1.2 Location of respondents

Respondents are asked to provide the postcode of their home address at the start of the survey. The vast majority were willing to give their full postcode, with others opting to provide a higher level postcode. These data were converted and mapped to show the distribution of respondents both in the UK and more specifically in Wales.

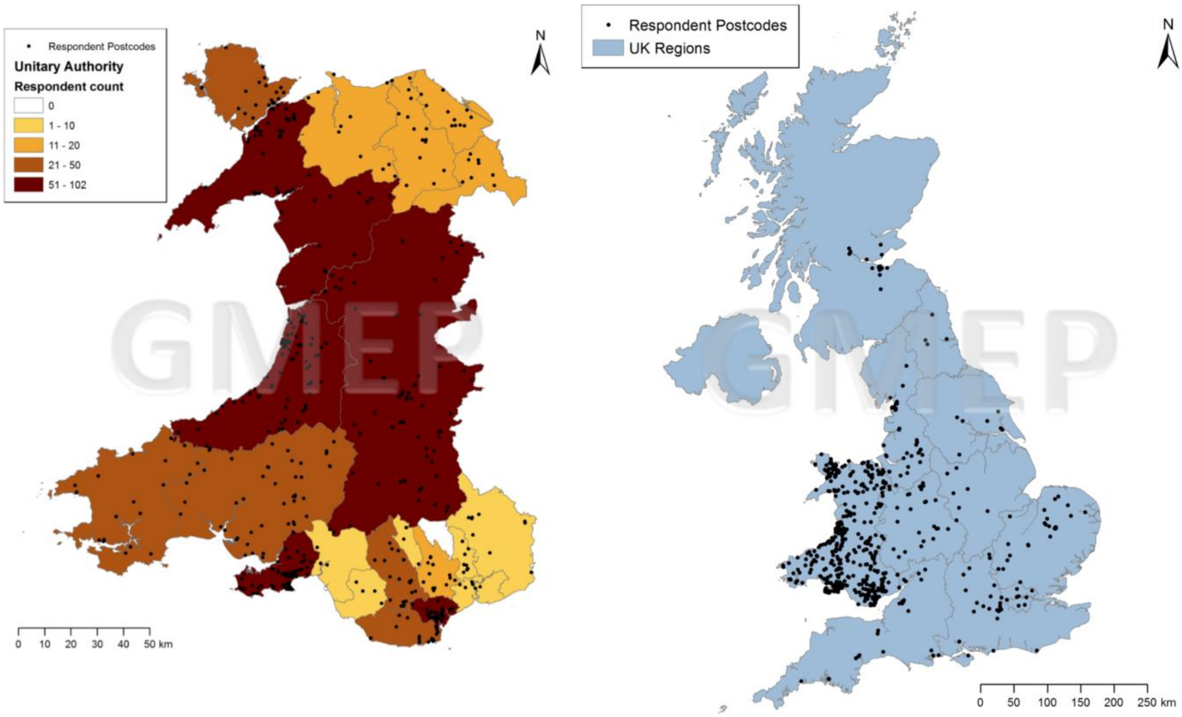


Figure 3.6.8.1.2.1 *Distribution of survey respondents from within Wales (left) and across the wider UK (right). Of the 976 completed surveys, 758 described themselves as Welsh (78%), 93 English (10%), 12 Scottish (1%), 113 as other which included those who chose British as their nationality and a small number of foreign visitors.*

3.6.8.1.3 Employment characteristics of respondents

The majority (72.3%) of respondents were employed either full time or part time, while around one fifth (21.2%) of respondents were retired. Wales does have the highest proportion of retired people within the four home nations of the UK, reflecting an aging population and a well-established trend for retirees to settle in the coastal communities. Around similar proportion were in education (3.4%) as in 'other' occupation. 'Other' occupations primarily included unemployed, volunteers, homemakers, carers and individuals who considered themselves as 'semi-retired' (Table 3.6.8.1.3.1)

Occupation Class	Frequency	Percent
In full-time education	33	3.4%
Employed (full time / part-time / self-employed)	706	72.3%
Retired	207	21.2%
Other (please specify, e.g. full-time carer)	30	3.1%
Total	**976**	**100.0%**

Table 3.6.8.1.3.1 *Employment of the GMEP PPS respondents (n = 976)*

3.6.8.1.4 Impact of childhood home / adult residence

The locations of where respondents grew up and currently live were proportionally similar. Around two thirds (58%) of respondents grew up in either a village or small town, with a slightly larger proportion (68.8%) currently living in a village or a small town (Figure 3.6.8.1.4.1).

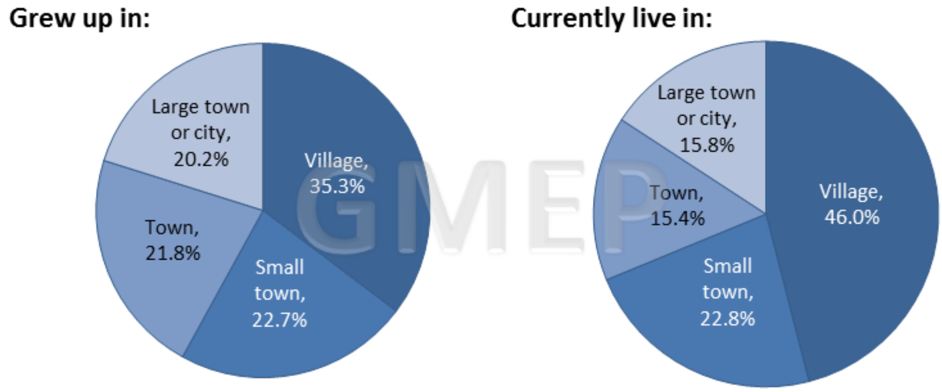


Figure 3.6.8.1.4.1 *Respondents childhood home versus current home, n = 976*

3.6.8.1.5 Nationality

The vast majority of respondents considered themselves either British (41.5%) or Welsh (40.1%). A smaller proportion considered themselves English (11.5%), while the 'other' nationalities (4.3%) primarily included individuals from other countries in Europe (1.1%, *n =11*), outside Europe (0.6%, n = 6) and those who considered themselves Welsh and British or other nationality (0.8%, n =8).

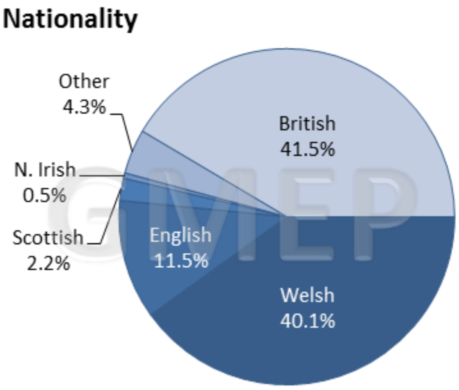


Figure 3.6.8.1.5.1 *Nationality of the GMEP Survey Respondents (n = 976).*

3.6.8.2 Countryside Visiting Habits

Figure 3.6.8.2.1 shows the frequency of respondents' visits to the countryside in an average month. Nearly half (44.9%) of the respondents make daily visits and a quarter (26.2%) visiting the countryside 2-3 times per week. A negligible proportion (0.2%) said they never visit the countryside.

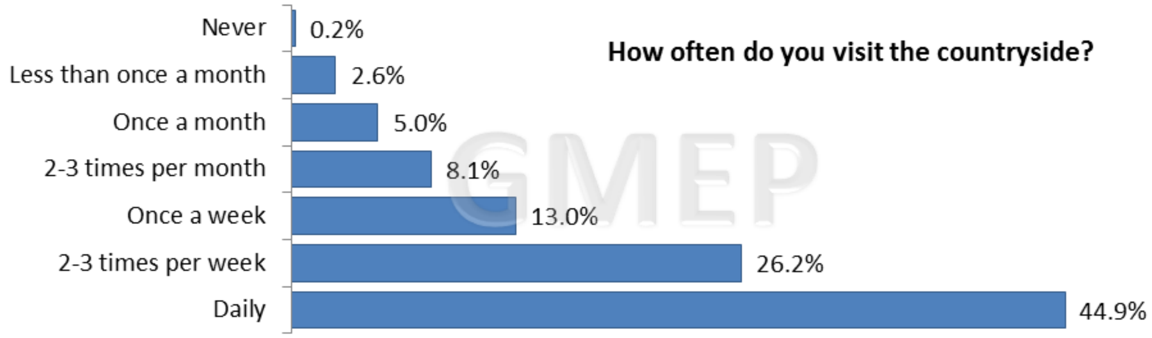


Figure 3.6.8.2.1 *Frequency (in a typical month) that the GMEP PPS respondents visited the countryside.*

The most common reasons for visiting the countryside (respondents could select as many of the options as they wanted) are summarised in Figure 3.6.8.2.2. The two main reasons were 'relaxation' and 'active recreation', which were selected by about two thirds (61%) of respondents. These were followed by 'health reasons', 'peace and quiet' and 'to explore and discover new places', which were selected by over half of the respondents.

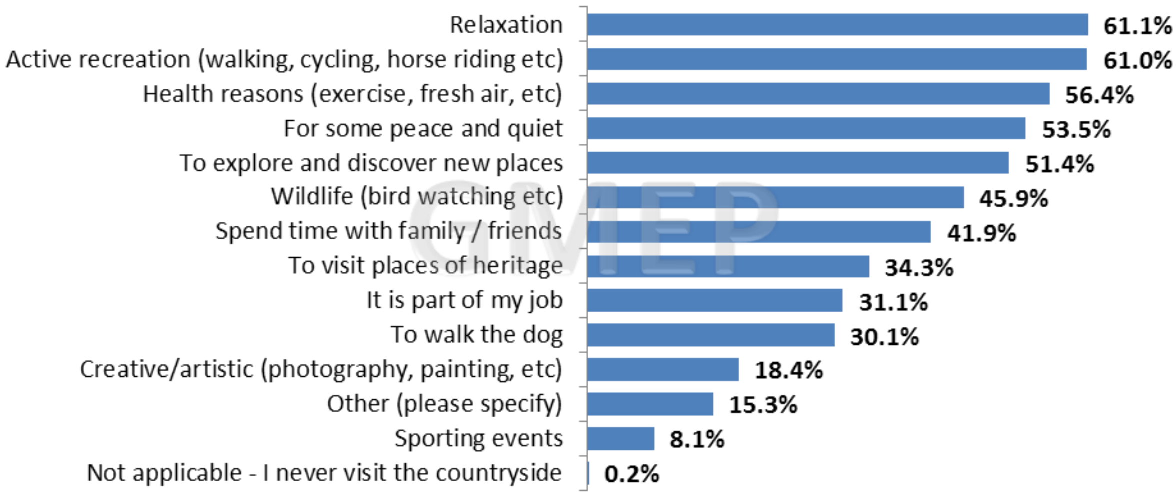


Figure 3.6.8.2.2 *Reasons given for visits to the countryside by the GMEP PPS respondents. Note that respondents were free to tick as many as applied so the % figures relate to how many of the total (n=967) chose that particular option.*

The majority of the 15.9% (149) respondents, who specified 'other' reasons for visiting the countryside, stated that they lived in the countryside (59%). Other reasons included astronomy and dark skies (11%), volunteering (7%), fishing/hunting (3%) and for visual enjoyment (3%).
When queried about how they accessed the countryside in order to engage in these activities, the majority of people used a private car (64%), followed by walking (28%) and more rarely by bicycle (4%). Only 3% of respondents stated that they typically used public transport which may well reflect the lack of service / coverage of such transport opportunities in many rural areas. The remainder either lived there and did not specify or used a mixed mode of transport, a small minority stated that they would run or use a horse.

3.6.8.3 Perceived value of the Welsh countryside

At the start of the GMEP PPS, before they had been shown any of the landscape photographs a baseline question was asked as to how important the Welsh countryside was to them. Bearing in mind that only 40% of the survey specifically identified themselves as Welsh it is clear that this landscape is valued and has an existence value for many. The vast majority of respondents (96.4%) considered the Welsh countryside to be either 'important' or 'very important' to them, with only a negligible proportion (0.3%) declaring it be 'unimportant' or 'not at all important'. Only 3.3% had neutral feelings.

3.6.8.4 Overall attractiveness of the Welsh countryside

In order to assess the general validity of the GMEP VQI, five sets of landscape photographs were included in the PPS (Figure 3.6.8.4.1). These sites represented the full range of VQI values (minimum, lower quartile, median, upper quartile, maximum). By asking the respondents to rate these landscapes from 1 (low – unattractive) to 10 (high – very attractive), we could check whether the VQI was capturing values that did in some way capture useful information about the aesthetic that could be perceived by the general public.

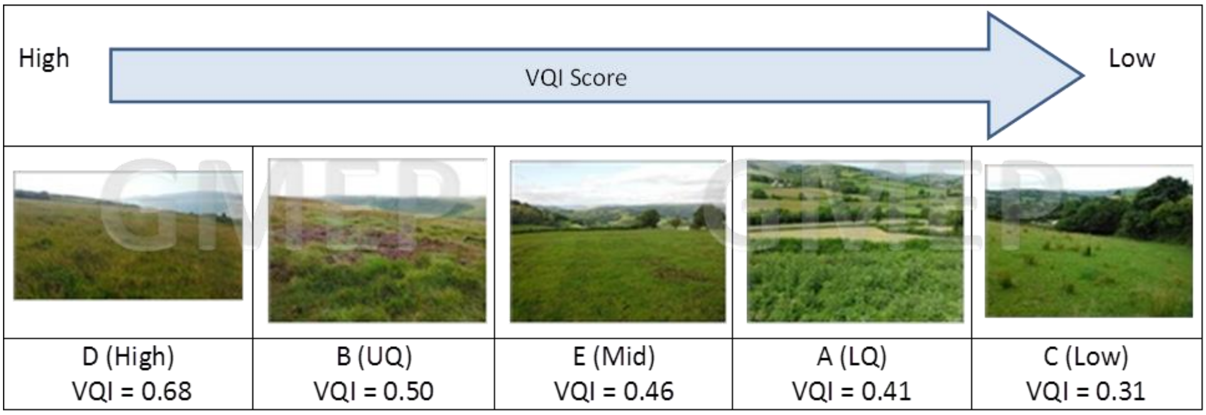


Figure 3.6.8.4.1 *The five landscape photographs representing the range of the VQI, used within the GMEP photographic preference survey.*

Overall, the order of landscape attractiveness indicated by the respondents matches the order indicated by the VQI except towards the higher end of the scale. Landscape B was considered most attractive when all respondents were grouped (M= 7.77, SD= 2.01), followed very closely by landscape D (M=7.70, SD=1.98). Landscape E (M=7.34, SD=2.14) ranked in the middle, followed by A

(M=6.94, SD=2.02) and lastly C (M=6.85, SD=1.98). There were however, some variations relating to age and gender.

3.6.8.4.1 Influence of gender on attractiveness ratings

Overall, the order of landscape preference was very similar between the females and males (Table 3.6.8.4.1.1). However, women chose Landscape D (High VQI) as the most attractive landscape followed by B (UQ VQI), while men chose B as the highest, followed by D (High VQI). This means that the women matched the order of the VQI ratings exactly whilst the men showed some variation. Women also rated all landscapes higher than men and this difference was statistically significant ($p<0.05$) for all of the landscapes except landscape A which was the LQ VQI site.

Ranking	Female (n=468)		**Landscape:**		Male (n=499)		Ranking
	Mean	SD			Mean	SD	
High	8.06	1.90	**D (High)**	**B (UQ)**	7.53	2.16	**High**
	8.01	1.80	**B (UQ)**	**D (High)**	7.35	1.99	
	7.68	1.93	**E (Med)**	**E (Med)**	7.01	2.22	
	7.05	2.03	**A (LQ)**	**A (LQ)**	6.82	1.99	
Low	7.03	1.95	**C (Low)**	**C (Low)**	6.71	1.96	**Low**

Table 3.6.8.4.1.1 *The order of landscape preference assessed by gender, means and standard deviation (SD) reported with the associated order of the five GMEP landscapes.*

3.6.8.4.2 Influence of age on attractiveness ratings

To facilitate analysis, respondents were grouped into four age categories; '29 and under', '30 – 44', '45 – 59' and '60 and above'– the mean rating scores and SD for these groups are shown in Table 3.6.8.4.2.1. While bearing in mind the different numbers of respondents in each age group, a number of interesting observations can be made: While younger (under 24) and older (55+) individuals score landscape B as most attractive followed by landscape D, individuals generally between 25 and 54 select Landscape D as more attractive (followed by landscape B). The mean rating scores indicate that age groups '29 and over', '45 – 59' and '60 and above' ranked the five landscaped in the same order - B (UQ) as highest, followed by D (High), E (Med), A (LQ), and C (Low) as lowest. Age group '30 – 44' ranked landscapes in the following order - D (High) as highest followed by B (UQ), E (Med), C (Low) and A (LQ) as last. Also, the mean scores indicate that younger age groups ('29 and over' and '30 – 44') gave lower overall ratings than the older groups ('45 – 59' and '60 and above'). Generally, younger respondents (in '29 and under' and '30 – 44') tended to rate landscapes A, B, C and E lower than the older respondents, particularly 45 to 59 year olds and those who are 60 and over.

Landscape	**29 and under (N = 120)**		**30 - 44 (N = 275)**		**45 - 59 (N = 302)**		**60 and over (N = 270)**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
A (LQ)	6.29	1.717	6.43	1.91	7.02	1.992	7.61	2.044
B (UQ)	**7.31**	2.329	7.63	1.829	**7.74**	2.015	**8.13**	1.969
C (Low)	6.27	1.969	6.64	1.92	6.97	1.774	7.24	2.145
D (Max)	7.29	2.056	**7.83**	1.854	7.65	1.881	7.77	2.15
E (Med)	7.28	1.991	7.09	2.158	7.32	2.001	7.63	2.211

Table 3.6.8.4.2.1 *Mean and standard deviation for four age groups, highest ranked landscapes are highlighted in **bold** in each case.*

3.6.8.4.3 Influence of nationality on overall preference ratings

The mean scores show no difference in the order of preference between individuals who considered themselves Welsh, English, or British. The few Scottish respondents however scored landscape D as highest, followed by landscapes B, A, C and lastly E. When the results were explored statistically, the only significant differences found were for Landscape A (LQ) and Landscape E (Median). For landscape A (LQ), the mean score of the 'Welsh' group (M=7.22, SD=2.056) was significantly different from the 'British' (M=6.79, SD=1.983) and 'other' nationalities (M=6.48, SD=2.062). For landscape E (Med), the mean score of the 'Welsh' group (M=7.73, SD=2.021) significantly different from the 'English' (M=7.09, SD=2.288), 'British' (M=7.10, SD=2.095) and 'Other' (M=6.90, SD=2.112) groups. Respondents who considered themselves Welsh rated these two landscapes higher than those considering themselves British, English or other nationality (Table 3.6.8.4.3.1)

Landscape:	**Groups compared (only significant comparisons shown)**			**Mean Difference**	***p***
A (LQ)	Welsh	vs	British	0.429	0.014
		vs	Other	0.739	0.027
E (Med)	Welsh	vs	English	0.637	0.024
		vs	British	0.629	0.000
		vs	Other	0.831	0.015

Table 3.6.8.4.3.1 *Comparisons between landscape assessments per nationality, results from Post-hoc comparisons using the Tukey HSD test.*

3.6.8.4.4 Influence of childhood home on overall preference ratings

The mean rating scores of respondents who grew in a village, town, or large town or city ranked the five landscapes in the same order - B (UQ) received the highest scores, followed by D (High), E (Med), A (LQ), and lastly landscape C (Low) (Table 3.6.8.4.4.1). Those who grew up in a small town ranked landscape D (High) highest, followed by B (UQ), E (Med), C (Low) and landscape A (LQ) as lowest. People who grew up in a village gave generally higher scores for each of the landscapes than those who grew up in a town or city.

Grew up in:	**Village (N=342)**		**Small town (N=220)**		**Town (N=212)**		**Large town or city (N=196)**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
A (LQ)	7.17	2.112	6.70	1.94	6.77	1.951	6.98	1.962
B (UQ)	**7.99**	1.869	7.35	2.167	**7.67**	2.176	**7.97**	1.81
C (Low)	7.01	2.027	6.72	1.848	6.68	1.991	6.88	2.014
D (High)	7.80	2.012	**7.49**	2.048	7.66	1.92	7.80	1.912
E (Med)	7.55	2.173	7.15	2.002	7.01	2.216	7.52	1.968

Table 3.6.8.4.4.1 *The order of landscape preference according to where respondents grew up or spent their childhood. Highest ranked landscapes are highlighted in bold.*

Post-hoc comparisons using the Tukey HSD and Games Howell tests indicated significant differences in the mean scores of the following groups (Table 3.6.8.4.4.2): For landscape A (LQ), the mean score of those who grew up in a village group (M=7.15, SD=2.107) was significantly different from those who grew up in a small town (M=6.68, SD=1.938). For landscape B (UQ), the mean score of those who grew up in a small town (M=7.35, SD=2.164) was significantly different from those who grew up in a village (M=7.97, SD=1.868) or large town or city (M=7.97, SD=1.810). Lastly, for landscape E (Med), the mean score of those who grew up in a village (M=7.54, SD=2.170) significantly differed from those who grew up in a town (M=7.01, SD=2.112).

Landscape	Groups compared (only significant comparisons shown)			Mean Difference	*p*
A (LQ)	Village	vs	Small town	0.468	0.037
B (UQ)	Small town	vs	Village	-0.623	0.003
		vs	Large town or city	-0.619	0.009
E (Med)	Village	vs	Town	0.524	0.023

Table 3.6.8.4.4.2 *Post-hoc comparisons using the Tukey HSD test for landscapes A and E, and the Games Howell test for landscape B (because data could not meet the homogeneity of variances assumption) of the type of settlement that the respondents grew up in or spent their childhood.*
When these data are analysed statistically, the results in Table 3.6.8.4.4.2 indicate that respondents who up in a village tended to rate landscapes A, B and E higher than those who grew up in a small town (for A and B) or a town (for E). Also, those who grew up in a large town or city rated landscape B higher than those from a small town.

3.6.8.4.5 Influence of current home on overall preference ratings

Mean scores indicate that respondents currently living in a village or small town rated landscape B (UQ) as highest followed closely by D (High), while those living in a town, large town or city rated D (High) as highest followed by B (UQ) (Table 3.6.8.4.5.1). All groups (except those living in a small town) rated landscape C (Low) as least attractive, with A (LQ) as second to last. Conversely, residents from small towns chose A (LQ) as least attractive, with C (Low) as second to last.

	Village (N=443)		Small town (N=219)		Town (N=150)		Large town or city (N=153)	
	M	SD	M	SD	M	SD	M	SD
A (LQ)	7.02	2.038	6.82	2.021	6.8	2.027	6.92	1.914
B (UQ)	**7.84**	2.03	**7.8**	2.023	7.59	1.943	7.62	1.984
C (Low)	7.00	1.968	6.89	1.97	6.63	1.916	6.63	2.025
D (High)	7.63	2.095	7.79	1.976	**7.61**	1.745	**7.8**	1.864
E (Med)	7.36	2.143	7.44	2.103	7.05	2.069	7.36	2.073

Table 3.6.8.4.5.1*: The order of landscape preference according to where respondents currently live. Highest ranked landscapes are highlighted in bold.*

3.6.8.5 Heatmap Results (Areas found most attractive)

Figure 3.6.8.5.1 shows the five landscapes (ordered from high VQI value (Landscape D) to low VQI value (Landscape C)) overlaid with a ‘heatmap’ of area(s) respondents favoured most. **Landscape D** shows a very clear single focus of preference on the beach area, and while few respondents selected the sea (close to the shore), there are virtually no selections anywhere else. For **landscape B** (UQ VQI value) three areas of preference can be discerned; the most prominent one being on the flowering heather, followed by a distinct focus on the livestock (sheep) and a more diffuse selection of the hillside. For **landscape E**, again three areas of focus can be seen; two prominent focal points are on the fields on a hill in the far distance and deciduous trees on the side of a hill in the middle distance. A third area of lower selection can also be noted on the fields and hedgerows on the right hand side in the middle distance. Six/seven areas of selection can be noted on **landscape A** (LQ VQI). The two most prominent ones are on grass fields and hedgerows on the hill in the top middle of the image and on the valley in the far distance, followed by one on the prominent hedgerow and another on the river. Another two (fainter) areas of selection can also be seen on the smaller valleys/hills. A seventh, but a very faint, area of selection can be seen on the farm buildings (top left hand corner). Approximately seven areas of selection can be seen on **landscape C** (lowest VQI value). The three most prominent areas are on deciduous trees/woodland, farm/house buildings and the fields/hedgerows in the distance. Other three prominent areas of selection are on the fields and hedgerows.

In general, higher VQI landscapes tended to show fewer, but more concentrated, areas of preference. The number of areas increased in landscapes with lower VQI values, but these ‘hot spots’ tended to be more diffuse (less concentrated) than the high VQI landscape areas of preference.

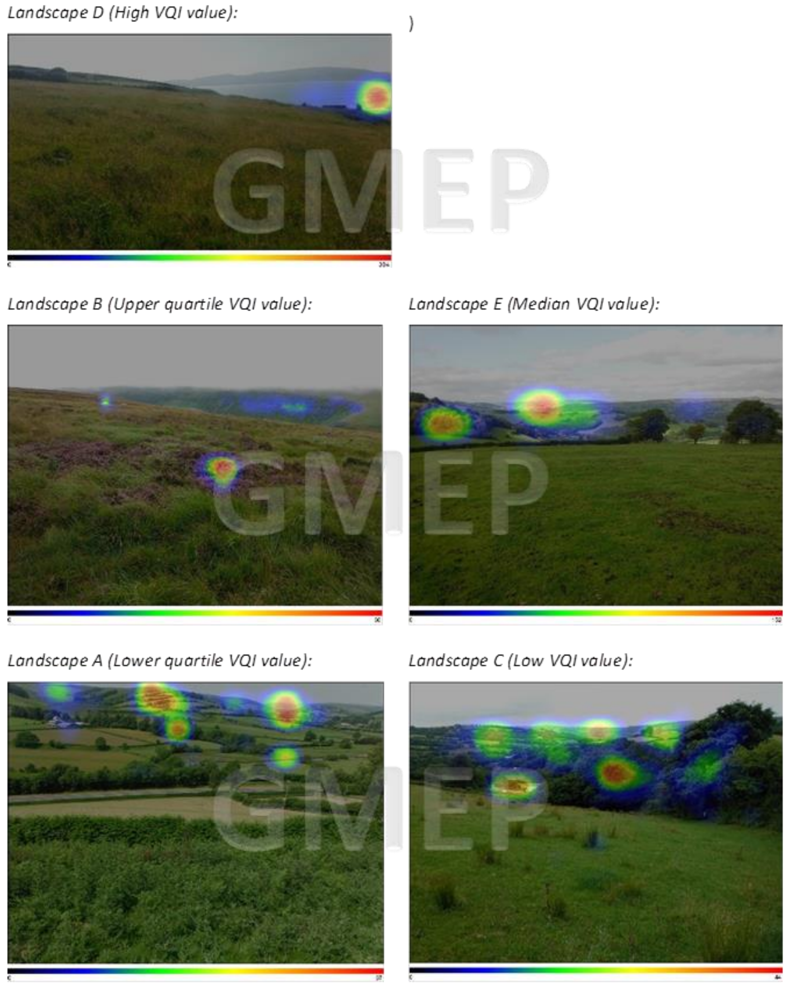


Figure 3.6.8.5.1 *Heatmaps showing the density of chosen locations from 976 respondent choices for each of the five landscape photographs.*

3.6.8.6 Feature Preference Results

Six landscape photographs were selected with particular landscape components that feature in the VQI and which can have either a positive or negative effect on it. These components were surrounded by a frame and respondents were asked to select whether they liked, disliked or had no opinion (neutral). The results for each feature in the six landscapes are presented below and it should be noted that respondents were not able to see the descriptions of the features in frames:

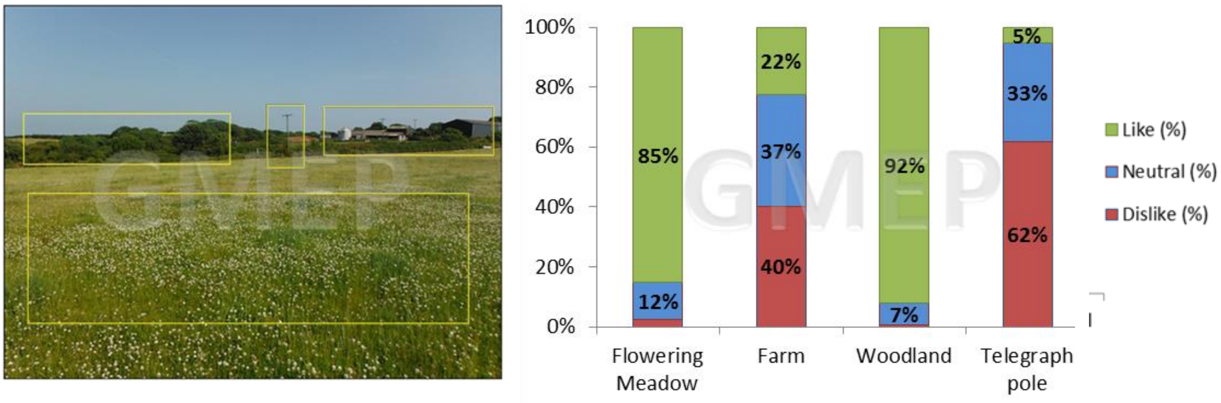


Figure 3.6.8.6.1 Landscape 1: *The two more 'natural' features of the flowering meadow and the woodlands were liked by the majority of respondents (85% and 92% respectively). The telegraph pole was mostly disliked – two thirds (62%) of responded disliked it and a third marked it as 'neutral' (33%). The farm buildings were also disliked, although by a smaller proportion of respondents (40%), which is similar to the number (37%) of people who marked it as a neutral feature. Only a fifth (22%) of respondents liked the farm.*

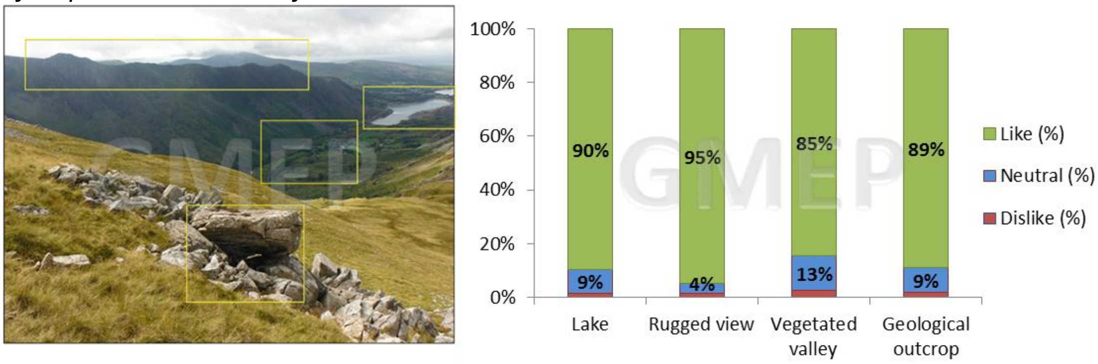


Figure 3.6.8.6.2: Landscape 2: *This appeared to be the most favoured of the six landscape images as all four of the framed features were liked by the majority of respondents.*

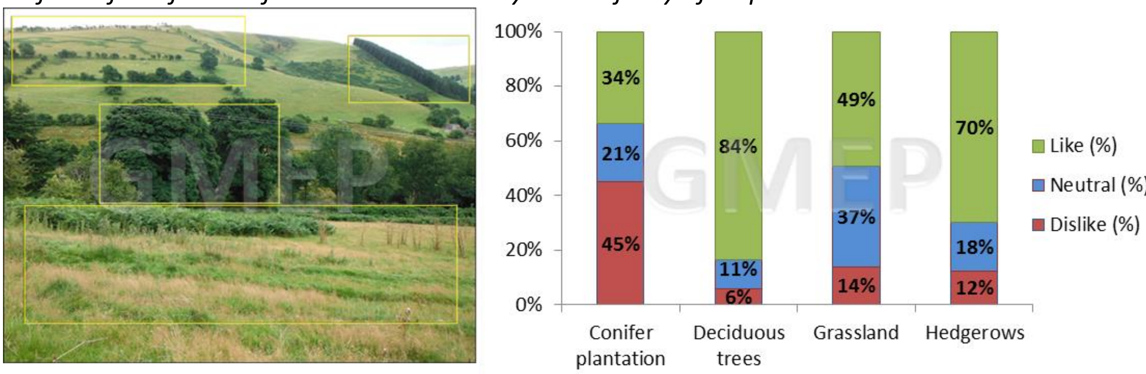


Figure 3.6.8.6.3 Landscape 3: *Deciduous trees were the most liked of the four features in this landscape followed by the hedgerows. Just under half of respondents said they liked the grassland at the forefront, with the rest marking either as 'neutral' (37%) or disliking it (14%). The opinion regarding the conifer plantation is less clear cut – while the larger proportion (45%) of respondents disliked it, over a third (34%) also liked it with a fifth (21%) marking it as 'neutral'.*

Figure 3.6.8.6.4 Landscape 4: *All of the features in this landscape were liked by the majority of respondents. Livestock (sheep) was liked slightly less (by 66%) of the respondents than the other two features – the stone wall and 'rugged view', which were liked by 91% and 95% of respondents respectively.*

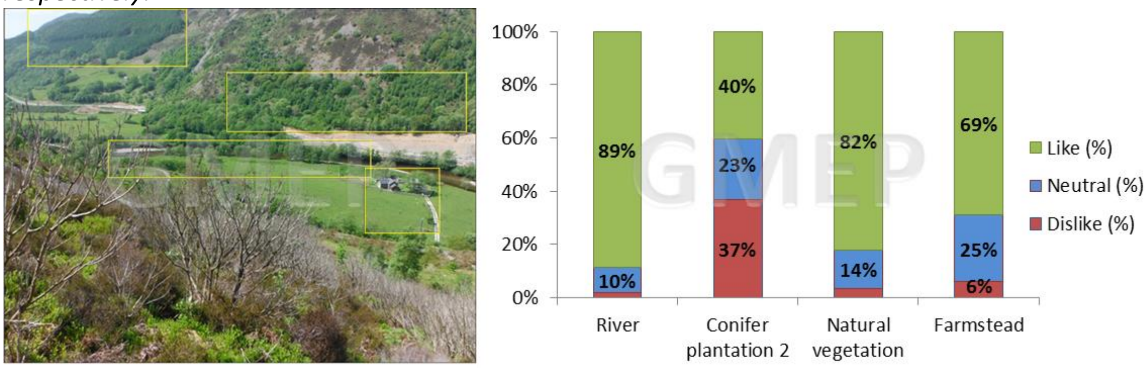


Figure 3.6.8.6.5 Landscape 5: *As in landscape 1, the more 'natural' features of the river and natural vegetation were liked by the majority of the respondents (89% and 82% respectively). Also, the overall preference for the conifer plantation was less clear cut with 40% respondents liking it and 37% disliking it. The slightly higher percentage of people liking the conifers in this image may be due to the plantation looking less prominent and better blended into the hillside than it is in landscape 1. The building labelled as farmstead was liked by 69% of the respondents – much more than the farm building in landscape 1. This is perhaps due to buildings in landscape 1 looking more 'industrial' (e.g. presence of silos, large cowsheds) than the building by the river in landscape 5.*

Landscape 3.6.8.6.6 Landscape 6**:** *The majority (72%) of respondents liked the livestock (cows). Opinion regarding the road was less definitive: while a third (31%) disliked the road and over a quarter (25%) liked it, most respondents (43%) marked it as 'neutral'.*

3.6.9 What is the condition of historic features in the GMEP survey?

Wales has a rich and distinctive historic environment that is revealed through its historic landscape character (fields, moors, lanes, settlements) and through its unique archaeological sites and material remains from previous industrial activity. There are currently 3 UNESCO World Heritage Sites, 30,000 listed buildings and over 4,000 Scheduled Ancient Monuments in Wales which are protected by law. These historic features are widely used in the promotion of Wales and are a key motivator for many visitors. It has been estimated that the historic environment supports over 30,000 jobs and in 2009 contributed approximately £840 million to the wider economy. The historic environment also creates social benefits for residents of Wales, including opportunities for leisure, volunteering and learning. As such maintaining these historical features in good physical condition is necessary as they play a key role in contributing to wider landscape values.

A range of designated features were present within the first and second year GMEP 1km survey squares including 23 Scheduled Ancient Monuments (SAM), and 107 Listed Buildings. In addition to the designated historic sites of Wales, there are a large number of important non-designated features within the landscape. These sites are documented by the four Welsh Archaeological Trusts which collate and continue to update the Historic Environment Features (HEF) dataset. The HEF dataset records the location and known information about these non-designated historic features. Together with the designated sites such as the Scheduled Ancient Monuments and listed buildings, these smaller features contribute to the overall historic and cultural value of a landscape. Existing datasets provide information on the location of historic features present within Wales. GMEP is providing an insight into the condition of those features within the GMEP 1km survey squares, the pressures they currently face and eventually will indicate how this changes over time.
With the 150 GMEP 1km survey squares of the first and second year survey, it has been possible to survey around 120 historic features. The most common types of feature were buildings (including houses and cottages), ponds and quarries.

An assessment of condition shows that 8% were judged to be in excellent condition at the time of survey and 35% were seen to be sound with minor defects. However, 33% were assessed to be showing major signs of deterioration while a further 7% were seen to have significant damage (Figure 3.6.9.1)

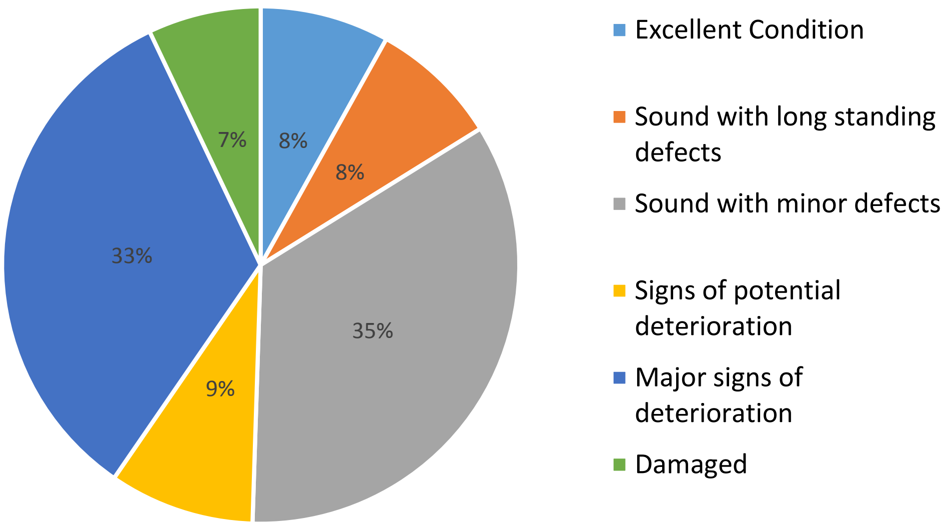


Figure 3.6.9.1 *Condition of Historic Environment Features (HEF's) from years 1 and 2 of GMEP 1km survey squares.*

Vegetation was the most prevalent threat (including scrub, bracken, brambles and rushes), with potential to not only visually obscure but also physically damage historic features Stock threats were also relatively frequent (including poaching, erosion and stock wear) while agricultural (for example surface tyre tracks, dumping, ploughing, drainage and pasture improvement) and other general threats (including natural decay, vandalism, development, flytipping) were less common. (Figure 3.6.9.2)

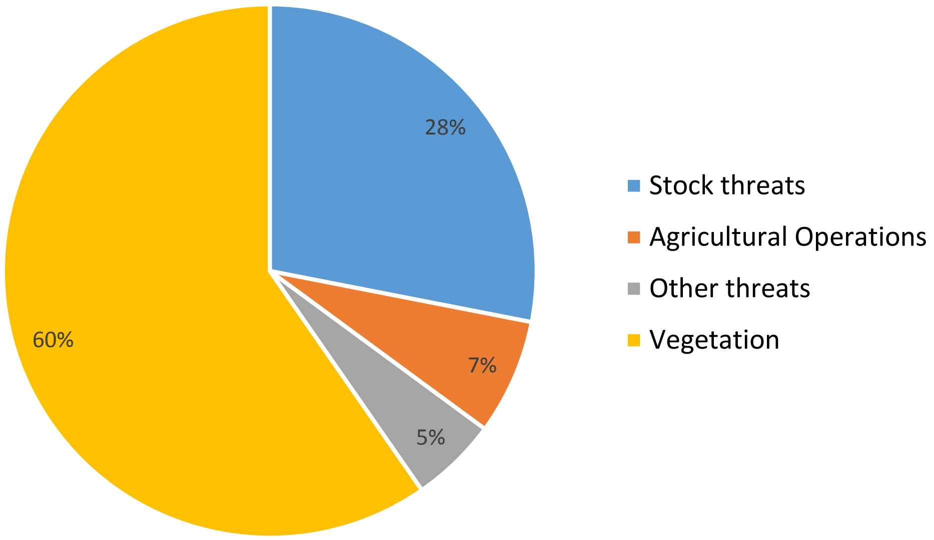


Figure 3.6.9.2 *Threats to Historic Environment Features (HEF's) or years1 and 2 of GMEP 1km survey squares.*

Non-designated historic features are common throughout all landscapes in Wales. On the whole, these features are found on private land so the long-term care of these cultural assets is frequently entrusted to individual landowners. Sometimes these features face neglect or suffer damage through lack of appropriate knowledge and management. Glastir provides funding to landowners to protect historic features through land use management such as switching from arable cropping to grass pasture or managing erosion by controlling stock better with fencing. In addition, payments are available to help manage scrub which is a particular problem on some historic sites. This type of active management has potentially positive impacts on visual landscape quality, where sightlines are clear, historic features can be seen and recognised as such by the general public.

3.7 Future Plans

- The repeat Wales Farm Practice Survey (WFPS) will be run in Year 4 (led by ADAS). It will generate important information from different cohorts of farmers (in and out of previous and current environmental stewardship schemes). The WFPS will generate data from which model estimates of the effectiveness of Glastir options to meet targets, e.g. for C sequestration, GHG emissions, water quality, woodland areas and biodiversity, can be adjusted for levels of uptake, thus making estimates more robust. We will seek opportunity to add key questions to the WFPS, which will improve the evidence base, and hence evaluation of the effectiveness of Glastir to meet its desired outcomes.
- We will return to the farms receiving Glastir Efficiency Grants (GEGs), which were C footprinted in 2014 to evaluate baseline GHG emissions and C sequestration. The repeated footprints will allow us to assess the effects of the GEGs on GHG emissions and C sequestration.
- Complete spatial disaggregation of the VQI for the 2nd year sites (n = 90) and finish a sensitivity analysis of the impact of different component weightings on the landscape weightings.
- Evaluate the impact of the three different scales of VQI data (250m, 1km, 3km).
- Explore the possibility of deriving a simplified VQI at the 1km scale for the whole of Wales.

- Analyse the detailed VQI data for these 150 sites, in particular to explore the quality of the landscape that is visually accessible to the general public by combining the results of the viewshed analysis with the VQI.
- Undertake a comparison of the outputs of the VQI with the landscape / sensory layers of the LANDMAP dataset.
- To begin the next stage of the landscape preference work. The GMEP photographic preference survey will enter a second phase where the public will be questioned about the impact of landscape changes promoted by the Glastir programme. A range of landscape photographs are currently being prepared to illustrate changes in the visual appearance of landscapes which may result from changed management.

Figure 3.7.1 *Examples of landscape photograph manipulations being prepared for the second phase of the GMEP PPS, the top row shows the landscapes currently, the bottom shows a range of landscape changes. (L to R) – with / without species rich grasslands; with / without stream and heather in flower; with / without hedges and woodlands.*

4 Woodlands

Maskell, L.[1], Jarvis, S.[1], Smart, S.[1]

[1]CEH Lancaster

4.1 Introduction

Woodlands are important for the provision of multiple ecosystem services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million (Read *et al*. 2009). A recent survey[1] demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community. There are two main woodland Broad Habitats; Broadleaved and Yew Mixed Woodland and Coniferous Woodland. In Wales, only Broadleaf-dominated Woodland is native, and this type is the main focus of nature conservation interest. It includes seven Priority Habitat types recognised in the UK Biodiversity Action Plan (Wet Woodland, Lowland Mixed Deciduous Woodland, Lowland Beech and Yew Woodland (confined to South Wales), Upland Mixed Ash Woodland and Upland Oak Woodland accounting for approximately 50% of semi-natural woodland (Russell *et al*. 2011), Wood Pasture and Parkland and Traditional Orchards) and Broadleaved, Mixed & Yew Woodland is recognised as a feature of interest on many SSSIs. Woodlands in Wales vary in size and distribution; areas of semi-natural and Ancient Woodland tend to be small and fragmented. There are also areas of Coniferous Woodland particularly located on poorer soils in upland Wales. The ecosystem services provided by Broadleaved Woodland and Priority Habitats tend to be more focused upon cultural services, aesthetic qualities and wildlife conservation and less on timber production, although there is activity in Wales to encourage sustainable management of Broadleaved Woodlands for environmental, social and economic outcomes[2]. Modified habitats and plantations, although less valuable for biodiversity, can still provide education and recreational opportunities as well as timber production, soil protection and flood prevention. As well as the area Broad Habitats woodland services and species are also represented in woody linear features (hedgerows and lines of trees) and smaller point features (individual trees including veterans and small clumps of trees and scrub). These features are extremely important in connecting woodland habitats within a landscape and used for shelter, dispersal, habitat by many species. An analysis of potential expansion of existing woodland and establish streamside corridors under low, medium and high uptake scenarios estimated a potential 10,000 additional hectares of woodland from these options alone (Emmett et al. 2014). Veteran trees are also important for species diversity, they are often more likely to be found in non-woodland situations (Read 2000) in open parks and wood pastures but may still be found within woodland. The UK has a relatively high density of veteran trees and it is a conservation priority to protect them.

Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland although this is low by European standards, only Scotland has a higher total woodland cover however this is a consequence of the much higher percentage cover of Coniferous Woodland there than elsewhere (Smart *et al*. 2009). About 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations (Russell *et al.* 2011).

[1] http://wales.gov.uk/newsroom/environmentandcountryside/2013/130910woodlands/?lang=en
[2] Coed Cymru http://www.coedcymru.org.uk/

4.2 Achievements of the GMEP project in Year 2

- The GMEP project is using a combined survey and modelling approach to identify the benefits of Glastir options at the national scale. Progress to date:
- Field protocols implemented for recording of woodland habitats and species in GMEP 1km survey squares which includes mapping of woodland habitat, dominant species, management information, land use, vegetation plots in small and large woodland patches and along woody linear features and bird and pollinator recording in 150 1km squares.
- Analyses of long term trends in woodland extent and condition using GMEP data alongside data from other surveys
- Assembly of Glastir Woodland data to analyse changes in woodland extent and condition and impacts on other environmental and biodiversity response variables.
- Developed a woody cover product to enable scaling from GMEP squares to larger scales
- Explored habitat connectivity metrics to develop methods for assessing impacts of Glastir options on connectivity of woodland habitats.

4.3 Findings in Year 2

4.3.1 Extent

- The area of woodland has increased in Wales over the past thirty years (Figure 4.9.2.1, Table 4.9.2.1) with an increase to 2014 (recorded by both GMEP and the National Forest Inventory (NFI)). Both Broadleaved and coniferous woodland types have increased in area.
- GMEP estimates the total area of all woodland in Wales to be 346 000ha (187000ha Broadleaved and 159,000ha Coniferous Woodland) (Figure 4.9.2.1, Table 4.9.2.1), this is 16.3% of Wales in 2013/14. This compares to 10% in England and approximately 15-18% in Scotland.
- NFI estimate the total area of all woodland in Wales in 2014 to be 306,000 ha, 14.8% of Wales[3], 156,000ha of which is Broadleaved Woodland and 151 000ha is coniferous.
- The total area of woodland in Wales is consistent between Countryside Survey (CS) and NFI (particularly considering the large confidence intervals for the estimates), the figure for Coniferous Woodland is very similar (GMEP 159 000ha, NFI 151,000ha) whilst Countryside Survey records a greater amount of woodland as Broadleaved, Mixed & Yew Woodland relative to Coniferous Woodland. More detail is provided on the methods and results in section 4.9
- NFI estimated new planting and restocking in Wales to be 3,100 ha between the two periods 2009-2010 and 2013-2014. This is less than in previous years and a small proportion of the UK new planting (50,900 ha) the majority of which was in Scotland.

4.3.2 Condition

- Coed Cymru state that 'Following a century of neglect and plunder the majority of Welsh Broadleaf Woodlands had been left in a state of serious decline. 85% showed no significant recruitment of young trees'[4]
- The total area of woodland known to be managed to the UK Forestry Standard has increased from 123,000 ha in 2001 to at least 203,000 ha in 2014[11].
- Since 2010, there have been outbreaks of two quarantine diseases affecting tree species in Wales (*Phytophthora ramorum* and *Chalara fraxinea*). A Wales specific *Phytophthora ramorum* disease management was launched in December 2013 which establishes management zones.

[3]http://www.forestry.gov.uk/pdf/ForestryStatistics2014.pdf/$FILE/ForestryStatistics2014.pdf
[4] Coed Cymru http://www.coedcymru.org.uk/

There are also a small number of non-quarantine pests and diseases known to be affecting tree species in Wales[5].

- There is inter-annual variation in the woodland bird indicator but there does not appear to have been a significant directional change in woodland bird species abundance. It is relatively stable in contrast to the farmland bird indicator (section 4.10).
- Current sequestration from Welsh woodlands is estimated to be about 1,419 gigagrams (1,419,000 tonnes) annually. Forestry is predicted to remain a net sink for atmospheric carbon[11,6]
- There was a general non-significant downward trend in Ancient Woodland Indicator (AWI) species in large 200m^2 woodland vegetation plots between 1990 and 2007 however the number of AWI species increased significantly in the 2013/14 GMEP sample (section 4.10).
- A similar trend was seen for total plant species richness in large vegetation plots (section 4.10).
- Scores for plant species preference for light (Ellenberg) are calculated as an average value per plot i.e. higher score= plants present prefer lighter conditions. There has been a decline in light score between 1990 and 2013/14 this indicates that plots are becoming more overgrown with increased shading, possibly due to less management.
- There has been no significant change in connectivity of broadleaf woodland between 1990 and 2013/14.
- No significant change in woody species diversity in hedgerows over the last 10-20 years has been observed. An increase in cutting of hedgerows has been recorded but large declines in new planting, layering and coppicing since 1990. An increase in the length of hedgerows becoming lines of trees also increased suggests a decline in management overall.
- Land coming into Glastir has a significantly higher length of hedgerows than that outside which needs to be taken into consideration in future assessments of Glastir impact.
- There are other relevant findings embedded within Chapter 5, Chapter 7 and Chapter 10.

4.4 Policy context

Woodland expanded significantly in Wales following the First World War (Quine *et al*, 2011) primarily as a result of increasing conifer plantations. This continued after the Second World War. Concern over the loss and degradation of ancient and native woodland led to formation of protected areas such as National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs) (Russell *et al.* 2011, Latham 2005). More recently there has been a shift for new planting to be Broadleaved rather than coniferous. There is also a move away from felling in even aged stands towards maintenance of forest cover (Mason 2007). The key threats/drivers identified to Semi-natural woodland (JNCC 2007, Quine 2011) are overgrazing, habitat fragmentation and isolation, invasion by non-native species, unsympathetic or lack of management, air pollution, landuse change, climate change and new pests and diseases. Climate change is both a threat affecting species composition and woodland condition and a driver of policy change e.g. pressure to increase carbon sequestration or increasing costs of fossil fuels and searches for alternatives may result in increased woodland planting. Although the tree species themselves being long-lived and relatively adaptable may not respond quickly to climate change, species using woodlands or those shifting niche in response to rises in temperature or changes in weather patterns (e.g. increased frequency and severity of storms) may change. There may be interactions between threats e.g. tree diseases are likely to have a more severe effect were trees are also suffering from climatic stress.

---

[5] http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en#/statistics-and-research/woodlands-wales-indicators/?lang=en

[6] http://uk-air.defra.gov.uk/reports/cat07/1407090749_Projections_of_emissions_and_removals_from_the_LULUCF_sector_to_2050-PUBLISHED_VERSION-JULY2014.pdf

The Land Use Climate Change report[7] recommended an expansion of woodland over 20 years by about 100,000ha (mainly deciduous but with a proportion of conifer) with tree provenance adapted to the projected climate. This initiative would create a Greenhouse Gas (GHG) sink and a fuel wood potential. They also recommended management to ensure that woodlands do not become an annual GHG source and that Welsh woods are managed to optimize long term GHG abatement. Tree disease and tree health has risen sharply up the political agenda recently with the spread of diseases e.g. *Chalara fraxinea*, *Phytopthora ramorum*, sudden oak death, Dothistroma red band needle blight, bleeding canker and the high number of potential threats that could adversely affect a number of species. *Phytopthora ramorum* was first found in larch trees in Wales in May 2010, since then the disease has spread across all of South Wales, to the west and a few sites in the north, a survey in May 2013 identified some new sites. Many larch trees have been felled and more areas are showing signs of infection and will require management (e.g. Cwmcarn forest, Bwlch Nant-yr-Arian near Aberystwyth). NRW has drawn up a disease control plan[8]. *Chalara* is also an issue and has been found in newly planted sites in Wales and more recently in the wider environment[9].

There is an increasing interest in the extent to which woodlands are functionally connected (Quine *et al.* 2011) and policy for new planting tends to be focused on increasing connectivity within a landscape. Glastir has a series of options specifically designed to address connectivity which have multiple aims and benefits; to allow the spread of native trees connecting woodland components in the landscape, to enhance the character of the landscape, to encourage habitat diversity and so species diversity, to sequester carbon, to act as a buffer for fields and to increase the extent of woodland.

The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy[10]. These include measures on extent, area of woodland of different types (urban, farm *etc.*) and how that is changing, habitat diversity and species, sustainability of woodland management, carbon balance, tree health, local benefits of woodland, accessibility, value of wood and water management; spanning the range of social, economic and environmental benefits[11].
Other policy drivers which may affect woodland include the water framework Directive, and strategic environmental impact assessments and the Rural Development Program. In Wales, the Glastir scheme is a significant component of the Rural Development Program and therefore contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act) which will apply to woodland habitats. Glastir has a specific Woodlands element which includes options on creating and managing woodland (see 4.5)[12].

---

[7] Land use Climate Change report to Welsh Assembly Government 2010. http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/landuseclimatechangegroup/?lang=en
[8] http://naturalresourceswales.gov.uk/our-work/policy-advice-guidance/phytophthora-ramorum/?lang=en
[9] http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en#/statistics-and-research/woodlands-wales-indicators/?lang=en
[10] http://wales.gov.uk/topics/environmentcountryside/forestry/woodlandsforwales/?lang=en
[11] http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en#/statistics-and-research/woodlands-wales-indicators/?lang=en
[12] http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/schemes/glastir/glastirwoodland/?lang=en

4.5 Aims of Glastir for Woodlands

Glastir has a Woodlands element which has been designed to support land managers to create new woodlands and manage existing woodland to promote ecosystem services; biodiversity, water, carbon, landscape, historic features and access. The Woodland element provides area and capital grants, these can be applied to land managers in Glastir entry who do not enter Glastir advanced or land managers including farmers and woodland only holders who do not hold a Glastir entry contract. There are options under the Glastir entry and advanced schemes that apply to woodland. Glastir Woodland management options include:

- Thinning-allowing more light to enter the woodland top improve ground flora and natural regeneration
- Restocking- improving species diversity
- Infrastructure- managing previously inaccessible woodlands
- Boundary work- to stock proof woodlands or improve stock management
- Protected and priority species- grants to conserve important species
- Vegetation management- to control invasive and exotic plants
- Pest control- including grey squirrels and deer
- Public access- to improve woodland access and provide visitor information

There are also woodland creation options:

- Small Simple Woodland (Max 0.5ha)
- Basic Mixed Woodland
- Enhanced Mixed Woodland
- Native Woodland – Carbon
- Native Woodland – Biodiversity
- Wildlife corridors including trees and shrubs
- Allowing woodland edge to develop out to adjoining field
- Planting and regeneration

The Minimum application area for the top five bullet points varies between 0.1, 0.25 and 0.5ha depending upon the option.

4.6 Benefits from options / past schemes.

In Wales, funding from agri-environment schemes (AES) that could be related to woodland management has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal, Better Woods for Wales and now Glastir. A few key results include

- Tir Gofal has been largely successful in maintaining the condition of woodlands and parklands. In woodland light grazing produces the most positive change[13].
- The area of farm woodland within a grant scheme doubled between 2000 and 2012, principally due to a large area of woodland within the Tir Gofal agri-environment scheme[14].

4.7 Methods

4.7.1 Woodland recording methods- General

4.7.1.1 Habitat mapping

In the GMEP field survey every habitat within the GMEP 1km survey square is mapped onto a field computer with a bespoke GIS system, this includes areas above 20m x 20m in size, as well as linear features such as hedgerows, smaller patches are not mapped but vegetation plots may be placed in

[13] http://wales.gov.uk/docs/drah/publications/130917report1habitatsen.pdf
[14] http://wales.gov.uk/docs/drah/publications/130514woodlandforwalesindicators2012en.pdf

these or some may be described as point features. Woodland is defined as ‘over 25% canopy cover of trees or shrubs over 1m high’. It is then classified using a vegetation key to a Broad or Priority Habitat classification, for woodland this is either; Broadleaved, Mixed & Yew Woodland or Coniferous Woodland. Each woodland parcel is also given a structure code as to whether it is Woodland/Forest, a belt of scrub, a Belt of trees, a clump of trees, Dead lying trees, Dead standing tree(s), a Patch of scrub, Ride/firebreak, Scattered scrub or trees (2-5, >6).
As with mapping of the other habitats 2-4 dominant or characteristic species are chosen to represent the parcel and presence and cover recorded. There are additional attributes which may be added by the surveyor to describe the woodland environment. These include;

- Deer fences
- Felling/Stumps
- Fenced (single trees)
- Grazing (stock)
- Grazing/browsing (non-stock)
- Grey squirrel damage
- Natural regeneration
- Open glade and rides
- Pheasants and pheasant pens
- Planted
- Pollarded/Shredded
- Regrowth - cut stump
- Signs of recent management
- Staked trees
- Tree protectors
- Underplanting
- Windblow

They will also be given a use code as to whether the use is Landscape, Nature conservation, Public recreation, Sporting, Shelterbelt or Timber production.
Surveyors also record linear features that pertain to forestry e.g. hedgerows, lines of trees. A lot of additional detailed information is captured on these important landscape features including the base height, most common (modal) diameter at breast height (DbH), historic management, staked trees, presence of tree protectors, whether there is a margin on each side and the species and proportion. Individual trees, scrub, clump of trees, scattered trees, scattered scrub, patch of scrub, dead standing trees and dead lying trees may be recorded as point features, additional information added to this survey asks for evidence of habitat boxes and signs of disease. When recording veteran trees surveyors are asked to identify the species, the modal DbH, the type (standard, pollard or lay), whether epiphytic species are present, the % of the canopy that is live, whether there are dead or missing limbs, tears, scars, lightning strikes, hollow trunk or rot.

4.7.1.2 Vegetation plots

Surveyors have to set up new vegetation plots in the GMEP 1km survey square. Some of these are randomly located and according to strict protocols and would likely sample different woodland features including area plots from 2m x 2m in size to large area plots of 200m^2 (years 1 and 2) which could be placed within Woodland, and Hedgerow plots and Boundary plots 1 x 10m that sample woody linear features. Other plots (Y plots) could be selected according to the requirement to capture information on potential Glastir prescriptions. The surveyors did not have the information on management of the land within a square (in years 1 and 2) but suggested locations for vegetation plot placement applicable to woodland were given.

4.7.1.3 Animal, soil and freshwater sampling

Bird and Pollinator surveys took place within and outside of woodlands as did soil sampling, streams and pond surveys. This provides a population from which woodland change can be followed within the context of its surrounding landscape.

4.8 Introduction to analyses

We have explored a series of questions identified as being the most critical for woodlands. These include the area extent of woodlands and how this has changed over time, here we compare findings from GMEP with the Forestry Commissions' national statistics calculated from NFI data. The condition of woodland has also been analysed using a number of indicators identified from GMEP data; these include plant species diversity, the richness of Ancient Woodland Indicator Species, average preference of light for plant species to indicate level of management or successional stage, abundance of woodland butterflies and woodland birds, trends over time in these indicators have been presented and analyses looking at land under Glastir management for woodlands and outside Glastir carried out. There are several analyses that look at co-benefits of multiple indicators (i.e. where you can get win-wins or trade-offs) and how they vary with the amount of land under woodland management

4.9 Is woodland cover increasing or decreasing?

Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland although this is low by European standards. Woodland is a very important habitat for biodiversity, 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations. The key threats/drivers identified to Semi-natural Woodland are overgrazing, habitat fragmentation and isolation, invasion by non-native species, unsympathetic or lack of management, air pollution, landuse change, climate change and new pests and diseases. Climate change is both a threat affecting species composition and woodland condition and a driver of policy change. The Land Use Climate Change report (2010)[7] recommended an expansion of woodland over 20 years by about 100,000 ha (mainly deciduous but with a proportion of conifer) with tree provenance adapted to the projected climate.

4.9.1 Methods

- The Habitat mapping data gives us an area extent of woodland within the sample squares. The national extent of woodland can then be estimated from the sampled survey data using a statistical approach based on the sampling design within landclasses (created using variables such as geology, soils and climate). The area was calculated for each of the Land Classes in Wales. The estimation of the total area of each Broad Habitat in a Land Class involves multiplying the mean area of woodland in the GMEP 1km survey square in a Land Class, by the total land area in the Land Class, excluding unsurveyed urban land and land below the mean high water mark. The estimates of the area of Woodland for Wales were achieved by the summation of the Land Classes found in each Broad Habitat for each survey year.
- Different methods are used to record woodland in GMEP and the NFI, as mentioned above GMEP records Broad and Priority Habitat woodland, the NFI has 9 forest types (including Broadleaved, Coniferous, Mixed, Coppice, Shrub land *etc*.). GMEP (and CS) record smaller patches of woodland than the NFI, the minimum mappable unit is 20m x 20m compared to the FC 0.5 ha (either under stands of trees or with the potential to achieve tree crown cover of more than 20% of the ground). This is consistent with recording more Broadleaved woodland as there are likely to be small woodlands and clumps of trees consisting of Broadleaved trees that wouldn't be captured by NFI recording. Another methodological difference is that GMEP (and

Countryside Survey CS) record Land cover rather than land use so if an area has been clear felled and there is another habitat present then that is recorded rather than woodland. The Forestry Commission record land use so if it is within a woodland cycle it is recorded as woodland even though the current land cover is another habitat. The Woodlands for Wales indicators 2013/14 comments that some of the woodland increase shown in the FC figures may be due to improved measurement techniques.

4.9.2 Results

The area of woodland has increased in Wales over the past thirty years (Figure 4.9.2.1, Table 4.9.2.1). Both Broadleaved and Coniferous Woodland types have increased in area. The area of woodland estimated from the GMEP sample in 2013/14 is more than 50,000 ha greater than the estimate for Countryside Survey (CS) in 2007. A more moderate increase is shown in Forestry Commission figures (19,000 ha) but it is likely that woodland area has increased, possibly the larger increase in GMEP is due to an increase in smaller woodlands which are more likely to be mapped in GMEP and CS.

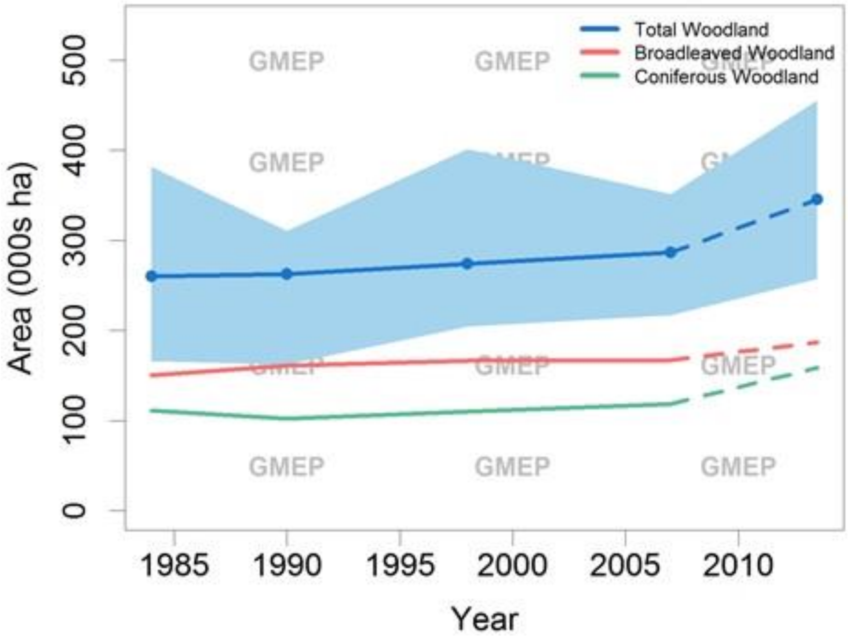


Figure 4.9.2.1 *The area of woodland in Wales over time, created by national estimates from field survey (CS and GMEP)*

Year	Total Woodland '000s ha	Lower confidence interval 2.5 %	Upper confidence interval 97.5 %	Broadleaved Woodland '000s ha	Coniferous Woodland '000s ha	FC year	FC Total Woodland '000s ha
1984	260	166	381	150	111	1980	241
1990	262	162	311	161			
1998	274	204	401	167	110	1995 -99	287
2007	287	217	351	167	119		
2013/14 GMEP	346	257	456	187	159	2014	306

Table 4.9.2.1 *Area of woodland in Wales, data presented from CS, GMEP and the Forestry Commission (FC)*

4.10 Is Woodland condition improving?

Woodland condition can be measured in different ways. The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy. These include measures on extent, area of woodland of different types (urban, farm *etc*.) and how that is changing, habitat and species diversity, sustainability of woodland management and tree health using data from the Forestry Commission and other sources. In the GMEP field survey a number of different measurements are taken which report on woodland condition, these could complement the current indicators (the BTO woodland birds data is used in the Woodland indicators), a selection of these are shown below. They are weighted towards biodiversity and habitat quality.

4.10.1 Methodology

Woodland condition can be measured using a number of different indicators. The indicators shown here are all biodiversity based, some taken from field survey vegetation plots from GMEP and the Countryside Survey and some square level metrics on woodland butterfly and bird diversity using long term data from the Biological Records Centre (BRC) and British Trust for Ornithology (BTO) surveys respectively. Results are shown from two sizes of vegetation plot 200m^2 and 2m x 2m (y plots) where the Broad or priority habitat was a woodland type. The larger plots are randomly placed within a GMEP 1km survey square, the 2m x 2m plots tend to be associated with small habitat fragments and priority habitats. Within the vegetation plots all higher plants were recorded to species level and both canopy species and ground flora have been recorded. The indicators; total species richness: the total number of plant species in a plot, Ancient Woodland Indicators; the number of species associated with Ancient Woodlands (agreed lists with conservation agencies and British Botanical Society) and Light scores (Ellenberg); each plant has an agreed light score indicating its preference for light. These have been calculated as an average for each vegetation plot. Countryside Survey data has been used for the historic vegetation data as methods are comparable.

4.10.2 Results

- There was a general non-significant downward trend in Ancient Woodland Indicator (AWI) species in the large 200m^2 woodland vegetation plots between 1990 and 2007 (Figure 4.10.2.1, Table 4.10.2.1), however in 2013/14 (GMEP) there are a significantly higher number of AWI species. In smaller plots there was no significant difference between years.
- There was no significant change in total plant species richness in the 200m^2 large woodland plots between 1990 and 2007 although there was a downward trend, (consistent with Smart et al. 2009) however there is a higher species richness in 2013/14 (Figure 4.10.2.2, Table 4.10.2.2). There has been a downward trend in species richness between 1990 and 2007 in the smaller 2m x 2m plots (Table 4.10.2.2) which tend to be located in small habitat fragments and priority habitats, however the 2013/14 (GMEP) plots are slightly higher in species richness (although not higher than 1990).
- Scores for plant species preference for light (Ellenberg) are calculated as an average value per plot i.e. higher score= plants present prefer lighter conditions. There has been a slight decline in light score between 1990 and 2007 in the 200m^2 plots (Figure 4.10.2.3, Table 4.10.2.3) although it is much more obvious in the 2m x 2m plots (Table 4.10.2.3), this indicates that plots are becoming more overgrown with increased shading, possibly due to less management.
- There is inter-annual variation in the Woodland Bird Indicator (Figure 4.10.2.4) but there does not appear to have been a significant directional change

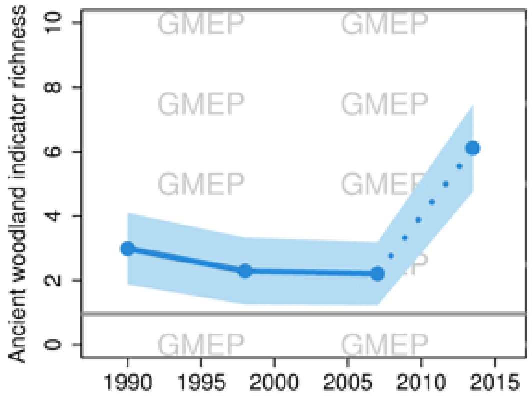


Figure 4.10.2.1 *Trend in mean number of Ancient Woodland Indicator species in 200m²plots.*

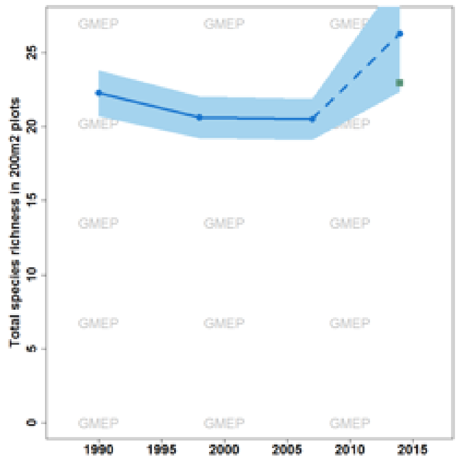


Figure 4.10.2.2 *Trend in mean Total plant species richness in 200m² plots*

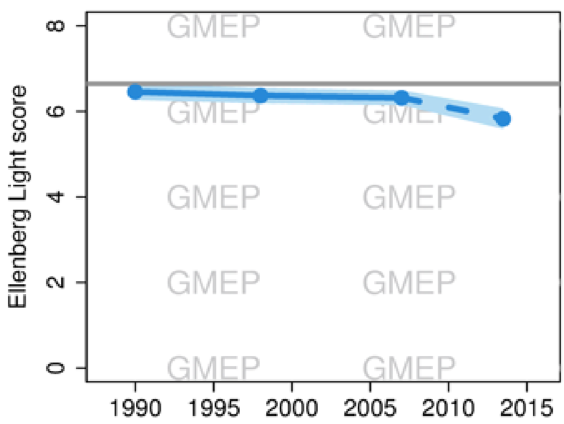


Figure 4.10.2.3 *Trend in Ellenberg Light scores 200m²plots*

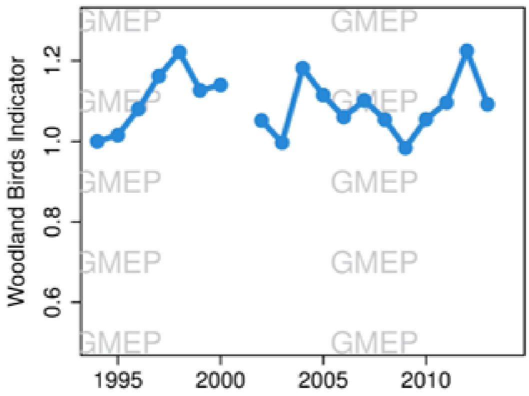


Figure 4.10.2.4 *Trend in woodland birds*

Year	Mean 200m^2 plot	Lower_est.	Upper_est.	Mean 2m x 2m plot	Lower_est.	Upper_est.
1990	3.0	1.9	4.1	2.1	1.5	2.7
1998	2.3	1.3	3.3	2.3	1.8	2.7
2007	2.2	1.2	3.2	2.0	1.7	2.4
2013/14: GMEP	6.1	4.8	7.5	2.5	2.1	2.9

Table 4.10.2.1 *Mean Ancient Woodland Indicator richness each year*

There are significant differences between all CS survey years and the 2014 sample in the 200m2 plots. There was no significant difference between years in AWI indicators in smaller 2m x 2m plots.

Year	Mean 200m^2 plot	Lower_est.	Upper_est.	Mean 2m x 2m plot	Lower_est.	Upper_est.
1990	25.2	21.4	29.0	12.0	10.4	13.6
1998	21.4	18.1	24.8	12.6	11.4	13.9
2007	21.0	17.9	24.1	11.3	10.4	12.2
2013/14: GMEP	26.3	22.2	30.4	11.7	10.6	12.7

Table 4.10.2.2 *Mean total plant species richness each year*

There are no significant differences between 1990, 1998, 2007 and 2014 in total species richness of 200m2 or 2m x 2m plots.

Year	Mean 200m^2 plot	Lower_est.	Upper_est.	Mean 2m x 2m plot	Lower_est.	Upper_est.
1990	6.5	6.3	6.6	6.0	5.9	6.2
1998	6.4	6.2	6.5	6.1	6.0	6.2
2007	6.3	6.1	6.5	5.8	5.7	6.0
2013/14: GMEP	5.8	5.6	6.1	5.8	5.7	6.0

Table 4.10.2.3 *Mean Ellenberg Light score each year*

There has been a significant decline in light score between 1990 and 2014 in 200m2 plots. In 2m x 2m plots the decline has been to 2007 and 2014 is not different.

4.11 What is the Coverage of Woodland habitats in the GMEP sample?

Coniferous Woodland is a commonly surveyed woodland habitat in the GMEP field survey (Figure 4.11.1). Areas in the Broad Habitat Broadleaved, Mixed and Yew Woodland have been separated from Broadleaved Woodland priority habitats so in total the area of Broadleaved Woodland surveyed is similar to Coniferous. All of the woodland priority habitats were found in the squares but the Lowland Mixed Deciduous Woodland and Wet Woodland were more frequent than the upland mixed ash, traditional orchard or Lowland Beech Woodland types.

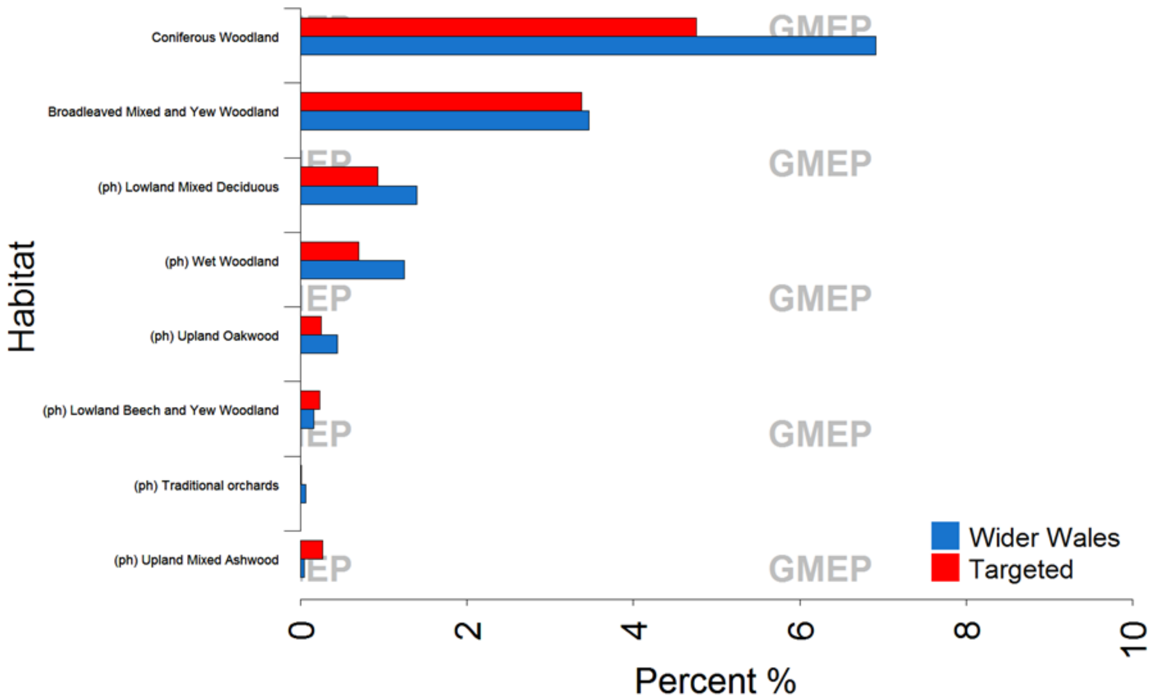


Figure 4.11.1 *Woodland habitats surveyed in GMEP*

4.12 What is the uptake of Glastir Woodland options and what extent of Woodland habitats are in the Glastir scheme?

Table 4.12.1 shows the distribution of Glastir options and landowners within the Woodland outcome for each Glastir scheme. The entry level involves the largest number of landowners unsurprisingly, however the Woodland management and advanced schemes have the greatest number of options. In terms of the extent of land 25% of land in Wales is under Glastir woodland management options and 4.1% Woodland creation. The majority of woodland management is on Broadleaved Woodland (Table 4.12.2).

	Unique option codes	**Number of landowners**
Entry level	8	1,183
Advanced	47	450
Woodland management	51	163
Woodland creation	5	569

Table 4.12.1 *Distribution of Glastir options and landowners uptake for each Outcome, split by Glastir element.*

	% Total land	Broadleaf Woodland habitats	Coniferous habitats
Woodland management	25	8.1	2.4
Woodland creation	4.1	N/A	N/A

Table 4.12.2 *% of habitats in Wales under Glastir Woodland options*

4.13 Is there a difference in woodland condition of land coming into the Glastir scheme relative to that outside the scheme?

The Glastir Woodland element and options within the Glastir Advanced scheme are designed to support land owners who wish to 'better manage' existing woodland (or to create new woodland) to provide beneficial outcomes for the woodland and a wider range of ecosystem services and elements of natural capital e.g. soil, water, carbon. Woodland condition can be measured in different ways. In the GMEP field survey a number of different measurements are taken which report on woodland condition which are weighted towards biodiversity and habitat quality. Glastir options for woodland management include options for woodland thinning, re-planting, fences for stock exclusion and management of scrub and invasive species.

4.13.1 Methods

The indicators shown here are all biodiversity-based, some taken from field survey vegetation plots and some square level metrics on woodland butterfly and bird diversity from the GMEP pollinators and bird surveys respectively. Results are shown from two sizes of vegetation plot 200m^2 and 2m x 2m. The larger plots are randomly placed within a GMEP 1km survey square; the 2m x 2m plots (y plots) tend to be associated with small habitat fragments and priority habitats. Within the vegetation plots, all higher plants were recorded to species level and both canopy species and ground flora have been recorded. The indicators total species richness, Ancient Woodland Indicators and Ellenberg Light score have been calculated from plots allocated to woodland broad and priority habitats. Countryside Survey data has been used for the historic vegetation trends as methods are comparable. Glastir woodland management options were identified, they are available under the Glastir advanced scheme or for land managers who are in the Glastir entry and wish to apply under the Woodlands element. The area of land that coincides with GMEP survey land was identified and then the presence or absence of Glastir woodland management options was used as a factor in the analysis.

4.13.2 Results

- There were no significant differences in Ancient Woodland Indicator species (Figure 4.13.2.1, Table 4.13.2.1), total species richness (Figure 4.13.2.2, Table 4.13.2.2), Ellenberg Light score (species preference for lighter conditions) (Figure 4.13.2.3, Table 4.13.2.3) or in the species richness of woodland butterflies (Figure 4.13.2.4, Table 4.13.2.4) in squares subject to woodland management options in Glastir and squares not under woodland management options.
- It was not expected that Glastir options would have had a significant effect this early in the process as the options will not have been in place long enough. Woodland habitats change on relatively slow timescales. This analysis provides the baseline for future analyses.

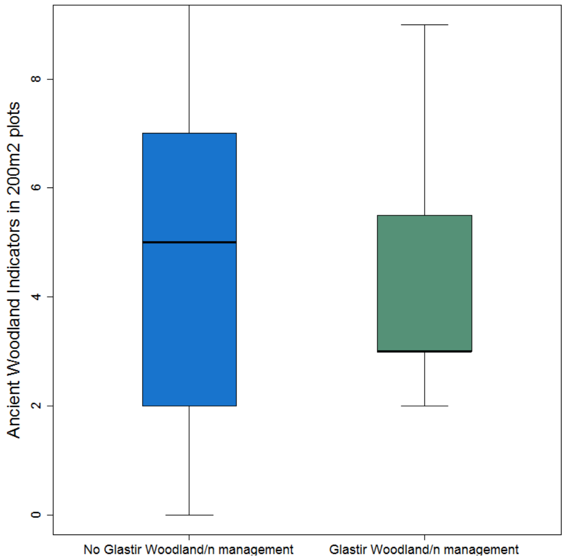


Figure 4.13.2.1 *Ancient Woodland Indicators in* 200m^2 *plots*

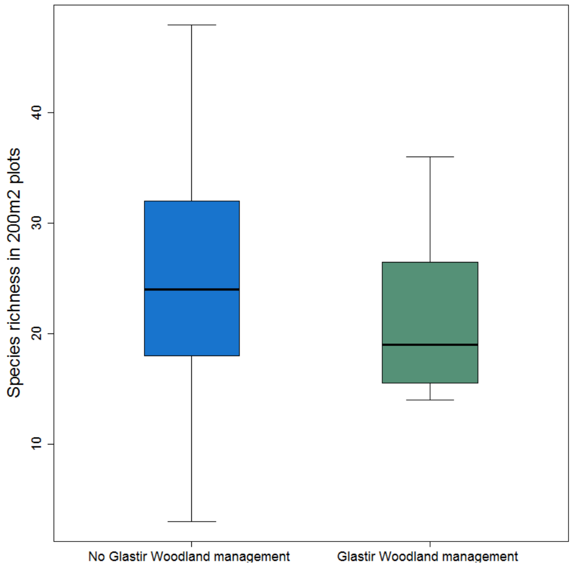


Figure 4.13.2.2 *Total species richness in* 200m^2 *plots*

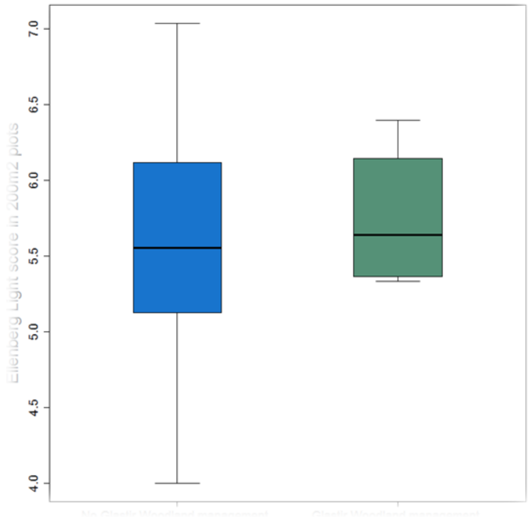


Figure 4.13.2.3 *Ellenberg Light score in* 200m^2 *plots*

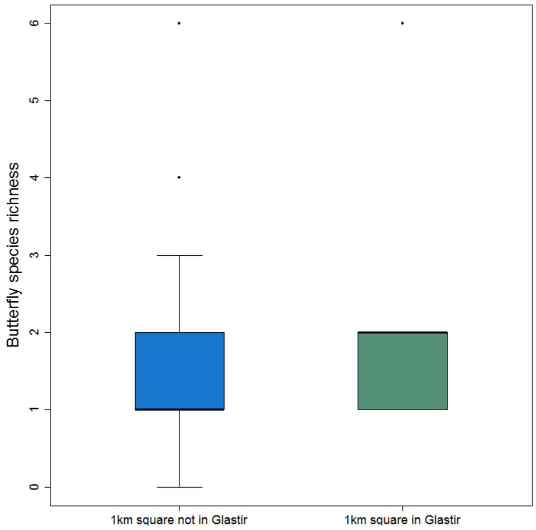


Figure 4.13.2.4 *Woodland butterfly species richness in 1km GMEP survey squares*

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	5.61	4.09	7.13
1	4.55	1.27	7.84

Table 4.13.2.1 *Ancient Woodland Indicators in* 200m^2 *plots*
There is no significant difference between land in Glastir woodland management and land outside

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	25.22	21.40	29.04
1	22.30	14.08	30.53

Table 4.13.2.2 *Total species richness in* 200m^2 *plots*
There is no significant difference between land in Glastir woodland management and land outside

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	5.68	5.43	5.93
1	5.78	5.25	6.31

Table 4.13.2.3 *Ellenberg Light score in 200m^2 plots*
There is no significant difference between land in Glastir woodland management and outside

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	1.35	1.13	1.56
1	1.81	1.20	2.43

Table 4.13.2.4 *Woodland butterfly species richness in GMEP 1km survey squares*
There is no significant difference between land in Glastir woodland management and outside

4.14 What are the co-benefits of new woodlands? (e.g. Water quality, carbon, landscape?)

Using data collected in GMEP some components of natural capital; biodiversity (plants and butterflies), soil carbon, above ground carbon can be measured and have been plotted against each other in the analysis to see how they relate to each other, whether there are trade-offs or benefits between them i.e. if one variable increases as the area of woodland increases and another decreases then this is a trade-off.

4.14.1 Methodology

Data has been taken from the GMEP field survey to calculate a number of metrics at the GMEP 1km survey square level. From the vegetation plot data- plant species richness, Ancient Woodland Indicator species, pH and light scores calculated from an individual plant species' preference for either pH or light (Ellenberg), this is from all vegetation plots, not just those in woodland. The species richness of woodland birds and the richness and abundance of woodland butterflies were included as square level variables. Above ground carbon and soil carbon have been calculated using Land Utilisation and Capability Indicator (LUCI) for the GMEP survey squares (Emmett et al. 2014). These metrics have been standardised and a Canonical Correspondence Analysis (CCA) carried out to create the above response plots with the ordination score on the X axis. In future the analysis can be adapted to include the Glastir woodland creation options as a constraining variable on the x axis to identify how metrics will vary under newly created Glastir woodland. This analysis is specifically designed to identify co-benefits and trade-offs. There are other measures which it would be useful to include e.g. the landscape Visual Quality Index (VQI), freshwater measures of biodiversity and water quality, soil variables from the GMEP 1 km survey squares, however, we currently only have data from year 1 for these measures and the sample size is reduced significantly if these are included.

4.14.2 Results

We do not yet have data on the uptake of woodland creation options in Glastir and where woodland creation options have been taken up woodland development will be at an early stage so the analysis uses data from all habitat types and plots it against the % of woodland within a square to determine what the trade-offs/co-benefits might be with increasing woodland.
Figure 4.14.2.1 shows relationships between indicators, all of the variables have been standardised i.e. plotted on a scale relative to each other, the absolute values shown on the axis are not important the relationships between them are what is of interest i.e. one variable high whilst another low = a potential trade-off.

There is a positive relationship between the number of Ancient Woodland Indicators and the amount of above and below ground carbon with the proportion of woodland in the GMEP 1km survey square. Light scores reflecting plant preference for light is negatively related to the amount of woodland which is to be expected as more above ground carbon is associated with more trees, with a greater degree of shading favouring Ancient Woodland plant specialists rather than species with a high preference for light. The pH and soil carbon are negatively related.
There are positive relationships between plant species richness and the number and abundance of woodland butterflies with the amount of woodland and some divergence with Ancient Woodland Indicator species although this levels out. Butterfly species benefit from a mixed woodland habitat with some dense understory and some rides and open spaces, whereas Ancient Woodland Indicator species are shade tolerant and do not require open glades

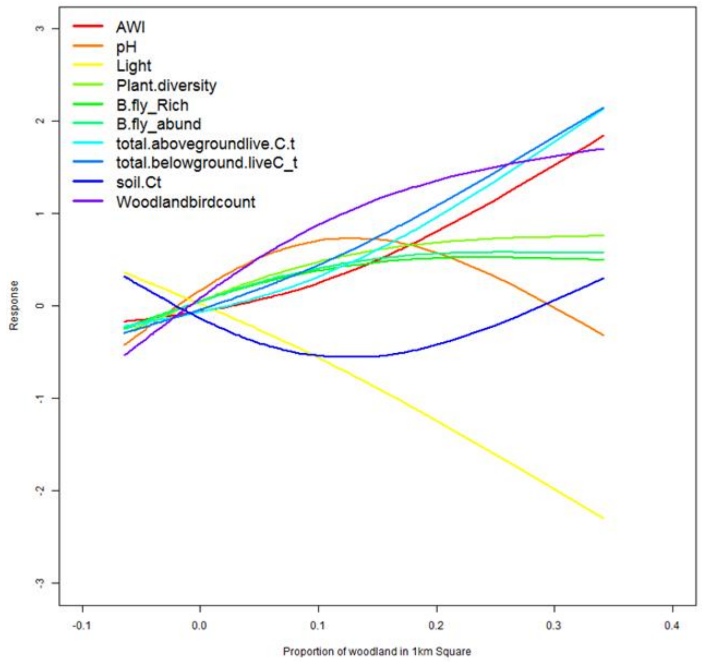


Figure 4.14.2.1 *relationships between standardised biodiversity/natural capital indicators; (AWI= Ancient Woodland Indicators, pH= pH score from plant preferences (Ellenberg), Light= plant preference for Light (Ellenberg), total.abovegroundlive.C.t= total above ground carbon tonnes per 1km square, soil.Ct= Soil carbon tonnes per 1km square,   Plant.diversity= total plant species richness in 200m2 plot, B.fly_Rich= total number of woodland butterfly species in 1km square, B.fly_abund=abundance of woodland Butterfly species)*

4.15 What are the co-benefits of better management of woodlands (e.g. for water quality, carbon, landscape?)

Using data collected in GMEP some of these elements of natural capital contributing to ecosystem services can be measured and have been plotted against each other in the analysis below constrained by the % of land within a Glastir square under woodland options.

4.15.1 Methodology

This is the same as that outlined in section 4.14.1, except that the percentage of the GMEP 1km survey square under Glastir woodland management options was used as a constraining variable on the x axis, this was not found to be significant. This approach can be used in the future when woodland management options have had more time to have a significant impact.

4.15.2 Results

Figure 4.15.2.1 shows relationships between indicators such as above ground carbon and bird and butterfly diversity, all of the variables have been standardised i.e. plotted on a scale relative to each other, the absolute values shown on the axis are not important the relationships between them are what is of interest i.e. one variable high whilst another low = a potential trade-off.
There are few clear messages from the current analysis, pH and plant diversity appear to be related. Where they are higher, above and below ground carbon tends to be lower. This may indicate areas where the canopy is less dense and there is a greater amount of disturbance. Woodland birds show some association with above and below ground carbon.

This analytical method is similar to that in 4.14.1, however this analysis uses only data from woodland plots for the plot based measurements. In the future it will be possible to incorporate the woodland management options carried out in Glastir to see how co-benefits and trade-offs vary with management.

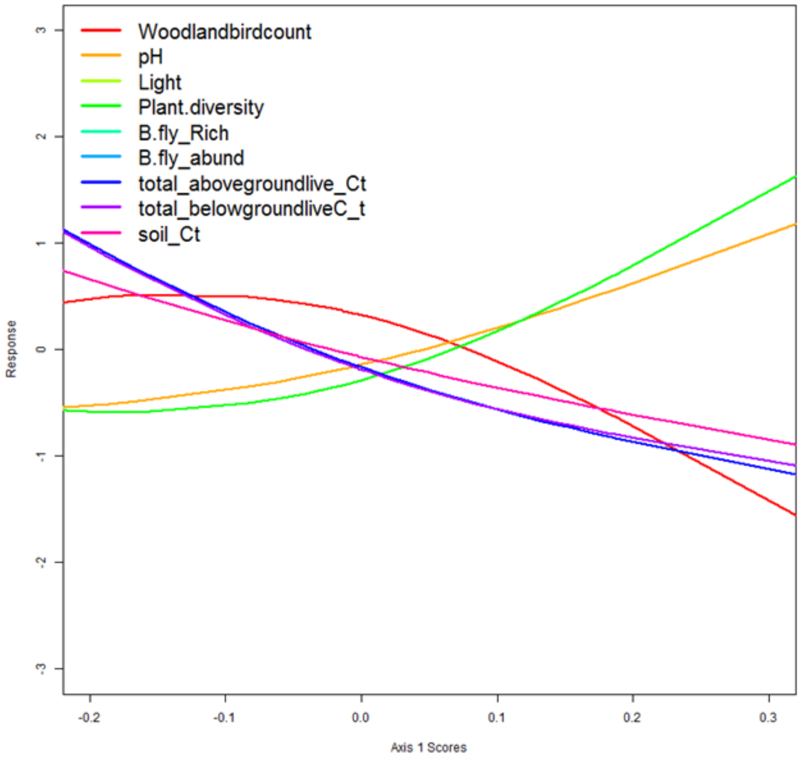


Figure 4.15.2.1 *relationships between standardised biodiversity/natural capital indicators in Woodlands using data from woodland plots;*
(Woodlandbirdcount= total count of woodland specialist birds, pH= pH score from plant preferences (Ellenberg), Light= plant preference for Light (Ellenberg), Plant.diversity= total plant species richness in 200m2 plot, B'fly_Rich= total number of woodland butterfly species in 1km square, B.fly_abund= abundance of woodland butterflies in a 1km square, total_abovegroundlive_Ct= total above ground carbon tonnes per 1km square, total_belowgroundlive_C_t= total above ground carbon tonnes per 1km square soil_Ct= Soil carbon tonnes per 1km square)

4.16 Development of a fine resolution Woody Cover Product (WCP).

Small-scale woody features such as hedgerows and small patches of trees provide valuable ecosystem services and are important for biodiversity conservation (Baudry et al., 2000). There are a range of datasets available for mapping woody vegetation in Wales, including products for mapping larger woodland areas (NFI and LCM2007) and hedgerows (EnvSys). We describe the development of the Woody Cover Product (WCP), which aims to map large hedgerows, individual trees and small patches of woodland, as well as larger woodland, across the whole of Wales. The product uses a combination of airborne radar data (NEXTMap®), optical imagery from satellites and data from the National Forest Inventory. The NEXTMap® DIFF product provides canopy height information at 5 x 5 m spatial resolution and this dataset was used to identify 'tall' features in the landscape. NDVI imagery was then used to separate tall vegetation from other tall features such as buildings and rocky outcrops. A preliminary study showed that this method was successful in identifying small-scale woody features but worked less well for large areas of woodland (Tebbs & Rowland 2014). Therefore, these larger areas were filled in using National Forest Inventory 2013 dataset to produce the final woody features product with a binary (woody/non-woody) classification at a 5 x 5 m spatial resolution. An initial version of the product has been produced for the whole of Wales. When validated against aerial photography for several test sites the product had a classification accuracy of 88 %. Work is ongoing to refine the thresholds used in the classification and extend the validation. The resulting product (Figure 4.16.1) has numerous potential applications, including investigations of habitat connectivity, modelling catchment run-off processes and quantification of carbon stocks.

Figure 4.16.1 *A scene from the new Woody Cover Product showing the areas identified as woody cover (red areas) overlaid onto aerial photography.*

4.17 Habitat connectivity

Habitat connectivity is the ability for species to move between areas of habitat and is a function of the number and size of habitat patches and how close together they are. Habitat connectivity is important to maintain species diversity, as habitats that are highly fragmented generally cannot support as many species, however, connectivity between habitats may assist in maintaining species populations and providing resilience to changing environmental conditions (e.g. climate change allowing species to move within the landscape through habitat with equivalent microclimatic conditions). Woodland creation and maintenance is an important part of the Glastir scheme and this may result in changes in connectivity. Connectivity measures were calculated for every survey square in GMEP and Countryside Survey to look at trends in connectivity over time. Several different approaches are available to estimate connectivity from the habitat data and a number of methods were assessed

I. Euclidean distances between habitat patches- the distance in metres between the edges of each habitat patch (termed Euclidean distance because it follows the rules of Euclidean geometry
II. Least cost distances using linear feature data recorded in the field survey
iii. Least cost distances using the Woody Cover Product

4.18 What are the long term trends in Habitat connectivity of broadleaved woodlands?

4.18.1 Methodology

Connectivity between woodland areas was calculated using the Conefor program using the Probability of Connectivity measure. This measure calculates the probability that a species living in one patch of woodland can move to another patch; the probability is high if the patches are close together. The Euclidean distance between all habitat patches recorded in the field survey mapping of GMEP squares was calculated for broadleaf woodland in ArcGIS 10.2 (ESRI, Redlands, CA, USA) using the Conefor Inputs GIS extension (Jenness Enterprises, Flagstaff, AZ, USA). The probability of connectivity values are relative values taken as a proportion of the highest value therefore the y axis runs from 0 to 1. Euclidean distance was used for the long term trends because the computational power required for least costs distance is high and it was not possible to run for all past Countryside Survey squares. We would hope to do this in future.

4.18.2 Results

There has been no significant change in the relative connectivity index of broadleaf woodland between 1990 and the GMEP survey in 2013/14 (Figure 4.18.2.1, Table 4.18.2.1).

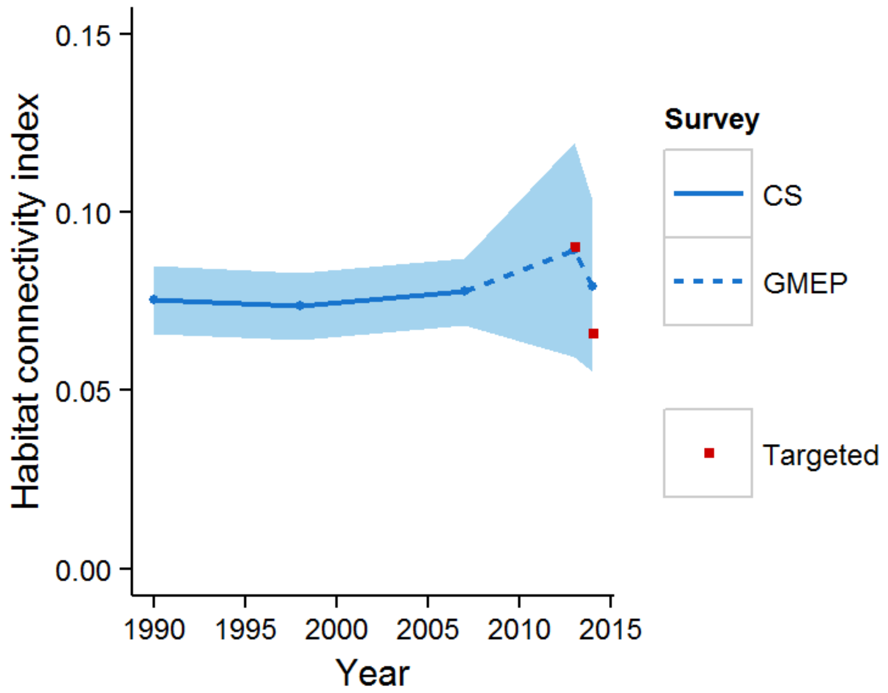


Figure 4.18.2.1 *Change in Habitat connectivity index for Broadleaved woodland over time using measure of Euclidean (straight line) distance.*

Year	Mean	Lower_est.	Upper_est.
1990: CS	0.08	0.07	0.08
1998: CS	0.07	0.06	0.08
2007: CS	0.08	0.07	0.09
2013: GMEP	0.09	0.06	0.12
2014: GMEP	0.08	0.06	0.10

Table 4.18.2.1 *Mean Habitat connectivity index of Broadleaved woodlands over time*
There were no significant differences in habitat connectivity between years

4.19 Does habitat connectivity of broadleaf woodland vary according to whether land is in Glastir?

To identify any differences in connectivity of broadleaf woodlands at the start of the scheme, connectivity measures were calculated for every survey square and connectivity compared between areas in and out of the Glastir scheme.

4.19.1 Methodology

Connectivity was measured using Euclidean (straight line) distances as above. However, using Euclidean distances to measure connectivity creates an assumption that all parts of the landscape are equally easy for a species to move through and the physical distance between habitat patches is the only barrier to movement. This is unlikely to be realistic; for example, roads and rivers provide obvious barriers to movement. More subtle barriers may also occur in the form of the habitats present in the landscape matrix. Some habitats are likely to be much easier to move through than others due to their habitat structure and food availability. For example, a species typical of broadleaf woodland might move more easily through a patch of coniferous woodland, which shares several habitat attributes, than an arable field. This information can be incorporated into the habitat connectivity metric by calculating distances between habitat patches using a least cost path instead of a simple Euclidean distance. Least cost paths are calculated as a function of the landscape occurring between two habitat patches; for example two patches separated by a habitat which is easy to move through will be calculated as being closer together than two patches separated by an impermeable habitat, even if the Euclidean distance between the patches is the same. Information on the relative ease of movement through different habitats can be obtained from the literature or by expert judgement. Here we use the results of an expert judgement of the movement of a generic broadleaf woodland species[15] to assign different weightings to the habitats in each GMEP square. A higher weighting indicates the habitat is more difficult to move through and are applied to habitats such as urban areas and freshwater.

To increase the realism of the analysis, the landscape between habitat patches included both the habitats present and any linear features. Linear features, particularly hedgerows, may be important for the dispersal of broadleaf woodland species as they can act as dispersal corridors through a landscape of otherwise impermeable habitat. The location of linear features containing woody components (i.e. excluding walls and fences) from the GMEP field survey was included in the analysis with the assumption that broadleaf species could move along linear features as easily as they could move within woodland.

Once least cost paths were calculated between all broadleaf woodland patches in each GMEP survey square the PC metric was again used to calculate the overall habitat connectivity index for each square. Again, this was scaled so that the square with the highest PC metric had a value of 1. No variation in connectivity calculated with least cost paths between GMEP squares in and out of the Glastir scheme was found, nor was there any variation between squares surveyed as part of the targeted or wider wales schemes (Figure 4.19.2.2, table 4.19.2.2).

4.19.2 Results

From the sample of 150 GMEP survey squares (including years 1 and 2 of the survey), 114 contained some broadleaf woodland and had a connectivity index of above zero. There were no differences in the relative connectivity index (PC scaled to between 0 and 1) between squares in and out of the Glastir scheme or between targeted and wider wales squares using two different approaches (Figure 4.19.2.1, Figure 4.19.2.2, Table 4.19.2.1, table 4.19.2.2). The distribution of values showed that most squares had low connectivity, with only a few squares being highly connected.

[15] This can be thought of as a species having the average requirements of all broadleaf woodland species (animals, plants etc.).

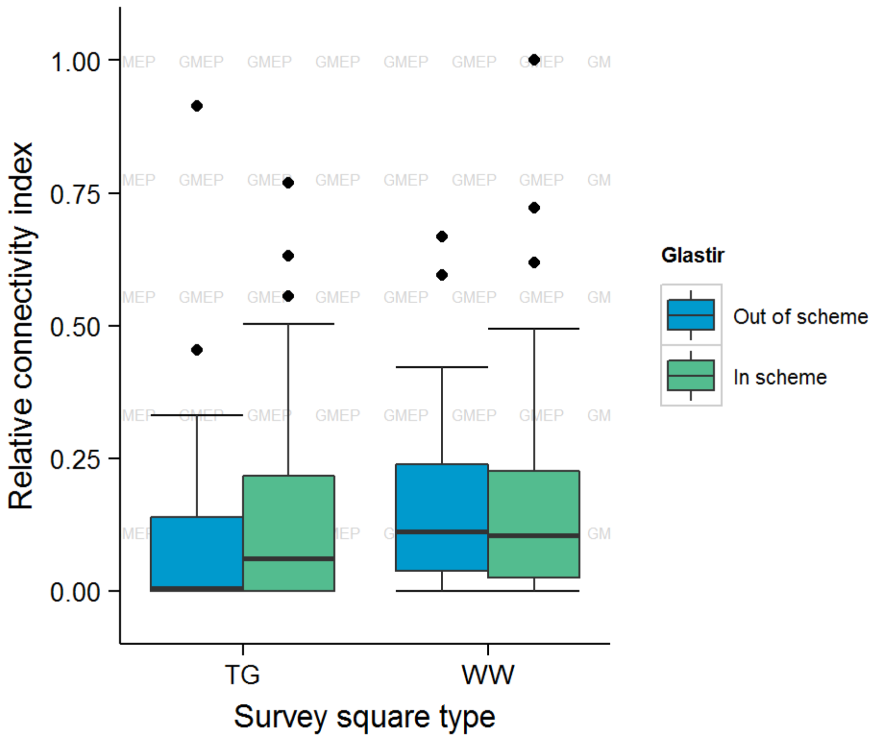


Figure 4.19.2.1. *Connectivity of broadleaf woodland habitat in Year 1 and 2 GMEP survey squares. Connectivity was measured using the Probability of Connectivity metric and was scaled to between 0 and 1 to provide a relative connectivity metric.*

Glastir	Estimated_Value	Lower_est.	Upper_est.
In Glastir	0.16	0.1	0.23
Out of Glastir	0.15	0.07	0.22

Table 4.19.2.1 *Connectivity calculated with Euclidean distances*

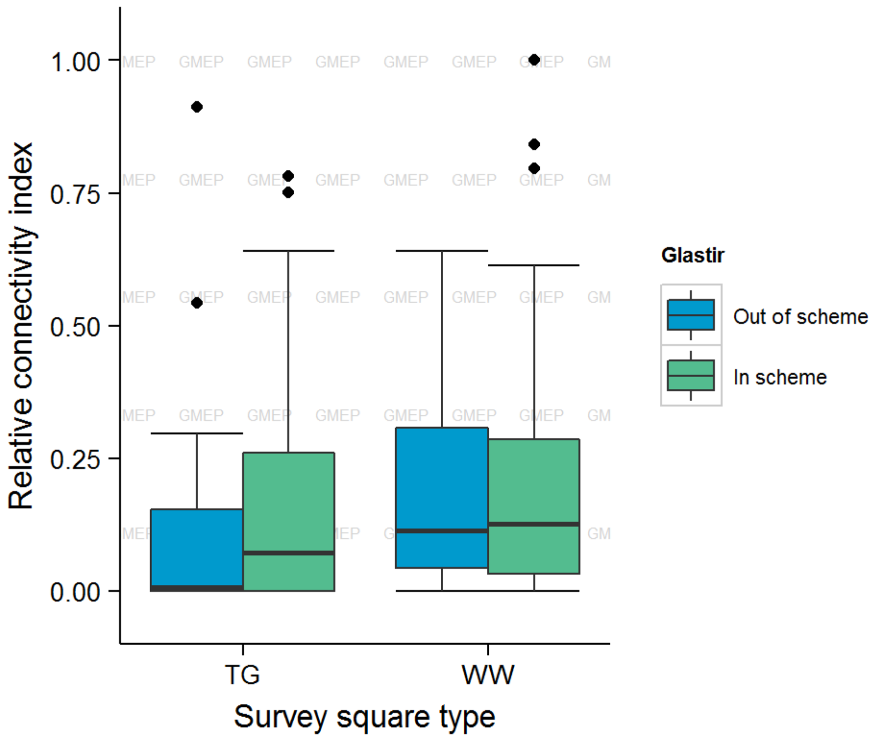


Figure 4.19.2.2 *Connectivity calculated with least cost distances*

Glastir	Estimated_Value	Lower_est.	Upper_est.
In Glastir	0.17	0.09	0.24
Out of Glastir	0.17	0.09	0.26

Table 4.19.2.2 *Connectivity calculated with least cost distances*

4.20 Does habitat connectivity of broadleaf woodland vary according to whether land is in Glastir using the Woody Cover product?

The Woody Cover Product (WCP) described above can also be used to inform least cost modelling for broadleaf woodland species. Briefly, this product produces a map of all the woody cover in a GMEP square, incorporating large areas of woodland, hedgerows and even isolated trees. These data were used in place of the linear feature data derived from the field survey to calculate least cost paths through the landscape; it was assumed that broadleaf species could move freely within the areas outlined by the WCP. The least cost distance methods is the best method for calculating a connectivity metric but does require a large amount of computational power. Including the woody cover product is not really necessary for analysing the GMEP squares on their own as we already have very good data from the field survey but when considering how best to scale up to squares where there has been no GMEP survey for instance for the work on HNV it is quite important.

4.20.1 Methodology

Habitat connectivity was calculated as in section 4.19.

4.20.2 Results

Figure 4.20.2.1 shows the results from the analysis using least cost distances calculated with the Woody Cover product, again no differences were observed between squares in and out of Glastir, or between targeted and wider wales squares. The ability to use the woody cover product to identify features such as hedgerows that contribute towards habitat connectivity will allow us to look at connectivity outside of the GMEP survey squares in the future.

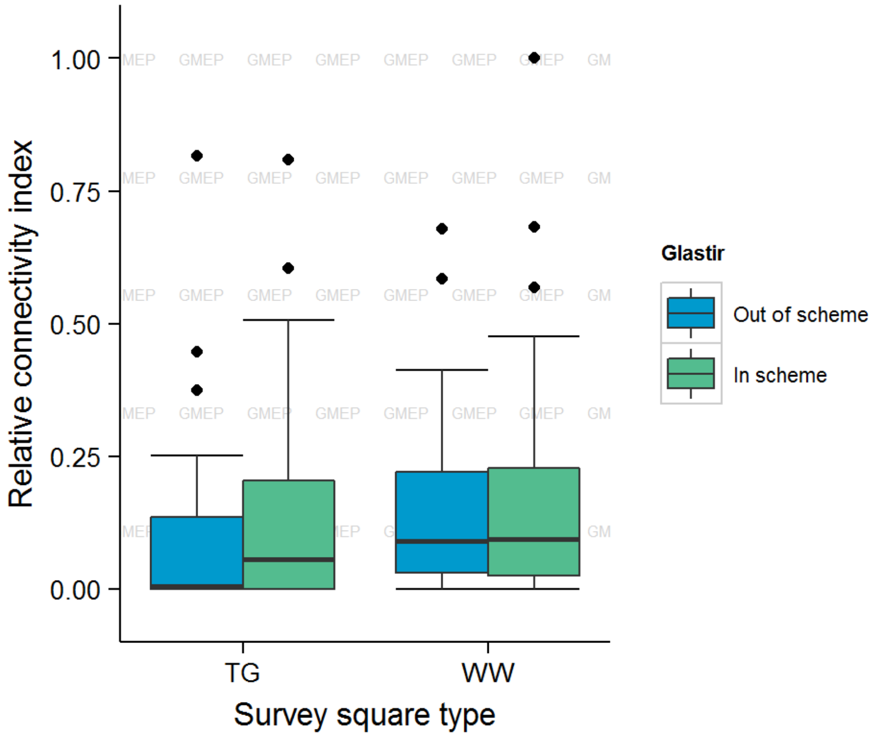


Figure 4.20.2.1 *Connectivity of broadleaf woodland in Year 1 and 2 GMEP survey squares using least cost distances between habitat patches using the Woody Cover Product. Connectivity was measured using the Probability of Connectivity metric and was scaled to between 0 and 1 to provide a relative connectivity metric.*

4.21 What are the long term trends in the length of Woody Linear Features?

Hedgerows, which incorporate both lines of trees and managed shrubby hedgerows are significant features in the Welsh lowland landscape. In landscapes otherwise dominated by pasture land, they provide habitats for a large number of invertebrate, plant, mammal, bird and even amphibian species which inhabit and use all parts of a hedgerow for shelter, food and nesting sites including the hedge base, shrubby vegetation and hedgerow trees. They provide valuable corridors between woodland areas and are particularly important in terms of connectivity for bat species which may use them for navigation, roosting and feeding. All hedgerows which consist of greater than 80% native species are Priority Habitats.

4.21.1 Methodology

Hedgerows consist of boundary lines of trees or shrubs, which include over 80% native species by cover, and which are over 20m long and less than 5m wide and where gaps between tree or shrub species are less than 20m wide. All features which fit these criteria are mapped in GMEP using a field computer and a bespoke GIS mapping system. Features are either mapped as features in which trees take their natural shape (lines of trees) or features in which trees do not take their natural shape (managed or 'shrubby' hedgerows).

Methodologies for GMEP are consistent with Countryside Survey so it is possible use data from both to determine long term trends. Note that length estimates are not national estimates and therefore not comparable with the national estimates provided for Wales in 2007.

4.21.2 Results

- There was no significant change in the total extent of woody linear features (lines of trees and hedgerows) across the period 1990 to 2007.
- There was a decrease in the length of managed hedges between 1998 and 2007 (Figure 4.21.2.1) with a large proportion of these hedges turning into lines of trees and relict hedges.
  Such a loss of features is a threat to biodiversity in the wider countryside because once managed hedgerows deteriorate into lines of scrub and relict hedge it is increasingly unlikely that they will be brought back into a management cycle. It is more likely that they will further deteriorate and will eventually be lost altogether as a woody linear boundary feature. In the GMEP sample there are more lines of trees than hedgerows.

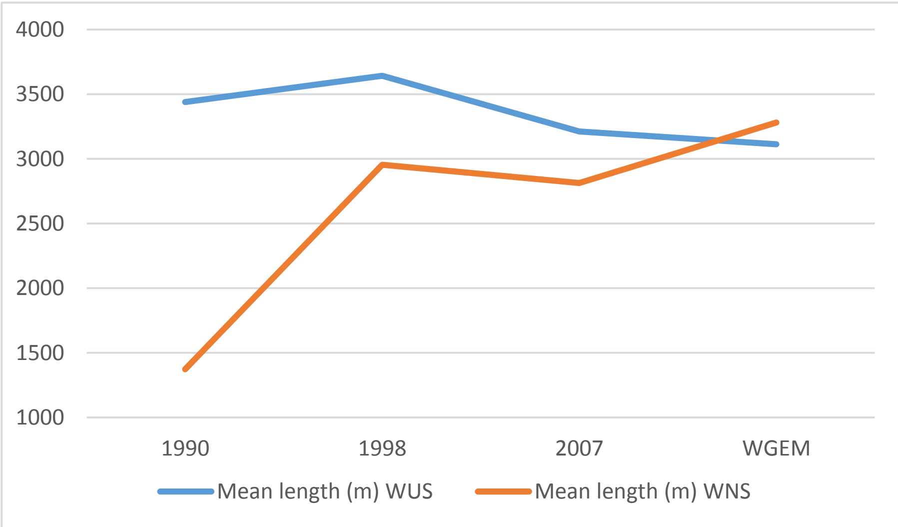


Figure 4.21.2.1 *Mean length of WUS (managed hedgerows) and WNS (lines of trees/relict hedges) in squares surveyed since 1990.*

4.22 Does the length of woody linear features vary according to whether land is in Glastir?

Hedgerows are a key focus of Glastir schemes with options for simple and enhanced hedgerow management, fencing and restoring hedgerows all available under entry and advanced Glastir. Hedgerows, which incorporate both lines of trees and managed shrubby hedgerows provide an important connectivity function in landscapes which are dominated by agriculture, particularly for species which are typical of wooded habitats.

4.22.1 Methodology

For this analysis total lengths of each woody linear feature type (see 4.21.1) per square were recorded. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the square was under Glastir management was used as a factor in the analysis. In future it will be possible to look at specific options spatially (allowing for suitable sample sizes) to assess whether a particular option is having an effect. The mean total lengths for squares containing land under Glastir agreement were compared with those not containing Glastir land.

4.22.2 Results

- There are significant differences in the mean length of linear features in a 1km square between land that is under Glastir management and land that is not in Glastir although there is more variability in the length of lines of trees than the hedgerows (Figure 4.22.2.1, Figure 4.22.2.2, Tables 4.22.2.1, 4.22.2.2).
- These results show that there are significantly more hedgerows and lines of trees in land that is being managed under Glastir. It is too early for this to be a result of Glastir management, however, it does suggest that the land going into Glastir has more hedgerows and lines of trees. It will be interesting to see how this changes over time.

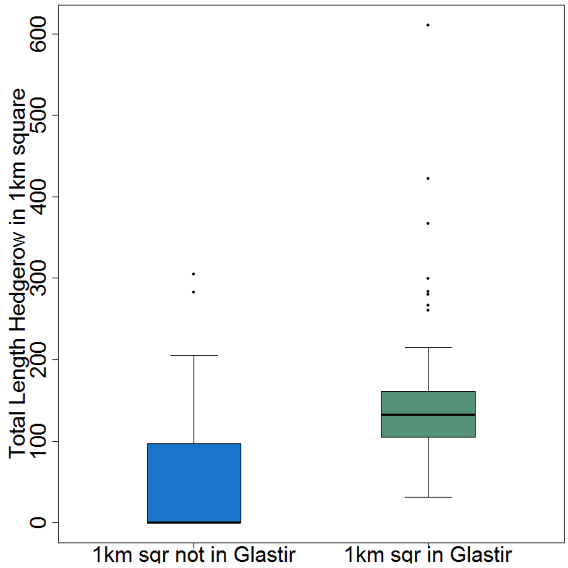


Figure 4.22.2.1 *The Total length of hedgerows in a 1km square in land managed under Glastir and land not in Glastir*

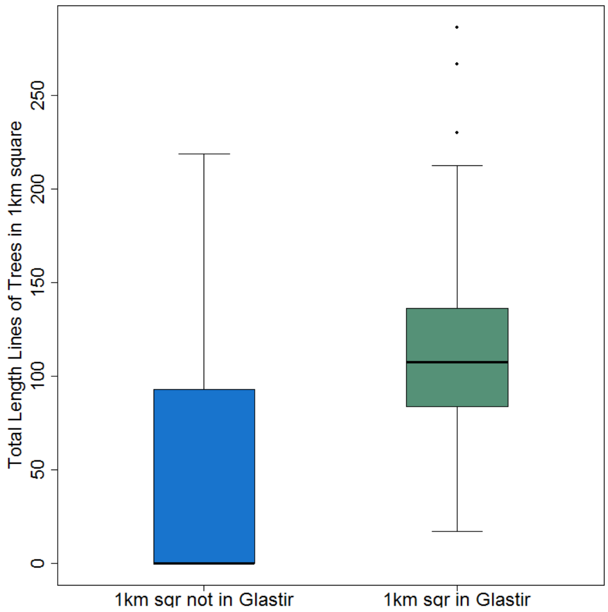


Figure 4.22.2.2 *The Total length of lines of trees in a 1km square in land managed under Glastir and land not in Glastir*

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	49.07277	30.66384	67.4817
1	150.3941	132.229	168.5592

Table 4.22.2.1 *Total Length of Hedgerow in a 1km square*

There is a significant difference between 1km squares under Glastir ownership and 1km squares not under Glastir ownership

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	46.32635	33.28281	59.36989
1	113.0464	102.0981	123.9948

Table 4.22.2.2 *Total length of Lines of trees in a 1km square*

There is a significant difference between 1km squares under Glastir ownership and 1km squares not under Glastir ownership.

4.23 What are the long term trends in the condition of priority (section 42) habitats: Hedgerows?

All hedgerows which consist of greater than 80% native species are Priority Habitats. Detailed favourable condition criteria were established for these 'shrubby' hedgerows by the Priority Habitat Steering group pre 2007, as data which could be measured from Countryside Survey (primarily from Hedgerow Diversity (D) plots).

4.23.1 Methodology

Information on species diversity of hedgerows is measured in Hedgerow Diversity plots (D) associated with both managed 'shrubby' hedgerows and lines of trees. Up to 10 D plots, each spanning the width of a 30m section along a hedgerow are recorded in each 1km square. Numbers of plots are dependent on the extent of hedgerows in a square, with no two plots being placed along the same length of hedgerow. Detailed information on species and species cover are recorded across a sample of hedges chosen to be representative of the square. General condition of mapped 'shrubby' hedgerows (rather than lines of trees) can be assessed from information on hedgerow height and evidence of management. Detailed condition criteria developed include; 1) width of perennial vegetation >1m, 2) distance to plough>2m, 3) width > 1.5m, 4) height >1m, 5) cross-sectional area >3m, 6) <10% non-native woody species, 7) base of canopy <0.5m, 8) no gaps >5m and 9) overall gappiness <10%. Detailed D plot recording to enable condition assessments of hedgerows did not begin until 2007.

4.23.2 Results

- Measures to assess whether or not a sampled hedgerow diversity plot is in good condition demonstrate that hedgerows in 2007 and hedgerows sampled in GMEP are similar in meeting structural criteria (41% in GMEP and 44% in CS 2007).
- There is no significant long term trend in the woody species richness of hedgerow diversity plots between 1998 and 2014 (Figure 4.23.2.1, Table 4.23.2.1).
- Most hedgerows are 1-2m in height (Figure 4.23.2.2, Table 4.23.2.2), this has remained fairly stable over the period 1990 2014. There has been a reduction in the number of hedgerows 2-3m in height but an increase in taller hedgerows >3m to some extent.
- Hedgerow management has increased over time (Figure 4.23.2.3, Table 4.23.2.3), with an increase in cutting in particular. There are a lower proportion of hedgerows that are newly

planted and less laying or coppicing. It should be noted that there was an increase in the length of managed hedges becoming lines of trees which indicates a decline in management overall so here the term 'hedgerows' only refers to those that have been maintained.

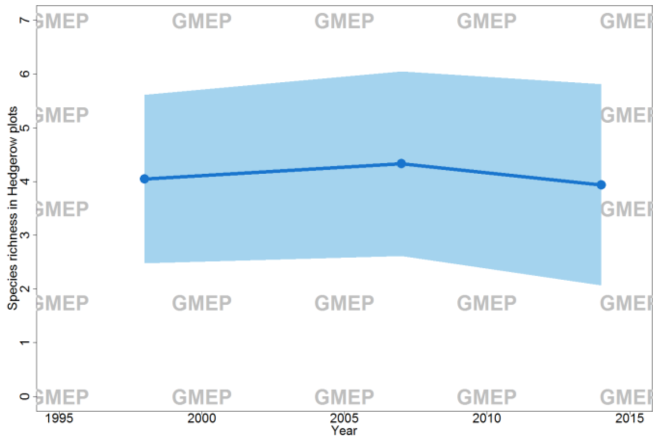


Figure 4.23.2.1 *Trends in Species richness in Diversity plots over time*

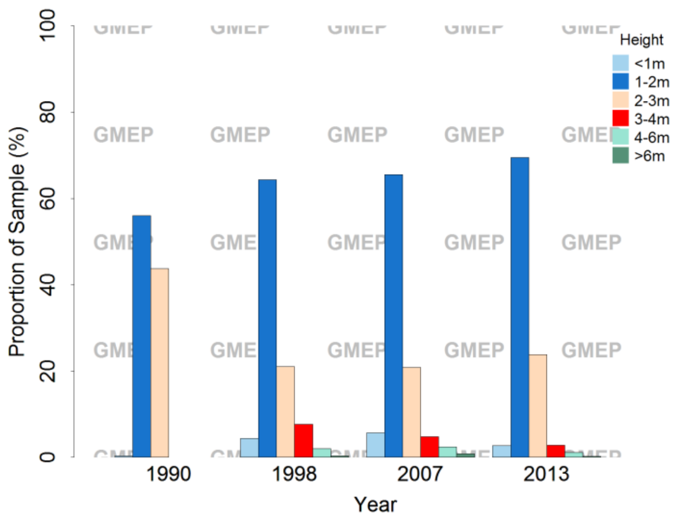


Figure 4.23.2.2 *Trends in hedgerow height categories over time*

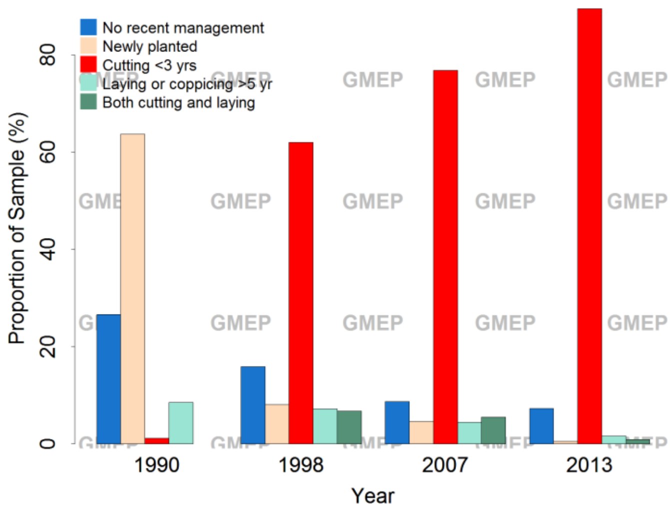


Figure 4.23.2.3 *Trends in hedgerow management activity over time*

Year	Estimated_Value	Lower_est.	Upper_est.	St Dev
1998: CS	4.04	2.47	5.61	1.57
2007: CS	4.33	2.61	6.05	1.72
2014: GMEP	3.94	2.07	5.81	1.87

Table 4.23.2.1 *The Mean number of species in a Hedgerow (D) plot from 1998 to 2014*

	proportion %			
Height	1990	2000	2007	WGEM
<1m	0.3	4.4	5.7	2.7
1-2m	56.0	64.4	65.5	69.5
2-3m	43.7	21.1	20.9	23.8
3-4m		7.7	4.8	2.8
4-6m		2.0	2.4	1.1
>6m		0.3	0.8	0.2

Table 4.23.2.2 *The proportion of managed hedges at different heights*

	proportion %			
Management type	1990	2000	2007	WGEM
No recent management	26.6	15.9	8.7	7.3
Newly planted	63.7	8.1	4.6	0.6
Cutting <3 yrs	1.2	62.0	76.8	89.5
Laying or coppicing >5 yr	8.5	7.2	4.5	1.6
Both cutting and laying		6.8	5.5	0.9

Table 4.23.2.3 *The proportion of managed hedges showing evidence of different management regimes*

4.24 How is the ecological condition of section 42 (priority) habitats Hedgerows related to Glastir?

The general condition of mapped 'shrubby' hedgerows (rather than lines of trees) can be assessed from information on hedgerow height and evidence of management and related to whether or not land is in Glastir. Condition is likely to be dependent on the length of time in Glastir and previous management. More detailed favourable condition criteria were established for these 'shrubby' hedgerows by the Priority Habitat Steering group pre 2007, as data which could be measured from D plots.

4.24.1 Methods

Information on hedgerow condition and species is measured in D plots associated with both managed 'shrubby' hedgerows and lines of trees. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the hedgerow diversity plot was under a Glastir hedgerow option was determined and used as a factor in analysis.

4.24.2 Results

Evidence shown below on the condition of hedgerows calculated using Hedgerow Diversity plot condition measures shows that hedgerows on land under Glastir are in better structural condition than those on land not in Glastir, however there is no significant difference in woody species richness (Figure 4.24.2.1, Table 4.24.2.1).

Table 4.24.2.2 shows that hedgerows in land under Glastir management are more likely to have had less recent management but to have shown some evidence of cutting, laying and coppicing.
Table 4.24.2.3 shows the average height of hedgerows in and out of Glastir.

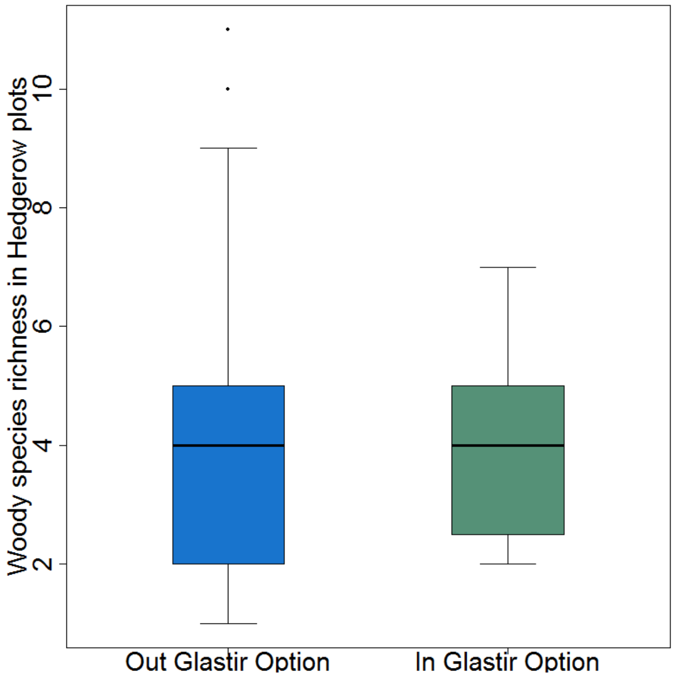


Figure 4.24.2.1 *Woody species richness in hedgerow diversity plots in and out of Glastir ownership*

D plot condition measures on D plots on managed hedgerows indicate that of the 560 plots, 229 (41%) reach the structural condition criteria set by the Priority Habitat Steering group pre 2007 (criteria 3 to 9 in methods). 41 (18%) of these plots were in squares containing no Glastir land, the remaining 88% of plots were in squares containing Glastir land. Probably as a result of the relatively small amount of arable land in Wales the number of plots reaching full condition criteria in terms of both structural condition, width of perennial vegetation and distance to plough greater than 2m was just 12 (2%). Of these plots 10 were in squares with land in Glastir and 2 were not.

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	3.87	3.63	4.12
1	3.84	3.14	4.54

Table 4.24.2.1 *Woody species richness in Hedgerow diversity plots.*

There is no significant difference between land under Glastir ownership and land not under Glastir ownership.

EVIDENCE_MANAGEMENT	ANY_GLASTIR	N Obs	Length
No recent management	0	33	3265.2
	1	180	20514.2
Newly planted	0	3	121.2
	1	18	1795.8
Cutting <3 yrs	0	361	47618.8
	1	1649	242323.7
Laying or coppicing >5 yrs	0	4	238.8
	1	20	4978
Both laying and cutting	0	11	1085.1
	1	19	1939.7
Total	0	412	52329.1
	1	1886	271551.4

Table 4.24.2.2 *Management of hedgerows in and out of Glastir*

HEIGHT	ANY_GLASTIR	N Obs	Length
<1m	0	26	1994.1
	1	73	6728.6
1-2m	0	242	33051.7
	1	1356	191965.2
2-3m	0	103	13290.7
	1	383	63818.5
3-4m	0	17	1869.7
	1	56	7131.5
4-6m	0	19	1773.7
	1	15	1666.8
>6m	0	5	349.2
	1	3	240.8

Table 4.24.2.3 *mean length of hedgerow under different height categories in and out of Glastir*

4.25 Future work

- Further analysis of GMEP data:
    a. Calculation of extent of woodland priority habitats
    b. Continued analysis of trends in indicators including year 3 data
    c. Analysis of baseline in and out of Glastir including year 3 data
    d. Continued Development of woodland connectivity indicator
- Continuation of woodland topic group to discuss approaches, results and analyses with other woodland stakeholders, in the context of policy requirements and external drivers, and comparing with and complementing other existing monitoring schemes.

5 Biodiversity

Smart, S.M.[1], Astbury, S[2]., August, T[3]., Botham, M[3]., Cooper, J[1]., Emmett, BA[2]., Goodwin, A[1], Hall, J[2]., Harrower, C.[3], Henrys, P[1]., Isaac, N.[3], Jarvis,S.[1], Maskell, L[1]., Norton, L.[1], Oliver, T[3], Peyton, J[3]., Powney, G[3]., Rorke, S[3]., Rowland, C[1]., Roy, D[3], Scholefield, P[1]., Siriwardena, G[4]., Tebbs, E[1], Wagner, M[3].,Wood, C[1], Beckmann, B[3]., Dadam, D.[4]

[1]CEH Lancaster, [2]CEH Bangor, [3]CEH Wallingford, [4]BTO

5.1 Introduction

The conservation of biodiversity in Wales is motivated by the value people place on a rich heritage of wild species and habitats. Particular habitats and species have a stronghold in Wales whilst being rare or absent elsewhere in the UK and Europe so that Wales has a particular responsibility for their monitoring and conservation. While the importance of biodiversity reflects the values placed on it by people, some of these values are harder to quantify than others. They are nonetheless important, including for example, conservation of wild species and habitats for their cultural, spiritual, aesthetic and recreational importance. In 2007 the Environment Agency Wales estimated that “wildlife-based activity” contributed a total output of £1.9 billion per year to the Welsh economy which exceeded the total agricultural output in 2011 of £1.3 billion (EA Wales 2007). Therefore the contribution of biodiversity to prosperity, well-being and job creation in Wales should not be underestimated.

5.1.1 Policy context

Policy drivers for the conservation of biodiversity in Wales reflect both global to regional trends and the need to engage with the human drivers of these trends. The goal of sustainable rural development within the EU Rural Development Program seeks to achieve economically and ecologically sustainable use of land and water. This recognises a requirement for reversing ecosystem degradation and the loss of underpinning biodiversity. In Wales, the Glastir scheme is a significant component of the Rural Development Program and so contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity. These are derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act). Of particular significance is target 3 of the EUBS that aims to ‘increase the contribution of agriculture and forestry to biodiversity’. Since 81% of Wales is farmed, agri-environment scheme funding is seen as one of the most important mechanisms for delivering a large-scale re-balancing of production, ecosystem service supply and biodiversity to achieve sustainable rural development.

5.1.2 Major achievements in Year 2:

- Proxy habitat indicators developed and species management reviews carried out for all Section 42 species that have been linked to option bundles in Glastir.
- Indicators applied to baseline survey data for six Section 42 species reflecting uptake of their associated options in year 1 and 2 GMEP 1km survey squares.
- New long-term trend indicators completed for birds, butterflies and priority invertebrate species. In the case of birds this is to overcome the limitation of the Farmland Bird Index which can potentially be driven by a trend of just one species.
- Over 30 new derived indicator variables computed for the year 1 and 2 vegetation plot data.
- Extensive analysis of the legacy effects of Tir Gofal and Tir Cynnal completed by BTO using Breeding Bird Survey squares in Wales.

- Headline questions about long term trends in habitat extent, condition, diversity and connectivity answered and web portal entries completed.
- Headline questions about the impact of Glastir addressed by characterizing the status of biodiversity indicators across the year 1 and 2 GMEP 1km survey squares contrasting habitat and features in and out of option.
- New analysis of the relationship between bird species in the GMEP field surveys and coincidence with Glastir management options.

5.1.3 Key Findings in Year 2

5.1.3.1 Long term trends

The overall picture for long term trends in biodiversity is some evidence of recent stability for some elements of biodiversity but little evidence currently of improvement. For example new analysis of long term data from sources such as the UK Butterfly Monitoring Scheme, data held by the Biological Record Centre from a wide range of monitoring programmes and the BTO/JNCC/RSPB Breeding Bird Survey and other bird survey data from a range of sources indicates:

- Composite measures of long term trends in butterfly species abundance in Wales indicates stable populations for wider countryside generalists and stability since 1998 for habitat specialists after a decline between 1976 – 1998.
- A new Priority Invertebrate Species Indicator for Wales based on 87 species with sufficient long term records had sufficient uncertainty which prevented any conclusions.
- Total abundance of target bird species and overall bird diversity is shown to be stable since 1994. It is important to note this type of composite metrics can mask important changes in individual species.
- A newly constructed Priority Bird species Index for 35 species with sufficient trend data available in Wales indicates at least half as increasing or stable since 1994 but with no pattern for an overall improvement in population health over time.

5.1.3.2 Direct assessment of Priority Habitats and Species from the GMEP survey

- From the GMEP survey itself, it is expected there will be sufficient sampling power to report on change in extent for 13 Priority Habitats in the future. Recent trends from analysis of historical data are currently being discussed with NRW.
- There may also be sufficient data for 14 of 50 priority bird species and 7 of 15 priority butterfly species.
- Methods for reporting change in ecological conditions that would be expected to favour other priority species such as the Dormouse and the Lesser Horseshoe Bat are described.

5.1.3.3 Impact of Glastir

Establishing a baseline to track future change is one of the main reasons for establishing GMEP to run alongside the Glastir Scheme from its inception. Analyses indicate how critical this will be if false positives benefits are to be avoided. For example:
Statistically significant higher habitat diversity of land entering the Glastir scheme needs to be included in future analyses.

Current figures from Years 1 & 2 of the 4 year survey indicate sufficient coincidence of uptake of Glastir options and priority species for four of 14 Glastir option types aimed wholly or partly at benefitting birds; marshland, winter food, summer food and woodland to enable direct reporting of bird populations to Glastir options. Critically, initial difference in baseline bird densities of land in and out of scheme are indicated which must be taken into consideration in future analyses of Glastir impact.

5.1.3.4 Impact of past agri-environment schemes

The impact of past agri-environment schemes on birds was assessed using bird population growth rates (changes from year to year) using BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1km squares. Positive associations with Tir Gofal options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management. The evidence therefore supports broadly positive effects of Tir Gofal, notably involving management of woodland, scrub, hedgerows and habitats providing winter seed in arable farmland.

The legacy effect of Tir Gofal on land coming into the Glastir scheme was also assessed for plant species. Despite these initial small sample sizes as it only includes years 1 and 2, a continued beneficial effect of two options was detected; a) terms of species richness in ungrazed broadleaves woodlands (option 1A) in plots that had entered Tir Gofal before 2006 and b) for the grass:forb ratio (a negative indicator) for upland heath.

5.1.4 Background to approach

GMEP consists of a rolling 4-year cycle of surveys. Analyses that seek to identify the impact of Glastir options on change over time will therefore begin in earnest once the next cycle begins and survey GMEP 1km survey squares are visited for a second time. During the first two years of the first 4-year cycle we have been developing methods for exploring Glastir impacts on Section 42 species determining the coincidence of options with species and habitats and deriving new indices of long term trends in biodiversity as the backdrop to GMEP. We are also developing methods to characterise High Nature Value (HNV) farmland (see chapter 9) and to extend our estimates of biodiversity change and impacts of Glastir outside of the sample of GMEP 1km survey squares and into wider Wales by integration with remotely sensed data products and biological records databases. . For brevity not all national trend data are reported here but are available within the GMEP Data Portal. Data on Priority Habitats extent and condition are not yet available.

5.1.5 Quantifying the impacts of Glastir on Section 42 species

We have developed the knowledge base required to identify sets of proxy indicator variables for Section 42 species and on the derivation of these indicators from GMEP survey data. This comprises comprehensive reviews of species' ecology and establishing how Glastir options targeted at particular species can be matched with performance indicators derived from field survey attributes. These indicators measure whether Glastir options have resulted in ecological changes assumed favourable to Section 42 species populations. Example applications are presented: Taking the most common Section 42 species from each group of organisms, sets of indicator variables were applied to the baseline survey data from years 1 and 2. As the time series grows we will determine whether these indicators diverge between locations in and out of Glastir. The results will show whether expected ecological changes have resulted from Glastir uptake and whether options are likely to have enhanced rare species populations where the two spatially coincide. Example application of indicators to the year 1 and 2 baseline are presented under the headline question '*What is the benefit of Glastir options?'* and have been formatted as they will appear on the GMEP data portal.

5.1.6 Developing high precision ecological indicators back to 1990: Linking GMEP to Countryside Survey

Work has also focussed on linking GMEP survey data for years 1 and 2 to the historical time series provided by Countryside Survey (CS). These analyses contribute to addressing the headline question '*What are the long-term trends in biodiversity in Wales?'* The strength of CS and GMEP is that spatial patterns and change over time can be referenced precisely to habitat types and features, such as hedgerows, watercourse banks and field boundaries, which are targeted by individual options. Examples include quantifying total cover of important nectar-providing plants from vegetation plots located in arable land, broadleaved woodland and neutral grassland going back to 1990. In arable land we also discriminate between the boundaries of arable fields and their interior.

5.1.7 New indices and data to describe long-term trends in Welsh habitats and biodiversity

Changes within CS and GMEP 1km survey squares also need to be set within the context of past biodiversity trends in the wider countryside. New indicators and data are presented exploiting the long-term time series from volunteer-based schemes. Examples are given for butterflies using the UK Butterfly Monitoring Scheme data for Wales. An extensive new analysis has also been undertaken to quantify long-term trends in Welsh breeding birds. This work utilised the BTO Breeding Bird Survey data for Wales. Trends for individual birds are described and then summarised into novel indices of change in Lowland Farmland, Upland Farmland and Woodland birds all based on Wales-only data. We also report progress on the assembly of recent biological records for Section 42 species at 1km resolution. Finally Biological Records Centre (BRC) data holdings have been used to develop a Priority Invertebrate Species Indicator for Wales, which is a Wales-only version of the the UK C4b indicator (http://jncc.defra.gov.uk/page-6850).

Substantial new work has also been carried out to quantify habitat diversity, habitat connectivity, extent and condition of Priority Habitats and Woody Linear Features. A new Woody Cover Product was developed by synthesising existing datasets combined with new analyses to providing a finely resolved map of woody linear features, hedgerows and woodlands across Wales. New habitat connectivity analyses were based on this improved product. These analyses are reported in Appendices 5.10-5.13 and Chapter 4.

5.1.8 Detecting the legacy effect of previous Agri-Environment Schemes (AES) within GMEP 1km survey squares

Two analyses have been carried out to detect the legacy effects of previous AES in Wales. An exhaustive analysis of BTO Breeding Bird Survey Squares has been completed. With the caveat that some rarer target species were not testable because of small sample sizes, the results of this study provide good evidence for broad, positive effects of several aspects of Tir Gofal management, especially that concerning woodland, scrub, hedgerows and arable seed-rich habitats on target bird species. Other management under the scheme has not been so conspicuously successful.
A second analysis searched for legacy effects of Tir Gofal in vegetation plots sampled in the year 1 and 2 GMEP 1km survey squares. Only 3 out of 45 option + habitat + indicator combinations showed any significant difference between locations previously in Tir Gofal versus those never in agreement. Because of the small sample sizes available per option and the restriction to just year 1 and 2 no firm conclusions can be drawn about the magnitude of legacy effects. The analysis will be repeated when year 3 and 4 data are available.

5.1.9 Priority (Section 42) Habitats

Areas of each habitat mapped within year 1 and 2 GMEP 1km survey squares are presented along with assessments of condition indicators for example habitats. A simple method has also been developed for estimating the sample size required to deliver robust estimates of extent given the likely total area of each habitat in Wales.

5.1.10 Remotely sensed data

Work has also been carried out using remotely sensed datasets in combination with field survey data and other spatial map products to estimate landscape and ecosystem attributes across Wales. We report progress calibrating earth observation data with detailed plant trait data to estimate above-ground Net Primary Productivity. We also report production of a woody linear feature map that fills a significant gap in existing land cover mapping. Results from both activities support the identification and mapping of HNV in Wales.

5.1.11 What is covered in this chapter?

This chapter summarises recent progress and future plans for assessment of the impact of the Glastir agri-environment scheme on Welsh biodiversity. We apply a combination of approaches including modelling and analysis of existing biological records and monitoring scheme datasets, and of the new data collected in years 1 and 2 of the 4 year rolling monitoring programme. We demonstrate how we will address two fundamental questions about biodiversity in Wales; what are the long term trends in species and habitats? What will be the impact of Glastir? Because field data are only available from years 1 and 2 of the baseline 4-year roll, answers to these questions focus on quantifying past trends in species abundance as a way of establishing the starting conditions and ecological context for Glastir. The impact of Glastir has also been addressed at this stage by characterising the baseline ecological variation in GMEP 1km survey squares and expressing whether there are any starting differences between land in and out of options taken up in the first two years of the scheme and whether these might reflect the legacy effect of previous schemes. BTO have also carried out new and exhaustive analyses of Tir Gofal and Tir Cynnal legacy effects in their Breeding Bird Survey squares in Wales. The reader is directed to extensive appendices for more detail on all the items summarised in this chapter.

5.2 Biodiversity - current status and trends

5.2.1 Long-term trends in biodiversity in Wales

Recent work has focussed on assembly of species distribution data from established recording schemes to produce new time series of change based on Wales-only data. These new indices are fully described in Appendices 5.3, 5.9 and 5.10.

5.2.1.1 Butterflies

Across the UK, butterfly numbers have declined at least since the 1970’s as a result of habitat loss through land converted to agriculture and subsequent intensification. Because insect populations fluctuate annually in response to weather, parasitism, predation and other factors, it is essential to determine patterns over long time series to see how populations are changing when these other effects are accounted for.

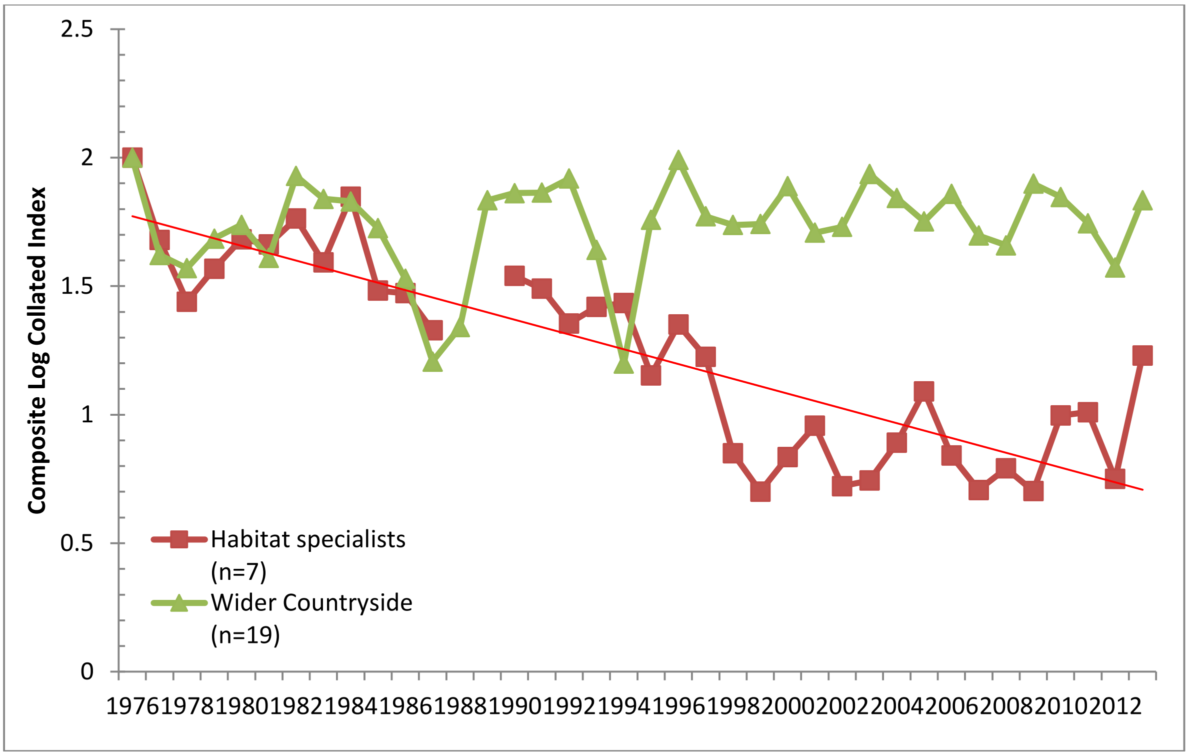


Figure 5.2.1.1.1 *Long term trends in butterfly species in Wales (UKBMS data).Wider countryside species trends were calculated from 207 sites (121 of these being WCBS 1km squares) and Habitat specialists from 121 sites (98 of these are non-transect sites (timed counts and larval web searches)). See Appendix 5.10 for further details.*

UK Butterfly Monitoring Scheme (UKBMS) data is shown for Wales going back to 1976 (Fig 5.2.1.1.1). Butterfly species abundance in 319 sites (comprising 91 standard BMS transects, 107 non-transect sites (these are timed counts and larval web counts), and 107 WCBS 1km squares) has been collated and trend lines are shown for two groups: Wider countryside species trends are derived from all the data including WCBS 1km squares. Wider Countryside species include generalists such as Meadow Brown (*Maniola jurtina*), Large White (*Pieris brassicae*) and Peacock (*Aglais io*), whose larvae feed on forbs and grasses abundant in productive farmland. These species are therefore able to survive better in the modern countryside and show a stable pattern with fluctuations reflecting the influence of the weather on population size. Habitat specialist trends are based only on BMS transect and non-transect data. Habitat specialist species such as Pearl-bordered (*Boloria euphrosyne*), High Brown (*Argynnis adippe*) Fritillaries, and the Grayling (*Hipparchia semele*) show greater restriction to less productive semi-natural habitats such as heathland and fen. The index for these species shows a rapid and highly significant decline in Wales since 1976, and appearing to stabilise at a lower abundance after 1998.

5.2.1.2 Wales-only version of the C4b Priority Invertebrate Species Indicator

A Wales-only version of this indicator was developed to allow direct comparison with the existing UK-wide version. The derivation of the indicator mirrors the approach applied at UK level (http://jncc.defra.gov.uk/page-6850) but uses data from Wales only. The indicator utilises opportunistic biological records to examine the long-term trends in priority invertebrate species in Wales. Species covered by other established recording schemes – birds, bats, plants - or where reliable data does not exist for the time period were excluded.

The priority invertebrate species indicator (Figure 5.2.1.2.1) illustrates the change in frequency of occurrence of well-recorded priority species in Wales between 1970 and 2010. The indicator was created by combining the annual frequency of occurrence estimates of 87 species, the majority of which are moths (81 moths, 1 dragonfly and 6 bee species). This number is smaller than the 179 species that contribute to UK Priority Species Indicator C4b, reflecting two differences between the UK and Wales versions of the indicators: 1) the UK indicator includes species that are considered priorities in England, Scotland and Northern Ireland, whereas the version presented here is restricted to Section 42 species (i.e. the Welsh priority list). 2) Some species had insufficient data to estimate their status in Wales. The indicator shows a marginal decline across all species, however the 95% confidence intervals surrounding the trend are large and span zero. Consequently there is considerable uncertainty in the status of these specific invertebrate priority species at the present time. See GMEP Year 1 report for more information on how this is calculated (Emmett et al. 2014).

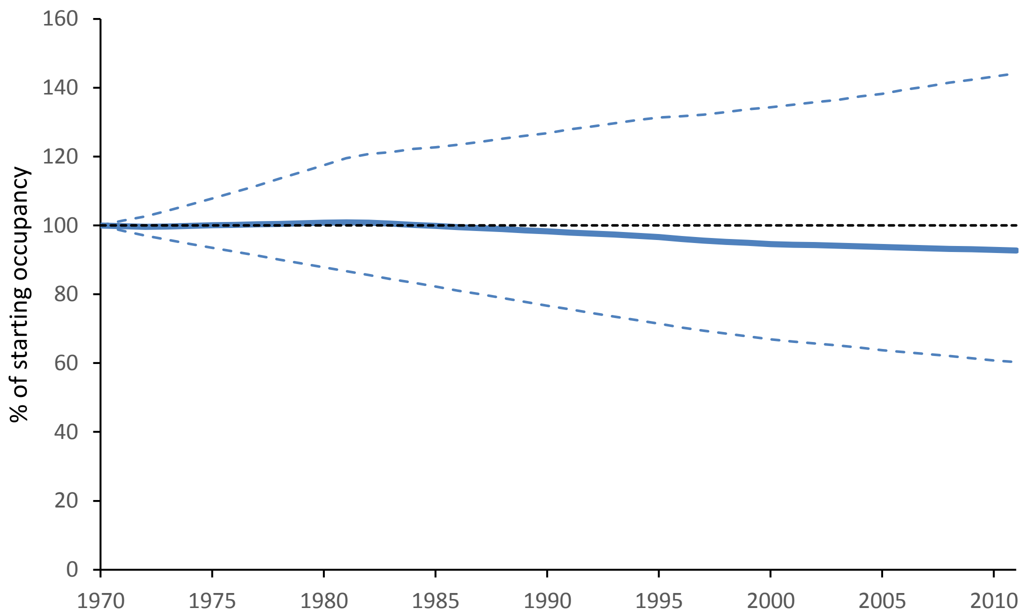


Figure 5.2.1.2.1 *Long term trends in 1km occupancy of priority invertebrate species based on Wales-only records. 95% Confidence Intervals around the trend line are shown. These diverge rapidly as variation in individual species trends reduces the influence of all abundances being centred at 100 at time 0. See Appendices 5.9 and 5.10 for details.*

These results are different from the draft indicator initially tested and presented in the year 1 report. This is because additional records for more species were added in the last year following the acquisition of new datasets. CEH is currently improving the methodology underpinning UK indicator C4b, and greatly expanding the taxonomic breadth of species that contribute to it. If this work were extended to the Welsh data for Section 42 species it would generate an indicator trend with considerably reduced uncertainty. The derivation of this indicator will also change in the next few years resulting in improvements in the way the indicator accounts for variation in recorder effort between locations and years. Additionally, we are developing ways to include covariates (such as Glastir option uptake) into the Bayesian occupancy models enabling us to test hypotheses about the impact of scheme management on occurrence trends (see Appendix 5.9). The ultimate aim is therefore to explore how future trends in many species might be influenced by scheme effects in all 1km squares not just those in the GMEP sample. This offers a complementary perspective to the GMEP analyses. The major strength of the latter is that Glastir effects can be sought by targeting specific combinations of option, habitat and landscape feature with high spatial precision within 1km squares.

5.2.1.3 Long-term trends in Welsh breeding bird populations

Patterns of long-term population change among Welsh birds are of considerable interest to identify both where there are specific conservation issues for Wales and where population trends are more positive or more negative than elsewhere. They are also critical to enable the Welsh Government to report on progress towards national and international biodiversity targets. GMEP field surveys are designed to deliver integrated, ecosystem-level monitoring complementing other monitoring in Wales. Thus, high intensity monitoring in GMEP is traded off against annual spatial coverage and sampling frequency. For birds, lower intensity, annual repeat sampling of a larger number of squares is provided by the BTO/JNCC/RSPB Breeding Bird Survey (BBS), as well as various bespoke monitoring for rarer species. These data are collated and reported annually within GMEP, primarily via the online portal (see Appendix 5.3).

Species-specific population trends reflect differences in ecology and are critical for understanding causes of change, so the primary focus of the regular reporting online is on species-specific trends. However, multi-species summary indices are useful to represent common patterns across communities or habitats, or to test specific hypotheses, so they are presented here and on the GMEP portal for information. In particular, the multi-species average trends that make up the Farmland Bird Index and related indicators at the UK level (Gregory et al. 2008) are also integrated into reporting at the European level. Wales-specific trends in these indices are, therefore, presented here: the Upland and Lowland Farmland Bird Index and the Woodland Bird Index.

The Farmland Bird Index is based on annual BBS indices for the component species, which include species with a range of prevailing population trends and omit those with smaller BBS sample sizes and those that the BBS does not sample effectively at all. Given that the latter, by definition, include many rarer species, a range of priority species for conservation are not considered in the index. In addition, increasing trends in the index can, in principle, be generated by increasing trends in just one species (say, woodpigeon), while all the others decline. This is clearly an undesirable property in an index used to assess conservation success.

As a result of the above, GMEP is producing further indices to monitor bird populations in Wales, including priority species in particular, which are then reported via the data portal. These are (i) average annual total abundance of target species per BBS square, (ii) average annual Simpson's diversity index across all bird species recorded in BBS squares, (iii) the mean total count of target species in GMEP 1km survey squares each year, (iv) average annual Simpson's diversity index across all bird species recorded in GMEP 1km survey squares and (v) the number of target species whose populations in Wales are stable or increasing, determined from the best available survey data, in five-year blocks. "Target species" are defined as those identified as Section 42 priorities (Table 5.2.4.3.1), excluding those that do not breed in Wales or that are effectively extinct.

5.2.1.3.1 Farmland and Woodland Bird Indices

The BBS is a volunteer survey conducted annually in a random sample of 1km squares across Wales using standardized methods (note that countryside closure due to a foot-and-mouth disease outbreak severely restricted survey coverage in 2001, so results for this year are not reported in some analyses). Counts of individual species from each square are analysed annually to update long-term trends using a standard approach (log-linear Poisson models), with confidence intervals estimated by bootstrapping by survey square. This approach was taken to produce the trends used in annual reporting (Appendix 5.3). Multi-species indices are constructed as annual geometric mean population indices across the species considered, where the indices are back-transformed categorical year effects from species-specific models. These indices are already in use by WG as indicators and are published annually. They are reproduced here as requested by the GMEP Advisory Group.

Summary trends for the multi-species indices for birds in Wales to 2013 are shown in Figure 5.2.1.3.1.1 for farmland (all species and divided into lowland upland species) and woodland, as derived from BBS data. The species sets used and percentage population changes over the whole BBS period are then listed in Table 5.2.1.3.1.1. BBS sample sizes have varied by species and over time, with some turnover as volunteer observers leave and join the scheme. However, active recruitment of surveyors has increased sample sizes for species that are not declining and new observers are sought for squares that drop out of the scheme, so long-term change in the survey coverage is lower than the annual changes in Table 5.2.1.3.1.1 suggest. Moreover, mean turnover across species is 13.3% after 2000, compared to 15.8% for the complete range of years shown in Table 5.2.1.3.1.1.

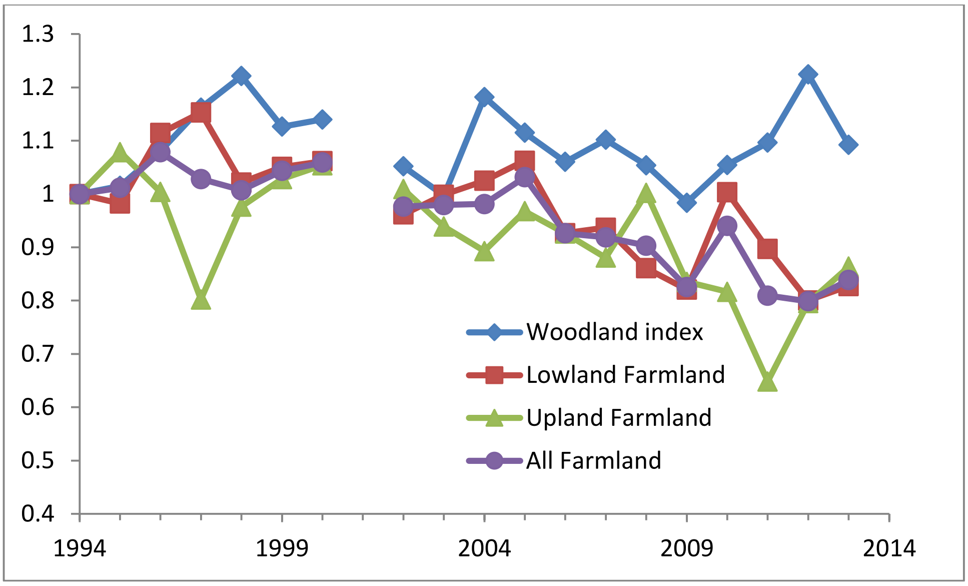


Figure 5.2.1.3.1.1 *Summary index trends for farmland (all species), lowland farmland, upland farmland and woodland in Wales. See Table 5.2.1.3.1.1 for lists of component species.*

Species	Indicator	Annual number of BBS squares with non-zero counts					Notes/ direction of significant change
		Mean	Min	Max	Turnover	% Index Change 1994-2013	
Blackbird	Woodland	197	102	269	17.8	35.2	Increase
Blackcap	Woodland	124	50	182	16.5	123.3	Increase
Blue Tit	Woodland	178	98	233	15.0	13.4	Increase
Bullfinch	Woodland	63	35	89	17.5	-27.8	
Buzzard	Upland Farmland	141	76	188	16.9	-10.1	
Chaffinch	Woodland	198	106	261	17.0	-11.6	
Chiffchaff	Woodland	140	65	208	17.8	52.5	Increase
Coal Tit	Woodland	74	35	93	15.9	-35.3	
Curlew	Upland Farmland	35	18	47	13.6	-55.6	Decline
Dunnock	Woodland	153	78	216	17.3	18.9	Increase
Garden Warbler	Woodland	57	34	62	12.9	-26.8	Increase
Goldcrest	Woodland	81	46	106	16.3	-48.6	Decline
Goldfinch	Lowland Farmland	128	59	176	13.8	73.7	Increase
Great Spotted Woodpecker	Woodland	79	26	130	17.8	208.1	
Great Tit	Woodland	171	88	226	17.1	52.2	Increase
Green Woodpecker	Woodland	46	24	63	15.9	-23.7	
Greenfinch	Lowland Farmland	112	46	152	17.3	-38.7	
Grey Wagtail	Upland Farmland	24	9	32	14.8	-19.9	Small sample
Jay	Woodland	74	25	102	15.5	30.8	Increase
Jackdaw	Lowland Farmland	139	73	179	17.6	38.3	
Kestrel	Lowland Farmland	22	9	29	15.5	-71.3	Small sample
Lesser Redpoll	Woodland	23	10	39	15.8	199.3	Small sample
Linnet	Lowland Farmland	91	49	117	14.4	-25.8	Decline
Long-tailed Tit	Woodland	60	30	84	15.3	22.3	
Meadow Pipit	Upland Farmland	87	51	115	17.3	-6.4	
Nuthatch	Woodland	71	33	94	16.2	47.3	Increase
Pied Flycatcher	Woodland	22	12	26	13.9	-48.9	Small sample
Raven	Upland Farmland	90	42	124	17.9	26.9	
Redstart	Woodland	59	41	92	14.3	31.8	Increase
Reed Bunting	Lowland Farmland	28	9	39	15.4	52.2	Small sample
Robin	Woodland	193	106	260	16.2	-16.8	Decline
Rook	Lowland Farmland	78	46	93	15.6	-9.1	
Siskin	Woodland	27	9	50	17.1	79.6	Small sample
Skylark	Lowland Farmland	103	63	127	13.3	-11.6	
Song Thrush	Woodland	167	83	220	12.1	3.6	
Sparrowhawk	Woodland	21	5	30	15.9	-12.3	Small sample
Spotted Flycatcher	Woodland	23	11	29	13.0	-23.7	Small sample
Starling	Lowland Farmland	79	50	99	13.9	-73.0	Decline
Stock Dove	Lowland Farmland	31	12	41	17.2	132.9	

Tree Pipit	Woodland	33	18	45	14.7	-12.2	
Treecreeper	Woodland	40	22	49	13.6	57.6	
Wheatear	Upland Farmland	53	27	81	17.2	9.5	
Whitethroat	Lowland Farmland	83	39	108	16.1	-2.4	
Willow Warbler	Woodland	160	100	201	13.9	-10.7	
Wood Warbler	Woodland	19	9	25	17.4	-32.3	Small sample
Woodpigeon	Lowland Farmland	188	105	252	17.6	10.8	Increase
Wren	Woodland	197	104	263	17.1	-9.3	
Yellowhammer	Lowland Farmland	34	19	42	15.0	-67.3	Decline

Table 5.2.1.3.1.1 *Species-specific changes in Welsh BBS population indices for the birds included in the summary trends shown in Fig. 5.2.1.3.1.1. Indicator habitat classifications are those used in the standard annual reporting of average trend indicators in Wales. Turnover is defined as the average percentage of squares surveyed in a given year that were not surveyed in the previous year. Detailed trends are shown in Appendix 5.3*

5.2.1.3.2 Diversity and total abundance of target species

High-level indices aiming to summarize broad variation in bird communities in Wales were requested and agreed by the GMEP Advisory Group and are described here. These indices necessarily average over significant variation in patterns of change in abundance of individual species. They also ignore subtleties in the conservation implications of changes in numbers, such as whether increases and decreases in different species' numbers are equally desirable. They should, therefore, be interpreted with care and finer divisions of the data, such as habitat-specific indices or population trends for individual species, should be investigated in making policy decisions.

Count data for all species recorded were extracted from BBS squares and the maximum counts per visit summed across all target species for all BBS squares in Wales in all years. These data were then used to calculate Simpson's diversity index for the entire bird assemblage recorded in the square each year and the total abundance of all target species recorded in the square. Temporal trends in these indices were estimated using a linear model with categorical site and year effects, thus accounting for variation in the composition of the BBS sample (due to survey square turnover) from year to year. The outputs were annual average index values for Wales, which were then plotted and summarized in five-year blocks.

For GMEP 1km survey squares, the total abundance of target species and Simpson's diversity of all bird species were calculated from the maximum counts across visits for GMEP 1km survey squares exactly as described above for BBS squares. Square-specific values were then simply averaged across the two survey years. GMEP surveys cover a different set of 1km survey squares each year, so it is important to recognise that some variation between years is likely to be spatial, rather than temporal. Separation of temporal from spatial variation will begin to be possible after the fifth year of GMEP, when GMEP 1km survey squares from year one are resurveyed.

The total abundance of target bird species in BBS squares has shown little variation over time (Figure 5.2.1.3.2.1). The analogous numbers found in GMEP 1km survey squares were rather more variable across the two years surveyed to date (and is not surprising given the complete change in sample from year to year, in contrast to the large proportion of annual repeats under the BBS), but the confidence interval for both years overlap almost all annual confidence intervals from the BBS. A mean total abundance of target species in GMEP 1km survey squares was 19.11 (SE 3.12) in 2013 and 37.48 (SE 4.58) in 2014. The mean Simpson's diversity index per GMEP 1km survey square was 0.961 (SE 0.006) in 2013 and 0.945 (SE 0.006) in 2014.

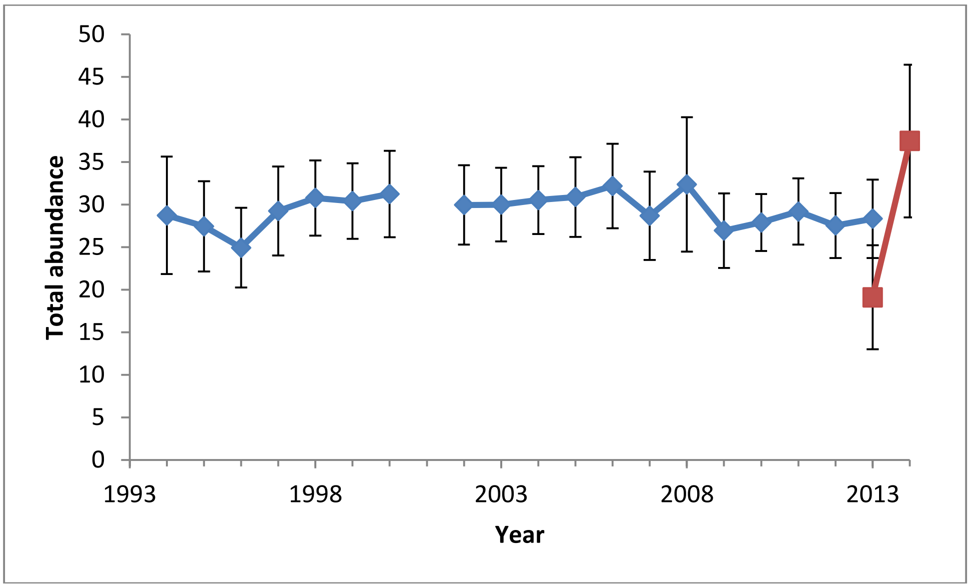


Figure 5.2.1.3.2.1 *Long-term trend in the total abundance of target species from the BBS (blue) and GMEP 1km survey squares (red).Error bars show 95% confidence intervals.*

Simpson's diversity index across all bird species in BBS squares was also rather constant over time, but shows a trend for slight increase since the mid-2000s (Figure 5.2.1.3.2.2). The diversity in GMEP 1km survey squares varied considerably between years, as with total abundance of target species, again probably reflecting differences in the sample of GMEP 1km survey squares from year to year. The diversity index values were significantly higher (Figure 5.2.1.3.2.2), however, showing the detection of more species at low levels of local abundance in the more intensive GMEP surveys. It is important to note that the indices in this section are very high-level summaries that are rather insensitive to changes in the environment and are certain to mask much variation in the data for individual species and habitats. It is impossible to find single indices that include information on multiple species and habitats, are sensitive to variation in these component parts and are widely representative. Hence, it would be unwise to interpret lack of change in these indices, in particular, as showing stability in all features of interest.

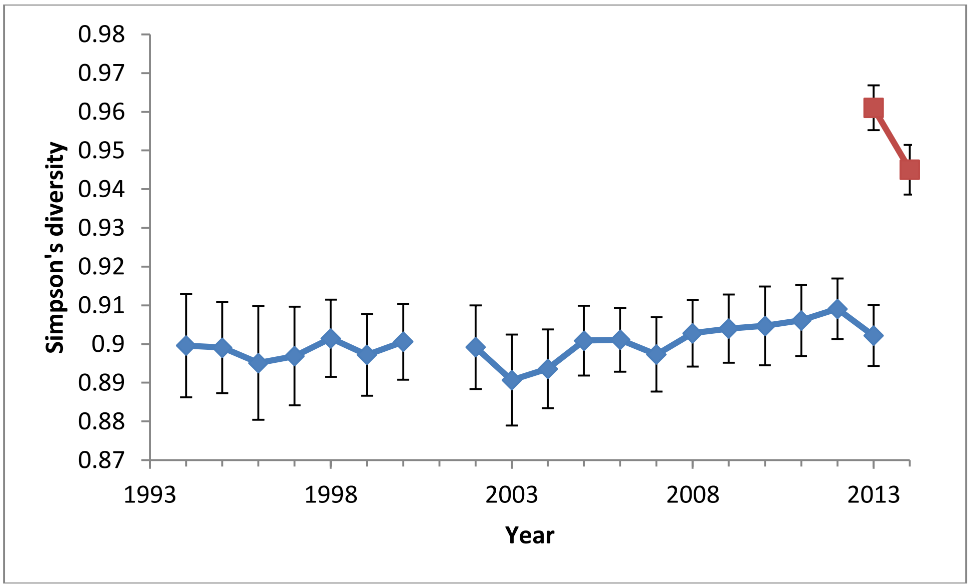


Figure 5.2.1.3.2.2 *Long-term trend in the Simpson's diversity across all bird species from the BBS (blue) and GMEP 1km survey squares (red). Error bars show 95% confidence intervals.*

5.2.1.3.3 Calculating population trends among target species

The available information on trends of species not monitored by the BBS is collated annually within GMEP, together with the relevant BBS data. Full details are presented in Appendix 5.3. The data considered vary in quality (standardisation of recording, frequency of repeat monitoring, geographical extent and representativeness of cover), but are the best available for each species. As well as those for which BBS trends are reported regularly elsewhere, a range of species are included for which the available BBS sample size is below the standard minimum threshold of 30 squares per annum. These population trends are less reliable, but the associated uncertainty in the temporal trends is reflected in their confidence intervals (because there is no reason to expect sampling bias in the random sample of BBS squares) and the sample size problem is highlighted. Note that, as for more common species, trends are presented as smoothed and unsmoothed annual indices. The unsmoothed data include fluctuations from year to year caused predominantly by weather effects on actual numbers or counts in the field. The smoothing process aims to remove these fluctuations to focus on the long-term change that is both a sound reason for cause for concern (where negative) and a rational measure of management impact (where positive). For species not covered at all by BBS, indices are calculated from data from other sources wherever possible. For breeding waterbirds with the most significant populations around large waterbodies (Black-headed Gull, Herring Gull and Ringed Plover), indices are calculated from Wetland Bird Survey (WeBS) data for April-June each year (see Appendix 5.3). For wintering waterbirds for which the Section 42 status is derived from winter populations, indices are calculated from winter WeBS trends (Appendix 5.3). For Chough, data from independent, ongoing, annual survey work will be collated and presented in the same way as the BBS data. These results will be included in the next GMEP report in September 2015. For Twite, Golden Plover, Hawfinch, Hen Harrier, Ring Ouzel, Tree Sparrow, Turtle Dove and Yellow Wagtail**,** data have been extracted from the annual "Birds in Wales" report that constitute county-specific counts of breeding birds. These data were then analysed similarly to the BBS data, using linear models of county and year. The data are unstructured and unstandardized, but should reveal gross changes in abundance within the time-frame considered and represent the best data available. It is intended that these analyses will be improved over time by integrating additional data sources as they are made available, for example including RSPB- or NRW-funded survey data and counts derived from individual, bespoke projects. Currently, the sensitivity and reliability of these analyses are unknown and likely to vary between species; further research using simulation or new field monitoring would be required to inform about these considerations. In the absence of such supporting evidence, the patterns revealed should be interpreted merely qualitatively (i.e. as providing evidence of change or not) and with caution, because the qualitative conclusions could be misleading.

Of 50 priority (Section 42) species, trend data were available for 35. To this number, data for Chough, Black Grouse and Hen Harrier are expected to be added once they are available from independent observers or RSPB. The estimates of trends for Golden Plover, Twite and perhaps other species currently dependent on Bird Report data may also be improved by the addition of available data from formal surveys. The other species for which trends were not available include Nightjar (nocturnal and poorly surveyed), five (now) very rare species that are not well-recorded in Bird Reports (Hen Harrier, Lesser Spotted Woodpecker, Grey Partridge, Red Grouse and Willow Tit) and six species that are now effectively extinct in Wales (Aquatic Warbler, Bittern, Corn Bunting, Corncrake, Red-backed Shrike and Woodlark).

5.2.1.3.4 Constructing a priority bird species index

A summary index of the numbers of priority species showing different population trends, considering all species and all forms of trend analysis described above, was constructed for five-year blocks aligned to those used for averaging multi-species average trend indices. For each five-year period, the trend for each priority species revealed by the best source available (as described above)

was assessed as increasing or stable (score=1) or declining (score=0), using expert judgement. Ideally, a finer definition of trend direction would be used, such as considering rates of decline or increase, or separating "increasing" from "stable", but such categorizations of non-linear trends are difficult to standardize, so fewer categories reduce the potential for subjective variation, and lack of decline reflects the broad policy targets for most species. For the rare species with trends constructed from bird report data, linear trends were fitted and the qualitative pattern revealed for the complete time series available was used to determine scores for all five-year periods. The assessment considered the statistical confidence associated with each trend, but was not bound by it; thus, species showing some evidence of decline or increase that was supported by general conservation opinion and/or trends in the wider UK were assessed as having this population trend direction, even if the pattern was not statistically significant in Wales because of small sample sizes,. This avoided a perverse result wherein conservation-priority species might be given an assessment of population stability simply because they were too rare to be monitored with high precision. A measure of the overall health of the populations of priority species was then provided by the number, or percentage, of them that were assessed as having a score of 1. Percentages were used to account for the fact that data were not available for all species of interest in all time periods and "no data" does not represent decline or increase/stability without assumptions that potentially introduce bias. A total score at its maximum value (reported as a percentage, so 100%) would indicate that all species of concern were at least stable, while increases towards this total over time would indicate that the direction of travel of was showing progress towards meeting of conservation priorities. The process of constructing this index was conducted using the trends shown in Appendix 5.3 and the matrix of estimated trend scores is provided in Annex 4 for transparency. In the future, it would be wise to undertake the scoring process using multiple experts, perhaps using a Delphi procedure to arrive at final outcomes, but resources did not permit this in the current project.
The numbers of species available for summarizing trends in different five-year blocks varied slightly because wintering Bewick's Swans effectively disappeared from Wales after c. 2002-03, so this species contributes to the ultimate index only before this time, wintering Greenland Greater White-fronted Goose has been monitored only since 2000, so there were no data to contribute to the first time period and reliable Hen Harrier change information is available (from an RSPB survey, Hayhow et al. 2013) only for 2004-11. Otherwise, trends were scored as increasing/stable or declining and the results across species were as summarized as percentages in Table 5.2.1.3.4.1.

	1994-1999	**2000-2004**	**2005-2009**	**2010-2014**
Number of species with trend data	34	35	35	34
Number increasing/stable	23	21	17	22
Percentage increasing/stable	67.6	60.0	48.6	64.7

Table 5.2.1.3.4.1 *Summary of population trends across priority (Section 42) species.*

At least half of the priority species were scored as increasing or stable in each of the periods considered, but there was considerable variation in trend direction within and between species, leading to considerable variation in the overall index of population trend health. Specifically, rather more population trends were negative during 2000-2009 than at either end of the time series considered and there was no pattern for an overall improvement in population health over time.

5.2.1.3.5 Overall conclusions regarding the long-term trends in Welsh breeding bird populations

Patterns of population change in birds are likely broadly to reflect the health of other groups at large spatial scales, as well as habitat quality, because birds are near the top of the food chain and depend upon these components of the environment. Therefore, large changes in the summary indicators in Figure 5.2.1.3.1.1 are likely to be associated with changes in other biodiversity. Note, however, that there is no evidence for specific relationships between these indicator values and indicators of other taxa.

In general, the Welsh farmland bird indices show a tendency to declines from around 2000, while the woodland index has remained relatively stable (Figure 5.2.1.3.1.1). This reflects the continuing downward trends in a number of farmland bird species, such as Yellowhammer and Skylark.
It is important to note that the multi-species indicators are simply average trends; they are intrinsically trade-offs between component species and positive or negative changes cannot be interpreted as showing that all share the overall pattern. It is very likely that the overall average masks diverse species-specific patterns, some of which are clear from the long-term changes summarized in Table 5.2.1.3.1.1. Therefore, within a declining indicator, it is likely that some component species will need no conservation action, but declining species may feature within an increasing trend and thus be conservation priorities. As a result, it will always be advisable to refer to the trends of individual species, as shown in the Welsh Bird Trends summary document (see Appendix 5.3) when making conservation decisions.

The total abundance of target species and overall species diversity show different patterns over time (Figures 5.2.1.3.2.1 and 5.2.1.3.2.2), although neither shows the clear pattern of increase that would be indicative of generally increasing bird populations. As with other indicators, however, the process of summarization will have masked some patterns of relative increase for individual species, while masking others of relative decline for other species.

The index of overall health of population trends of priority species consisting of the percentage that are increasing or stable is attractive in that it is easy to understand and that it reflects directly what most conservationists and policy-makers will be concerned about, namely whether populations of species of interest are in decline or not. It also implicitly weights all species equally, unlike the average trend approach, which allows more variable species to influence the outcome more. Unlike the specific average trends in use at the Wales, UK and EU levels (Gregory et al. 2008), this index also considers only priority species, so that the outputs cannot be influenced by changes in the populations of common (or even pest) species (e.g. Woodpigeon). Clearly, the species list included can readily be revised, subject to data availability. Weaknesses with the approach include that it inevitably incorporates a degree of subjectivity because it would be unwise to consider only statistically significant changes, given the sample size (and power) constraints inherent in assessing rare or declining species. Data on rarer species are also often less reliable or unavailable, when these may be both the highest priority and the most targeted by conservation action, and therefore the most critical for monitoring. Finally, it would be difficult to introduce this approach at a temporal resolution of less than five years or so, so the index will not respond rapidly to environmental change or management. Finer temporal resolution for presentation purposes could be achieved by using a five-year (say) moving window to evaluate trends for individual years, but the influence of multiple years on the trend estimate for any given time point would still entail a slow response to external drivers. With those caveats in mind, overall the results indicated at least half of the priority species were scored as increasing or stable in each of the periods considered, but there was considerable variation in trend direction within and between species, leading to considerable variation in the overall index of population trend health. Specifically, rather more population trends were negative during 2000-2009 than at either end of the time series considered and there was no pattern for an overall improvement in population health over time.

5.2.2 Priority Habitats

5.2.2.1 Introduction

There are a number of habitats of principle importance to conservation in Wales which are known as 'Priority' habitats or Section 42 habitats. The production of a Section 42 list is a requirement of the Natural Environment and Rural Communities Act 2006, and is used to guide and prioritise future conservation action in Wales. Some of these priority habitats are specifically mentioned as targets in

Glastir e.g. Lowland heathland, wetland and there are options in the scheme designed to optimise management to ensure that they are in good condition. Many of these habitats are important to priority and Section 42 species and management and creation options in Glastir are designed to benefit them. In GMEP, priority and Broad Habitats are mapped in every GMEP 1km survey square, this includes large areas of habitat e.g. blanket bog but also linear features such as streamsides, hedgerows and belts of trees. How many priority habitats are sampled in the GMEP field survey and how many Priority habitats coincide with Glastir agreement maps by the end of year 2? This question addresses the number and type of priority and Broad Habitats surveyed in GMEP and examines the proportion of mapped habitat that coincide with Glastir uptake to date.

5.2.2.2 Methods

In the GMEP field survey the habitats and features of every GMEP 1km survey square are mapped using a bespoke GIS software system on field computers. As well as classifying each habitat type using a vegetation key many detailed attributes are recorded such as the height of the vegetation, the species composition, the management and use and the condition. This gives us a detailed complex database that can be queried to determine how habitats and features vary spatially and how they are changing and how they are influenced by management actions. It is also valuable information to contribute to studies of priority species.

5.2.2.3 Results

Figure 5.2.2.3.1 shows the % of the GMEP 1km survey square area attributed to different habitat types.

The most commonly surveyed habitats are the Broad Habitats improved, neutral (largely semi-improved) and acid grasslands and coniferous and Broadleaved woodland. These make up a large proportion of the Welsh countryside. The most frequently surveyed priority habitats include Purple Moor-grass and Rush Pasture, Upland Heath, Blanket Bog and some of the woodland priority habitats wet woodland and Lowland Mixed Deciduous. Most of the priority habitat types are recorded in the GMEP survey but some make up a very low percentage of the survey. Upland habitats are better represented in the targeted GMEP 1km survey squares which is to be expected as these were chosen to reflect the Welsh Government priorities in the first two years of Carbon and water. Condition assessments of a subset of these Priority Habitats are reported in the GMEP Data Portal.

Figure 5.2.2.3.2 shows the percentage of the total area of different habitats in Wales GMEP year 1 and 2 1km survey squares that are currently under a Glastir scheme. Acid, calcareous and marshy grassland (includes Purple Moor-grass and Rush Pasture) are well covered by Glastir agreements as are bogs, mires and heathlands. Woodland habitats are less well covered with only 22.7 % of semi-natural broadleaved woodland being under Glastir agreement.

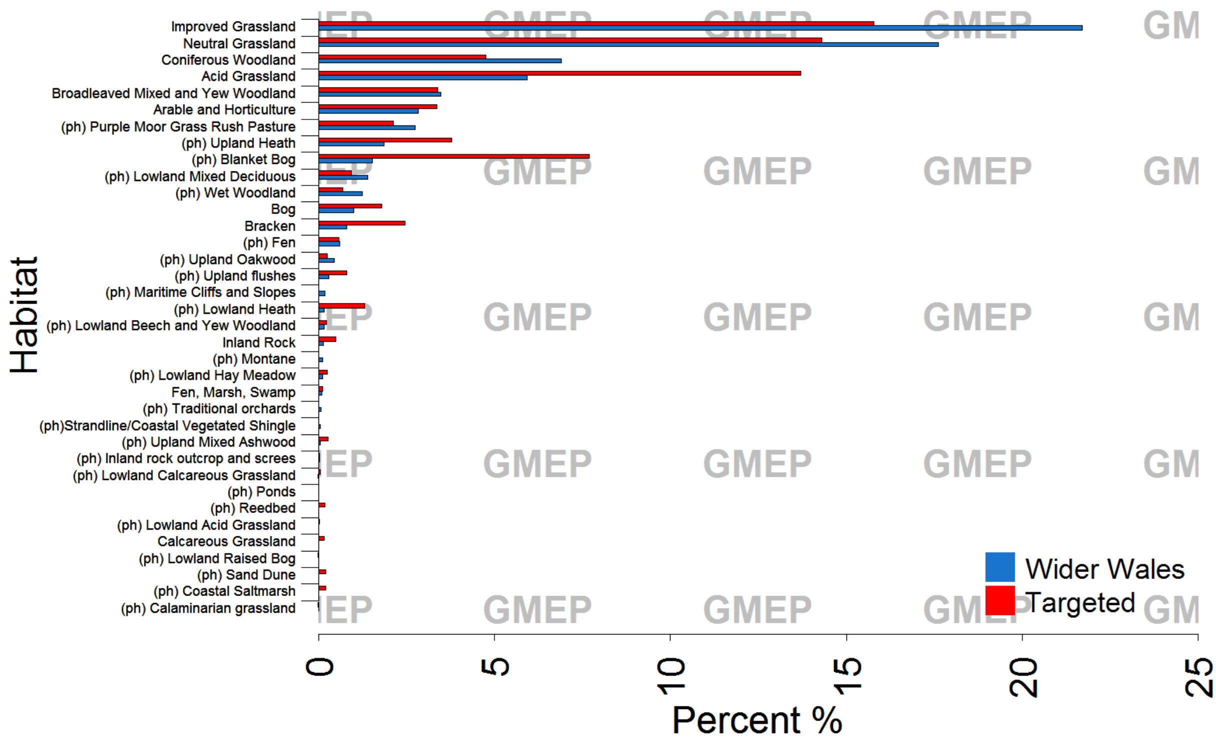


Figure 5.2.2.3.1 *Percentage of the area surveyed in the GMEP field survey in year 1 and 2 GMEP 1km survey squares. The Broad Habitat figures do not include those areas also identified as priority habitat (ph).*

Habitat	%WW	%Targeted
Improved Grassland	21.7	15.77
Neutral Grassland	17.61	14.29
Coniferous Woodland	6.91	4.76
Acid Grassland	5.93	13.7
Broadleaved Mixed and Yew Woodland	3.47	3.38
Arable and Horticulture	2.83	3.37
(ph) Purple Moor-grass and Rush Pasture	2.74	2.13
(ph) Upland Heath	1.86	3.79
(ph) Blanket Bog	1.53	7.7
(ph) Lowland Mixed Deciduous	1.4	0.93
(ph) Wet Woodland	1.25	0.7
Bog	1.01	1.79
Bracken	0.81	2.47
(ph) Fen	0.61	0.58
(ph) Upland Oakwood	0.45	0.25
(ph) Upland flushes	0.3	0.81
Standing Open Waters and Canals	0.2	1.32
(ph) Maritime Cliffs and Slopes	0.19	0.01
(ph) Lowland Heath	0.16	1.31
(ph) Lowland Beech and Yew Woodland	0.16	0.23
Inland Rock	0.15	0.5
Rivers and Streams	0.14	0.19
(ph) Montane	0.13	0
(ph) Lowland Hay Meadow	0.12	0.26

Fen, Marsh, Swamp	0.1	0.12
(ph) Traditional orchards	0.07	0.01
(ph)Strandline/Coastal Vegetated Shingle	0.05	0.01
(ph) Upland Mixed Ashwood	0.05	0.27
(ph) Inland rock outcrop and screes	0.03	0.03
(ph) Lowland Calcareous Grassland	0.02	0.05
(ph) Ponds	0.01	0.01
(ph) Reedbed	0	0.19
(ph) Lowland Acid Grassland	0	0.04
Calcareous Grassland	0	0.16
ph) Lowland Raised Bog	0	0.02
ph) Sand Dune	0	0.2
(ph) Coastal Saltmarsh	0	0.22
(ph) Calaminarian grassland	0	0.02

Table 5.2.2.3.1 *Data from GMEP field survey showing the coverage of different Broad and Priority habitats (ph) as a % of the total area surveyed.*

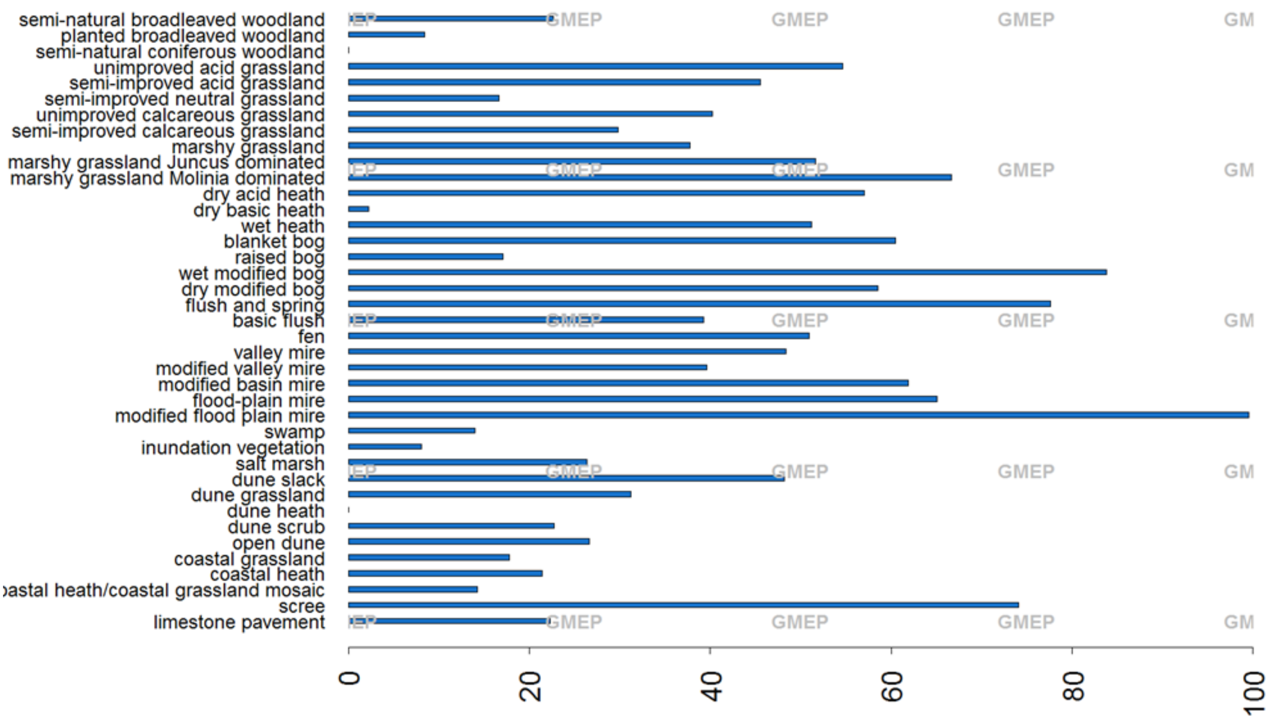


Figure 5.2.2.3.1 *Percentage of total area of each habitat in the whole of Wales covered by a Glastir scheme (includes all schemes, entry, advanced, Woodland element, commons, GEG) and uses NRW Phase 1 survey data to represent habitat coverage.*

5.2.2.4 Estimation of national stock and change in extent and Glastir impacts on Section 42 habitats

Using existing estimates of the extent of Section 42 habitats in Wales and mapped extent of habitats through years 3 and 4, we will be able to determine for which of these habitats the GMEP field survey will yield estimates of stock and change with different levels of uncertainty attached. These uncertainties reflect sample size (number of GMEP 1km survey squares surveyed) and the variation between GMEP 1km survey squares in the coverage of each habitat. An example of this approach is shown below for two habitats. The uncertainty around the sample-based estimate of extent is expressed by the Coefficient of Variation (CV) (the standard deviation as a percentage of the mean). The example below shows the CV for two habitat areas of 2000ha and 20000ha over the whole of Wales). We do not currently have sufficient sample size for the smaller area (Figure 5.2.4.4.1a) as the current sample size after 2 years (red line) only provides a coefficient of variation of just over 25%. By the end of the roll (blue line) we should have sufficient sample size. For the larger area (Figure 5.2.4.4.1b) we already have enough GMEP 1km survey squares to report on the area of the habitat with sufficient confidence. The next stage is to use the observed habitat areas surveyed in years 1 and 2 plus national estimates for the rarer habitats not yet encountered and use these data to initially estimate the levels of power achievable for reporting stock and change in extent likely over the 4 year roll. The importance of using prior information on the distribution of each habitat is that the estimation of power needs to account for the deviation of the distribution of habitats from a random spread. For example coastal habitats are likely to require a separate stratification to achieve robust estimation. At present survey squares are optimised for sampling Glastir in conjunction with the wider countryside reflecting the principal objective of GMEP.

Currently we anticipate being able to report on change in extent for 13 priority habitats (0f 36 terrestrial and freshwater priority habitats): Blanket bog; Upland heath; Lowland Heath; Purple Moor-grass and Rush Pasture; Fen; Upland flushes; Ponds; Lowland Mixed deciduous woodland; Wet Woodland; Lowland Beech and Yew Woodland; Upland Oak Wood; Upland mixed Ashwood; Hedgerows. Change for condition may be possible for: Arable field margins; Upland heath; Lowland Heath; Purple Moor-grass and Rush Pasture; Lowland Acid Grassland; Lowland Hay Meadow; Upland calcareous Grassland; Lowland Calcareous Grassland; Hedgerows. For rarer habitats, insufficient area within GMEP 1km squares may rule out useful estimation of extent however in those areas surveyed, fixed vegetation plots will be recorded since all mapped areas of Priority Habitat are sampled by default. While it may be possible to derive and report condition for these areas based on coincident plots the question arises as to how representative the vegetation plot sample might be of the total extent. Thus reporting of these condition measures will need to be accompanied by a characterisation of the resource they represent, for example in terms of geographical location, patch size and other spatial or ecological biases.

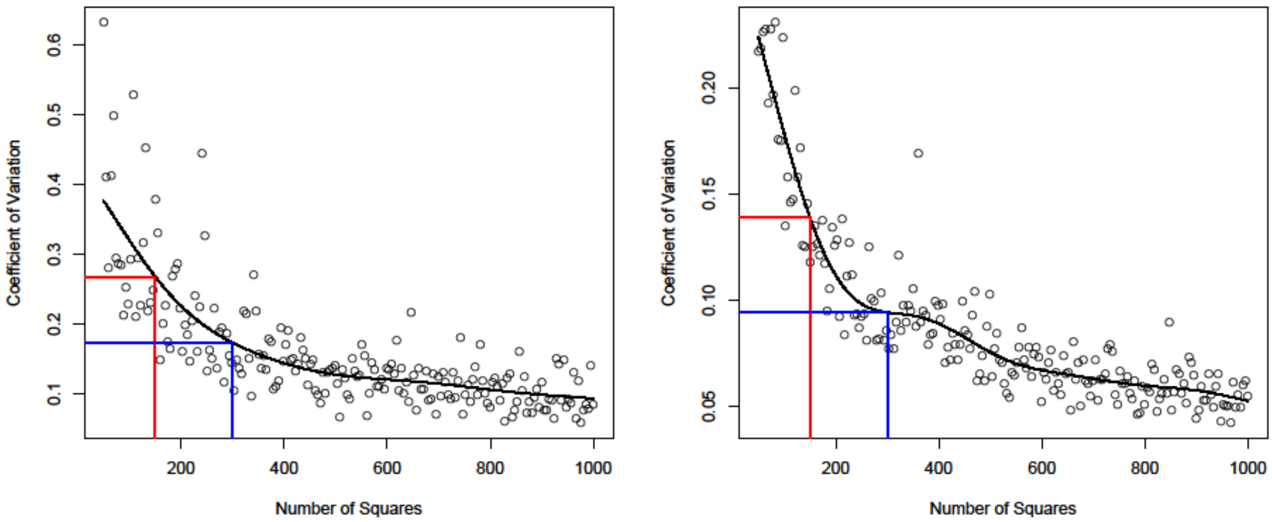


Figure 5.2.4.4.1 a (left) & b (right) *Estimating uncertainties for national estimates of extent based on the GMEP sample of 1km squares for a hypothetical habitat assumed to cover 2000 (a) or 20000ha (b) of Wales. Points are the CV values that arise from a random distribution of areas of habitat among different numbers of GMEP 1km survey squares assuming different national extents of each habitat.*

5.2.3 Distribution of Section 42 species and their coincidence with GMEP 1km survey squares

Work in years 2 and 3 has focussed on gathering up-to-date distribution data for Section 42 species that are associated with their own bundles of specific options within the Glastir scheme. These data are required at 1km resolution to determine whether recently recorded populations coincide with GMEP 1km survey squares where associated Glastir options have been taken up (see Section 5.2.2). Coincidence is reported for the analyses of habitat indicator variables for a range of Section 42 species covering Dormouse, rare arable plants, Lapwing, Lesser Horseshoe Bat, Curlew and Marsh Fritillary Butterfly (see section 5.3.3 and Appendix 5.10). Because GMEP includes butterfly and bird surveys, Section 42 species in these groups have been recorded where possible in GMEP 1km survey squares. These records are reported below for years 1 and 2. Other taxa are not recorded in GMEP and so we rely on records from other schemes and recorders to fill the gap. The Biological Records Centre at CEH Wallingford issued a request to data providers for updated distributional data at 1km square resolution. In addition the Bat Conservation Trust and Plantlife kindly provided recent records for Section 42 bats, lichens, plants and fungi (Table 5.2.3.1). The coincidence between these recently acquired 1km square records and GMEP 1km survey squares is shown in Table 5.2.3.2. These numbers should increase once year 3 and 4 GMEP 1km survey squares are included.
The numbers of post-1970 records coinciding with year 1 and 2 GMEP 1km survey squares are low (Table 5.2.3.2). This is not surprising given the rarity of the species concerned. Our approach to exploring the potential effect of Glastir is therefore to measure the impact of Glastir options associated with each rare species on ecological conditions in all locations, including those where the rare species has not been recently recorded in GMEP 1km survey squares. Thus the question of whether options can successfully drive ecological changes that would be expected to favour each species is treated separately from whether option-induced ecological change spatially coincides with rare species populations. However, if the number of coincidences between species records and option uptake is large enough then it will be possible to examine Glastir effects in these situations thus providing a more direct test of the relevance of options to the target species. Accumulating as much distributional data as possible for each species is therefore important. Whilst efforts have been made to accumulate recent records at 1km resolution, gaps in coverage remain. Mammals in particular require further effort. For example, the number of Dormouse records visible on the NBN portal greatly exceeds the number acquired by BRC at 1km resolution because data owners were reluctant to allow access to these data. Ongoing work will further engage the recording community including Welsh Local Record Centres. We will attempt to provide the assurances needed to secure access to greater numbers of records. BTO surveyors also record mammal sightings in GMEP 1km survey squares and these data will also be added to the 1km observational database as they accumulate.

S42 Species	Data Resolution	Received from	Year	Organisation	Total number of 1km records
Arable plants	1km-100m	Trevor Dines	post-1987	Plantlife	79
Artic-Alpine plants	1km-100m	Trevor Dines	post-1987	Plantlife	44
Heathland plants	1km-100m	Trevor Dines	post-1987	Plantlife	146
Lichens of waysides and parkland trees	1km-100m	Trevor Dines	post-1987	Plantlife	301
Metal-mine lichens	1km-100m	Trevor Dines	post-1987	Plantlife	5
Fungi	1km-100m	Trevor Dines	post-1987	Plantlife	214
Barbastelle Bat	1km 10km 1 & 10km	Bjorn Beckmann Bjorn Beckmann Kate Barlow	post-1970 post-1970 post-1970	BRC/CEH BRC/CEH BCT	8
Bechstein's Bat	No distribution data available from BRC or BCT				
Lesser horseshoe Bat	1km 10km 1 & 10km	Bjorn Beckmann Bjorn Beckmann Kate Barlow	post-1970 post-1970 post-1970	BRC/CEH BRC/CEH BCT	659
Great horseshoe bat	1km 10km 1 & 10km	Bjorn Beckmann Bjorn Beckmann Kate Barlow	post-1970 post-1970 post-1970	BRC/CEH BRC/CEH BCT	149
Dormouse	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	66
Great Crested Newt	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	297
Red Squirrel	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	70
Water Vole	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	54
Brown-Banded Carder Bee	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	8
Shrill Carder Bee	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	6
High Brown Fritillary	1km	Bjorn Beckmann	post-1970	BRC/CEH	42
Marsh Fritillary	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	606
Pearl Bordered Fritillary	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	176
Welsh Clearwing	1km	Bjorn Beckmann	post-1970	BRC/CEH	103

Table 5.2.3.1 *Number of 1km square records for Section 42 species that have dedicated bundles of Glastir options. Bird distribution data is covered separately in 5.3.2.3.* ***Abbreviations:*** *CEH – Centre for Ecology and Hydrology; BCT – Bat Conservation Trust; BRC – Biological Records Centre.* ***Notes:*** *Complete data sets for all S42 species were not received due to organisations not providing permission to share third party data sets. This issue alone is the reason why no Bechstein's bat data could be provided for analysis. The incompleteness of the distribution data is particularly visible on*

the NBN interactive map. For example, only 66 1km dormouse records were received by BRC, yet the NBN gateway holds a total of 358 dormouse records at 1kmresolution within Wales.

Section 42 species associated with Glastir options	Number of post-1970 records that coincide with yr 1 & 2 GMEP 1km survey squares
Lesser Horseshoe Bat	**14**
Greater Horseshoe Bat	**2**
Barbastelle Bat	**1**
Hazel Dormouse	**0**
Water Vole	**2**
Red squirrel	**1**
Great Crested Newt	**2**
Arable plants	**0**
Arctic-Alpine plants	**0**
Grassland plants	**0**
Heath plants	**1**
Lichens of wayside and parkland trees	**5**
Metal-mine lichens	**0**
Grassland fungi	**1**
Brown-Banded Carder Bee	**0**
Shrill Carder Bee	**0**
High Brown Fritillary	**1**
Marsh Fritillary	**13**
Pearl Bordered Fritillary	**5**
Welsh Clearwing	**2**

Table 5.2.3.2 *Coincidence between post-1970 records for Section 42 species associated with Glastir options and surveyed GMEP 1km survey squares from 2013 and 2014. Bird distribution data and coincidence are covered separately in section 5.3.*

5.2.4 Occurrence of Section 42 species directly reported by the GMEP field surveyors

Species of principal importance in Wales listed under Section 42 of the NERC Act, are a key policy priority. It is therefore of interest to determine which of these species could potentially be monitored under GMEP and which will require additional survey effort, either via independent surveys or via specific targeting through the Targeted element of GMEP. Since the field survey component includes butterfly and bird surveys and census of vegetation plots there is potential for encountering Section 42 taxa in these groups. Results for the year 1 and 2 surveys are shown below. Other Section 42 taxa are not directly measured in GMEP. They require other methods particularly with regard to detecting impacts of Glastir options. Our approach to this problem is two-fold: current distribution data is used to determine whether a target species coincides with GMEP 1km survey squares in which options linked to the species have been taken up. Then, irrespective of the distribution of the target species, we separately quantify indicators of change in ecological conditions associated with the expected impact of the species-specific Glastir options. See section 5.3.3 and Appendix 5.10.

5.2.4.1 Plants

No Section 42 plant species were recorded in year 1 and 2 vegetation plots.

5.2.4.2 Butterflies

Of the 15 Section 42 butterflies 7 have been recorded in GMEP 1km survey squares in years 1 or 2. Pearl-bordered and Marsh Fritillary have not yet been recorded in GMEP. Of the 3 species specifically targeted by Glastir only High Brown Fritillary has so far been recorded (Table 5.2.4.2.1).

SPECIES	No. GMEP 1km survey squares 2013-14	% GMEP s1km survey squares 2013-14
Brown Hairstreak	1	1
White-letter Hairstreak	2	1
Small Pearl-bordered Fritillary	6	4
High Brown Fritillary	1	1
Wall Brown	24	16
Grayling	3	2
Large Heath	2	1

Table 5.2.4.2.1 *Non-zero counts of Section 42 butterflies in GMEP 1km survey squares from the year 1 and 2. The remaining eight Section 42 species have not yet been recorded.*

5.2.4.3 Birds

The GMEP field surveys are designed to cover a representative sample of the common and widespread habitats found in Wales, with the addition of a targeted sample considering priority habitats or forms of management. To date, the sample has not been targeted towards birds of conservation concern, but such species are nevertheless of interest for monitoring. Specifically, the species of principal importance in Wales listed under Section 42 of the NERC Act. 504 are a key policy priority. It is therefore of interest to determine which of these species could potentially be monitored under GMEP and which will require additional survey effort, either via independent surveys or via specific targeting through the Targeted element of GMEP.

The bird survey results from the GMEP field surveys were summarized to reveal GMEP 1km survey squares where the bird species that have been identified as Section 42 priorities (http://www.eryri-npa.gov.uk/__data/assets/pdf_file/0003/486156/SpeciesList.pdf) were recorded in 2013 and 2014.

Species name	Number of GMEP 1 km survey squares		Notes
	2013	2014	
Aquatic Warbler	0	0	Globally endangered, not in Wales
Bar-tailed Godwit	0	0	Winter - WeBS
Common Bullfinch	27	31	
Black-headed Gull	2	6	Colonial - will always be in a small number of locations; monitored by WeBS
Great Bittern	0	0	Extinct?
Black Grouse	0	0	Surveyed regularly by RSPB
Tundra Swan	0	1	Winter - monitored by WeBS
Corn Bunting	0	0	Extinct
Corn Crake	0	0	Extinct
Chough	5	3	Surveyed annually independently
Common Cuckoo	13	12	
Eurasian Curlew	6	13	
Common Scoter	0	0	Winter - monitored by WeBS
Dunnock	48	61	
Dark-bellied Brent Goose	0	0	Winter - monitored by WeBS
Red-backed Shrike	0	0	Extinct
Grasshopper Warbler	9	9	
Golden Plover	1	0	Surveyed periodically by RSPB
Hawfinch	1	0	
Herring Gull	11	24	monitored by WeBS
Hen Harrier	1	3	Surveyed periodically independently
House Sparrow	33	43	
Kestrel	5	5	
Northern Lapwing	6	5	
Common Linnet	32	35	
Lesser Redpoll	19	26	
Lesser Spotted Woodpecker	0	0	Now very rare
Marsh Tit	10	3	
European Nightjar	0	0	Nocturnal
Greenland Greater White-fronted Goose	0	0	Winter - monitored by WeBS
Grey Partridge	2	1	
Pied Flycatcher	8	4	
Reed Bunting	16	25	
Red Grouse	1	4	
Ringed Plover	0	2	Monitored by WeBS
Ring Ouzel	2	1	
Roseate Tern	0	0	Very rare
Sky Lark	31	38	
Spotted Flycatcher	15	4	

Common Starling	15	23	
Song Thrush	42	58	
European Turtle Dove	0	1	Now very rare
Tree Pipit	13	12	
Eurasian Tree Sparrow	0	1	Now very rare
Twite	1	0	Surveyed regularly by RSPB
Wood Lark	0	0	Extinct
Wood Warbler	7	1	
Willow Tit	5	0	
Yellowhammer	10	9	
Yellow Wagtail	1	1	Rare in Wales, only near English border

Table 5.2.4.3.1 *Coverage of Section 42 bird species by GMEP field surveys. Species that are now extinct in Wales are identified, as are wintering and breeding wetland or coastal species that are monitored by the Wetland Bird Survey (WeBS).*

The numbers of GMEP 1km survey squares where each Section 42 species was recorded in the GMEP 1km survey squares are listed in Table 5.2.4.3.1. This indicates that there is good potential to monitor change, or to investigate habitat relationships such as the selection or otherwise of Glastir option habitat, in many of these species. Exceptions include those that now extinct as breeding species in Wales, one nocturnal (or crepuscular) species and those that are only winter visitors. Nocturnal species require bespoke monitoring, but wintering wetland species, especially those found in coastal locations, are well monitored by the BTO/JNCC/WWT Wetland Bird Survey (WeBS), which provides monthly data on near-complete counts of UK wintering waterfowl and wader populations each year. It also provides data on breeding populations for those waterbirds that also breed in Wales; these data may be more useful than any available BBS counts for species that are mostly found on larger water bodies. Summary data on these populations are freely available and patterns of population change have been summarized within GMEP reporting with reference to long-term trends (Appendix 5.3). This leaves around 14 species which do not fall into these categories and had counts of 10 or more in 2 years of the baseline survey with another 2 years of baseline still to come.

Nevertheless, some species are too rare to be monitored under GMEP without specific targeting and, perhaps, bespoke survey methods. Their coverage therefore reflects the targeting strategy behind GMEP sampling set by the Welsh Government, but it is important to note that specific surveys for a wide range of ecologically different and geographically separated species will always be difficult to manage logistically in the context of limited resources. Changes in very rare species are reported independently via periodic atlas projects, such as the recent Bird Atlas 2007-11 (Balmer et al. 2013), while some species are subject to formal or informal monitoring by independent observers. GMEP will endeavour to collate data from such sources to inform about long-term population trends (see Section 5.2.1.3) and, for well-monitored species, analyses specifically investigating the effects of Glastir management may be possible. Chough is one species for which the latter should be feasible.

5.2.5 What are the long term trends in Habitat diversity?

5.2.5.1 Background

Habitat diversity can be a good thing in that a mixture of habitats provides variety in abiotic conditions, food and shelter and is preferable to a species-poor monoculture. High habitat diversity should provide resilience from changing environmental conditions (e.g. climate change) enabling species to move between habitats when conditions change. However, high habitat diversity can also be a sign of increasing fragmentation and it is important that larger continuous areas of habitat are also maintained for example, in unenclosed upland environments. Habitat diversity and connectivity (reported elsewhere) can both contribute to the creation of ecological networks which have an important role to play in the conservation of habitats and species in an increasingly fragmented landscape.

5.2.5.2 Methods

Habitat diversity and the mean area of a habitat patch within a 1km square have been calculated from field survey data. All Habitats are mapped within a 1km square to Broad and Priority habitat classification by surveyors in the field using a computer with bespoke GIS technology. This classification has been applied continuously from 1984 to 2014. The Shannon diversity index (H´) following the formula $- \Sigma p_i \ln p_{i,}$ was used to calculate habitat diversity where $p_{i,}$ is the proportion of habitat $_{i.}$. Habitats were substituted for species and 1km squares for quadrats. Urban areas were excluded and all Priority Habitat types were included as separate habitats. The mean patch size was calculated from the area data as a mean per 1km square.

5.2.5.3 Results

There has been no significant change in habitat diversity between 1984 and 2014.
Although Figure 5.2.5.3.2 does suggest an increasing trend in mean patch size there has been no significant change in mean patch size between 1984 and 2014.

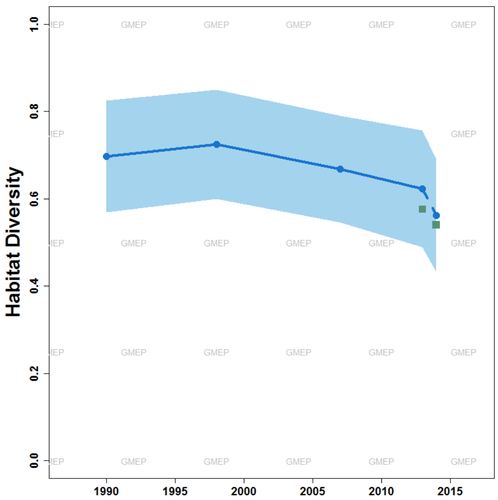


Figure 5.2.5.31: *Trends in habitat diversity (Shannon diversity index) between 1984 and 2014*

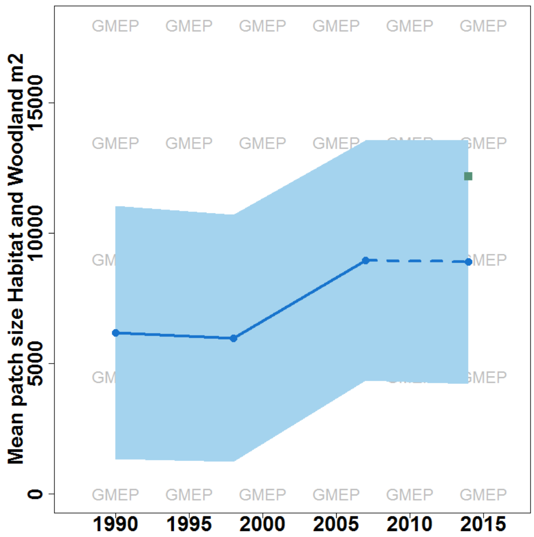


Figure 5.2.5.3.2: *Trends in mean habitat patch size ('habitat' land and woodland) between 1984 and 2014*

Table 5.2.5.3.1: *Mean Habitat Diversity over Time.*

Year	Estimated_Value	Lower_est.	Upper_est.
1990	0.70	0.58	0.82
1998	0.73	0.61	0.84
2007	0.67	0.55	0.78
2013 GMEP	0.62	0.47	0.70
2014 GMEP	0.56	0.43	0.69

There are no significant differences between years

Table 5.2.5.3.2: *Changes in mean patch size over time*

Year	Estimated_Value	Lower_est.	Upper_est.
1984	6190.023	1330.801	11049.24
1990	5983.114	1240.993	10725.23
1998	8960.202	4349.773	13570.63
2007	8913.32	4219.516	13607.12
2013/14 GMEP	6190.023	1330.801	11049.24

There are no significant differences between years

5.3 Glastir impacts on Section 42 bird species

One of the six objectives of Glastir is to "conserve and enhance wildlife and biodiversity", a goal that is inherited from the preceding Tir Gofal (TG) scheme. Quantifying the role of Glastir in conserving and enhancing wildlife and biodiversity requires measuring the impacts of options on Section 42 species. While our starting point is the GMEP survey that began in 2013, our expectations about the impact of Glastir and interpretation of future analyses of ecological change should take into account how previous schemes may already have shaped the baseline that we characterize during the first 4 years of survey. There are three aspects to this;
1) Reviewing evidence of the impacts of previous schemes based on monitoring across Wales;
2) Quantifying the legacy effects of these schemes by answering the question 'can we detect the influence of previous scheme impacts within GMEP survey data?' Answering this question is restricted at this stage to just survey data for years 1 and 2;
3) Investigating whether legacy effects are detectable in other recording schemes.
We present new evidence on all three fronts. Below we briefly review the evidence from previous monitoring of AES impacts on biodiversity in Wales. Then we summarize two new analyses that seek to detect legacy effects of previous Welsh schemes. The first is an analysis of the impacts of Tir Cynnal and Tir Gofal on bird species across the 1km squares visited as part of the Breeding Bird Survey in Wales. The second analysis is a preliminary attempt to detect differences in plant species compositional indicators in year 1 and 2 GMEP vegetation plots between those that were managed under habitat-specific Tir Gofal options versus plots never in agreement land but referable to the same habitat types.

5.3.1 Evidence for previous AES impacts in Wales; a summary of the Tir Cynnal and Tir Gofal monitoring and evaluation programme

The Tir Cynnal and Tir Gofal monitoring and evaluation was split into three components; habitats, species and soil, carbon and water. The results for habitats (Medcalf et al. 2012) and species (McDonald et al. 2012) are relevant to biodiversity and are summarized below.

5.3.1.1 Habitats

- Tir Cynnal habitat monitoring occurred over a three year period, with a baseline established in the first year.
- Remote sensing was used to assess habitat distribution
- Tir Gofal habitats were monitored for 11 years with a baseline survey and two re-surveys after 6-8 and 9-11 years.
- Importantly, success of habitat prescriptions was evaluated against performance indicators which were set for each habitat. These generally looked at vegetation characteristics which were thought to be indicators of habitat condition. This is the most similar approach to that being applied in GMEP. The indicators were then evaluated against a set of conditions to identify whether the habitat had undergone positive ecological change
- Key results for Tir Cynnal:
    - Generally evaluated as successful at habitat protection
    - Habitat loss was greater in farms out of the scheme, indicating the scheme was reducing habitat loss.
- Key results for Tir Gofal:
    - Grassland reversion had generally been successful. Species-rich grassland and grazed coastal grassland had been successfully maintained and enhanced
    - Tir Gofal had been successful in maintaining other habitats included woodland and parkland, blanket bog and marshy grassland
    - Tir Gofal was not successful in enhancing fen and flush habitats
    - Heathland was being maintained where present but heathland reversion was generally not successful.

5.3.1.2 Species

- Monitoring of both Tir Cynnal and Tir Gofal occurred between 2009 and 2012 with most effort was spent on assessing Tir Gofal impacts
- Monitoring focused on specific taxa of plants, fungi, bats, butterflies, birds and mammals chosen based on conservation importance and because their expected responses to AES were known.
- No baseline data were available so comparisons were made with non-AES farms and between fields in option and out of option. Therefore it is not possible to distinguish between TG effects and initial condition
- Overall relatively few taxa showed differences between in and out-of-option land.
- Key findings are summarized below, grouped by target species

Taxon group	**Indicators used**	**Options with evidence of benefit**	**Options with no benefit/other issues**
Bats	Activity	Soprano pipistrelle activity higher with unimproved neutral grass (8B), hedgerow restoration (TG18) and broadleaf woodland stock excluded (1A).	No difference in activity between TG farms and non-AES farms.
Birds	Abundance, territory occupancy, hatching, productivity	Yellowhammer positively linked to Tir Gofal in general. Lapwings positively associated with option 34A (manage Improved Grassland for lapwing). Chough preferentially foraged in fields under TG options in winter	Black grouse lek counts not linked to AES

Arable plants and grassland fungi	Diversity	Increased diversity under 24A (unsprayed fields) and 29 (fallow margins). Fallow margins had a greater diversity of plants providing overwinter seed resources	No effect of TG on crystalworts, hornworts or liverworts No evidence of TG effects on grassland fungi.
Butterflies	Occupancy, abundance, habitat quality	Some evidence of improved habitat quality on TG farms for brown hairstreak and marsh fritillary. Heathland (5 and 6) had higher small pearl-bordered fritillary occupancy and brown hairstreak was more abundant in semi-improved (10) fields cf. improved	No evidence of improvement for three species (small pearl-bordered fritillary, marsh fritillary and brown hairstreak) No changes in abundance for any target species Prescriptions may not be specific or restrictive enough to affect butterflies
Mammals	Population size, abundance, occupancy	Brown hare populations were greater on TG farms	No effect of TG on water voles, occurrence maybe related to habitat characteristics not affected by TG or predation

Table 5.3.1.2.1 *Summary of evidence for the effects of Tir Gofal (TG) scheme options on species groups (from McDonald et al. 2012).*

5.3.2 Legacy effects of agri-environment schemes on birds in Wales

5.3.2.1 Introduction

Birds are a key component of biodiversity, both for their own, intrinsic, conservation interest and as indicators of the broader health of the environment, as is reflected in the policy targets that involve bird populations. Agri-environment schemes (AES), including Glastir and its predecessors, typically include multiple management options aimed wholly or partly at benefiting birds, including conservation-priority species. It is critical to monitor AES to ensure that public funds are being spent effectively and the successes and failures of legacy schemes are important in that they inform the ongoing development of ongoing and future management, such as is found under Glastir.
Previous studies have successfully tested the impacts of English AES on birds using national-scale survey data (e.g. Baker et al. 2012), so the same approach has been applied to Wales, measuring the effects of all management options that might benefit birds on all relevant individual species for which sufficient data were available. A full description of the methods and results of this part of the GMEP project is available in Appendix 5.1, but the key points are summarized here.

5.3.2.2 Methods

The BBS is a volunteer survey conducted annually in a random sample of 1km squares across Wales using standardized methods. Counts of individual species from each square were analysed using an established method to estimate population growth rates and the effects thereon of quantities of AES options in the survey squares each year. The AES data were option areas and lengths, combined with maps of the boundaries of individual Tir Gofal (TG) and Tir Cynnal (TC) agreements. Rather than an in-scheme/out-scheme comparison, the analyses compared bird population changes between squares with different quantities of management.

Following studies done on Environmental Stewardship in England (Baker et al. 2012), TC and TG effects were assessed for individual species-option combinations, using data from two years before each scheme began to the present day. Population growth rates (changes from year to year) were analysed to reveal variation with different quantities of relevant AES management in and around BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1km squares. Analyses used generalized linear models and controlled for potentially confounded habitat factors. Data on management under TC (2005-2013) were not available, so proxies had to be used (amounts of different land cover types overlapping TC agreement). TG management (1999-2013) was tested considering groups of options providing Grassland habitat, Arable winter seed, Arable invertebrates, Woodland creation & stock exclusion, Heathland, Scrub management and hedgerow management.

5.3.2.3 Results

The analyses of proxies for TC management failed to produce clear results, but analyses of TG data were more successful. Positive associations with TG options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management (Figure 5.3.2.3.1).

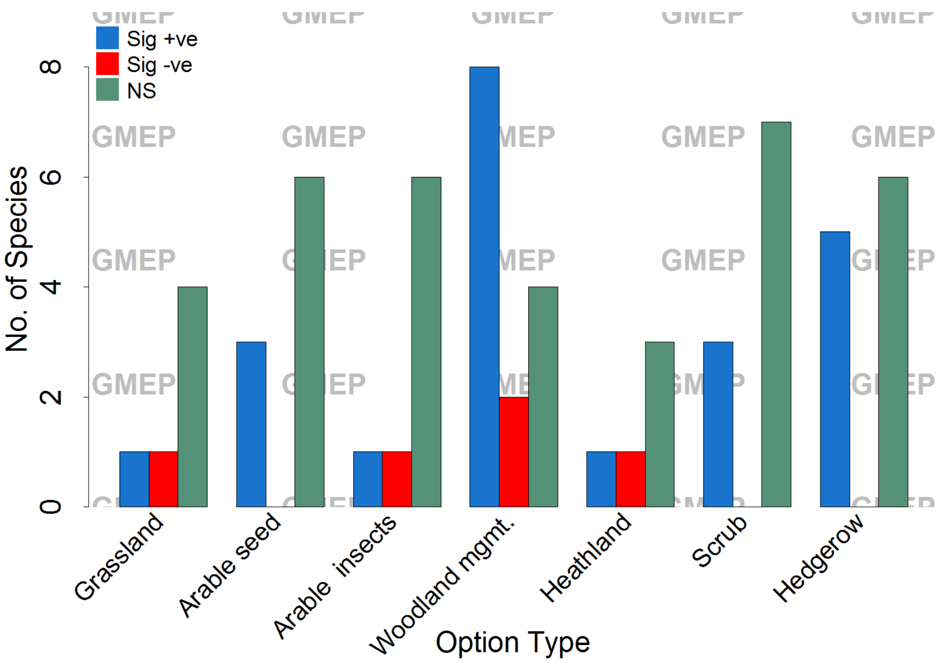


Figure 5.3.2.3.1 *Numbers of species with positive, negative and non-significant associations with TG option groups.*

Table 5.3.2.3.1 shows the results in more detail, by species. The balance of positive versus negative patterns, given that 5% of the results would be expected to be "significant" by chance and that the power to detect effects of many option types is likely to have been low because sample sizes of both AES management and areas of some land-uses (e.g. arable) were small, is informative. The evidence therefore supports broadly positive effects of TG, notably involving management of woodland, scrub, hedgerows and habitats providing winter seed in arable farmland.

Option type	Species tested	Significant effects	
		Positive	Negative
Grassland management	CU, L, LI, MP, S, SG	LI	S
Arable winter seed	CH, D, GR, HS, LI, RB, SD, S, Y	Y, GR, SD	
Arable invertebrates	CH, D, HS, RB, S, SG, WH, Y	WH	HS
Woodland creation & stock exclusion	B, BC, BT, CC, CH, GT, PF, R, RT, SF, ST, WO, WR, WW	B, BC, CC, R, SF, ST, WO, WR	BT, R
Heathland	CU, MP, S, SC, L	S	L
Scrub management	BC, CC, D, LI, R, SC, WH, WR, WW, Y	CC, WR, WW	
Hedgerow management	BF, CH, D, GO, GR, HS, LI, RB, SD, ST, WH	D, ST, LI, HS, GR	

Table 5.3.2.3.1 *Details of bird species for which the effects of each TG option type were tested and for which the results were significantly positive or negative.*

5.3.2.4 Discussion

The benefits of TG for birds identified here probably reflect effects on resources used by birds, including physical habitat structure and other biodiversity. There are, therefore, likely to be co-benefits to those other elements of the environment. However, many co-benefits are likely to involve resource quantities (e.g. prey biomass), rather than, necessarily, the occurrence of priority species. Note also that birds will respond to the alleviation of their limiting factors, so bird changes will reflect those in other groups (and vice versa) only if the latter are directly or indirectly associated with those limiting factors.

Weaknesses with this study include the inability to assess rarer species and options because of small sample sizes, so the results may not reflect high conservation priorities. The balance of effects across species for several option types suggests that TG has been broadly beneficial; for other options, either small sample size effects (e.g. heathland) or failure to address limiting factors (e.g. arable invertebrate options) probably underlie the limited effects.

The failure of the study to provide convincing tests of TC management effects was disappointing, but probably reflects the lack of good data for the types and quantities of management undertaken. If data on this scheme existed, they appear now to have been lost. However, should such data be found (i.e. spatially explicit information on areas of types of “wildlife habitat” created or protected under TC and the natures of each of those habitat patches), it would be valuable (and straightforward) to repeat the analyses described above.

BBS code	**English name**	**Scientific name**	**BBS code**	**English name**	**Scientific name**
B.	Blackbird	*Turdus merula*	P.	Grey Partridge	*Perdix perdix*
BC	Blackcap	*Sylvia atricapilla*	PF	Pied Flycatcher	*Ficedula hypoleuca*
BO	Barn Owl	*Tyto alba*	R.	Robin	*Erithacus rubecula*
BK	Black Grouse	*Tetrao tetrix*	RB	Reed Bunting	*Emberiza schoeniclus*
BT	Blue Tit	*Cyanistes caeruleus*	RG	Red Grouse	*Lagopus lagopus*
BZ	Buzzard	*Buteo buteo*	RK	Redshank	*Tringa totanus*
CB	Corn Bunting	*Emberiza calandra*	RT	Redstart	Phoenicurus phoenicurus
CC	Chiffchaff	*Phylloscopus collybita*	RZ	Ring Ouzel	*Turdus torquatus*

CF	Chough	*Pyrrhocorax Pyrrhocorax*	S.	Skylark	*Alauda arvensis*
CH	Chaffinch	*Fringilla coelebs*	SC	Stonechat	Saxicola rubicola
CU	Curlew	*Numenius arquata*	SD	Stock Dove	*Columba oenas*
D.	Dunnock	*Prunella modularis*	SE	Short-eared Owl	*Asio flammeus*
DN	Dunlin	*Calidris alpina*	SF	Spotted Flycatcher	*Muscicapa striata*
DW	Dartford Warbler	*Sylvia undata*	SG	Starling	*Sturnus vulgaris*
GO	Goldfinch	*Carduelis carduelis*	SH	Sparrowhawk	*Accipiter nisus*
GR	Greenfinch	*Chloris chloris*	SN	Snipe	*Gallinago europeo*
GL	Grey Wagtail	*Motacilla cinerea*	ST	Song Thrush	*Turdus philomelos*
GP	Golden Plover	*Pluvialis apricaria*	TS	Tree Sparrow	*Passer montanus*
GS	Great-Spotted Woodpecker	*Dendrocopos major*	W.	Wheatear	*Oenanthe oenanthe*
HH	Hen Harrier	*Circus cyaneus*	WC	Whinchat	*Saxicola rubetra*
HS	House Sparrow	*Passer domesticus*	WH	Whitethroat	*Sylvia communis*
K.	Kestrel	*Falco tinnunculus*	WO	Wood Warbler	*Phylloscopus sibilatrix*
KF	Kingfisher	*Alcedo atthis*	WP	Woodpigeon	*Columba palumbus*
L.	Lapwing	*Vanellus vanellus*	WR	Wren	*Troglodytes troglodytes*
LI	Linnet	*Carduelis cannabina*	WT	Willow Tit	*Poecile montana*
ML	Merlin	*Falco columbarius*	WW	Willow Warbler	*Phylloscopus trochilus*
MP	Meadow Pipit	*Anthus pratensis*	Y.	Yellowhammer	*Emberiza citrinella*
MR	Marsh Harrier	*Circus aeruginosus*			
MT	Marsh Tit	*Poecile palustris*			
OC	Oystercatcher	*Haematopus ostralegus*			

Table 5.3.2.4.1 *Key to BBS species codes: English and scientific names.*

5.3.3 Preliminary analysis of GMEP vegetation plots: can we detect a legacy effect of Tir Gofal on baseline habitat condition?

5.3.3.1 Introduction

A complete account of this analysis is in Appendix 5.2. To investigate and quantify legacy effects we analysed differences in vegetation between plots that were on land that had previously been under the Tir Gofal scheme and plots that had never been under Tir Gofal. Tir Gofal was a higher level agri-environment scheme with a focus on enhancing existing habitats. The scheme ran from 1999 to 2012 and had components for both maintenance of existing habitats ("maintain" options) and for conversion or extensification of improved land ("enhance" options) (Medcalf *et al*. 2012). The evidence for a legacy effect on current performance indicators as a result of previous Tir Gofal prescriptions was evaluated from vegetation plot data from the Year 1 and 2 GMEP surveys. Increased statistical power will arise when Years 3 and 4 of the first GMEP roll are included and so the results of this analysis should be considered preliminary.

5.3.3.2 Methods

Coincidence between GMEP survey plots and land previously under Tir Gofal was assessed using spatial data provided by the Welsh Government for the extent of Tir Gofal options. This information was resolved at the parcel and linear feature level so that coincidence between plots and locations could be established with a high level of precision. Initial investigation showed that 1,043 out of 4,135 (25%) of year 1 and 2 GMEP plots were in land that had previously been under a Tir Gofal option. Of these, most had been under options to maintain unenclosed grassland, wet grasslands, raised and blanket bog. The nine options present in more than 40 GMEP 1km survey squares were investigated further.

For each option, or combination of options, differences in a number of habitat condition indicators were evaluated between plots on land that had been under the relevant Tir Gofal option and plots on land where the option had never been applied. Each Tir Gofal option only applies to a certain number of habitats, for example marshy grassland maintenance option (11) only applies to habitat already containing marshy grassland (Broad Habitat classification fen, marsh and swamp). Therefore, when comparing plots in land that had been in Tir Gofal to land never in Tir Gofal, it is important to only use comparable habitat types. For example, to look at the effect of option 11 on maintaining marshy grassland only plots in fen, marsh and swamp that had never been under Tir Gofal option 11 would be used as the counterfactual. The same process was used to determine counterfactual datasets for other options: the habitat and landscape location (area of habitat or linear feature) impacted by the option were used as criteria to select equivalent plots sampling the same kind of habitat and feature but never subject to Tir Gofal options according to the spatial data layers provided.

The Tir Gofal scheme ran between 1999 and 2012, with new entrants only accepted until 2009. Plots that entered in the first half of the scheme (1999 to 2006) had therefore been under options for longer, and might be expected to show more change, than plots which only entered in the latter half of the scheme (2006-2012). To account for this, differences were investigated between three groups of plots: Never in Tir Gofal, Entered Tir Gofal post-2006 and Entered Tir Gofal pre-2006. Differences in performance indicators between these groups were assessed using linear mixed models where Tir Gofal group (Never in Tir Gofal, entered post-2006, entered pre-2006) was a fixed effect and survey square was a random effect. Where the indicator was a count variable (e.g. total richness) generalised linear mixed models with a Poisson distribution were used. The expectation was for greater differences to be present between counterfactual plots and Tir Gofal plots that had entered earlier rather than later. Without more intensive time series monitoring it is not possible to say however whether such effects are evidence of a positive change over time or better targeting of habitat that entered the scheme earlier.

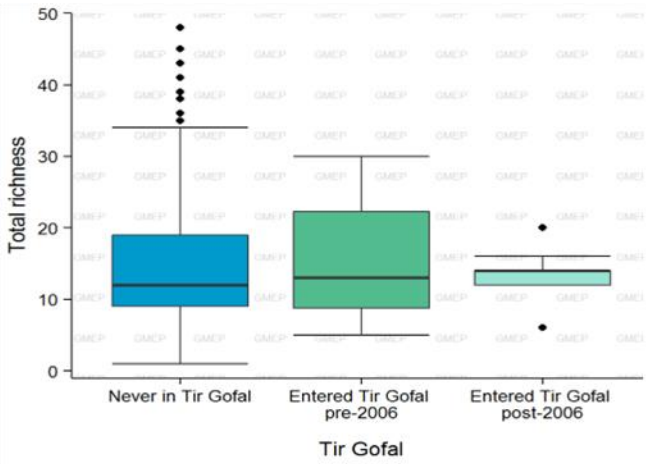
5.3.3.3 Results

For the vast majority of indicators (42 out of 45) there was no evidence that plots occurring on land previously subjected to Tir Gofal prescriptions had different values to plots on land which had never been under Tir Gofal (see Appendix 5.2). In three cases a significant difference was observed between the Tir Gofal groups (Table 5.3.3.3.1). For one of these cases, a difference in bracken cover under options 7A and 7B, there was very little data available and therefore the confidence in this result is low. For the other cases where a significant difference was seen, one (total species richness under option 1A) only showed significant differences between the two time periods of Tir Gofal application and no difference from land where Tir Gofal was never applied. This is due to the larger variation in richness in land where Tir Gofal never occurred, even after filtering for habitat and plot type (Figure 5.3.3.3.1 a). For option 1A (Ungrazed broadleaved woodland) species richness was higher in plots that had entered Tir Gofal before 2006. In one case there were significant differences between plots in land that had entered Tir Gofal before 2006 and plots that had never been under Tir Gofal. Plots that had entered option 5 (maintain upland heath) before 2006 had lower grass:forb ratio in 2013/14 than plots never in Tir Gofal (Figure 5.3.3.3.1 b).

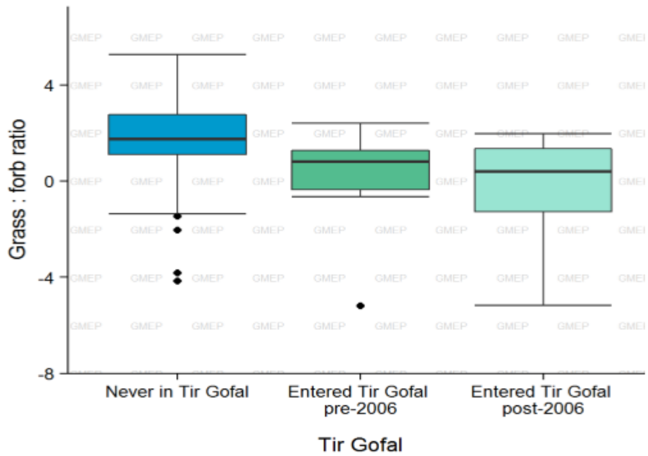
Option	Indicator	Comparison	Estimated difference	P value
1A	Total species richness	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.39215	0.0272
5	Grass:forb ratio	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-1.82549	0.0077
7A/7B	Bracken cover	Entered Tir Gofal pre-2006 - Never in Tir Gofal	1.544481	0.0425†

† There was very little data to support this result so it is not discussed further.

Table 5.3.3.3.1 Tests *of the difference between each indicator variable in groups of plots that came into Tir Gofal earlier (pre-2006) or later (post-2006) versus counterfactual plots never in Tir Gofal but in equivalent habitat type.*



Option 1a



Option 5

Figure 5.3.3.3.1 *Significant differences in indicator variables between plots in land that entered Tir Gofal in two different time periods (before or after 2006) and plots that had never been in Tir Gofal. Corresponding significance tests are presented in Table 5.3.3.3.1 and total numbers of plots in each analysis in Table 5.3.3.3.2*

Option code	Number of plots in option	Number of plots in counterfactual
11	28	183
18	33	534
1A	21	221
40A	28	170
5	19	217
7A/7B	55	143
7B/12	38	156

Table 5.3.3.3.2 *Number of GMEP vegetation plots from the year 1 and 2 surveys that coincided with Tir Gofal options and counterfactual plots never in Tir Gofal.*

5.3.3.3.4 Discussion

In interpreting the impacts of legacy schemes on the baseline conditions observed in GMEP 1km survey squares it is important to note that the GMEP survey was not designed to evaluate legacy scheme effects and therefore our results may differ from the monitoring conducted by past agri-environment schemes. In particular, we only attempted to detect the signal of Tir Gofal in the first two years of GMEP survey data. Our sample sizes were therefore small compared to previous more intensive evaluation of Tir Gofal in which a wider range of scheme effects were detected (Medcalf et al. 2012). In addition, we have only evaluated one past scheme and our sample size is small for most Tir Gofal options, therefore caution should be used in evaluating the results. However, despite these concerns, it is important to consider the potential effects of previous agri-environment schemes on the baseline conditions recorded by the GMEP survey. If there was evidence that Tir Gofal was responsible for differences in the baseline levels of indicators recorded then it would be important to account for this effect in future analyses of Glastir impact to avoid incorrectly attributing change. Our analysis suggests that, within the first and second years of GMEP recording, there was little evidence that Tir Gofal had led to lasting changes in the indicators measured. Only three out of 45 option-indicator combinations showed any influence of Tir Gofal occurrence or duration and only two of these showed differences between plots that had been in Tir Gofal and those that had not which were well supported by the data (i.e. excluding the difference in bracken cover in option 7A/7B).

Grass:forb ratio was found to be significantly lower in upland heathlands that had been maintained under Tir Gofal option 5 than in heathlands that had never been in Tir Gofal. Low grass:forb ratio is considered to be indicative of better ecological condition, as a high proportion of graminoids is often a result of excessive nutrient enrichment or over-grazing. Unfortunately, grass:forb ratio was not used as a performance indicator in the Tir Gofal monitoring surveys and therefore a direct comparison with this evaluation cannot be made. However, the Tir Gofal monitoring report (Medcalf et al. 2012) did conclude that heathland sites were generally being well protected by Tir Gofal, with 45% of sites improving in ecological condition. The report also concluded that changes in condition in heathland were likely to occur in the long term as most changes were observed in only the second of two resurveys, eight years after the start of Tir Gofal. Our results support this conclusion, with only plots that entered Tir Gofal before 2006 having a significantly lower grass:forb ratio.

Overall our results suggest that, in most cases, there is no evidence that Tir Gofal has led to long term changes in the indicators assessed which would need to be accounted for in any analysis of change due to Glastir options. However, this result does not necessarily mean that the Tir Gofal scheme did not have any long term impacts. At this stage it is more likely to reflect our inability to detect effects given the small sample size available. Hence, based on just years 1 and 2, we do not have enough coincidence between GMEP plots and past Tir Gofal option land to adequately test whether the positive changes seen in grasslands, woodland and blanket bog in Medcalf et al. (2012) are reflected in the GMEP sample. These analyses will have greater power when all four years of data have been accumulated. At that point we will re-run these analyses in preparation for analysing change in time once the second roll starts to yield repeat data.

5.3.4 Application of indicators of Glastir impacts on Section 42 species; characterizing the GMEP baseline

5.3.4.1 Introduction

By definition Section 42 species are rare and many of these taxa are not directly monitored in GMEP. It therefore makes sense to separate the investigation of Glastir impacts on these species into two questions; 1) Does the target species coincide with GMEP 1km survey squares in which linked options are present? 2) By looking at all land under these option bundles even in GMEP 1km survey squares where the target species is absent, is their evidence that options are driving the changes in ecological conditions that would be expected to favour the species if it were present? To answer the first question we have assembled species distribution data at 1km square resolution and overlaid this with GMEP 1km survey squares (see section 5.2.1). To answer the second we have developed proxy indicator variables derived from the GMEP field surveys. Because ecological recording within each GMEP 1km survey square is done at the level of habitats and landscape features, these indicators can be precisely derived for those areas and features targeted by specific options within each GMEP 1km survey square. This greatly increases the sensitivity of analyses but accumulating enough data to adequately test bundles of options relies on enough uptake of each option across GMEP 1km survey squares.

5.3.4.2 Methods

In order to construct proxy indicators for each Section 42 species we start by reviewing the extent to which the likely ecological impact of each Glastir option could be captured by measured changes in attributes recorded in the GMEP field surveys (see Appendix 5.10 and 5.15). In some instance instances these attributes may include direct counts of the target species (see 5.2.4) but in most these attributes centre on measurements of change in extent or condition of habitats and features. The assumption is that the option if implemented correctly will result in enhancement or maintenance of the species population. While we do not question the link between option and species performance it is possible that other factors not altered by Glastir options could result in lack of expected ecological change. Examples include predation of ground-nesting birds where such predation is not directly controlled by Glastir, long term weather effects on animals and plants, species pool depletion, residual fertility and ongoing application of fertilisers, all of which are potential obstacles to the reassembly of plant and invertebrate communities. To identify the likely importance of these additional factors on species performance and to support the prescribed link between each option and ecological impact a literature review was carried out. This focused on each Section 42 species. The reviews are summarized in Appendix 5.15. These also specify the indicator variables drawn from the field survey that will be used to measure the ecological changes expected to result from each option.

5.3.4.3 Results and Discussion

A subset of Section 42 species are associated with their own bundles of Glastir options (Table 5.3.4.3.1). To illustrate the application of the approach, indicators were assembled and applied to baseline data from GMEP year 1 and 2 survey squares (Table 5.3.4.3.2). Species were selected representing Section 42 invertebrates, mammals, birds and plants focusing on those that are more widely distributed in Wales. These baseline assessments characterize the starting point of the rolling program illustrating initial differences between habitats and features in and out of specific options. Whether any significant differences across the baseline are attributable to legacy effects of previous schemes is critical to assess and will be ultimately tested via the inclusion of explanatory variables that classify land in terms of exposure to previous scheme options. Preliminary analyses of years 1 and 2 are presented in 5.3.2 and Appendix 5.2. The analysis will eventually be repeated with the inclusion of years 3 and 4 increasing statistical power.

Target objective	Number of associated Glastir options
Arable Plants	9
Arctic Alpine Plants	7
Barbastelle Bat	57
Bechstein's Bat	53
Black Grouse	11
Brown-Banded Carder Bee	65
Chough	20
Corn Bunting	22
Curlew	17
Dormouse	20
Pearl Mussel	46
Golden Plover	13
Grassland Fungi	32
Great Crested Newt	94
Greater Horseshoe Bat	93
White Fronted Goose	11
Heathland Plants	22
High Brown Fritillary	22
Lapwing	14
Lesser Horseshoe Bat	91
Lichens	40
Marsh Fritillary	27
Pearl Bordered Fritillary	19
Rare Plants	52
Red Grouse	16
Red Squirrel	19
Ring Ouzel	12
Shrill Carder Bee	65
Turtle Dove	24
Twite	38
Water Vole	64
Welsh Clearwing	16

Table 5.3.4.3.1 *Count of Glastir management options linked to each species. Options counted are those "more likely to deliver in a wider range of situations" according to the scheme. Capital works are excluded. Species in red have been used as initial examples of the application of proxy indicator variables. For full details and results see Appendix 5.10 and 5.15. Gwyniad is excluded since it only occurs in Bala Lake.*

Target species	Number of GMEP 1km survey squares with recent species records / number with Glastir species options	Expected indicator variable status in-option versus out-of-option	Consistent with expectation? [3]
Dormouse	0/27	Understorey cover-weighted canopy height higher (broadleaf wood)	NS (2)
		Bramble cover higher (broadleaf wood)	**Yes** (1), NS (1)
		Honeysuckle cover higher (broadleaf wood)	Too few data
		Total tree and shrub richness higher (hedgerows)	NS (2)
Rare Arable Plants	0/16	Annual forb richness higher	No (1) [1]
		Fertility score lower	NS (1)
		Cover of arable crop higher	NS (1) [1]
Curlew	2/29	Vegetation height heterogeneity higher	NS (4)
		Wetness score [2]	NS (4)
		Rush (*Juncus* spp.) cover [2]	NS (4)
		Vegetation height [2]	Not tested
Lapwing	2/27	Vegetation height heterogeneity higher	NS (4)
		Wetness score [2]	NS (4)
		Rush (*Juncus* spp.) cover [2]	NS (4)
		Vegetation height [2]	Not tested
Lesser Horseshoe Bat	5/81	Fertility score lower	**Yes** (1), NS (5)
		Plant species richness higher	NS (6)
		Wetness score higher	NS (6)
Marsh Fritillary Butterfly	6/69	Foodplant cover higher	Too few data
		Grass:forb ratio lower	**Yes** (1), NS(9), No (0)
		Wetness score higher	**Yes** (1), NS(9), No (0)

Table 5.3.4.3.2 *Summary of tests of the difference in indicator values between subsets of plots in or out of Glastir options where these options are associated with enhancement or maintenance of conditions for Section 42 species. Note that these results are preliminary because they include data from years 1 and 2 only. See Appendix 5.10 for full details of the derivation and testing of indicators for each species.*

[1] While arable forb richness would be expected to be higher as a result of the extensifying options included for Rare Arable Plants, the in-option land was found to be still in Improved Grassland prior to ploughing. It is not surprising that arable forb richness was higher in the counterfactual dataset because this comprised out-of-option plots in cultivation.

[2] Whether the values of these indicators should be higher or lower in-option versus out-of-option depends on the values of the observed data because the desired status is not too high nor too low. In these instances, movement toward, or no movement away from, the desired range of values over time yields the expected direction of change over time.

[3] Numbers in brackets indicate the number of data subsets analysed. For example so as to contrast like-with-like, where possible separate analyses were carried out within different Broad Habitats and by plots sampling linear features or areas of habitat away from linear features (see Appendix 5.10).

5.3.4.4 Application and further development of Section 42 species indicators

The large number of options associated with each Section 42 species yields a large number of possible indicator values that can be analysed (see Appendix 5.15). While this level of detail will hopefully be of interest to species experts, ways are needed of summarizing these many results into an aggregated indicator of performance. An option would be to simply count up the numbers of consistent or inconsistent and significant plus non-significant differences in indicator variables across all indicators and species. The danger in so doing is that species-specific details are lost. The advantage is that multiple trajectories of change over many habitats are distilled into a simple, albeit simplistic, aggregate indicator (Smart et al. 2012). Applying the approach to the baseline assessments we can summarise across all indicators for the six target objectives as follows:

Number of Non-significant tests	54
Number of significant differences consistent with expected option impact	4
Number of significant differences NOT consistent with expected option impact	1

This analysis provides the baseline against which future changes will be assessed. Significant differences identify a difference in the baseline condition not actual responses to options. Once repeat data is available the test will be whether the rate of change in time differs between in and out of option habitats and landscape features. We would envisage that a similar summation of trends should be possible to derive.

5.3.4.5 Options and areas of further work

The analyses reported above are preliminary in that they are only based on year 1 and 2 data and only for an example of set of Section 42 species. However we have carried out a detailed assessment of the relationships between options linked to all the species included in Glastir and available field survey data. This has enabled us to identify ecological indicator variables for all options and species (Appendix 5.15). These are numerous and so prior to spending effort applying all these to all species we plan to engage with species experts to determine their views about the ecological importance and sensitivity of the suggested indicators. An outcome of this consultation process could be an agreed set of weightings such that some indicators contribute more than others. This could reflect experts' views about the likely ecological importance of different options independent of their actual area of uptake.

Additional activities could include deriving reference values for indicators associated with habitats, features and landscapes considered optimal on the basis that they are known support healthy, stable populations of Section 42 species. This not likely to be a straightforward process. For example the largest extant populations may well be associated with highly atypical locations where our generalised suite of indicators prove less relevant at highlighting those positive factors present and where equivalent conditions may constitute unrealistic goals for the wider countryside represented in GMEP 1km survey squares.

The most important next step is to establish an increasingly automated workflow where a larger range of indicators for more species and more options are assembled and tested alongside a counterfactual dataset. The variable that exerts the greatest influence on the feasibility of such testing is option uptake across the GMEP sample. By the end of year 4 we will be able to identify a stable pattern of option uptake across species and all GMEP 1km survey squares. These levels of uptake will then determine how many indicator+option+habitat/feature combinations can be meaningfully analysed.

5.3.5 Evidence for associations between breeding birds and Glastir management options

5.3.5.1 Introduction

It is critical to monitor the multiple Glastir options that are aimed wholly or partly at benefiting birds, including conservation-priority species, to ensure that public funds are being spent as effectively as possible. For birds, ultimately, this means measuring responses of population trends to Glastir management (as tested for legacy schemes: Section 5.3.1, see also Baker et al. 2012), but such responses inevitably take several years to occur and to be detectable. In the short-term, tests of the mechanisms through which Glastir is expected to act can be conducted through analyses of bird field data collected under GMEP: habitat managed under Glastir would be expected to be selected by priority species relative to comparable non-Glastir habitat.

5.3.5.2 Methods

The bird surveys in GMEP are designed to provide accurate data on abundance within GMEP 1km survey squares (subject to less stochasticity than the transect counts from national volunteer monitoring under the BTO/JNCC/RSPB Breeding Bird Survey) and also precise bird locations, permitting bird locations to be investigated in respect of small-scale habitat features.
The locations of birds recorded in GMEP 1km survey squares in 2013 and 2014 were mapped digitally using ArcGIS 10. These spatially referenced bird data (omitting flying birds) were then overlain onto maps of habitat types identified from the field survey (Chapter 1) and of Glastir option (Table 5.3.5.2.1) locations. It could therefore be identified whether birds appeared to be selecting Glastir-managed areas of each habitat types. By chance, birds would be expected to be distributed between Glastir and non-Glastir habitat in proportion to their availability, so the difference from this expectation was used as a test of baseline differences between land coming into the scheme and that remaining outside. The habitats considered as the background or baseline for the bird-relevant Glastir options are listed in Table 5.3.5.2.1. Background habitat availability was considered in terms of areas, except for hedgerow management, for which the underlying habitat was considered to be the length of the boundaries between agricultural fields. Birds were considered to be associated with boundaries if they were mapped as being present within 10 metres of an agricultural field boundary.

Birds are highly mobile and the nature of survey protocols means that they are more likely to be recorded during some activities (e.g. singing or flying) than others (e.g. incubating or feeding). It is possible, therefore, that the precise locations of birds in respect of habitat features may be misleading about the importance of local habitat features. For example, a bird may be recorded singing in a given tree because the location had become good breeding habitat after the addition of Glastir management 50m away. Therefore, in addition to testing whether precise bird locations were associated with Glastir management, locations were compared at the GMEP 1km survey square level, asking whether GMEP 1km survey squares with Glastir management were more likely to contain the target species than other GMEP 1km survey squares with similar land-use (Table 5.3.5.2.2). These analyses also included records of birds in flight, which were excluded from the smaller-scale association tests, because association with the habitat at a larger scale can reasonably be assumed for most species in this context.

To date, all analyses have focused on total counts summed across all target species, weighted by the number of visits to each GMEP 1km survey square listed for each option type, and comparing the distribution of these counts between Glastir and non-Glastir areas, either within or between GMEP

1km survey squares. Future analyses will consider species-specific patterns, once more years of data are available.

Option type	**Option(s) included**
Heathland	Management of Coastal and Lowland Heath; Lowland Wet Heath
Hedgerow	Enhanced Hedgerow Management on Both Sides; Hedgerow management - both sides
Marshland	Management of Lowland Marshy Grassland; Management of Lowland Marshy Grassland with Mixed Grazing; Lowland Marshy Grassland; Lowland Bog and Other Acid Mires
Saltmarsh	Management of Grazed Saltmarsh; Management of Grazed Saltmarsh with Mixed Grazing
Winter food‡	Retain Winter Stubbles; Unsprayed Spring Sown Cereals Retaining Winter Stubbles; Unharvested Cereal Headland
Summer food	Fallow Crop Margin; Unsprayed Spring Sown Cereals and/or Pulses; Establish a Wildlife Cover Crop on Improved Land; Unfertilised and Unsprayed Cereal Headland
Woodland	Woodland: Stock Exclusion; Trees and Scrub: Establishment By Planting; Trees and Scrub: Establishment By Natural Regeneration; Scrub: Stock Exclusion; Wood Pasture
Reedbed	Reedbed: Stock Exclusion; Reedbed: Creation
Chough	Grassland Management for Chough (Feeding)
Corn Bunting	Unsprayed Autumn Sown Cereal Crop for Corn Bunting (Nesting and Feeding); Unsprayed Spring Sown Barley Crop for Corn Bunting (Nesting and Feeding)
Curlew	Grassland Management for Curlew (Nesting and Chick Feeding) ; Grassland Management for Curlew (Adult Feeding); Haymeadow Management for Curlew (Nesting)
Golden Plover	Grassland Management For Golden Plover (Feeding)
Lapwing	Grassland Management for Lapwing (Nesting and Feeding); Unsprayed Spring Sown Cereals; Oilseed Rape; Linseed or Mustard Crop For Lapwing (Nesting); Uncropped Fallow Plot For Lapwing (Nesting)
Ring Ouzel	Grassland Management for Ring Ouzel (Feeding)

Table 5.3.5.2.*1 List of Glastir option groups and single options combined in each option group.*

Option type	Species tested	Habitat(s) used for comparison with Glastir
Heathland	Skylark, Tree Pipit, Linnet, Cuckoo, Kestrel, Curlew, Meadow Pipit, Stonechat, Green Woodpecker	Dwarf Shrub Heath
Hedgerow	Linnet, Yellowhammer, House Sparrow, Tree Sparrow, Grey Partridge, Dunnock, Bullfinch, Turtle Dove, Song Thrush	Boundaries between fields identified as Arable and Horticulture, Lowland Calcareous Grassland, Improved Grassland or Neutral Grassland.
Marshland	Reed Bunting, Kestrel, Barn Owl, Curlew, Lapwing, Redshank, Snipe	Blanket Bog, Purple Moor-grass and Rush Pasture, Lowland Raised Bog, Lowland Acid Grassland, Bog
Saltmarsh	Skylark, Twite, Bar-tailed Godwit, Curlew	Coastal Saltmarsh
Winter food‡	Skylark, Linnet, Corn Bunting, Yellowhammer, Reed bunting, Kestrel, Barn Owl, House Sparrow, Tree Sparrow, Grey Partridge, Dunnock, Bullfinch, Starling, Meadow Pipit, Chaffinch	Arable and Horticulture
Summer food	Skylark, Corn Bunting, Yellowhammer, Reed Bunting, Kestrel, Barn Owl, House Sparrow, Tree Sparrow, Grey Partridge, Dunnock, Bullfinch, Turtle Dove, Starling, Song Thrush, Lapwing, Chaffinch	Arable and Horticulture
Woodland	Tree Pipit, Linnet, Yellowhammer, Pied Flycatcher, Spotted Flycatcher, Willow Tit, Marsh Tit, Wood Warbler, Dunnock ,Bullfinch, Song Thrush, Stonechat, Blackcap, Chiffchaff, Redstart, Sparrowhawk, Great Spotted Woodpecker, Whitethroat	Broadleaved Mixed and Yew Woodland, Lowland Mixed Deciduous, Upland Mixed Ashwood, Upland Oakwood
Reedbed	Bittern, Cuckoo, Reed Bunting, Marsh Harrier, Reed Warbler, Sedge Warbler, Swallow	Reedbed
Chough	Chough	Calcareous Grassland, Neutral Grassland, Maritime Cliffs and Slopes
Corn Bunting	Corn Bunting	Arable and Horticulture
Curlew	Curlew	Lowland Hay Meadow, Acid Grassland, Lowland Acid Grassland
Golden Plover	Golden Plover	Lowland Calcareous Grassland, Calcareous Grassland, Upland Calcareous Grassland
Lapwing	Lapwing	Lowland Hay Meadow, Acid Grassland, Lowland Acid Grassland, Arable and Horticulture
Ring Ouzel	Ring Ouzel	Upland Calcareous Grassland, Neutral Grassland

Table 5.3.5.2.2 *Species tested and land-use associated with each option group used to compare association between species and Glastir options.*
‡ Tested only at the GMEP 1km survey square level as winter food could not be directly related to abundance of breeding birds at patch level.

5.3.5.3 Results

A summary of the area of each Glastir option type found in the GMEP 1km survey squares 2013/14 is presented in Table 5.3.5.3.1. Only five options were present within GMEP 1km survey squares: Hedgerow, Marshland, Winter Food, Summer Food and Woodland, although the area of woodland management was less than 2ha. The most widespread management was in the marshland category, with more than 100ha included in GMEP 1km survey squares. Only four of the 14 option types considered were present within GMEP 1km survey squares considered in 2013 and 2014: two of them farmland types, as well as marshland and woodland. None of the species-specific option types was found in GMEP 1km survey squares. Within GMEP 1km survey squares where they were present, option coverage was generally low, except for marshland management, which covered up to around half of a 1km square (Table 5.3.5.3.2).

Management option group	Total option area (ha) (length (m) for hedgerow)	Sum of area of suitable habitat in Glastir square outside relevant option (ha) (length (m) for hedgerow)	Sum of area of suitable habitat across all GMEP 1km survey squares with no relevant option (ha) (length (m) for hedgerow)	Total habitat area (ha) (length (m) for hedgerow)
Heathland	0	0	525.18	525.18
Hedgerow	3,946.94	46,391.41	490,126.90	1,752,976.41
Marshland	144.11	94.15	1041.71	1,279.97
Saltmarsh	0	0	1.90	1,082.44
Winter food	NA	NA	460.05	479.78
Summer food	6.79	12.94	460.05	479.78
Woodland	1.87	0.59	772.56	775.02
Reedbed	0	0	14.27	14.27
Chough option	0	0	2,397.8	2,397.8
Corn Bunting option	0	0	479.78	479.78
Curlew option	0	0	1,293.48	1,293.48
Golden Plover option	0	0	8.88	8.88
Lapwing option	0	0	1,773.27	1,773.27
Ring Ouzel option	0	0	2,388.06	2,388.06

Table 5.3.5.3.1 *Habitat and option areas. Winter Food was tested* only at GMEP 1km survey square *level as it could not be directly related to abundance of breeding birds at patch level.*

Option group	Number of GMEP 1km survey squares with non-zero area	Mean area of relevant option per GMEP 1km survey square (ha) (length (m) for hedgerow)	Min area (ha) (length (m) for hedgerow)	Max area (ha) (length (m) for hedgerow)	LCI (ha) (length (m) for hedgerow)	UCI (ha) (length (m) for hedgerow)	Sum of total option area (ha) (length (m) for hedgerow)
Hedgerow	8	493.36	58.61	1758.62	29.37	957.35	3946.94
Marshland	18	8	0.21	52.95	1.65	14.36	144.11
Summer food	6	1.13	0.003	3.37	0	2.44	6.79
Woodland	2	0.93	0.86	1.02	0	1.95	1.87

Table 5.3.5.3.2 *Summary of option groups with non-zero area within GMEP 1km survey squares.*

The breakdown of individuals of target species and the number of GMEP 1km survey squares in which options in each group were found are presented in Table 5.3.5.3.3. The rarer species for which there are bespoke options in Glastir were only recorded rarely: three were not recorded at all, reflecting their rarity or range-restriction. The exceptions were Chough, Curlew and Lapwing, which, were recorded in three, one and five GMEP 1km survey squares, respectively. Good numbers of birds of the target species for the other, more general options were found in GMEP 1km survey squares, but most option types were rare in the sample and few target birds were associated with the option areas. Only management of Marshland registered target species in more than one GMEP 1km survey square.

Ultimately, given sufficient sample sizes, these data should be sufficient to support formal statistical tests of the selection of Glastir-managed habitat relative to the availability of the background habitat. Currently, this is only possible for marshland, for which 16 of the 19 individuals of the target species were found in Glastir-managed habitat; this shows a statistically significant positive association with Glastir, by area (χ^2_1=8.89, P<0.05).

When the numbers of target species found in GMEP 1km survey squares with each Glastir option type were considered (Table 5.3.5.3.3), target species were found in GMEP 1km survey squares featuring three Glastir option types (Marshland, Summer food and Woodland).

Management option group	Number of individuals of target species associated with management option	Number of GMEP 1km survey squares with non-zero management area (number of which also with target species)	Number of individuals of target spp associated with suitable habitat across all GMEP 1km survey squares	Number of GMEP 1km survey squares with relevant habitat (number of which also with target species)
Heathland	0	0	551	54 (35)
Hedgerow	0	8 (0)	625	119(92)
Marshland	16	18 (6)	62	118 (21)
Saltmarsh	0	0	66	89 (18)
Winter Food	NA	NA	247	51 (35)
Summer food	4	6 (1)	247	51 (33)
Woodland	1	2 (1)	1,547	117 (96)
Reedbed	0	0	48	4 (3)
Chough option	0	0	4	125 (3)
Corn Bunting option	0	0	0	51 (0)
Curlew option	0	0	3	81 (1)
Golden Plover option	0	0	0	2 (0)
Lapwing option	0	0	8	116 (5)
Ring Ouzel option	0	0	0	125 (0)

Table 5.3.5.3.3 *Summary of Glastir option categories and associations with target birds. All figures are sums across 2013 and 2014 GMEP 1km survey squares.*

The individually targeted species were mostly not associated with the background habitats deemed broadly suitable for them, reflecting the target species' rarity or range-restriction. The exceptions were Curlew and Lapwing, which, were recorded in one and five GMEP 1km survey squares, respectively.

When the numbers of target species found in GMEP 1km survey squares with each Glastir option type were considered (Table 5.3.5.3.1), four Glastir option types (Marshland, Winter food, Summer food and Woodland) were associated with target species.

A summary of option areas in GMEP 1km survey squares, omitting squares with zero area, is presented in Table 5.3.5.3.2. Marshland was the most widespread option, present in the highest number of GMEP 1km survey squares and covering the widest area (as much as half of a 1km square) across all GMEP 1km survey squares. Two of the other three options (Summer food and Woodland) had been recorded in five or fewer squares, whilst option for the management of hedgerows was present in eight GMEP 1km survey squares (Table 5.3.5.3.2) but they all typically covered/extended for only small areas/stretches of land.

As well as numbers of individuals associated with Glastir management, it is possible that birds respond in respect of relative densities, with more being supported per unit area of habitat once it is managed under Glastir. A comparison between the densities of target birds found in patches of relevant options and those in the relevant background habitat elsewhere within the same GMEP

1km survey squares is presented in Table 5.3.5.3.2. Two options, Marshland and Summer Food had higher overall densities of birds within the habitat entered into the option than outside of it, whilst Woodland management had considerably lower densities associated with the Glastir option than the background habitat.

The comparison between densities of birds found in appropriate habitat in GMEP 1km survey squares with and without some relevant Glastir management is also presented in Table 5.3.5.3.4. When the entire GMEP 1km survey square with Glastir management was considered, densities of birds where there was relevant Glastir management nearby were considerably higher in all three option groups for which target birds were recorded in GMEP 1km survey squares with the options: Marshland, Summer food and Woodland. Note that sample sizes here were small (Table 5.3.5.3.1), but formal statistical tests will be possible once more data are available.

Option	Density of birds per 10 ha (or per 10m of agricultural boundary) in relevant habitat within Glastir squares		Density of birds per 10 ha (or per 10m of agricultural boundary) of relevant habitat across entire GMEP 1km survey squares:		Number of birds of target species in:	
	In Glastir option patches	Outside Glastir option patches	With Glastir options	Without Glastir options	Glastir squares	Non-Glastir squares
Heathland	0	0	0	2.34	0	123
Hedgerow	0	0.007	0.007	0.01	33	592
Marshland	<u>1.11</u>	0.32	<u>0.79</u>	0.04	19	4
Saltmarsh	0	0	0	0	0	0
Winter Food	NA	NA	1.01	1.95	2	90
Summer food	<u>5.89</u>	1.54	<u>3.04</u>	1.74	6	80
Woodland	5.35	16.94	<u>12.80</u>	5.01	2	387
Reedbed	0	0	0	11.91	0	17
Chough option	0	0	0	0.01	0	4
Corn Bunting option	0	0	0	0	0	0
Curlew option	0	0	0	0.02	0	3
Golden Plover option	0	0	0	0	0	0
Lapwing option	0	0	0	0.03	0	5
Ring Ouzel option	0	0	0	0	0	0

Table 5.3.5.3.2 *Comparison between density of birds (including flying individuals) of relevant target species for each Glastir option group and that expected in suitable habitat outside of Glastir within GMEP squares. Higher density of target species associated with relevant Glastir management compared to suitable habitat are underlined.*

5.3.5.4 Discussion

There is an indication that the Glastir options for marshland management, woodland management and the option group designed to provide food to farmland birds in summer may be attracting higher densities of individuals of target species than are found in the relevant background habitats. However, formal statistical tests have not been conducted because the sample sizes are currently too small, so this result should be interpreted with caution. In particular, over a third of Marshland management was present in only one square (53 ha). More generally, it is important to note that associations between birds and management in this analysis will not prove positive effects of Glastir. They could also show that Glastir has been adopted disproportionately in areas of higher quality habitat; however, the results could then be interpreted as showing the extent to which Glastir has been targeted effectively. In this way, the results of the present analysis add to those measuring targeting efficacy using Bird Atlas 2007-11 data that are currently in progress and will be reported in September 2015.

Nine of the 14 option types considered could not be tested because they have yet to be found in GMEP squares. Others were limited by small sample sizes. This partly reflects the rarity of some management types, but partly also reflects the targeting of the GMEP sample in 2013 and 2014, which aimed to cover management providing water- and carbon-related ecosystem services. With larger sample sizes after further years of GMEP, it is to be expected that more tests will be possible and that the power associated with the tests that have been conducted will increase, but it should be noted that direct targeting of this management, or of the background habitats in which it is found, may be necessary before sample sizes that support strong analyses of effect are achieved. Winter management requires winter survey data to test associations because even resident birds can move considerable distances between seasons. Winter bird surveys have been conducted during 2014-15 and will report in March 2016; note, however, that many winter-relevant Glastir options are rare and it is highly unlikely that analysable data will be obtained without several years of winter survey, given the current prioritization for Targeted sampling.

5.3.6 Does habitat diversity vary according to whether land is in Glastir?

Within Glastir high habitat diversity as such is not an objective of the scheme but maintaining areas of habitat land in good condition is important. It is a useful measure to assess whether land in and out of Glastir consist of higher habitat diversity at this stage of the scheme.

5.3.6.1 Methods

Habitat diversity was calculated as described above. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the square was under Glastir management was used as a factor in the analysis. In future it will be possible to look at specific options spatially (allowing for suitable sample sizes) to assess whether a particular option is having an effect.

5.3.6.2 Results

Habitat Diversity is higher in 1km squares that are subject to Glastir management.

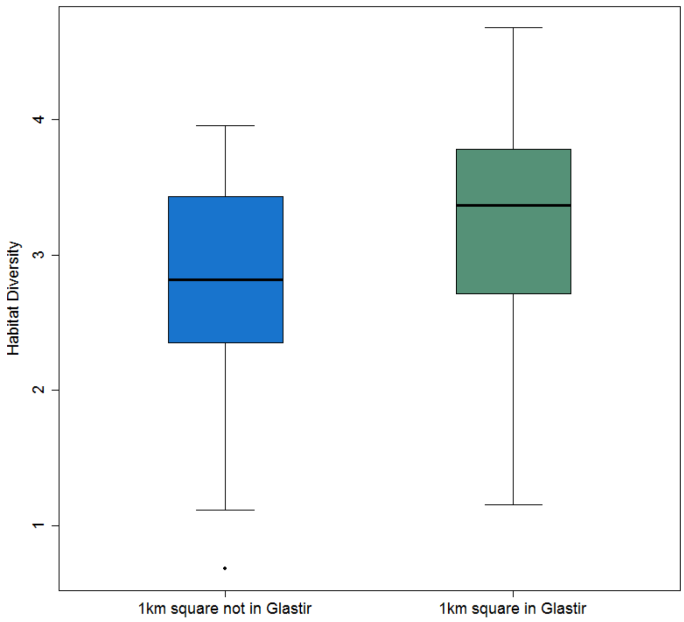


Figure 5.3.6.2.1: *Mean Habitat diversity per 1km square where land is managed under Glastir and is not in Glastir.*

Table 5.3.6.2.1: *Mean Habitat diversity per 1km2 in a 1km square where land is in Glastir and land is not in Glastir*

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	2.815193	2.549823	3.080562
1	3.185736	3.042068	3.329405

There is a significant difference between squares where the land owner is in Glastir and squares where the land owner is not in Glastir

5.3.7 What is the relationship between Habitat diversity and other diversity indicators?

5.3.7.1 Background

As mentioned previously it is generally assumed that habitat diversity is a good thing to promote within a landscape, many species benefit from a mosaic of habitat types providing different functions. High habitat diversity should provide resilience from changing environmental conditions (e.g. climate change) enabling species to move between habitats when conditions change. For the habitat themselves high habitat diversity could provide resilience or it could be a sign of increasing fragmentation. The relationship between habitat diversity and the number of characteristic plant species (Common standards monitoring) was tested.

5.3.7.2 Method

Habitat diversity was calculated as before in GMEP 1km squares. The number of Characteristic plant species was calculated as mentioned in section? Using species identified by experts for the JNCC and updated with lists from the BSBI. The number of CSM species within each vegetation plot was calculated, then for this analyses a total number of CSM species within a 1km square was derived.

5.3.7.3 Results

There is a significant positive relationship between habitat diversity and the number of characteristic plant species within a 1km square. This is evidence that habitat diversity is a good thing in that there are more habitat types but they consist of characteristic plant species indicators of condition in the habitat.

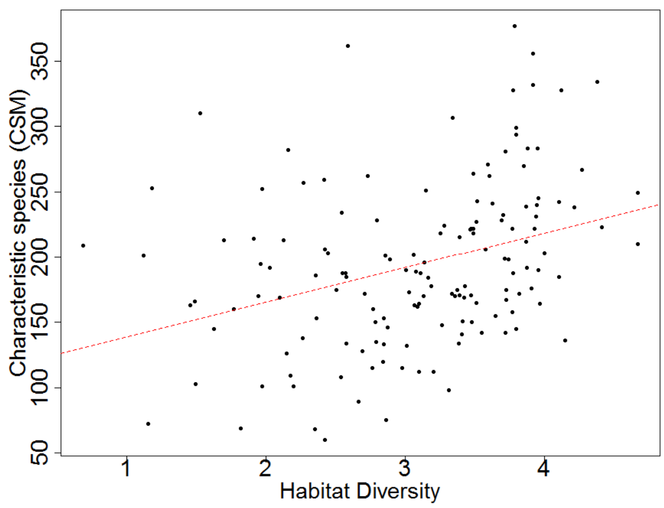


Figure 5.3.7.3.1 *The relationship between Habitat diversity (1km square) and the number of characteristic habitat species (CSM indicators).*

There is a positive relationship between Habitat diversity and Characteristic plant species ($p<0.001$)

5.3.8 Does habitat connectivity of wetlands vary according to whether land is in Glastir?

Habitat fragmentation is a threat to biodiversity by both reducing the total area of habitat available and by reducing connectivity between habitat fragments. Habitat connectivity is the ability for species to move between areas of habitat and is a function of the number and size of habitat patches and how close together they are. Many, large habitat patches which are close together will have higher connectivity and would be expected to support higher biodiversity. Habitat connectivity has been estimated for two different habitats recorded in GMEP squares; broadleaf woodland (see woodland chapter) and wetland. Both of these habitats have been targeted by Glastir prescriptions which aim to increase the total area of habitat; these prescriptions would be predicted to lead to an increase in habitat connectivity.

To assess the potential for Glastir prescriptions to increase connectivity of wetland it is important to know the initial level of connectivity within each GMEP square. The number, size and distance between habitat patches are estimated from the habitat maps recorded by the field survey team. The method used for assessing the connectivity of wetland in GMEP squares is to calculate the Euclidean distances between habitat patches. This is simply the distance in metres between the edges of each habitat patch (termed Euclidean distance because it follows the rules of Euclidean geometry). The Euclidean distance between all habitat patches in GMEP squares was calculated for wetland in ArcGIS 10.2 (ESRI, Redlands, CA, USA) using the Conefor Inputs GIS extension (Jenness Enterprises, Flagstaff, AZ, USA).

To convert the pairwise distances between each of the habitat patches into a metric of habitat connectivity the Probability of Connectivity was calculated using the Conefor program (Saura & Torné, 2009). The Probability of Connectivity (PC) metric is the probability that two individuals of a species randomly occurring in the landscape (in this case the GMEP square) are in habitat patches that are interconnected, given the distribution of habitat patches and the ability of the species to disperse across the landscape[1]. To look at the relative differences between GMEP survey squares the results were scaled so that the square with the highest PC metric had a value of 1.

Wetland was defined as any habitat falling under the broad habitat classifications of Fen, Marsh Swamp or Bog. This included several priority habitats e.g. Fen and Blanket bog. It was assumed in the calculations that species could move freely between fen and bog habitats, this may not be the case in reality and therefore connectivity may be overestimated. From the sample of year 1 and 2 GMEP survey squares, 104 contained some wetland and had a connectivity index of above zero. As with broadleaf woodland there were no differences in the relative connectivity index (PC scaled to between 0 and 1) between squares in and out of the Glastir scheme or between targeted and wider wales squares (Figure 5.3.8.1). Again, the distribution of values showed that most squares had low connectivity, with only a few squares being highly connected.

[1] The model was parameterised with a dispersal distance of 200 metres and a probability of 0.5. These are arbitrary choices but serve to illustrate the variation in connectivity between squares.

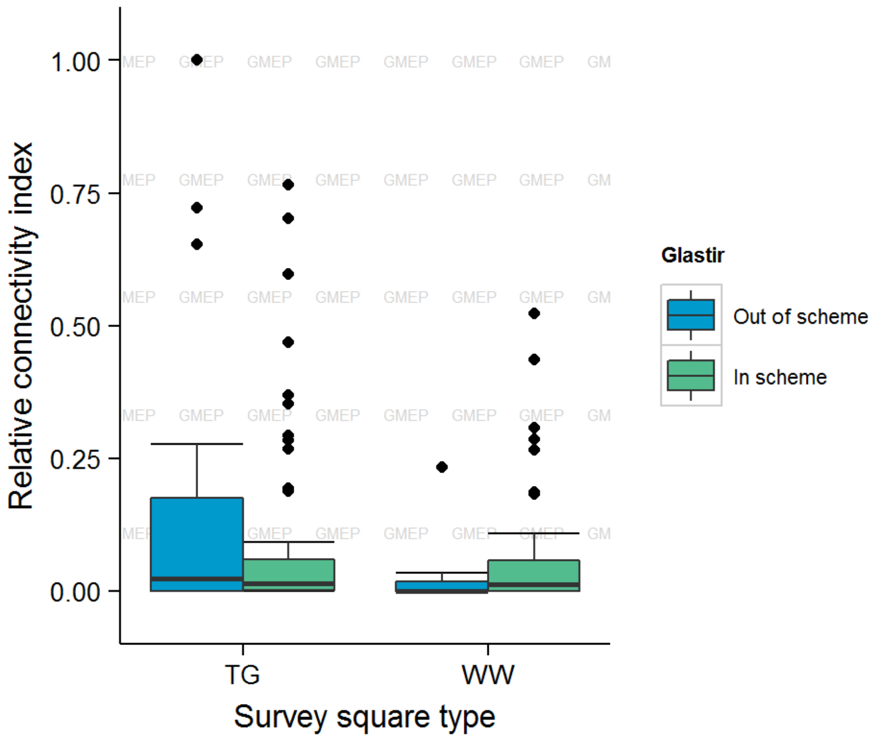


Figure 5.3.8.1. *Connectivity of wetland habitats in Year 1 and 2 GMEP survey squares. Connectivity was measured using the Probability of Connectivity metric and was scaled to between 0 and 1 to provide a relative connectivity metric.*

Glastir	Estimated_Value	Lower_est.	Upper_est.
In Glastir	0.010	0.043	0.156
Not in Glastir	0.076	0.011	0.141

5.4 Remote sensing applications

A large amount of new work has been carried out in the past year using remotely sensed data in combination with GMEP survey data and biological records. The objectives of this work are principally to explore ways in which satellite derived products can be combined with field survey data and other data products to develop new capacity for predicting attributes and quantities of interest across Wales outside of the 1km survey squares. New results have been produced in three areas.

1. Application, comparison and analysis of Land Cover Map with other survey products has been carried out in support of the objective to identify and map HNV land in Wales. This work is fully described in the HNV chapter in this report (Chapter 9).
2. Testing whether satellite imagery can be calibrated against finely resolved field survey data to produce predictive maps of ecosystem function at fine resolution outside of survey squares. This work is in its early stages and is reported in Appendix 5.14. Using a dataset of independent GB site measurements and plant trait composition a regression model was produced predicting above-ground Net Primary Production (ANPP) in terms of cover-weighted Specific Leaf Area. This was used to estimate ANPP for GMEP vegetation plots and these estimates were then compared with remotely sensed NDVI values for pixels containing the field plots. The strength of this relationship (r-sqrd=0.53 to 0.71) justified interpolating the relationship to produce a finely resolved predictive map of ANPP for Wales. Primary Production is a fundamental measurement of ecosystem function and further work will progress the validation of our initial model and explore further relationships with ecological attributes and natural capital across Wales and within survey squares.
3. See also the development of a fine resolution Woody Cover Product (WCP) in Chapter 4 which captures small-scale woody features such as hedgerows and small patches of trees. These provide valuable ecosystem services and are important for biodiversity conservation.

5.5 Future work; priorities for years 3 and 4

- Ongoing campaign to gain further access to updated species distribution records at 1km square resolution.
- Consultation and dialogue with species experts to explore and develop the proxy indicators for Section 42 species.
- Extension and development of proxy indicator approach so that it can be automatically and flexibly applied given Glastir uptake levels in year 3 and 4 squares.
- Consultation and dialogue with NRW to explore representativeness of Priority Habitat mapped areas and their vegetation quadrats.
- Production of high-level biodiversity indicators.
- Production of national estimates of Priority (Section 42) Habitat extent where possible.
- Ongoing development of up and downscaling approaches to provide interpolated biodiversity estimates outside of GMEP squares and thus to provide new datasets for quantification of biodiversity and characterization of HNV land across Wales.

5.6 Acknowledgements

We thank Claire Carvell (CEH Wallingford), Trevor Dines and Cath Shellswell (Plantlife) and Lisa Hundt (Bat Conservation Trust and the UK Bat Steering Group) for expert advice on species requirements and species distribution data.

6. Climate Change and Diffuse Pollution Mitigation

Chadwick, D[1]., Abdalla, M[2]., Anthony, S[3]., Malcolm, H[4]., Moxley, J[4]., Smith, P[2]., Taylor, R[5].

[1]Bangor University, [2]University of Aberdeen, [3]ADAS, [4]CEH Edinburgh, [5]BTO

6.1 Introduction

Agriculture continues to be a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to improve water quality and reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets. In consequence, the Glastir scheme has been developed with sufficient flexibility to target priority themes (such as soil carbon) in a spatial context, and introduce options on farms to e.g. enhance carbon sequestration, reduce greenhouse gas emissions and diffuse water pollution from the agricultural sector. The Welsh Government has prioritised funding for options focussed on climate change mitigation and diffuse water pollution for Years 1 and 2 of the scheme.

As a first step to determine the potential impacts of Glastir on greenhouse gas and diffuse pollution emissions and carbon sequestration, the Welsh Government tasked the Glastir Monitoring and Evaluation project to assess the potential impact of Glastir options on these priority areas through modelling (including emission source not included in the greenhouse gas inventories), work to identify the wider benefits of the Glastir Efficiency Grants and a scoping study to identify barriers for uptake of the Woodland Creation Scheme (see chapter 3). The Year 1 GMEP Report provided an initial description of the *modelling ensemble* approach we used (the full report on the models used is provided as Appendix 5.6 in that report) with model outputs for three uptake scenarios presented for five Glastir options. Below we give a broad overview of greenhouse gas emissions for land use and agriculture in Wales as an introduction and then outline Year 2 activities. For work on diffuse pollution see Year 1 report and Chapter 10 (Emmett et al. 2014).

6.1.1 Overview of Greenhouse Gas Emissions from Agricultural Land Use in Wales and the contribution from different sectors

In 2012, Agriculture contributed 13% of CO_2e emissions in Wales, with CH_4 and N_2O representing 64% and 79% of total Welsh emissions of these two gases, respectively. In total, 6,142 kt CO_2e were emitted by agriculture in Wales in 2012; comprising 47% as CH_4 (2,864 kt CO_2e), 44% as N_2O (2,707 kt CO_2e), and the remainder associated with transport (AEA, 2014).

6.1.1.1 Methane

Enteric fermentation by ruminant livestock contributed >80% of total agricultural CH_4 emissions in Wales (2,294 kt CO_2e), manure management representing the remaining CH_4 emission. Dairy and beef cattle were responsible for 63%, and sheep 34% of agricultural CH_4 emissions (Figure 6.1.1.1.1). Manure management, although an important source of CH_4, represents only around 20% of the total CH_4 emissions.

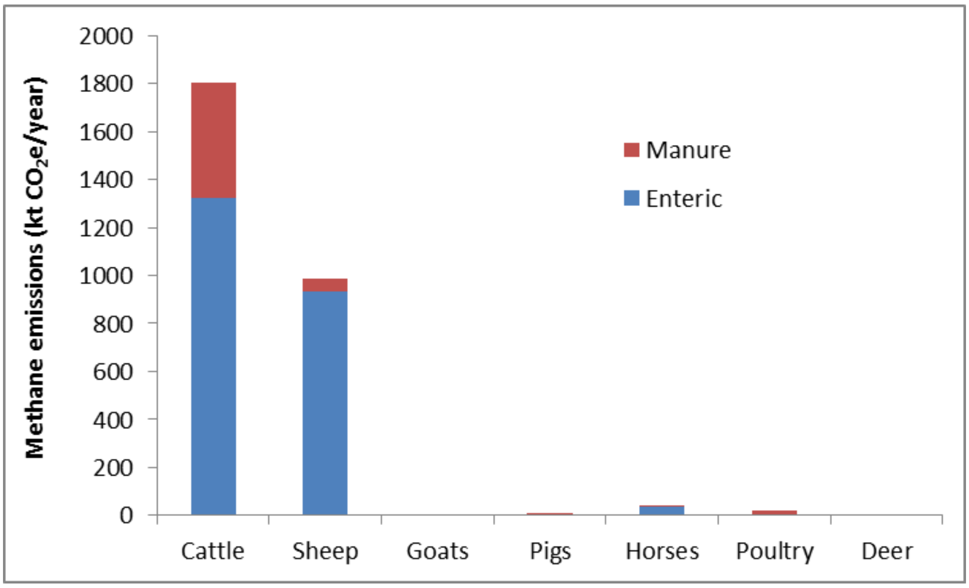


Figure 6.1.1.1.1 *Methane emissions from livestock sectors in Wales (2012) [Source: NAEI, 2013].*

6.1.1.2 Nitrous oxide

Agriculture is the dominant source of N_2O in Wales, with >90% (2,491 ktCO_2e) of this arising from agricultural soils. The key sources of N_2O from agricultural soils are direct N_2O emissions from the soil to the atmosphere following fertiliser nitrogen, grazing returns (in the form of dung and urine) and manure applications. However, a proportion of nitrogen that is deposited to soil from the atmosphere (in wet and dry deposition) is subsequently emitted as N_2O from the soil, whilst N_2O is also emitted from leached nitrate in watercourses. N_2O emissions from deposited N and nitrate leaching are known as 'indirect' soil losses. Table 6.1.1.2.1 illustrates the significance of indirect N_2O emissions, especially those associated with nitrate leaching.

N_2O (kt CO_2e)	**Direct**	**Indirect**	
		Leaching	N deposition
Fertiliser	403	269.7	37.2
Grazing returns	895.9	334.8	89.9
Manure application	186	142.6	37.2
Crop residues	31	0	0
Biological fixation	0	0	0
Improved grassland	27.9	0	0
Histosols	0	0	0
Sewage sludge	12.4	9.3	3.1
Total	1556.2	756.4	167.4

Table 6.1.1.2.1 *Sources of N_2O from agricultural soils in Wales (2012)*

The cattle (dairy+beef) sector is responsible for 65% of the total N_2O emissions from Welsh agriculture (Table 6.1.1.2.2.). Direct soil emissions from fertiliser nitrogen and manure nitrogen applications, and following urine and dung deposition by grazing livestock represents 57% of the total N_2O emissions from Welsh agriculture. Indirect N_2O losses associated with nitrate leaching to water courses, and nitrogen deposition from the atmosphere, represent 34% of the total agricultural emission, while N_2O emissions from manure management in livestock buildings and manure stores are relatively small sources, ca. 9%. Therefore, options taken to reduce indirect N_2O emissions, e.g. nitrate leaching, will reduce the total N_2O emission from Welsh agriculture.

kt CO_2e	Total	Direct	Indirect	Manure management
Cattle	**1100.5**	573.5	347.2	179.8
Sheep	**672.7**	440.2	213.9	18.6
Pigs	**3.1**	0	0	3.1
Horses	**74.4**	49.6	24.8	0
Poultry	**71.3**	18.6	18.6	34.1
Sewage sludge	**24.8**	12.4	12.4	0
Fertiliser	**709.9**	403	306.9	0
Crop residues	**31**	31	0	0
Improved Grassland	**27.9**	27.9	0	0
Total	**2715.6**	1556.2	923.8	235.6

Table 6.1.1.2.2 *Nitrous oxide emissions from livestock sectors in Wales (2012) [Source: NAEI, 2013].*

6.1.2 National Trends from the Land Use and Agriculture Sectors

6.1.2.1 Agricultural Greenhouse Gas Emissions

Agricultural sector GHG emissions in Wales have decreased by >20% since 1990 (see Figure 6.1.2.1.1). There was a small increase of less than 1% in emissions from 2011 to 2012 mainly due to a 1% reduction in cattle numbers balanced by an increase of 3% in sheep numbers. The overall trend in reductions of (N_2O) emissions from soil have been the result of reductions in fertiliser nitrogen use (particularly in grasslands) and reduced numbers of livestock (manures and urine deposition) over the past decade. Current (2012) annual emissions of N_2O for Wales are 2707 kt CO_2e (8.73 kt N_2O). The trend in the reduction of livestock numbers has also resulted in lower CH_4 emissions. The stabilisation of numbers in recent years means that there has been little change in emissions between 2011 and 2012 (0.2% increase).

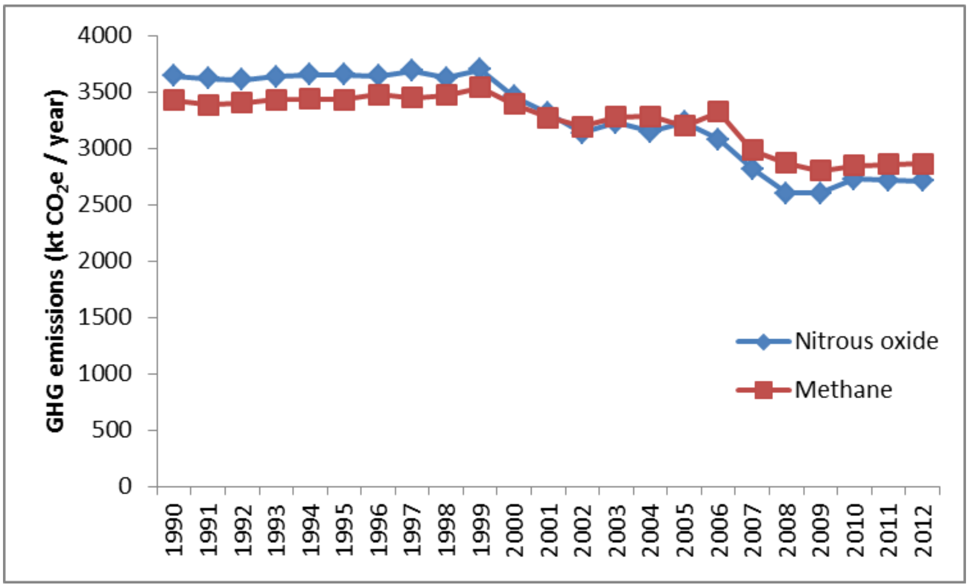


Figure 6.1.2.1.1 *Total Annual Nitrous Oxide and Methane Emissions from Welsh Agricultural Sector inventory, 1990-2012. Source: NAEI, 2013.*

6.1.2.2 Land Use, Land Use Change and Forestry(LULUCF)

Whilst Wales is a small net sink of greenhouse gases from LULUCF activities, Figure 6.1.2.2.1 shows land which is a net greenhouse gas sink. Between 1990 and 2012, the carbon sink in Welsh grassland has increased slightly (emissions have become more negative), while emissions from cropland have decreased. These trends reflect net conversion of cropland to grassland dating back several decades, as it takes many years for the amount of carbon stored in soils to stabilise after conversion between one land use and another.

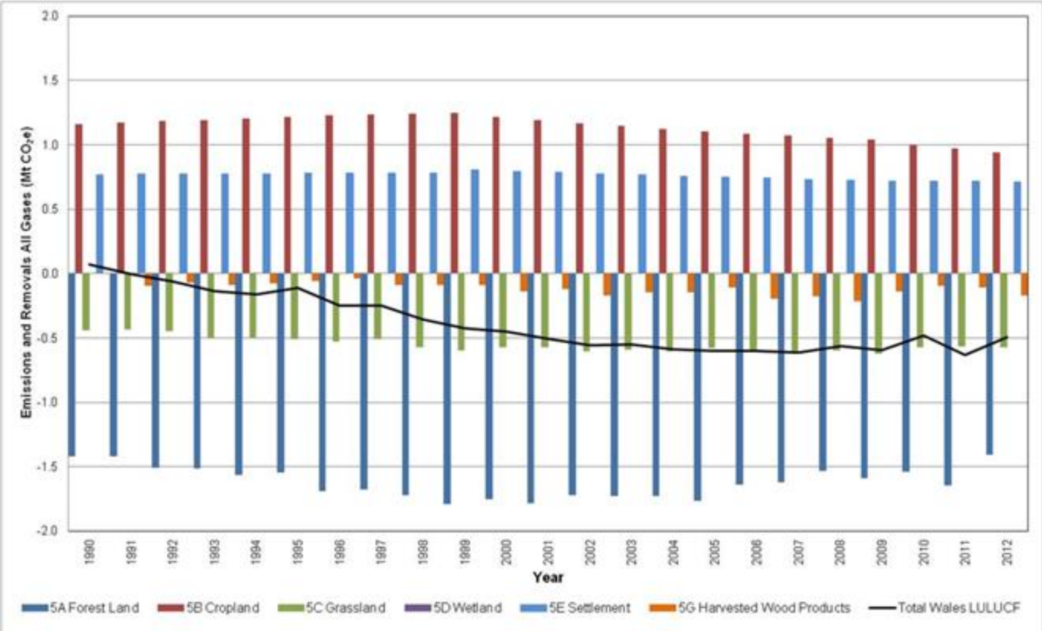


Figure 6.1.2.2.1 *Annual Emissions from LULUCF in Wales. Source: AEA (2014) - Emissions and Removals of Greenhouse Gases from Land Use, Land Use Change and Forestry (LULUCF) for England, Scotland, Wales and Northern Ireland: 1990-2012.*

6.2 Year 1 Achievements and Year 2 Aims and Highlights

6.2.1 Reminder of the Overall Achievements in Year 1

- In year 1 we brought together an ensemble of models to assess the potential of Glastir options to reduce GHG emissions, store carbon and reduce diffuse water pollution from agriculture
- The initial runs of four Glastir options with the Bangor footprinting life cycle approach on 16 model farms showed that the carbon footprint could be reduced by between 0-24% (combined effect of direct within-farm emissions and embedded emissions associated with feed and fertiliser production). Reductions in greenhouse gas emissions are associated with measures that reduce fertiliser nitrogen use and reductions in livestock numbers.
- The ADAS modelling tool was used at the national scale for five Glastir options to assess potential changes in gaseous emissions (nitrous oxide, methane) and diffuse water pollution (nitrogen, phosphorus and sediment). GHG emissions could be reduced by a maximum of X% (if maximum adoption of the zero N fertiliser Glastir option was achieved)
- Datasets for future spatial GHG and C sequestration were acquired in preparation for the ECOSSE model
- We planned the approach for assessing the impact of Glastir Efficiency grants on i) the carbon footprint of farms which have made use of them, and ii) the wider (off-farm) benefits to the rural economy
- We developed a draft protocol for the repeat Wales Farm Practice Survey, including the proposed stratification strategy, for discussion with funders and the wider project team

6.2.2 Year 2 Aims

- Provide an indication of relative GHG emissions from different farm types in Wales, and complete a more comprehensive assessment of the effect of limited Glastir options on the carbon footprints of model farms, typical of Welsh agriculture
- Assess the effect of additional options to reduce GHG emissions from Welsh agriculture (using the ADAS model)
- Determine the baseline spatial GHG emissions and soil carbon storage across Wales, and assess the effects of reducing N fertiliser use on GHG emissions, and the impacts of a changing climate would have on GHG emissions and soil carbon storage (ECOSSE model)
- Evaluate the barriers that may exist which limit uptake of woodland creation options in Glastir
- Determine the wider benefits of the Glastir Efficiency Scheme grants on i) socio-economics of the farm and rural communities within Wales, and ii) farm carbon footprints.

6.3. Year 2 Highlights

6.3.1 Carbon Footprinting

- On this set of 16 Welsh model farms, the 4 Glastir options explored is projected to have had the intended effect of reducing GHG emissions and (in most cases) increasing C-sequestration in biomass and soils.
- The effectiveness of the different options in reducing GHG and increasing C sequestration varied between farm types.
- The tool indicated the GHG reductions were mediated primarily through reductions in livestock, with small additional reductions associated with lower requirements for farm inputs associated with stock management. These reductions to inputs extend the impact of the scheme option beyond the boundaries of the participating farm, and into the upstream agricultural supply chain.
- Reductions in livestock numbers may or may not lead to reductions in farm productivity and hence the economic and supply performance of the farm, although this is difficult to predict with confidence.
- The tool indicated the conversion of grassland to woodland resulted in a net increase in carbon sequestration but the overall impact of the “woodland margin extension” and “streamside corridor” options is limited by the small number of farms with applicable land.

6.3.2 Effects of Reduced Fertiliser N Use and Climate Change on Spatial GHG Emissions

- The ECOSSE model differs with respect to the models used in the GMEP Year 1 scenario work in that is a process-based model ,so is capable of quantifying changes to GHG emissions in the longer term when emission factors which underpin other models may change e.g. in response to climate change. These models are the ideal but require a great deal of data and there remain uncertainties in the science and the scale of results is significantly reduced compared to the other models.
- ECOSSE estimated the mean annual net GHG balance at baseline climate of 0.2 t CO_2e /ha/y.
- The Glastir option of reducing N fertilizer to reduce GHG and soil organic carbon (SOC) fluxes could reduce the annual net GHG balance from 0.20 to 0.17 (for a 20% N reduction), and to 0.15 (for a 40% N reduction) t CO_2e /ha/y, respectively.

- The model indicated climate change will not significantly affect net GHG fluxes from Welsh soils or Net Primary Productivity by vegetation by 2050. This is primarily a result of the small differences between the baseline and 2050 climate scenarios (about ±2%).

6.3.3 Simultaneous Measurements of nitrous oxide, methane and carbon dioxide from Welsh grasslands

- Methane and carbon dioxide fluxes are now being measured, with nitrous oxide measurements to follow imminently.

6.4 Methods

6.4.1 Carbon Footprinting

The Bangor carbon footprinting (CF) tool was used to estimate which type of farm is responsible for the greatest GHG emissions and C sequestration, and also to evaluate the potential effects of a limited number of Glastir options on GHG emissions and C sequestration. The approach include indirect or embedded sources of emissions which are not included in the IPCC methodology for country level greenhouse gas emission inventories.

The CF tool takes real farm data on all inputs, land management practices (and history for Land Use Change) and monthly stock diary data to generate annual C footprints that are PAS 2050 compliant (unless soil and biomass C sequestration effects are included). It adopts simple, default (Tier 1) emission factors for most N_2O and CH_4 emissions (enteric fermentation based on animal category numbers and bodyweights x average EFs; soil emission factors; manure storage by type *etc*…). But it includes a slightly more complex (Tier 2) estimate of soil C accumulation under grassland, and accounts for on-going C sequestration in tree biomass. A monthly stocking diary enables more accurate estimation of annual enteric fermentation (x animal numbers) and manure management (N excretion and CH_4 EFs). It takes a Life Cycle Analysis approach, and takes account of embedded GHG emissions associated with feed and fertiliser production and transportation to the farm.
The CF tool was used to determine individually the effects of the following Glastir options: Grazed Permanent Pasture – No Inputs; Grazing Management of Open Country; Woodland margin extension; Create New Streamside Corridor – Both Sides / Tree Planting, on GHG emissions and C sequestration.

6.4.2 Estimating Effects of Reduced N Fertiliser Use and Climate Change on Spatial Emissions of Greenhouse Gases

The Welsh Government is committed to reduce greenhouse gas emissions from agricultural systems. One of the Glastir options is to reduce fertiliser application rates, specifically to remove nitrogen (N) inputs to some fields. Since N fertiliser applications to soil represent a key source of the greenhouse gas nitrous oxide (N_2O), a reduction in fertiliser nitrogen use will result in a reduction in the production and loss of this gas. The ECOSSE model was applied to estimate the effect of reducing fertiliser N use across Wales on the net soil greenhouse gas balance, i.e. on the difference between the sum of N_2O and CH_4 fluxes, minus the change in soil organic carbon (SOC) (as CO_2).
The ECOSSE model was developed to simulate highly organic soils similar to those found in Wales. ECOSSE uses data describing climate, plant inputs, nutrient applications and timing of management operations to drive the model and simulate carbon sequestration and soil GHG emissions (note ECOSSE does not simulate methane emissions from ruminant livestock and their manures, but does estimate methane emissions from waterlogged soils). The decomposition process results in CO_2 and CH_4, with CO_2 losses dominating under aerobic conditions and CH_4 losses under anaerobic conditions. The spatial simulation of GHG and SOC fluxes is carried out for Wales on a 1 km^2 soil grid

basis using 5 dominant soil types in each grid cell. The model output represents the area-weighted mean of the simulations carried out for each soil type in the grid cell. The Land Cover Map (LCM2007; 8) was applied, and four main ecosystems were simulated (arable, grassland, forest and natural).

The model was applied spatially using Welsh soil data 2005 and UKCP09 climate data (1961-1990) as inputs data. The arable and grass lands are assumed to be fertilised whilst the forest and natural lands are assumed to remain unfertilised. Results were reported in terms of CO_2-equivalent values (CO_2e) using the IPCC 100-year global warming potentials (GWPs). We report a net greenhouse gas balance. A positive net greenhouse gas balance is harmful and a negative net GHG balance is beneficial.

6.4.3 Simultaneous measurements of N_2O, CH_4 and CO_2 from Welsh grasslands

All greenhouse gases from soil are produced by microbial processes and thus are sensitive to environmental conditions such as soil moisture and temperature. Ruminant methane emissions are controlled by factors such as age and type of livestock, dietary composition and intake rate. These environmental factors contribute to natural variability in greenhouse gas emissions. However, human activities such as fertilisation, livestock management, drainage and land-use change have greatly altered these natural cycles, commonly leading to increases in emissions.

In the GMEP project, we have procured state-of-the-art analysers capable of simultaneously quantifying small changes in atmospheric concentrations of N_2O, CH_4 and CO_2, for quantifying fluxes of GHGs using Eddy Covariance. This unique measurement system for quantifying N_2O, CH_4 and CO_2 is the first of its kind in Wales, and has been challenging in its development. Delays in procurement of specialist analysers and complex integration of hardware and software has delayed deployment to the grassland farms in Wales.

The analysers have been set up in mobile laboratories that have now been towed to a commercial farm to assess the relative importance of environmental conditions and management practices on the emissions of CH_4 and CO_2. N_2O and soil moisture analysers are being integrated and will be deployed to the commercial farm imminently. These unique measurements will contribute to our understanding of the impact of Glastir management practices on net carbon balances of grazed pastures.

6.5 Results

6.5.1 Carbon Footprinting

6.5.1.1 Baseline GHG emissions and C sequestration from different farm types

Methane dominated direct GHG emissions (i.e. compared to N_2O emissions), with >2 times the direct CO_2e arising from CH_4 compared to N_2O in the beef, dairy and mixed farms. On the sheep farms, contributions of CH_4 and N_2O emissions to the total direct GHG emissions were more similar.
At the farm level, 19-36% of total GHG emissions are embedded GHG emissions associated with imported feed, manufacturing of fertiliser and livestock purchases.

Total GHG emissions per hectare (CO_2e/ha) were greatest from the dairy farms, with similar total CO_2e emissions/ha from the Beef and mixed farms, and least from the sheep farms (Table 6.5.1.1.1). At the farm level, the major sink for carbon is soils under grassland (62 -82 % of total C sequestration), with woodland, other trees and hedgerows providing the remaining C sequestration. Total C sequestration rates appear to be lower in the Mixed farms compared to the Beef and Dairy farms (Table 6.5.1.1.1).

kg CO_2e/ha	Mean total GHG emissions	Standard error of the mean	Mean total C sequestration	Standard error of the mean
Beef (4)	6,464	867.1	1,354	517.6
Dairy (4)	11,237	1,314.3	1,401	358.5
Mixed (3)	8,334	1,208.4	838	102.7
Sheep (4)	1,699	405.5	1,070	122.6

Table 6.5.1.1.1 *Typical total GHG emissions per hectare from different farm types in Wales (kg CO_2e/ha).*

6.5.1.2 Effects of Glastir Options on GHG Emissions and C Sequestration

6.5.1.2.1 Zero inputs

Reducing nitrogen inputs to grazed permanent grassland reduces the carrying capacity of the grassland, and therefore animal numbers carried by the farm. Overall, the tool calculated GHG emissions for the 15 farms were reduced by an average of 7%,. This scheme option affected land use primarily through the effects of land-use change, which in this case increases soil C sequestration under grassland by removing and reducing nitrogen inputs. The net impact on carbon sequestration was an increase of 6% overall; with the largest impacts on the more extensive beef and sheep farms (4.5% and 17% respectively) and a much smaller impact on the dairy and mixed farms (1.4% and 2.5%) because of their lower proportion of permanent grassland.

6.5.1.2.2 Grazing Management of Open Country

Sheep numbers reduced by 13% overall; with smaller reductions where sheep were the secondary enterprise (beef farms 7%, dairy farms 14%). Overall, GHG emissions for the 10 affected farms on which this option was applied was calculated to be reduced by an average of 5%. This scheme option result in no effects which could be modelled regarding the effect on C sequestration, since no land management change was applied.

6.5.1.2.3 Woodland Margin Extension

The land area converted from grassland to woodland was very small. Modelled nitrogen reductions averaged 1.5% and livestock were reduced by only about 1%. Reducing livestock numbers has a consequential effect on modelled productivity, with meat sales down by 0.5% and milk by 3.8%. Overall, GHG emissions for the five farms were calculated to have been reduced by an average of 1.5%.. The modelled conversion of grassland to woodland has a net positive impact on C storage although the farm impacts are small (an average increase of 0.03%) because woodland boundary length (i.e. applicable land area for this option) on most farms is small.

6.5.1.2.4 Create New Streamside Corridor – Both Sides / Tree Planting

The land area converted from grassland to woodland was very small. Nitrogen reductions modelled were less than 0.5% and livestock were reduced by only 0.02%. Overall, GHG emissions for the five farms were calculated to have been reduced by an average of 0.11%, or 1.4 metric tonnes of CO_2 equivalent per annum. The modelled conversion of grassland to woodland has a net positive impact on C storage although the farm impacts are small because riparian boundary length (i.e. applicable land area for this option) on most farms is small.
The full report with detail of the Carbon Footprinting of model Welsh Farms can be found as Appendix 6.1.

6.5.2 Estimating Baseline Soil-Borne GHG Emissions and Effects of Reduced N Fertiliser Use and Climate Change on Spatial Emissions of Greenhouse Gases

6.5.2.1 Baseline Emissions

The map below (Figure 6.5.2.1.1) illustrates the simulated net GHG fluxes (t CO_2e /ha/y) from Welsh land use at baseline climate scenario 1961-1990 using the ECOSSE model. Nitrous oxide fluxes were the highest and major contributor to the net GHG balance especially for the grass and arable ecosystems, where N fertilizer was applied. However, fluxes of N_2O from the forest and natural ecosystems were low and contributed less to net GHG balance. Fluxes of CH_4 and SOC were very low and represent a small sink for atmospheric C. The model underestimated CH_4 fluxes from saturated areas due to lack of observed spatial data on water table depth.

The overall average net GHG balance combining all gas fluxes was projected by the model as 0.198 t CO_2e/ha/y. The highest emitters are the grass and arable ecosystems with net GHG balance of 0.449 and 0.205 t CO_2e/ha/y, respectively. However, the net fluxes from the forest (0.053 t CO_2e/ ha/y) and natural (0.086 t CO_2e/ha/y) ecosystems are relatively small compared with that from the grass and arable ecosystems. Considering the net GHG balance of 0.198 t CO_2e/ ha/y, and the Welsh land use area of 1857690 ha (NS, 2004), the calculated annual net fluxes for the whole of Wales based on landuse in agriculture and forestry sectors at baseline climate (1961-1990) is 0.37 Mt CO_2e/y. It should be remembered that these estimates include emission sources not included in the Agriculture and LULUCF inventories.

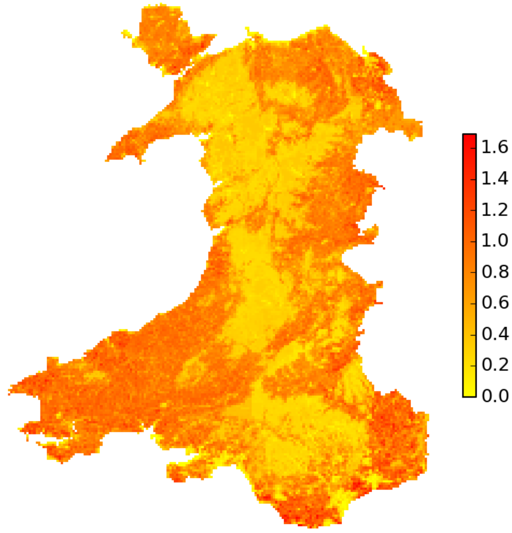


Figure 6.5.2.1.1 *Greenhouse gas emissions (t CO_2e /ha/y) at baseline climate (1961-1990) from Welsh soils as projected by the ECOSSE model.*

6.5.2.2 Effects of predicted climate change on soil-borne GHG emissions in Wales

If the current N fertilizer application rate continues, future climate change by the year 2050 would not significantly affect the net GHG fluxes or net primary production (NPP) from Welsh soils according to the ECOSSE model. The difference between the two climate scenarios is, however, small (±2%). These results are explained in more detail in Appendix 6.2.

6.5.2.3 Effects of Reduced N Fertiliser Use on Soil-Borne GHG Emissions from Wales

Table 5.5.2.3.1 summarises the net effect of reductions in fertiliser N use by 20% and 40% on the net GHG balance as projected by the ECOSSE model. Reducing N fertilizer by 20% and 40% from the baseline resulted in 13% and 22% less N_2O fluxes and thereby, lower net greenhouse gas (GHG) balance (Table 6.5.2.3.1). However, in this study, methane production and SOC fluxes were not much affected by reducing N fertilizer. The amounts of net CH_4 and SOC fluxes, under all fertilisation scenarios, represented a small sink for the atmospheric C. Nitrous oxide has a high global warming potential (GWP), thus reducing its emissions would result in beneficial change to net GHG balance. Mineral N has a direct influence on N_2O production by provision of N for both nitrification and denitrification. The spatial variability in N_2O fluxes is high and controlled by interacting abiotic and biotic factors, such as plants, micro-organisms, precipitation and nutrients. The flux is also expected to vary on a temporal basis depending on the dominant controlling factor.

(kt CO_2e)	Grasslands	Arable lands	Forestry	Natural lands	Net GHG balance (CO_2e)
Baseline	817	372	93	204	368
20% N reduction	687	316	n/a	n/a	321
40% N reduction	613	260	n/a	n/a	286

Table 6.5.2.3.1 *Effects of fertiliser N reduction on the N_2O emissions and Net GHG balance for Welsh soils as projected by the ECOSSE model. The Welsh land use area of 1,857,690 ha has been used in the calculations (kt CO_2e).*

A comprehensive report of the ECOSSE modelling can be found as Appendix 6.2

6.6 Future Plans

6.6.1 Year 3

6.6.1.1 Carbon Footprinting

Options for further work depending on resource availability includes:

- Locate the major land owner (farmer) in selected visited/surveyed 1 km^2 and conduct C footprints for their farms as a baseline, then repeat in 4 years' time. This will provide an indication of the effects of changes in farm management (as a result of Glastir or not, farms could be targeted to be in and out of Glastir) on C footprints. This adds value to the farms that GMEP is already investing its resources in.
- Identify farms in Wales for which we have little information within the current C footprinting data base, e.g. arable. Footprint a cohort of these to allow future scenario testing across Wales.
- Conduct C footprinting on typical farm types in Wales to generate 'per ha' footprints for use in scaling effects of Glastir options – this could also coincide with farms on which the flux towers will be making measurements, i.e. the flux measurements would provide some validation data for this C footprinting in those fields (and source area) where measurements are made.
- Quantify N_2O, CH_4 and CO_2 fluxes from grassland fields using Eddy Covariance. Data will be used in the generation of net carbon balances for a range of intensities of grasslands. In field campaigns of 2-3 weeks will quantify N_2O, CH_4 and CO_2 fluxes from improved and unimproved upland grassland aligned with key on-farm management practices (e.g. livestock turnout, fertiliser/manure applications?). Where possible we will attempt to quantify the effects of Glastir options on these emissions.

7 Soil Quality

Robinson D.A.[1], Barrett, G.[1], Creer, S.[2], G., Emmett, BA.[1], Evans, C.[1], Giampieri, C.[1], Hughes, S[1]., Jones, D.L.[2], Keith, A.[3], Lallias, D.[2], Lebron, I.[1], MacDonald, J.[2], Pereira, MG.[3], Rawlins, B.[4], Thomas, A.[1], and Turner G[4].

[1] CEH Bangor, [2] Bangor University, [3]CEH Lancaster, [4]British Geological Survey

7.1 Introduction

The Welsh Government has commissioned the comprehensive Glastir Monitoring and Evaluation Programme (GMEP) to monitor the effects of Glastir, its new land management scheme, following on from former schemes such as Tir Cynnal, Tir Gofal and the Organic Farming Scheme. The monitoring contributes towards reporting on a range of international biodiversity and environmental targets. The data, models and tools collected and developed within GMEP will also help inform future planning of Wales' natural resources in a joined-up way to ensure the development of a green economy and the aspirations of the Environment Bill. Healthy soils produce our food, feed and fibre, whilst providing other important functions such as regulating climate and water and attenuating pollutants. They are a biodiverse ecosystem in themselves needing to be fed and watered, and contain an estimated quarter of global biodiversity, whilst remaining relatively unexplored with only ~1% of species as yet identified. It is the diversity of life below our feet that provides the engine fuelling nutrient cycling, breakdown of waste, water filtration and plant growth which is why soils are central to environmental and biodiversity monitoring.

7.2 Status and trends

The status and trend of topsoil change across Wales has been captured by the Countryside Survey since 1978. The last survey in 2007 presented changes for a wide range of physical, chemical and biological properties of soil Reynolds et al. (2013). A previous assessment of the "Critical Appraisal of State and Pressures and Controls on the Sustainable Use of Soils in Wales" was reported by Stevens et al. in 2002 which also reported on data from the National Soil Inventory as well as Countryside Survey and other data. Overall, the more recent report in 2013 indicated a picture of stable or improving soil quality with the exception of arable soils. It should be noted the methods used in CS (and other soil monitoring programmes such as the National Soil Inventory) are recognised as being inadequate for Peat Soils monitoring and thus new approaches have been commissioned within GMEP to tackle this, see chapter 2.

7.3 Aims of Glastir

The aim of the Glastir monitoring of soil quality is to collect evidence for the effectiveness of bundles of management options in helping to deliver improved soil quality that will address the outcomes of interest related to climate change, biodiversity, soil and water quality and woodland expansion. The compatibility of the current monitoring with Countryside Survey means it can draw on this data record to understand and disentangle changes in national trends from the specific impact of option bundles. The monitoring is also required to collect evidence to quantify the status and trend of water and soil quality in general for other reporting requirements and this work will provide an important counterfactual evidence base. Synthesis and analysis of this data will seek to identify how the Welsh environment is being impacted by drivers of change, such as landuse, climate and pollution over and above Glastir options. Much of the data from the soils work provides evidence for the integrated analysis, and also helps support modelling studies.

When expecting to see the impact of options it is important to consider that based on the findings of the soil quality monitoring performed under Glastir, alongside previous national surveys (e.g.

Countryside Survey), it can be expected that major changes in soil quality at the national level will not be revealed in the short-term. For example, 10 years of monitoring are typically required to reveal significant changes in many soil attributes (e.g. carbon status). Although the rolling monitoring programme implemented under Glastir has greater statistical power than previous surveys, it is still unlikely that trends in soil C will become apparent for at least 5 years or possibly longer, though it has the advantage of linking to the 30 year Countryside Survey data set which provides greater statistical power.

7.4 Benefits of past schemes

In Wales, funding from agri-environment schemes (AES) has been available since the late 80's including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal and now Glastir. Monitoring of farms under Tir Gofal (Anthony et al., 2012) reported that, 'Soil pH and extractable phosphorus levels were observed to be lower on Tir Gofal farms compared to non- scheme farms. However, this difference may not be due to Tir Gofal management, and was thought instead more likely to be attributable to Tir Gofal management options being applied to areas of more marginal land. Across all the remaining soil quality indicators (bulk density, erosion vulnerability, depth of peat material, organic carbon and carbon to nitrogen ratio) no positive differences were recorded between Tir Gofal and non-scheme farms.' Although the report revealed few positive benefits to soil quality in comparison to farms that had not entered the scheme, this finding could be due to several factors. Firstly, the monitoring timescales (< 3 years) may have been too short to determine significant change, secondly the pair-wise comparison of farms in and out of the scheme may have been the wrong sampling approach (i.e. not enough samples, incorrect pairing), and thirdly there may actually have been no significant benefit from the scheme. As it is impossible to resolve which of these three are valid, it is hoped that the current Glastir monitoring statistical design will help resolve these issues.

7.5 Key findings

- Topsoil (0-15cm) quality for a range of metrics has been characterised for Welsh Broad Habitats
- Analysis of Countryside Survey data with the 2013 GMEP data provides long term trend information for topsoil condition. In summary:
    - There has been no over little change in topsoil carbon concentration in Wales since 1978.
    - During the same period soil acidity was reduced probably due to decreased inputs of acidic atmospheric deposition.
    - Nutrient levels since 1998 when records started indicate no change in nitrogen levels and a stabilisation of a recent decline in soil available phosphorus levels. Levels are still acceptable for production but will have reduced the risk of phosphorus leaching to freshwaters.
    - No change in soil animal populations were found since 1998.
    - It should be noted these national topsoil statistics may mask changes within habitat types which should be reviewed individually. Of particular concern is whether arable systems are maintaining carbon levels. At the UK scale they are known to be in decline but sample numbers after only 2 years of GMEP are currently not sufficient to detect a similar level of change within Wales.
- Evidence for water and wind erosion is sparse at national scales across the UK including Wales. GMEP does not have the resources to fill this gap however we need to quantify the impacts of Glastir. We are therefore using a modelling approach which provides both erosion estimates and are of land likely to be at risk of erosion loss and mitigating sediment delivery. See the GMEP year 1 report for more information.

- No evidence of the limited samples in the Year 1 survey of any difference in topsoil quality of land coming into the Glastir scheme. This analysis will be repeated when the full Year 1-4 survey is complete.
- Exploration of the impacts of management using differences under existing land management suggests land management will change topsoil condition.
- Topsoils in Wales are incredibly diverse and appears most responsive to land management regime compared to soil type indicating Glastir has real potential to influence soil quality.
- We present a proof of concept approach for determining the area of soils for national accounting.

7.6 Main Achievements

Work to establish an effective and efficient monitoring programme for soils has been undertaken in Year 1. Major achievements include:

- Main 2014 survey
    - Trained 12 surveyors in soil sampling methods.
    - Surveyors sampled ~450 plots and collected 4 soil samples from each (~1800 samples in total).
    - CEH Labs measured cores from 435 plots to determine 45 parameters for physical, microbial, chemical, carbon and invertebrate analysis. This data supports the outcome analysis in all categories.
    - Implemented new lab protocols to improve efficiency including methods for soil water repellency using video to determine hydraulic function.
- GMEP data analysis
    - Analysed all 2013 data and submitted to the GMEP data portal.
- Soil Natural Capital Accounting
    - Proof of concept conducted combining soil and land cover data sets to assess soil resource areas under different Broad Habitats

The statistical design of the sampling is robust and intended to determine status and trend of the countryside and the Glastir options particularly those prioritised by the Welsh Government in the Advanced Element. Thus location for sampling in our Targeted Survey is proportional to the points available in the Advanced Element for different parcels of land whilst sampling methodology for national trends in soil quality has been used effectively by the Countryside Survey for the last 30 years (Reynolds *et al*., 2013) and a similar approach is now used by the EU for the monitoring of agricultural ecosystems across Europe under the LUCAS program (Toth *et al*., 2013).

7.7 Methods

7.7.1 Carbon and organic matter content (Loss-on-ignition)

Soil samples are collected each year in plastic sleeves, 15 cm long and 5cm wide. Loss-on-Ignition, (LOI) was measured on a 10 g air dried sub-sample taken after sieving to 2 mm. The sub-sample was dried at 105°C for 16 hours to remove moisture, weighed, then combusted at 375°C for 16 hours. The cooled sample was then weighed, and the loss-on-ignition (%) calculated. Soil carbon concentration was determined, using a total elemental analyser; the method used was the Centre for Ecology and Hydrology, Lancaster accredited method SOP3102. The LOI values were calibrated to carbon concentration using a multiplication factor of 0.55 determined from the calibration with the total carbon in order to be consistent with Countryside Survey data. For interpretation of the scale, soil type based on soil organic matter content is defined as mineral soil (0-44 g C kg^{-1}), humus-mineral (44-165 g C kg^{-1}), organo-mineral (165-330 g C kg^{-1}) and organic soil (330-550 g C kg^{-1}), the maximum carbon content is 550 g C kg^{-1}. Soil carbon density was calculated by combining with bulk density data.

7.7.2 pH

Once the 15cm soil cores from the field survey arrive back in the laboratory soil pH determination is carried out on a suspension of fresh field-moist soil sub-sampled from the core. The measurement is made in deionised water; the ratio of soil to water is 1 to 2.5 parts by weight. The method used is based upon that employed by the Soil Survey of England and Wales.

7.7.3 Nitrogen

Glastir soil samples were analysed at the Centre for Ecology and Hydrology for total nitrogen using an accredited method. Samples were analysed using an Elementar Vario-EL elemental analyser (Elementaranalysensysteme GmbH, Hanau, Germany). The Vario EL is a fully automated analytical instrument working on the principle of oxidative combustion followed by thermal conductivity detection. Following combustion in the presence of excess oxygen the oxides of nitrogen and carbon flow through a reduction column which removes excess oxygen. Carbon is trapped on a column whilst nitrogen is carried to a detector. Carbon is then released from the trap and detected separately. Sample weights are usually 15 mg for peat and 15-60 mg for mineral soil samples. The concentration of total nitrogen is expressed in % dry weight of soil.

7.7.4 C:N

The concentration of total nitrogen and carbon is expressed as a % dry weight of soil.

7.7.5 Phosphorus

Olsen-P was used to measure available phosphorus in the soil samples collected in the countryside Survey and which provides a strong argument for using the same method in Glastir to establish a time-series. The Countryside Survey began monitoring nutrients in 1998 with measurements of available phosphorus measured using Olsen-P. Olsen-P is widely used across England and Wales to assess the fertility of agricultural soils, and has also been assessed as part of several national soil monitoring schemes.

The method for Olsen-P is well established and involves extraction of 5 g of air-dried, sieved soil with 100 ml of 0.5M sodium bicarbonate at pH 8.5. The phosphorus in the extract is then determined colorimetrically using a Skalar continuous flow analyser. The Skalar method uses molybdenum blue at 880nm with the addition of a dialysis step to overcome the effect of the Olsen's reagent.
The method is known to be unreliable for acid and organic-rich soils so values for unimproved land and bogs should be treated with caution. The method was used to ensure continuity with the CS data but other methods are being tested under the NERC Macronutrient Turf-2-Surf project which we will exploit if resources are available.

7.7.6 Texture

The particle size distribution of a soil, typically presented as the proportions of clay (<2 µm), silt (2-63 µm) and sand (63-2000 µm) sized mineral particles is a fundamental property of the soil. Prior to analysis it is essential that all OM has been removed, for most soils it is recommended that hydrogen peroxide is used. The Soil Survey of England and Wales typically used a combination of the pipette method and sieving to determine the particle size of soils. There are fundamental differences between this method and the laser granulometer approach and it is necessary to use a different size threshold for the clay fraction, here we use <8 µm.

7.7.7 Bulk density

Soil samples, were collected from the field using a plastic core (15cm long and 5cm in diameter) sleeved inside a metal volumetric coring device. In the laboratory, samples were weighed and dried. Once dry, the soils were sieved, separated to 2mm fine earth fraction, and stones and debris removed. All components were weighed and the bulk density was calculated excluding stones and other debris.

7.7.8 Topsoil water repellency

Soil water repellency (surface) measurement is carried out by measuring the time for a fixed volume droplet of deionised water to be fully absorbed into the soil surface (Water Drop Penetration Time (WDPT))

7.7.9 Soil microbial diversity

Soil samples are collected each year using a soil corer. In each sampling location, 5 individual soil cores, each 15 cm long and 1 cm wide, are taken and bulked. These are then stored cold in sterile containers until they are returned to the laboratory where they are frozen at -80°C. The samples are then sieved to pass 2 mm and the DNA extracted from the whole microbial community from a sub-sample of the soil (1 g) using a MO-BIO PowerSoil® DNA Isolation Kit. The DNA is then molecular barcoded (i.e. DNA code characterised to identify different types of microorganisms present in the sample) and subjected to high throughput sequencing using the Illumina MiSeq sequencing platform at the NERC Biomolecular Analysis Facility. The sequences for bacteria, fungi, archaea and microbial eukaryotes are then processed using the bioinformatics program QIIME on the High Performance Computing Wales network.

7.7.10 Topsoil mesofauna

Soil cores are collected each year in plastic sleeves, 8 cm long and 4cm wide. The soil cores are removed from their sleeve and the mesofauna are extracted using a dry Tullgren extraction method. This consists of placing the soil cores over a mesh and gently heating and drying them by exposure to a light bulb. The soil mesofauna move downwards through the mesh into a funnel and are collected in ethanol preservative. Once collected, the different groups of soil mesofauna are sorted and counted using a stereomicroscope (up to ×100 magnification). The sum of these groups is used as an indicator of soil mesofauna abundance (or Total catch).

7.8 Results, status and trends

The results presented here also appear in the portal, they are presented as questions, most of which for the first year regard the long-term trends as compared with historic data from the Countryside Survey. As the survey progresses in time, we will be able to report on more Broad Habitats and the impact of specific bundles of options proposed in Glastir. Any detection of change will to a large degree depend on the uptake of options across the Glastir scheme. The status and trend results are shown first, then there is a short section at the end with a feasibility / scoping study of determining the Soil Natural Capital Assets in Wales, as part of improving reporting in the context of Natural Capital and Ecosystem Services in relation to national accounting.

7.8.1 What are the long term trends for soil chemical and physical properties in Wales?

7.8.1.1 Carbon

Soil organic carbon (SOC) is important for maintaining the structure and function of soils. It is involved in nutrient retention and cycling whilst enhancing soil physical structure, helping soils to retain water (reducing flood risk) and allowing improved root growth (enhancing food production). Moreover, it is an important store of carbon, which needs to be protected to avoid it being emitted to the atmosphere as carbon dioxide. A healthy soil may even accumulate more carbon over time, locking up atmospheric carbon dioxide and contributing to climate change mitigation.
Under the Kyoto Protocol the UK is required to make estimates of net carbon emissions to the atmosphere, including emissions and removals by soils linked to land-use. However, knowledge of soil carbon stocks and changes is limited; previous work from the National Soil Resources Institute and partners suggested that soils in England and Wales were losing carbon due to climate change, but this has been contested by subsequent studies based on more comprehensive soils data which suggest that the soil carbon stocks have remained stable.

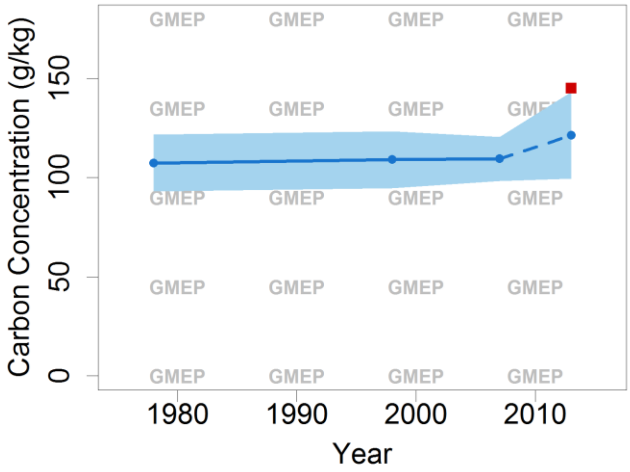


Figure 7.8.1.1.1 *GMEP data for topsoil carbon concentration for 2013 compared with data collected since 1978 by the Countryside Survey. Solid blue line (CS data); dashed blue line (GMEP 2013 Wider Wales Survey); Red squaredot (GMEP Targeted survey).*

The results for Wider Wales sampling (2013 blue circle), show that no significant change in soil carbon concentration has occurred between the last Countryside Survey sampling in 2007 and GMEP in 2013. The red square shows the Targeted sampling mean carbon concentration lying above the Wider Wales value; these GMEP 1km survey squares are monitored specifically for soil carbon and pollution. The fact they lie above indicates they are being targeted correctly.

One of the powers of the Glastir monitoring is that it helps relate soil carbon stocks to vegetation, habitat and other environmental data allowing easier assessment, and potentially better targeting of land-management activities aimed at mitigating greenhouse gas emissions. The data provided by this survey contributes to the knowledge of how soil carbon is changing, how this relates to vegetation change and land use and management and provides evidence of the effectiveness of soil protection legislation in Wales. There is generally a trade-off between maintaining high levels of soil organic carbon (SOC) and productivity. The most carbon is stored in peat bogs which are low productivity systems, whereas the least amount of SOC is stored in arable mineral soils which are continually ploughed and cropped. Fens are perhaps the exception to this being high in carbon and productivity, having been drained; but we are losing carbon from these soils. Maintaining healthy levels of soil organic matter can provide an economic buffer against market price spikes, for example against fuel and fertiliser costs in some agri-ecosystems. The soil organic matter acts as a nutrient reserve that can be accessed at times when prices are high and rebuilt in between.

The reported results are split into two groups, those representing the Wider Wales (Blue circle, 2013) part of the survey and those that represent the Targeted (Red square, 2013) part of the survey. The Wider Wales sampling is joined to the Countryside Survey long-term monitoring by the dashed line, and provides a baseline against which change can be assessed. The targeted sampling contains areas that are prioritised in Glastir for targeted options. The results presented here serve as a check to see if the samples in the targeted GMEP 1km survey squares differ from Wider Wales.

7.8.1.2 Soil acidity

Soil pH is probably the most commonly measured soil chemical parameter. It gives an indication of soil acidity and alkalinity and is of relevance to agriculture and forestry as it impacts plant growth, both directly and indirectly. Many plants have a wide tolerance of pH, but changes in pH bring about changes in the solubility of a number of important nutrients which can have an adverse effect on plant growth. Phosphorus availability decreases below pH 6, whilst some other micro-nutrients also become less available as acidity increases; calcium and magnesium may also become deficient. Moreover, if pH drops below ~5 other metal cations become soluble, particularly aluminium which is toxic to plants; manganese and iron can also be problematic becoming toxic to plants in acid soils. In Wales, recovery from acidification is important and of direct relevance to farmers and policy makers. It is currently estimated that 58% of terrestrial semi-natural habitats across Great Britain receive acidic deposition in excess of their buffering capacity thus potentially causing long term damage according to the critical load methodology. Change in soil pH has been documented by both the Countryside Survey for Great Britain and the National Soil Survey for England and Wales. Compared to Great Britain, Welsh soils are more acidic than in other countries across most Broad Habitat types. In general pH of soils has been increasing across Wales as soils recover from acidification; the results shown here are consistent with that. There is no significant change in soil pH compared with the last Countryside Survey.

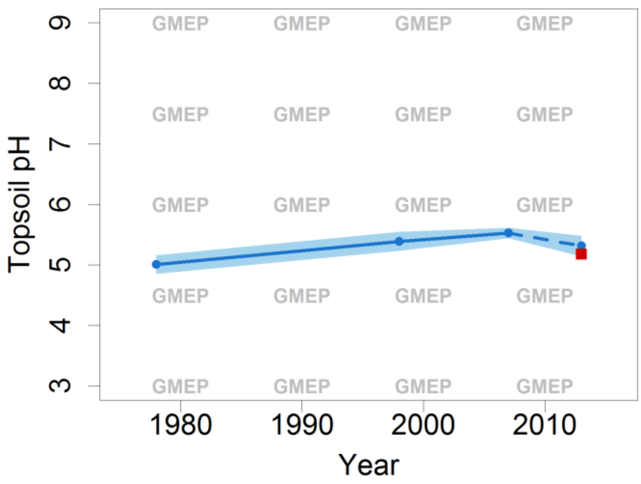


Figure 7.8.1.2.1 *Long term trends in topsoil pH using CS data (blue line); dotted line GMEP Wider Wales Survey; and re square (GMEP Targeted survey).*

The Wider Wales sampling is joined to the Countryside Survey long-term as methods were identical and together they provide a baseline against which change can be assessed. The targeted sampling contains areas that are prioritised in Glastir for targeted options. The results presented here serve as

a check to see if the samples in the targeted GMEP 1km survey squares differ from Wider Wales. The results show both samples are not significantly in contrast to carbon concentrations.
Evidence from Countryside Survey indicates that soils are recovering from air pollution and acidification and the Glastir Monitoring and Evaluation Program data is consistent with that. This provides benefits to growers who require less inputs like lime to raise pH, it is also good for plant life and biodiversity. However, there may also be a trade-off with carbon storage, as more carbon is stored in acidic soils. This will be something to watch and determine from the Glastir survey, whether changes in carbon concentration are observed between acid and neutral and improved grasslands.

Results from the Countryside for particular Broad Habitats show that the most acid soils in Wales in 2007 were those beneath Coniferous Woodland (pH 4.14), whilst soils beneath enclosed farmland Broad Habitats were the least acid. Since 1978 the average pH of improved and neutral grassland has been increasing, with mean values approaching pH 6 in 2007.

7.8.1.3 Nitrogen

Nitrogen (N) availability commonly limits plant productivity, and so is important for determining agricultural and forest production and as a control on plant diversity. Soil total nitrogen concentration is a basic indicator of soil fertility so to a limit is desirable in agricultural and forestry soils but undesirable in habitat / conservation areas. Soil total nitrogen concentration generally increases with organic matter content, and so is greater on infertile peaty soils, but within a particular soil type an increase in concentration, particularly when expressed relative to carbon concentration, implies that nitrogen is accumulating. Most soils have a large stock of relatively unreactive nitrogen, so total nitrogen concentration is relatively insensitive to short-term changes, but over a longer time period gives an overall indication of trend in soil fertility and change in nutrient status in relation to other parameters such as carbon. Changes in plant species composition, primarily homogenisation with loss of specialist species, were observed following the Countryside Survey in 1998 and these were ascribed to ecosystem nitrogen pollution following enhanced deposition of atmospheric nitrogen compounds which are emitted from both agricultural sources (animals and fertilisers) and combustion of fossil fuels (e.g. within the transport & energy sectors).

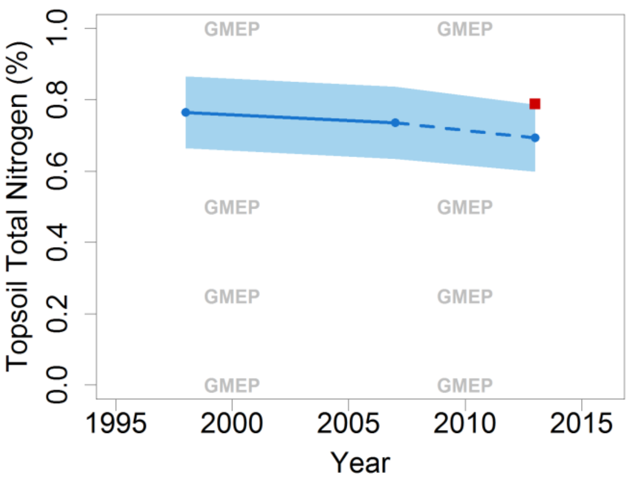


Figure 7.8.1.3.1 *Long term trends in topsoil total nitrogen content using CS data (blue line); dotted line GMEP Wider Wales Survey; and re square (GMEP Targeted survey).*

The Wider Wales sampling is joined to the Countryside Survey long-term monitoring and provides a baseline against which change can be assessed. The targeted sampling contains areas that are prioritised in Glastir for targeted options. The results presented here serve as a check to see if the samples in the targeted GMEP 1km survey squares differ from Wider Wales. There was no significant change in soil nitrogen concentration across Wales as a whole between 1998 and 2007 or between 2007 and 2013.

Enhanced soil nitrogen status can influence plant species assemblages in two ways. Reactive nitrogen limits plant production in many terrestrial ecosystems, so increased exposure to anthropogenic nitrogen is likely to result in increased plant growth. Consequent changes to competitive interactions have been implicated as a cause of plant diversity loss. Secondly, some plants are known to respond to changes in the ratio of available ammonium to available nitrate in the soil.

7.8.1.4 C:N

The soil nitrogen concentration data were combined with total carbon concentration data to calculate changes in soil carbon to nitrogen ratio (C:N) (0-15 cm). The C:N ratio is more informative about the availability of reactive nitrogen than is the nitrogen concentration in soil. Countryside Survey didn't have enough data to report change in C:N ratio for Wales, but provided general data for Great Britain. Tir Gofal monitoring found no difference between control and Tir Gofal managed sites.

Habitat	Indicator	CS 1998	CS 2007	GMEP 2013	Significant differences
Broadleaved, Mixed and Yew Woodland	Mean C/N ratio	14.0	14.2		
Coniferous Woodland	Mean C/N ratio	20.1	21.5		↑ 98-07
Arable and Horticulture	Mean C/N ratio	11.7	11.3		↓ 98-07
Improved Grassland	Mean C/N ratio	11.8	12.0		
Neutral Grassland	Mean C/N ratio	12.3	12.7		↑ 98-07
Acid Grassland	Mean C/N ratio	17.7	18.2		
Bracken	Mean C/N ratio	15.2	16.5		
Dwarf Shrub Heath	Mean C/N ratio	22.9	23.1		
Fen, Marsh and Swamp	Mean C/N ratio	16.4	17.7		
Bog	Mean C/N ratio	26.2	28.2		
All Habitat types	Mean C/N ratio	15.6	16.0		↑ 98-07

Table 7.8.1.4.1 *Topsoil C:N change over time for CS and GMEP habitats and Wales as a whole.*

Countryside Survey data showed that the general trend across all Broad Habitats in Great Britain is for no change or an increase in carbon to nitrogen ratio (C:N). The trend for increased C:N ratios (significant for Coniferous Woodland and Neutral Grassland) indicates that there is either increased removal of nitrogen from the soil by vegetation, leaching or gaseous pathways and / or greater inputs and storage of carbon due to increased plant productivity. Change in plant fixation of carbon and uptake of nitrogen may be driven by the combined and possibly interactive effects of nitrogen deposition and climate change on plant productivity.

For cropped systems, a decline in % nitrogen and C:N ratios was observed for Great Britain suggesting the loss of soil carbon (0-15cm) found in Countryside Survey for these habitats is matched by a loss of nitrogen (9 and 7.5% respectively between 1998 and 2007). As there was only a small decline in nitrogen fertiliser application rates to tilled land across Great Britain between 1998 and 2007 (e.g. in England 6% drop for tilled land), it is most likely that processes which would remove soil carbon and nitrogen in equal proportions may be responsible e.g. erosion or deep ploughing resulting in lower soil horizons characterised by lower C:N coming to the surface. Lower values in improved grass suggest too much nitrogen, nitrogen levels were still high in 2007 in improved grass.

7.8.1.5 Phosphorus

Olsen-Phosphorus (Olsen-P) is one of a number of measures of available phosphorus. Phosphorus is one of the three macronutrients, nitrogen and potassium being the others, that plants need a lot of for growth, and are key inputs in NPK fertilizer. High Olsen-P levels had been observed in agricultural, especially arable, soils where excessive applications of phosphorus had been made. Efforts have been made over the last few decades to reduce inputs and bring phosphorus levels down to increase efficiency and reduce waste and pollution.

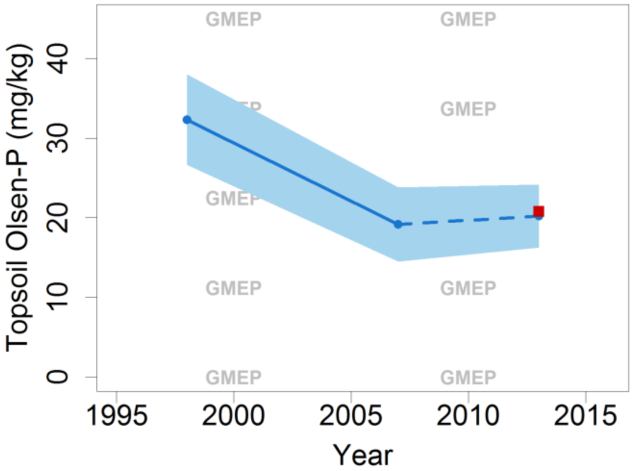


Figure 7.8.1.5.1 *Long term trends in topsoil phosphorus availability (Olsen-P) using CS data (blue line); dotted line GMEP Wider Wales Survey; and re square (GMEP Targeted survey).*

The Wider Wales sampling is joined to the Countryside Survey long-term monitoring and provides a baseline against which change can be assessed. The targeted sampling contains areas that are prioritised in Glastir for targeted options. The results presented here serve as a check to see if the samples in the targeted GMEP 1km survey squares differ from Wider Wales. The results show both samples are not significantly different.

Overall the data for Glastir probably indicates a stabilising of Olsen-P levels in Welsh soils, but cannot be confirmed until Countryside Survey and GMEP are run in the same year. This follows on from data collected by the Countryside Survey which reported that Olsen-P values declined across Wales between 1998 and 2007 across all Broad Habitats (41%). The largest significant decrease (47%) was in the Improved Grassland Broad Habitat. This is consistent with data on fertiliser use compiled by Defra for England and Wales, which shows fertiliser inputs on grasslands have decreased dramatically since the 1980's.

Managing available P levels in the agricultural context will reduce the risk posed by phosphorous in surface water (< 20 µg/l) which can cause detrimental effects to water quality. Moreover, applying excess fertilizer to land simply results in losses and wasted economic investment. The scientific benefit of using Olsen-P is that it has been widely used in England and Wales to assess the fertility of agricultural soils and is also an integral part of several national soil monitoring schemes including the Representative Soil Sampling Scheme, the National Soil Inventory and Countryside Survey.

7.8.2 Is there any evidence of a difference in soil condition of land coming into the Glastir scheme?

Setting a base line is important, and in this first year of Glastir we want to determine if the soils selected for the Glastir scheme differ from soils that are not selected for Glastir. In future years, this will help us to determine the impact of being in Glastir for soil quality and health. The data is limited at present due to only one year of data being available out of the total four years of baseline to be collected. Improved power of detection of differences are likely as sample size increases.

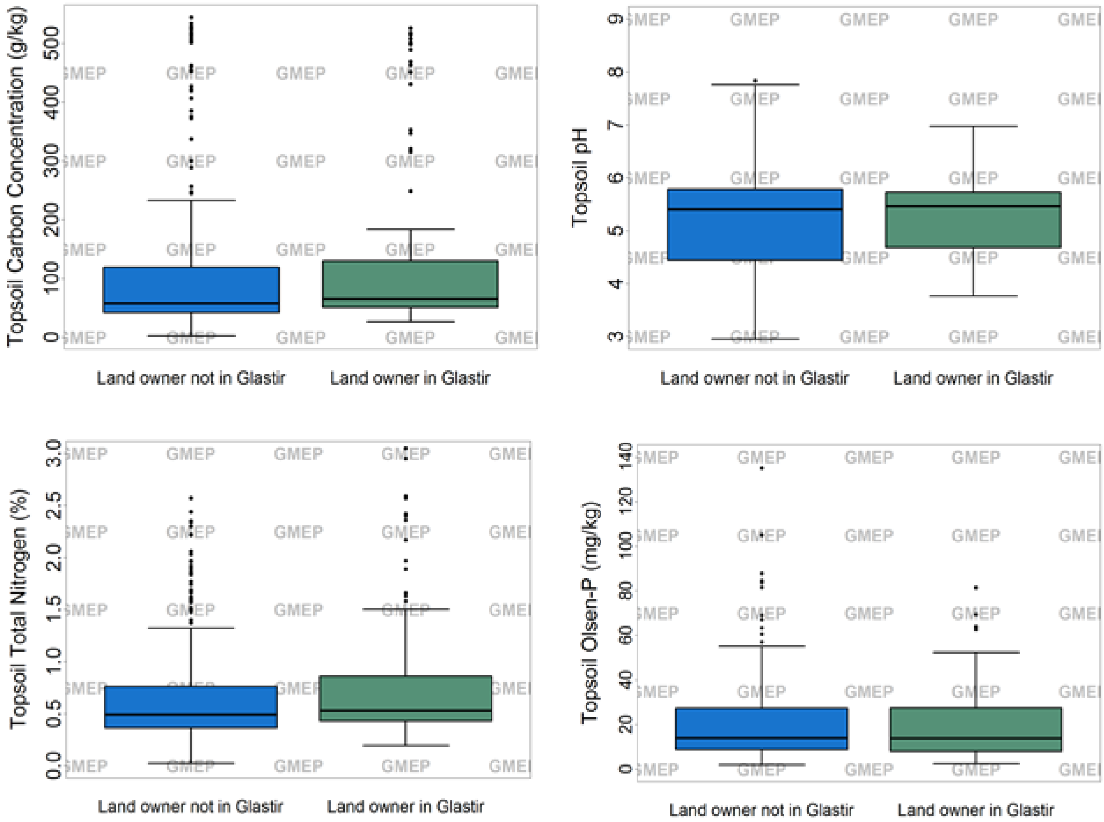


Figure 7.8.2.1 *Soil chemical properties of land in and out of the Glastir scheme in 2013; carbon, pH, total nitrogen and available phosphorus (Olsen-P). The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots. There are currently no significant differences between soil chemical properties on land in and out of scheme.*

Soil texture is a classification of the size of particles in soil and describes the amount of sand, silt and clay. It is a description of the fabric of a soil and is important for agricultural practice and engineering as well as underpinning much of the science of soils. The texture impacts both the physical and biogeochemical behaviour of soil. The smaller the soil particles are, the more reactive surface area they have. It is on these surfaces that nutrients are stored or transformed. Soil texture is important for assessing physical flow and transport behaviour as well as erodability, and workability. The most detailed survey of soil texture is held by the Soil Survey of England and Wales.

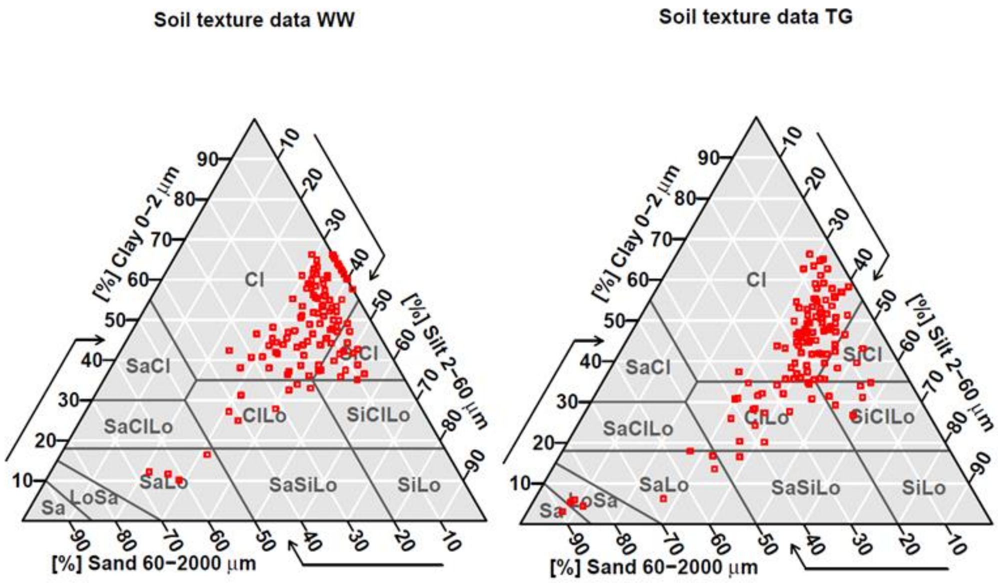


Figure 7.8.2.2 *Textures for soil of land in and out of Glastir in 2013.*

The data shows the soil textures for samples measured in the Wider Wales (WW) GMEP 1km survey squares which are representative of Wales. The second figure shows soil texture for the Targeted (TG) GMEP 1km survey squares, which were chosen by the Welsh Government for specific targeted options. The data show that much of Wales has a high proportion of clay and clay loam soils and there are subtle differences between soil texture of land coming into the scheme which we explore as more samples come in.

7.8.3 Is there any evidence that the soil condition is higher in soils which were in past AES schemes, Tir Gofal, Tir Cynnal, compared to those that were not in schemes?

Setting a base line is important, and in this first year of Glastir we want to determine if the legacy from past agricultural environment schemes (AES), e.g. Tir Gofal, Tir Cynnal, has had any detectable influence on the soils across Wales with regard to altering carbon concentrations.

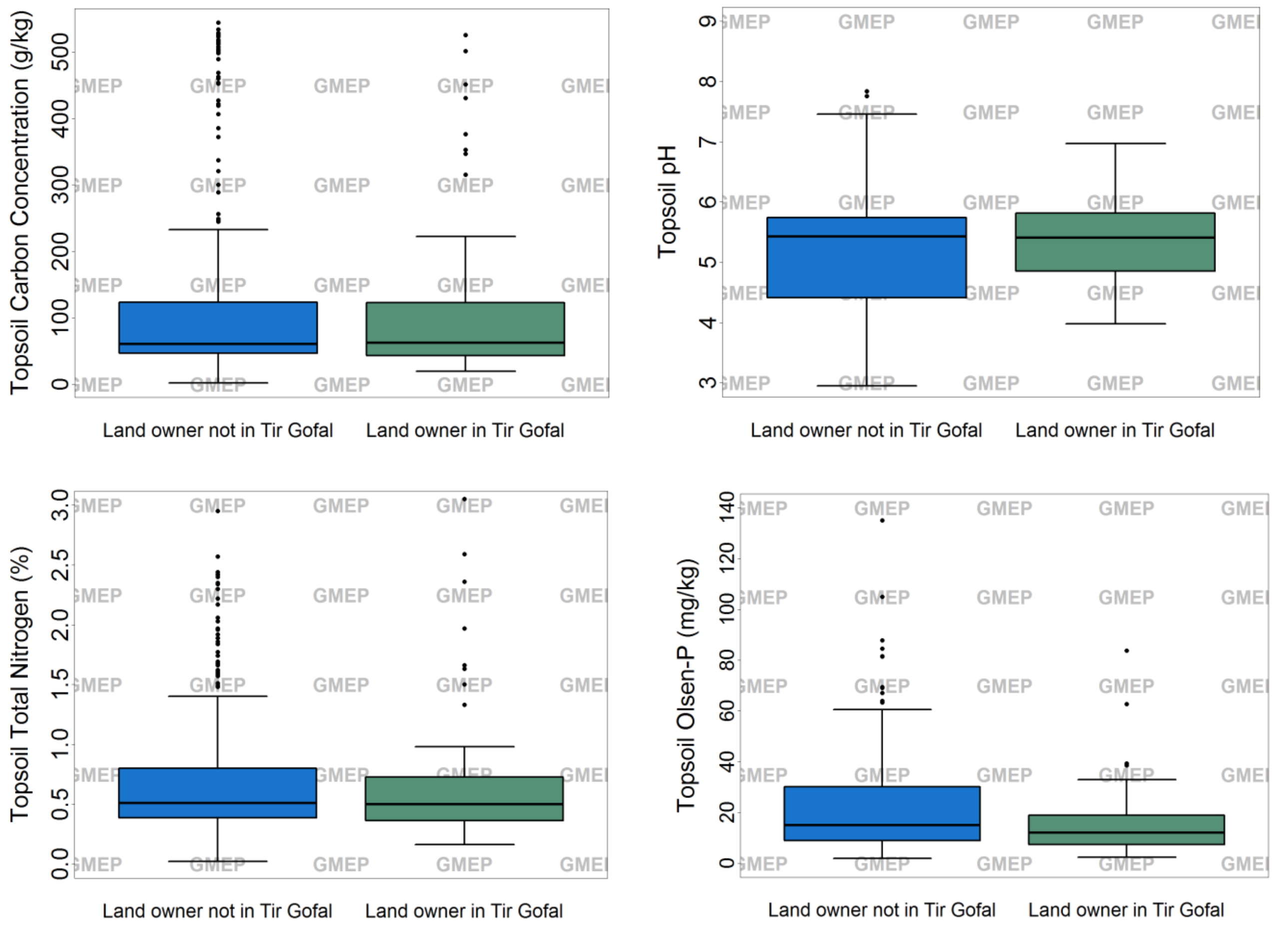


Figure 7.8.3.1 *Condition of soils that were in a past agri-environment scheme, e.g. Tir Gofal, or Tir Cynnal in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

Data indicates there is not a significant difference between the two groups. However, it is noticeable that the lower range of the Tir Gofal managed plots is higher than those outside a scheme. This might indicate that the soils selected for the scheme had higher carbon, or management practices have increased carbon levels. The boxplots show that there is no statistical difference between the pH of soils where the landowner was in Tir Gofal versus a landowner that was not in Glastir. The results do however indicate that the range of soil pH for the soils entered into Tir Gofal is narrower than those outside, which may be a function of the land entered in the scheme rather than a change. The Tir Gofal monitoring program found that Olsen-P levels were similar between sites, other than with some of the neutral grassland sites under prescription 32 A/B ('Conversion of Improved Grassland to Semi-improved Grassland' with no lime or fertilizer to be spread). The difference between sets of Tir Gofal prescription and 'control' sites was not thought to be due to the influence of the Tir Gofal scheme itself, but rather due to the fact that Tir Gofal prescriptions tend to be allocated to sites where extractable P is lower. This reflects the tendency for Tir Gofal prescriptions to be located on sites of lower potential productivity (relative to non-Tir Gofal prescription sites) and with a history of minimal or no lime and fertiliser use. Within GMEP Year 1 samples, the available phosphorous levels are significantly lower on the land that was under agri-environment scheme management. According to the Tir Gofal report, this was most likely due to the land being entered into the scheme having lower available phosphorous to start.

7.8.4 How do soils vary in condition by Broad Habitat?

7.8.4.1 Carbon

Soils represent a major terrestrial carbon store that we want to protect for both soil quality, hydraulic function and to protect against climate change. We need to understand which habitats have the highest carbon concentrations and seek to maintain these.

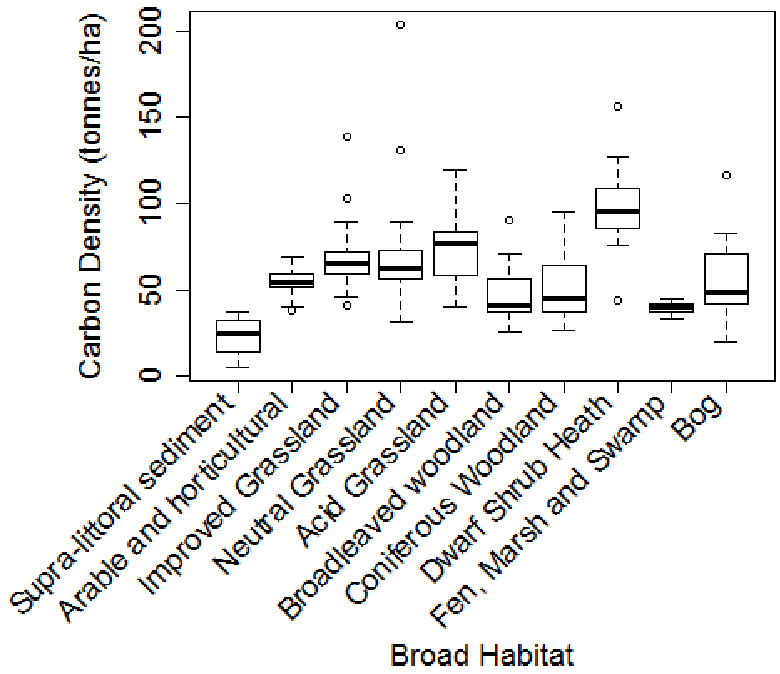


Figure 7.8.4.1.1 *Topsoil (0-15 cm) carbon density within different Broad Habitats across Wales in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

The highest topsoil stocks are in the heath and grassland soils; most likely in the heathlands as they are often associated with organo-mineral soils with a dense organic soil horizon. Grasslands on the other hand contain high concentrations of carbon and are relatively dense. Countryside Survey reported that between 1978 and 2007 there had been no change in the carbon stocks in fertile or infertile grassland. It is important to remember that these figures are only for topsoils (0-15 cm), where we would expect to see the greatest levels of change. Peat soils represent the largest overall soil carbon store because, accounting for high soil organic carbon below this depth, they are greater than 40 cm deep, and often several metres.

7.8.4.2 Soil acidity

It is useful as a baseline for future assessment of GMEP data to know how topsoil pH changes across habitats. The data indicates that more than 75% of neutral and improved grasslands have soil pH above 5. Bogs, Coniferous Woodlands and Dwarf shrub heath all have the lowest values of pH with more than 75% of the data below pH 5. The 2008 UK Soil Indicators Consortium assessed values for soil pH to ‘prompt’ management action. The testing of these prompt values suggested that managed grasslands should aim to maintain soil pH values above 5, and dwarf shrub heath above pH 4.5, to maintain habitat support.

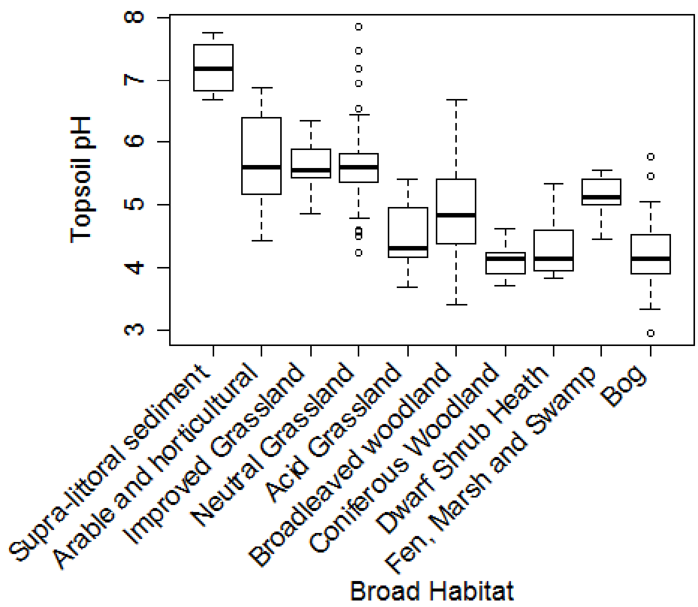


Figure 7.8.4.2.1 *Topsoil pH across Welsh Broad Habitats in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

7.8.4.3 C:N

The soil nitrogen concentration data were combined with soil carbon concentration data to calculate the soil carbon to nitrogen ratio (C:N) (0-15cm). The C:N ratio is more informative about the availability of reactive nitrogen than is total nitrogen concentration in soil. The 2008 UK Soil Indicators Consortium proposed 'prompt value' ranges for C:N within which a habitat should sit for optimal function:

Calcareous grassland 11-14
Neutral grassland 10-14
Broadleaf woodland 12-17
Coniferous woodland 16-26
Improved grassland 10-12
Acid grassland 14-21
Arable and horticultural 9-13
Bog 20-31
Dwarf Shrub Heath 19-29
Bracken 13-18

In an indicator testing exercise they found that the ranges were too narrow, and so we propose these ranges be viewed as desirable values.

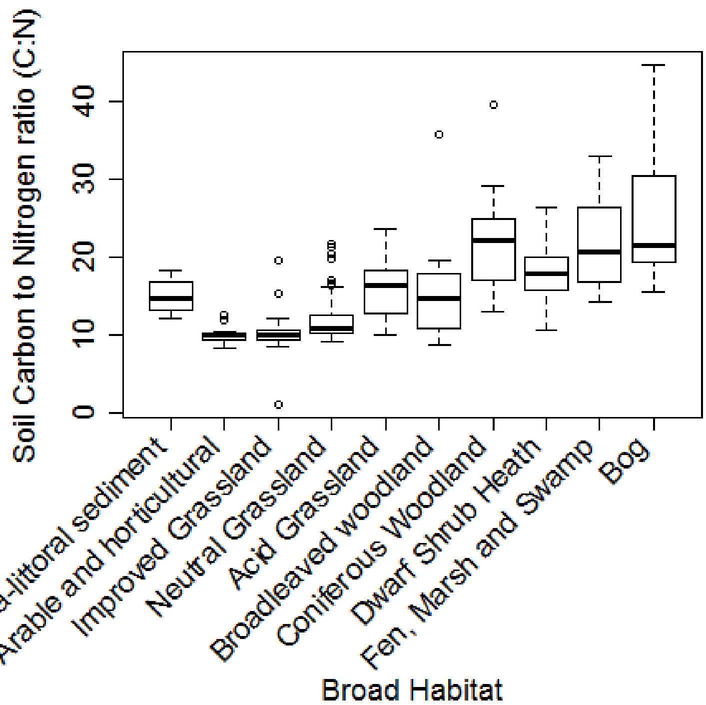


Figure 7.8.4.3.1 *Topsoil C:N ratios for Welsh Broad Habitats in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

Countryside Survey data showed that the general trend across all Broad Habitats in Great Britain is for no change or an increase in C:N ratio. The boxplot shows that for the Broad Habitats measured by Glastir Monitoring and Evaluation Program across Wales all the middle values fall within the expected range for habitat support. Generally we might be concerned if C:N ratios were declining below 10 for neutral and improved grassland as this might indicate more reactive nitrogen in the soil system.

7.8.4.4 Phosphorus

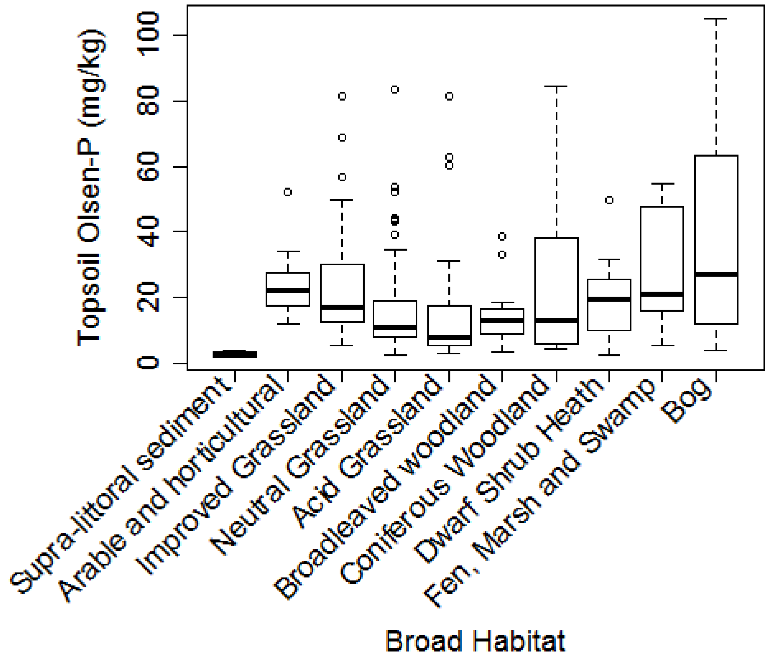


Figure 7.8.4.4.1 *Topsoil available phosphorus (Olsen-P) for Welsh Broad Habitats in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

Following the management intervention prompt values proposed by the UK Soil Indicators Consortium we propose that values for agricultural soils should not exceed 60mg/kg, whilst for grass lands, keeping below 15mg/kg is advisable to maintain habitat support. The Soil Indicators Consortium's general finding was that it was hard to provide specific prompt values for such a diversity of communities. In testing their prompt values they suggested that 30% of acid grasslands exceeded a prompt value of 10 mg/l and still had valuable species; whilst the value of 16 mg/l for calcareous grasslands should probably be brought down to 10mg/l. It appeared that a prompt value was not particularly appropriate for neutral grasslands. As a consequence we've suggested a prompt value of 15mg/kg as a guide suggesting 75% of acid grasslands should fall below this level. In the future, co-located soil and plant measurement data from the Glastir survey will help us to identify prompt values most suitable for the Welsh countryside.

7.8.4.5 Bulk density

Soil bulk density (BD) is the single most useful parameter for assessing soil physical structure and porosity. It is a direct measure of soil compaction (or loosening) and is essential to assess total available pore space within a soil (that is, total porosity). This question seeks to determine the general status of Welsh soils with regard to bulk density. Compacted soils act as a focus for storm water runoff and soil erosion whilst inhibiting the growth of plant roots. There is usually a strong relationship between bulk density and soil organic carbon content, the bulk density decreasing, and porosity increasing, as organic carbon increases.

The boxplots show bulk density declining from the habitats dominated by mineral soils to those dominated by organic soils like the upland bogs. No definitive 'trigger points' have been identified, or agreed, for bulk density for all soils by the 2008 UK Soil Indicators Consortium. However, 'prompt' values above which mineral and peat soils in grasslands and heaths are liable to be suffering from compaction have been proposed. These are 1.3 gcm^3 for mineral soils and 1.0g/cm^3 for peat soils. All grassland and heath soils were below prompt values, except one of the improved, and one of the neutral grassland sites. Further investigation indicated this was not simply due to high sand content and might indicate compaction. The Supra-littoral Broad Habitat has the highest values which are associated with sandy soils which we commonly expect to have bulk densities in the region of 1.4-1.6 g/cm^3. The data findings are in broad agreement with the Tir Gofal monitoring which also found very few soils above 1.3gcm^3 and no difference between control and sites in the Tir Gofal scheme.

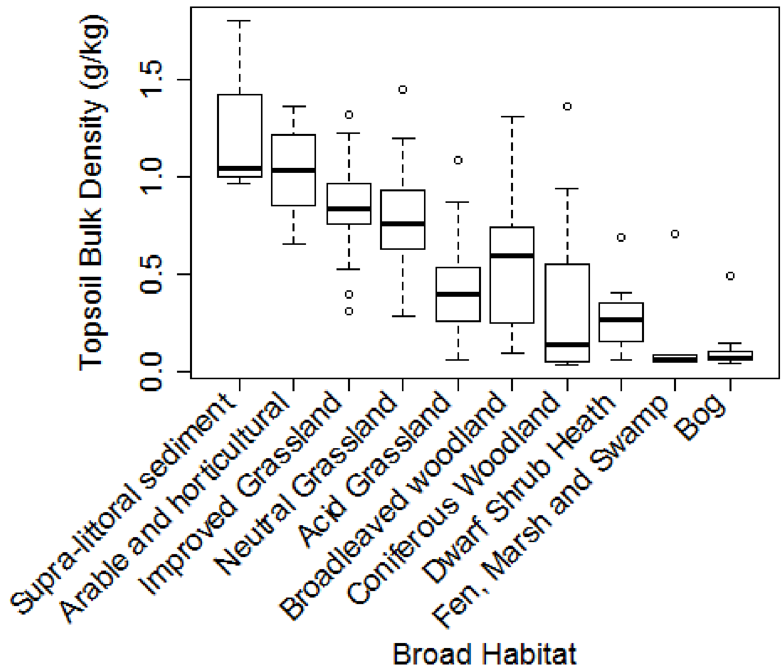


Figure 7.8.4.5.1 *Topsoil bulk density in Welsh Broad Habitats in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

7.8.5 What is the potential for land management to change soil condition

GMEP in the long term will be able to address this question but in the meantime we have three approaches to start exploring this issue; a) assessment of past AES scheme outcomes, b) experimental data and c) comparing data from different land management/uses. All have some fundamental problems.

a) Past AES scheme monitoring have struggled to separate differences of land coming into the scheme from the effect of the scheme;
b) Experiments frequently being too short term to quantify change thus making assessments e.g. for inventory work challenging
c) An assumption that current changes are due to land management rather than pre-existing differences before the land management took place.

Despite these differences, we have undertaken two of these analyses using the GMEP data. See Section 7.8.3 for a discussion on soil quality from past AES schemes. Here we explore the differences in soil condition under different land management types. For a summary of experimental evidence this has been summarised most effectively recently with respect to grassland management for the Land Use, Land Use Change and Forestry Inventory (see http://ecosystemghg.ceh.ac.uk/).

7.8.5.1 Is carbon concentration increasing under Improved Grassland?

Results from the Countryside Survey (Emmett et al., 2010) indicated that there had been an increase in the carbon concentration in fertile grasslands and a decline in infertile grasslands. Although not statistically different, it indicated a general direction of change. The Glastir monitoring will seek to determine if differences and changes in carbon concentrations in grassland systems can be detected. Not sufficient GMEP data yet, but evidence from Countryside Survey 2007 presented in the figure shows the change in soil C concentration (0-15 cm) for Wales between 1978 and 2007 for fertile and infertile grassland. No significant change was observed. Clearly the increased number of samples within GMEP will enable us to detect change with greater power.

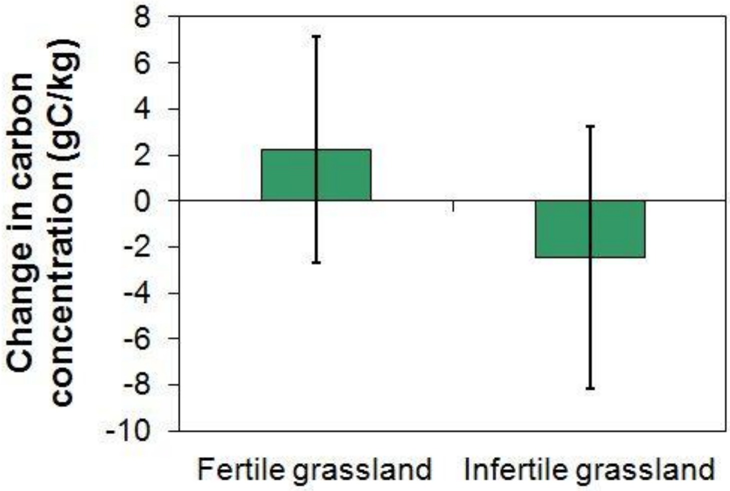


Figure 7.8.5.1.1 *Change in soil C concentration (0-15 cm) for Wales between 1978 and 2007 for fertile and infertile grassland (Countryside Survey data). Bars indicate 95% Confidence Intervals.*

7.8.5.2 Is soil water repellency greater in woodlands compared to grassland and other habitat types?

Soil water repellency (SWR) is a measurement of how wettable the soil surface is. It alters the way water infiltrates into soils potentially enhancing infiltration in soils with big pores like many woodlands, hence reducing flood risk. Recently SWR has also been linked to the increased stabilization of carbon in soils by protecting organic matter from breakdown by microbes and enzymes (Goebel et al., 2011). Schmidt et al. (2011) touched upon this role of SWR when reviewing our understanding of soil carbon as an ecosystem property. The Glastir monitoring program is the first UK survey to contain this measurement. Often only considered an issue in Mediterranean-type climates it is increasingly being observed in temperate climates and has been shown to be damaging to UK agriculture, for instance potato production in East Anglia. Our scientific understanding of the development and persistence of soil water repellency is still not mature. However, its presence can lead to erratic behaviour with regard to water movement in soils. Some may be aware of the problems green keepers have with dry spots on golf courses, this is induced by water repellency and causes the grass to die. Moreover, it affects the way water infiltrates into soils and may impact nutrient cycling. Given concern over extreme weather events, drought and flooding, anything that changes how rainfall infiltrates, or runs off at the soil surface in response to extremes is of both agronomic and policy interest. In Mediterranean climates soil water repellency is often associated with forestry. Therefore, land use change to forest from other land uses may alter the way water runs off the landscape.

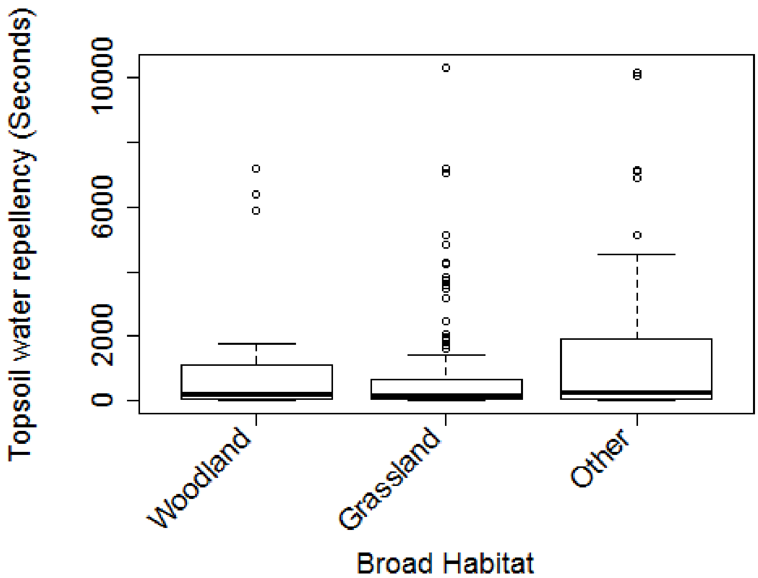


Figure 7.8.5.2.1 *Topsoil water repellency for three habitat groups in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

The data are currently limited and have been aggregated together into woodland, grassland and other habitat types. At this level of aggregation the 'other' category have the most repellent soils, (average = 1452 seconds) whilst the woodlands (average = 1043 seconds) are more repellent than the grasslands (average = 663 seconds). However, the average for the grasslands still puts them in the severely water repellent class according to the Dekker and Ritsema classification; wettable soils are those into which a water drop enters in less than 5 seconds. The test whether this is linked to land use or inherent soil properties will be explored as land is re-visited which have changed from e.g. from grassland to woodland.

Our understanding of the disadvantages of soil water repellency are best understood, potentially causing dry-patches in turf or enhanced runoff and erosion after fire. Our understanding of the benefits is much more limited, but recent research in drylands suggests that water repellency can be an advantage, enhancing infiltration through macropores and moisture storage and increasing soil organic matter stability in soils. Others have suggested that repellent soil may protect nitrogen preventing its rapid mineralisation. The relationship with flood risk is not known, but in soils with plenty of macropores soil water repellency might reduce flood risk, the converse may also be true. Many Glastir options will lead to changes in the composition of the vegetation community and will also alter key properties and functions of the soil. This is likely to lead to changes in the soil microbial community (e.g. bacteria, fungi, archaea, protozoa, collembola, earthworms etc.). These could impact on a range of ecosystem services linked directly and indirectly to the soil microbial community including: (1) the recycling of nutrients within the plant-soil system, (2) regulating the balance between the release of greenhouse gases and the sequestration of carbon in soil, (3) the decontamination of organic pollutants, (4) enhancing plant growth through symbiotic relationships, (5) the provision of food for birds, (6) the purification of water, and (7) regulating soil structure and water infiltration.

7.8.6. What is the current status of soil biodiversity in Wales and what influences its spatial and temporal pattern?

7.8.6.1 How does soil microbial diversity differ across Broad Habitat types in Wales?

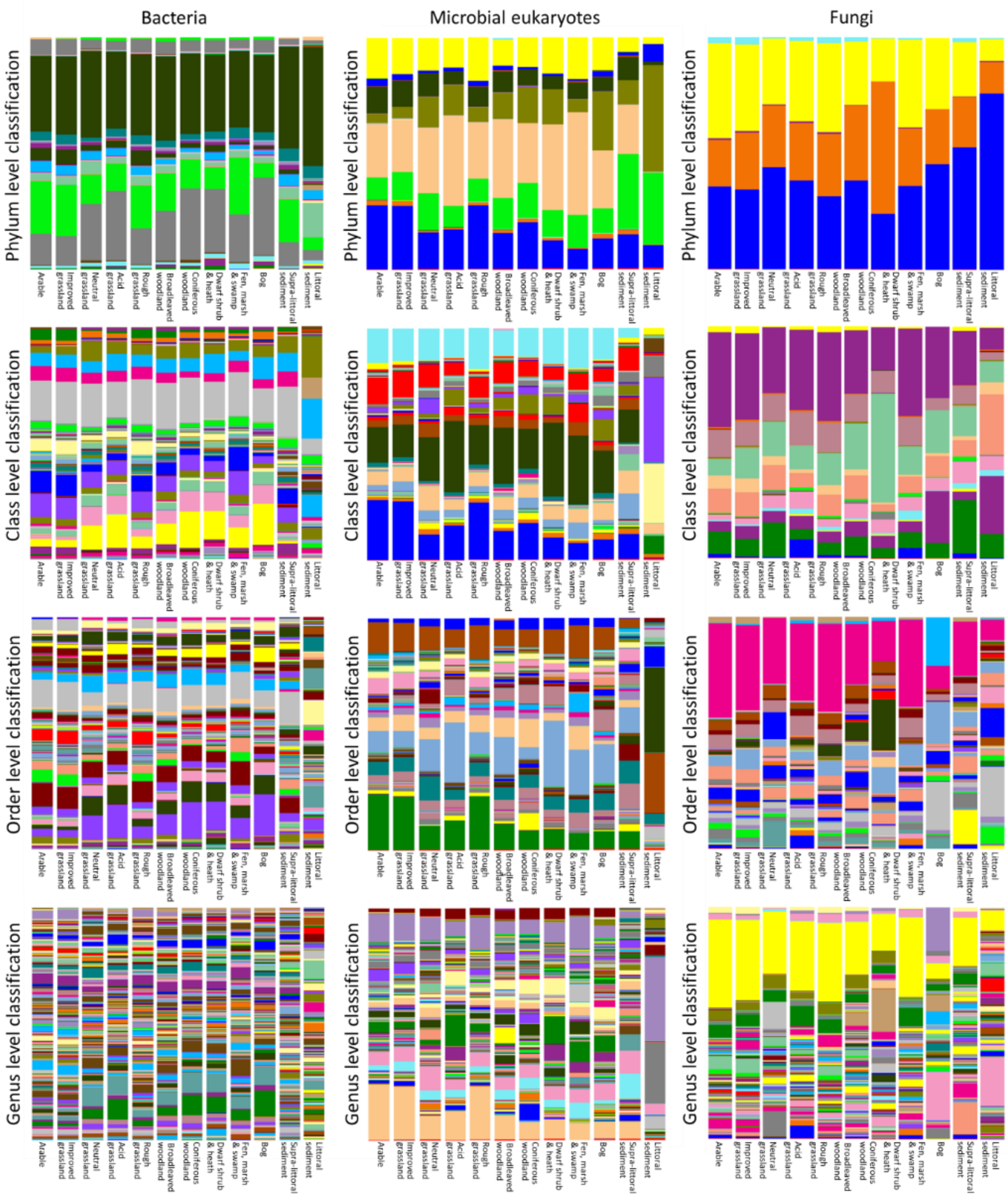


Figure 7.8.6.1.1 *Bacterial, non-fungal eukaryotes and fungal communities at a range of taxonomic levels starting at the highest level (Phylum level) and ending at the lowest level (Genus level) for Broad Habitat types in Wales in 2013. The coloured bars represent different bacterial and fungal types at each taxonomic level. At the lowest taxonomic level (Genus), some coloured bars are too small to be seen (i.e. genus of low abundance).*

The reported results show that Broad Habitat types in Wales have unique microbial communities and thus land use has a major impact on the structure of soil microbial communities. This can be seen when the microbial communities are classified by Broad Habitat type. The figure below shows bacterial community composition at a range of taxonomic levels (Phylum → Class → Order → Genus) for 12 different Broad Habitat types within Wales. It is clear that each Broad Habitat has a unique community composition and that these are most apparent at the lower taxonomic levels (e.g. genus level). Of particular note are that improved grassland and arable soils have very similar community compositions. These, however, are vastly different from unimproved grasslands suggesting that land use change and a reduction in inputs (e.g. fertiliser, lime) will induce shifts in community composition. Littoral soils showed a vastly different community composition in comparison to all other Broad Habitat types. This is the first ever holistic survey of soil biodiversity in Wales and consequently we cannot evaluate how this is changing over time.

Although our knowledge of soil biodiversity is still in its infancy we know that the soil community underpins a wide range of ecosystem services which are being promoted under Glastir. The current consensus is that a more biodiverse community will also be more resilient to stress conditions. In addition, it is also apparent that microbial communities respond to change and therefore act as sentinels of change. In Glastir we are therefore looking for soils that have high levels of diversity which should be promoted by reducing fertiliser inputs, by planting trees at low density and via the enhanced storage of organic matter. In addition, we are looking for shifts in keystone species which control processes associated with greenhouse gas emissions (e.g. methanogens), nutrient cycling (e.g. nitrifiers), water repellency (e.g. fungi) or animal disease and loss of water quality (e.g. *E. coli*). There is the potential for ecosystem trade-offs in shifts in the microbial community. For example, a reduction in the number of nitrifiers may reduce greenhouse gas emissions and nitrate leaching, but this may limit the supply of available nitrogen to grassland, forage crops etc.

7.8.6.2 How does soil organic carbon affect microbial biodiversity in the soils of Wales?

Sequestering more carbon in Welsh soils is a key goal of Glastir as this is known to improve soil quality and also help reduce climate change. Many Glastir options will lead to changes in soil organic carbon which are likely to lead to changes in the structure and activity of the soil microbial community (e.g. bacteria, fungi, archaea, protozoa, collembola, earthworms etc.). These could impact on a range of ecosystem services linked directly and indirectly to the soil microbial community including: (1) the recycling of nutrients within the plant-soil system, (2) regulating the balance between the release of greenhouse gases and the sequestration of carbon in soil, (3) the decontamination of organic pollutants, (4) enhancing plant growth through symbiotic relationships, (5) the provision of food for birds, (6) the purification of water, and (7) regulating soil structure and water infiltration.

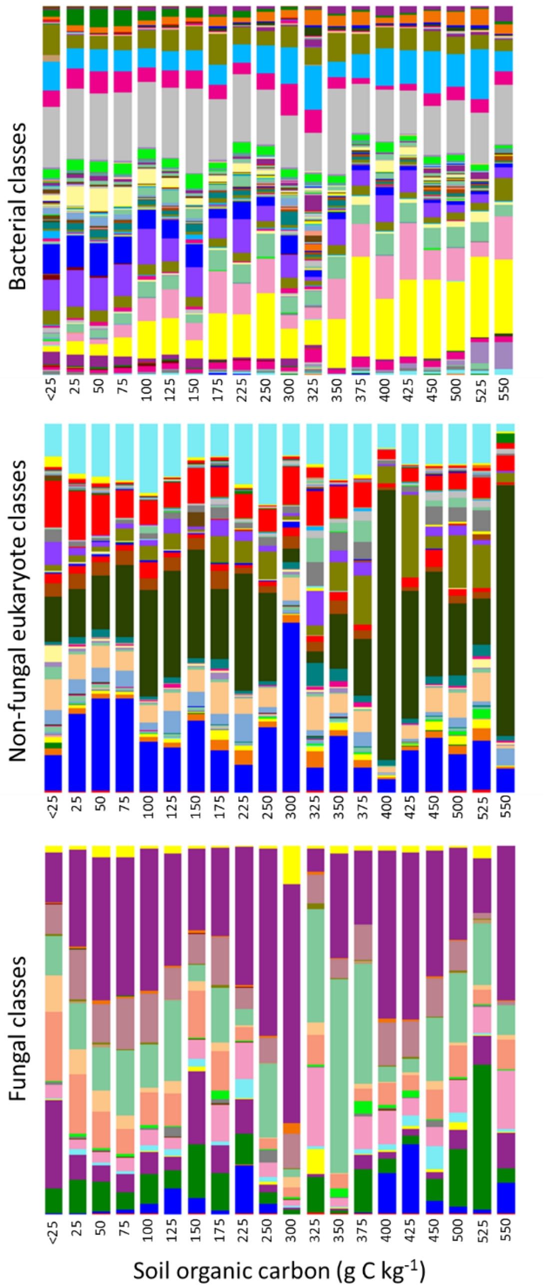


Figure 7.8.6.2.1 *The relative abundance of bacterial, non-fungal eukaryotes and fungal communities living in the soil for different soil organic carbon contents in 2013. The microbial communities are presented at the Class taxonomic level. The coloured segments in each bar represent the relative abundance of different bacterial, non-fungal eukaryotes and fungal taxonomic classes.*

The results show that soil organic matter status has a major impact on the structure of soil microbial communities. This is most apparent in the types of bacteria present in the soil with trends less apparent in the fungal and non-fungal eukaryotes. The results suggest that changes in soil organic matter status will induce a shift in soil microbial communities. It should be noted that the amount of soil organic carbon and pH are closely correlated and it is likely that bacterial diversity is responding to both an increase in soil organic matter and reduction in pH simultaneously.

7.8.6.3 How does soil pH affect soil microbial biodiversity in the soils of Wales?

Many Glastir options will lead to changes in soil pH which are likely to lead to changes in the soil microbial community (e.g. bacteria, fungi, archaea, protozoa, collembola, earthworms etc.). These could impact on a range of ecosystem services linked directly and indirectly to the soil microbial community including: (1) the recycling of nutrients within the plant-soil system, (2) regulating the balance between the release of greenhouse gases and the sequestration of carbon in soil, (3) the decontamination of organic pollutants, (4) enhancing plant growth through symbiotic relationships, (5) the provision of food for birds, (6) the purification of water, and (7) regulating soil structure and water infiltration.

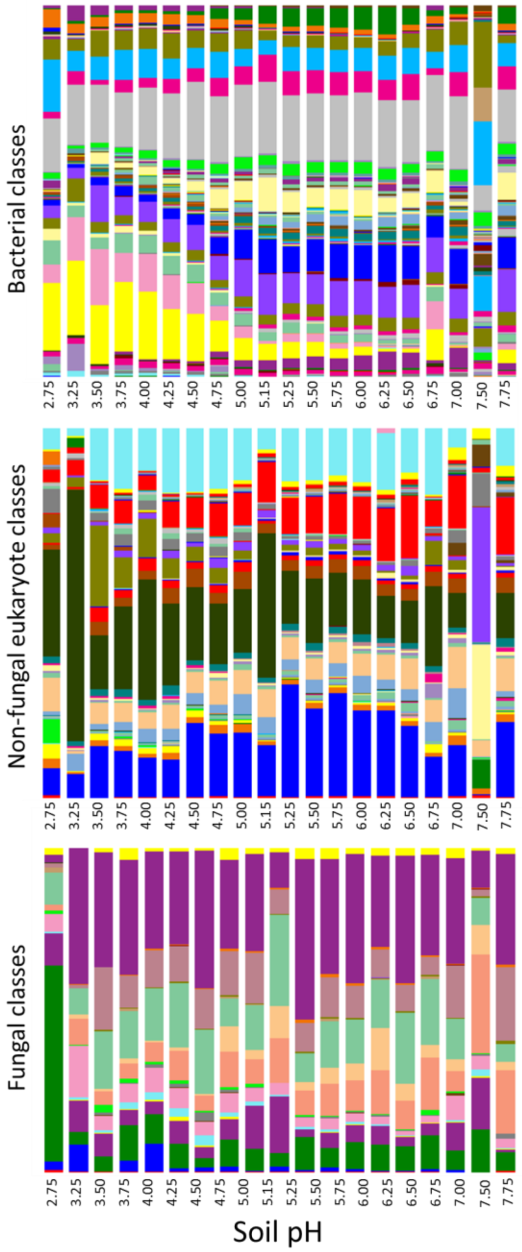


Figure 7.8.6.3.1 *The relative abundance of bacterial, non-fungal eukaryotes and fungal communities living in the soil in soil of different soil pH classes in 2013. The microbial communities are presented at the Class taxonomic level. The coloured segments in each bar represent the relative abundance of different bacterial, non-fungal eukaryotes and fungal taxonomic classes.*

The results show that pH has a major impact on the structure of soil microbial communities. This is most apparent in the bacterial community while pH trends are less apparent in the fungal and non-fungal eukaryotic communities. The results suggest that a reduction in liming, and concomitant reduction in soil pH, will induce a shift in soil microbial communities.

7.8.6.4 How does soil type influence microbial communities across the Welsh landscape?

Habitat class, soil chemical composition and soil type may all be expected to impact in topsoil microbial biodiversity. Here we explore the evidence for the influence of soil type influence.

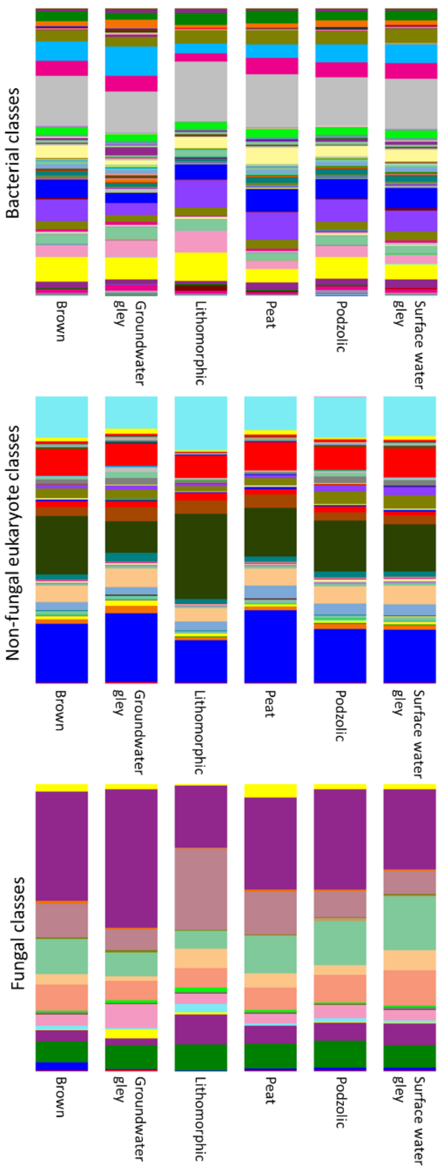


Figure 7.8.6.4.1 *The relative abundance of bacterial, non-fungal eukaryotes and fungal communities by major soil types in Wales in 2013. The microbial communities are presented at the Class taxonomic level. The coloured segments in each bar represent the relative abundance of different bacterial, non-fungal eukaryotes and fungal taxonomic classes.*

Despite the differences in the relative abundance in bacterial classes it also apparent that the same classes of microorganisms are mostly represented in all soils across Wales. The results indicate that in comparison to other factors which greatly affect soil biodiversity (e.g. Broad Habitat type), soil type has only a small influence on soil microbial communities. This suggests that it is the changes in land use under Glastir which will have a significant effect on the structure and probably functioning of the community.

7.8.6.5 Is the abundance of topsoil mesofauna changing across Wales?

Soil mesofauna (e.g. mites and collembolans) are invertebrate organisms which tend to be highly abundant and diverse in soils. Hundreds of thousands can be found in a square metre of soil. The feeding activities of these mesofauna have an important influence on a range of services provided by the soil including the breakdown of waste and organic matter, the regulation of the microbial community, nutrient cycling and pest control. In turn, the abundance and biodiversity of mesofauna can be used as an indicator of the quality or 'health' of soils.

Increasing pressures on soil biodiversity, such as land use intensification, soil organic matter decline, soil compaction and climate change, have been identified at EU level. Comparing mesofauna abundance with that recorded in previous Countryside Surveys can therefore help us establish whether soil biodiversity in Wales is increasing, decreasing or stable.

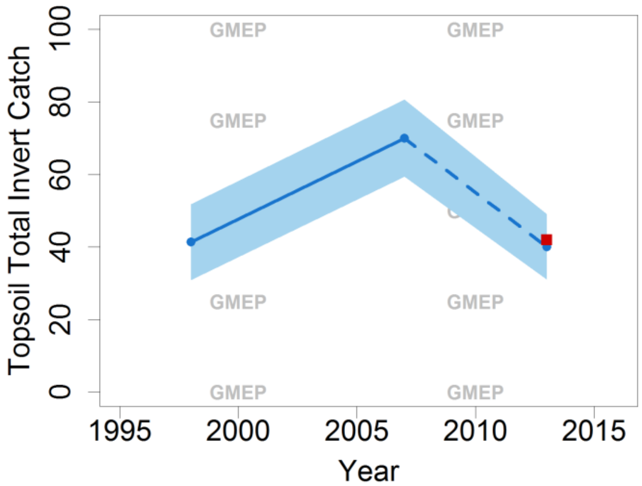


Figure 7.8.6.5.1 *Trend in topsoil mesofauna abundance using CS data (blue line); dotted line GMEP Wider Wales Survey; and re square (GMEP Targeted survey).*

The reported results are split into two groups, those representing the Wider Wales (Blue circle, 2013) part of the survey and those that represent the Targeted (Red square, 2013) part of the survey. The Wider Wales sampling is joined to the Countryside Survey long-term monitoring by the dashed line, and provides a baseline against which change can be assessed. The targeted sampling contains areas that are prioritised in Glastir for targeted options. The results presented here serve as a check to see if the samples in the targeted GMEP 1km survey squares differ from Wider Wales. The results show both samples are not significantly different. Comparing GMEP and the previous Countryside Surveys helps us to understand how soil mesofauna abundance has changed over time. This can help to establish the general status of soil quality in Wales.

The figure shows the GMEP data for soil mesofauna abundance (Total catch) in 2013 compared to data collected by the Countryside Survey in 1998 and 2007. The results show that soil mesofauna abundance in Wales has decreased since 2007 but that it is similar to data from Countryside Survey in 1998.

A healthy abundance and biodiversity of soil mesofauna is important for the breakdown of waste and organic matter, the regulation of the microbial community, and the recycling of nutrients to crops and grass. Agricultural land management which encourages a healthy soil biological community can therefore reduce requirements for external inputs e.g. fertiliser. Different groups of soil mesofauna perform varied but overlapping roles in the soil. This means that, where we can support a greater biodiversity of mesofauna, soil services will be more resilient to land management practices and environmental pressures.

7.8.6.6 How does the abundance of topsoil mesofauna vary across Broad Habitats?

While it is important to understand the overall status of soil mesofauna abundance across Wales, different habitats contain different soil biological communities. To unravel the effects of land management and environmental pressures on soil biodiversity from natural fluctuations we need to understand both the differences between these habitats and the variability within them.

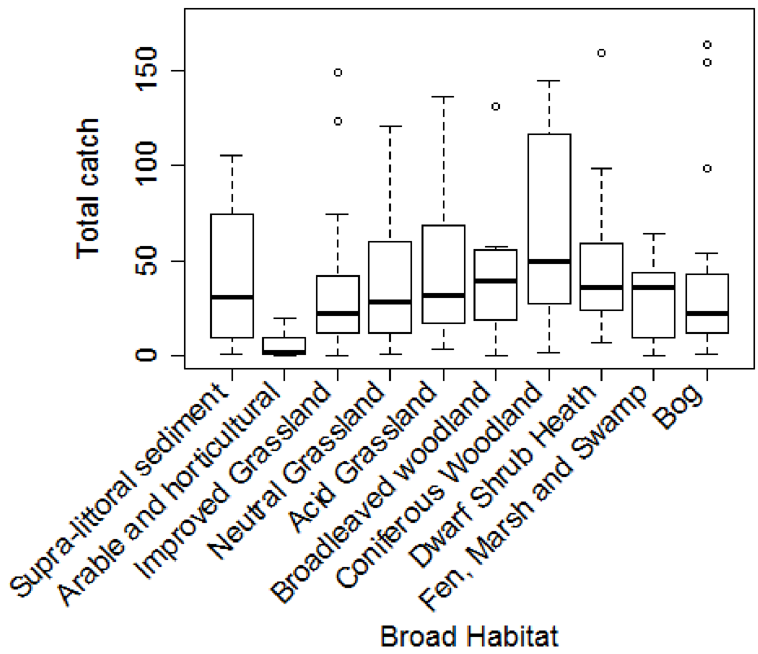


Figure 7.8.6.6.1 *Topsoil mesofauna abundance by Broad Habitats in Wales in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

Whilst there are differences between Broad Habitats they differ less than for physical and chemical characteristic which is surprising. The highest abundance of soil mesofauna are found in Broadleaved and Coniferous Woodlands, and the lowest abundance in Arable soils possibly due to inherent properties but more likely due to repeated tillage and low organic matter contents. Arable and Bog soils also have the lowest variability, while grasslands, woodlands and heath generally have much greater variability, in soil mesofauna abundance. The relative differences in soil mesofauna abundance between Broad Habitats are very similar to those reported from the Countryside Survey in 1998 and 2007, and in agreement with the wider literature.

7.8.6.7 Is there a legacy effect of past AE schemes on mesofauna?

Agri-environment schemes are expected to have a positive effect on soil mesofauna biodiversity by reducing physical disturbance and increasing soil organic matter. So that an appropriate baseline is set we want to determine if the legacy from past agricultural environment schemes e.g. Tir Gofal, Tir Cynnal, has had any detectable influence on the soil mesofauna across Wales.

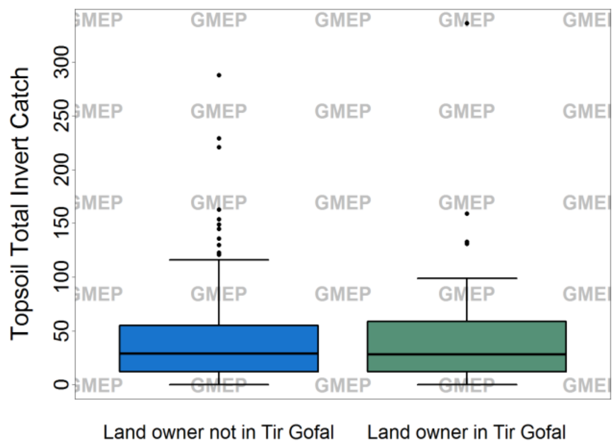


Figure 7.8.6.7.1 *Topsoil mesofauna abundance for land which was in and out of Tir Gofal using samples from 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

The figure indicates that with regard to total invert catch there was no difference between land that was in a past agri-environment scheme and land that wasn't.

7.8.6.8 Is there any difference in soil mesofauna biodiversity between soils under Glastir management compared to those out of scheme?

Setting a baseline is important, and in this first year of Glastir we want to determine if the soils selected for the Glastir scheme differ in soil mesofauna biodiversity from soils that are not selected for Glastir. In future years, this will help us to determine the impact of being in Glastir for soil quality and health.

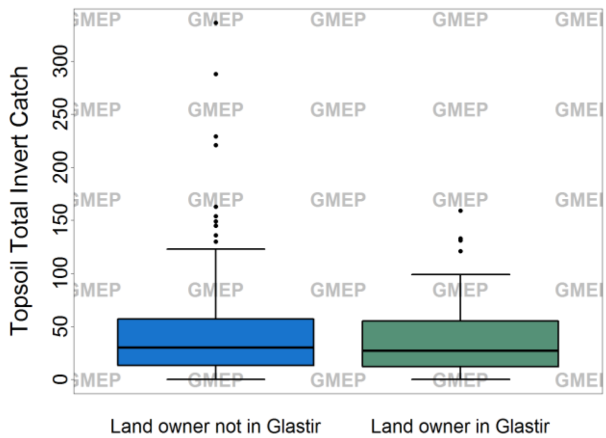


Figure 7.8.6.8.1 *Topsoil mesofauna abundance for land in and out of Glastir in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

These data indicate that there is no statistically significant difference in soil mesofauna abundance between soils being entered into Glastir, and soils outside of the scheme.

7.8.6.9 How does the biodiversity of soil mesofauna change with increasing soil organic matter?

Agri-environment schemes such as Glastir are expected to have a positive effect on soil mesofauna biodiversity. Such changes in the biodiversity may be brought about by increasing soil organic matter. While mesofauna abundance is known to increase with organic matter, it is less well understood how different groups of mesofauna respond.

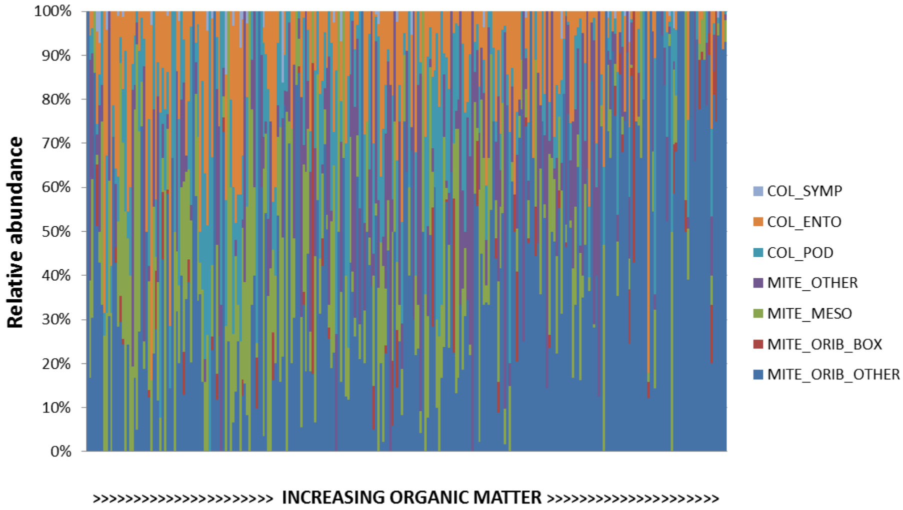


Figure 7.8.6.9.1 *Relative abundance of topsoil mesofauna by organic matter content for individual samples in 2013. These have been ordered by the associated organic matter data from these locations.*

While we can see that the different groups of soil mesofauna are found across all soils and there is much variation between samples, it is evident that their relative abundances change across the gradient of organic matter representing Welsh soils. These data can help to predict the effects of Glastir options which increase organic matter on soil biodiversity and the services to which they contribute.

7.8.6.10 Does extensification of grassland management increase mesofauna levels?

Agri-environment schemes such as Glastir are expected to have a positive effect on soil mesofauna biodiversity. Such changes in biodiversity may be brought about by increasing soil organic matter. Inputs to the soil such as mineral fertiliser can also have a negative effect on soil biodiversity. Reducing these inputs can therefore encourage greater soil biodiversity and the services to which they contribute.

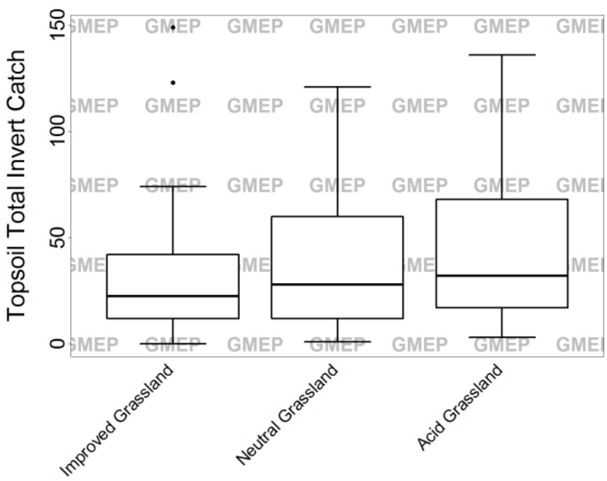


Figure 7.8.6.10.1 *Topsoil mesofauna abundance for different grassland types in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

There is not sufficient GMEP data yet on the effect of Glastir options, but differences in soil mesofauna abundance between Broad Habitats from GMEP in 2013 suggests that extensification of grassland could have a positive effect. The data show that there is a trend of increasing soil mesofauna abundance from Improved grassland to Neutral grassland to Acid grassland.

7.8.6.11 Does encouraging woody vegetation benefit mesofauna levels?

Soil mesofauna abundance and biodiversity is known to be greatest in woodland or forest systems. It is important to understand how long it would take for soil biodiversity to respond to options encouraging woody vegetation such as establishing trees or scrub.

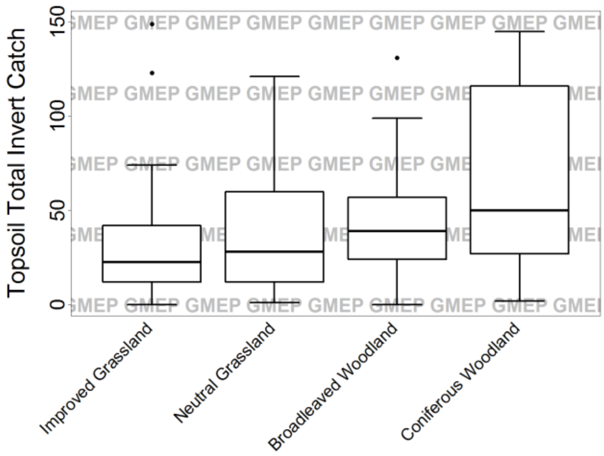


Figure 7.8.6.11.1 *Topsoil mesofauna abundance comparing grassland woodland habitats in 2013. The box indicates where 50% of the data sit with the lines showing minimum and maximum values excluding outliers which are shown by the dots.*

There is not sufficient GMEP data yet on the effect of Glastir options, but differences in soil mesofauna abundance between Broad Habitats from GMEP in 2013 suggests that encouraging woody vegetation could benefit mesofauna abundance. The data show that there is generally higher soil mesofauna abundance under Broadleaved and Coniferous Woodland compared to Improved and Neutral grassland.

7.8.7 How can we quantify the Soil Natural Capital Assets in Wales?

Soils are a fundamental resource in Wales supporting the ecosystems that in turn support agriculture and tourism. A number of initiatives are underway to recognise the value that natural resources provide to the economy. In most countries, national accounts of economic activity are recorded, and indicators such as gross domestic product (GDP) are widely used in government and policy to assess economic activity and progress. However, indicators such as GDP measure mainly market based transactions and are not good indicators of welfare; GDP ignores social costs, environmental impacts and income inequality (Costanza et al., 2014). GDP also does not deduct the direct cost of the depletion of natural resources on national income nor does it take into account the impact that our resource extraction and use of nature has on the continued functioning of the earth system for life support.

One proposal to address the deficiency of the current national accounts is to have a set of complementary accounts to augment the national accounts. Since the early 1990s, the international accounting and statistics community has been developing such a set of accounts, through the United Nations, named the system of environmental economic accounting (SEEA). The over-arching objective of the SEEA approach is to develop an accounting structure that integrates environmental information with the standard national accounts and hence mainstream environmental information in economic and development policy discussion.

The SEEA accounts are presented in two volumes. First, the SEEA Central Framework (UN et al, 2014) which was adopted as an international statistical standard in 2012, and second, the SEEA Experimental Ecosystem Accounting (UN et al., 2013). The SEEA Central Framework deals with individual environmental assets (minerals, timber, fish, water, soil, etc.), the flows of mass and energy between the environment and the economy, and the space in which this occurs. It provides a basis that can underpin accounting for soils and other natural resources in Wales.

Soils form an important part of the Central Framework, being recognized as an environmental asset in their own right. However, the detail of how to collate and present soil information and data is in its infancy. Soil resources are the volume of biologically active topsoil, and its composition in the form of nutrients, soil water and organic matter. The accounts are structured to recognize, and distinguish between, the use of an asset, e.g. soil volume and area within the asset accounts; or the use of the soil resource or elements of the soil resource e.g. carbon, nutrients and soil moisture in the physical flow accounts. Fundamental to the accounting process is the measurement of change for both the environmental and ecosystem accounts.

Using data available to GEMP we present a proof of concept approach for determining the area of soils for accounting. Using the rare and occasional soils previously identified in the HNV work, we cross analysed these with land cover data from 2007. This allows us to identify the percentage of each soil type under a particular Broad Habitat type (Table 7.8.7.1).

Analysis of land cover and soil information (Table 7.8.7.2) found that 63% of fen, marsh and swamp areas have rare soils due to the presence of peat, while 77% of saltmarsh areas contain occasional soils, predominantly of the raw gley soil type. Approximately one-fifth of urban and suburban areas also contain rare or occasional soils, along with a similar proportion for areas classified as inland rock. All of these land cover types make up a small proportion of total land cover in Wales. These landcover/soil units could then be used as the basis for area accounting. Then using historical and future landcover maps, changes in the area of soils under particular habitat types could be determined and accounted for. Hence changes in the area of soil resources could be tracked and accounted for. Decisions could then be made on whether a set of physical accounts with area changes are sufficient to inform policy, or whether economic valuation should be attempted. This preliminary work provides an important step towards the development of an internationally recognised method of accounting for soil and other natural capital in Wales.

	Broadleaved Woodland	Coniferous Woodland	Arable & Horticulture	Improved grassland	Rough grassland	Neutral grassland	Calcareous grassland	Acid grassland	Fen, marsh, swamp	Dwarf shrub heath	Heather grass	Bog	Montane habitats	Inland rock	Saltwater	Freshwater	Supra-littoral rock	Supra-littoral sed	Littoral rock	Littoral sed	Saltmarsh	Urban	Suburban
Rare Soils																							
10.2.4 Earth eutro-amorphous peat soils	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	**53.5**	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.7	0.0	0.0	0.1	0.6	0.0	0.0
10.2.2 Earthy eu-fibrous peat soils	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	**9.8**	0.1	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.3.1 Typical cambic gley soils	0.0	0.0	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.5.2 Humus-ironpan stagnopodzols	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.2**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Occasional Soils																							
7.1.2 Pelo-stagnogley soils	1.1	0.2	1.2	1.1	0.4	**12.8**	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.3	0.4	0.0	0.0	1.1	0.2	0.2	1.1	2.1
6.3.1 Humo-ferric podzols	0.5	0.5	0.1	0.2	0.8	0.0	0.0	1.9	0.0	5.1	3.0	0.1	0.0	1.0	0.0	0.2	**7.4**	0.0	2.1	0.0	0.0	0.2	0.1
5.7.2 Stagnogleyic argillic brown earths	29.1	33.5	12.1	22.2	25.4	0.7	**43.6**	24.6	0.4	16.4	24.7	1.3	4.6	12.6	10.1	10.4	9.5	0.3	1.4	1.7	0.8	7.5	9.9
3.6.1 Typical sand pararendzinas	0.5	0.9	0.2	0.2	0.6	0.0	0.0	0.0	0.2	0.4	0.1	0.0	0.0	0.7	1.8	0.5	12.6	**88.5**	2.8	36.3	3.7	4.9	1.2
9.6.2 Permeable, seasonally wet raw made ground soils	0.8	0.7	0.3	0.4	1.3	0.0	0.0	0.2	0.0	0.7	0.8	0.0	0.0	**5.6**	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.6	1.1
8.1.4 Pelo-calcareous alluvial gley soils	0.1	0.0	1.7	0.3	0.4	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	6.8	2.2	3.1	0.0	0.6	**12.2**	0.3	3.1	5.5	1.7
6.5.1 Ironpan stagnopodzols	0.0	0.4	0.0	0.0	0.3	0.0	0.0	1.0	0.0	**2.2**	2.1	0.2	0.0	1.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.5.1 Typical brown sands	2.2	0.3	3.9	2.2	0.7	26.9	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.8	**29.3**	0.0	0.0	0.1	0.1	0.4	5.6	4.8
8.1.3 Pelo-alluial gley soils	0.1	0.0	1.1	0.4	0.2	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	1.1	0.0	0.1	0.2	2.0	0.2	**2.4**	0.8
8.1.2 Calcareous alluvial gley soils	0.0	0.0	1.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**2.3**	1.9	0.0	0.0	0.0	1.7	**2.3**	**4.7**	0.7
3.1.3 Brown rankers	0.8	0.0	0.1	0.1	0.3	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	2.4	4.5	0.5	**4.9**	0.2	4.1	2.3	0.2	0.3	0.3
2.2.0 Unripened gley soils	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	2.7	0.6	0.0	1.7	0.1	20.4	**69.6**	0.0	0.1
8.2.1 Typical sandy gley soils	0.1	0.0	0.1	0.2	0.5	0.1	0.0	0.0	**11.8**	0.0	0.1	0.0	0.0	0.0	0.7	0.7	6.1	0.7	1.4	2.0	0.9	0.4	0.3
5.4.3 Gleyic brown earths	0.2	0.1	0.9	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.0	3.4	0.2	2.2	0.0	**5.0**	0.0	0.0	0.5	0.9
4.3.1 Typical argillic pelosols	0.3	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.0	0.0	0.2	**0.9**
8.7.1 Typical humic gley soils	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.3	**0.6**	0.0	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0
5.4.2 Stagnogley brown earths	**0.2**	0.1	0.1	**0.2**	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
9.2.4 Well aerated raw made ground soils'	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	**10.6**	1.3	1.8	0.0	0.0	0.0	0.1	0.0	0.7	0.1

Table 7.8.7.1 *Rare and occasional soils as a percentage of land cover type. Maximum amounts for each soil highlighted.*

	Broadleaved Woodland	Coniferous Woodland	Arable & Horticulture	Improved grassland	Rough grassland	Neutral grassland	Calcareous grassland	Acid grassland	Fen, marsh, swamp	Dwarf shrub heath	Heather grass	Bog	Montane habitats	Inland rock	Saltwater	Freshwater	Supra-littoral rock	Supra-littoral sed	Littoral rock	Littoral sed	Saltmarsh	Urban	Suburban
Rare soils																							
10.2.4 Earth eutro-amorphous peat soils	0.11	0.01	0.08	**0.45**	0.05	0.00	0.00	0.00	0.19	0.01	0.06	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01
10.2.2 Earthy eu-fibrous peat soils	0.07	0.15	0.03	0.05	0.00	0.00	0.00	0.00	0.09	0.04	0.03	**0.53**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
8.3.1 Typical cambic gley soils	0.00	0.00	**0.60**	0.38	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
6.5.2 Humus-ironpan stagnopodzols	0.19	0.04	0.01	0.06	0.01	0.00	0.00	0.14	0.00	**0.45**	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Occasional soils																							
7.1.2 Pelo-stagnogley soils	0.08	0.02	0.12	**0.55**	0.05	0.06	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09
6.3.1 Humo-ferric podzols	0.04	0.05	0.01	0.10	0.12	0.00	0.00	**0.37**	0.00	0.15	0.14	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
5.7.2 Stagnogleyic argillic brown earths	0.08	0.11	0.05	**0.41**	0.12	0.00	0.00	0.15	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
3.6.1 Typical sand pararendzinas	0.05	0.10	0.02	0.12	0.09	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	**0.39**	0.00	0.05	0.01	0.06	0.06
9.6.2 Permeable, seasonally wet raw made ground soils	0.08	0.09	0.05	**0.28**	0.24	0.00	0.00	0.05	0.00	0.03	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07
8.1.4 Pelo-calcareous alluvial gley soils	0.01	0.00	**0.30**	0.27	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.09	0.12
6.5.1 Ironpan stagnopodzols	0.01	0.09	0.00	0.01	0.11	0.00	0.00	**0.42**	0.00	0.14	0.20	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.5.1 Typical brown sands	0.07	0.01	0.18	**0.49**	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00 0	0.00	0.00	0.00	0.00	0.02	0.09
8.1.3 Pelo-alluial gley soils	0.02	0.00	0.29	**0.45**	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.06	0.08
8.1.2 Calcareous alluvial gley soils	0.01	0.00	**0.39**	0.21	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0. 0	0.00	0.00	0.01	0.02	0.15	0.10
3.1.3 Brown rankers	**0.25**	0.01	0.06	0.20	0.17	0.00	0.00	0.09	0.00	0.01	0.03	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.06
2.2.0 Unripened gley soils	0.01	0.00	0.00	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.09	**0.69**	0.00	0.01
8.2.1 Typical sandy gley soils	0.04	0.01	0.04	**0.47**	0.28	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.05
5.4.3 Gleyic brown earths	0.04	0.01	0.23	**0.47**	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.10
4.3.1 Typical argillic pelosols	0.12	0.01	0.23	**0.30**	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.26
8.7.1 Typical humic gley soils	0.02	0.13	0.00	0.01	0.25	0.00	0.00	**0.32**	0.00	0.06	0.16	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.4.2 Stagnogley brown earths	0.11	0.05	0.07	**0.62**	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
9.2.4 Well aerated raw made ground soils'	0.05	0.05	0.01	0.02	0.14	0.00	0.00	0.05	0.00	0.04	0.09	0.00	0.00	**0.42**	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.05	0.05

Table 7.8.7.2 *Proportion of rare and occasional soils under each land cover type. Maximum amounts for each soil highlighted.*

7.9 Future Plans

GMEP is producing large quantities of data that will need to be analysed to synthesize the information. Bangor University and CEH have together won two prestigious PhD scholarships from NERC for students to work on data analysis. The students will start in September 2015 and work on the linkages between soil properties, soil biodiversity and above ground biodiversity.

Chapter 8 Freshwaters

Edwards,F.[1], Greene,S.[1], Henrys,P[2], Kelly, M.[3], Kneebone, N.[4], Scarlett, P[1], Vincent, H[1], Webb, G[1], Williams, P [5]

[1] CEH Wallingford, [2] CEH Lancaster, [3] Bowburn Consultancy, [4] APEM Ltd, [5] Freshwater Habitats Trust

8.1 Introduction

The aim of this chapter is to provide a summary of the current quality of pond and headwater stream habitat in Wales through the results of a field survey, and identify the influence of Glastir on their condition. We also include an analysis of long term national trends, and of the influence of past agri-environment schemes (Tir Gofal) on headwater stream habitats.

8.2 Headwater streams

8.2.1 Introduction

Headwater streams are an important part of the river network, they typically account for most of river length in catchments (typically 70 to 80 % across the EU). They occur across a wide range of geological, biogeographic and riparian settings, and display a wide range of temperatures, substrates, hydrological regimes and water chemistry which shape their biodiversity (Meyer et al, 2007). They route precipitation to downstream water bodies, supporting these larger ecosystems as well as key societal services such as potable water, water for industry and agriculture. The biota of headwater streams makes a significant contribution to biodiversity at a national level with many plants and animals geographically restricted to these characteristic habitats, while some use these habitats seasonally or intermittently. EU legislation aims to protect headwater streams through the Water Framework Directive (European Commission, 2000), where all water bodies are expected to reach good or high ecological status, the Habitats Directive (European Commission, 1992), and the UK Biodiversity Action Plan where headwater streams are considered 'priority habitat' and hence a focus for conservation. Headwaters also harbour species protected under the Wildlife and Countryside Act 1981 and its amendments (e.g. white clawed crayfish), nationally important species of fish such as Atlantic salmon, brook lamprey and bullhead, and can support protected species of mammals and birds (e.g. otters, kingfishers).

Headwater streams are upstream of most point sources of pollution such as industrial discharges, sewage effluent and water abstraction. This means that they are not routinely monitored by the agencies responsible for environmental quality assessments. However headwater streams are small water bodies, strongly connected with the adjacent landscape (Richardson and Danehy, 2007) and are vulnerable to non-point sources of pollution, including diffuse discharges of nutrients and sediments for agriculture and forestry, and habitat loss/modification. Upland headwater streams are also considered to be particularly vulnerable to atmospheric deposition and climate change. In some areas, headwater streams can be affected by water abstraction, and by habitat loss due to land intensification or urbanisation. Conversely, headwaters are typically less impacted by species invasions because of limitations on dispersal, so provide important refugia for native species. Some upland headwaters are also free of fish and provide rare habitats for invertebrates where predation pressure is low. More generally, headwater streams are recognised as refugia for species that have been extirpated downstream (Saunders et al. 2002).

Agricultural practices such as livestock grazing and tilling can lead to soil erosion and run-off of fine sediments, nutrients and pesticides into headwater streams. This has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types. Cumulative impacts across headwaters are reflected further down the river network, decreasing the water quality of larger waterbodies, with negative consequences for their biota, and for ecosystem services such as the provision of clean water for human consumption, fish farming and recreation. Hence it is not surprising that water quality is a key target of many agri-environment schemes, including Glastir, with options that aim to reduce run off and increase ecological buffering along streams and rivers.

Headwater streams are currently under-represented in NRW monitoring programmes which GMEP is intended to fill. The NRW target ultimately is all surface waters to reach good ecological status as required by EU legislation. However, the size and vast numbers of headwaters means that it may be a strict WFD approach may not be practical. As headwater streams also need to be reported under the habitats directive as they are 'priority habitats' is may be more appropriate to report impacts results for headwaters under Priority habitats rather than the WFD compliance. In this report, we describe ecological quality of headwater streams but do not translate this to WFD classification. GMEP and NRW will collaborate on further analyses so that GMEP results can be expressed in a way that is consistent with WFD requirements and approaches, because the data field collection methods that were used in GMEP are consistent with the methods used in WFD assessments. Impact of Glastir on larger rivers will be explored using a modelling approach to quantify change in the contribution of agriculture to nutrient inflow in Year 4 however formal WFD assessment will rely on NRW ecological assessments. There is no benefit of GMEP repeating this assessment.

8.3 Freshwater highlights from Year 2

One headwater stream and pond were surveyed when they occurred in the GMEP 1km survey squares in 2013. Due to the time required for identifying the many invertebrate and diatom samples. The 2014 is not yet ready for reporting. Selected highlights of the results include:

8.3.1 Streams

- 57% of GMEP 1km survey squares had at least one headwater stream
- Lowland sites demonstrated nutrient enrichment vs upland sites
- 85% of sites had phosphorous concentrations consistent with supporting good ecological quality, sites that did not achieve this were all in lowland bar one.
- 53% of sites had nitrogen concentrations that exceeded the range associated with unimpacted European rivers. No site exceeded the drinking water standard for the UK.
- 91% of sites were modified in some ways, with 32% of sites displaying high levels of modification.
- Lowland sites demonstrated higher levels of habitat modification
- Macroinvertebrate indicators indicated 62% of sites had macroinvertebrate communities consistent with good ecological quality.The principal drivers of macroinvertebrate communities were biogeographic (altitude, alkalinity, conductivity) but human habitat modification was also a driving factor
- Diatoms were more responsive to the altitude gradient, with better ecological quality in uplands (expected as diatom indicators principally respond to nutrient status) but higher diversity in lowlands, as expected.
- The principal Diatom score was less conservative, indicating 91% of sites had diatom communities deemed of good ecological quality
- Macrophyte indicators reflected the higher nutrient status of lowlands. Most sites showed intermediate levels of enrichment, only 1 lowland site could be diagnosed with clear eutrophication impacts and 12 sites (9 of which in uplands) could be diagnosed as unlikely to be impacted by eutrophication or organic pollution

- Long term trends using NRW data indicated an improvement in ecological quality of streams over the last two decades, linked to improvements in water quality. This is consistent with the UK wide pattern.
- There was a trend (not significant at present but likely to become so as more baseline samples are taken) of higher quality headwater streams on land within the Glastir scheme which needs to be taken into consideration in future analysis of the benefits of Glastir.
- No significant legacy effect of previous agri-environment schemes was detected though there was a trend for a positive effect on ecological quality and sample size was low as this represents only Year 1 of the full 4 year GMEP sampling period.
- Impacts of Glastir on nutrient enrichment levels in freshwaters more generally will be quantified using a modelling work as described in the GMEP Year 1 report.

8.3.2 Ponds

- 48% of GMEP 1km survey squares had at least one pond
- There was a trend for nutrient enrichment in lowlands which was not significant
- Macrophyte indicators reflected the nutrient conditions, though more uncommon species were found in uplands
- The main drivers of the macroinvertebrate community were natural (alkalinity, altitude) but phosphorous concentrations were also an important driver and are likely to be influenced by human activity
- Only 8% of ponds were judged to be of good ecological quality, most others were of moderate ecological quality
- As for streams, no significant difference between pond condition in and out of scheme was detected but there was a trend for a positive effect of Glastir on ecological condition which will need to be taken into consideration when the impact of Glastir is assessed. Further survey data will clarify this.

8.4 Freshwater Methods

GMEP 1km survey squares are sampled for 1 headwater stream and 1 pond when present. The techniques deployed in headwater streams are recognised biomonitoring techniques as adopted at the UK and EU level, thus our results can be compared to NRW/EA monitoring data,. In ponds, the techniques most widely used, and recommended by the Freshwater Habitats Trust, were used (there is no recognised standard technique at either the UK or EU level) to monitor macroinvertebrates, macrophytes and habitats. These techniques allow us to determine chemical water quality as well as ecological quality.

In brief, the physical, biological and chemical condition of headwater streams are recorded to assess the impact of Glastir options on water quality. To be eligible for inclusion within the GMEP survey streams had to be 1st or 2nd order, at least 500m long, with most of its catchment in the GMEP 1km survey square. Where GMEP 1km survey squares had more than one stream suitable, the most representative of the square (based on length of stream in the actual square) was selected. Water chemistry, diatom community, macroinvertebrate community, aquatic plant community, hydromorphological and physical characteristics of the watercourse (River Habitat Survey Amended) were recorded. The length of the headwater stream sampling site is 500m of watercourse which defines the limits of the River Habitat Survey area. A 100m aquatic plant survey, 10m macroinvertebrate and diatom survey and water chemistry sampling points were all nested within this length centred on the mid-point. The River Habitat Survey is a description of over 150 potential river characteristics recorded on a one 500m stretch of river in each 1km^2 such a pools and riffles, overhanging trees and physical structures. The macrophyte survey recorded species presence and

abundance over a 100m length to give a mean trophic rank index of water quality. Five diatom samples were collected and bulked from the central 10m reach –diatoms for assessing ecological quality. Timed searches for macroinvertebrates across a 10-15m reach were undertaken using standard RIVPACS methodology. Environmental variables such as stream width, depth; surface velocity: substrate; algae; plants; street lighting; sketch + photo; GPS were recorded with the 10m reach. The conductivity and pH of the water was recorded on-site; and an additional water sample taken and filtered on site before being sent for alkalinity, soluble reactive phosphorus and total oxidisable nitrogen analysis the in laboratory.
For more information, please see GMEP year 1 report. (Emmett et al. 2014)

8.5 GMEP: what is the condition of headwater streams?

Headwater streams were monitored in 60 x GMEP 1km survey square across Wales in 2013 (Year 1 of the survey), with 1 stream from each square selected for detailed surveying.
Of the 60 GMEP 1km survey squares, 57% (34) had at least one headwater stream. Of these 34 streams, 17 (50%) were situated in lowland (< 200m) and the other 50% in upland (>200m).

8.5.1 Stream habitat

River Habitat Surveys indicated significant human modification of stream habitats (Table 8.5.6.1). The habitat modification score (HMS) average was 754 (±172) corresponding to an overall Habitat Modification Class of 4 out of 5 possible classes were 5 is the most modified. The habitat quality assessment of natural structural diversity (HQA) average was 53.7 (±2), a value in line with expectations for headwater streams but higher than that recorded for Welsh streams in the 1998 and 2007 Countryside surveys (42.3 and 49.2 respectively). The HQA and HMS were negatively correlated ($r = -0.541$, $p < 0.001$) demonstrating that natural habitat quality decreased with the extent of human modification. However this correlation was driven by the lowland sites (-0.712, $p = 0.001$) as no such pattern occurred in the highlands. Analysis of HMS and HQA indicated a strong negative correlation of HMS with altitude (-0.427, $p = 0.01$), which ranged from 7 m to 537 m, so that the HMS was lower in upland areas (Figure 8.5.6.1) however the HQA was not correlated to altitude, and neither were correlated to distance from source, which ranged from 0.2 to 4 km.

8.5.2 Water chemistry

Analysis of water chemistry samples (Table 8.5.6.2) indicated strong differences between uplands and lowlands in alkalinity and conductivity, with higher values in lowland, which reflects natural biogeochemical processes. The stream water pH did not differ significantly between lowland and upland, and was generally above the recommended threshold of 5.95 (WFD UK TAG, 2012) higher. Only 5 sites fell below this pH(4 upland sites, 1 lowland site). Nutrients displayed significant differences in their concentrations between upland and lowland (Figure 8.5.6.2). Nitrogen expressed as Total Dissolved Nitrogen (TDN) and phosphorus expressed as phosphate (PO_4P) were an order of magnitude higher in the lowlands. Cardoso et al (2001) reviewed TDN concentration for pristine European rivers (and excluding larger rivers) and observed that they lied in the range 0.2 – 1 mg/l. In our survey, despite their headwater status, 52.9% of sites had TDN concentrations above this range, representing 18 sites, 14 of which were in the lowlands. No site exceeded current drinking water standards for nitrogen (10.9 mg/l). TDN was not correlated to either the HMS and HQA or distance from source. We calculated phosphorous concentrations expected from unimpacted sites using a model based on altitude and alkalinity, which reflect concentrations if the ecosystem is undisturbed (WFD UK TAG, 2014), plotted these values against observed values (Figure 8.5.6.3) and derived a ratio of observed to expected values, which also differed between upland and lowland (Table 8.5.6.2). In upland areas this ratio was below 1, i.e. observed values did not exceed predicted reference values. However in the lowland it was clear that observed measurements exceeded reference P values in approximately a third of the sites.

8.5.3 Macroinvertebrates

Invertebrate communities were assessed at each stream site using a standard biomonitoring technique (the RIvPACS approach; Wright et al, 1993). A range of indicators based on the invertebrate community were calculated (Table 8.5.6.3). Habitat variables recorded in the field were used in the RIvPACS model to predict some of these indicators at the sites, if the site was unimpacted by human stressors (reference condition). Observed values were then compared to the predicted values of the RIVPACS model as a ratio.

The Average Score per Taxon (ASPT) and Number of Scoring Taxa (Ntaxa) are related to the Biological Monitoring Working Party score (BMWP, 1978, Armitage et al, 1983), and are indicators designed to detect eutrophication, but are also considered indicators of general degradation. Higher values indicate higher ecological quality. The ASPT describes the sensitivity of species to water quality and was higher (though not significantly so) in upland areas which are known to be associated with sensitive taxa. Ntaxa describes the number of water quality sensitive taxa used in the assessment, and this was significantly higher in the lowland areas, principally because lowland areas sit in a wider species pool.

We also calculated an ASPT based on the Acid Water Indicator Community (AWIC, Davy-Bowker et al, 2005) score, an indicator of acid conditions. Higher values indicate less acid conditions, but the score doesn't differentiate between naturally acid conditions and anthropogenic acidification. The score was significantly higher in lowland areas, in line with the trend for higher pH and conductivity. The Proportion of Sensitive Invertebrates (PSI, Extence et al, 2013) is an indicator of fine sediment deposition, where higher values, expressed as percentages, indicate better ecological quality. Though values were highest in the upland areas, the difference with lowlands was not significant. Mean values for both upland and lowland placed the sites in the 'slightly sedimented' band (the second highest).

The Lotic Invertebrate Flow Evaluation (LIFE, Extence et al, 1999) score is an indicator of flow conditions, where higher values indicate better flow conditions. There was no significant difference between lowland and upland.

The Community Conservation Index (CCI, Chadd et al, 2004) is a measure of the conservation value of the invertebrate community, it ranges from 0 to 40 where 40 is the highest conservation value. There was no significant difference between upland and lowland. Mean values in both areas (~ 11) indicated an invertebrate community of '*fairly high conservation value*' driven by high taxon richness and species of restricted distribution.

We calculated two species richness indices: Margalef richness (M, Margalef, 1958) is a measure of richness corrected for the number of individuals (as the number of species increases passively with the number of individuals) and true richness (n) i.e. the number of recorded taxa (principally at species level though some taxa were recorded at higher levels of taxonomic organisation). Neither index differed significantly between upland and lowland though there were marginally more species in lowland areas.

We calculated the expected values of ASPT and Ntaxa (using the RIvPACS model, which predicts the reference state invertebrate community of a stream based on a range of environmental variables. We then calculated the ratio of observed to expected values (Table 8.5.6.4), or ecological quality ratio, where 1 or above indicates a community under reference conditions (near unimpacted by human activity). The mean O/E ASPT was high (above 0.86 indicating good ecological quality). Though lowlands and uplands did not differ significantly, the ASPT was higher in uplands, near 1,. The mean O/E Ntaxa also indicated good ecological quality , but lowland sites had a higher mean. We used the occurrence and abundance of macroinvertebrates in the samples to produce an ordination using a technique called canonical correlation analysis (CCA). This technique attempts to explain patterns in variation in the community using selected environmental variables. It has the advantage of producing a graphical representation of patterns. We used a range of variables and tested their contribution to the CCA model using permutation tests. This indicated that TDN, PO4P, distance from source, altitude of source, water pH and the HQA score did not contribute significantly to the model, but retained water conductivity, the HMS score, water alkalinity and altitude as significant explanatory variables. The model was then plotted in an ordination, where the distance between samples is a measure of their ecological distance, and where the graph axes represent a combination of the driving variables, which are plotted as vectors, the length of which is an indicator of the influence of the variable (Figure 8.5.6.4). The graph shows that the HMS is a strong driver, especially in lowland sites. Alkalinity and conductivity also have some influence, though these are likely to act as proxies for geology and location. There is a strong effect of altitude, which differentiates upland sites more strongly than their water chemistry. Though correlation is not causation, this analysis indicated that important determinants of invertebrate community structure were in line with the geography of the land, and habitat modification is the principal driving human influence rather than water chemistry.

8.5.4 Macrophytes

Macrophyte communities were assessed at each site using the Mean Trophic Rank (MTR, Holmes et al. 1999), an indicator of eutrophication. This approach yields an overall MTR score and also a number of scoring plants and a number of high scoring plants, where higher values represent higher ecological quality (Table 8.5.6.5). Uplands and lowland sites differed significantly in their mean MTR score. The mean for upland sites indicated that eutrophication was very unlikely. However the lowland mean indicated a potential risk of eutrophication, consistent with the higher nutrient concentrations and signal from the macroinvertebrate scores. Only 1 (lowland) site had an MTR below 25, a recognised threshold at which sites are degraded by either eutrophication or organic pollution. Another 12 sites had an MTR > 65 so were unlikely to be impacted by eutrophication and organic pollution (9 upland, 3 lowland). The remaining sites had intermediate values for which a clear diagnosis is not possible, where some level of organic pollution was possible.

8.5.5 Diatoms

Diatom communities were assessed at each site (Table 8.5.6.6) using a standard biomonitoring technique DARLEQ (Diatoms for Assessing River and Lake Ecological Quality) which yields a suite of ecological quality scores (Kelly and Whitton, 1995; Kelly et al. 2008).
The Trophic Diatom Index (TDI) is an indicator of eutrophication ranging from 0 to 100 where low scores indicate better ecological conditions. The TDI showed a significant difference between uplands and lowlands, and the mean values was higher in the lowland sites. We also calculated the expected value of the TDI in the absence of human influence (reference condition) using the DARLEQ predictive model, based on site environmental variables. We calculated the observed to expected ratio, where values of 1 or above correspond to the expectations of reference conditions. The mean O/E ratio of the TDI was highest in the uplands sites, where it exceeded one. The mean was considerably lower in lowland sites, indicating greater eutrophication pressure.
The Diatom Acidification Metric (DAM, Juggins and Kelly, 2013) was developed to assess the impact of acidification, though it is not possible to distinguish between naturally acid and acidified sites in this survey. Higher values indicate less acidic conditions, as calculated from benthic diatom assemblages. The mean DAM was significantly higher in lowland sites, in line with water chemistry

results and the macroinvertebrate acidification indicator (AWIC). The mean DAM in uplands corresponded to the ‘slightly acidic’ range, and the mean for lowland sites corresponded to the circumneutral range. In total 4 sites were considered to be very acid, 3 sites were alkaline, 11 were slightly acidic and the rest circumneutral.

The percentage of motile diatoms is an indicator of fine sediment deposition, it increases with increased siltation. The mean value was higher in lowland sites, but differences between upland and lowland were not significantly different.

8.5.6 Ecological quality

We classified the sites based on their putative ecological quality using observed to expected ratios of the indicators only for indicators with established predictive models and classification thresholds. This is not a WFD assessment because this would integrate all elements to produce a final site classification. We do not present a WFD classification, nor assign the sites to an overall status. Each indicator is treated separately. In further years we will integrate all monitored elements into an assessment protocol that be compatible with WFD assessments.

The headwater sites were classified according to their habitat modification score using established thresholds into five modification classes. (Near natural, predominantly unmodified, obviously modified significantly modified, severely modified). Only 8.8% of sites were deemed near natural with a further 38.2% classified as predominantly unmodified, while 52.9% of sites fell in the top three modification categories. Moreover 32.3 % of the sites were either severely or significantly modified, and these modification classes are general accepted as being inconsistent with supporting high ecological quality (Figure 8.5.6.5).

Phosphorous concentrations were compared to predicted modelled values (WFD UK TAG, 2014) , and the model also yields thresholds for O/E ratios to assign sites into 5 bands (bad, poor, moderate, good , high) which are intended to reflect the ecological quality that the concentrations would be able to support (though this model/tool is used in WFD assessments, we simply use it here to classify sites according to their phosphorous concentrations). We found that 85.2% of sites had phosphorous concentrations consistent with supporting high/good ecological quality, only 2 sites had phosphorous concentrations that would be expected to be associated with bad/poor ecological quality.

We classified the headwater sites based on their diatom communities using the ratio of observed TDI to that predicted by the DARLEQ tool. We used this ratio to classify sites into 5 equal bands (TDI of 0.2, 0.4, 0.6, 0.8) corresponding as above to 5 putative ecological quality classes. This gave an overwhelmingly positive snapshot of ecological quality, with 90.9% of sites falling in the top two categories (high or good), only 3 sites were deemed of moderate ecological quality based on diatoms, and no sites fell in the bottom two categories (poor/bad).

We used a similar process for macroinvertebrates ASPT and NTAXA, using the ratio of observed values to that predicted by the RIvPACS model. For these scores thresholds are established to classify the sites into 5 putative ecological quality classes as above.(ASPT: 0.63,0.75,0.86,0.97 Ntaxa: 0.47, 0.57, 0.71, 0.85). THE ASPT indicated 88.2% of sites fell in the top two ecological quality categories, while Ntaxa indicated this for 64.7% of the sites. Considering both scores together so as to classify the sites based on the lower of the two metrics, 61.7% of sites fell in the top two ecological quality bands.

		Mean	± SE	Min	Max
Habitat Modification Score	Overall	762	177	0	4110
	Lowland	1035	292	0	4110
	Upland	490	186	0	2925
Habitat Quality Assessment	Overall	53.71	2.2	31	80
	Lowland	52.53	3.75	31	80
	Upland	54.88	2.38	35	70

Table 8.5.6.1 *River habitat survey results for 34 headwater streams surveyed in GMEP 2013.*

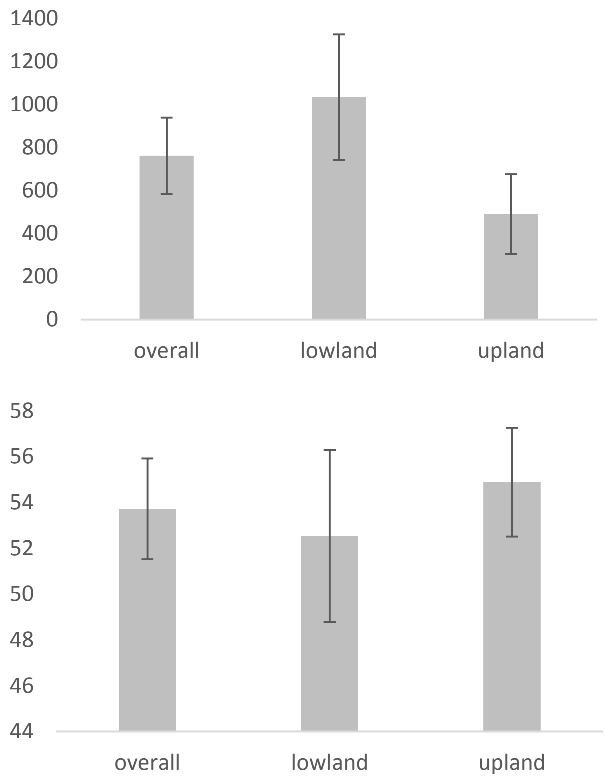


Figure 8.5.6.1 *River habitat survey results. Mean HMS (TOP) and HQA (Bottom) ± 1SE.*

		Mean	SE	Min	Max
Alkalinity (mg/L)	Overall	48.38	9.03	0.10	218.00
	Lowland *	72.30	14.90	0.90	218.00
	Upland	24.48	6.64	0.10	74.60
PO4-P (mg/L)	Overall	0.020	0.007	0.001	0.179
	Lowland *	0.037	0.012	0.001	0.179
	Upland	0.005	0.001	0.001	0.018
PO4-P (O/E)	Overall	1.52	0.40	0.06	9.88
	Lowland *	2.35	0.76	0.06	9.88
	Upland	0.73	0.19	0.12	2.34
TDN (ppm)	Overall	1.40	0.24	0.07	5.56
	Lowland *	2.16	0.38	0.07	5.56
	Upland	0.69	0.16	0.15	2.88
pH	Overall	6.58	0.12	5.31	7.81
	Lowland	6.72	0.18	5.31	7.81
	Upland	6.45	0.15	5.60	7.68
Conductivity (µS.cm^{-1})	Overall	188.00	23.20	22.00	526.00
	Lowland *	266.00	33.10	62.00	526.00
	Upland	110.00	18.90	22.00	247.00

Table 8.5.6.2 *Water chemistry results for 34 headwater streams surveyed in GMEP 2013. Asterisks denote significant higher values*

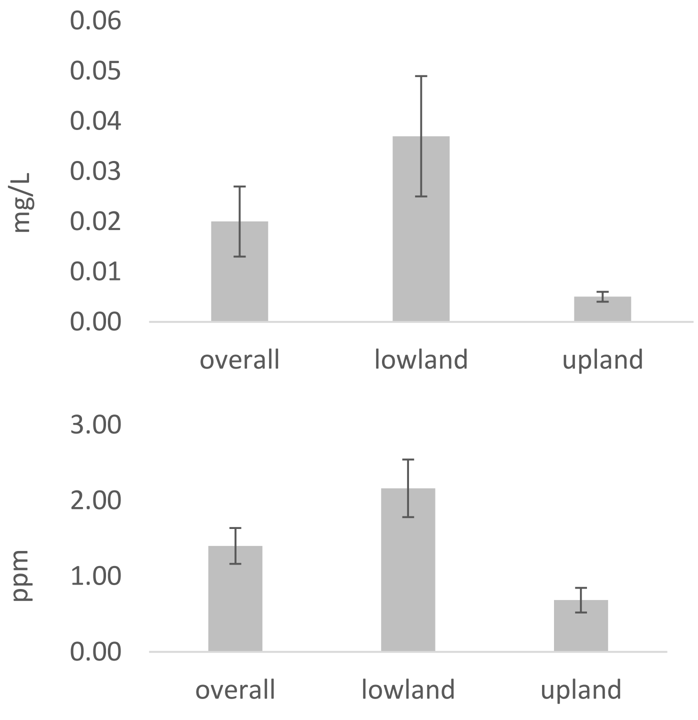


Figure 8.5.6.2 *Concentration of PO4P (Top, mg/L) and TDN (Bottom, ppm) in stream water samples*

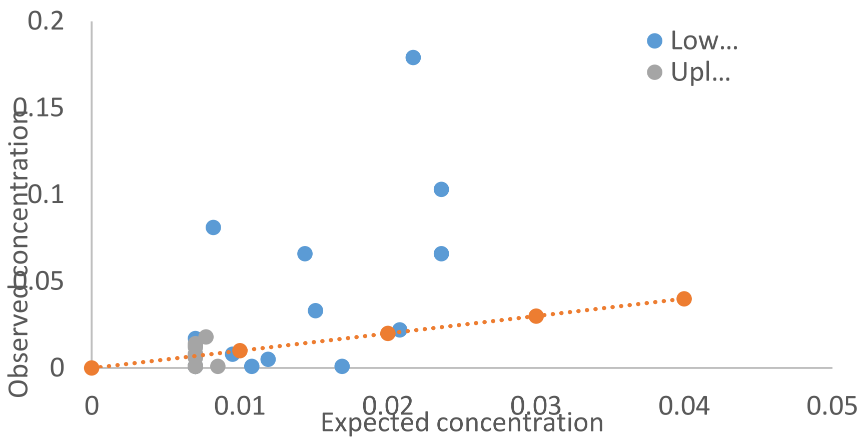


Figure 8.5.6.3 *Observed PO4P concentrations plotted against expected values (blue points) with 1:1 line plotted in orange (where observed equals predicted)*

		Mean	SE	Min	Max
ASPT (BMWP) (Eutrophication/general degradation)	Overall	5.84	0.13	4.00	7.00
	Lowland (<200m)	5.60	0.19	4.00	6.73
	Upland (>200m)	6.01	0.14	4.86	7.00
Ntaxa (BMWP) (Eutrophication/general degradation)	Overall	18.56	0.94	7.00	28.00
	Lowland (<200m) *	20.47	1.05	11.00	26.00
	Upland (>200m)	16.65	1.44	7.00	28.00
ASPT (AWIC) (Acidification)	Overall	4.55	0.09	3.25	5.67
	Lowland (<200m) *	4.88	0.10	4.13	5.67
	Upland (>200m)	4.23	0.11	3.25	4.92
PSI (Sedimentation)	Overall	67.06	3.62	14.29	100.00
	Lowland (<200m)	60.45	5.35	14.29	80.00
	Upland (>200m)	73.66	4.48	38.46	100.00
LIFE (Water flow)	Overall	7.23	0.13	5.13	9.09
	Lowland (<200m)	7.08	0.20	5.13	8.10
	Upland (>200m)	7.38	0.17	6.09	9.09
CCI (conservation value)	Overall	11.63	0.75	4.15	21.00
	Lowland (<200m)	11.93	1.17	4.15	21.00
	Upland (>200m)	11.33	0.95	4.71	18.20
Richness (Margalef) (Biodiversity)	Overall	5.28	0.27	1.82	8.69
	Lowland (<200m)	5.61	0.32	3.17	7.94
	Upland (>200m)	4.96	0.43	1.82	8.69
Richness (Biodiversity)	Overall	35.62	2.35	7	60
	Lowland (<200m) *	40.65	2.86	22	60
	Upland (>200m)	30.59	3.39	7	59

Table 8.5.6.3 *Macroinvertebrate indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other.*

		Mean	SE	Min	Max
O/E ASPT (BMWP)	Overall	0.96	0.02	0.70	1.16
	Lowland (<200m)	0.93	0.03	0.70	1.08
	Upland (>200m)	0.99	0.02	0.77	1.16
O/E Ntaxa (BMWP)	Overall	0.83	0.05	0.30	1.42
	Lowland (<200m)	0.88	0.06	0.30	1.31
	Upland (>200m)	0.78	0.07	0.31	1.42

Table 8.5.6.4 *Observed vs Expected ratio (O/E) of the two main macroinvertebrate indicators*

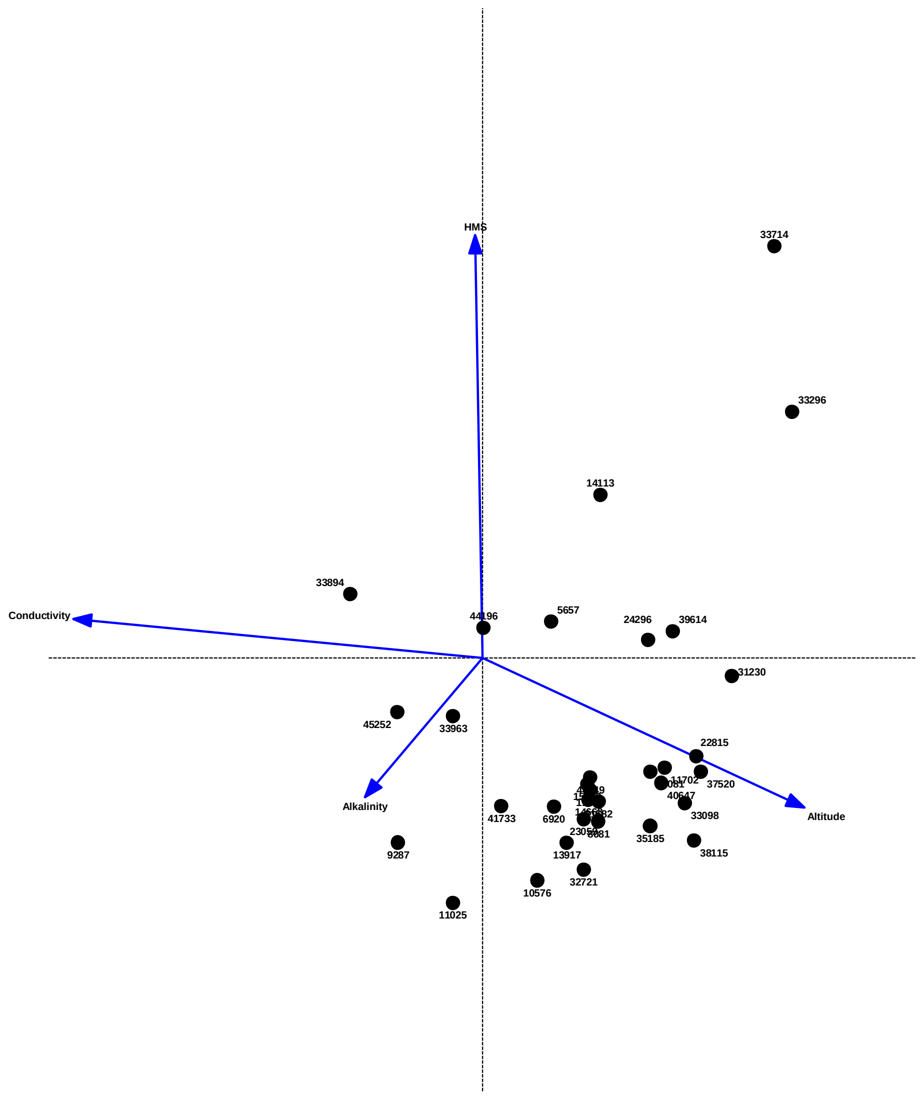


Figure 8.5.6.4 *CCA graph of stream macroinvertebrate community data with retained driving variables.*

		Mean	SE	Min	Max
MTR score	Overall	63.63	4.06	24.55	100.00
	Lowland (<200m)	49.07	4.38	24.55	70.00
	Upland (>200m) *	78.19	3.78	60.00	100.00
Ntaxa (MTR)	Overall	2.62	0.42	0.00	8.00
	Lowland (<200m)	2.33	0.48	0.00	6.00
	Upland (>200m)	3.00	0.76	0.00	8.00
Nhigh (MTR)	Overall	1.50	0.26	0.00	4.00
	Lowland (<200m)	1.33	0.29	0.00	4.00
	Upland (>200m)	1.73	0.47	0.00	4.00

Table 8.5.6.5 *Macrophyte indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other.*

		Mean	SE	Min	Max
TDI	Overall	29.41	3.60	0.16	64.62
	Lowland (<200m) *	42.09	4.47	11.09	64.62
	Upland (>200m)	17.48	3.80	0.16	51.72
O/E TDI	Overall	0.92	0.03	0.53	1.28
	Lowland (<200m)	0.82	0.05	0.53	1.28
	Upland (>200m) *	1.01	0.03	0.67	0.16
% Motile	Overall	16.68	2.62	0.32	53.72
	Lowland (<200m)	21.47	4.26	1.93	53.72
	Upland (>200m)	12.17	2.84	0.32	35.95
DAM	Overall	46.64	4.20	3.75	92.32
	Lowland (<200m) *	56.69	5.87	6.07	91.94
	Upland (>200m)	37.17	5.16	3.75	92.32
Ntaxa (TDI)	Overall	26.91	1.69	10.00	52.00
	Lowland (<200m) *	30.56	2.71	10.00	52.00
	Upland (>200m)	23.47	1.76	10.00	35.00

Table 8.5.6.6 *Diatom indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other.*

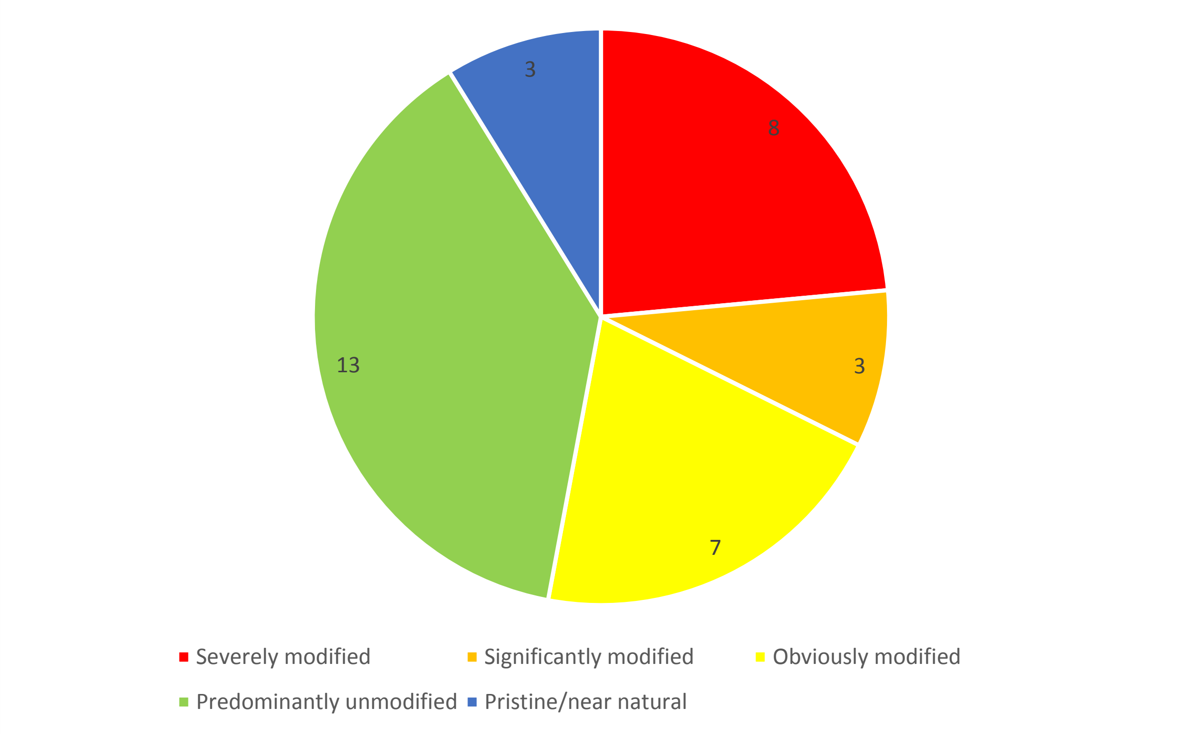


Figure 8.5.6.5 *Number of headwater sites in each habitat modification class in GMEP*

8.6 Long term trends

Data were obtained from NRW for all their macroinvertebrate samples from 1990 onwards, and screened to include only smaller headwater streams.

Three key indicators of ecological quality derived from macroinvertebrate communities were plotted against time (Figure 8.6.1), the BMWP score and its Ntaxa and ASPT. The BMWP score is an index of eutrophication and general degradation, Ntaxa is the number of water quality sensitive taxa that contribute to the BMWP score and ASPT is the sensitivity of the taxa to water quality which contribute to the BMWP score. The graphs show change in ecological quality over time with a decrease followed by an increase in the early to mid-2000s. The pattern was statistically significant for all 3 indicators. The overall pattern in BMWP score was driven by the ASPT rather than Ntaxa, so that there was over time species replacement by water quality sensitive species rather than just more species *per se*. This pattern is entirely consistent with that described by another study by Vaughan & Ormerod (2012) for England and Wales using a wider national dataset of which this is a subset restricted to Wales and to smaller streams. Our analyses demonstrates that patterns for Welsh headwaters are on par with the national UK trend.

Vaughan & Ormerod cited changes in water chemistry as the main reason for this trend, principally reflecting decreases in organic pollution over several decades. Patterns for the ecological indicators do appear to be inversely related to changes in N concentrations in stream water, as can be seen from NRW time series (Figure 8.6.2)(the sampling locations used were matched to the invertebrate sampling locations). However patterns in P matched ecological indicators only weakly (except perhaps for Ntaxa), although lags in the response of the ecology to the chemistry may be responsible for the lack of patterns.

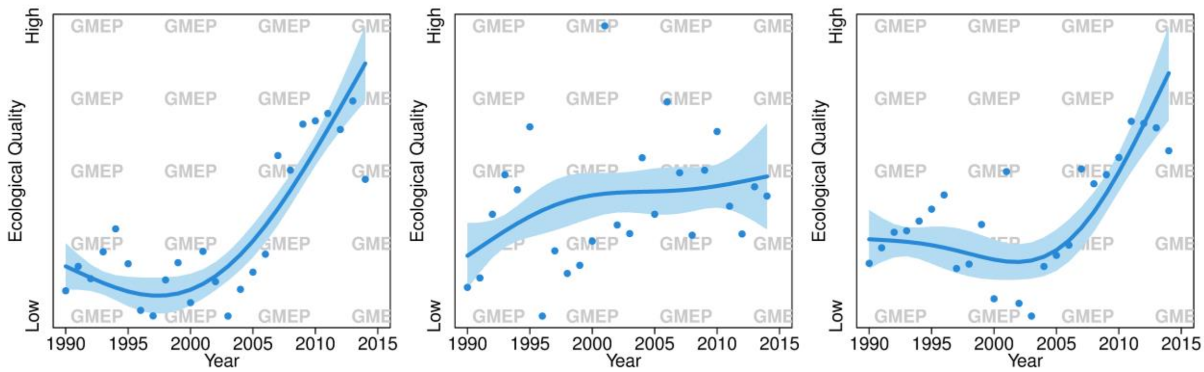


Figure 8.6.1 *BMWP score (left; an index of eutrophication and general degradation), Ntaxa (middle; the number of water quality sensitive taxa that contribute to the WHPT score) and ASPT (right; the sensitivity of the taxa to water quality which contribute to the WHPT score) time series derived from NRW data for Small Welsh streams.*

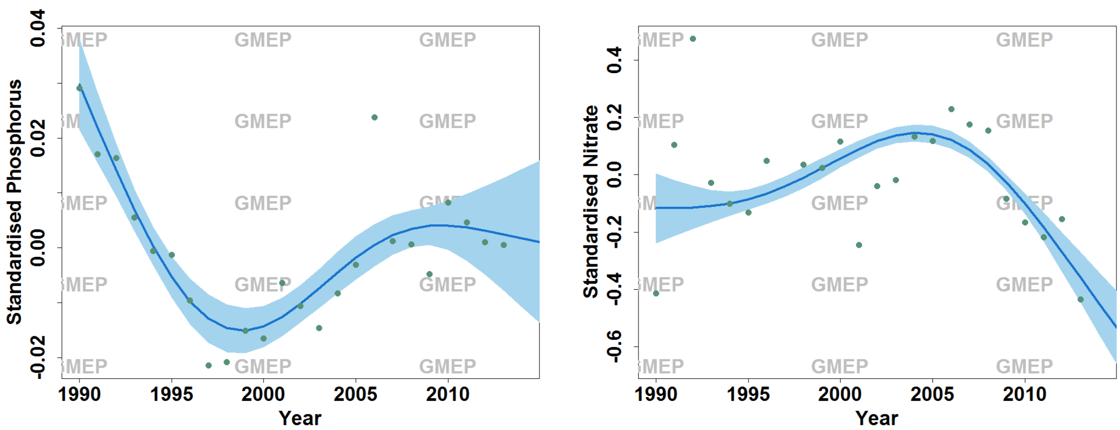


Figure 8.6.2 *Time series of left: SRP (mg/L) and right: TDN (ppm) derived from NRW monitoring*

8.6.1 Quality of headwater stream conditions in and out of the Glastir scheme

Main indicators were compared according to whether site was in or out of Glastir, and the relationship between indicator and % of upstream catchment in Glastir was analysed using regression methods (Table 8.6.1.1) No significant relationships were found based on the limited sample size of first year data, but the analysis will be repeated as survey years are added.

Variable	P Value	Outside Glastir		In Glastir	
		Mean	Std Error	Mean	Std Error
O/E ASPT	0.37	0.97	0.03	0.98	0.02
O/E Ntaxa	0.35	0.75	0.06	0.92	0.06
HMS	0.89	395.27	134.79	976.61	289.91
HQA	0.75	56.20	2.35	51.78	3.65
O/E TDI	0.56	0.95	0.07	0.91	0.04
TDN (ppm)	0.60	1.19	0.27	1.58	0.38
PO4P (mg/L)	0.27	0.03	0.01	0.01	0.01
O/E PO4P	0.32	1.71	0.60	1.35	0.55

Table 8.6.1.1 *Mean principal indicators of ecological quality according to sites that fall in or out of Glastir. P values indicate significance of a regression of indicator vs % of upstream catchment that is in Glastir, in this case none of the relationships are significant ($p > 0.05$).*

8.6.2 Influence of past agri-environment schemes (Tir Gofal)

We examined the influence of past AES on the ecological quality of survey sites using the main macroinvertebrate indicators linked to water quality (as most AES focus on nutrient levels, though it is worth noting that nutrients are only one component of chemical quality) (Table 8.6.2.1). Although there was a consistent pattern for higher indicator values in sites under past AES schemes, error terms were large so means did not differ significantly between sites falling in or out of previous AES.

	Status	Mean	SE
Ntaxa	Outside Past AES	16.44	2.06
	In Past AES	19.19	0.98
ASPT	Outside Past AES	5.66	0.28
	In Past AES	5.83	0.14
BMWP	Outside Past AES	93.44	11.69
	In Past AES	110.12	7.17

Table 8.6.2.1 *mean values of three main macroinvertebrate indicators of ecological quality in survey sites falling in or out of previous AES*

8.7 Ponds
8.7.1 Introduction

Ponds are more abundant than rivers and lakes, and are found in virtually all environments. Though the diversity of an individual pond will generally be less than that of a river or lake, their biodiversity value lies at wider spatial scales. At the landscape level ponds typically support a wide array of species (Céréghino et al. 2008, Williams et al. 2004), and are a particularly important habitat for rare and protected species. In Wales, this includes many species which are declining internationally such as yellow centaury and three-lobed crowfoot, as well as European protected species including great crested newt and floating water-plantain. In addition, ponds provide both habitat and food for terrestrial wildlife such as birds, bats, small mammals, reptiles, and pollinating insects, making them important in agricultural and urban landscapes that have few natural refugia. Ponds, are recognised in Article 10 of the EU Habitats Directive for their role as 'stepping stones', between other waterbodies and wetlands, increasing freshwater habitat connectivity at wide spatial scales. Ponds also act as small reservoirs as they collect and slow the flow of water off fields and other areas, trapping and recycling nutrients and sediments before they can enter a flowing water body.
Ponds have been widely lost through urbanisation and intensification of agriculture, and their numbers declined greatly during the 20th century (Nicolet et al. 2007). Ponds, like headwater streams, are vulnerable habitats that experience the common pressures which affect all freshwater habitats, but they are also exposed to localised pressures. Due to their small size, compared to a river or lake, they are particularly sensitive to pollution and have a limited buffering capacity (Williams et al. 2004), similar to headwater streams. In agricultural landscapes ponds receive sediments, nutrients and pesticides which has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types.

Five ponds types are included partly or wholly as habitats of high conservation importance in Annex 1 of the EU Habitats Directive (H3160, H3170, H3180, H3110, H3140), with another habitat types potentially including ponds (H3130) although few ponds have been designated as Special Areas of Conservation in their own right. The Water Framework Directive protects all surface waters, though in practice, in the UK a minimum size limit of 50 ha is applied to water bodies (5 ha in SAC's) that are subject to monitoring thus excluding ponds (usually designed as <2ha). The most relevant policy to ponds is perhaps the UK Biodiversity Action Plan which designates high quality ponds as Priority Habitat (based on a number of criteria), and confers them some protection. Hence it is not surprising that ponds are a target of many agri-environment schemes, including Glastir, with options that aim to reduce run off, increase ecological buffering and create new habitats.

8.7.2 Condition of ponds

Ponds were monitored in 60 x GMEP 1km survey square across Wales in 2013, with 1 pond in each square (if present) selected for detailed surveying (the pond most central to the square was used if more than one pond was present).

Of the 60 GMEP 1km survey squares surveyed, 48% (29) had at least one pond. In total 99 ponds were recorded over the 60 GMEP 1km survey squares with 28% (17) of the squares having more than 1 pond (between 2 and 7). Of the GMEP 1km survey squares with ponds approximately half had only ponds, and half had both ponds and headwater streams.
Pond area was recorded for 52 ponds of the 99 ponds averaging 305 m^2 (±56). Only 3 ponds were judged to have been created recently (less than 5 years).

8.7.2.1 Water chemistry

The results of the water chemistry sample analysis (Table 8.7.2.4.1) are harder to interpret for ponds than for streams, because of the inherent variability that arises from the diverse nature of ponds and their surroundings. All chemical determinands had a higher mean for lowland sites than for upland sites, however differences between upland and lowland sites were not statistically significant for most determinands, which all displayed wide value ranges, including nutrients (Figure 8.7.2.4.1). Only alkalinity was significantly higher in lowland vs upland, as would be expected from geology, and consistent with the chemistry of the headwater streams.

8.7.2.2 Macrophytes

Wetland plant species were surveyed in each pond and used to derive three pond quality metrics (Table 8.7.2.4.2). Contemporaneously collected environmental variables were run through the PSYM model (Freshwater Habitats Trust, 2015) to predict the pond quality metric values that would be expected if the pond was minimally impaired by human activity (i.e. in reference condition). The ratio of observed to predicted metrics (Table 8.7.2.4.3) or ecological quality ratio at each pond indicates the pond's quality, where a value of 0.75 or above indicates a plant assemblage in reference condition. Thresholds for the ratios, provided by the PSYM method, allowed each metric to be ranked into one of 4 categories (very poor, poor, moderate, and good).
Results for each of the three PSYM plant metrics are outlined below.

The Trophic Ranking Score (TRS) is a measure of the average trophic rank of ponds, and is based on the affinity of each plant to nutrient status of the water. In contrast to most metrics, which have a linear relationship with degradation (i.e. the higher the metric score the lower the degradation, or vice versa), Tropic Ranking Score has a U-shaped relationship with increasing degradation: where observed values that are significantly higher than expected this suggests degradation from nutrient enrichment, where observed values are lower than expected this suggests degradation through acidification. Amongst the GMEP ponds (Table 8.7.2.4.2) TRS was significantly higher in lowland sites than at upland sites, as well as its observed to expected ratio. Mean values of TRS O/E corresponded to poor ecological quality in lowland but good ecological quality in upland ponds.

The submerged and emergent species index (SM) is the number of submerged and emergent plant species recorded from the pond. The mean value did not differ significantly between lowland and

upland sites, albeit slightly higher in lowlands. The observed to expected ratio did not differ either between upland and lowland sites and was consistent with moderate ecological quality.
The uncommon species index (U) is the number of species with a rarity score of two or more. Values were always low, consisting of either 1 or 2 species. The mean of this index was significantly higher for upland sites, as was the ecological quality ratio, which corresponded to poor ecological quality. The mean was extremely low in lowland sites, corresponding to very poor ecological quality. Overall most uncommon plants (defined by FHT as having a rarity score of 2 or more, based on the occurrence of species in their data holdings) occurred in upland ponds, species included the rarer *Utricularia australis* as well as less rare species such as *Ranunculus omiophyllus*, *Riccia fluitans, Stellaria palustris, Glyceria declinata, Potamogeton obtusifolius, Lythrum portula, Hypericum elodes, Scutellaria minor, Callitriche platycarpa*.

An additional measure was also calculated: the percentage cover of emergents (%E), which is the percentage of the pond surface area that is overhung by emergent plants. This measure was significantly greater at lowland sites, which included ponds with 100% cover by emergent plants.

8.7.2.3 Macroinvertebrates

Invertebrate species were surveyed at each pond site using a standard biomonitoring technique (the national pond survey; Biggs et al, 1998). Three invertebrate-based pond quality metrics were calculated based on the invertebrate assemblage recorded (Table 8.7.2.4.4). Habitat variables recorded in the field, and the observed invertebrate metric values were used in the PSYM model (Freshwater Habitats Trust, 2015) as described above for macrophytes. Results for each of the three PSYM invertebrate metrics are outlined below. Observed values were then compared to the predicted/expected values as a ratio, as described above for macrophytes (Table 8.7.2.4.5). Thresholds for the ratios, provided by the PSYM method, allowed to rate each indicator in 4 categories (very poor, poor, moderate, good).

The average score per taxon (ASPT) is derived the same way as it is for streams, based on BMWP scores, and describes the sensitivity of species to water quality. It is an indicator of eutrophication, but is also considered an indicator of general degradation. Higher values indicate higher ecological quality. The ASPT did not differ between upland and lowland ponds, nor did the ratio observed to expected values. The mean observed to expected ratios were consistent with good ecological quality in lowland and upland.

The Odonata-Megaloptera index (OM) is the number of families of odonates (dragonflies and damselflies) and megalopterans (alder flies) at the site. These invertebrates are particularly sensitive to water quality and habitat quality. This indicator did not differ significantly between lowland and upland but was slightly higher in upland ponds. The observed to expected ratio did not differ either, despite also being higher in upland areas. The mean values of this indicator were consistent with poor quality in lowland and moderate quality in uplands. Four upland ponds and 3 lowland ponds had no Odonata/Megaloptera.

The Coleoptera (CO) index is the number of coleopteran families (beetles) recorded. This indicator is linked to both water quality and bank quality. Higher values indicate better ecological quality. The mean CO did not differ significantly between upland and lowland ponds, though it was higher in uplands. The observed to expected ratio did not differ significantly either but showed a similar pattern. The mean values of this indicator were consistent with moderate quality in lowland and good quality in uplands.

In addition to the PSYM metrics, we calculated two species richness indices: Margalef richness (Margalef, 1958) is a measure of richness corrected for the number of individuals (as the number of species increases passively with the number of individuals) and true richness (n) i.e. the number of recorded taxa (principally at species level though some taxa were recorded at higher levels of taxonomic organisation). Neither index differed significantly between upland and lowland though there were marginally more species in lowland areas.

We used the occurrence and abundance of macroinvertebrates in the samples to produce an ordination graph using canonical correlation analysis (CCA) as described in the headwater streams section. This technique explain patterns in variation in the community using selected environmental variables. We used a range of variables and tested their contribution to the CCA model using permutation tests. This indicated that, pond area, water pH, nitrogen, conductivity and the percentage cover of emergent plants did not contribute significantly to the model, but retained phosphate, alkalinity and altitude as significant explanatory variables. The model was plotted in an ordination, where the distance between samples is a measure of their ecological distance, and where the graph axes represent a combination of the driving variables, which are plotted as vectors, the length of which is an indicator of the influence of the variable (Figure 8.7.2.4.2). The graph suggests that altitude is the principal driver of differences in macroinvertebrate assemblages. There was a lesser effect from another natural variable: alkalinity, which in part co-varied with altitude but also accounted for some of the variability in itself. Phosphate was the second strongest driver after alkalinity and explained the majority of variability along the horizontal axis. Phosphate levels do vary naturally in ponds, but this nutrient is also strongly related to anthropogenic impacts, and together with the plant Tropic Ranking Score results (above), suggests that nutrient pollution may be impacting both plant and invertebrate communities in some of the ponds.

8.7.2.4 Ecological quality

The PSYM model sums the value from all six plant and invertebrate metrics to produce an overall index of biological integrity that summarises the ecological quality of the pond. The pond can then be classified according to thresholds in the overall index into four categories: very poor, poor, moderate or good, where good is equivalent to the high quality reference condition (Figure 8.7.2.4.3). Because PSYM score is one of the criteria used to identify Priority Ponds (a term used by FHT that is not related to ‘pond priority habitat’ under EU and UKBAP regulation), any pond that classifies as good quality, automatically qualifies as a Priority Pond. Amongst the GMEP ponds, the vast majority of sites fell in the *moderate* quality class, as for headwater streams. Two sites (8%) were classified as good, both situated in upland areas. Two sites (8%) were classified as very poor, also both in upland areas.

		Mean	SE	Min	Max
Alkalinity (mg/L)	Overall	51	15.4	-1.2	290.0
	Lowland (<200 m) *****	94.6	29.1	4.4	290.0
	Upland (>200m)	16.7	7.67	-1.2	104.0
Phosphate (PO4-P) (mg/L)	Overall	0.09	0.03	0.01	0.36
	Lowland (<200 m)	0.10	0.04	0.01	0.36
	Upland (>200m)	0.07	0.03	0.01	0.14
Nitrogen (TDN) (ppm)	Overall	2.05	0.65	0.22	13.50
	Lowland (<200 m)	3.21	1.37	0.41	13.50
	Upland (>200m)	1.13	0.34	0.22	4.48
pH	Overall	5.78	0.16	4.07	7.19
	Lowland (<200 m)	5.99	0.18	5.18	6.70
	Upland (>200m)	5.62	0.25	4.07	7.19
Conductivity ($\mu S.cm^{-1}$)	Overall	226.6	39.0	22.0	779.0
	Lowland (<200 m)	304.5	72.5	42.0	779.0
	Upland (>200m)	165.4	34.6	22.0	448.0

Table 8.7.2.4.1 *Water chemistry of GMEP ponds. Asterisks indicate where one altitude category is significantly higher than the other.*

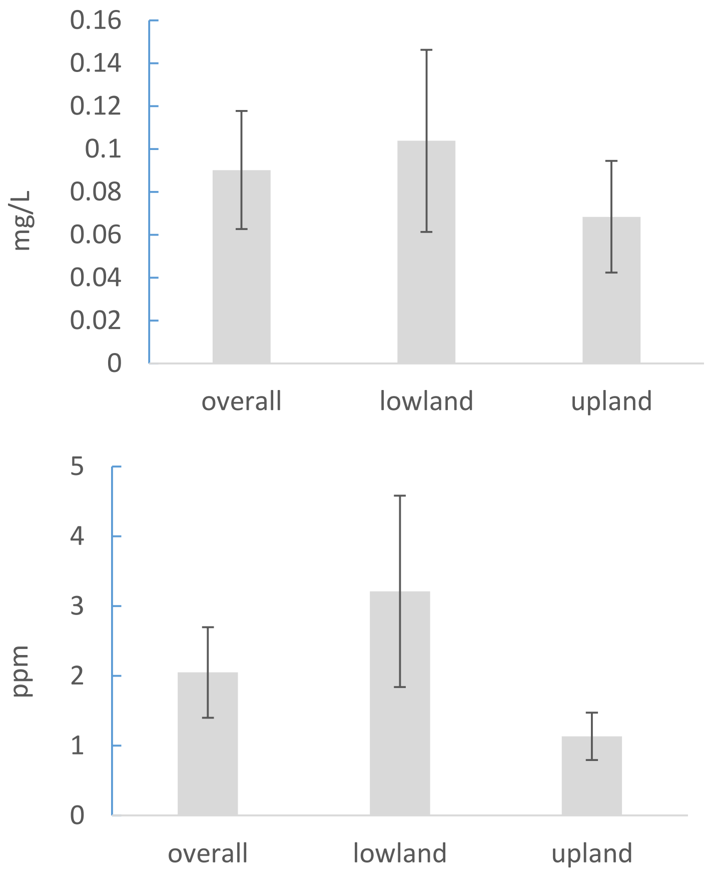


Figure 8.7.2.4.1 *Concentration of nutrients in pond water samples. Top: phosphate: PO4P (mg/L) and bottom nitrogen: TDN (ppm).*

		Mean	SE	Min	Max
Trophic Ranking Score (TRS)	Overall	7.3	0.56	2.5	10.0
	Lowland (<200 m) *	9.1	0.21	8.1	10.0
	Upland (>200m)	6.2	0.74	2.5	10.0
Number of submerged and marginal species (SM)	Overall	10.62	1.21	1.00	23.00
	Lowland (<200 m)	13.00	2.3	4.00	23.00
	Upland (>200m)	11.2	1.48	3.00	21.00
Number of uncommon plant species (U)	Overall	0.62	0.15	0.00	2.00
	Lowland (<200 m)	0.25	0.16	0.00	1.00
	Upland (>200m) *	1.00	0.21	0.00	2.00
E (%)	Overall	33.16	5.67	1.00	100.00
	Lowland (<200 m)*	47.73	9.83	1.00	100.00
	Upland (>200m)	21.71	4.97	1.00	65.00

Table 8.7.2.4.2 *Macrophyte indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other. Data from 29 ponds.*

		Mean	SE	Min	Max
O/E Trophic Ranking Score (TRS)	Overall	1.2	0.08	0.45	1.73
	Lowland (<200 m) *	1.43	0.08	1.06	1.73
	Upland (>200m)	1.01	0.11	0.45	1.73
O/E Number of submerged and marginal species (SM)	Overall	0.73	0.07	0.23	1.32
	Lowland (<200 m)	0.72	0.11	0.34	1.32
	Upland (>200m)	0.74	0.10	0.23	1.27
O/E Number of uncommon plant species (U)	Overall	0.21	0.05	0.00	0.72
	Lowland (<200 m)	0.06	0.04	0.00	0.26
	Upland (>200m) *	0.29	0.06	0.00	0.72

Table 8.7.2.4.3 *Ratio of observed mean to expected means using predictions of PSYM model. Data from 29 ponds.*

		Mean	SE	Min	Max
Average Score per Taxon (ASPT, BMWP)	Overall	4.64	0.11	3.50	5.89
	Lowland (<200m)	4.51	0.21	3.50	5.89
	Upland (>200m)	4.74	0.12	4.00	5.64
Number of dragonflies and alderfly families (OM)	Overall	1.62	0.27	0.00	4.00
	Lowland (<200m)	1.18	0.30	0.00	3.00
	Upland (>200m)	1.93	0.41	0.00	4.00
Number of water beetle families (CO)	Overall	2.81	0.22	1.00	5.00
	Lowland (<200m)	2.64	0.28	1.00	4.00
	Upland (>200m)	2.93	0.32	1.00	5.00
Richness (Margalef)	Overall	5.09	0.39	0.65	8.31
	Lowland (<200m)	5.21	0.46	3.24	8.06
	Upland (>200m)	5.00	0.60	0.65	8.31
Richness	Overall	37.85	3.38	4	65
	Lowland (<200m)	38.45	3.79	21	63
	Upland (>200m)	37.40	5.27	4	65

Table 8.7.2.4.4 *Macroinvertebrate indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other. Data from 29 ponds.*

		Mean	SE	Min	Max
O/E Average Score per Taxon (ASPT, BMWP)	Overall	0.86	0.02	0.65	1.16
	Lowland (<200 m)	0.87	0.04	0.65	1.16
	Upland (>200m)	0.86	0.02	0.70	1.02
O/E Number of dragonflies and alderfly families (OM)	Overall	0.56	0.09	0.00	1.60
	Lowland (<200 m)	0.42	0.10	0.00	0.99
	Upland (>200m)	0.67	0.14	0.00	1.60
O/E Number of water beetle families (CO)	Overall	0.78	0.06	0.65	1.16
	Lowland (<200 m)	0.69	0.07	0.27	1.04
	Upland (>200m)	0.84	0.09	0.28	1.37

Table 8.7.2.4.5 *Observed vs Expected ratio (O/E) of the three main macroinvertebrate indicators used in PSYM. Data from 29 ponds.*

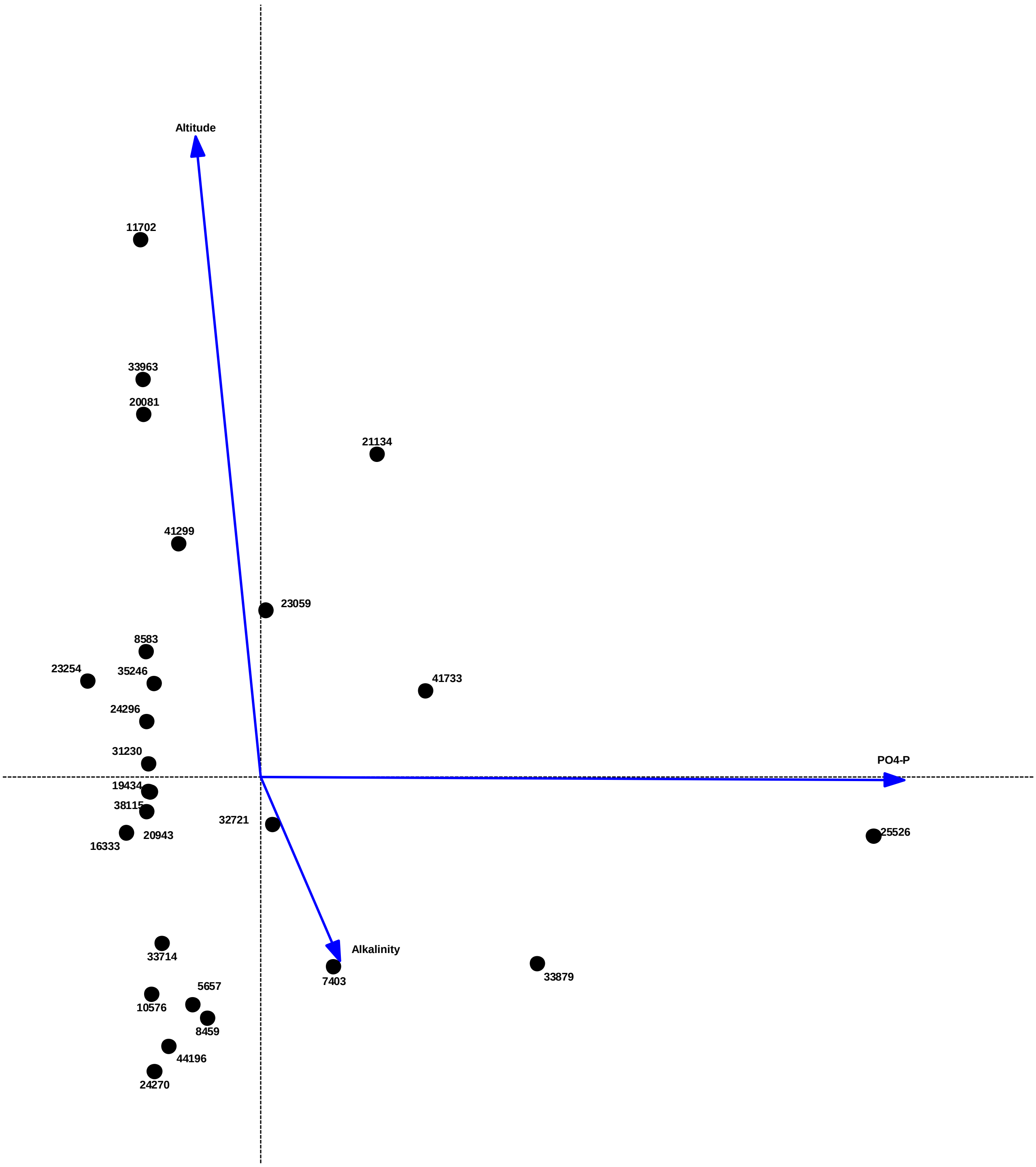


Figure 8.7.2.4.2 *CCA graph of pond macroinvertebrate community data with retained driving variables.*

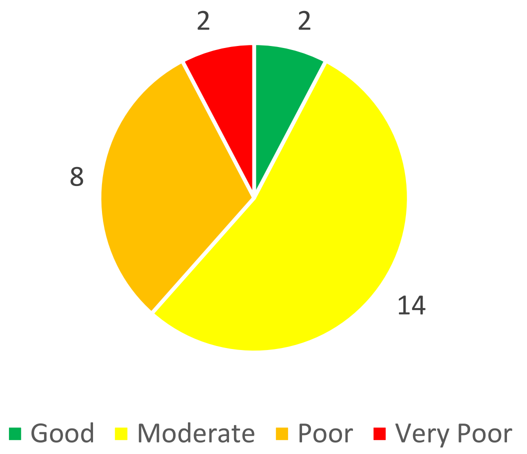


Figure 8.7.2.4.3 *Ecological quality of ponds in GMEP survey: number of ponds in each quality band*

8.7.2.5 Condition of ponds on land in and out of Glastir

We calculated mean values for the pond quality metrics (the ones for which reference values can be predicted by PSYM) for ponds falling in and outside of the Glastir scheme (Table 8.7.2.5.1; Figure 8.7.2.5.1). Three of the six metrics showed a significant difference in their means: the number of uncommon macrophytes (U), the number of water beetle families (CO) and the number of dragonfly and alderfly families (OM), which were all higher for sites falling in the Glastir scheme. Error terms indicated these differences were not statistically significant. Although the number of sites in the analysis was small 14 sites in Glastir, 15 not in in Glastir), the consistent trend in three of the six metrics are suggestive of a higher quality of ponds on land in Glastir.

We also analysed the response of the metrics to the percentage of the GMEP 1km survey square under Glastir. No significant relationships were found for any of the indicators, but a general positive trend was observed for all indicators (Figure 8.7.2.5.2), which may prove significant with the addition of more sites to the dataset each year.

	Status	Mean	SE
TRS	Outside Glastir	4.31	0.31
	In Glastir	4.67	0.12
SM	Outside Glastir	7.00	3.00
	In Glastir	10.92	1.28
U	Outside Glastir	0.00	0.00
	In Glastir	0.67	0.16
ASPT (BMWP)	Outside Glastir	4.31	0.31
	In Glastir	4.67	0.12
CO	Outside Glastir	1.50	0.50
	In Glastir	2.92	0.22
OM	Outside Glastir	0.00	0.00
	In Glastir	1.75	0.28

Table 8.7.2.5.1 *Mean values of 6 indicators according to whether the sites are in or out of Glastir*

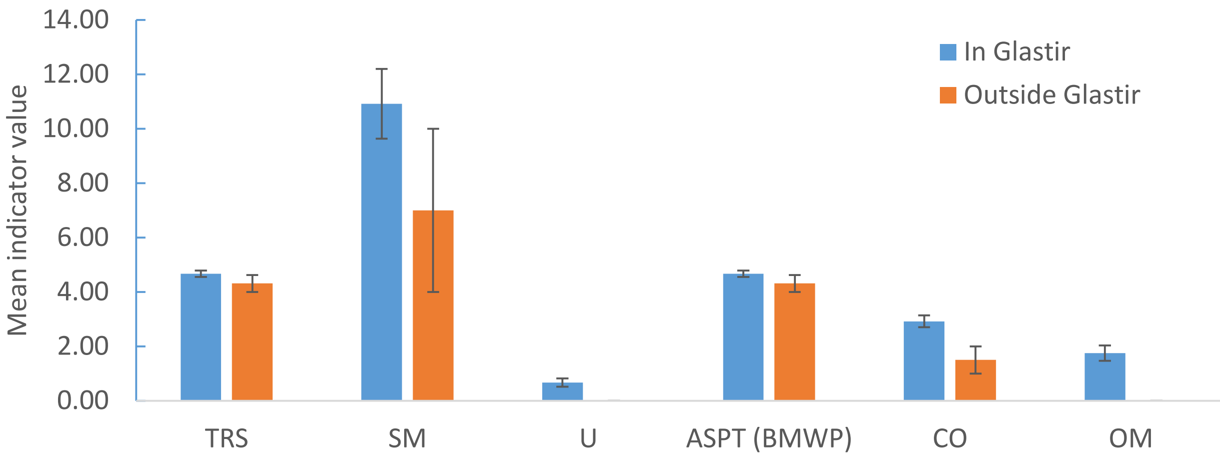


Figure 8.7.2.5.1 *Mean ± 1SE of each indicator for sites in and outside Glastir scheme*

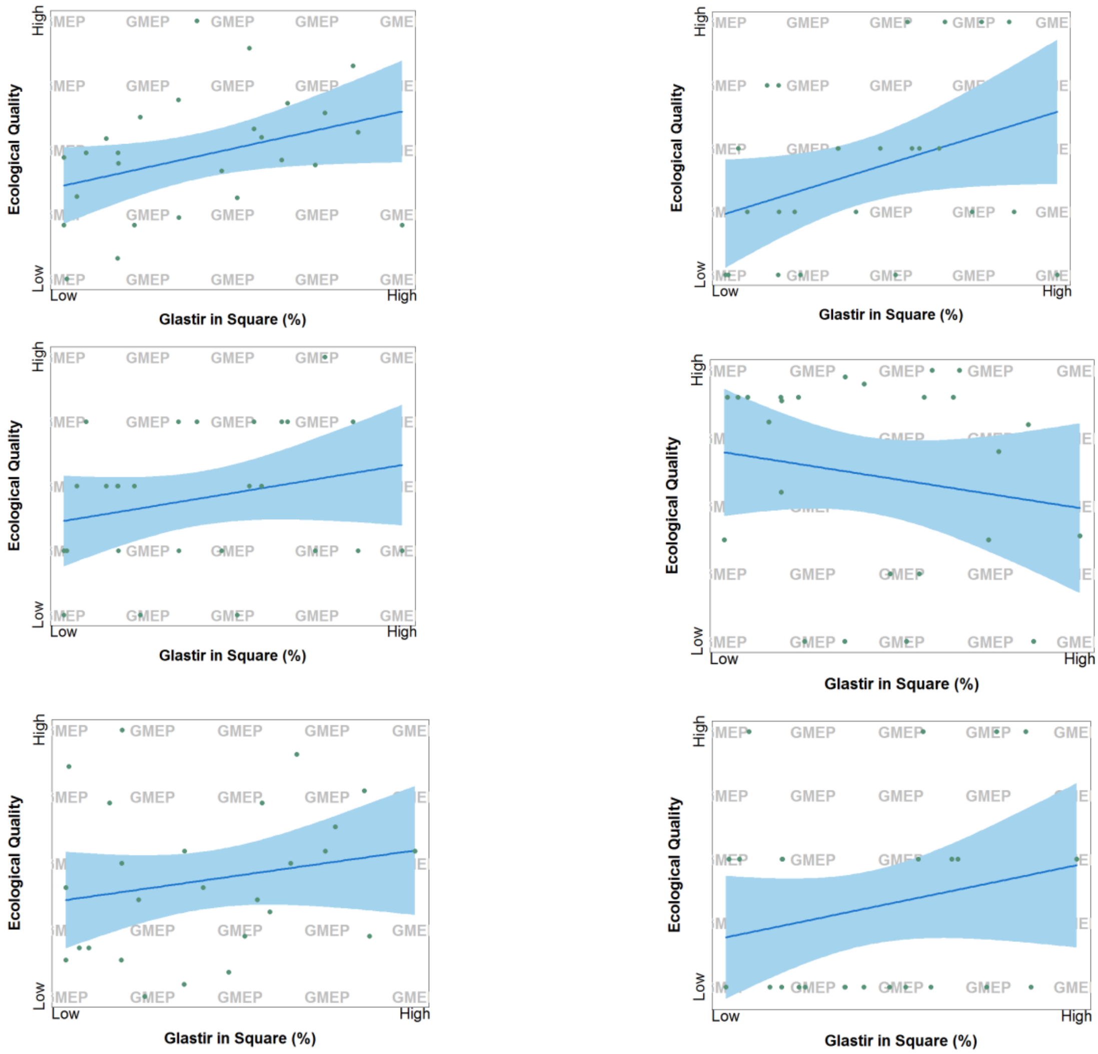


Figure 8.7.2.5.2 *Relationship between indicators of pond ecological quality and percentage of GMEP 1km survey square in Glastir. Left: macroinvertebrates, top: ASPT, middle: CO, bottom: OM. Right: macrophytes, top: SM, middle: TRS, bottom: U. n = 29*

8.8 Plans for year 3

Monitoring of headwater and ponds will continue in years 3 and 4 to complete the baseline survey subject to resources being available. The data will be analysed with respect to area of land in scheme, and with respect to ongoing trends as identified in the Wider Wales GMEP 1km survey squares. For streams this will include all land which contributes to the land upstream beyond the confines of the GMEP 1km survey square. For ponds it may be down-scaled to below GMEP 1km survey square level if the data is available. GMEP and NRW will work together to produce an assessment framework for headwater streams from the survey data, which will be consistent with WFD reporting. Data analysis will also be included in an integrated assessment of the data to identify trade-offs and co-benefits between different ecosystem elements and Glastir Outcomes i.e. combined analysis of the data from the vegetation, soil and habitat mapping. The data is also already being used in the landscape perception work.

9 High Nature Value Farmland

Maskell, L.[1], Jackson, B.[2], Jarvis, S.[1], Maxwell, D.[2], Robinson, D.[3], Siriwardena, G.[4], Smart, S.[1], Tebbs, E.[1], Thomas A.[3], and Emmett, B.[3]

[1] CEH Lancaster [2] Victoria University of Wellington [3] CEH Bangor [4] BTO

9.1 Introduction

Previous work (Parrachini *et al*., 2008) carried out at the European scale and within Wales looked at the concept of High Nature Value farmland and how it might be defined and applied. HNV farmlands have been defined as *'areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European concern or both*' (Anderson et al. 2003, Beaufoy et al. 1994, Lomba et al. 2014). Low intensity agricultural practices may be important in maintaining these areas of high diversity or they may exist despite the farming activities. Spatial heterogeneity is important with habitat mosaics and different structural elements e.g. scrub and linear features to be considered. Land which is of 'High Nature Value' is not easily defined, it may be a subjective and contentious exercise choosing which elements best represent 'high value'. Within the EU, Member States are committed to identifying and maintaining HNV farming; however, there are no specific rules or generic metrics and criteria established at EU level to determine HNV farmland. Each member state therefore interprets the concept and decides how best to apply it to their state. It is inevitable that there will be disparities in HNV farmland definitions, individual countries will have different indicators (particularly for type 3 indicator species), farming systems and landscape features, however, there is a need for a more integrated approach across European countries with common standards and definitions (Lomba et al. 2014).

The GMEP team have been tasked by WG to explore these concepts and propose new ideas, criteria and metrics that might be applied to define land of 'High Nature Value' and to form an indicator to create a baseline extent and to measure changes in extent and quality. We are conducting this work in consultation with a range of partners and stakeholders who are also interested in the potential value of this metric. Specifically this has included a small working group involving CEH, BTO, RSPB and WG who first met in April 2013; a RSPB workshop with a wide range of participants from across the farming and conservation section in May 2013; a GMEP Steering Committee in June 2013 with representative from the farming community, WG, NRW and NGOs and a number of subsequent working group meetings in 2013/2014. A wide range of views were expressed which range from this "is a metric of little value which could confuse rather than illuminate" to "a potentially useful metric to communicate overall trends in biodiversity".
It has been generally agreed that HNV farmland (e.g. Andersen *et al.* 2003) can be broken down into 3 types:
Type 1: Farmland with a high proportion of semi-natural vegetation
Type 2: Farmland with a mosaic of habitats and/or land uses
Type 3: Farmland supporting rare species or a high proportion of European or world populations
And Not HNV: Typically the major arable areas, intensively managed land.
Type 3 may overlap with types 1 and 2 but some rare species may be associated with biologically simplified agricultural areas with low habitat diversity.

In their paper Lomba et al. (2014) present an extremely useful conceptual framework based on work by Andersen et al. (2003) and modified according to Parrachini et al. 2008, Oppermann et al. 2012, Pedroli et al. 2007). This figure also incorporates the gradient in farming intensity with a threshold where land is no longer considered to be HNV, this could be particularly problematic in type 3 land where there are small pockets of rare species in an intensively farmed landscape.

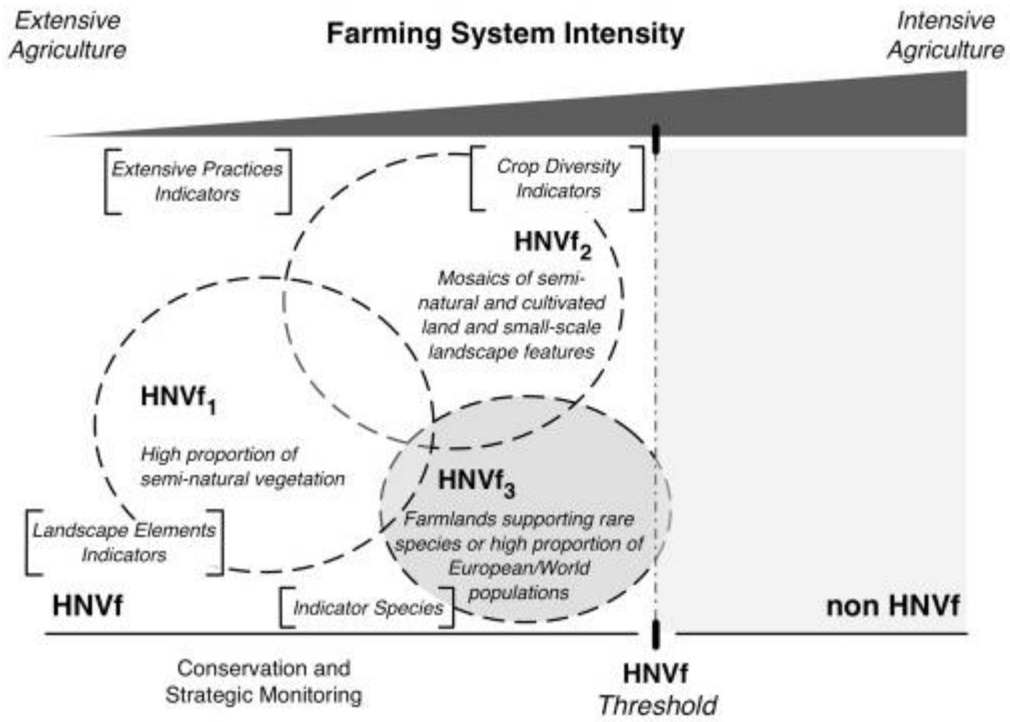


Fig. 9.1.1 *Taken from Lomba et al. (2014) High Nature Value farmlands (HNVf) conceptual framework in relation to the intensity of farming systems, and features underlying the classification of the three broad types as proposed by Andersen et al. (2003).*

The Common Monitoring and Evaluation Framework (CMEF; EC 2005) includes Baseline, (area of land under HNV) Result, (total hectares under successful land management) and Impact (changes in extent and condition indicators) and these need to be incorporated into planning for reporting on HNV.

It is important to create a metric structure that uses objectively measured criteria. In particular the temporal aspect needs to be considered, detection of change is important. Much of the data that could be used to derive indicators is not consistently collected at regular temporal intervals, so even if an estimate of HNV extent across Wales is created from the best available data a method for repeating this needs also to be developed. GMEP is a sample based monitoring system, the sampling system is a stratified random system which was used specifically to enable scaling up and creation of national estimates. If similar metrics are used only within GMEP 1km survey squares then with continuous monitoring from GMEP it will be possible to estimate changes in the HNV farmland metric even when it is not possible to repeat continuous national surveillance. Although it is also possible that it may be possible to obtain some of the other spatially continuous datasets e.g. remotely sensed land cover data (Morton and Rowland, 2014) on a more systematic and regular basis.

The need for options to prevent the loss of High Nature Value farmland is widely acknowledged (Parrachini et al. 2008) as part of the Habitats and Birds directives and rural Development Policy. The challenge is to identify such land based on consistently collected data, at a suitable resolution and then review if the information provides a useful addition to the reporting system for GMEP.

9.2 Achievements in Years 1 and 2

- Convened and met with a range of stakeholders to discuss possible approaches and agree a way forward

- Collated a table of possible metrics for HNV
- Collation of potential datasets from which to calculate metrics
- Development and calculation of metrics e.g. connectivity, habitat diversity, rare species, rare soils etc.
- Analysis and discussion of the potential to downscale from coarse resolution recording datasets- dataset for plant species produced
- Metrics calculated for four case study areas with proposals presented for next steps
- We present several methods of potentially assessing the contribution of soil to High Nature Value land.

9.3 Approach

There have been a number of meetings with stakeholders to discuss the concept of HNV and how we might develop an indicator in the Glastir Monitoring and evaluation project resulting in some decisions in scope and terminology and proposals for future work. A small working group involving members of the GMEP team (CEH, British Trust for Ornithology (BTO) and Staffordshire University), Royal Society for the Protection of Birds (RSPB), National resources Wales (NRW) and the Welsh Government (WG) was convened in April 2013 and met several times in 2013 and 2014. It was agreed that:

- The term HNV farmland would be used rather than HNV farming, farm type has been looked at in previous case studies (e.g. WG, Natural England (NE)) but its usefulness has been questioned so the type of farming will not be included in a classification system.
- The concept of HNV forestry would not be pursued as there appeared to be a move away from this as a requirement by the EC.
- We should keep it simple – there is flexibility in the guidance which means that we have flexibility
- The stakeholders and GMEP project team were asked to propose criteria and datasets that might contribute to an indicator and we have constructed a summary spreadsheet resulting from this consultation which links criteria to metrics and datasets.
- It was agreed that it would be useful to look at case study areas for HNV that the HNV topic group were familiar with

Indicators were investigated for mapping Types 1, 2 and 3 HNV farmland. The metrics that were considered included: percentage of semi-natural habitat, habitat richness (total number of habitats), habitat diversity (Simpsons and Shannon indices), habitat evenness, mean patch size, area of priority habitat, density of linear features (e.g. Hedgerows), connectivity for different species/habitats, and species data from BRC and BTO. A range of different datasets, available for calculating each of these indicators, was considered.

Four case study areas were selected: Conwy Valley, Carmarthenshire, Brecon Beacons National Park and Llyn Peninsula. Conwy Valley is already a CEH study area so there is existing knowledge and data for the area. East Carmarthenshire was part of a pilot HNV study (EFCNP). For each of the potential HNV indicators, maps were produced for the whole of Wales and for each of the four case study areas.

9.3.1 Available habitat/land cover data

There are a number of datasets available for mapping habitat/land cover across Wales, which have the potential to be useful for monitoring HNV farmland. These datasets are summarised in Table 9.3.1.1

Dataset	***Characteristics***
CCW/NRW Phase 1	• *Records priority habitats* • *Continuous data* • *Last surveyed 1999* • *Unlikely to be repeated so cannot be used for change*
Land Cover Map 2007 (LCM2007)	• *No priority habitats* • *Continuous data* • *Available to use now* • *Historical algorthims being standardised to allow for historic change to be more accurately reported* • *Rolling LCM under development which would allow use for change at more frequent time period*
Fused habitat map for Wales	• *Records priority habitats* • *Not consistently recorded- different rule bases applied in different areas* • *Not yet available?* • *Unlikely to be able to report change*
GMEP 1km survey squares	• *Fine detail, including linear features* • *Can use Glastir management data to look at impacts of options* • *Can be used for change* • *Sample based data*
Woody Cover Product (Section 5.4)	• *maps woody features that support biodiversity (hedges, individual trees, clumps of trees) and complements LCM* • *repeatable*

Table 9.3.1.1 *Summary of available datasets for mapping habitat/land cover across Wales*

9.4 Approach

The potential indicators have been assigned to different HNV types and presented under those sections with discussion. For HNV type 1 this is fairly straightforward and only one indicator is currently proposed, however for other HNV types data may be more complex and methods for combining metrics are also discussed.

9.5 Type 1 HNV: Proportion of semi-natural habitat

The proportion of semi-natural habitat in the landscape is an important indicator of biodiversity and of Type 1 HNV farmland. Land cover data from LCM2007 was used to calculate the percentage of semi-natural habitat (% SN habitat) in each 1km^2 across Wales. Appendix 5.5 gives a list of the LCM2007 classes that were considered to be semi-natural.

The % SN habitat was calculated as:

% SN habitat = (area of semi-natural habitat)/(total area of habitat)x100

The resulting map is show in Figure 9.5.1

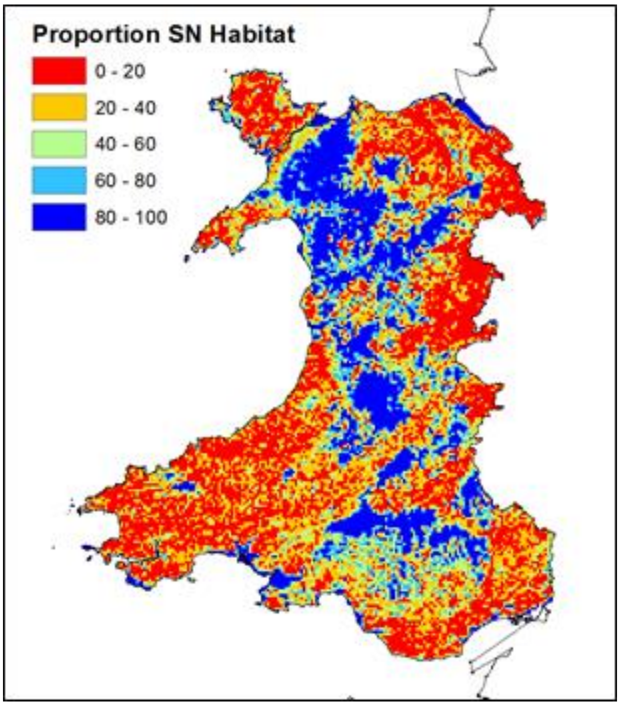


Figure 9.5.1 *Map showing the proportion (%) of semi-natural habitat in each 1km² across Wales based on LCM2007.*

9.6 Type 2 HNV: Farmland with a mosaic of habitats and/or land uses

9.6.1 Landscape heterogeneity

A number of indicators for landscape heterogeneity were considered for identifying Type 2 HNV farmland, including: habitat count; habitat diversity (Shannon and Simpsons indices) and habitat evenness. These indicators are calculated based on LCM2007 using similar methods to Hill & Smith (2005). The resulting maps are shown in Figure 9.6.1.1.

1. Habitat count (C): Total number of habitats per $1km^2$ grid cell
2. Habitat diversity – Simpson's Index (D_{si}):
$$Simpson's = \sum p_i^2$$
3. Habitat diversity – Shannon's Index (D_{sh}):
$$Shannon's = -\sum p_i \ln p_i$$
4. Habitat Evenness (E):
$$E = D_{si}/C$$

N.B. Simpson is an inverse index

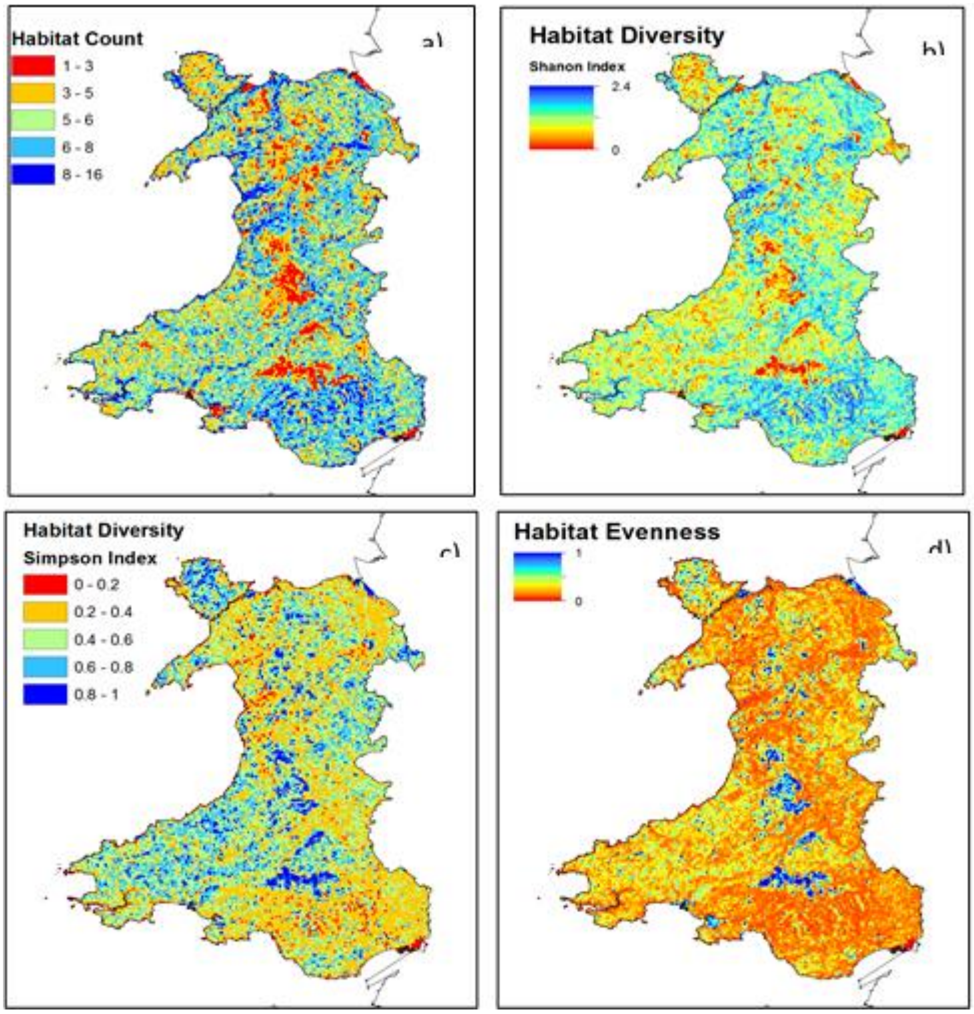


Figure 9.6.1.1 *Maps of habitat count (a); habitat diversity - Shannon index (b) and Simpson index (c); and habitat evenness (d), for each 1km² across Wales based on LCM2007.*

9.6.2 Woodland connectivity for HNV

Connectivity between habitat fragments is important to maintain species populations and diversity. Highly connected habitats allow species to move around with ease and can support a greater number of species. Connectivity is under threat through the fragmentation of habitats in the landscape as a result of agriculture or urbanisation. Connectivity is a component of Type 2 HNV and was assessed for Broadleaved woodlands in the four case study areas (Brecon, Carmarthenshire, Conwy and Llyn). To assess variation in connectivity over the case study areas the areas were divided into 1 km² grid cells. The distribution of Broadleaf woodland in case study area was mapped using the Land Cover Map for 2007. For each grid cell the pairwise distances between all the woodland habitat patches from Land Cover Map were calculated using the Conefor Inputs tool (Jenness Enterprises, Flagstaff, AZ, USA). These distances were then used as input to the Conefor tool (Saura & Torné, 2009) which calculated a connectivity metric (Probability of Connectivity) for each 1 km² in each case study area[1]. The connectivity metric was rescaled to between 0 and 1 to look at relative differences between grid cells.

[1] The tool was parameterised with a dispersal kernel with a distance of 200 metres at a probability of 0.5.

9.6.3 Density of field boundaries

Type 2 HNV farmland can be defined as a mosaic of low intensity farmland and other semi-natural landscape features. The density of field boundaries (which is inversely related to parcel size) is a proxy for management intensity. In general, smaller fields are likely to be less intensively managed. Figure 9.6.3.1 shows the density of field boundaries across Wales. Areas with high field boundary density, for example in the Llyn Peninsula, are potential areas of Type 2 HNV farmland. A similar metric could be produced which captures the density of woody linear features, work is ongoing to produce a Woody Linear Product which could be used for this purpose.

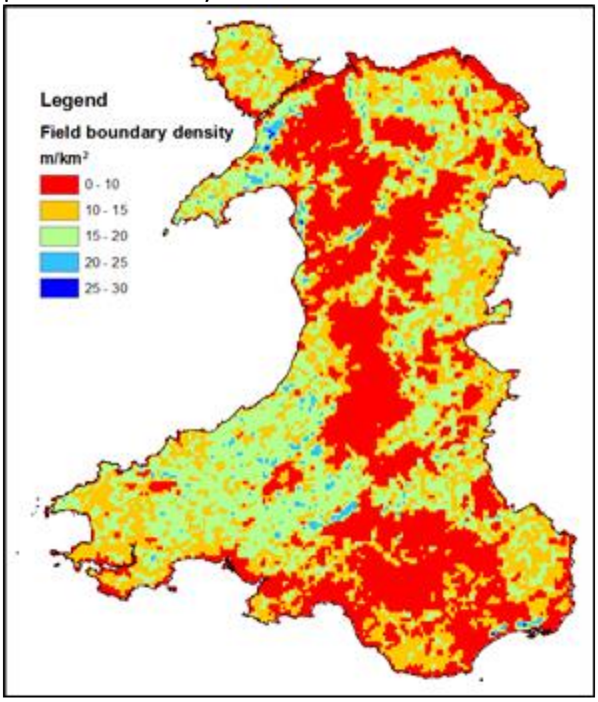


Figure 9.6.3.1 *Map of field boundary density across Wales, based on data for the Land Parcel Information System (LPIS).*

9.6.4 Species

Following meetings with stakeholders, it was felt that species data should be incorporated into the metrics for Types 2 and 3 HNV farmland. The following BRC species datasets at 10km resolution were assembled: Ants, Bees, Craneflies, Carabidae, Centipedes, Millipedes, Cerambycidae, Hoverflies, Isopoda, Ladybirds, Fish, Orthoptera, Bryophytes, Higher Plants, Birds. Figure 9.6.4.1 shows example maps produced using these data.

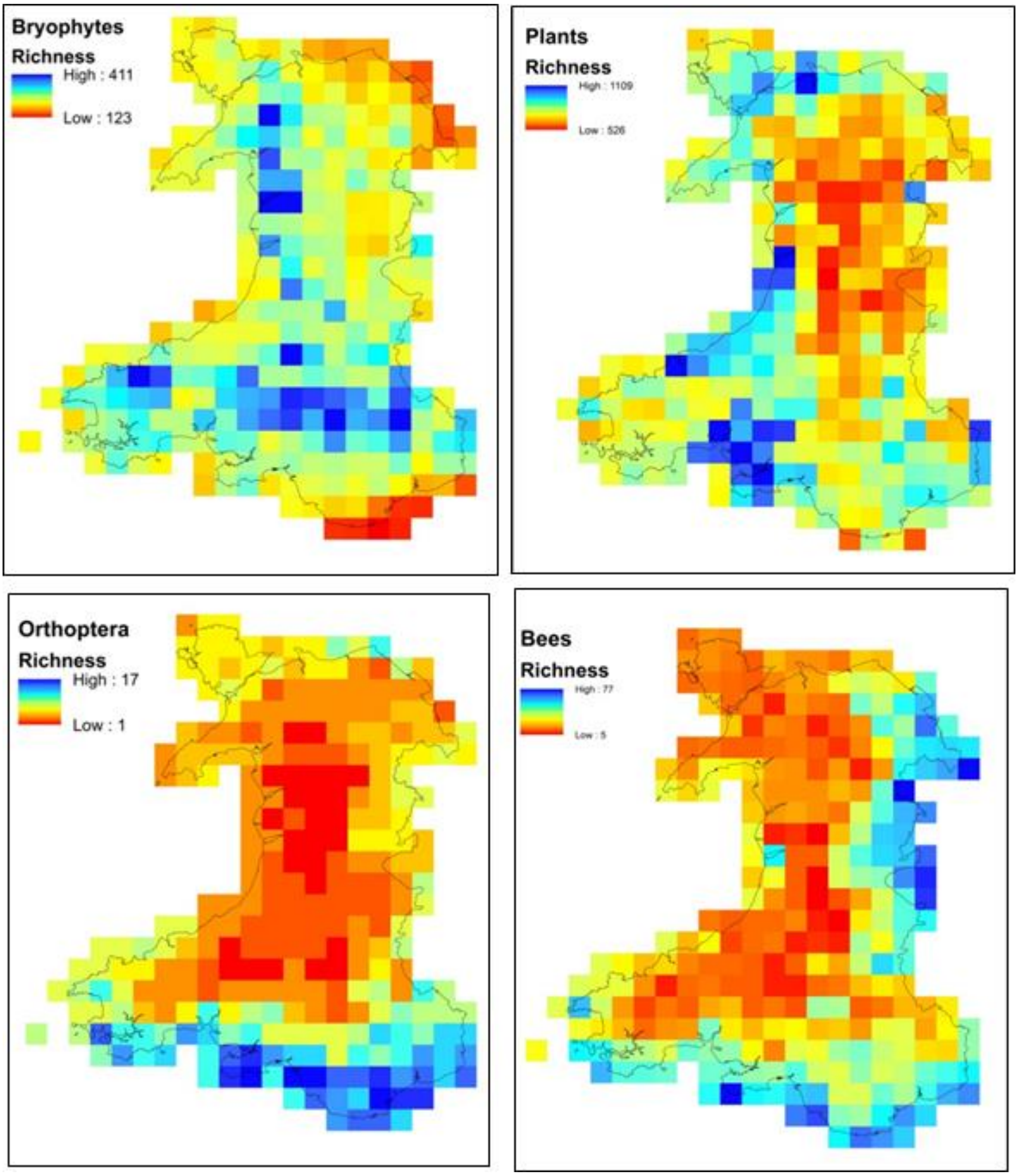


Figure 9.6.4.1 *Example maps of species richness within each 10km x 10km grid cell across Wales for different groups of species, based on BRC data.*

It is also possible to use bird data and there are various choices to make in creating a metric. Should a selection of bird species be used or should all bird species be included? It is possible to summarize the bird data in multiple ways – total abundance, various diversity indices. Here, a simple approach has been taken, avoiding decisions about how to combine species data to represent HNV best that have no clear evidential basis.

Figure 9.6.4.2a shows the distribution of conservation-relevant farmland bird species from the Bird Atlas 2007-11[2] and Figure 9.6.4.2b shows the distribution of all bird species, in each case

[2] All birds from the lowland and upland farmland lists for the standard indicator set, plus other S42 species (e.g. corn bunting) that are classified as "farmland" at UK level but too rare to be used in the Wales indicators. The species list is: Buzzard, Corn Bunting, Chough, Curlew, Grey Wagtail, Goldfinch, Greenfinch, Jackdaw, Kestrel, Lapwing, Linnet, Meadow Pipit, Grey Partridge, Reed Bunting, Raven, Rook, Skylark, Stock Dove, Starling, Tree Sparrow, Wheatear, Whinchat, Whitethroat, Woodpigeon, Yellowhammer, Yellow Wagtail.

summarized as simple species richness (the number of species per square found and interpolated from Bird Atlas 2007-11, Balmer et al. 2013). This data is at a 4km resolution which should be adequate for birds as they are mobile species and have varying range sizes.

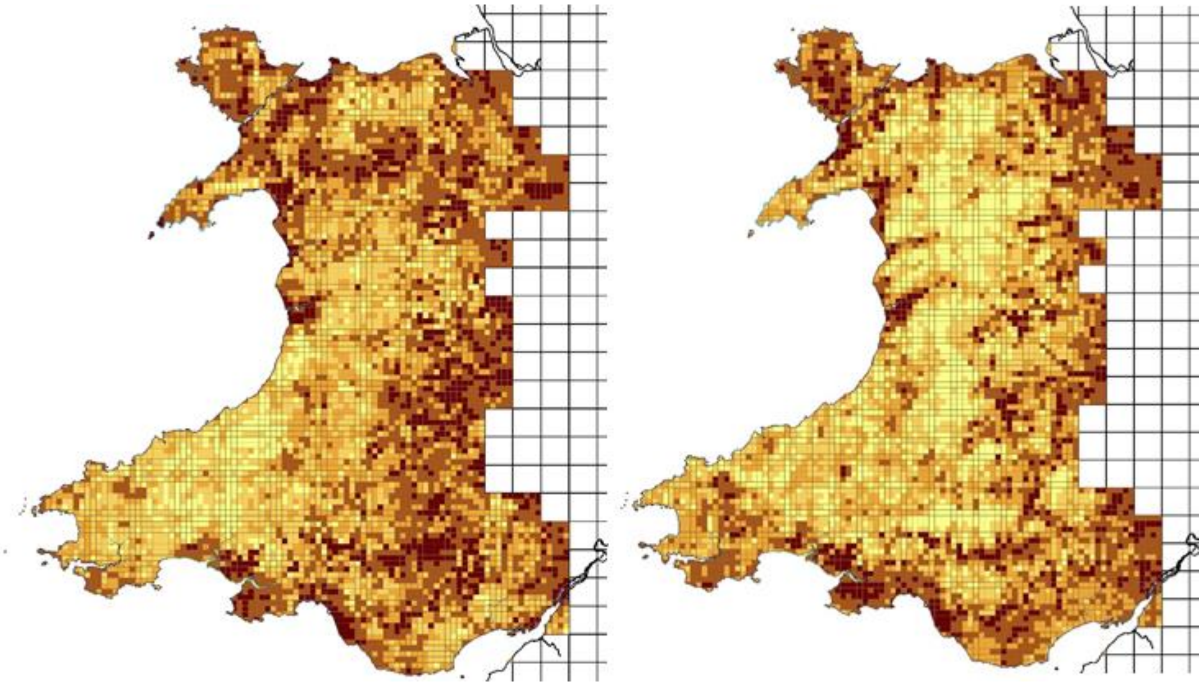


Figure 9.6.4.2a *(Left) richness of farmland bird species at a 4km square resolution*
Figure 9.6.4.2b *(Right) richness of all bird species at a 4km square resolution*

It would seem more appropriate to use the richness of farmland bird species (i.e. the number of species found within a defined area) as the metric to incorporate to identify HNV farmland. The coarse resolution of some datasets (hectad) makes it difficult to incorporate them into a metric for monitoring HNV farmland, small scale differences in species abundance are important. Work has taken place in GMEP to investigate the potential of downscaling (and upscaling) species data and plant species data is now available at 1km resolution. The technique used for the plants requires species-specific habitat associations mapped to the land cover map categories. This is not available for many groups, e.g. the pollinators. Work is ongoing using recently developed Bayesian techniques to develop datasets at a 1km resolution for other groups, however they are very computationally intensive and take a long time to run. Hopefully some progress will be made in this area to enable the use of finer scaled species data for a number of groups. It is possible to use some field survey based data for rare species (see section below).

9.6.5 Combining metrics

9.6.5.1 Ordination and response curves

Deciding how to identify High Nature Value areas is difficult because there will be variation in the relationships between diversity variables e.g. high plant species richness may not be correlated with high richness of bees, and agreement on prioritisation or optimisation of diversity will need to be decided between stakeholders. It is important to understand these relationships both at a national scale across Wales (Figure 9.6.5.1.1) and in individual case study areas (Figures 9.8.2.1a to d) to identify where there are tradeoffs and co-benefits. The figures below are created by carrying out a Principal components analysis (PCA) in R using the vegan program on standardised biodiversity metrics (scaled from 0 to 1 instead of using real values), these appear as the coloured curves in the figures below. Potential explanatory variables; Habitat diversity, NPP and connectivity have been included. A similar method was used in Maskell et al. (2013) to look at relationships between ecosystem service indicators.

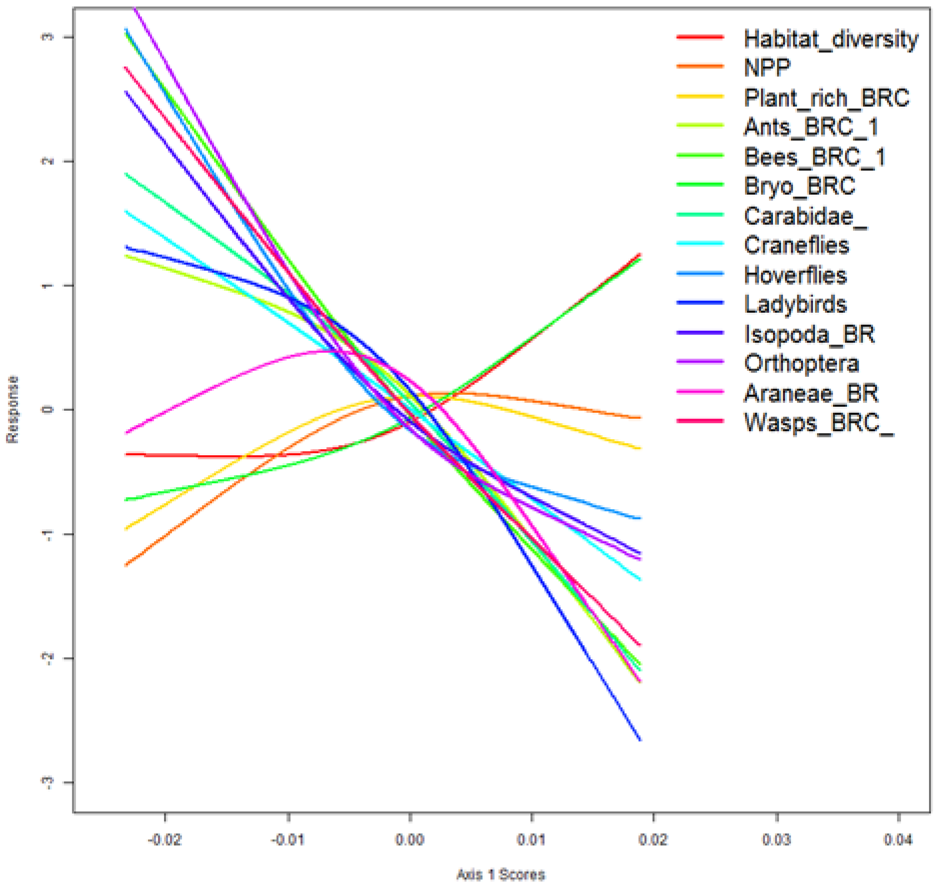


Figure 9.6.5.1.1 *Relationships between diversity variables across all of Wales.*

Figure 9.6.5.1 shows that relationships between biodiversity variables, NPP and Habitat diversity are complex. At a national scale there is an overall loss of biodiversity with increased productivity (NPP) and Habitat diversity, with some association between habitat diversity and bryophyte richness. Many of the species groups e.g. carabidae, hoverflies, bees, ants decline with habitat diversity but it must be remembered that data for all species other than plants is at a crude 10km resolution. This type of analysis needs to be repeated with the best possible data when more progress has been made at downscaling. A metric for HNV can be obtained by extracting the ordination score and using that as a single measure.

9.6.5.2 Other methods for combining metrics

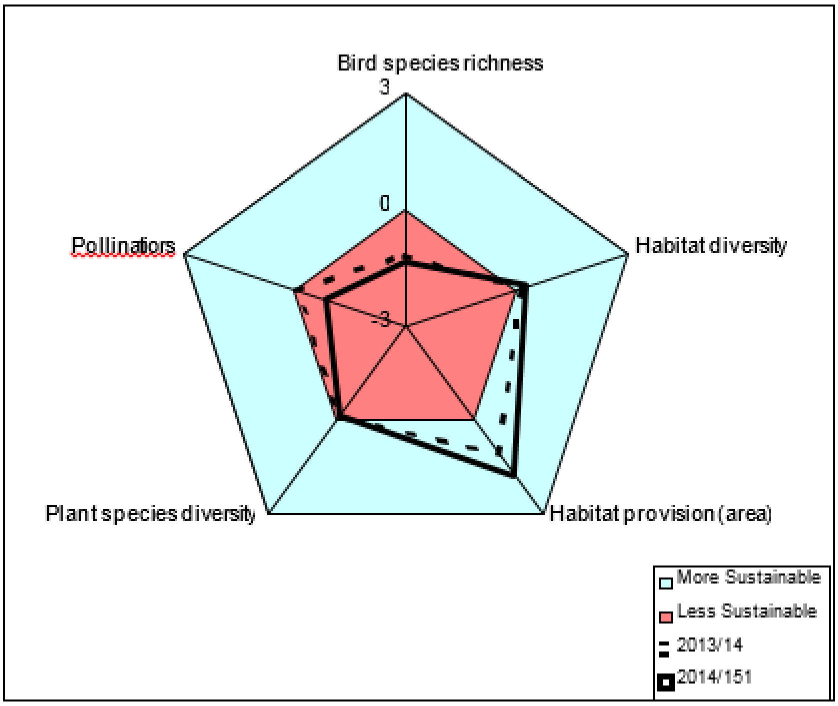


Figure 9.6.5.2.1 *Spider diagram of selected metrics/ecosystem services*

Figure *9.6.5.2.1* is a spider diagram of chosen metrics/ecosystem services, it uses a similar principal to the ordination, that you are using multiple indicators to indicate the condition of your HNV area and that there will be tradeoffs and co-benefits. The single metric could be the area contained within the graph shown here by the dashed and solid lines for different years, so for 2014/15 there is a larger provision of habitat but other indicators pollinators, plant species diversity, bird species richness there have been declines, the coloured areas reflect how sustainable the underlying resources are i.e. in this diagram some indicators have declined critically.
For both the ordination/response diagrams and the spider diagrams the choice of metrics can be discussed and the most appropriate agreed, these may include ecosystem variables such as soil quality (discussed later) in addition to diversity. Once we have chosen the most suitable metrics at the most appropriate resolution analyses can be carried out to create an HNV metric. An ordination method was used by Boyle et al. 2015 to create an index score based on selected variables in a study in Ireland.

9.7 Type 3 HNV farmland: Farmland supporting rare species or a high proportion of European or world populations.

9.7.1 Species

It is possible to use data on rare species from field survey/monitoring schemes. Figure 9.7.1.1 shows the distribution of Section 42 plant species taken from data provided by Plantlife. Figure 9.7.1.2 shows the distribution of rare bird species.

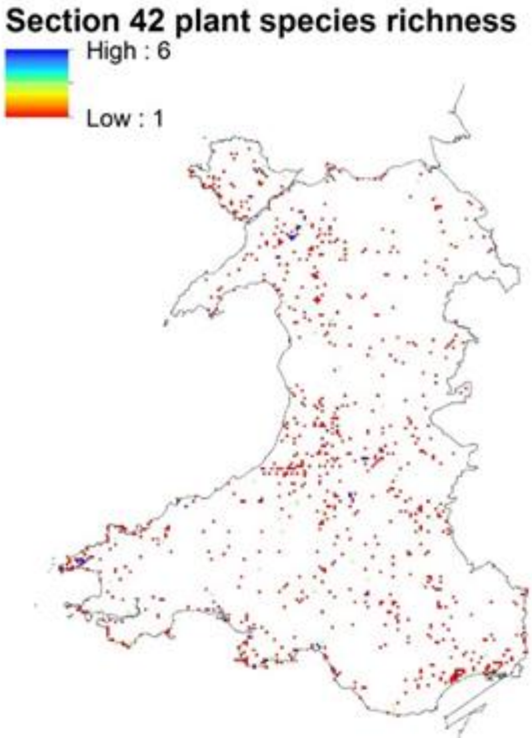


Figure 9.7.1.1 *Map showing the distribution of rare plant species (Section 42) across Wales*

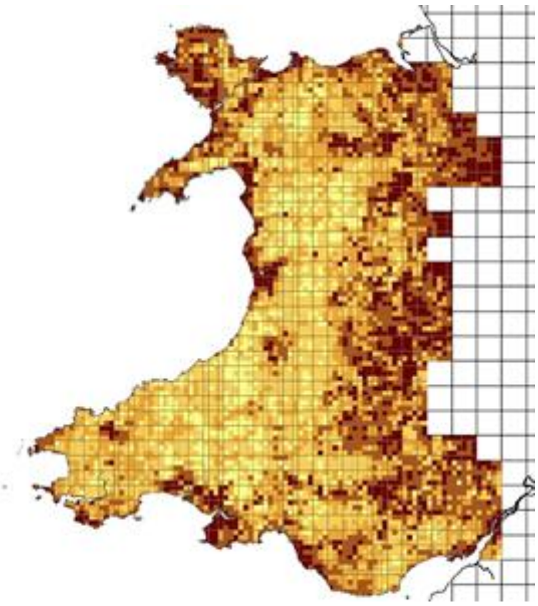


Figure 9.7.1.2 *Map showing the distribution of rare bird species (Section 42) across Wales*

Another potentially useful metric is the area of all SPAs SACs and SSSIs in a region. This was a metric used in HNV work carried out in Scotland, however, following meetings with stakeholders it was decided that, for this work, it may be more appropriate for the indicator of Type 3 HNV farmland to be based on species data. This data has been mapped for the case study areas to inform discussions.

9.8 Case study areas

For each of the case study areas, a set of maps was produced showing the different metrics with the potential to be used for mapping HNV farmland, produced from LCM2007 data. These maps were used to assess the usefulness of the different metrics as HNV indicators. Figures 9.8.1 and 9.8.2

below show example maps for the Conwy Valley case study area. Figure 9.8.1 is a map of land cover for the Conwy Valley from LCM2007, which was used to derive the metrics.
Type 1 HNV farmland can be represented by a map of all semi-natural land parcels (Figure 9.8.2a) or alternatively as the % SN habitat in each 1km^2 (Figure 9.8.2b). The advantage of the former is that it maintains the resolution of the input dataset so that small parcels of SN habitat are still visible. Conversely, the advantage of the % SN habitat is that it gives an aggregate value for each 1km^2 grid cell. This % SN habitat metric can be categorised, as in Figure 9.8.2b, or a threshold can be selected (e.g. 20 % SN habitat) below which the grid cell is not considered to contain HNV farmland.

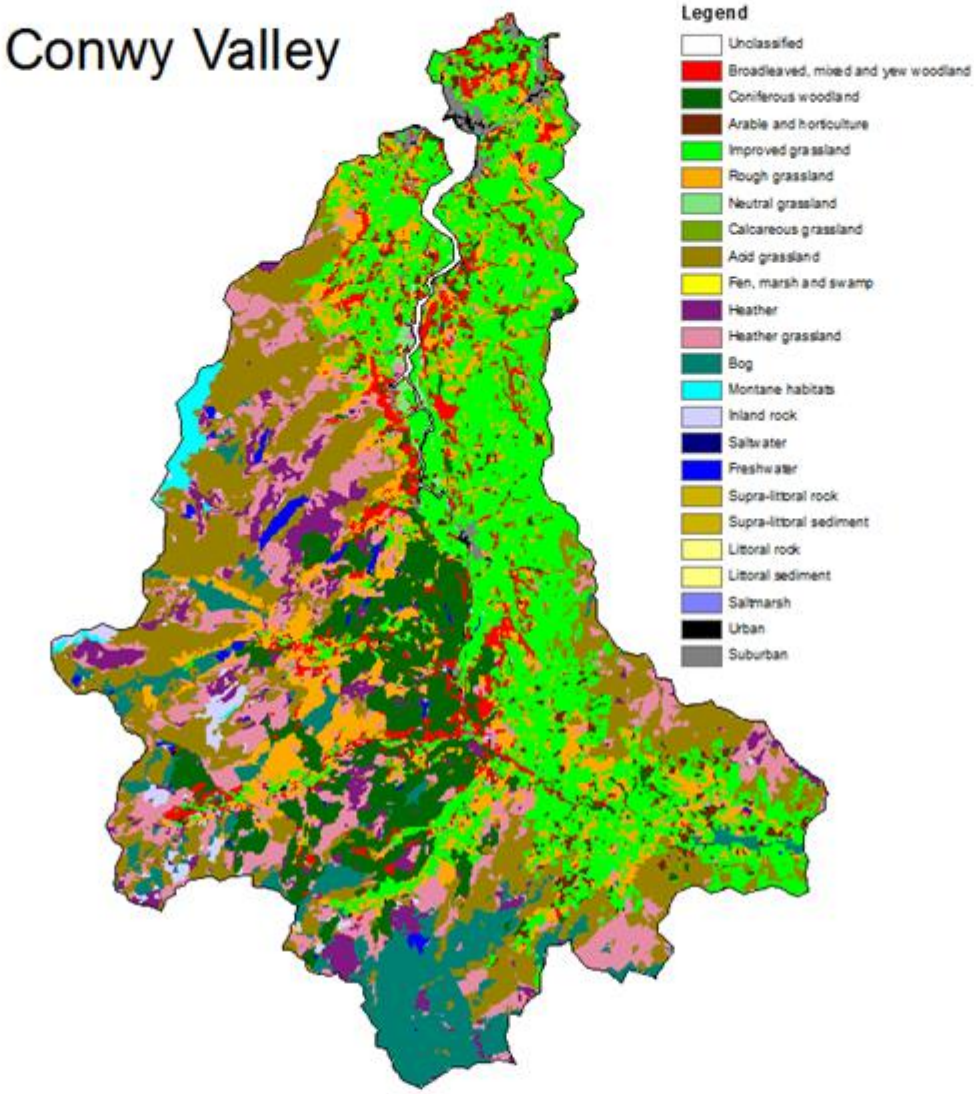


Figure 9.8.1 *Land cover map for the Conwy Valley from LCM2007.*
Figure 9.8.2c and 9.8.2d show the habitat count and habitat diversity (Shannon) in each 1km^2 grid cell for the Conwy Valley. The Shannon's Index of habitat diversity was thought to be the most useful metric for representing the mosaic of habitats representative of Type 2 HNV.

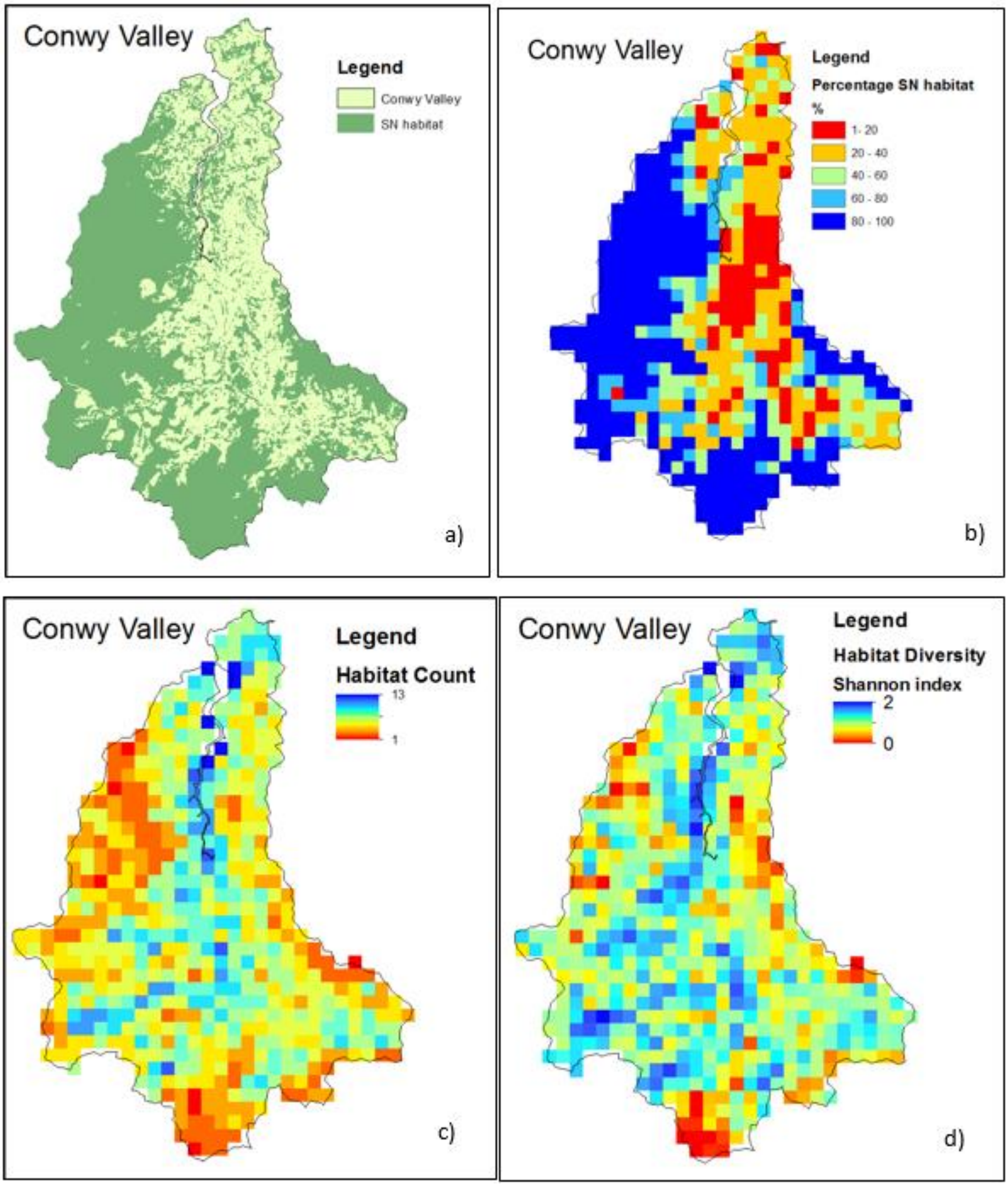


Figure 9.8.2 *Maps of potential HNV indicators for the Conwy Valley case study area, including: semi-natural habitat (a); % semi-natural habitat per 1km²(b); habitat count (c); and habitat diversity – Shannon index (d).*

9.8.1 Preliminary HNV metrics

Based on the work undertaken so far the following metrics are proposed for HNV farmland:

Type 1:

- Option 1. Areas of all semi-natural land parcels (Figures 9.8.1.1a, 9.8.1.2a, 9.8.1.3a, 9.8.1.4a)
- Option 2. Use % semi-natural habitat and define a threshold – e.g. > 20 % - for HNV farmland

Type 2:

- Use upper quartile of habitat diversity (Shannon's Index) (Figures 9.8.1.1b, 9.8.1.2b, 9.8.1.3b, 9.8.1.4b)

- Incorporate connectivity into the metric (Figures 9.8.1.1f, 9.8.1.2a, 9.8.1.3a, 9.8.1.4a). The connectivity maps show the distribution of woodland connectivity over the case study areas. Grey areas have no connectivity because there are no areas of woodland. Blue cells have low connectivity and red cells have high connectivity, indicating woodland areas are highly connected. For each case study area most cells are blue, indicating that connectivity is low in most areas with a few hotspots of higher connectivity.
- Incorporate a metric of field boundary density as a surrogate of farmland intensity
- Incorporate species richness or presence/abundance of selected species, particularly species which are characteristic of a mosaic of habitats including low intensity farmland (not yet done).

Type 3:

- Could incorporate data on protected areas SPAs, SACs, SSSIs (Figures 9.8.1.1c, 9.8.1.2c, 9.8.1.3c, 9.8.1.4c) or might be used as a separate dataset to compare HNV metric to.
- Glastir target layers and protected zones could be used to identify HNV areas or as a dataset for comparison with an HNV metric (Figures 9.8.1.1d, 9.8.1.2d, 9.8.1.3d, 9.8.1.4d)
- Develop an indicator based on species data, particularly species which are rare or species for which a high proportion of European or world populations are found in the UK Figures 9.8.1.1e, 9.8.1.2e, 9.8.1.3e, 9.8.1.4e show data for Section 42 rare plants).

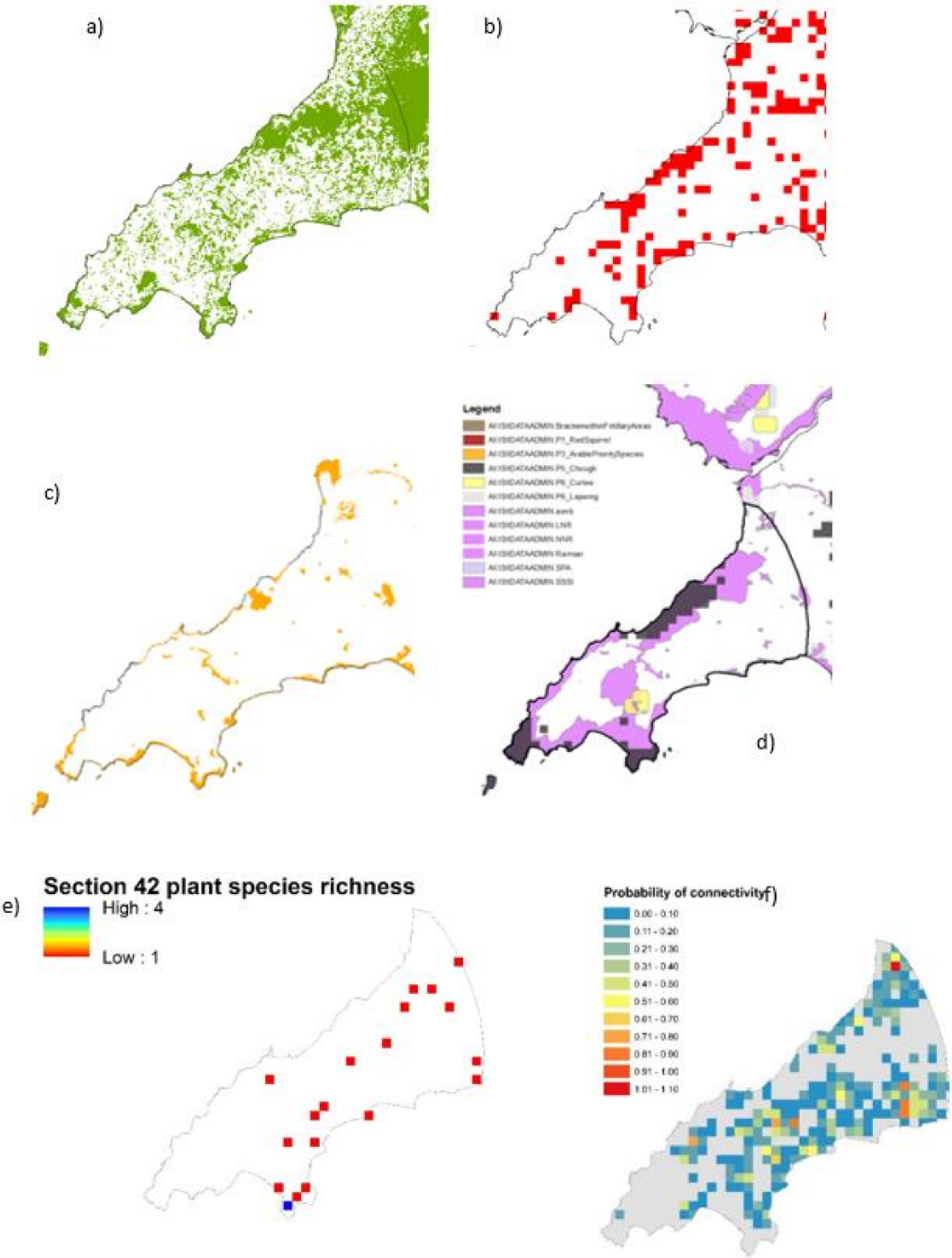


Figure 9.8.1.1 Maps of potential HNV indicators for Llyn Peninsula, including Type 1 – semi-natural habitat patches (a); Type 2 – Upper quartile of habitat diversity (Shannon Index; species data not yet incorporated) (b); Type 3 - SPAs, SACs and SSSIs (species data not yet included) as c; a map showing protected areas and protected zones (d), a map showing the distribution of rare plant species ((Section 42)(e), and Broadleaf woodland habitat connectivity metrics for each 1 km grid cell (f)

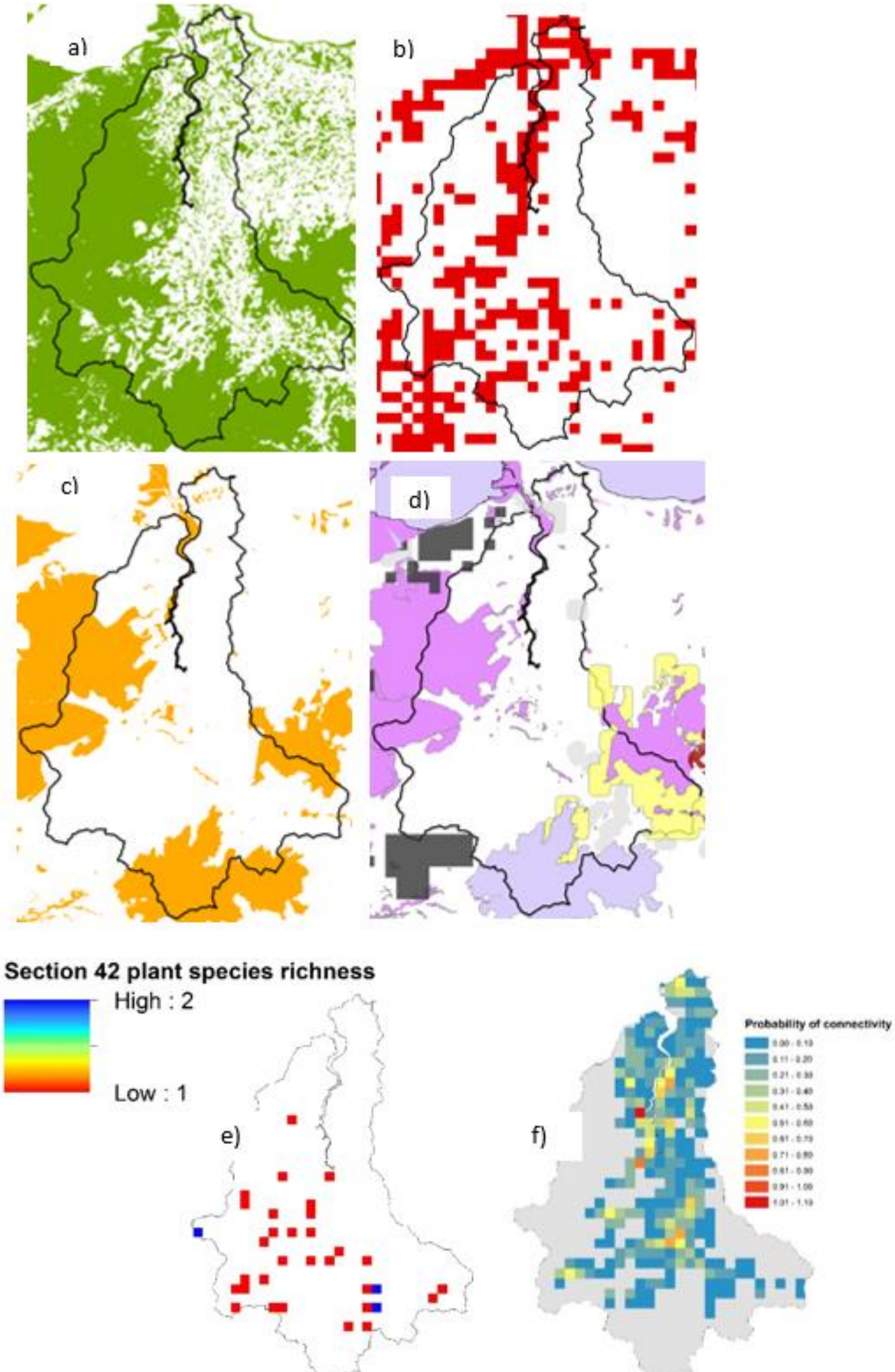


Figure 9.8.1.2 Maps of potential HNV indicators for the Conwy Valley, including Type 1 – semi-natural habitat patches (a); Type 2 – Upper quartile of habitat diversity (Shannon Index; species data not yet incorporated) (b); Type 3 - SPAs, SACs and SSSIs (species data not yet included); a map showing protected areas and protected zones (d) a map of rare plant species (Section 42) as e.) and Broadleaf woodland habitat connectivity metrics for each 1 km grid cell (f).

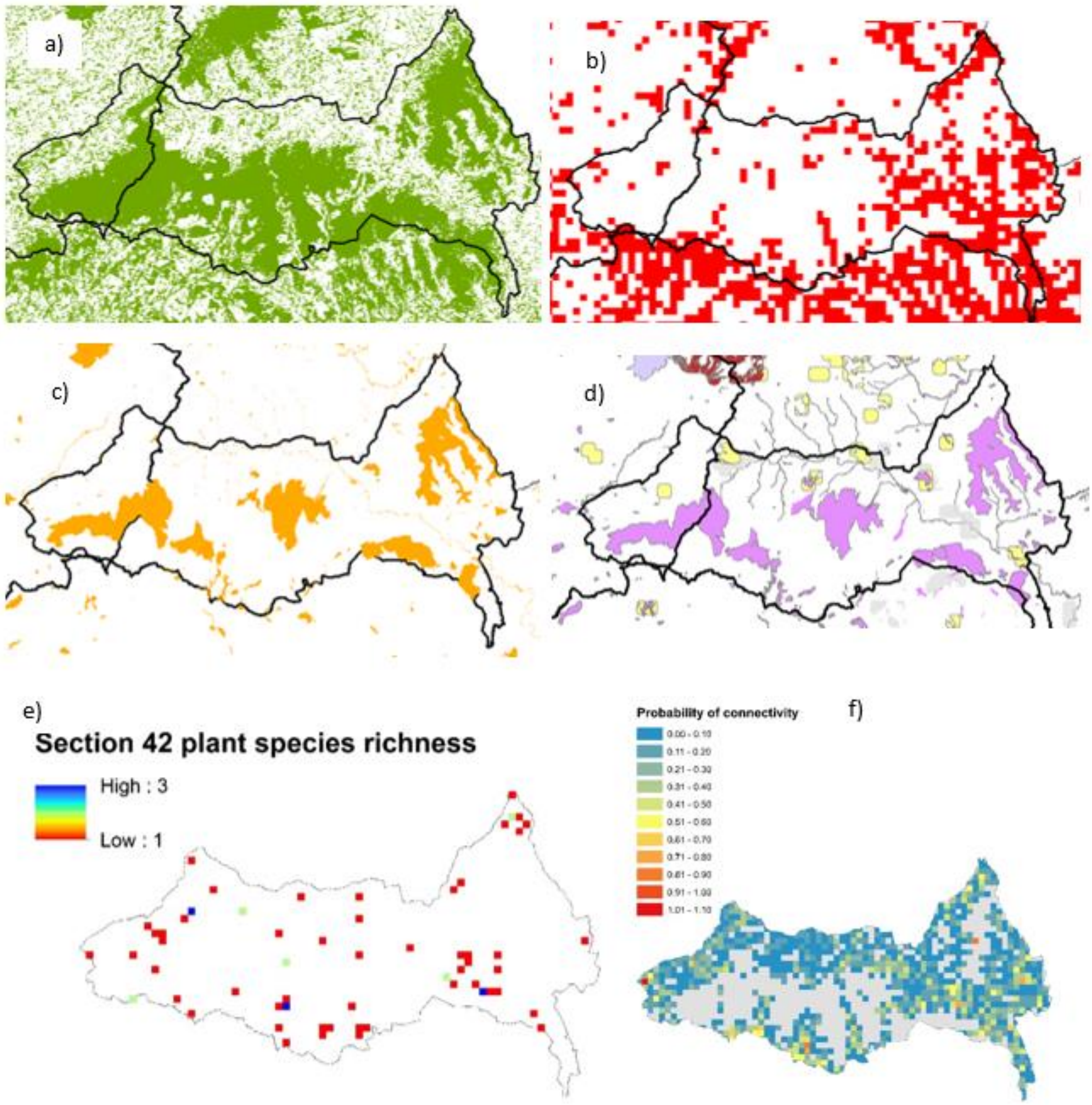


Figure 9.8.1.3 Maps of potential HNV indicators for the Brecon Beacons, including Type 1 – semi-natural habitat patches (a); Type 2 – Upper quartile of habitat diversity (Shannon Index; species data not yet incorporated) (b); Type 3 - SPAs, SACs and SSSIs (species data not yet included); a map showing protected areas and protected zones (d); a map of rare plant species (Section 42) in e.), and Broadleaf woodland habitat connectivity metrics for each 1 km grid cell (f).

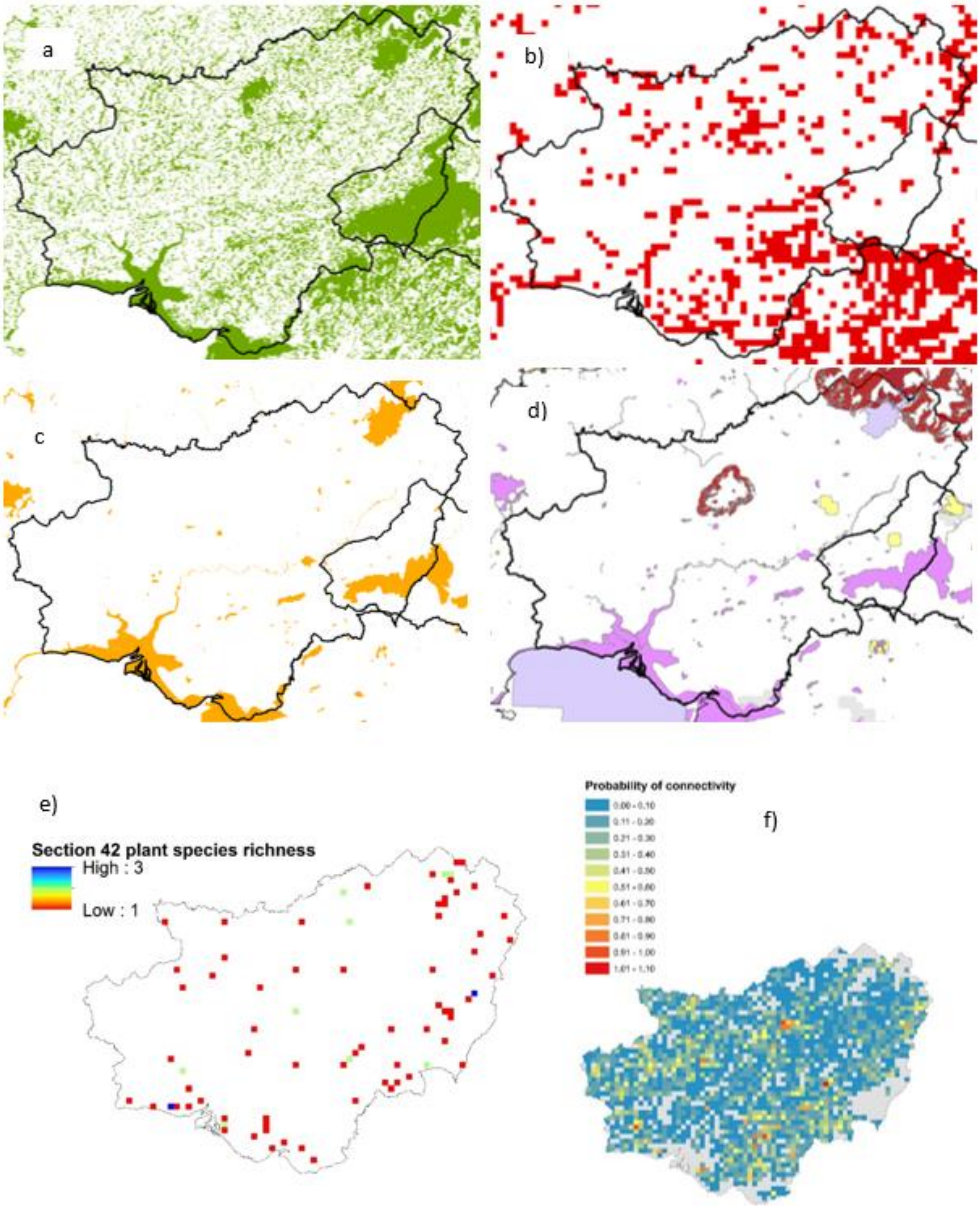


Figure 9.8.1.4 Maps of potential HNV indicators for Carmarthenshire, including Type 1 – semi-natural habitat patches (a); Type 2 – Upper quartile of habitat diversity (Shannon Index; species data not yet incorporated) (b); Type 3 - SPAs, SACs and SSSIs (species data not yet included); a map showing protected areas and protected zones (d) a map of rare plant species (Section 42) as e), and Broadleaf woodland habitat connectivity metrics for each 1 km grid cell (f)

9.8.2 Combining metrics and comparing case study areas

Figures *9.8.2.1*a to d show the relationships within the case study areas. For understanding how relationships vary between areas, plots were created using relative metrics within each area although they could also be calculated based on national relationships.

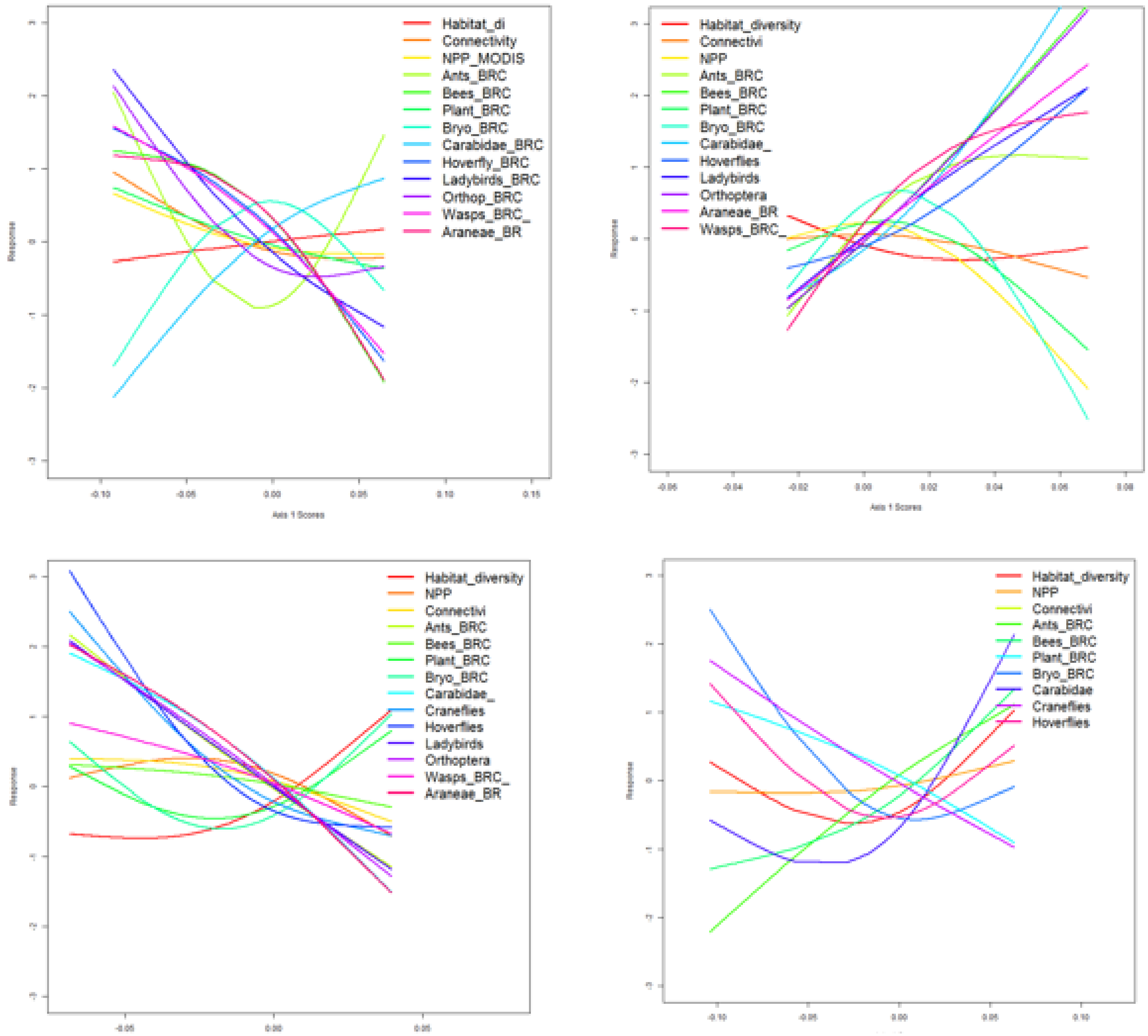


Figure 9.8.2.1a *(Top Left) relationships between diversity variables in Conwy*
Figure 9.8.2.1b *(Top Right) relationships between diversity variables in Carmarthen*
Figure 9.8.2.1c *(Bottom Left) relationships between diversity variables in Brecon*
Figure 9.8.2.1d *(Bottom Right) relationships between diversity variables in the Llyn Peninsula*

In most of the case study areas higher NPP was associated with lower diversity of all species types. The Llyn peninsula was slightly different as there was not a strong differential in NPP across the area. Habitat diversity was slightly more complex, in Conwy and Carmarthen higher habitat diversity tended to be associated with lower species diversity but in Brecon and the Llyn peninsula habitat diversity was positively associated with higher species diversity. There are also potential tradeoffs between different species metrics e.g. ants and bryophytes show different patterns in Conwy, In the Llyn peninsula plants and craneflies have opposing relationships to Bees and ants and in Brecon bryophytes and plants show curves in a different direction to most other forms of diversity. As mentioned above these are not final results, we do not yet have data at the most appropriate resolution and there needs to be more discussion of which would be the best metrics to use and whether they should be applied within an area (noted for particular important aspects of biodiversity and ecosystem services) or applied as more general metrics across Wales.

9.9 Soil HNV

The emphasis for HNV farmland is focused on above ground biodiversity, however, given the importance of the soil resource, and the potential links between above and below ground biodiversity it is of interest to explore the relationship between the soil resource and HNV areas. There is no accepted methodology for identifying HNV soil ecosystems, whilst a brief survey of the literature indicates that neither is there any agreed approach for identifying what might be considered rare or endangered soil ecosystems.

9.9.1 Why should we care about the soil resource in this way?

Historically, valuation of soils has been utilitarian, where by soils are valued by virtue of their use for agriculture and food production. However, soils fulfil a variety of often unseen functions of value both to mankind and the health of the earth system. In particular, the soil ecosystem provides an important habitat and gene pool. Historically this gene pool has provided us with many important organisms that have benefited mankind and yet we are aware of perhaps less than 1% of its diversity and function. Major advances were made last century with the extraction of antibiotics from soils (D'Costa et al., 2006) which are used widely in human health and agriculture. Health research continues to benefit from the extraction of organisms from soil, especially for drug delivery (Parkinson, 2011) and new antibiotics (Ling et al., 2015; Roberts, 2015). Moreover, soils provide a range of other functions that are valuable for maintaining the earth system which include, soil being the largest terrestrial store of carbon (Tipping, 2002), helping regulate climate; whilst moisture, texture, and soil structure control the partitioning of precipitation between infiltration and runoff at the land surface, and hence the regulation of surface water flows and flooding. Soil moisture also buffers climate extremes such as heat waves (Seneviratne et al., 2006). It is these climate extremes which are now seen as the most major threat to UK food security (HC 243, 2014). Furthermore, soils fulfil a range of other functions that we could not survive without including nutrient transformation and waste recycling etc.

9.9.2 Overview of the soil resources of Wales

The soils of Wales are mapped as part of the soil survey of England and Wales (Avery, 1980; Rudeforth et al., 1984). The national soil map for Wales is available at reconnaissance scale, 1:250,000, although there are some maps with greater detail (Reynolds et al., 2002). The soil survey of England and Wales (NATMAP) uses a hierarchical classification scheme that identifies 4 hierarchical levels, 11 Main Groups, 44 Groups, 125 Sub Groups and 747 Series. There is no entire coverage of Wales at the series level of classification, so the 1:250,000 scale map groups series into soil associations, for which 298 are recognised in England and Wales (Cranfield University, 2015), with 98 being mapped in Wales. Analysis using the dominant method assumes that each mapped association contains its dominant soil series, whereas analysis using the estimated method assumes that each association may contain all series found in that association, in standard proportions as distributed with the dataset. When aggregated up from association level, 9 of the 11 Main Groups are to be found in Wales (Table 9.9.2.1). Given the 98 associations, and based on the percentage of dominant soil series in the association, one can estimate that as many as 434 soil series may occur in Wales.

Eleven major soil groups are recognized in the soil survey of England and Wales, of those, nine are found in Wales (Table 9.9.2.1.). 3 major groups are dominant the *brown soils*, *podzolic soils* and *surface-water gley soils*. The brown soils tend to be well drained and have iron oxides bound to silicate clays giving them their characteristic brown colour. Podzols are leached acidic soils, whilst the surface water gleys are subject to periodic saturation. There is not a one-to-one translation of England and Wales soil types into the IUSS Working Groups, World Reference Base (2006) reference soil groups. Those that correspond, and are found in Wales, are shown in the fourth column of Table 9.9.2.1 Conversion to WRB is useful because it allows comparison at global scales. The final column in Table 9.9.2.1 shows the approximate % abundance for WRB reference soil groups globally. The three major groups, brown soils, podzolic and surface water gley, though common in Wales are less common globally, particularly the podzols (umbrisols) and surface water gleys (stagnosols) which are amongst the least common soils globally. Wales has a particularly high abundance of surface-water-gley soils (25%), whereas globally these represent ~1% of soils, and podzolic soils (33%) ~3% globally. This is important because these soils though common in Wales can still represent an important ecosystem globally and the processes that make the soils unique may well result in rare or unique soil ecosystems containing unusual organisms that may be of benefit to humanity.

Soils of Wales NATMAP (NSRI) 1:250,000					
Main Group	Area (ha)	Name of Main Group	WRB 2006 name	Abundance in Wales (%)	Abundance Globally (%)
1	0	Terrestrial raw soils		0.00	
2	3846	Raw gley soils	Fluvisol	0.19	2
3	48797	Lithomorphic Soils	Leptosol / Arenosol / Histosol	2.36	11 / 6 / 2
4	2652	Pelosols	Luvisol	0.13	4
5	651862	Brown soils	Cambisols / Luvisol / Arenosol	31.55	10 / 4 / 6
6	681136	Podzolic soils	Podzolic / Umbrisol	32.97	3 / 1
7	526706	Surface-water gley soils	Stagnosol	25.50	1
8	68275	Ground-water gley soils	Gleysol	3.30	5
9	12707	Man made soils	Regosol	0.62	2
10	69867	Peat soils	Histosol	3.38	2
11	0	Compost-deepened man-modified soils		0.00	
	2065848	Soil total		100	
	10990.29	Other, lakes etc			
	2076838	Wales terrestrial area			

Table 9.9.2.1 Area of soil Main Groups determined based on the dominant soil type in each association. Natmap (NSRI, 2001). The dominant soils in Wales are the brown soils, podzolic and surface water gleys.

9.9.3 Soil Abundance

Abundance: A number of attempts have been made to assess soil pedodiversity or abundance (Ibanez, 1995; Amundson et al., 2003; Nikitin et al., 2007). This is not trivial given that most countries use different soil classifications, exemplified by the fact that England and Wales differ from Scotland. Attempts to unify classifications into a single typology is attempted through the World Reference Base (2006) and soils have been analysed at European (Ibanez, 2013) and global (Minasny et al., 2010) scales using the WRB database. No agreed classification of soil abundance exists, so a number of workers tend to follow the criteria proposed by Amundson (2003) who analysed the USA using the STATSGO database, a similar 1:250,000 scale reconnaissance soils map as that available for Wales. The following criteria were proposed:

a) rare soils—less than 1,000 ha total area in US,
b) unique soils (for example, "endemic")—exist only in one state, and
c) rare-unique soils—occur only in one state, total area less than 10,000 ha.
d) endangered soils: rare or rare-unique soil series that have lost more than 50% of their area to various land disturbances

In Scotland work has been undertaken to identify, soils of national conservation importance (Towers et al., 2005; 2008); soils are assessed based on conservation and functional importance. Abundance was one of the criteria used (Towers et al., 2005), and they tested 3 methods of assessing abundance. The first of their methods wasn't applicable to Wales so we modified the other two for use with the Wales data.

b) Dominant soil sub-group method Wales: Each soil association map unit is allocated to the predominant Major Soil Sub-Group within it. The area for each soil subgroup is summed and the hectares of soil estimated and compared to 1 million ha (Equ 1).

c) Soil series estimated sub-group summation method Wales: The percentage cover of each soil series sub-group, in all associations, is estimated based on the Soils Guide (Cranfield University, 2015). The area for each soil subgroup is summed and the hectares of soil estimated and compared to 1 million ha (Equ 1).

$$ha\ of\ soil\ in\ 1\ million\ ha = \frac{Soil\ area\ (ha) \times 1{,}000{,}000\ ha}{Total\ area\ of\ soil\ in\ Wales\ (=2{,}065{,}848\ ha)} \qquad \text{(Equ 1)}$$

A substantial body of work is available from ecology that is used to define rare and endangered species, which are compiled in the IUCN Red List (IUCN, 2001; Rodrigues et al., 2006). We use a synthesis of the red list approach (IUCN, 2001) and soil pedodiversity approaches (Amundson et al., 2003) to classify the soils of Wales. The soils were analysed based on the area occupied by a soil sub-group in 1 million ha of Wales according to the following criteria:

A) Abundance: Area of Occupancy (ha) = area covered by soil subgroup / total area of political boundary >1 million

<1000 ha per 1000000 ha = 0.001 = <0.1%	Rare
<10,000 ha per 1000000 ha = 0.01 = <1%	Occasional
<50,000 ha per 1000000 ha = 0.05 = <5%	Frequent
<100,000 ha per 1000000 ha = 0.1 = <10%	Common
>100,000 ha per 1000000 ha = >0.1 = >10%	Abundant

B) Extent: of occurrence (ha) = Perimeter length of a polygon around all the exposures / outcrops

C) Uniqueness: Number of locations = 1 million ha from the political boundary of interest.

1 location in 1,000,000 ha =	Unique
<10 locations in 1 million ha =	Occasional
<50 locations in 1 million ha =	Frequent
<100 locations in 1 million ha =	Common
>100 locations in 1,000,000 =	Abundant

Results using the dominant soil Sub-Group method (a) are presented in Table 9.9.3.1. Thirty four soil sub-groups are found in dominant amounts, occurring in 94 soil associations. Of these soil sub groups 4 would be classified as rare occupying less than 1000 ha, and 18 would be occasional, occupying less than 10,000 ha. Of the rare soils, 3 are unique with only one exposure at this scale and are thus of limited extent. These rare soils occur due to a confluence of unusual processes. For example, the Cors Erddreiniog fens on Anglesey are organic soils with alkaline water draining into them, organic soils normally form in acid environments. We don't know if the soil organisms associated with these ecosystems are unusual compared to other soils but the technology is developing in terms of genetic profiling that will enable us to determine whether they are or not (see Section 7.7.9), however, the Fens support a wide range of rare above ground biodiversity. Research priorities need to focus on understanding soil change on the whole (Robinson, 2015) which will then allow us to put data from rare or unique environments into perspective.

Soils of Wales NATMAP (NSRI) 1:250,000									
Subgroup	Area (ha)	Name of subgroup	Abundance %	Abundance	Criteria	Cumulative abundance %	Extent (proportional to greatest extent)	Number of occurances	Percentage of extent occupied by subgroup (area/ extent)*100
541	545751	Typical brown earths	26.418	Abundant	>=10%	100.000			
611	453114	Typical brown podzolic soils	21.934	Abundant	>=10%	73.582			
713	308997	Cambic stagnogley soils	14.957	Abundant	>=10%	51.649			
654	179201	Ferric stagnopodzols	8.674	Common	<10% >=5%	36.691			
721	164033	Cambic stagnohumic gley soils	7.940	Common	<10% >=5%	28.017			
1013	67543	Raw oligo-amorphous peat soils	3.270	Frequent	<5% >=1%	20.077			
571	42767	Typical argillic brown earths	2.070	Frequent	<5% >=1%	16.807			
811	40673	Typical alluvial gley soils	1.969	Frequent	<5% >=1%	14.737			
561	37925	Typical brown alluvial soils	1.836	Frequent	<5% >=1%	12.768			
711	36216	Typical stagnogley soils	1.753	Frequent	<5% >=1%	10.932			
311	31807	Humic rankers	1.540	Frequent	<5% >=1%	9.179			
612	26830	Humic brown podzolic soils	1.299	Frequent	<5% >=1%	7.640			
712	17459	Pelo-stagnogley soils	0.845	Occasional	<1% >=0.1%	6.341	0.525	50	1.44
631	14899	Humo-ferric podzols	0.721	Occasional	<1% >=0.1%	5.496	1.000	45	0.64
572	13444	Stagnogleyic argillic brown earths	0.651	Occasional	<1% >=0.1%	4.774	0.387	26	1.50
361	13142	Typical sand-pararendzinas	0.636	Occasional	<1% >=0.1%	4.124	0.873	49	0.65
962	10474	Permeable, seasonally wet raw made ground soils	0.507	Occasional	<1% >=0.1%	3.488	0.316	44	1.44
814	9828	Pelo-calcareous alluvial gley soils	0.476	Occasional	<1% >=0.1%	2.981	0.012	16	36.05
651	6950	Ironpan stagnopodzols	0.336	Occasional	<1% >=0.1%	2.505	0.035	14	8.64
551	6898	Typical brown sands	0.334	Occasional	<1% >=0.1%	2.168	0.490	14	0.61
813	6837	Pelo-alluvial gley soils	0.331	Occasional	<1% >=0.1%	1.835	0.439	30	0.67
812	4925	Calcareous alluvial gley soils	0.238	Occasional	<1% >=0.1%	1.504	0.005	6	42.36
313	3848	Brown rankers	0.186	Occasional	<1% >=0.1%	1.265	0.722	25	0.23
220	3846	Unripened gley soils	0.186	Occasional	<1% >=0.1%	1.079	0.327	60	0.51
821	3512	Typical sandy gley soils	0.170	Occasional	<1% >=0.1%	0.893	0.180	13	0.84
543	2795	Gleyic brown earths	0.135	Occasional	<1% >=0.1%	0.723	0.002	2	52.72
431	2652	Typical argillic pelosols	0.128	Occasional	<1% >=0.1%	0.587	0.010	5	11.51
871	2294	Typical humic gley soils	0.111	Occasional	<1% >=0.1%	0.459	0.022	10	4.49
542	2282	Stagnogleyic brown earths	0.110	Occasional	<1% >=0.1%	0.348	0.056	8	1.77
924	2233	well aerated raw made ground soils	0.108	Occasional	<1% >=0.1%	0.238	0.065	10	1.50
1024	1659	Earthy eutro-amorphous peat soils	0.080	Rare	<0.1%	0.129	0.163	13	0.44
1022	665	Earthy eu-fibrous peat soils	0.032	Rare	<0.1%	0.049	0.000	1	72.55
831	207	Typical cambic gley soils	0.010	Rare	<0.1%	0.017	0.000	1	66.97
652	144	Humus-ironpan stagnopodzols	0.007	Rare	<0.1%	0.007	0.000	2	23.34
Total	2065848		100						

Table 9.9.3.1 *Soil metrics determined from Natmap (NSRI, 2001) data according to the rarity, extent and uniqueness outlines above. Where "extent" is calculated as the minimum bounding convex hull polygon.*

The dominant method used to identify the soils in Table 9.9.3.1 can be compared with the estimated method. Figure 9.9.3.1a shows the exposures of rare soils using the dominant method (a) and estimated method (b). Using the estimated method there is no guarantee that the mapped association will actually contain a soil series of interest. The number of associations that might include rare soils is greater and when plotted appears to cover a greater area simply because the association is plotted, not the exposure of the soil series that might be contained within it (Figure 9.9.3.1b). The rare soils tend to occur in North and South Wales, with little in mid Wales and are often close to coastal areas or water courses.

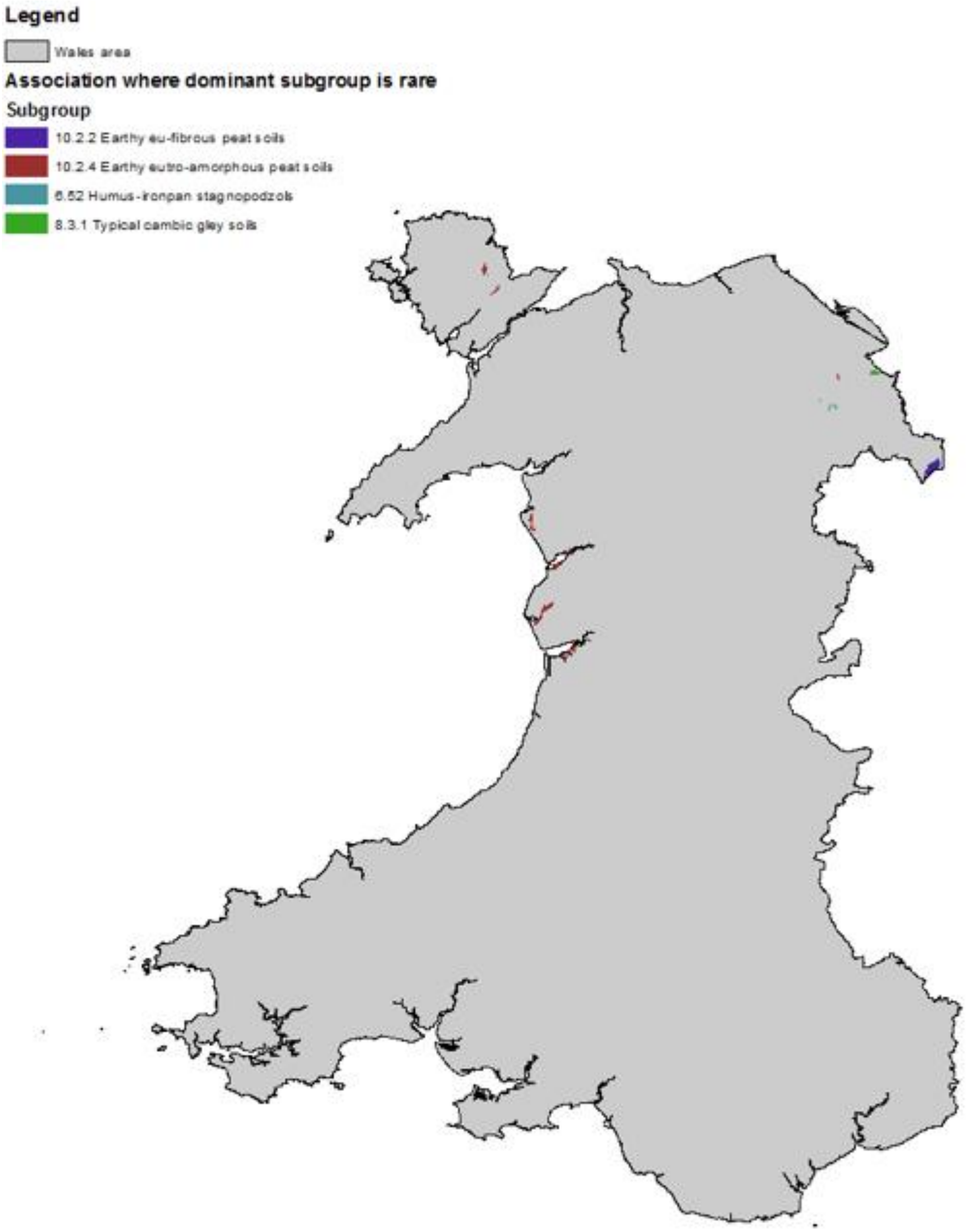


Figure 9.9.3.1a. *Associations which probably contain rare soils (<0.1%) mapped according to the dominant soil sub-group method. The dominant sub group assumes that each soil association (as mapped by NSRI) is made up of the dominant series for that association; this soil may make up 100% of the relevant association, but where the percentage is lower, there is a possibility that the association mapped does not contain the soil of interest.*

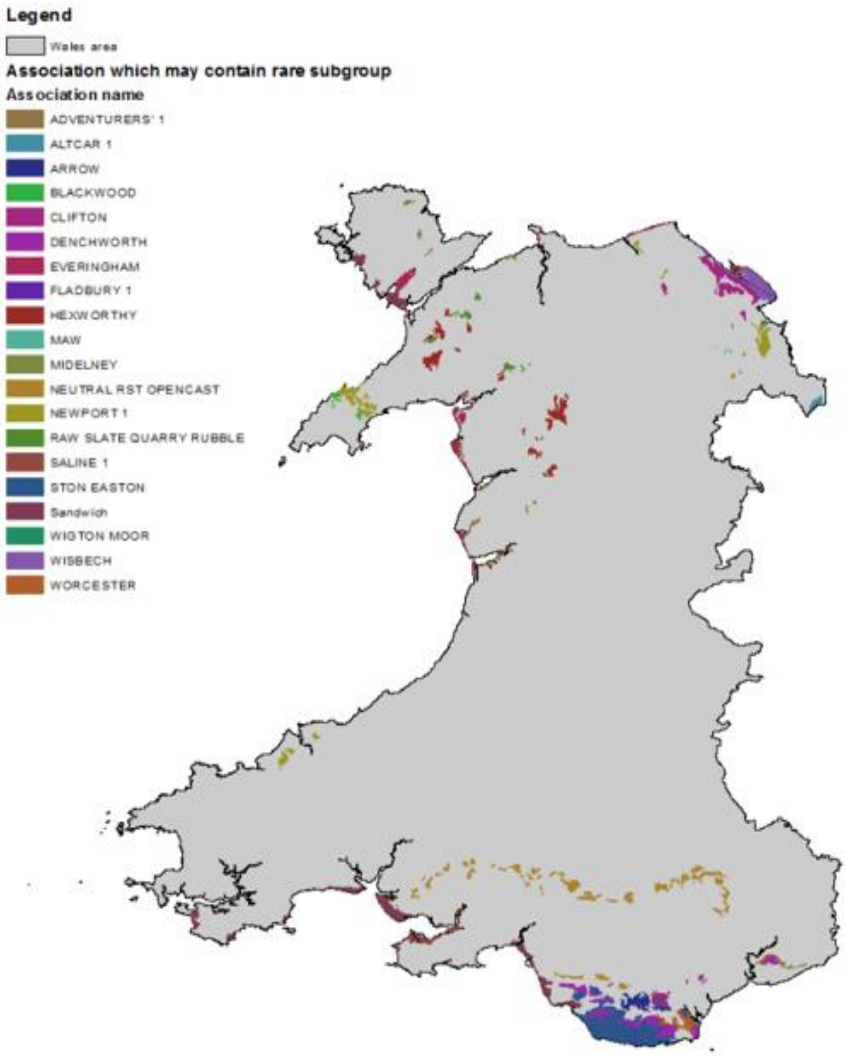


Figure 9.9.3.1b *Associations which may contain rare soils (<0.1%) mapped according to the estimated soil series sub-group method. The estimated approach assumes that each soil association (as mapped by NSRI) contains all soil series which may be found in that association, in proportions consistent with the average for that association. This approach identifies a greater number of soils which may be present, although there is no guarantee that the mapped association will actually contain the soil series of interest.*

Similarly plots can be created for the occasional soils using the dominant (Figure 9.9.3.2a) and estimated methods (Figure 9.9.3.2b). The estimated method is informative showing the existence of complexes on the Llyn Peninsula, Anglesey, the South Wales Valleys, the Gower Peninsula and the Dee valley in North Wales. These areas are consistent with more complex geology, providing a diversity of parent materials that is perhaps reflected by the soils. This leads to the question as to whether these areas are also associated with higher above ground biodiversity.

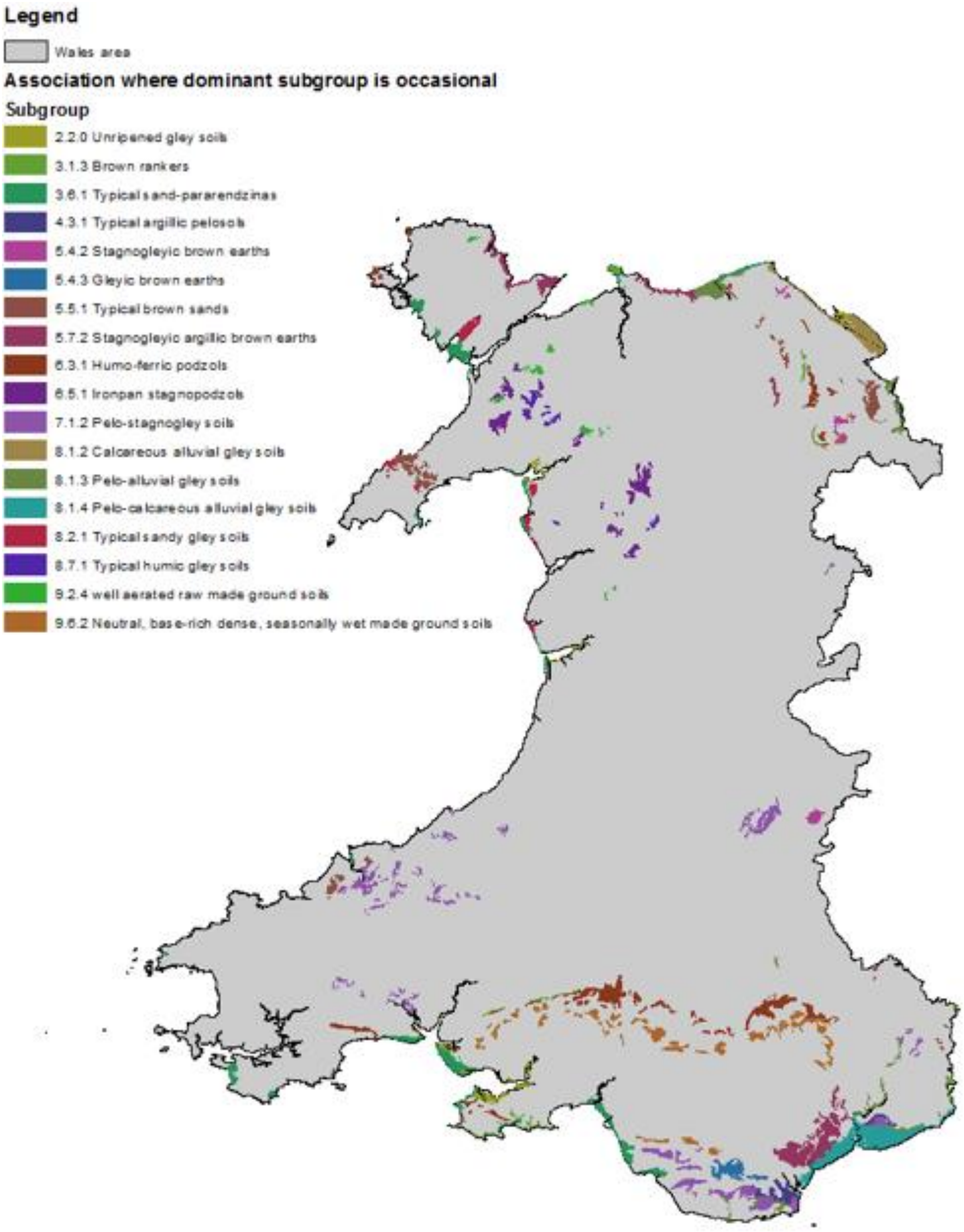


Figure 9.9.3.2a *Associations which probably contain occasional soils (<1%) mapped according to the dominant soil sub-group method. The dominant sub group assumes that each soil association (as mapped by NSRI) is made up of the dominant series for that association; this soil may make up 100% of the relevant association, but where the percentage is lower, there is a possibility that the association mapped does not contain the soil of interest.*

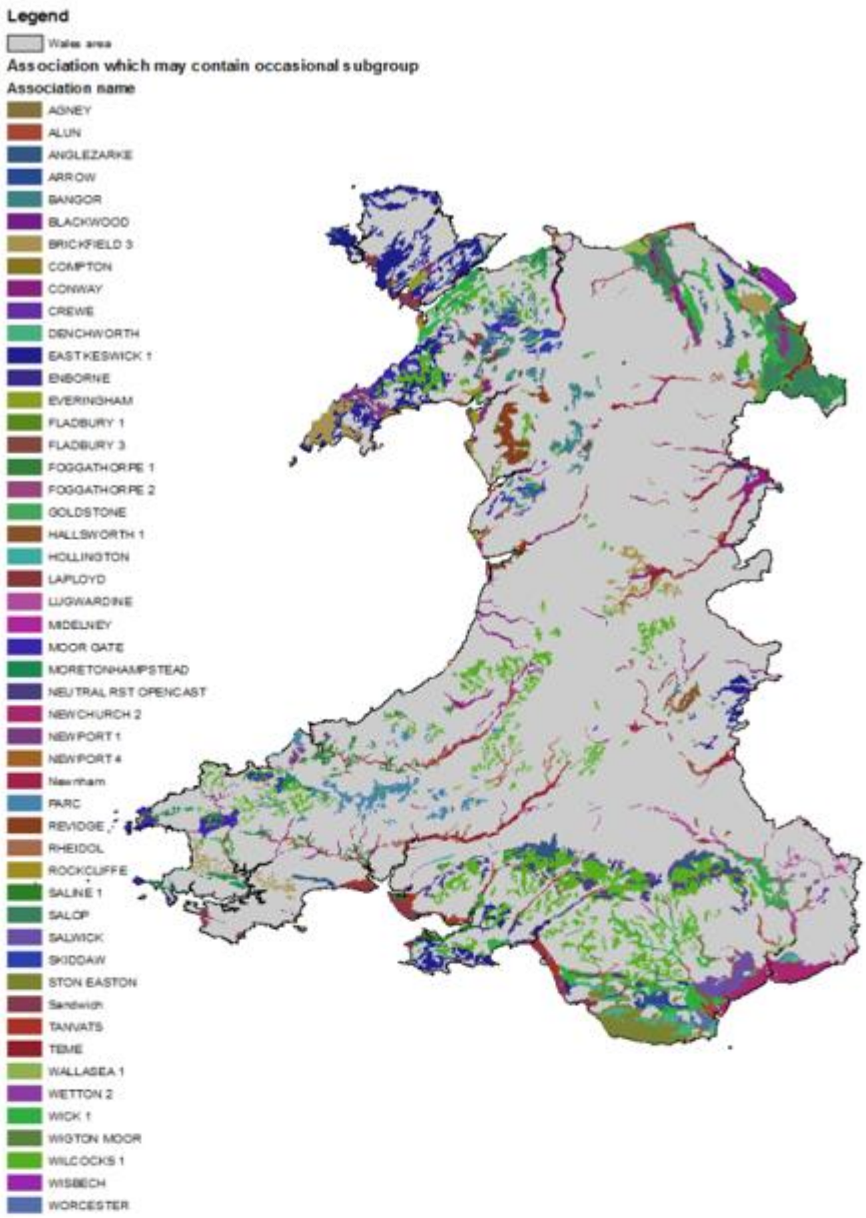


Figure 9.9.3.2b *Associations which may contain occasional soils (<1%) mapped according to the estimated soil series sub-group method. The estimated approach assumes that each soil association (as mapped by NSRI) contains all soil series which may be found in that association, in proportions consistent with the average for that association. This approach identifies a greater number of soils which may be present, although there is no guarantee that the mapped association will actually contain the soil series of interest.*

9.9.4 Relationships between soil, land cover and SSSI's

Many of the rare (51%) and occasional soils (29%) can be found within Sites on Special Scientific Interest in Wales. There are 1061 SSSIs in Wales, covering 261849 ha or 13% of the Welsh land area. Rare and occasional soils make up 7% of this area. Of the rare soils, 54% of rare peat soils (including 95% of earthy eu-fibrous peat soils) and 72% of humus-ironpan stagnopodzols are found within SSSI areas. Pelo-calcareous alluvial gley soils are the most common occasional soils within SSSIs making up 2.3% of the total SSSI area. Land cover in SSSI areas can be quite diverse, with areas of rare and occasional soils in SSSI areas associated with slightly more land cover richness and diversity than other SSSI.

In terms of diversity, a range of diversity metrics have been used to calculate above and below ground diversity. Using the Land Utilisation and Capability Indicator (LUCI) tool (Jackson et al., 2014) at 1km squares across Wales, four options of diversity were determined including richness, mean patch size, Shannon diversity index and Simpson diversity index (as used above). These metrics are commonly used in above ground biodiversity studies, and are increasingly receiving attention in soil pedodiversity (Minasny et al., 2010). All four diversity indices show very little relationship between current land cover and soil diversity across Wales, possibly due to extensive modification of climax vegetation in the area. Areas underlain by rare and occasional soils, using both dominant (Figures 9.9.4.1a-d) and estimated (Figures 9.9.4.2a-d) methods, also had little relationship with above ground diversity with a wide range of diversity values for each of the four metrics observed. Despite this, some of the areas in which rare and occasional soils are present also have some of the highest diversity in land cover, particularly in north-western areas (dominant method) and areas in the north-east and south (estimated method).

Statistical analysis comparing average habitat metric values for all of Wales and those over rare and occasional soils indicate that above ground diversity is slightly higher in these areas (Table 9.9.4.1). Although the differences do not appear large, three of the four metrics were statistically significantly at the 5% level (Table 9.4.4.2). Rare and occasional soils were also analysed separately. Habitat metric values in areas of occasional soils are greater than average Welsh values, and significant at the 5% level. Areas of rare soils also tend to have greater diversity (compared to the Welsh average and areas of occasional soils). However, due to the smaller sample size (50 cells) these results were not statistically significant.

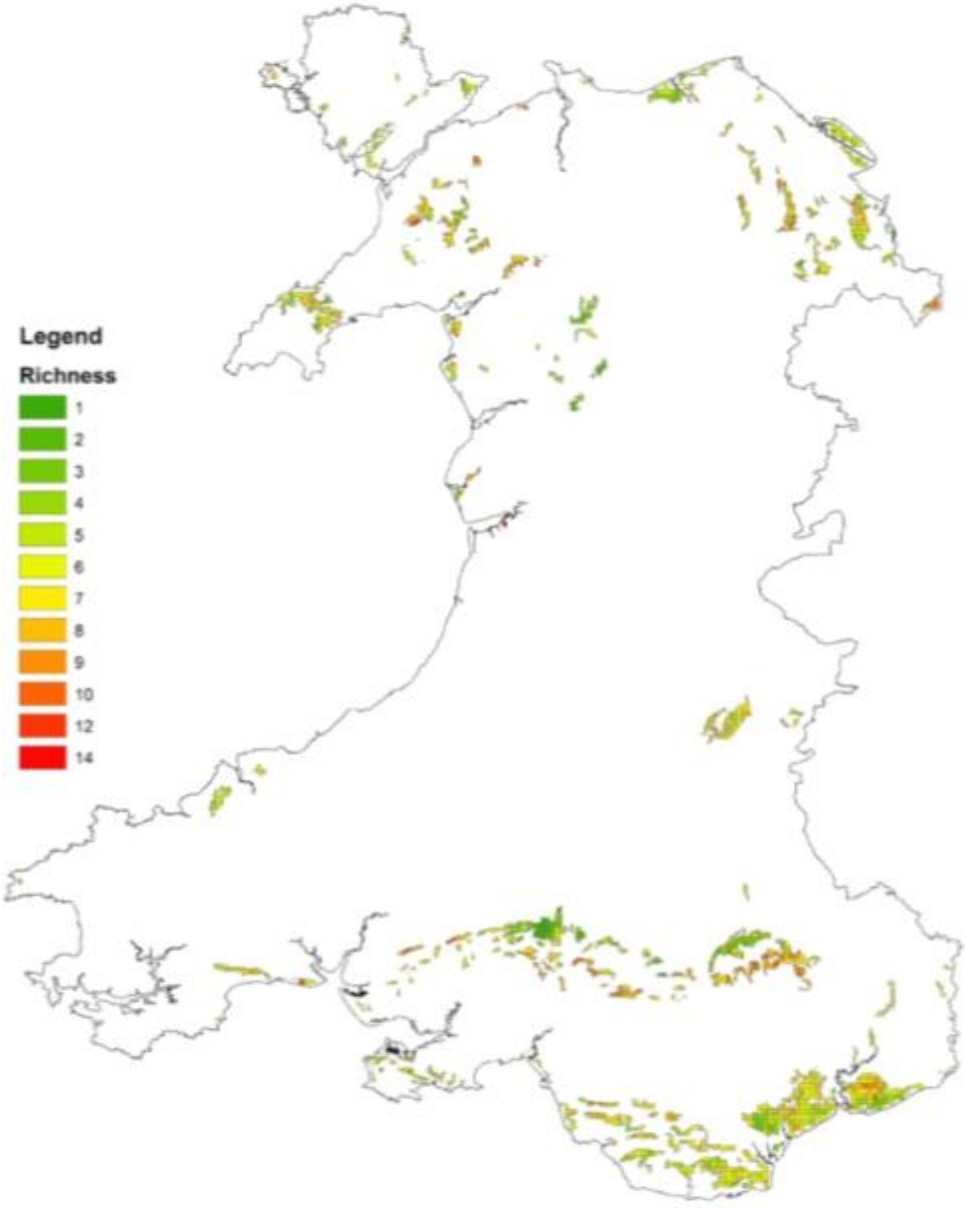


Figure 9.9.4.1a. *Land cover richness in areas of rare and occasional soils (dominant method). Red areas identify rare or occasional soils with high levels of above ground richness, determined by the number of different land covers within each 1km^2 square. These areas are found largely in north-western regions, and to a lesser extent in the south. The highest richness is found in a single square located near the River Dyfi, north of Aberystwyth.*

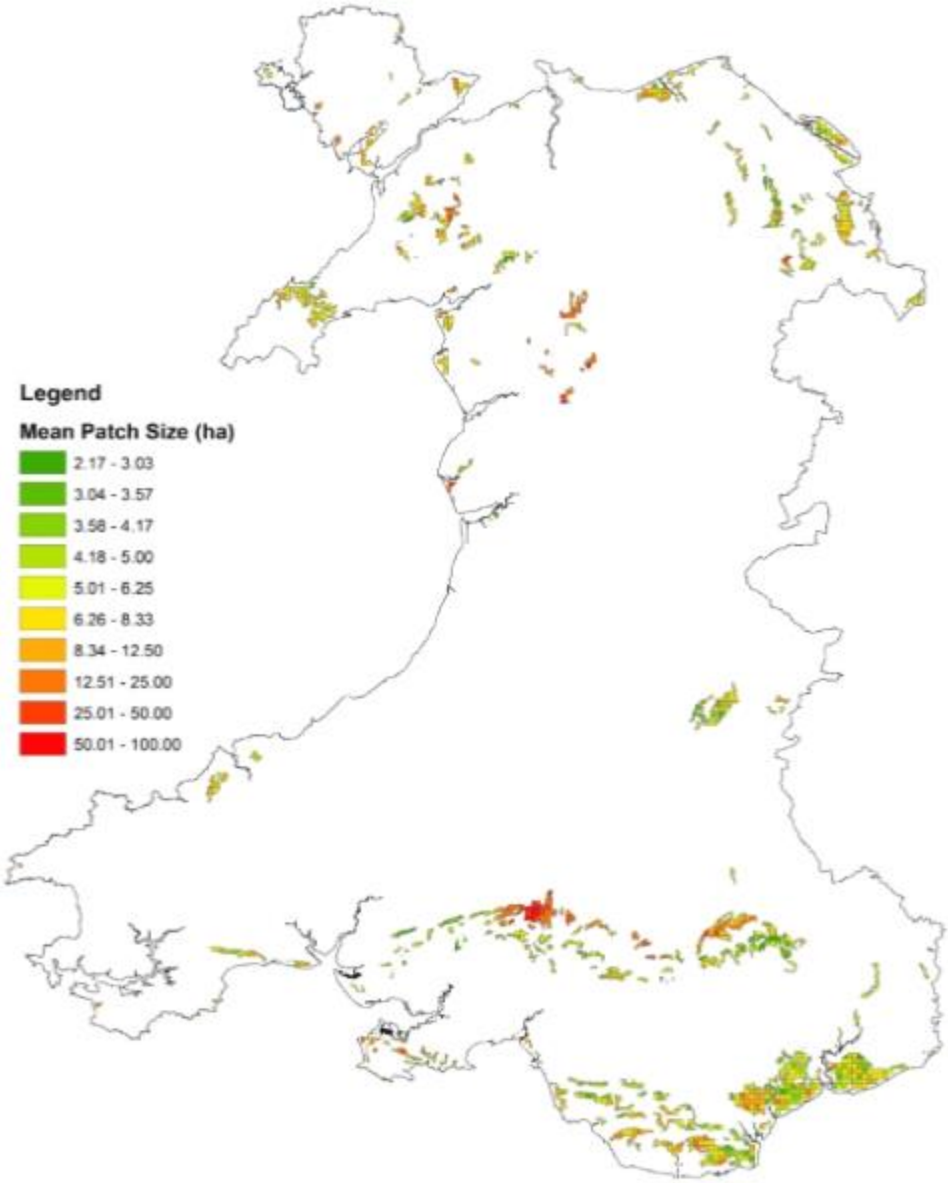


Figure 9.9.4.1b *Land cover mean patch size (ha) in areas of rare and occasional soils (dominant method). Red areas identify rare or occasional soils with larger mean patch size. These areas tend to be in the uplands, in the north around Snowdonia and in the South around Brecon and the Black Mountains. Areas with lower richness generally have higher mean patch size.*

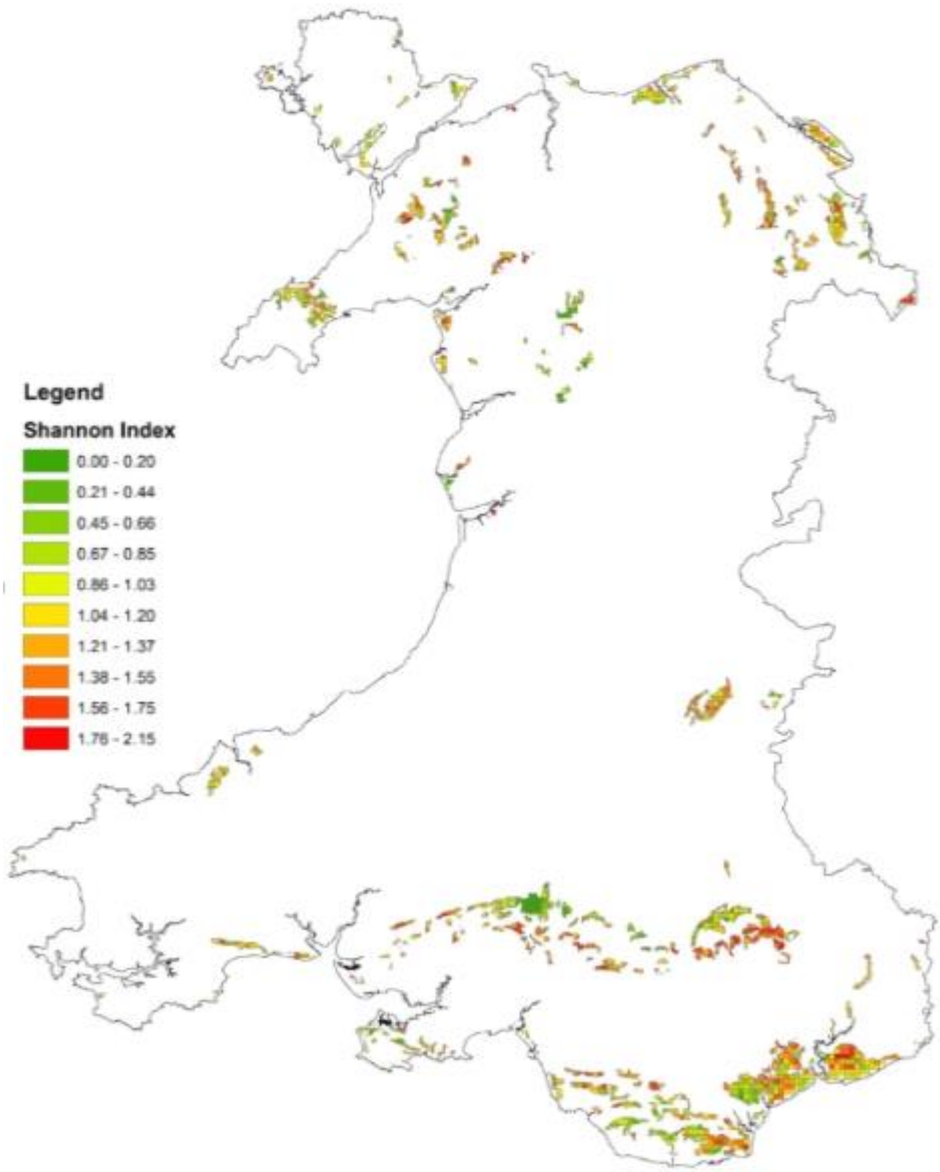


Figure 9.9.4.1c. *Land cover Shannon Index in areas of rare and occasional soils (dominant method). Larger values indicate higher diversity, with greater weight to areas with higher richness, regardless of whether one land cover is dominant. Red areas identify rare or occasional soils with high levels of above ground biodiversity. These occur throughout Wales, but more widely in the uplands, in the north around Snowdonia and in the South around Brecon and the Black Mountains, as well as the area around Newport.*

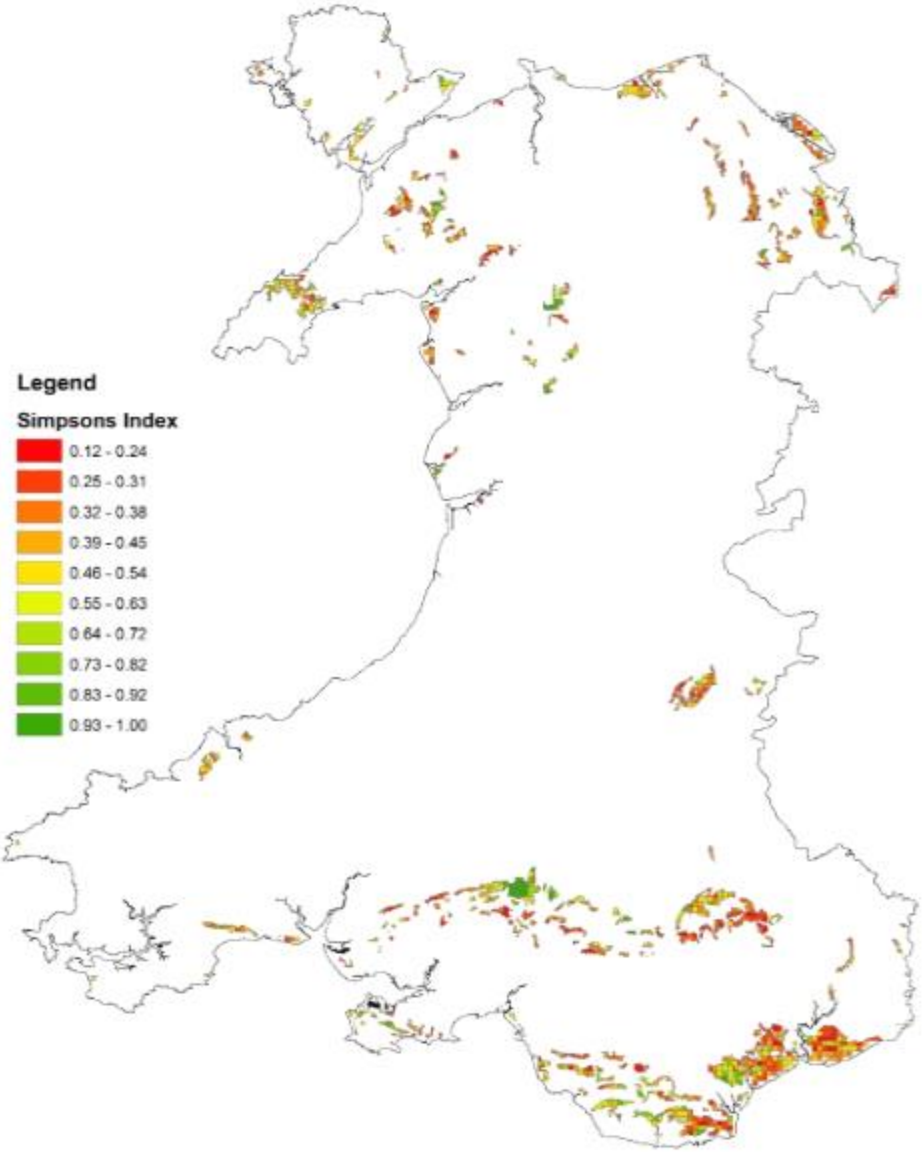


Figure 9.9.4.1d. *Land cover Simpsons Index in areas of rare and occasional soils (dominant method). In contrast to the Shannon Index, lower values indicate higher diversity with more weight given to areas where land covers are more evenly represented. Red areas identify rare or occasional soils with high levels of above ground biodiversity. These areas are found in almost all areas where rare and occasional soils are found.*

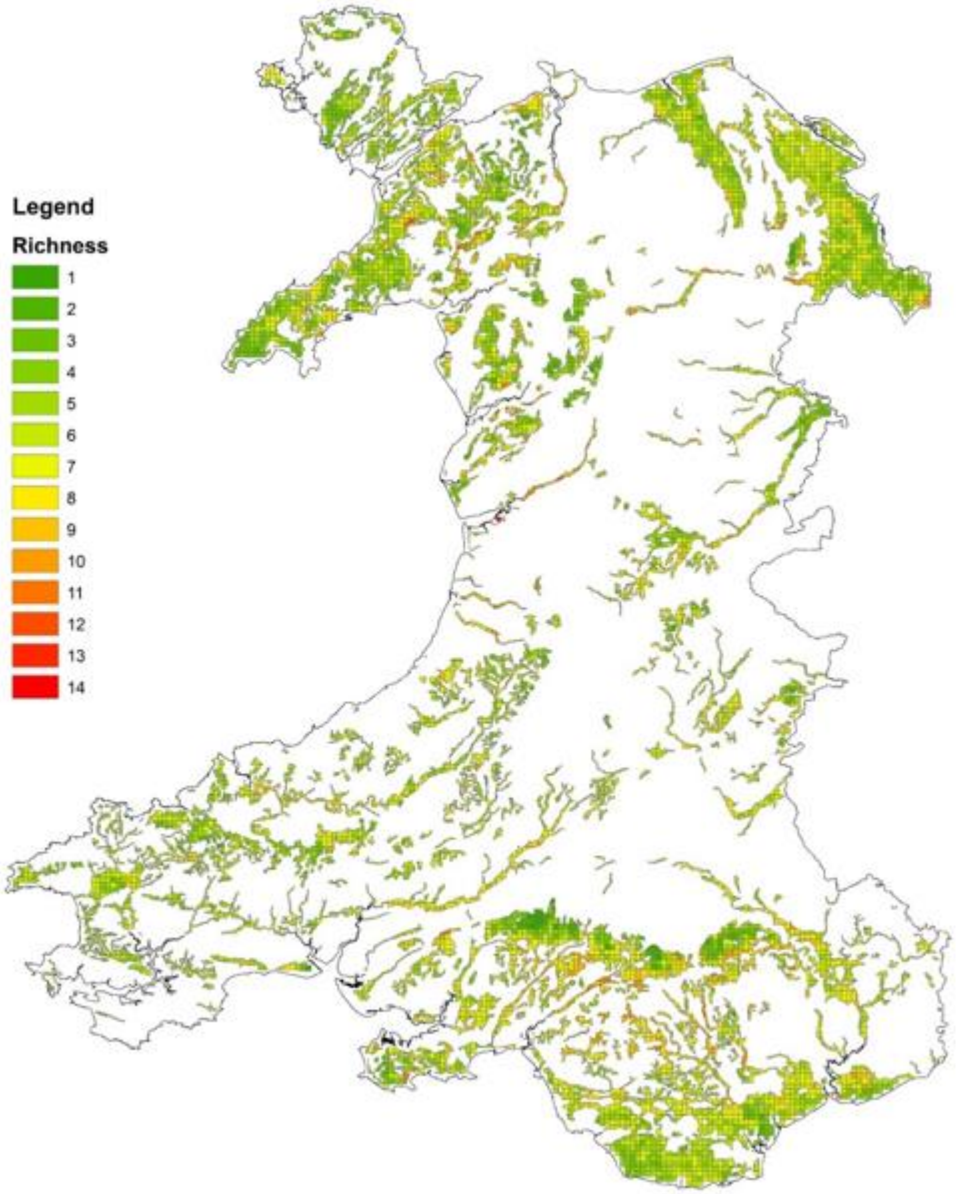


Figure 9.9.4.2a. *Land cover richness in areas of rare and occasional soils (estimated method). Areas of red indicate high above ground richness, determined by the number of different land covers within each 1km² square. Richness is generally low across Wales, with high richness in north-western regions, and moderate richness in the south. The highest richness is found in a single square located near the River Dyfi, north of Aberystwyth.*

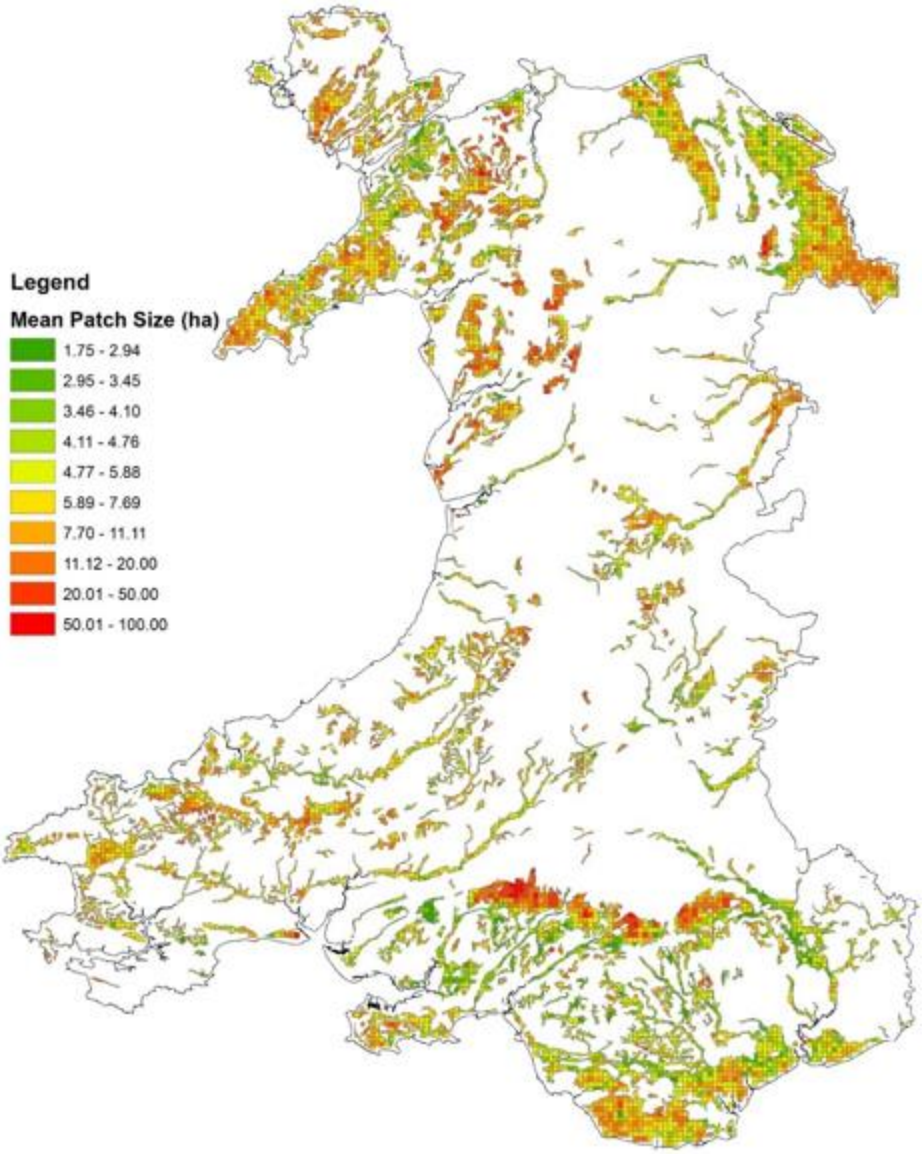


Figure 9.9.4.2b. *Land cover mean patch size (ha) in areas of rare and occasional soils (estimated method). Red squares indicate areas of larger mean patch size, and are widespread across Wales. Areas with higher richness generally have lower mean patch size.*

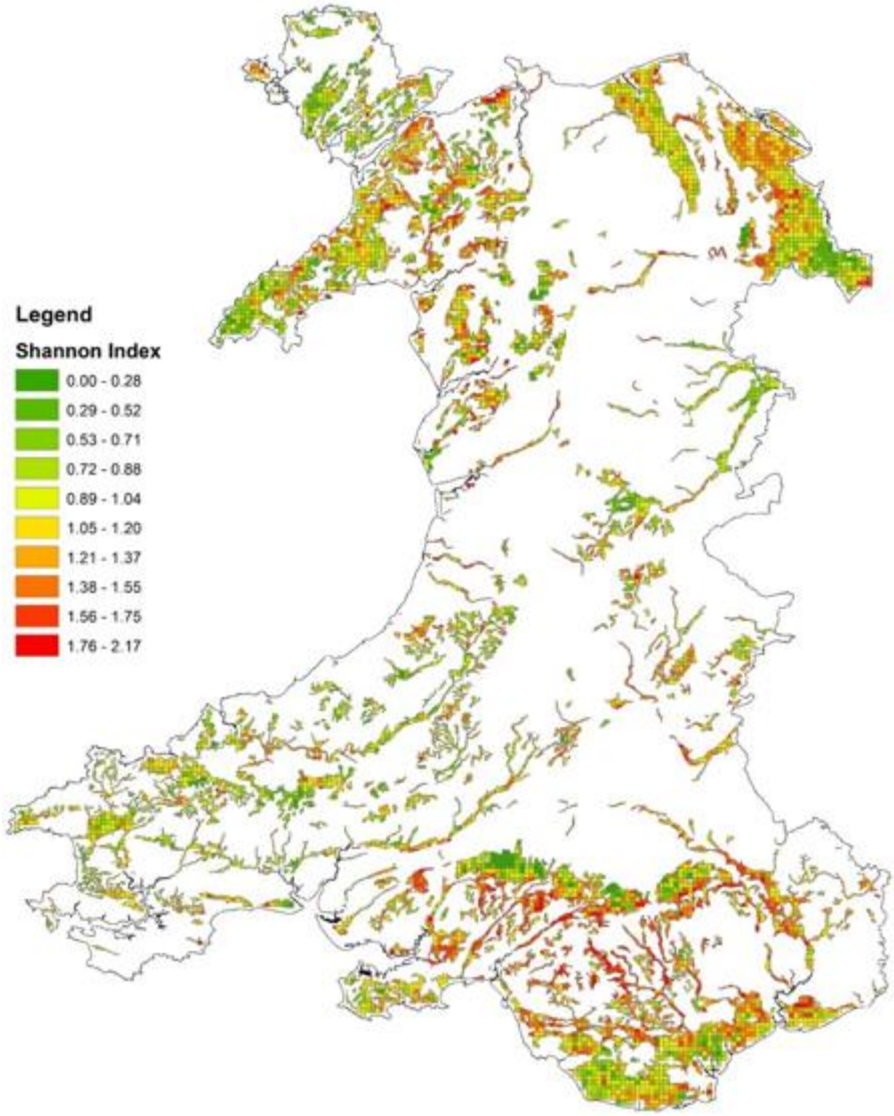


Figure 9.9.4.2c. *Land cover Shannon Index in areas of rare and occasional soils (estimated method). Larger values indicate higher diversity, with greater weight to areas with higher richness, regardless of whether one land cover is dominant. Red areas identify rare or occasional soils with high levels of above ground biodiversity. These occur ostensibly in the South Wales valleys, along the Llyn Peninsula, Snowdonia, Flintshire and the Clwyd River valley.*

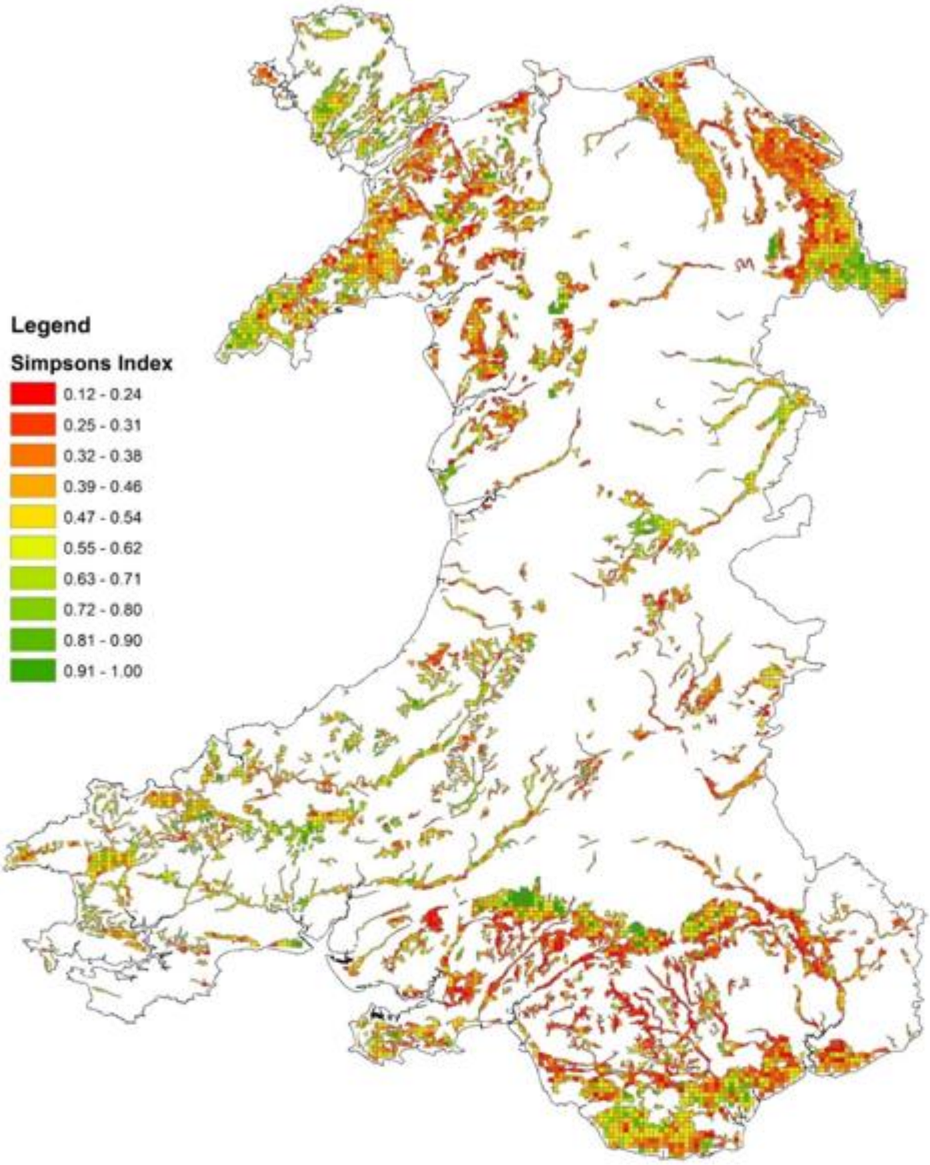


Figure 9.9.4.2d. *Land cover Simpsons Index in areas of rare and occasional soils (estimated method). In contrast to the Shannon Index, lower values indicate higher diversity with more weight given to areas where land covers are more evenly represented. Red areas identify rare or occasional soils with high levels of above ground biodiversity.*

	Total Area (ha)	*Area within SSSIs (ha)*	*Proportion of Soil within SSSIs*	*Percentage of total SSSI area*
Rare Soils				
10.2.4 Earth eutro-amorphous peat soils	*1659*	*642*	*0.39*	*0.25*
10.2.2 Earthy eu-fibrous peat soils	*665*	*632*	*0.95*	*0.24*
8.3.1 Typical cambic gley soils	*207*	*0*	*0.00*	*0.00*
6.5.2 Humus-ironpan stagnopodzols	*144*	*103*	*0.72*	*0.04*
Occasional Soils				
7.1.2 Pelo-stagnogley soils	*17459*	*312*	*0.02*	*0.12*
6.3.1 Humo-ferric podzols	*14899*	*6501*	*0.44*	*2.48*
5.7.2 Stagnogleyic argillic brown earths	*13444*	*122*	*0.01*	*0.05*
3.6.1 Typical sand pararendzinas	*13142*	*6688*	*0.51*	*2.55*
9.6.2 Permeable, seasonally wet raw made ground soils	*10474*	*161*	*0.02*	*0.06*
8.1.4 Pelo-calcareous alluvial gley soils	*9828*	*5922*	*0.60*	*2.26*
6.5.1 Ironpan stagnopodzols	*6950*	*2375*	*0.34*	*0.91*
5.5.1 Typical brown sands	*6898*	*211*	*0.03*	*0.08*
8.1.3 Pelo-alluial gley soils	*6837*	*696*	*0.10*	*0.27*
8.1.2 Calcareous alluvial gley soils	*4925*	*576*	*0.12*	*0.22*
3.1.3 Brown rankers	*3848*	*3635*	*0.94*	*1.39*
2.2.0 Unripened gley soils	*3846*	*1914*	*0.50*	*0.73*
8.2.1 Typical sandy gley soils	*3512*	*1392*	*0.40*	*0.53*
5.4.3 Gleyic brown earths	*2795*	*14*	*0.00*	*0.01*
4.3.1 Typical argillic pelosols	*2652*	*24*	*0.01*	*0.01*
8.7.1 Typical humic gley soils	*2294*	*389*	*0.17*	*0.15*
5.4.2 Stagnogley brown earths	*2282*	*9*	*0.00*	*0.00*
9.2.4 Well aerated raw made ground soils'	*2233*	*62*	*0.03*	*0.02*

Table 9.9.4.1 *Rare and Occasional Soils within SSSIs*

Average Values	Richness (no.)	Mean Patch Size (ha)			Shannon Index	Simpsons Index
All of Wales	***5.71***	***9.80***			***1.03***	***0.48***
Rare + Occasional Soils		***6.11***	***8.75***	***1.15***	***0.42***	
p-value		*0*	*0*	*0*	*0*	
Rare soils		***6.54***	***7.79***	***1.16***	***0.43***	
p- value		*0.0006*	*0.1061*	*0.0059*	*0.0346*	
Occasional Soils		***6.10***	***8.78***	***1.15***	***0.42***	
p-value		*0*	*0*	*0*	*0*	

Table 9.9.4.2 *Average above ground diversity metrics and corresponding significance value using two-sample t-test at 5% significance level. Note that smaller values for the Simpson Index indicate greater diversity.*

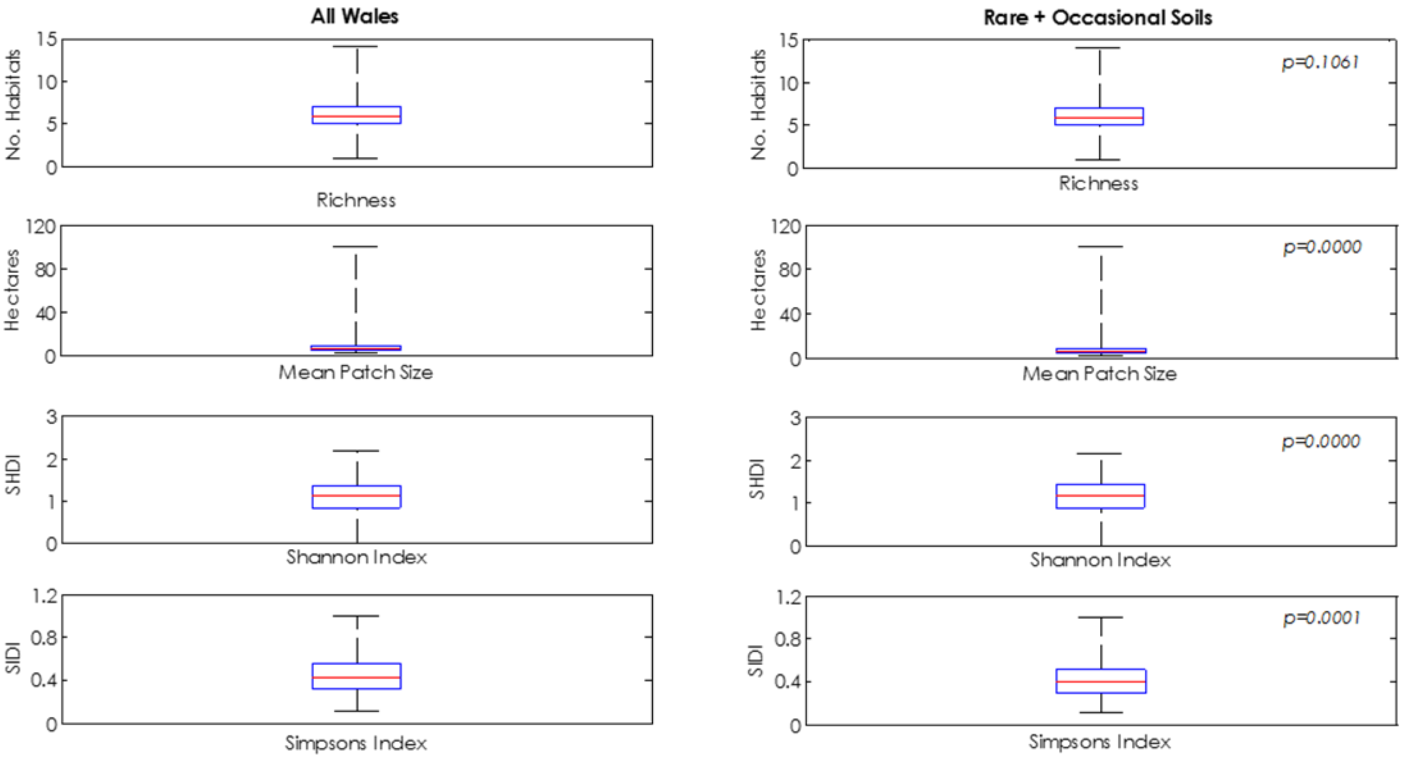


Figure 9.9.4.3 *Boxplots of habitat metrics for all of Wales compared to areas of rare and occasional soils (as determined from the dominant method). A two sample t-test is used to determine if there is any significant difference between above ground biodiversity metrics across all of Wales and that from rare and occasional soils. p-values indicate significance at the 5% level. While richness index is not significantly different compared to the Welsh average, mean patch size, Shannon Index and Simpsons index tends to be greater in areas of rare and occasional soils.*

9.9.5 Summary of soils work

We present several methods of potentially assessing soil contribution to high nature value.
An initial assessment considers the abundance of Welsh soil groups in the context of global abundance according to the WRB (2006) classification. This indicates that even common Welsh soils are relatively unusual in the global context, especially the surface-water-gley soils and to a lesser extent the podzols.

We go on to make an assessment of Welsh soils based on rarity using two methods similar to those used for soil rarity assessment in Scotland.

We found that all of the rare or occasional soils are covered by SSSI's bar 1.
Whether rare soils should be included within the HNV assessment is something for the working group to decide.

9.9.6 Summary and Future for HNV metric

1. Methods for downscaling coarse resolution species data will be refined. This may be coupled with identification of datasets for rarer species where coverage is more consistent.
2. Further work is needed to explore how species data can best be incorporated into the metrics for Type 2 and 3 HNV farmland e.g. choice of metrics, methods for including them including that of rare soils.
3. The Woody Cover Product and linear density will be incorporated into the habitat metrics.
4. HNV approaches could assess whether land areas are also on rare or occasional soils resources? Moreover, it may be feasible to develop a bench marking scheme to assess areas such as catchments, to determine the abundance of rare or occasional soils and compare how their diversity levels compare to the national average.
5. Another thing to consider is whether it is useful/necessary to combine metrics with the single farm payment to ensure that only farmed land is included.
6. We have not yet incorporated farming intensity into potential HNV metrics, this could be done using NPP as a measure, work elsewhere (section) proposes a method for calculating NPP from NDVI. It would also be possible to incorporate data from the Agcensus or IACS e.g. stocking density
7. Decide which indicators to use to calculate HNV metric- potential indicators shown below and which datasets to use dependent upon spatial consistency and temporal repeatability.
8. As a first step a real-time participatory approach by the GMEP Advisory Group comparing outcomes from different combination of metrics using a web based data mapping tool CEH is developing which will be available in January 2016.

HNV Type 1	***HNV Type 2***	***HNV Type 3***
Proportion of semi-natural land	*Habitat diversity*	*Distribution of rare plant species*
Single farm payment?	*Habitat connectivity*	*Distribution of rare bird species*
Stocking density?	*Density of linear features*	*Distribution of rare and occasional soils*
	Plant species richness- possibly 1km resolution data available	*Protected areas*
	Bird species richness- tetrad resolution available- farmland birds or all birds?	*Area of priority Habitats?*
	Other species richness e.g. Ants, Bees, Craneflies, Carabidae, Centipedes, Millipedes, Cerambycidae, Hoverflies, Isopoda, Ladybirds, Fish, Orthoptera, Bryophytes- only available at 10km resolution	
	Distribution of rare and occasional soils	
	Single farm payment?	
	Stocking density?	

Table 9.9.6.1 Potential metrics for HNV

9. Once a final set of HNV metrics are produced they can be tested against other datasets such as:

- Agricultural management and farming system
- Protected areas
- Other types of Natural capital
- Glastir target layers
- Commons

For example, Figure 9.8.1.1 shows protected areas and protected zones for the Llyn Peninsula which if not used as part of the HNV metric could be tested for coincidence with the final HNV metrics when they are produced.

10. Finally, metrics for potential HNV farmland will be investigated in order to assess current versus potential future HNV farmland.
11. All of above will be discussed within an expanded HNV working group to include the whole GMEP Advisory Group to ensure consensus as to the final outcome across government, agencies and NGOs.

10 Trade-off and opportunity mapping

Thomas, A.[1], Jackson, B.[2], Cooper, D.[1], Cosby, B.[1], Maxwell, D.[2], Reuland, O.[2] and Emmett, B[1]

[1] CEH Bangor, [2] Victoria University of Wellington

10.1 Introduction

Underlying ecological and environmental constraints for ecosystem services have resulted in their current complex spatial distribution in the Welsh landscape. Some services often co-exist as they require similar environmental conditions e.g. carbon storage and water regulation whilst other services are often negatively associated (agriculture production and water quality). The GMEP Year 1 report reported on an initial analysis of the data which highlighted how the GMEP data could be used to quantify these trade-offs and co-benefits. Agricultural productivity and carbon storage were identified to be positioned at different extremes of a gradient of from high to low land intensification with biodiversity often at its most species rich at intermediate levels as previously reported at the UK scale by Countryside Survey (Maskell et al. 2013; Emmett et al. 2014). In the future GMEP data will be used to explore these relationships at different scales and for different regions but there is a need now to provide a tool which can help policy makers and land managers target specific areas in the Welsh landscape where opportunities are greatest to increase ecosystem service provision with minimal trade-offs. We have exploited the LUCI modelling tool described in the GMEP Year 1 report to start this process.

10.2 Highlights from Year 2 and major findings

Calculations have been made on the spatial data to identify for each ecosystem service the total area with good provision, total area with opportunity to improve, and area with opportunity to improve without risk to existing services in good condition for Wales. Further calculations were then performed for each ecosystem service to identify where opportunities to improve ecosystem services coincide spatially with good existing condition for other ecosystem services. Finally, calculations were performed for each ecosystem service pair to identify where both have opportunities to improve.

- Significant areas have opportunity to improve carbon (C) status (10508km^2), however for the vast majority of these sites, there are other services in good condition, so care must be taken to avoid detrimental effects if options are targeted at improving C status. Many of these trade-offs are with priority habitats (7488 km^2) (largely heather dominated grasslands), agricultural utilisation (5424 km^2) areas reducing erosion risk (9693 km^2), and potential nitrogen (N) (7731 km^2) and phosphorus (P) (9834 km^2) loss to freshwaters. It is likely that changes to improve C status would not increase erosion risk, or potential N and P loss to freshwaters, however the need to protect priority habitats, and socioeconomic value of agricultural production may reduce potential to achieve carbon status improvements.
- Potential N loss to freshwaters has reasonable opportunities (104 km^2) to improve (reduce) without risk of damaging other ecosystem services (ES) or agricultural productivity. Significant proportions of the 5231 km^2 of sites with opportunity to improve (reduce) potential N loss to freshwaters also have opportunities to improve (reduce) potential P loss to freshwaters (1228 km^2), C status (2777 km^2), Broadleaved woodland habitat connectivity (1038 km^2) and mitigation of overland flow which may contribute to flood mitigation (3955 km^2).
- Over 321km^2 were classified as non-mitigated land in terms of runoff, and had no other ecosystem services in good condition, which may indicate significant potential for interventions to reduce flood risk, without damaging other ES or agricultural productivity. However, additional data to improve representation of soil drainage is being explored, and

depending on flow regimes not all non-mitigated features currently create flood risk, hence further assessment of these opportunities is necessary.

- Locations with low agricultural productivity that are not in good condition for other ES were mapped as over 97 km^2. Whilst there may be potential to increase agricultural productivity in these locations, land may be less suitable for agriculture, and interventions to improve other ES may be more appropriate.
- Calculations have been performed on all outputs to identify where there are trade-offs and win-wins across all 7 ecosystem services considered. 36 km^2 have opportunities to improve 6 of the 7 modelled ecosystem services; all of this area has opportunity to improve (reduce) N potential loss to freshwaters, whereas 16 km^2 have good existing provision of agricultural productivity. Looking at co-location of opportunities to improve ecosystem services for all 7 services indicates that ca. 10% has existing multiple service provision whilst almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.

An assessment of the amount of land inside and outside of the scheme which was either mitigating or mitigated for rainfall runoff / flood mitigation was calculated. The results suggests there is little difference between the land inside and outside of the Glastir scheme with respect to either mitigating or mitigated features. The values are 19% and 21% for land in and out of scheme for mitigating features and 19% and 17% for mitigated features respectively.

Ordination of spatial variation with environmental constraints indicated that only 3% of spatial variation in combined ecosystem service status can be explained by precipitation, temperature regime, elevation, slope and soil drainage and acidity. This indicates the importance of simulation of topology and topography when assessing condition of the relevant ecosystem services; for this reason spatially explicit modelling as applied in LUCI has significant benefits over simplified point combination of spatial data.

Opportunities to:

- Improve (reduce) N and P potential loss to freshwaters tend to be characterised by lower calcium carbonate ('lime') rank, higher maximum and minimum temperature, lower precipitation, lower elevation and gentler slopes.
- Improve carbon status tend to be characterised by higher lime rank, lower maximum and higher minimum temperature and gentler slopes.
- Improve erosion risk tend to be characterised by lower lime rank, lower maximum and minimum temperature, higher precipitation and steeper slopes.
- Improve Broadleaved woodland connectivity tend to be characterised by lower lime rank, higher maximum and minimum temperature and gentler slopes.
- Mitigate overland flow tend to be characterised by lower lime rank, higher maximum and minimum temperature, lower precipitation, lower elevation and gentler slopes. Low utilisation status tend to be characterised by higher lime rank, lower maximum and minimum temperature, higher precipitation, higher elevation and steeper slopes.

Testing of LUCI outputs has continued and suggests findings are robust for water flow, agriculture potential and current agriculture utilisation and nitrate export to rivers. As LUCI does not include point sources of phosphorus such as sewage works, further work is required to include these or mask them out from LUCI assessments for phosphorus assessments. Erosion and sediment delivery are not well represented by any models available at this time, and there is a need for further research to improve predictions in this area. Current assessment only includes the inherent structure of the landscape such as slope and water, so inclusion of land management such as tillage may improve simulation by LUCI in future, however this has not been a focus for model development. However, it should also be noted there is a lack of good quality national erosion data to test LUCI functionality for this service.

10.3 Methods

LUCI is a second generation extension and software implementation of the Polyscape framework described in Jackson *et al.* (2013). It is specifically tailored to investigate the cumulative impact of individual farm scale interventions within larger catchments, and its use in Year 1 of GMEP is described in Emmett *et al*., 2014. The major achievement for the LUCI modelling work within Year 1 of GMEP was its deployment over all of Wales. A number of individual service maps and associated tables were generated at 5x5m scale for the entire 20,600 km^2, the first ever deployment of an ecosystem service model with such fine spatial resolution at a national scale. Each map (and intermediate calculation) consisted of ~825 million “data” points. In this second year, we have consolidated on this, adjusting the setup and data handling and increasing automation of the “all-Wales” calculations to make the model more tractable for regular use. With these improved processes in place, we focused on verifying model integrity and identifying further development and research priorities through comparing results with national data and/or independent estimates, and exploring trade-offs and “win-win” opportunities for preservation of status quo or change within the landscape. Example outcomes from these verification exercises and trade-off analyses are described within this chapter.

Service	Description
P potential loss to freshwaters	Accumulation of P over the landscape, based on export coefficients for land use, and tracking of flow of water and nutrients over the landscape. This is classified into low, high and very high before being fed into trade off calculations.
N potential loss to freshwaters	Accumulation of N over the landscape, based on export coefficients for land use, and tracking of flow of water and nutrients over the landscape. This is classified into low, high and very high before being fed into trade off calculations.
Carbon Status	Status classification based on the amount of carbon present in biomass and soil, and whether this may be accumulating or decreasing under current land use. Sites which are sequestering, or high carbon and steady state are assigned as good. Sites which are low and not sequestering were assigned as moderate and sites losing or low carbon which are not sequestering are assigned as bad.
Erosion risk	Risk of erosion based on calculations of slope, flow accumulation and curvature
Broadleaved woodland connectivity	“Opportunity to improve” where existing habitat can be extended, based on cost distance for focal species to cross surrounding terrain – i.e. how far species from the habitat of interest are likely to travel. “good condition” for existing habitat and other protected habitats.
Flood mitigation class	“Opportunity to improve” where flow concentration is high or moderate. “good condition” for features which increase infiltration and reduce overland flow e.g. forest.
Potential agricultural utilisation	Level of agriculture that the land can support based on soil, slope and aspect
Current agricultural utilisation	Categorisation of current land use in terms of agricultural productivity
Relative agricultural utilisation	Difference between current and potential agricultural utilisation – i.e. a measure of how appropriate the current level of agricultural utilisation is

Table 10.3.1 *Description of LUCI model ecosystem service outputs used in this chapter.*

10.3.1 LUCI trade-off mapping approach

The ecosystem approach offers an opportunity to consider how adaptations in response to policy and other drivers might impact on multiple sectors. However, exploration of the interactions between these multiple sectors remains challenging. Although the mathematical theory of optimising management with respect to outcome values is well-developed, it is usually difficult to apply to agricultural landscapes in practice, particularly at scales meaningful for farm management decision making (sub-field to farm scale), where computational costs of robust optimisation methodologies become prohibitive. Often improving one ecosystem service will mean a deterioration in another, so a model needs to accommodate trade-offs and highlight potential win-win situations if it is to be a useful decision-support tool. The model outputs used for LUCI tradeoffs, as shown in Table 10.4.1.3 and figure 10.4.1.3 are; relative agricultural productivity, carbon status, Broadleaved woodland habitat connectivity, flood risk mitigation, erosion risk mitigation, reduction of N potential loss to freshwaters and reduction of P potential loss to freshwaters.

For agricultural productivity, carbon status, broadleaved woodland habitat connectivity and flood risk mitigation, the trade-off tool considers areas with opportunity to improve, areas with risk of deterioration, and areas where neither improvements or deterioration are likely to significant. For these services risk of deterioration is identified under the conditions stated in Table 10.3.1.1 and good conditions can be clearly defined and identified. Change in land use would be at high risk of damaging that good status. The trade-off tool also identifies priority areas where erosion could be reduced, and where N and P could be intercepted to preserve freshwater quality. It does not currently distinguish between areas where modification to existing use might have insignificant effects or risk deterioration of erosion risk and/or N and P impacts on freshwaters. This is because the distinction between "good" or "insignificant unimportant" status for these services cannot be defined with enough confidence to warrant assignment of a trade-off where there is potential to improve another service. It is particularly difficult to identify such "risk" for reduction of potential N and P loss to freshwaters, because this status reflects conditions in upslope areas as well as conditions at the site, a change at this point may not be detrimental to good provision for this service.

Service	Conditions for good status/risk of deterioration	Conditions for poor status/opportunity to improve
Relative agricultural productivity	Typical and near typical agricultural production	Land very unusually utilised (either unusually high utilisation or unusually low utilisation)
Carbon status	C stock high to very high and not losing, or gaining stock at high to moderate rate	Losing C at a moderate to rapid rate
Broadleaved woodland habitat connectivity	Existing habitat of interest or other priority habitat	Opportunity to extend existing habitat
Flood risk mitigation	Mitigating feature	Moderate to high flood concentration
Erosion risk mitigation	Not assigned – current trade off calculations target areas at risk (however sediment calculations assign good status to areas that trap sediment from high risk erosion lands).	Moderate to high erosion risk
Reduction of potential N loss to freshwaters	Not assigned; calculations target high risk areas only	High to very high concentration
Reduction of potential P loss to freshwaters	Not assigned; calculations target high risk areas only	High to very high concentration

Table 10.3.1.1 *Ecosystem service conditions for assignment of status as risk or opportunity for trade-offs.*

LUCI includes algorithms to examine trade-offs and co-benefits between the individual ecosystem services in a number of ways. They are primarily designed to highlight areas where interventions provide multiple benefits and areas where intervention is clearly undesirable because existing socioeconomic or ecological value is high (Jackson *et al*., 2013). For input into the trade-off mapping, each service (TSi) takes a value to indicate potential losses or gains with change in land use or management at that point. For agricultural productivity, carbon status, Broadleaved woodland habitat connectivity and flood risk mitigation; the value is assigned as -1, 0, or 1, where -1 indicates anticipated losses arising with change, 0 indicates no significant losses or gains associated with change, and 1 indicates gains ("wins") anticipated with some changes. For erosion risk mitigation and reduction of potential N and P loss to freshwaters; the value is assigned as 0, or 1, where 0 indicates no significant losses or gains associated with change, and 1 indicates gains ("wins") anticipated with some changes. Values of -1 for anticipated losses were not assigned to erosion N and P, even where condition is relatively good, for the reasons explained above.

Even with this coarse three-way categorisation of "win/loss" potential, the number of possible combinations is 3^N where N is the number of services being considered. This inflates rapidly as the number of services increase, as can be seen from the second to last row of Table 10.3.1.2 To simplify communication, LUCI initially highlights the summary combinations, categorising each cell in the landscape according to the overall number of wins, losses and "no significant impact" rather than by specific service combinations. These summary combinations inflate less rapidly (see last row of Table 10.3.1.2), but still quickly pose an issue for detailed analysis.

	Number of services being considered							
	2	3	4	5	6	7	8	N
Potential individual combinations	9	27	81	243	729	2187	6581	3^N
Potential summary combinations	6	10	15	21	28	36	45	$\sum_{i=1}^{N+1} i$

Table 10.3.1.2 *Number of possible combinations of trade-offs/co-benefits as services increase.*

Even after these simplifications, there remain an almost infinite number of options for taking them forward to numerical evaluation of trade-offs. Five mathematical representations are included in the current version of LUCI:
1= equal arithmetic (an unweighted additive approach),
2 = conservative (opportunities to improve are considered only where there is no risk of degradation to another service),
3 = standard (an "expert opinion", subjective balance between the equal arithmetic and conservative approach; somewhat weighting the importance of not degrading services above improving services while still allowing some degradation if major gains in improvement can be achieved),
4 = weighted arithmetic (a weighted additive approach),
5 = mixed conservative/weighted additive

For this report, which contains our first analysis of trade-offs and co-benefits at a national scale, we used the equally weighted additive option, implicitly treating all services as being of equal value. The generic equation defining the arithmetic multiple criteria opportunity mapping is:

$$NonCat\_OTS = \frac{\sum_{i=1}^{N} w_i TS_i}{\sum_{i=1}^{N} w_i} \quad , \qquad \text{(Equation1)}$$

where N represents the number of services being analysed and w_i represents the weights assigned to each service. All values lie between -1 and 1. Maximum potential for change is indicated by a value of 1, while maximum prioritisation for the status quo is indicated by a value of -1. In the case of equal weighting between all services, as assumed in this study, Equation 1 simplifies to:

$$NonCat\_OTS = \frac{\sum_{i=1}^{N} TS_i}{N} \qquad \text{(Equation 2)}$$

In "English", another way to think of Equation 2 is

$$NonCat\_OTS = \frac{[number\_of\_wins - number\_of\_losses]}{[number\_of\_wins + number\_of\_losses + number\_of\_"no\_change"]}$$

The categorisation for either Equation 1 or 2 then proceeds as follows to define values for mapping:

if	*NonCat_OTS* > TCT1,	High change opportunity
elseif	*NonCat_OTS* ϵ [TCT2, TCT1],	Moderate change opportunity
elseif	*NonCat_OTS* ϵ TCT3,TCT2],	Negligible opportunity or near-balanced trade-offs
elseif	*NonCat_OTS* ϵ TCT4,TCT3]	Moderate preservation opportunity
elseif	*NonCat_OTS* < TCT4,	High preservation opportunity

In this application (which uses the default LUCI thresholds), *TC1* = 0.6, *TC2* = 0.3, *TC3* = -0.3 and *TC4* = -0.6. Synergies and trade-offs in existing and potential service provision are then identified. These trade-off maps offer a means for recognising the value of existing landscape features and targeting and prioritising opportunities for landscape change by being explicit about where trade-offs and synergies between these services occur within the landscape.

10.4 Results

10.4.1 Ecosystem services condition, opportunities to improve, and trade-offs or co-benefits between services

Ecosystem services condition, opportunities to improve, and trade-offs or co-benefits between services were identified, based on combining spatial data on model classifications of ecosystem service condition as high existing service, negligible existing or potential service, or opportunities to improve existing service provision for reduction of N and P potential loss to freshwaters, status of carbon in soil and biomass, and erosion risk. This differs from the default LUCI trade off calculations and mapping, which do not consider potential risk of loss of good condition for reduction of N and P potential loss to freshwaters, and erosion risk, however it is interesting to consider the areas which might be affected if these trade-offs were considered.

For habitat connectivity, separate consideration was given to locations with potential to expand existing Broadleaved woodland, and locations occupied by other priority habitat, since these may be protected from land use change or other interventions. For flood mitigation, it must be remembered that not all locations classified as "non-mitigated" represent opportunities to reduce flood risk;

rather they represent opportunities to reduce contributions from those areas to stream flow in high flow conditions. Interventions which increase infiltration and slow transit of water into the main watercourse will act to stabilise flow levels, increasing base flow and reducing flow peaks, and associated flood risk, following precipitation events. However where interventions increase evapotranspiration losses significantly, the reduction in volume of water reaching the stream may be detrimental to flow regime if low flow or over abstraction are more significant issues in that catchment. For agricultural land utilisation, assessments were based on whether current production was classified as high, moderate, or low, since it is desirable to improve ecosystem service provision without significantly impacting agricultural productivity where possible. This differs from the default LUCI trade off calculations and mapping, which instead consider relative agricultural productivity, i.e. whether the land is under an appropriate level of production for the site.

Calculations have been made on the spatial data to identify for each ecosystem service the total area with good provision, total area with opportunity to improve, and area with opportunity to improve without risk to existing services in good condition; these numbers are shown in Table 10.4.1.1. Further calculations were then performed for each ecosystem service to identify where opportunities to improve ecosystem services coincide spatially with good existing condition for each other ecosystem service; these numbers are shown in Table 10.4.1.2. Finally, calculations were performed for each ecosystem service pair to identify where both have opportunities to improve; these numbers are shown in Table 10.4.1.3.

Service	**Good existing service provision**	**Moderate existing service provision**	**Opportunity to improve service provision (A)**	**Affected by trade-off with another service (B)**	**Opportunity to improve without risk to existing good status for another service (A-B)**
P potential loss to freshwaters	19169		1263	1226	37
N potential loss to freshwaters	15201		5231	5127	**<u>104</u>**
Carbon Status	2830	6648	**<u>10508</u>**	10498	10
	Existing low risk	Existing moderate risk	Opportunity to reduce risk	Affected by trade-off with another service	Opportunity to improve without risk to existing good status for another service
Erosion risk	18608	1610	220	211	9
	Good existing service provision	Other priority habitat	Opportunity to extend habitat	Affected by trade-off with another service	Opportunity to extend, without risk to existing good status for another service
Broadleaved woodland connectivity	1224	1565	**<u>4595</u>**	4501	**<u>94</u>**
	Good existing service provision		Non-mitigated features	Affected by trade-off with another service	Opportunity to improve without risk to existing good status for another service
Flood mitigation class	7785		12654	12333	**<u>321</u>**
	High productio n	Moderate production	Low production	Affected by trade-off with another service	Opportunity to increase production without risk to existing good status for another service
Current agricultural utilisation	10106	5059	4387	4290	**<u>97</u>**

Table 10.4.1.1 *Existing ecosystem service provision, opportunities to improve, and trade-offs where these opportunities to improve coincide with other ecosystem services in good condition. All areas given in km^2. Figures commented on in text are shown in bold and underlined to help the reader navigate the tables. Reduction of N and P potential loss to freshwaters, and erosion risk have among the highest numbers for "Good existing service provision" under this approach, and would thus result in significant areas of trade-offs if this approach had been adopted in the LUCI default trade-off tool.*

Table 10.4.1.2 indicates that significant areas have opportunity to improve carbon (C) status (10508km^2), however for the vast majority of these sites, there are other services in good condition, so care must be taken to avoid detrimental effects if interventions are targeted at improving C status. Table 10.4.1.2 indicates that many of these trade-offs are with priority habitats (7488 km^2) (largely heather dominated grasslands), agricultural utilisation (5424 km^2) erosion risk (9693 km^2), and nitrogen (N) (7731 km^2) and phosphorus (P) (9834 km^2) potential loss to freshwaters. It is likely that changes to improve C status would not increase erosion risk, or N and P potential loss to freshwaters (which may help to justify the exclusion of "good status" for these services in the LUCI default trade-offs), however the need to protect priority habitats, and socioeconomic value of agricultural production may reduce potential to achieve carbon status improvements.

N potential loss to freshwaters has reasonable opportunities (104 km^2) to improve (reduce) without risk of damaging other ES or agricultural productivity. Significant proportions of the 5231 km^2 of sites with opportunity to reduce N potential loss to freshwaters also have opportunities to reduce P potential loss to freshwaters (1228 km^2), and improve C status (2777 km^2), Broadleaved woodland habitat connectivity (1038 km^2) and mitigation of overland flow which may contribute to flood mitigation (3955 km^2), as indicated in Table 10.4.1.3

Table 10.4.1.1 indicates that over 321km^2 were classified as non-mitigated in terms of runoff, and had no other ecosystem services in good condition, which may indicate significant potential for interventions to reduce flood risk, without damaging other ES or agricultural productivity. However depending on flow regimes not all of these non-mitigated features currently create flood risk, hence further assessment of these opportunities is necessary.

Locations with low agricultural productivity that are not in good condition for other ES were mapped as over 97 km^2 as can be seen in Table 10.4.1.1. Whilst there may be potential to increase agricultural productivity in these locations, land may be less suitable for agriculture, and interventions to improve other ES may be more appropriate.

Service with opportunity to improve	Area with opportunity to improve service provision (km²)	Area coinciding with good existing provision for other (specified) ecosystem service (km²)							
		P accumulation load	N accumulation load	Carbon Status	Erosion risk	Broadleaved woodland connectivity	Other priority habitat	Flood mitigation class	Current utilisation
P potential loss to freshwaters	1263	X	14	65	2260	59	958	146	858
N potential loss to freshwaters	5231	3915	X	232	4559	205	3900	1187	3936
Carbon Status	10508	**9834**	**7731**	x	**9693**	637	**7488**	3264	**5424**
Erosion risk	220	156	117	62	x	51	97	115	48
Broadleaved woodland connectivity	4595	4292	3479	453	3993	x	x	2162	0
Flood mitigation class	12654	11246	8387	81	11422	0	9988	x	7869
Current agricultural utilisation	4387	4211	4027	2723	3715	2714	1017	4171	x

Table 10.4.1.2 *Opportunities to improve ecosystem services often coincide spatially with other ecosystems in good existing condition, leading to trade-offs, in the sense that the target ecosystem service cannot be improved without risk of detriment to existing service provision. This table indicates for each ecosystem service the area with opportunities to improve, and how much of this coincides with existing good condition for each other ecosystem service. All areas given in km². Figures commented on in text are shown in bold and underlined to help the reader navigate the tables.*

Win-wins: areas with opportunities to improve both ecosystem services	P potential loss to freshwaters	N potential loss to freshwaters	Carbon Status	Erosion risk	Broadleaved woodland connectivity	Flood mitigation class	Current utilisation
P potential loss to freshwaters	x	1228	674	61	225	1096	79
N potential loss to freshwaters	**1228**	X	**2777**	100	**1038**	**3955**	263
Carbon Status	674	2777	x	88	**2382**	7244	1312
Erosion risk	61	100	88	x	70	103	84
Broadleaved woodland connectivity	225	1038	2382	70	x	2355	560
Flood mitigation class	1096	3955	7244	103	2355	x	119
Current agricultural utilisation	79	263	1312	84	560	119	x

Table 10.4.1.3 *Opportunities to improve ecosystem services may coincide spatially with other ecosystem services with opportunity to improve, leading to "win-wins". This table indicates for each ecosystem service the area of opportunities to improve which coincide with opportunity to improve for each other ecosystem service: i.e. for each pair of ecosystem services, what area has*

opportunities to improve both. All areas given in km². Figures commented on in text are shown in bold and underlined to help the reader navigate the tables.

Opportunity to expand Broadleaved woodland without damaging agricultural productivity or other ES was mapped over 94 km² as shown in Table 10.4.1.1., and this habitat expansion is likely to also benefit carbon status and water quality, since of the 4595 km² total area identified for potential habitat expansion 2382 km² have opportunity to improve C status and 1038 km² have opportunity to reduce potential N loss to freshwaters, as shown in Table 10.4.1.3. Looking at co-location of opportunities to improve ecosystem services for carbon, nitrogen and phosphorus and expand Broadleaved woodland in Figure 10.4.1.1 indicates that areas with co-benefits for habitat expansion, C and N do not always coincide; although a significant proportion of the country was identified as having opportunities for improvement in two services, very few had opportunities for three; these are only visible when smaller areas are examined as in Figure 10.4.1.2. Large areas have more opportunities to improve than services with existing good status; the output table indicates that for this comparison, these "win-wins" account for 67% of Wales.

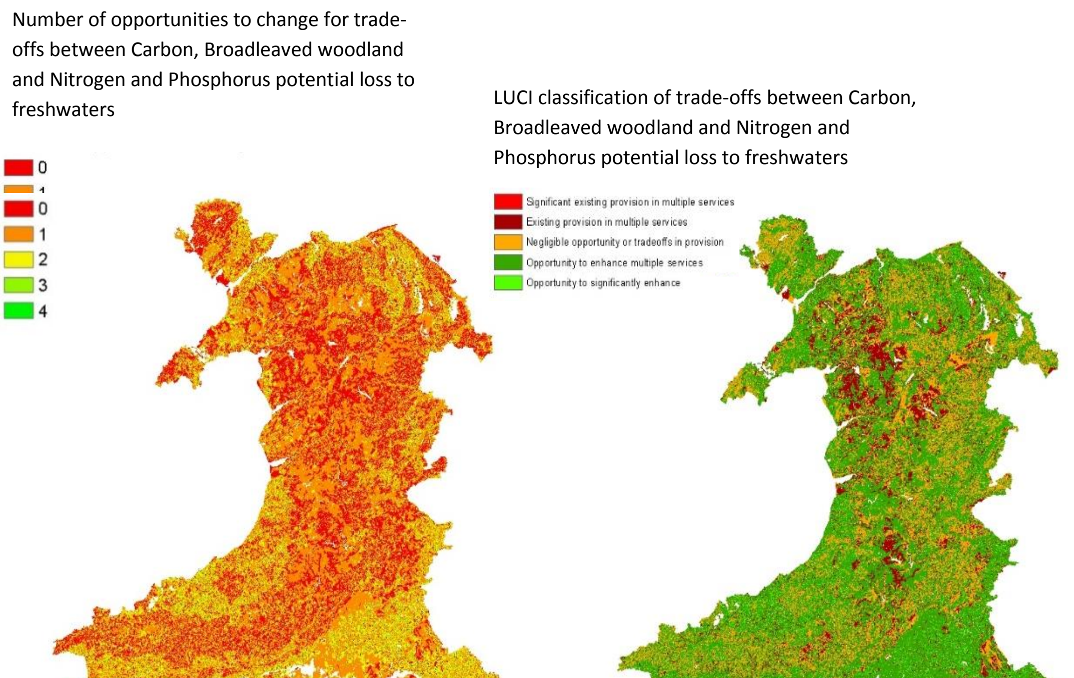


Figure 10.4.1.1 *Trade-offs between ecosystem services for carbon, nitrogen, phosphorus and Broadleaved woodland. A. shows number of opportunities to improve; note values of 3 and 4 (greens) do occur but are barely visible at national scale. B. maps opportunities and trade-offs, and indicates that although most sites shown in A. only have opportunity to improve one or two services, large areas have more opportunities to improve than services with existing good status; the output table indicates that for this comparison, these "win-wins" account for 67% of Wales.*

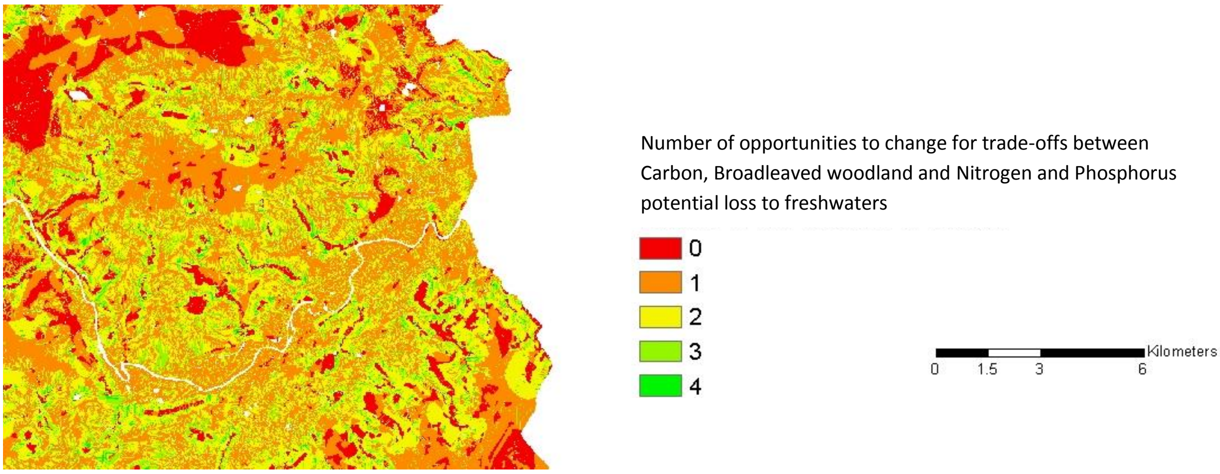


Figure 10.4.1.2 *Opportunities to improve ecosystem services for carbon, nitrogen and phosphorus or expand Broadleaved woodland for a small area in south Wales*

To explore this issue further, calculations have been performed on all outputs to identify where there are trade-offs and win-wins across all 7 ecosystem services considered, i.e. for combinations of 1-7 ecosystem services, the total area with opportunity to improve the stated number of services, and a breakdown of which services are in good condition and which have opportunity to improve for the relevant area. For example, as indicated in Table 10.4.1.3., 36 km^2 have opportunities to improve 6 of the 7 modelled ecosystem services; all of this area has opportunity to improve (reduce) potential loss of N to freshwaters, whereas 16 km^2 have good existing provision of agricultural productivity.

Looking at co-location of opportunities to improve ecosystem services for all 7 services Figure 10.4.1.3 indicates that ca. 10% has existing multiple service provision whilst almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.

No. Of services with opportunities to improve		**Opportunities to improve service (km²)**							**Service already in good condition(km²)**			
	total	**AGP**	**CAR**	**HAB**	**FLO**	**ERO**	**NIT**	**PHO**	**AGP**	**CAR**	**HAB**	**FLO**
7	1	1	1	1	1	1	1	1	0	0	0	0
6	**<u>36</u>**	15	35	28	35	32	**<u>36</u>**	33	**<u>16</u>**	0	0	<1
5	292	93	269	147	282	144	291	236	157	0.5	<1	1
4	1154	262	968	412	1070	273	1080	552	730	4	1	5
3	2783	270	2083	924	2322	432	1981	336	2057	1	0	18
2	1302	348	1059	357	606	85	148	1	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0

Table 10.4.1.3 *Breakdown of areas with more opportunities to improve services than services to be preserved, according to LUCI default trade off tool. Where AGP= relative agricultural productivity, CAR= carbon status, HAB= Broadleaved woodland habitat connectivity, FLO=flood risk mitigation, ERO= erosion risk mitigation, NIT= N potential loss to freshwaters and PHO= P potential loss to freshwaters. Figures commented on in text are shown in bold and underlined to help the reader navigate the tables. Note declining numbers as more services are considered from 3 to 7. ERO, NIT and PHO are not listed under "Service already in good condition" because the LUCI trade of tool does not assign trade-offs for such sites.*

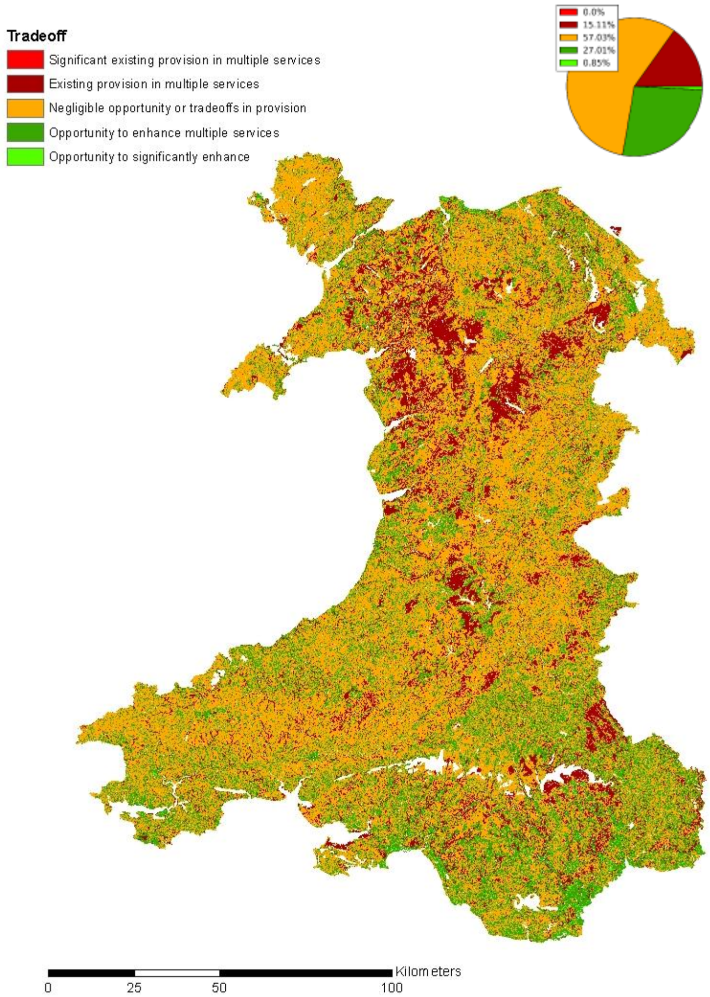


Figure 10.4.1.3 *Outcomes for trade-offs between relative agricultural utilisation, carbon status, nitrogen and phosphorus status, erosion status, Broadleaved woodland connectivity and flood mitigation ecosystem services; almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved. This map was produced using LUCI default trade off mapping approach, applying equal weighting to all services (as described in Section 10.1.3).*

10.4.2 What determines ecosystem service distribution across the landscape?

Figure 10.4.2.1 shows an ordination of spatial variation in combined ecosystem service status across the 7 services considered; further ordination analysis with environmental constraints applied, indicated that only 3% of spatial variation in combined ecosystem service status can be explained by precipitation, temperature regime, elevation, slope and soil drainage and acidity. This indicates the importance of simulation of topology and topography when assessing condition of the relevant ecosystem services; for this reason spatially explicit modelling as applied in LUCI has significant benefits over simplified point combination of spatial data. Around 40% of variation in combined ecosystem service status can be attributed to land use classification, however this artificial constraint was not considered in the environmental typologies analysis. The remaining 60% requires explicit simulation of spatial relationships between land types, taking into account topography and location of watercourse in order to simulate ecosystem service condition.

Nonetheless some trends with environmental variables can be observed for the ecosystem services assessed. Opportunities to reduce N and P potential loss to freshwater tend to be characterised by lower CACO3 rank, higher maximum and minimum temperature, lower precipitation, lower elevation and gentler slopes. Opportunities to improve carbon status tend to be characterised by higher CACO3 rank, lower maximum and higher minimum temperature and gentler slopes. Opportunities to improve erosion risk tend to be characterised by lower CACO3 rank, lower maximum and minimum temperature, higher precipitation and steeper slopes. Opportunities to improve Broadleaved woodland connectivity tend to be characterised by lower CACO3 rank, higher maximum and minimum temperature and gentler slopes. Opportunities to mitigate overland flow tend to be characterised by lower CACO3 rank, higher maximum and minimum temperature, lower precipitation, lower elevation and gentler slopes. Low utilisation status tend to be characterised by higher CACO3 rank, lower maximum and minimum temperature, higher precipitation, higher elevation and steeper slopes.

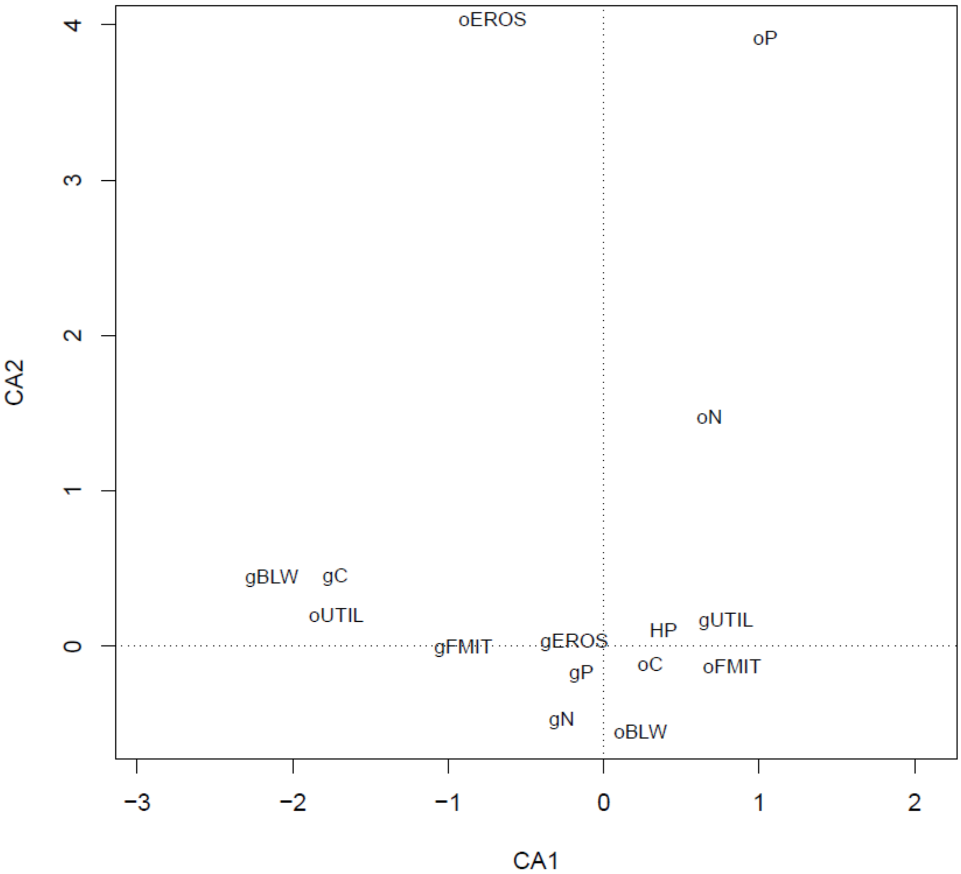


Figure 10.4.2.1 *Ordination of Ecosystem service condition*
Where: gUTIL = high current agricultural utilisation, gEROS = low erosion risk status, gP = low P potential loss to freshwater , gN = low N potential loss to freshwater , gFMIT = Flow accumulation mitigation or mitigated feature, gC = good C status, gBLW = Broadleaved woodland, HP = other priority habitat, oUTIL = low current agricultural utilisation, oEROS = opportunity to improve erosion status, oP = opportunity to reduce potential P loss to freshwater, oN = opportunity to reduce potential N loss to freshwater, oFMIT = No mitigation of overland flow accumulation, oC = opportunity to improve C status and oBLW = opportunity to expand Broadleaved woodland

10.5 Is land inside the Glastir scheme providing better flood mitigation protection to that outside the scheme?

An assessment of the amount of land inside and outside of the scheme was calculated.

Wales	Wales (ha)	% of Wales	Land in Glastir (ha)	% of land in Glastir	Land outside of Glastir (ha)	% of land outside of Glastir
Mitigating features	422499	20	114366	19	308134	21
Mitigated features	355983	17	112955	19	243028	17
Non-mitigated features	1265396	61	374980	62	890415	61
Water bodies	31268	2	5875	1	25393	2
Total	2075146		608176	100	1466970	100

Table 10.5.1 *Breakdown on land in and out of Glastir according to mitigation status for overland flow of water, N and P. This is a conservative estimate, and values are expected to increase slightly with Inclusion of the HOST dataset to account for mitigation from* well drained soils.

The results suggests there is little difference between the land inside and outside of the Glastir scheme with respect to either mitigating or mitigated features. The values are 19% and 21% for land in and out of scheme for mitigating features and 19% and 17% for mitigated features. This provides a baseline for future reporting as Glastir options are implemented.

10.6 Testing LUCI Model performance

GMEP has an ongoing programme for testing LUCI and its outputs. Here we present some latest assessments of model output.

Agricultural utilisation has been mapped across Wales using the LUCI (Land Utilisation & Capability Index) model according to soil type data from Cranfield University (NSRI) and land cover data collected in 2007 by the Centre for Ecology and Hydrology. The model calculates predicted optimal agricultural utilisation based on soil type, using assigned values of fertility and waterlogging (yes, no or seasonal) and topographic data, using calculated values for aspect slope and elevation. Current agricultural utilisation has been mapped according to the land cover data, ranking land use from highest productivity to lowest: Arable; Improved grassland; Unimproved grassland; Woodland and heath; Bog sand and rock. A weighting was applied to account for the relative suitability of Welsh farmland for intensive agriculture compared to optimal conditions for intensive agriculture; this weighting appears to be appropriate since over 75% of land was identified as having predicted usage from comparison of current and optimal usage.

The model also performs well when compared to other national level datasets of land quality and land use. For example Figure 10.6.1.1 indicates that predicted optimal utilisation (calculated from NSRI soil type data) correlates with Defra Agricultural Land Classification values which rank land from good (1) to poor (5). High or very high production is simulated for areas of land which are only in land class 3 or 4, due to the weighting applied in the model to account for the majority of Wales being in land classes 3-5. By taking this into account, the model is able to simulate optimal and relative utilisation of land in the context of overall availability of suitable land for agriculture in Wales.

10.6.1. LUCI model validation work

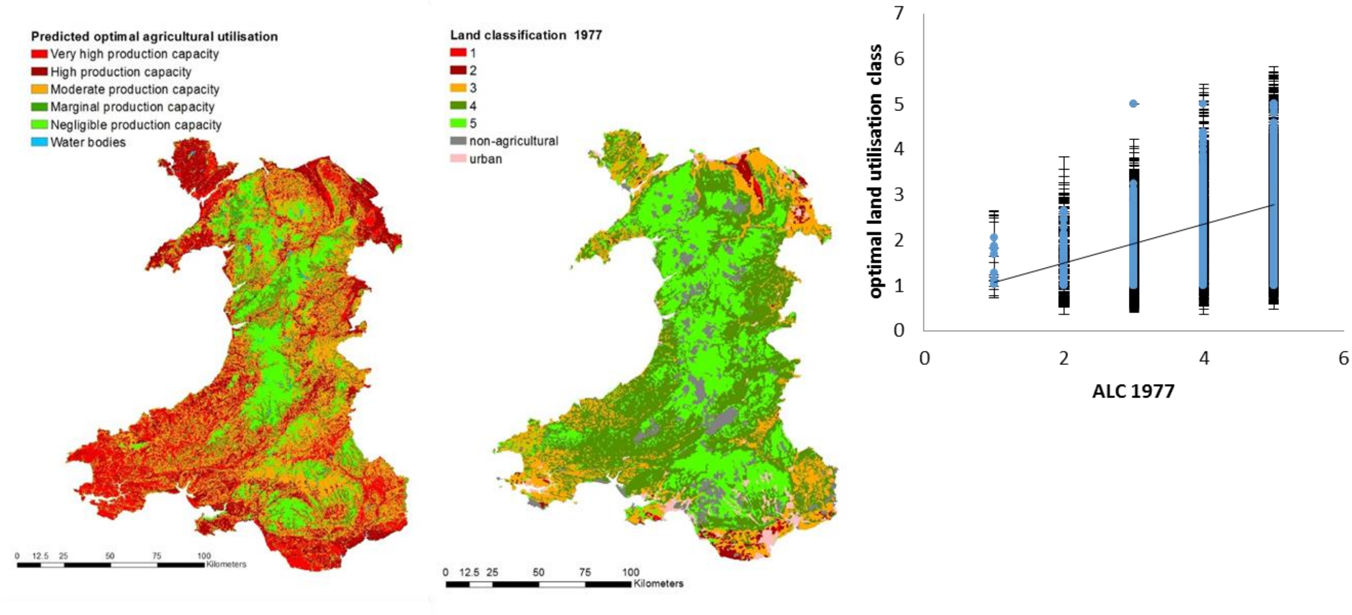


Figure 10.6.1.1 *Comparison of LUCI simulated 'optimal' agricultural land utilisation with Defra Agricultural Land Classification (ALC) values*

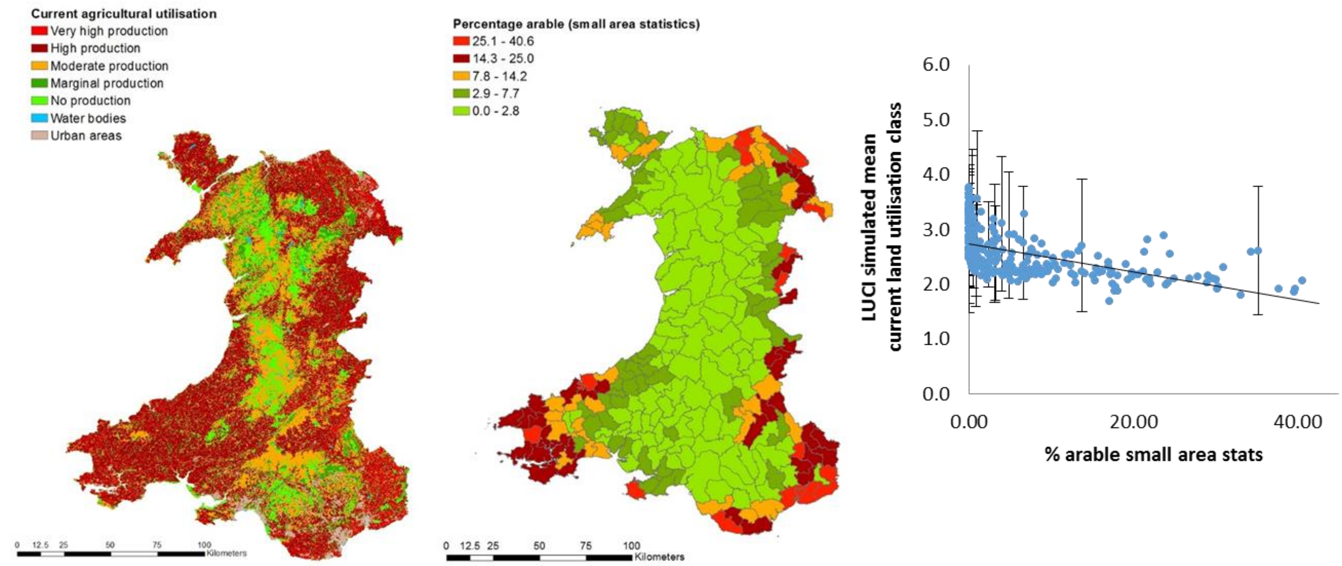


Figure 10.6.1.2 *Comparison of LUCI simulated 'current' agricultural utilisation with current area of arable land. LUCI scores high production land by a score of 1.*

Figure 10.6.1.2 indicates a good relationship between current agricultural utilisation (calculated from CEH 2007 land class data) and Defra Small Area Agricultural Census data, although the comparison is slightly limited by the fact that LUCI assigns high agricultural utilisation for intensively managed grassland, however data were not available to include in the comparison from the Defra agricultural survey.

The LUCI (Land Utilisation & Capability Index) model calculates flow over the landscape using GIS functions for calculating flow direction and accumulating water through the landscape through use of flow accumulation routines modified to account for spatial differences in rainfall, evaporation and soil properties. In these results, spatial data on precipitation and evapotranspiration were provided by the Met Office and input to LUCI as the annual average over 30 and ~50 year periods respectively. “Mitigating features” which prevent the movement of water downslope, such as woodland, swamp, bog and marsh are identified from land use data; in this case land cover data collected in 2007 by the Centre for Ecology and Hydrology. Flow from areas which route through these mitigating land use features are considered to be mitigated, i.e. water does not travel to the watercourse as overland or other rapid flow. Areas of well drained soils may also provide this type of mitigation, and further work utilising HOST data is expected to reveal a slight increase in mitigated area.

The model performs well at simulating annual average stream flow across Wales; modelled values are shown in Figure 10.6.1.3 plotted against the mean measurements taken at National River Flow Archive stations. NRFA station means are taken over the full recording period for that station (with start dates varying from 1879 to 1995), whereas modelled values are based on precipitation averages for 1961-1990 and estimated actual evapotranspiration values for 1961-2012. Note that the LUCI model for Wales has been set up over the extent of the country but not beyond; it therefore does not currently account for transboundary river crossings between England and Wales. Flow out to England is not conserved when the river returns to Wales, nor is additional input from England accounted for. As a result, the model significantly underestimates flow at NRFA stations on rivers which cross the border. Additional data for these transboundary catchments have been requested from the Welsh Government to allow the river border crossings to be accounted for in future work.

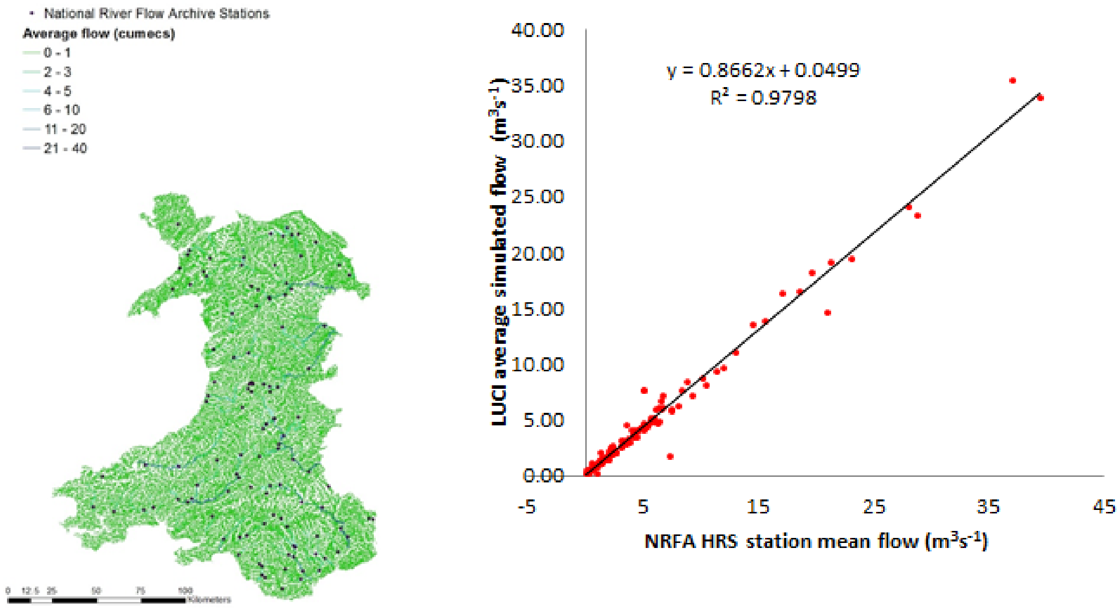


Figure 10.6.1.3 *Comparison of LUCI simulated annual average flow with NRFA mean flows*

The LUCI (Land Utilisation & Capability Index) model estimates nitrogen loading contributed at individual points in the landscape based on land cover, but additionally taking into account stocking rate and fertiliser input. Accumulated nitrogen and phosphorus loading is calculated by combining this data layer with a flow direction layer calculated from topography. Nutrient flow accumulation for near surface flow is calculated by weighting spatial data on flow direction by the appropriate nutrient export coefficients, and a factor for the solubility of nitrogen. “Mitigating features” which prevent the movement of water downslope, such as woodland, swamp, bog and marsh are identified from land use data. Later work to include the HOST dataset to account for mitigation from well drained soils may improve performance of this model component. For overland flow, spatial location of these mitigating features is used to remove areas which are not connected to the stream from the flow direction data layer, and then for the remaining areas flow direction is weighted by the appropriate export coefficients. The model was run using land cover data collected in 2007 by the Centre for Ecology and Hydrology to establish a baseline distribution of nitrogen and phosphorus loading generating and mitigating land, and in-stream concentrations. The output from this is simulated values of spatially distributed annual mean stream concentrations of dissolved nitrogen and dissolved phosphorus in the DEM-defined Welsh stream network.

These simulations may be compared with measured values of water quality to assess the performance of the LUCI model. Field data on total in stream P and N concentrations were not available on national scale for direct comparison with LUCI model output. Comparisons between modelled total P and measured soluble reactive P, and likewise between modelled total N and measured reactive soluble N should not be considered absolute, but are nonetheless indicative of model performance. These data were collected by NRW and formerly the EA in their routine monitoring, and are held by CEH in the Water Information Management Solution (WIMS) database. We have extracted mean concentrations for the year 2007 from the database, amounting to 834 sites for TON and 775 sites for SRP. Typically these individual means are based on twelve monthly samples, though the number may vary between sites.

As previously noted, the current LUCI setup does not consider flows into Wales from England, and therefore does not currently account for the effects of transboundary river crossings between England and Wales. The rivers Wye and Dee in their lower reaches, in particular, cross between the two countries. Where, for example, the Dee renters Wales, LUCI does not recognise it as the same river that left Wales, but as a new river. The concentrations in this “new” river are then estimated from the local land use characteristics, not accounting for the true upstream contribution from upland Wales. This tends to give overestimation of nutrient concentrations by LUCI. There are a small number of examples of such sites.

Having collocated simulation and measurement river cells, we can plot values against each other, as shown in Figure 10.6.1.4 and Figure 10.6.1.5 using a logarithmic scale. For nitrogen an unconstrained straight-line fit gives the following statistics: intercept 0.15; se 0.02; slope 1.03 se 0.02; r^2 0.72. These figures indicate a slight upward bias in the simulated nitrogen concentrations. These can partly be attributed to the transboundary phenomenon alluded to. For phosphorus, the equivalent model gives intercept -2.11 se 0.12; slope 0.6 se 0.04; r^2 0.26. These statistics reflect the notable upward bias in the simulated values compared to the measured, which is apparent from Figure 10.6.1.5. Simulated values are approximately half the measured values. Here it should be borne in mind that LUCI simulates only diffuse sources of phosphorus, and it is known that approximately half of the phosphorus in rivers is from point sources (although this proportion is declining). This suggests that once LUCI has been adapted to take account of point sources of phosphorus, its simulation performance should approximate its performance for nitrogen.

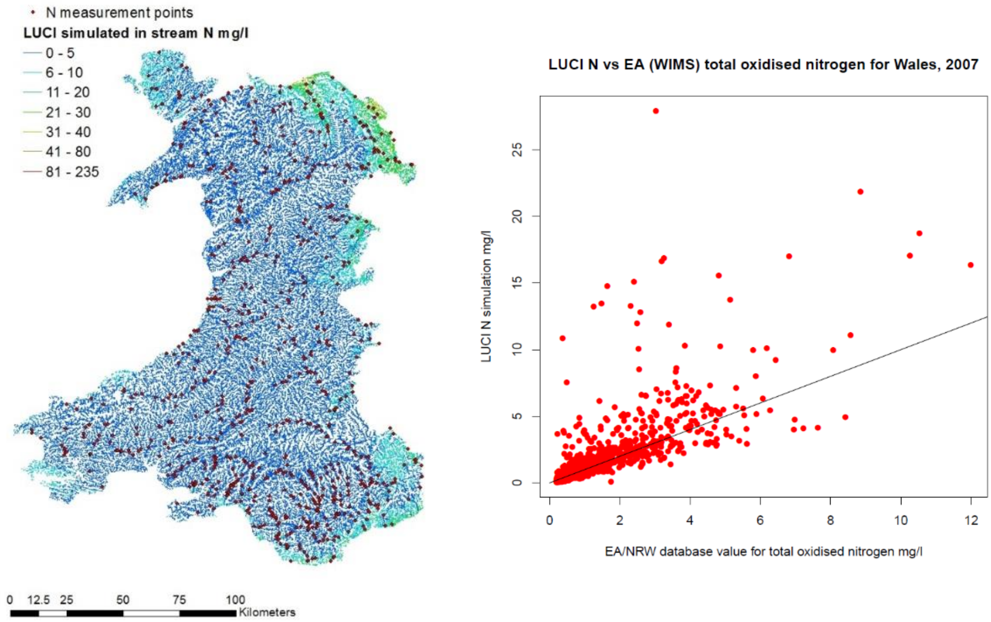


Figure 10.6.1.4 *Comparison of LUCI simulated in-stream total N concentrations attributed to diffuse sources, based on 2007 land use and long term annual averages for effective precipitation, versus EA (WIMS) measured total oxidised nitrogen annual average over 2007.*

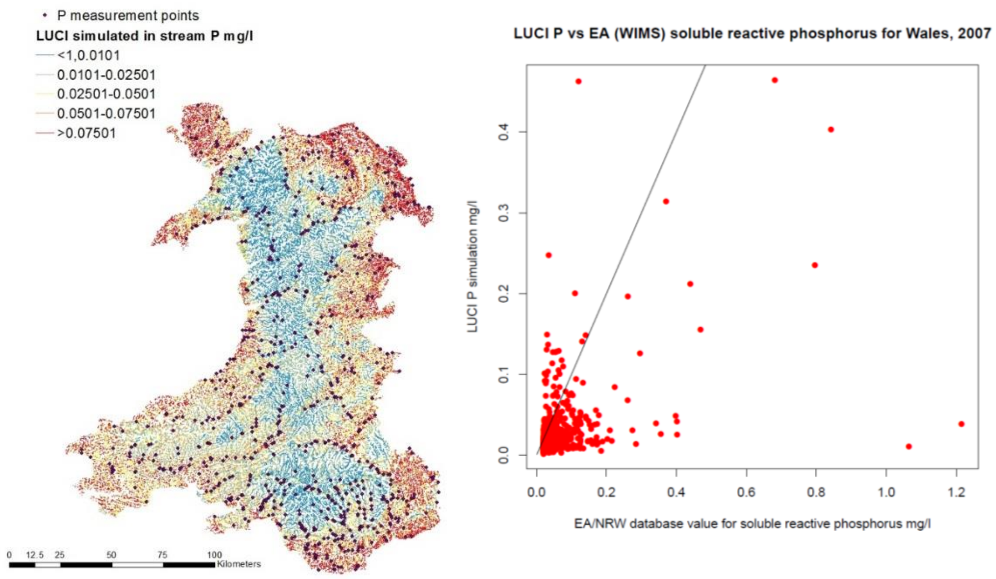


Figure 10.6.1.5 *Comparison of LUCI simulated long-term annual average in-stream total P concentration attributed to diffuse sources, based on 2007 land use and long term annual averages for effective precipitation, versus measured EA (WIMS) soluble reactive P annual average over 2007.*

10.7 LUCI model progress and anticipated developments for GMEP year 3 reporting

In future years LUCI will provide metrics for Glastir Outcome reporting for the change in % of land mitigated with respect to rainfall runoff / flood mitigated due to Glastir options.
Testing of the LUCI model will continue with respect to both ecosystem service delivery but also tested for outcome of land management interventions.

As part of both Year 2 and Year 3 work, we have also made significant progress on deploying a web-mapping service appropriate for Welsh catchments, and setting up for more temporal /event reporting from LUCI over Wales. Unfortunately we are unable to report or finalise testing due to data licensing issues. These are being addressed, and we will be reporting on this for Year 3.
More generally, LUCI development has been progressing through other projects, outcomes from which are all becoming available for use with the GMEP work. Changes of particular relevance for GMEP are:

- A new "native to LUCI" habitat and vegetation classification system is being introduced, allowing a wide variety of habitats, land cover and condition to be considered. This replaces the original system where exploration of impacts of management interventions or updates to data were somewhat restricted by the specific input habitat or vegetation dataset used.
- There is a significant project underway in New Zealand funding improvements to on-farm detail within LUCI, with a particular focus on how small scale interventions or changes in management practices modify export of water, sediment, nitrogen and phosphorus to streams. Many of these will translate directly to supporting more detail on Glastir options.
- LUCI is now formally version controlled so code changes/issues can be easily tracked, using the established "github" repository system. Results reported in this chapter are from LUCI v0.4
- Funding from the NERC INNOVATE funding stream has been won together with York University to develop methods for increasing the transparency and uncertainty level of the evidence base for users of ecosystem service models with LUCI as one of those test models.

11 References

ADAS and Agra CEAS Consulting (2010) Mid Term Evaluation of the Wales Rural Development Plan 2007-13.Final report to the Welsh Assembly Government, ADAS, Wolverhampton, UK http://ec.europa.eu/agriculture/rurdev/countries/uk/mte-rep-uk-wales_en.pdf

AEA (2014). Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990-2012. NAEI Report Reference ED59802/2012/CD8331/GT. ISBN 9780-9573549-5-1. 111 pp. http://naei.defra.gov.uk/reports/.

Agra (2005) Socio-economic evaluation of Tir Gofal. Final Report for CCW and the Welsh Assembly Government. January 2005 http://www.ceasc.com/Images/Content/2143%20final%20report.pdf

Amundson, R., Guo, Y. & Gong, P. (2003) Soil diversity and land use in the United States. Ecosystems, 6, 470-482.

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Bouwer, F., Elbersen, B., Eiden, G., Giodeschalk, F., Jones, G., McCracken, D., Nieuwenhuizen, W., Eupen, M.v., Hennekes, S., Zervas, G., 2003. Developing a High Nature Value Farming Area Indicator: Final Report, pp. 75.

Anthony, S., Jones, I., Naden, P., Newell-Price, P, Jones, D., Taylor, R., Gooday, R., Hughes, G., Zhang, Y., Fawcett, L., Simpson, D., Turner, A., Fawcett, C., Turner, D., Murphy, J., Arnold, A., Blackburn, J., Duerdoth, C., Hawczak, A., Pretty, J., Scarlett, P., Laize, C., Douthwright, T., Lathwood, T., Jones, M., Peers, D., Kingston, H., Chauhan, M., Williams, D., Rollett, A., Roberts, J., Old, G., Roberts, C., Newman, J., Ingram, W., Harman, M., Wetherall, J. and Edwards-Jones, G. (2012) Contribution of the Welsh agri-environment schemes to the maintenance and improvement of soil and water quality, and to the mitigation of climate change. Welsh Government, AgriEnvironment Monitoring and Technical Services Contract Lot 3: Soil, Water and Climate Change (Ecosystems), No. 183/2007/08, Final Report, 477 pp + Appendices.

Armitage, P. D., Moss, D., Wright, J. F. & Furse, M. T. (1983) The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Research, 17, 333-347.

Avery, B. W. (1980) Soil classification for England and Wales [higher categories]. Technical Monograph, Soil Survey of England and Wales.

Baker, D.J., Freeman, S.N., Grice, P.V. & Siriwardena, G.M. (2012) Landscape scale responses of birds to agri-environment management: a test of the English Environmental Stewardship scheme. *Journal of Applied Ecology* 49: 871-882.

Balmer, D.E., Gillings, S., Caffrey, B.J., Swann, R.L., Downie, I.S. & Fuller, R.J. 2013. Bird Atlas 2007-11: the breeding and wintering birds of Britain and Ireland. BTO Books, Thetford.

Beaufoy, G., Baldock, D., Clarke, J., 1994. The Nature of Farming e Low Intensity Farming Systems in Nine European Countries. IEEP, London, pp. 68.

Bhogal, A. Boucard, T. Chambers, B. J. Nicholson, F. A. Parkinson, R. 2008. Road Testing of 'Trigger Values' for Assessing Site Specific Soil Quality. Phase 2 – Other Soil Quality Indicators Science Report – SC050054SR2 EA report.

Biggs, J., Fox, G., Nicolet, P., Walker, D., Whitfield, M. & Williams, P. (1998) A guide to the methods of the national pond survey. Pond Action, Oxford. pp 22.

Biological Monitoring Working Party (1978) Final report: Assessment and presentation of the biological quality of rivers in Great Britain. Unpublished Report. . D.o.E. Water Data Unit pp37.

Burns, F., Easton, MA., Gregory, RD., et al., (2013) *State of Nature: Wales.* In the State of Nature Report, The State of Nature partnership available from www.rspb.org.uk/stateofnature

Cadw (2012) The Welsh Historic Environment: Position Statement, 2010-11. Published by Cadw for the Welsh Government 2012. Available from http://cadw.gov.wales/docs/cadw/publications/The%20Welsh%20Historic%20Environment%20Position%20Statement%202010-11_EN.pdf

Cardoso, A. C., Duchemin, J., Magoarou, P. & Premazzi, G. (2001) Criteria for the identification of freshwaters subject to eutrophication: their use for the implementation of the 'Nitrates' and Urban Waste Water Treatment directives. Luxembourg: Office for Officila Publications of the European Communities.

Centre for Ecology & Hydrology (2007) Wales Results from 2007. NERC/Centre for Ecology & Hydrology, Welsh Assembly Government, Countryside Council for Wales, 94pp. (CEH Project Number: C03259).

Céréghino R, Biggs J, Oertli B & Declerck S (2008) The Ecology of European ponds: defining the characteristics of a neglected freshwater habitat Hydrobiologia 597: 1-6.

Chadd, R. & Extence, C. (2004) The conservation of freshwater macroinvertebrate populations: a community-based classification scheme. Aquatic Conservation: Marine and Freshwater Ecosystems, 14, 597-624.

Church, A., Fish, R., Haines-Young, R., Mourato, S., Tratalos, J., Stapleton, L., Willis, C., Coates, P., Gibbons,S., Leyshon, C., Potschin, M., Ravenscroft, N., Sanchis-Guarner, R., Winter, M., & Kenter, J. (2014) UK National Ecosystem Assessment Follow on. Work Package Report 5: Cultural ecosystem services and indicators. UNEP-WCMC, LWEC,UKEcotec (2010) Valuing the Welsh Historic Environment. http://cadw.gov.wales/docs/cadw/publications/ValuingWelshHistoricEnvironment_EN.pdf

Costanza, R., Kubiszewski, I., Giovannini, E., Lovins, H., McGlade, J., Pickett, K. E., Vala Ragnarsdóttir, K., Roberts, D., De Vogli, R. & Wilkinson, R. (2014) Time to leave GDP behind. Nature, 505.

Cranfield University (2015) The Soils Guide. Available: www.landis.org.uk. Cranfield University, UK. Last accessed 23/02/2015

Davy-Bowker, J., Murphy, J. F., Rutt, G. R., Steel, J. E. C. & Furse, M. T. (2005) The development and testing of a macroinvertebrate biotic index for detecting the impact of acidity on streams. Archiv für Hydrobiologie, 163, 383-403.

D'Costa, V. M., McGrann, K. M., Hughes, D. W. & Wright, G. D. (2006) Sampling the antibiotic resistome. Science, 311, 374-377.

Emmett, B., Reynolds, B., Chamberlain, P., Rowe, E., Spurgeon, D., Brittain, S., Frogbrook, Z., Hughes, S., Lawlor, A., Poskitt, J., Potter, E., Robinson, D., Scott, A., Wood, C. & Woods, C. (2010) Countryside Survey: Soils Report from 2007. pp. 192. Centre for Ecology and Hydrology, Wallingford, Oxon UK.

Emmett, B. et al. 2014. Glastir Monitoring & Evaluation Programme. Report to Welsh Government. Year 1.

European Commission. (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Communities*.

European Commission. (2000) Directive 2000/60/EC of the European Parliament and of the Council 23 October 2000: Establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities*.

Extence, C. A., Balbi, D. M. & Chadd, R. P. (1999) River flow indexing using British benthic macroinvertebrates: a framework for setting hydroecological objectives. Regulated Rivers- Research & Management, 15, 543-574.

Extence, C., Chadd, R., England, J., Dunbar, M., Wood, P. & Taylor, E. (2013) The assessment of fine sediment accumulation in rivers using macro-invertebrate community response. River Research and Applications, 29, 17-55.

Freshwater Habitats Trust (2015) A guide to monitoring the ecological quality of ponds using PSYM pp16. Available from http://www.freshwaterhabitats.org.uk/wordpress/wp-content/uploads/2013/09/ PSYM_MANUAL.pdf

Gregory, R. D., Voříšek, P., Noble, D. G., Van Strien, A., Klvaňová, A., Eaton, M., & Burfield, I. J. (2008). The generation and use of bird population indicators in Europe. *Bird Conservation International*, 18(S1), S223-S244.

Hayhow, D. B., Eaton, M. A., Bladwell, S., Etheridge, B., Ewing, S. R., Ruddock, M., & Stevenson, A. (2013). The status of the Hen Harrier, *Circus cyaneus*, in the UK and Isle of Man in 2010. *Bird Study*, 60: 446-458.

Hill, R. A., and Smith, G. M. (2005). Land cover heterogeneity in Great Britain as identified in Land Cover Map 2000. International Journal of Remote Sensing, 26(24), 5467–5473. doi:10.1080/01431160500259931

House of Commons C 243 (2014) House of Commons Environment, Food and Rural Affairs Committee, Food security, Second Report of Session 2014–15.

Holmes, N. T. H., Newman, J. R., Chadd, S., Rouen, K. J., Sharp, L. & Dawson, F. H. (1999) Mean Trophic Rank: A users' manual. R&D Technical Report No E38. Bristol: Environment Agency.

Ibañez, J. J., De-Albs, S., Bermúdez, F. & García-Álvarez, A. (1995) Pedodiversity: concepts and measures. Catena, 24, 215-232.

Ibáñez, J., Zinck, J. & Dazzi, C. (2013) Soil geography and diversity of the European biogeographical regions. Geoderma, 192, 142-153.

IUCN (2001) 2001 IUCN Red List Categories and Criteria version 3.1. http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria

Jackson, B., Pagella, T., Sinclair, F., Orellana, B., Henshaw, A., Reynolds, B., Mcintyre, N., Wheater, H. & Eycott, A. (2013) Polyscape: A GIS mapping framework providing efficient and spatially explicit landscape-scale valuation of multiple ecosystem services. Landscape and Urban Planning, 112, 74-88.

JNCC (2007) Second Report by the UK under Article 17 on the implementation of the Habitats Directive from January 2001 to December 2006. Peterborough: Joint Nature Conservation Committee. [Online] Available at: <http://www.jncc.gov.uk/article17> [Accessed 17.01.11].

Juggins, S. & Kelly, M.G. (2013). A WFD compatible approach to assess acidification using diatoms in UK and Irish rivers. Report – SC070034/TR2. Environment Agency, Bristol.

Kelly, M., Juggins, S., Guthrie, R., Pritchard, S., Jamieson, J., Rippey, B., Hirst, H. & Yallop, M. (2008) Assessment of ecological status in UK rivers using diatoms. Freshwater Biology, 53, 403-422.

Kelly, M. G. & Whitton, B. A. (1995) Trophic diatom index - a new index for monitoring eutrophication in rivers Journal of Applied Phycology, 7, 433-444.

LANDMAP (2015) Accessible from: http://www.ccw.gov.uk/landscape--wildlife/protecting-our-landscape/.aspx?lang=en

Latham, J., Miller, H., Mountford, E.P., Kirby, K.J. & Ioras, F. (2005) Country Report – United Kingdom. COST Action E27 –Protected Forest Areas in Europe – Analysis and Harmonisation

Latham, J., Frank, G., Fahy, O., Kirby, K., Miller, H. & Stiven, R (2005) PROFOR – Reports of Signatory States , pp 399– 413. BFW, Vienna.

Ling, L. L., Schneider, T., Peoples, A. J., Spoering, A. L., Engels, I., Conlon, B. P., Mueller, A., Schäberle, T. F., Hughes, D. E. & Epstein, S. (2015) A new antibiotic kills pathogens without detectable resistance. Nature, 517, 455-459.

Lomba et al. (2014) Mapping and monitoring High Nature Value farmlands: Challenges in European landscapes Journal of Environmental Management 143:140–150.

MacDonald,.A., Morris, A.J., Dodd, S., Johnstone, I., Beresford, A., Angell, R., Haysom, K., Langton, S., Tordoff, G., Brereton, T., Hobson, R., Shellswell, C., Hutchinson, N., Dines, T., Wilberforce, E.M., Parry, R., Matthews, V. (2012) Wales Agri-Environment Monitoring Lot 3: Species Monitoring. Final Report. Welsh Assembly Government Contract 183/2007/08 .Welsh Government.

Margalef, O. R. (1958) Information theory in ecology General Systematics 3, 36–71.

Maskell, LC.; Crowe, A; Dunbar, MJ.; Emmett, B; Henrys, P; Keith, AM.; Norton, LR.; Scholefield, P; Clark, DB.; Simpson, IC.; Smart, SM. (2013) Exploring the ecological constraints to multiple ecosystem service delivery and biodiversity. J Appl. Ecol. 50:561-571

Mason, W.L. (2007) Changes in the management of British forests between 1945 and 2000 and possible future trends. *Ibis*, 149, 41–52.

Medcalf K., Whittick E., Turton, N., Cross, D. 2012. Wales Agri-Environment Monitoring Lot 1: Habitats. Final Report. Welsh Government.

Meyer, J. L., Strayer, D. L., Wallace, J. B., Eggert, S. L., Helfman, G. S. & Leonard, N. E. (2007) The Contribution of Headwater Streams to Biodiversity in River Networks. Journal of the American Water Resources Association, 43**,** 86-103.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC. http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Minasny, B., McBratney, A. B. & Hartemink, A. E. (2010) Global pedodiversity, taxonomic distance, and the World Reference Base. Geoderma, 155, 132-139.

Morton, R. D. & Rowland C. S. Developing and Evaluating an Earth Observation-enabled ecological land cover time series system. *JNCC Report No* *

National Agricultural Emission (2013). NAEI Inventory of Greenhouse Gases (spreadsheet). From Rothamsted Research, North Wyke.

National Soil Resources Institute (2001), NSRI NATMAPVECTOR: LandIS, Cranfield University, Cranfield, UK.

Nicolet, P., Weatherby, A., Biggs, J., Williams, P. & Hatton-Ellis, T. (2007) A preliminary assessment of important areas for ponds (IAPs) in Wales. Report produced for CCW. Pond Conservation, Oxford. pp 86.

Nikitin, E., Skvortsova, E., Kochergin, A., Nikitina, O., Sabodina, E. & Myakokina, O. (2007) Integrated red data book of natural resources. Eurasian Soil Science, 40, 335-340.

Office for National Statistics (2013) Annual Mid-year Population Estimates, 2013 Release. Available from http://www.ons.gov.uk/ons/dcp171778_367167.pdf Accessed February 2015.

Oppermann, R., Beaufoy, G., Jones, G. (Eds.), 2012. High Nature Value Farming in Europe. 35 European Countries: Experiences and Perspectives. Verlag Regionalkultur, Ubstadt-Weiher, Germany, pp. 455.

Parkinson, C. (2011) Soil bacterium helps kill cancers. http://www.bbc.co.uk/news/health-14761417

Paracchini, M.L., Petersen, J.-E., Hoogeveen, Y., Bamps, C., Burfield, I., Van Swaay, C., 2008. High Nature Value Farmland in Europe e an Estimate of the Distribution Patterns on the Basis of Land

Pedroli, B., Van Doorn, A., De Blust, G., Paracchini, M.-L.,Wascher, D., Bunce, F., 2007. Europe's Living Landscapes. Essays on Exploring Our Identity in the Countryside. Landscape Europe/KNNV, pp. 432.

Pielou, E. C. (1966) Species diversity and pattern diversity in study of ecological succession. Journal of Theoretical Biology, 10, 370–383.

Pond Action [now Freshwater Habitats Trust] (2002) A guide to monitoring the ecological quality of ponds and canals using PSYM. Oxford Brookes University pp15. Available from http://www.freshwaterhabitats.org.uk/wordpress/wp-content/uploads/2013/09/NPMN_PSYM_MANUAL_July09.pdf

Quine, C., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A. and Valatin, G. (2011) Woodlands. *In*: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. & Snowdon, P.R. (eds) (2009) Combating climate change—a role for UK forests. The Stationery Office, Edinburgh.

Read, H.J. (2000) Veteran tree management handbook. English Nature, Peterborough.

Riley, S. J., DeGloria, S. D., Elliot, R (1999) A Terrain Ruggedness Index that Quantifies Topographic Heterogeneity. Intermountain Journal of Sciences, 5(1-4): 23-27

Reynolds, B., Chamberlain, P. M., Poskitt, J., Woods, C., Scott, W. A., Rowe, E. C., Robinson, D. A., Frogbrook, Z. L., Keith, A. M., Henrys, P. A., Black, H. I. J. & Emmett, B. A. (2013) Countryside Survey: National "Soil Change" 1978-2007 for Topsoils in Great Britain-Acidity, Carbon, and Total Nitrogen Status. Vadose Zone Journal, 12.

Reynolds, B., B.A. Emmett, T.R.E. Thompson, P.J. Loveland, S.C. Jarvis P. Haygarth, H.R. Thomas, D-H. Owen, R. Roberts, T. Marsden (2002). Critical Appraisal of State and Pressures and Controls on the Sustainable Use of Soils in Wales. Centre for Ecology and Hydrology report, CEH Project C01920, Environment Agency/ National Assembly for Wales Contract 11406. (http://www.ceh.ac.uk/sections/bef/wales_soil_scoping_study.html) Feb 25 2015

Richardson, J. S. & Danehy, R. J. (2007) A synthesis of the ecology of headwater streams and their riparian zones in temperate forests. Forest Science, 53, 131-147.

Roberts, M. (2015) Drugs in dirt: Scientists appeal for help. http://www.bbc.co.uk/news/health-30877343

Robinson, D. (2015) Moving toward data on soil change. Science, 347, 140.

Rodrigues, A. S., Pilgrim, J. D., Lamoreux, J. F., Hoffmann, M. & Brooks, T. M. (2006) The value of the IUCN Red List for conservation. Trends in Ecology & Evolution, 21, 71-76.

Rudeforth, C., Hartnup, R., Lea, J., Thompson, T. & Wright, P. (1984) Soils and their use in Wales. Soil Survey Bulletin.

Russell, S., Blackstock, T., Christie, M., Clarke, M., Davies, K., Duigan, C., Durance, I., Elliot, R., Evans, H., Falzon, C., Frost, P., Ginley, S., Hockley, N., Hourahane, S., Jones, B., Jones, L., Korn, J., Ogden, P., Pagella, S., Pagella, T., Pawson, B., Reynolds, B., Robinson, D., Sanderson, B., Sherry, J., Skates, J., Small, E., Spence, B., Thomas, C. . (2011) Status and Changes in the UK's Ecosystems and their services to society: Wales. *In*: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Saunders, D. L., Meeuwig, J. J. & Vincent, A. C. J. (2002) Freshwater Protected Areas: Strategies for Conservation. Conservation Biology, 16**,** 30-41.

Saura, Santiago, and Josep Torné. “Conefor Sensinode 2.2: A Software Package for Quantifying the Importance of Habitat Patches for Landscape Connectivity.” *Environmental Modelling & Software* 24, no. 1 (January 2009): 135–39. doi:10.1016/j.envsoft.2008.05.005.

Seneviratne, S. I., Luthi, D., Litschi, M. & Schar, C. (2006) Land-atmosphere coupling and climate change in Europe. Nature, 443, 205-209.

Smart, S.M.; Allen, D.; Murphy, J.; Carey, P.D.; Emmett, B.A.; Reynolds, B.; Simpson, I.C.; Evans, R.A.; Skates, J.; Scott, W.A.; Maskell, L.C.; Norton, L.R.; Rossall, M.J.; Wood, C. 2009 Countryside Survey:

Smart, SM, Henrys, P *et. al.* 2012. Clarity or confusion? – problems in attributing large-scale ecological changes to anthropogenic drivers. *Ecological Indicators* 20, 51-56.

Tebbs, E., J. & C.S. Rowland. 2014. A high resolution woody cover product for Great Britain: preliminary results. Proceedings of RSPSoc 2014 Annual Conference, 2 – 5 September 2014, Aberystwyth, UK.

Tipping, E. (2002) Cation binding by humic substances. Cambridge University Press.

Tóth, G., Jones, A., & Montanarella, L. (2013). The LUCAS topsoil database and derived information on the regional variability of cropland topsoil properties in the European Union. Environmental monitoring and assessment, 185(9), 7409-7425.

Towers, W., Bradley R.I., Mayr, T., Feeney, I. & Bruneau P.M.C. (2008). Nature conservation value of soils: bringing functionality into practice. Scottish Natural Heritage Commissioned Report No. 228 (Roame No F05AC101).

Towers, W., Malcolm, A. & Bruneau, P.M.C. (2005). Assessing the nature conservation value of soil and its relation with designated features. Scottish Natural Heritage Commissioned Report No. 111 (ROAME No. F03AC104).

United-Nations (2013) System of Environmental-Economic Accounting (SEEA). Experimental ecosystem accounting. https://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf.

United-Nations (2014) System of Environmental-Economic Accounting (SEEA). Central framework. https://unstats.un.org/unsd/envaccounting/White_cover.pdf.

Vaughan, I. P. & Ormerod, S. J. (2012) Large-scale, long-term trends in British river macroinvertebrates. Global Change Biology, 18, 2184-2194.

VisitBritain (2015) Inbound visitor statistics for Wales. Summarised by the Welsh Government and available from http://gov.wales/topics/tourism/researchmain/latest-stats/?lang=en Accessed February 2015.

Welsh Government (2013) - Historic Environment Strategy for Wales. www.cadw.gov.wales/docs/cadw/publications/Hist_Env_Strat_Wales_John_Griffiths_EN.pdf

Wales Landscape Partnership (2009) An agenda for Wales' Protected Landscapes.

WFD-UKTAG (2006) UK Environmental Standards and Conditions (Phase 1). SR1-2006. SEPA, Stirling UK.

WFD-UKTAG (2012) Acidification environmental standards. FTT017., SEPA, Stirling UK.

WFD-UKTAG (2014) River Assessment Method: Phosphorous. Phosphorous Standards. ISBN: 978-1-906934-54-5. SEPA, Stirling, UK.

Williams, P., Whitfield, M., Biggs, J., Bray, S., Fox, G., Nicolet, P. & Sear, D. (2004) Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. Biological Conservation, 115, 329-341.

Wright, J. F., Furse, M. & Armitage, P. (1993) RIVPACS - a technique for evaluating the biological quality of rivers in the UK. European Water Pollution Control, 3, 15-25.

World Reference Base (2006) World Reference Base for Soil Resources. World Soil Resources Report No 103. FAO Rome.

SEPTEMBER 2015

GLASTIR MONITORING & EVALUATION PROGRAMME

SECOND YEAR ANNUAL REPORT

APPENDICES

Prepared by CEH on behalf of the Glastir Monitoring & Evaluation Programme Team

Canolfan Ecoleg a Hydroleg
CYNGOR YMCHWIL YR AMGYLCHEDD NATURIOL

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

TABLE OF CONTENTS

Answers to some questions you might have

What is Glastir?
Glastir is a land management scheme aimed at improving water and soil management, maintaining and enhancing biodiversity, improving our climate, managing and protecting the historic Welsh landscape, creating new opportunities to improve access and increasing the area and management of woodlands.

What's the survey all about?
The Glastir Monitoring and Evaluation Programme (GMEP) uses a scientifically-rigorous approach to monitor and evaluate the impacts of Glastir. The evidence-gathering components of GMEP are split into two elements;

i) A targeted survey to identify impacts of specific Glastir measures within the advanced element of the scheme.
ii) A wider survey to identify ongoing changes to the countryside in Wales against which changes to land within the Glastir advanced element can be compared.

The information gathered during the survey will be used to assess the likely success of Glastir and inform the Welsh Government and public.

What will the survey teams be doing?
Specialist field teams will visit your landholding to collect data on i) freshwater quality and biodiversity; ii) pollinating invertebrates; iii) birds; and iv) habitats, landscapes and historic features and soils.

When will the survey teams arrive on my land?
The surveys are carried out between April and September 2014. We will contact you two weeks prior to the survey teams arriving to make final arrangements and discuss any other issues you might want the surveyors to know about. Your valuable contribution helps strengthen the survey and contributes to Wales providing global leadership in agricultural and environmental stewardship.

How was I selected?
No individual person was selected. Land eligible for Glastir advanced payments and land outside the advanced scheme were chosen at random and landowners contact details provided by Welsh Government. So you personally weren't selected, your land was.

What about privacy?
The Centre for Ecology & Hydrology is committed to the highest levels of data security and maintaining individual privacy. All information collected through the survey will be treated in the strictest confidence and will be used for statistical purposes only. Individuals or their landholdings are never identified when reporting the results of the survey.

Who can I contact about the survey?
If you have any questions or thoughts regarding the survey, please don't hesitate to contact the GMEP Survey Office on: **01248 374500** or email gmep@ceh.ac.uk

Atebion i rai cwestiynau yr hoffech efallai eu gofyn

Beth yw Glastir?
Cynllun rheoli tir yw Glastir a'r nod yw gwella rheolaeth dŵr a phridd, , cynnal a gwella bioamrywiaeth, gwella ein hinsawdd, rheoli a diogelu tirwedd hanesyddol Cymru, creu cyfleoedd newydd i wella mynediad a chynyddu ardal a rheolaeth coetiroedd.

Beth mae'r arolwg yn ei olgyu?
Mae Rhaglen Fonitro a Gwerthuso Glastir (RhFGG) yn defnyddio dull manwl wyddonol o fonitro a gwerthuso effeithiau Glastir. Mae cydrannau casglu tystiolaeth RhFGG wedi'u rhannu'n ddwy elfen;

i) Arolwg wedi'i dargedu er mwyn nodi effeithiau mesurau penodol Glastir o fewn elfen ddatblygedig y cynllun.
ii) Arolwg ehangach i nodi newidiadau parhaus i gefn gwlad yng Nghymru, yn erbyn yr hwn y gellir cymharu newidiadau i dir o fewn elfen ddatblygedig Glastir..

Bydd y wybodaeth a gesglir yn ystod yr arolwg yn cael ei ddefnyddio i asesu llwyddiant tebygol Glastir ac i ddarparu gwybodaeth i Lywodraeth Cymru ac i'r cyhoedd.

Beth fydd timau'r arolwg yn ei wneud?
Bydd timau maes arbenigol yn ymweld â'ch daliad tir i gasglu data ar i) ansawdd dŵr croyw a bioamrywiaeth; ii) infertebratau sy'n peillio; iii) adar; a iv) cynefinoedd, tirweddau a nodweddion hanesyddol a phriddoedd.

Pryd fydd y timau arolygu yn cyrraedd fy nhir?
Mae'r arolygon yn cael eu gwneud rhwng mis Ebrill a mis Medi 2014. Byddwn yn cysylltu â chi bythefnos cyn i'r timau arolwg gyrraedd i wneud trefniadau terfynol ac i drafod unrhyw faterion eraill yr hoffech chi efallai i'r syrfewyr gael gwybod amdanynt. Mae eich cyfraniad gwerthfawr yn help i gryfhau'r arolwg ac mae'n gymorth i Gymru ddarparu arweinyddiaeth fyd-eang mewn stiwardiaeth amaethyddol ac amgylcheddol.

Sut cefais i fy newis?
Ni chafodd unrhyw berson unigol ei ddewis. Cafodd tir sy'n gymwys am daliadau uwch Glastir a thir y tu allan i'r cynllun uwch eu dewis ar hap a Llywodraeth Cymru wnaeth ddarparu manylion cyswllt tirfeddianwyr . Felly, nid chi yn bersonol gafodd eich dewis , ond eich tir.

Beth am breifatrwydd?
Mae'r Ganolfan Ecoleg a Hydroleg wedi ymrwymo i'r lefelau uchaf o ddiogelwch data ac i sicrhau preifatrwydd unigol. Bydd yr holl wybodaeth a gesglir drwy'r arolwg yn cael ei drin yn gwbl gyfrinachol a chaiff ei defnyddio at ddibenion ystadegol yn unig. Ni fydd unigolion, na'u tirddaliadau yn cael eu nodi wrth adrodd canlyniadau'r arolwg.

Gyda phwy allaf i gysylltu ynglŷn â'r arolwg?
Os oes gennych unrhyw gwestiynau neu sylwadau ynglŷn â'r arolwg, mae croeso i chi gysylltu â Swyddfa Arolwg RhFG Glastir ar : 01248 374 500 neu e-bostiwc bpgmep@ceh.ac.uk

Centre for
Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Canolfan Ecoleg a Hydroleg/
Centre for Ecology & Hydrology
Canolfan yr Amgylchedd Cymru/
Environment Centre Wales
Ffordd Deiniol/Deiniol Road, Bangor
Gwynedd, LL57 2UW, United Kingdom

Ffôn/Tel: +44 (0) 1248 374500
Ffacs/Fax: +44 (0) 1248 362133
www.ceh.ac.uk

Ref no.

15th November 2013

Dear ,

Re : Glastir Monitoring and Evaluation Programme – Summer 2014

I am writing to let you know that the Centre for Ecology & Hydrology (CEH), on behalf of the Welsh Government, will be undertaking field surveys next summer as part of the Glastir Monitoring and Evaluation Programme (Glastir MEP).

The Glastir MEP will monitor and evaluate Glastir against broader baseline environmental information from across Wales, including those farms NOT participating in Glastir. The Glastir MEP is a partnership of 17 institutions who will evaluate the impact of the scheme and the wider Wales countryside on habitats, species, water, soils, climate, landscape, wider social benefits and economics.

Your land has been randomly identified for survey

We have randomly selected areas of land across Wales to assess the Welsh countryside and impacts of Glastir. This letter is to let you know that your land has been randomly identified for survey and we would like to visit your farm to carry out this work. If you are not a Glastir contract holder and have any reservations can you please contact me to discuss.

The survey we are conducting is not related in any way to compliance or the inspection process for Glastir, Single Payment Scheme, or any other scheme, and will not affect your payments.

The surveyors will be visiting your area during summer 2014. You are not required to accompany the surveyors. I or the survey team leader will contact you nearer the time to let you know details of our movements on the day, and registration of the vehicle. If you wish, the surveyors can meet you during the visit and explain what the survey involves. An overview of the survey is included with this letter.

Your personal data is protected by the Data Protection Act 1998. The information we gather through the survey will be the property of the Welsh Government and will be subject to the appropriate data security restrictions. Individual land owner's names and land holdings will not be identified in reporting. Data collected from the survey will be presented in summary form only (e.g. by region or habitat type).

We assure you that we will take great care of your land and property and follow strict bio-security measures required by Welsh Government when undertaking the survey. If there are other people who will need to know of our presence e.g. tenant farmers, gamekeepers, please could you let the surveyors know who to contact.

In any future correspondence I will use the password "*Jackdaw*" to confirm my identity.

Yours Sincerely,

A Owen

Anthea Owen,
Glastir MEP Farmer Liaison Officer

Canolfan
Ecoleg a Hydroleg
CYNGOR YMCHWIL YR AMGYLCHEDD NATURIOL

Canolfan Ecoleg a Hydroleg/
Centre for Ecology & Hydrology
Canolfan yr Amgylchedd Cymru/
Environment Centre Wales
Ffordd Deiniol/Deiniol Road, Bangor
Gwynedd, LL57 2UW, United Kingdom

Ffôn/Tel: +44 (0) 1248 374500
Ffacs/Fax: +44 (0) 1248 362133

www.ceh.ac.uk

Rhif cyf.

15ed Tachwedd 2013

Annwyl

Par : Rhaglen Fonitro a Gwerthuso Glastir – Haf 2014

Rwy'n ysgrifennu atoch i roi gwybod i chi fod y Ganolfan Ecoleg a Hydroleg (CEH), ar ran Llywodraeth Cymru, yn cynnal arolygon maes yn ystod yr haf nesaf fel rhan o 'Raglen Fonitro a Gwerthuso Glastir (RhFG Glastir).

Bydd RhFG Glastir yn monitro a gwerthuso Glastir yn erbyn gwybodaeth waelodlin amgylcheddol ehangach a gasglwyd ledled Cymru, gan gynnwys y ffermydd hynny sydd DDIM yn rhan o Glastir. Partneriaeth o 17 o sefydliadau yw RhFG Glastir a bydd yn gwerthuso effaith y cynllun a chefn gwlad ehangach Cymru ar gynefinoedd, rhywogaethau, dŵr, priddoedd, hinsawdd, tirwedd, buddiannau cymdeithasol ehangach ac economeg.

Mae eich tir wedi cael ei nodi ar hap ar gyfer cynnal arolwg

Rydym wedi dewis ar hap ardaloedd o dir ledled Cymru i asesu cefn gwlad Cymru ac effeithiau Glastir. Diben y llythyr hwn yw rhoi gwybod i chi bod eich tir wedi cael ei nodi ar hap i fod yn rhan o'r arolwg a byddem yn hoffi ymweld â'ch fferm i wneud y gwaith yma. Os nad oes gennych gontract Glastir a'ch bod yn bryderus ynglŷn â hyn a wnewch chi os gwelwch yn dda gysylltu â mi i drafod.

Nid oes cysylltiad o gwbl rhwng yr arolwg rydym ni yn ei wneud â chydymffurfio nac â phroses arolygu Glastir, y Cynllun Taliad Unigol nac unrhyw gynllun arall ac ni fydd yn effeithio ar eich taliadau.

Bydd y syrfewyr yn ymweld â'ch ardal yn ystod haf 2014. Nid oes angen i chi hebrwng y syrfewyr o gwmpas y tir. Byddaf i neu arweinydd tîm yr arolwg yn cysylltu â chi yn nes at yr amser i roi gwybod i chi beth fydd ein cynlluniau ar y diwrnod a rhif chofrestru ein cerbyd. Pe baech yn dymuno hynny, gall y syrfewyr gwrdd â chi yn ystod yr ymweliad i egluro beth fydd yn digwydd yn ystod yr arolwg. Mae trosolwg o'r arolwg wedi'i atodi gyda'r llythyr hwn.

Mae eich data personol yn cael ei ddiogelu gan Ddeddf Diogelu Data 1998. Eiddo Llywodraeth Cymru fydd y wybodaeth y byddwn yn ei gasglu yn ystod yr arolwg a bydd yn atebol i'r cyfyngiadau diogelwch data perthnasol. Ni fydd perchenogion tir unigol yn cael eu henwi na manylion daliadau tir yn cael eu datgelu yn yr adroddiad. Bydd data a gasglwyd yn ystod yr arolwg yn cael ei gyflwyno ar ffurf crynodeb yn unig (e.e. yn ôl rhanbarth neu'r math o gynefin).

Rydym yn eich sicrhau y byddwn yn cymryd pob gofal o'ch tir a'ch eiddo a byddwn yn dilyn y mesurau bio-ddiogelwch llym sy'n ofynnol gan Lywodraeth Cymru wrth gynnal yr arolwg. Os oes yna bobl eraill sydd angen gwybod am ein presenoldeb e.e. tenantiaid fferm neu giperiaid, buasem yn ddiolchgar petaech yn gadael i'r syrfewyr wybod â phwy y dylent gysylltu.

Er mwyn i chi wybod mai fi sy'n cysylltu â chi, byddaf yn defnyddio'r cyfrinair 'Jac Do' mewn unrhyw ohebiaeth yn y dyfodol.

Yr eiddoch yn gywir,

A Owen

Anthea Owen
Swyddog Cyswllt Ffermwyr RhFG Glastir

GLASTIR
QUALITY ASSURANCE EXERCISE

FIRST DRAFT (2/12/2104)

Hilary Wallace and Mike Prosser
Ecological Surveys (Bangor)

The School House, Canon Pyon, Herefordshire, HR4 8PF.
MikeHilary@ecosurvey.demon.co.uk

Report to Centre of Ecology and Hydrology, Lancaster.

GLASTIR: QUALITY ASSURANCE EXERCISE

SUMMARY

Introduction

It is recognised that all field investigation involving a large number of surveyors must produce an inherent degree of variation despite the provision of a training course, a field handbook and on-site visits by supervisors (Quality Control). It is therefore important to attempt a measure of the consistency and reliability of the work done within the major components of the field programme (Quality Assurance). This report addresses the quality of the botanical recording across the various plots types surveyed during the 2014 Glastir field season.

A sample comprising 6 squares surveyed in 2014 was selected and in each of these one quarter was selected for re-surveyed. Within each quarter 2 examples of each plot type were selected; where 2 plots were not available the survey extended to the next quarter of the square. The re-survey involved the recording of 67 plots.

Species-richness

A basic measure of the standard of botanical recording is given by comparing the mean number of species per plot recorded by the surveyors compared with that found by the assessors. The values across all plots for Glastir 2014 are Surveyors 20.0 species/plot, QA assessors 22.0 species/plot. This is an improvement from CS 20007 when the equivalent values were surveyors 17.5 species/plot and assessors 21.7 species/plot.

Mis-matches in the species record.

Mis-matches have been apportioned into a series of categories which reflect the nature of individual non-concordances.

Variation at time of survey (T1 variations)

- Mis-identification
- Species present but overlooked
- Over-zealous recording
- Mysteries including tablet errors
- Location/orientation errors.

Variations at time of QA (T2 variations)

- Management changes
- Seasonal changes
- Orientation errors
- Species present but overlooked

Of these, by far the greatest source of error was the over looking of species by the surveyors (53.0% of all mis-matches). Management changes, seasonal changes and over-zealous recording make only very modest contributions to the total non-concordance. The mis-identification of species (at 7.1% of errors) is very similar to that found in previous CS surveys.

Recording of plot types.

The different plot types have been recorded more consistently than in previous surveys, falling within a range of 87.3% of species recorded in the QA appearing in the surveyors record for Hedge plots to 95.5% for the U plots. The value for the U plots is misleading since there were only six plots compared to the 19 of CS 2007 when the corresponding

value was only 74.1%; for Glastir 2014 three of the U plots were in a square that was exceptionally well surveyed.

Percentage accuracy of survey.

Percentage accuracy (common species/cumulative species list from T1 plus T2 species - T2 errors) shows an improvement on CS2007 of 66.8% compared to 62.2% though the range across the six squares is considerable, ranging from 75.2% for square 12334 to only 58.6% for square 41349.

Recommendations.

- Introduce sighting compasses.
- Always make clear whether a tape or range finder has been used
- Keep sketches simple
- Carry out a pre-survey trial to test the efficiency of the Trimble for plot relocation
- More practice is grass ID during training courses
- Emphasise the importance of photograph and necessity of indicating position of photograph on sketch
- Better instruction in individual plot location protocols - return to CS survey where much emphasis was placed on the positioning of individual plots relative to the X plot. In particular relative position of Hedge to Boundary and Diversity to Hedge.
- Cover a wider range of landscape types in future QA exercises

INTRODUCTION

1 It was recognised during the Countryside surveys of 1990, 1998 and 2007 that field investigations involving large numbers of recorders and surveyors must produce an inherent degree of variation despite the provision of a training course, a field handbook and on-site visits by supervisors (Quality Control). It is therefore important to attempt a measure of the consistency and reliability of the work done within the major components of the field programme (Quality Assurance).

2 The current exercise is confined to an examination of the botanical recording of vegetation plots during the 2014 Glastir survey and follows the same methodology as that developed for the quality assurance (QA) exercises conducted during the 1990, 1998 and 2007 Countryside Surveys. The efficiency of the mapping component of Glastir was tested in a separate exercise.

3 Six of the 90 squares surveyed during the 2014 field season was selected for QA, comprising two from each of the three regions. In each of these one quarter of the 1km square was targeted. As far as possible two examples of each plot type were included in the QA programme for each square though the scarcity of U plots and A (arable) plots resulted in these being under-represented in the total.

4 In addition to the need for a measure of the dependability of the botanical recording during the current Glastir survey it was felt desirable to make some comparison between the Glastir QA exercise and those of the CS exercises.

5 In total 67 plots were recorded across the eight plot types. Seven of these plot types were also recorded during the CS surveys; however road verges were not recorded during Glastir but P-plots were introduced; a 10m linear plot running perpendicular from the stream (S or W) into the adjacent land parcel.

6 During the 2007 Countryside Survey a number of parameters were considered in order to assess the efficiency of botanical recording and most of these have been measured during the Glastir exercise, albeit with a much smaller sample size. The principal factors include the efficiency of plot location (relocation errors on the part of the surveyors are not covered in the current exercise since all squares were surveyed for the first time in 2014), measures of species-richness and reasons for discrepancies in the total species record. Measures of species' frequency and cover are not addressed here due to the small sample size. Finally, an assessment is made of the likely consequences of these variations on assessments of vegetation change.

METHODS.

Plot selection

7 The protocol for the selection of the quarter of the square to be used in the QA exercise was as follows:

The quarter should ideally include examples of all the different plot types
It should be relatively easily accessible
It should have few land owners.

The map of plots recorded was initially studied for the SE quarter of the square: if this area met the criteria it was selected for QA, if not, attention shifted to the SW quarter, then NW and finally NE until the most appropriate quarter had been established.

8 The full list of squares monitored, with times of original survey and assessment resurvey, is given as Annex A.

9 The eight plot types used in the survey and re-examined as part of the QA exercise may be sub-divided into quadrats and linear plots:

Quadrats:

$200m^2$	X plots	Random points
$4m^2$	Y plots	Targeted habitats
$4m^2$	U plots	unenclosed (BAP) broad habitats.

Linear plots, all 10m x 1m, which comprise:

H: Hedges, running parallel with the hedge line and commencing at the mid-point of the hedge. Simple 50m hedgerow diversity plots, introduced in 1998, were also included in the QA exercise but data are not presented here.

S: Streamsides, from normal water level or at the lower limit of vegetation cover in the case of water courses with extensive gravel or pebble beds etc. Additional plots on larger water ways are designated W and are amalgamated with the S plots in the analyses.

P: Perpendicular streamside plots, upslope habitats adjacent to and centred on the S/W plots. A new plot type introduced as part of the Glastir monitoring program.

B: Boundaries, in enclosed land only; recorded at the boundary marker (GPS) point associated with the $200m^2$ X plot.

A: Arable. 100m x 1m arable field margin plots. Recently introduced to CS, only a single sample was recorded during the Glastir QA exercise.

Field survey

Plate and plot relocation

10 No metal plates were used during the Glastir botanical survey, instead an accurate dGPS was used to fixed the corner/end of plot previously marked with a metal plate. Since the dGPS was not available during the QA exercise the accuracy of relocation using this device has not been tested. The Glastir QA exercise therefore relied entirely on the sketch maps and photographs for plot relocation. In unenclosed areas the internal GPS of the Getac was often used to get within 2-3m of the plot with final positioning relying on sketches and photos.

The species record

11 The same basic methodology for recording the species complement of the plots was adopted as that used for the CS QA exercises. Plots were recorded using a standardised data sheet, all species of vascular plant and allowed cryptogams were listed and then assigned cover values using 5% cover bands. The plots were first recorded 'blind' (without reference to the surveyors data) and then compared with the surveyors record. Discrepancies between the two species lists were initially identified in the field and reasons sought for the non-concordant records.

DATA PRESENTATION

12 *Plot location.* A summary of the plot relocation rates for all QA exercises is presented (Annex B).

13 *Species richness*. The simplest comparison between the Surveyors and QA species records involves assessment of species number/plot. ANOVA and Tukey Pairwise comparisons are used to test for significant differences between Surveyors and QA assessors. Results are also compared against those of the CS surveys (1990, 1998 and 2007).

14 *Mis-matches in the species record*. Although a basic comparison for each plot can be made between the results of the initial survey and the subsequent QA record, it is more instructive to compare the species lists critically and to apportion the mis-matches into a series of categories which reflect the nature of individual non-concordances. Ten such categories were established during the CS exercise and these have been adopted for Glastir with a few minor modifications. These data are used to arrive at values for the actual efficiency of the surveyors recording both by plot and by square.

15 **T1 variations.** Species recorded by Glastir Surveyors but not confirmed for the plot by the Assessors (QA) or species present in the QA assessors plot but omitted from the Surveyors plots. Some categories recognised in the CS1990 QA assessment were amalgamated for the 1998 and 2007 assessments and this protocol has been adopted for the Glastir exercise.

***A:** mis-identifications.* Three forms of non-concordance are amalgamated under this heading.

i. Species incorrectly identified and forming a couplet with the, hopefully, correctly identified species recorded at QA; *Rumex crispus (*Surveyor) *versus Rumex sanguineus* (QA) being a common example.

ii. Species not apparently forming a couplet with any species recorded during the QA exercise e.g. where both *Ranunculus repens* and *R.bulbosus* appear in the T1 record but only one of these species was found at T2.

iii. Apparent inputting errors: in previous surveys it was not unusual for a surveyor to tick the wrong box on the data sheet thus allocating a record to an adjacent species. *Primula vulgaris-Prunella vulgaris* and *Ranunculus flammula-Ranunculus ficaria* were the most frequently encountered examples. An analogous error seems to occur with the use of the Tablet.

***B:** Species considered to have been overlooked during the initial recording*

In contrast to CS all the plots recorded in Glastir 2014 were 'new' plots and thus no errors can be associated with incorrect relocation of plots by the surveyors.

In some instances it was clear that a plot was not placed in accordance to the guidelines, but was none the less relocatable during the QA exercise. In these cases the plot was recorded and its incorrect positioning just noted for guidance to future surveyors. Where QA relocation/orientation was uncertain and it was apparent that the original and QA plots only partially overlapped, a search was made of the extended area missed by the QA assessor for species recorded at T1 and these are assigned to J rather than B errors.

C:** Over-zealous recording.** During the QA exercise particular care was taken to restrict recording to the exact plot size stipulated. The surveyors had, in some instances, not adequately measured the plot or had included species adjacent to but not strictly within the defined area. Such errors were most prevalent with stream plots where an inflated distance from water level was sometimes used and hedge plots where the recording area extended too far into the adjacent sward.

***D:** Mysteries*. Species records, apparently incorrect, for which no reasonable explanation could be advanced. Some of these are likely to be ‘tablet’ errors where a ghost record of a most improbable record may occur. A possible source of this error is where a common species is selected to get into the drop down list and then the wrong species is selected; e.g. *Trifolium repens* registered rather than *Triglochin palustre*. These errors are not always easy to spot and quantify.

J:** Location / orientation errors.** In previous QA exercises distinctions were made between non-concordances due to the incorrect orientation of a plot which was otherwise adequately located and mis-matches in the records due to the surveyors either being in the wrong place e.g. a B plot starting from the wrong whitebeam, or recording in the wrong direction e.g. going the wrong way from a plate. A further distinction was made between species recorded that should not have been and species missed as a result of incorrect position. These causes of mis-matches with the QA have been amalgamated into a single T1 location error.

16 **T2 Variations.** Species not recorded by the QA assessors but recorded by the Glastir surveyors or, *vice versa*, where the species concerned was most probably part of the T1 ‘real’ plot record.

***E:** Species mis-matches due to management changes in plots between Glastir survey and QA assessment.* These involve changes in crop type, changes in species recorded due to crop management, hay cutting etc. They represent species which were very probably present when the Surveyors recorded the plot but which were no longer evident at the time of the QA. Conversely, regrowth of species by the time of the QA assessment in plots which had been recently mown at time of the original survey.

F: *Species mis-matches due to seasonal changes between Survey and QA assessment.*

These non-concordances often represent vernal species which were not identifiable late in the season when the QA was undertaken. For the Glastir QA most plots were re-visited within 3 weeks of initial survey and hence 'F' errors should be low.

G/H mis-matches: *Orientation errors.* In early QA work a distinction was made between non-concordances due to misalignment of the position of the plot by the assessors and misorientation of a plot. These have been amalgamated. For CS surveys recourse to previous plot records was often helpful in recognising these errors of positioning on the part of the assessors; no such historic records exist in Glastir and so these errors may be greater.

I: *Species missed by the QA assessors*. Species which were in the plot but only recorded when the plot was searched a second time during the comparison of the initial QA record with the Surveyors record.

17 **Other variations.**

K: *Species mis-match due to location problems.*

Mismatches due to uncertainty of whether the Surveyor or QA assessor is in the wrong place. This was used in assessing change over time in CS; since all the Glastir plots are first time records this error has not been used in 2014.

18 **Summary of recorder errors.**

19 *Percentage Agreement*. A crude but objective means of comparing two species lists. Percentage Agreement = Species common to both samples/Aggregated species list from both samples expressed as a percentage. % Agreement is presented for each plot in each square (Annex B, see excel file Glastir_QA14.xls).

20 *Percentage Efficiency*. This is a measure of the surveyors' accuracy and is calculated having removed discrepancies which can be attributed to the QA assessor, usually relating to changes in species present due to seasonal effects, management or location errors.

RESULTS

21 Annex A presents a summary of the squares surveyed during the QA exercise with dates of initial survey and QA assessment. Annex B provides a summary of the allocation of species mis-matches.

Plot relocation.

22 One of the specific objectives of the QA exercise was to assess the efficiency of plot location prior to recording. Using a combination of the sketch maps and, crucially, the original photographs, the assessors failed adequately to locate (within 2m) 11 of the 68 plots: a percentage recovery of 83.8%. This recovery rate is remarkably similar to previous QA exercises CS1990 (87.1%), CS1998 QA (86.7%) and CS2007 QA (86.5%). This is a clear demonstration of the effectiveness of the sketches and photos approach to the re-finding of plots.

The species record

Species richness.

23 Across the 67 plots assessed the Surveyors recorded, on average, fewer species per plot than the QA assessors. The sample size for each individual plot type was small, and significant differences were only noted for the B, S and Y plots.

24 The expression of the Glastir surveyor's species richness value as a percentage of the QA assessor's value provides a simple means of comparing the efficiency of recording of the different plot types. The overall value of 90.9% compares favourably with the previous CS QA exercises of CS1998 (87.7%) and CS2007 (80.71%). The Glastir range is small (between 87.3 for the H plots and 95.5% for the P plot), and thus shows a similar level of consistency across the plot types to the 1998 survey (82.4-90.2). In CS2007 variation was greater, most plot types fell below 80% with a range of 74.1% to 95.8%.

25

Table 1a.Comparison of species number per plot recorded by the Glastir 2014 Surveyors (Glastir) and the 2014 Quality Assurance assessment (QA). Values are mean species/plot; *p* values are for paired t-test. The final column expresses the Surveyor surveyors' records as a percentage of the QA assessors.

Plot type	Number of samples	Surveyors	QA	Paired t-test	Surveyor % of QA
All plots	67	20.00	22.00	<0.001	90.9
X	12	22.08	23.75	0.222	93.0
Y	9	13.88	15.33	0.044	90.5
H	9	18.33	21.00	0.057	87.3
P	10	21.5	22.5	0.148	95.5
B	10	19.30	21.90	0.040	88.1
U	6	21.5	22.5	0.148	95.5
S	10	27.6	31.0	0.027	89.0

Table 1b.Comparison of species number per plot recorded by the CS 2007 surveyors (CS2007) and the 2007 Quality Assurance assessment (QA 2007). Values are mean species/plot; *p* values are for paired t-test. The final column expresses the CS 2007 surveyors' records as a percentage of the QA assessors.

Plot type	Number of samples	CS 2007	QA 2007	Paired t-test	CS 2007 % of QA
All plots	266	17.49	21.67	<0.001	80.71
X	51	19.82	24.57	<0.001	80.67
Y	44	12.23	15.82	<0.001	77.31
H	26	18.04	19.19	0.257	94.01
R	39	20.59	25.90	<0.001	79.50
B	43	16.86	21.37	<0.001	78.90
U	19	12.84	17.32	<0.001	74.13
A	7	19.71	20.57	0.861	95.82
S	37	19.60	24.73	<0.001	79.26

26 In common with the results from the Countryside Surveys and their QA programmes, the mean species per plot recorded by the assessors was greater than that for the same plots at the time of the initial survey. The impression gained in the field in the Glastir QA was that grasses had been more poorly recorded than in previous surveys but that recording of allowable bryophytes and lichens present was possibly better than in CS 2007. Table 2 presents values for the under-recording of species (as a percentage of the QA record) when partitioned into species groups. Data presented are the total records for each taxonomic group. Overall, the percentage recorded by Surveyors has dropped compared to the CS2007 (80.7%) suggesting a generally poor search image. Grasses were better recorded in CS2007 (85.3%) but the Glastir recording of cryptograms (67.5%) has improved considerably in comparison to the CS2007 value of only 40.2%.

Table 2. Effectiveness of recording by species group.

Species group	Glastir Records	QA Record	Percentage recorded by surveyors
All species	1339	1747	76.7
Cryptograms	156	231	67.5
Grasses	370	470	78.7
Others	813	1046	77.7

Allocation of sources of error in the species record

27 Table 3 presents a summary of the allocation of the mis-matched species records as a proportion of the total mis-matches. For example, there were 1353 records of species

having been over-looked by the CS surveyors, this equates to 48.9% of the total errors. Annex B presents the attribution of mis-matches to each of the 10 categories used for each plot recorded together with the values for % accuracy by plot.

28 Table 4 presents a summary of the equivalent values for the CS QA exercises.

Table 3. Allocation of sources of error in the species record for the Glastir Survey. Total errors = 613 mis-matched species records. These can be apportioned between errors arising from the 2014 surveyors (T1 errors) and those occurring during the QA exercise (T2 errors).

T1 MIS-MATCHES

Category	Description	Number of records	% of total
A	Species mis-identified	43	7.1
B	Species overlooked	325	53.0
C	Over-zealous recording	17	2.8
D	Mysteries	66	10.8
J	Plot mis-alignment/orientation	12	1.9

T2 MIS-MATCHES

E	Species change due to management	4	0.6
F	Seasonal changes	17	2.8
G/H	T2 Location/orientation uncertain	62	10.1
I	Overlooked by the assessor	67	10.9

UNCERTAIN LOCATION ERRORS

K	Location problems: unclear if Surveyor or QA in wrong place	0	0

Table 4. Allocation of mis-matched records: Summary comparison CS 1990, 1998 and 2007 CS surveys.

Type	% total error 1990	% total error 1998	% total error 2007	% total error Glastir 2014
Surveyor mis-matches				
A	6.3	8.5	7.8	7.1
B	34.5	39.8	48.9	53.0
C	5.8	1.9	1.9	2.8
D	2.8	4.6	5.2	10.8
J	3.7	19.9	14.5	1.9
QA mis-matches				
E	3.4	2.0	1.6	0.6
F	20.8	3.7	5.0	2.8
G/H	17.7	9.2	5.2	10.1
I	5.0	10.4	4.2	10.9
Uncertain location errors			5.6	0.0

29 The percentage of mis-identified, overlooked or over zealous records are very similar to the CS 2007 results. However, the percentage of mysteries has more than doubled, many of these are likely to be tablet errors; a good example being the lack of *Hypnum jutlandicum* whilst random records for species that were not apparently present were also common. The lack of metal plates for confirmation of accurate plot relocation has resulted in a rise in T2 errors due to uncertain relocation of plots. The lack of sighting compasses for the Surveyors often resulted in impossible triangulation for the QA assessor resulting in both location and orientation errors between the Surveyor and Assessor. The rise in species overlooked by the assessor can, in part, be attributed to the QA exercise being carried out by a single assessor. Also, the proportion of lowland relative to upland squares in which species turnover tends to be higher.

30 An alternative approach is to express the mis-matches as a proportion of the total species record: in this case the combined Surveyor and QA species record is 1747. This is the crudest form of comparison, and gives an overall % agreement based on the total species record. The cumulative T1 error of 26.4% equates to a % agreement of 73.6%. The comparable CS figures were 79.3% (CS1990), 73.1% (CS1998) and 65.6% (CS 2007).

Tablet errors.

31 An attempt had been made in 2007 to assess the likely increase in recorder error introduced through the use of the computer tablet. During that QA exercise a number of plots were recorded simultaneously on the tablet and as paper copy by the pair of QA assessors. Since the Glastir QA was conducted by a single assessor this was not possible; however plots were entered onto the tablet either during field survey or subsequently in the office. Comparisons of the species record, and cover values, could be used to give some insight into the likely errors arising from tablet use.

32 Surveyor tablet errors are harder to assess as there is no paper trail to follow. A few plots appeared to have a large number of ghost records (assigned D errors), these may counter balance 'B' errors where a wrong species has been ticked. If a species present at T1 has been mis-recorded due to the tablet picking the wrong species e.g. *Molinia caerulea* recorded when the original species was *Montia fontana*, then *Montia* will be classed as overlooked whilst *Molinia* becomes a 'Mystery' when the QA assessor visits the plot. Similar errors were noted for *Ranunculus ficaria* versus *Ranunculus flammula, Trifolium repens* versus *Tripleurospermum, Trifolium repens* versus *Triglochin palustre*. At least 7 instances of this type were noted. The omission of *Hypnum jutlandicum* from the tablet records has hopefully been resolved.

33 The use of the computer tablet has introduced an additional dimension to the recording which is akin to the ‘wrong’ box ‘mis-identification’ error of the 1990 QA exercise. Wrong entries on the tablet may also account for some of the unknowns where the wrong species is selected from the drop-down extended species list. Whether the increases in overlooked species can in any way be attributed to the use of the tablet is less clear; it is possible that in trying to add extra species from the drop down menu a previously recorded species has been over-written, also the time taken to find species might have resulted in the next called species being missed; however, on balance it would seem that the greater reason for an increase in overlooked species is the failure of the recorder to recognise species that are present.

Percentage Agreement

34 This is the crudest, and simplest, measure of the level of agreement between two independently collected species lists. The number of species common to both lists is divided by the aggregate of all species recorded at time one (T1) and at time two (T2) and then expressed as a percentage (Annex B).

35 Percentage agreement = Common species / cumulative species list from T1 and T2 * 100.

Percentage accuracy

36 A number of species mis-matches will have resulted from the time elapsed between the surveyors recording and the QA assessment; these arise from management activities (crop harvesting, herbicide treatment, silage/hay cutting, hedge and verge cutting) and seasonal changes (die-back of early spring flowers e.g. *Arum maculatum, Ranunculus ficaria).* In addition, there will be instances of the QA plot being slightly mis-placed, and of the QA assessor overlooking species that are present. If these mis-matches are removed from the calculation then a new value of efficiency of initial recording is arrived at (Annex B).

37 Percentage accuracy = Common species / cumulative species list from T1 plus (T2 species minus T2 errors) * 100

38 In 2007 it was apparent that the recording of species on the list of common cryptogams (mosses, liverworts and lichens) was very inconsistent and was often depressing both the species richness and the number of ‘common’ species records, especially in the upland plots. In order to assess the impact of poor cryptogram recording on the overall species record the Percentage accuracy index has been recalculated for all plots omitting all cryptogam records (Annex B).

39 In CS it was clear that recording of cryptogams had a marked impact on the accuracy of the upland squares where bryophytes are often a major component of the vegetation whilst in the lowland squares, where bryophytes are less prominent, the increase in accuracy has been only modest. The Glastir QA exercise only covered 6 squares, of which only 1 was unenclosed upland, hence broader landclass comparisons are not possible. Perhaps at the end of the first phase of survey there will be a sufficiently large data set of QA squares to make these comparisons.

40 Annex B presents a summary of the % agreement and % accuracy for each of the 6 squares in the QA exercise.

41 A summary of these data by plot type forms Table 6. Only a single Arable and arable margin plot were recorded and this was misplaced by the Surveyors within the crop rather than within the cultivated margin. It might be expected that accuracy in the small ($4m^2$) U and Y plots would be depressed in comparison with the linear plots but this has not proved the case. For the U plots this may be largely explained by the relative homogeneity of the upland vegetation in which these are concentrated: a failure to precisely relocate the plot is likely to have a much lesser effect than for other plot types.

42 Percentage accuracy is slightly higher compared to the CS2007. Across all plot types the Glastir value was 66.8% compared to 62.2% for CS2000. Eliminating cryptogram species has made little difference to the Glastir results, rising to just 68.2% compared to 66.8% for CS2000. The greater efficiency is most apparent in the recording of boundary plots, only the small 'U' plots demonstrate a slight drop in efficiency of recording.

Table 6a. Summary of agreement by plot type.

CS2007 values for accuracy (excluding cryptogram) included for comparison.

Plot type	Number	% Agreement	% Accuracy	% Accuracy (-cryptogams)	CS2007 Accuracy (-crypto)
All	67	60.69	66.5	68.2	66.83
X	12	57.8	65.0	69.1	66.25
B	10	64.3	71.3	71.7	63.23
Y	9	56.2	64.1	66.4	64.27
H	9	62.9	66.1	68.4	67.74
U	6	59.3	66.8	68.1	76.91
S/W	10	62.6	66.0	67.0	69.44
P	10	62.3	68.1	68.9	

Table 6b. Summary of Glastir agreement by plot size. X ($200m^2$ plots), linear (10m x 1m plots, H, B, S, P) and small ($4m^2$ plots, U + Y)

Plot type	Number	% Agreement	% Accuracy	% Accuracy (-cryptogams)
All	67	60.6	66.5	68.2
X	12	57.8	65.0	69.1
Linear	38	62.7	67.5	68.4
Small	15	57.5	65.2	67.1

DISCUSSION.

GENERAL: RETAINED FROM CS2007 REPORT.

43 Problems associated with variations in accuracy rates in vegetation recording have long been appreciated, especially in the identification of grassland species (Ellison 1942; Hope-Simpson 1940; Smith 1944) but also in mire (Clymo 1980) and forest situations (Hall & Okali 1978).

44 Many long-term plot-based monitoring programmes rely on teams of surveyors, often with new teams being recruited for each repeat survey. This inevitably introduces variation in the data set, within and between years, due to differences in the surveyors' accuracy of species recording (Kirby *et al*. 1986; Prosser & Wallace 1992; Scott & Hallam 2002) and in their assessment of species cover (Kercher *et al.* 2003; Klimes 2003; Sykes *et al.* 1983) over and above genuine vegetation change.

45 Studies have used various measures to assess the level of mis-match between teams of surveyors. Within and between team sampling errors have been assessed using pseudo-turnover (Leps & Hadincova 1992; Nilsson & Nilsson 1985) which estimates the magnitude of species turnover due to recorder error above any natural change in species lists. It is based on the non-concordance of species in two lists collected in the same area at two different times, or by two different surveyors at the same time, expressed as a proportion of the total number of species recorded at each time. Nilsson & Nilsson (1985) found an average between-team pseudo-turnover of 13% for species lists from stands on small islands. Leps & Hadincova (1992) also report a turnover of 13% for two experienced observers recording 40 releves in 5m x 5m plots. A similar value (16%) can be calculated from the data of Hope-Simpson (1940) for chalk grassland plots. A rather higher value of 22% was found in small plots within a wide range of habitat types by Scott and Hallam (2002).

46 Other workers have approached the problem by considering the level of agreement between two lists; the number of common species is expressed as a percentage of the cumulative species list from the two records; reported values include a value of 83% for chalk grassland (Hope-Simpson 1940), a range of 32 to 80% for woodland (Kirby *et al.* 1986) and an average of 57% over a range of habitats (Scott & Hallam 2002). Prosser and Wallace (1992), as part of pre-CS1990 trial, reported average percentage agreements of 56% when two surveys were undertaken by different recorders, compared to 62% when the same recorders were used for both studies.

47 Where causes for differences in the lists are considered it seems that misidentification is relatively uncommon but the inability of surveyors to identify young plants and hence their omission from the record is probably often underestimated (Klimes, *et.al.* 2001). Similarly, surveyors with more field experience tend to overlook (omit) fewer species; the importance of training is emphasized (Smith 1944) as is care in the choice of surveyors (Oredsson 2000); Nilsson (1992) proposes that all vegetation analyses be based on teams of two investigators rather than a single recorder. Individual surveyors can thus have very different levels of survey accuracy; this may pose serious limitations in the use of such data sets for the assessment of changes in species diversity over time (Rich & Woodruff 1992; West & Hatton 1990).

48 The accuracy of plot relocation will also affect measures of species and community turnover (Prosser & Wallace 1992; West & Hatton 1990) and in this respect many authors have stressed the value of permanent quadrats (Bakker *et al.* 1996; Dodd *et al*.

1995; Herben 1996; Hill & Radford 1986). Klimes *et.al.* (2001) found a greater lack of concordance in smaller plots compared to larger quadrats.

SPECIFIC TO GLASTIR QA EXERCISE.

49 When mis-matches are expressed as a proportion of the total species record, the Glastir overall % agreement of 73.6%, based on the total species record of 1747, is comparable to the 1998 and 1990 QA exercises (73.1% and 79.3%) and higher than the CS2007 value of 65.6%. The range of % agreement values obtained on a plot by plot basis is similar to those from the previous QA exercises. The better recording of cryptogams in 2014 has probably assisted in the agreement scores for bryophyte-rich habitats.

50 Average % agreement values for individual squares (55.5% to 68.5%) are similar to previous QA exercises. Values were highest for the Boundary plots and lowest for the X plots. Some squares seem to produce consistently low scores (41349) whilst others were consistently good (12334).

51 The main factors affecting % agreement in Glastir were the overlooking of species and the appearance of seemingly random species records. The level of overlooked species was similar to CS2007 and higher than previous surveys, and may be attributable to the ever increasing number of tasks asked of the surveyors. This not only puts pressure on the time spent recording each plot once it is set up but often results in plots not always being searched by a pair of surveyors; or only partially surveyed by the pair such that species are missed. The increase in 'mystery' records seems best attributed to use of the tablets, but it is not possible to quantify. Since all plots were 'new' it is not surprising that location/orientation errors were low for the Surveyors.

52 % accuracy, taking account of mis-matches arising from the QA assessor, was very similar to CS2007. The main difference between the two surveys was in the accuracy of recording bryophytes. In 2007 removal of bryophytes from the species record substantially increased the % accuracy of the upland squares from 59% to 71%. In the lowland grassland and marginal upland land classes the differences were much less. In the Glastir survey there was little increase in % agreement through removal of bryophytes (66.8% to 68.2%) partly reflecting the generally lowland nature of most of the QA squares.

RECOMMENDATIONS.

53 *Plot relocation.* Many of the issues relating to plot relocation resulted from inaccurate measurements and compass bearings such that many plots were only approximately relocated and orientated. It was not always clear if a tape or range finder had been used. For accurate plot relocation over a distance of <50m there should be a presumption of using a tape. The lack of sighting compasses resulted in impossible triangulation issues. It is recommended that sighting compasses be provided to each team and also that the technique of lining up series of distance objects be considered where plots are >50m from a boundary or any other feature. When using the compass always stick to recording magnetic north, rather than making corrections which are often inaccurate. Some sketches needed considerable interpretation - more training on 'good' sketches. Usually the simplest are the best - not works of art. Often a seemingly small and insignificant feature may be very useful once one is close to the plot.

54 *dGPS*. All the QA exercise was carried out without the use of dGPS. In past QA trials the assessors used a metal detector to good effect in re finding metal plates and thus providing greater confidence that plots had been accurately refound. Since the repeat survey will be assessing change it is important to ensure that relocation errors are kept to a minimum. It would seem imperative that a proper trial be carried out to test the efficiency of using the Trimble for plot relocation. To achieve this an example square needs to be visited, plots set up and sketches and photos taken. A metal plate needs to be buried at the same point that the dGPS is used to 'Stamp' the plot. A second team then needs to return to the square and set up the plot using (a) dGPS alone (b) sketches and photos alone, (c) combination of sketches, photos and dGPS and finally (d) find the metal plate using a metal detector. An assessment of the distance discrepancies between the different methods can then be made.

55 *Plot positioning.* More training on where the individual plots go, especially relative to each other. Hedge plots were consistently put in the wrong place, and rarely linked to boundary plots on sketches and usually placed at one end of the 'D' plot.

56 *Grasses*. Need for more practice in vegetative ID during training courses.

57 *Photos*. Emphasise importance of photographs – do not take close-ups of plots if poorly illuminated; include salient background features; always indicate position of photo on plot sketch.

58 *Tablet.* Default for ‘presence’ cover value in the ‘selected species’ table to avoid lengthy data inputting

59 *Species cover values.* Assess this once more squares have been surveyed.

60 *Tablet.* Needs an intelligent system for typing in and recognising additional species from the long list. The keyboard tab could be used to input the first 3 letters of the generic name and first 3 letters of the species name thus providing a short list (or a unique ID) for the target species which can then be selected. Urge surveyors to be patient when inputting - take time to ensure correct species has been recorded from the drop down menu. Partner to recall previous records to avoid over writing records. More effort to record as pairs and always call out species as recorded else species will be missed by both assuming the other has recorded it.

References

Bakker,J.P., Olff,H. & Willems,J.H.&.Z.M. 1996. Why do we need permanent plots in the study of long-term vegetation dynamics? *J. Veg. Sci*. 7: 147-156.

Clymo,R.S. 1980. Preliminary survey of the peat-bog Hummel Knowe Moss using various numerical methods. *Vegetatio* 42: 129-148.

Dodd,M.E., Silvertown,J., McConway,K., Potts,J. & Crawley,M. 1995. Community stability: a 60 year record of trends and outbreaks in the occurrence of species in the Park Grass experiment. *J. Ecol.* 83: 277-285.

Ellenberg,H. 1988. Vegetation Ecology of Central Europe. 4th. CUP, Cambridge.

Ellison,L. 1942. A comparison of methods of quadratting short-grass vegetation. *J.agric. Res.* 64: 595-614.

Hall,J.B. & Okali,D.U.U. 1978. Observer-bias in a floristic survey of complex tropical vegetation. *J. Ecol*. 66: 241-249.

Herben,T. 1996. Permanent plots as tools for plant community ecology. *J. Veg. Sci*. 7: 195-202.

Hill, M. O. & Radford, G. L. 1986. Register of permanent vegetation plots. Abbots Ripton, Institute of Terrestrial Ecology.

Hope-Simpson,J.F. 1940. On the errors in the ordinary use of subjective frequency estimations in grassland. *J. Ecol*. 28: 193-209.

Kercher,S.M., Frieswyk,C.B. & Zedler,J.B. 2003. Effects of sampling teams and estimation methods on the assessment of plant cover. *J. Veg. Sci*. 14: 899-906.

Kirby,K.J., Bines,T., Burn,A., Mackintosh,P., Pitkins,P. & Smith,I. 1986. Seasonal and observer differences in vascular plant records from British Woodlands. *J. Ecol*. 74: 123-131.

Klimes,L. 2003. Scale-dependent variation in visual estimates of grassland plant cover. *J. Veg. Sci*. 14: 815-821.

Klimes, L., Dancak, M., Hajek, M., Jongepierova, I., and Kucera, T. 2001. Scale-dependent biases in species counts in a grassland. *J.Veg.Sci.* 12: 699-704.

Leps,J. & Hadincova,V. 1992. How reliable are our vegetation analyses? *J. Veg. Sci*. 3: 119-124.

Nilsson,C. 1992. Increasing the reliability of vegetation analyses by using a team of two investigators. *J. Veg. Sci*. 3: 565.

Nilsson,I.N. & Nilsson,S.G. 1985. Experimental estimates of census efficiency and pseudoturnover on islands: error trend and between-observer variation when recording vascular plants. *J. Ecol*. 73: 65-70.

Oredsson,A. 2000. Choice of surveyor is vital to the reliability of floristic change studies. Watsonia 23: 287-291.

Prosser, M. V. & Wallace, H. L. 1992. Countryside Survey 1990: a Quality Assurance Exercise. London, DoE.

Prosser, M.V. & Wallace, H.L. Countryside Survey 2007. 2008. Quality assurance exercise. First draft report to CEH Lancaster.

Rich,T.C.G. & Woodruff,E.R. 1992. Recording bias in botanical surveys. *Watsonia* 19: 73-92.

Scott,W.A. & Hallam,C.J. 2002. Assessing species misidentification rates through quality assurance of vegetation monitoring. *Plant Ecol*. 165: 101-115.

Smith,A.D. 1944. A study of the reliability of range vegetation estimates. *Ecology* 25: 441-443.

Sykes,J.M., Horril,A.D. & Mountford,M.D. 1983. Use of visual cover assessment as quantitative estimators of some British woodland taxa. *J. Ecol*. 71: 437-450.

West,N.E. & Hatton,T.J. 1990. Relative influence of observer error and plot randomisation on detection of vegetation change. *Coenoses* 5: 45-49.

Annex A. List of squares surveyed.

Square	Team	Survey date	QA date
12334	Mid	03/09 - 05/09/2014	09 /09 - 10/09/2014
12768	Mid	21/08 - 25/08/2014	27/08 - 29/08/2014
14994	South	17/07 -21/07/2014	23/09 - 24/09/2014
18367	South	22/07 - 24/07/2014	6/08 - 8/08/2014
36931	North	7/07 -11/07/2014	21/07 -23/07/2014
41349	North	16/06 -18/06/2014	30/06 - 2/06/2014

Annex B. Glastir 2014. Sources of error and plot relocation issues

Square	Plot	T1	T2	Total	Common	A	B	C	D	J	E	F	G	I	% Agreement	% Accuracy
12334	X1	36	44	44	35		5						4		79.5	87.5
12334	X3	25	24	30	20	4	3		2				1		66.7	69.0
12334	Y2	22	23	28	16		6		1				3	2	57.1	69.6
12334	S1	34	42	45	28	4	10		1				2		62.2	65.1
12334	S2	41	41	49	34	2	7		5					1	69.4	70.8
12334	P1	32	33	38	28		6		1				3		73.7	80.0
12334	P2	18	20	21	15	2	1		2				1		71.4	75.0
12334	U5	11	12	14	9		2						3		64.3	81.8
12334	U9	17	15	19	13		2		2				1	1	68.4	76.5
12334	U10	15	16	18	13	2	2						1		72.2	76.5
															68.5	
12768	X1	26	29	33	22	2	5		1					2	66.7	71.0
12768	X2	23	28	30	21		5					1	2	1	70.0	80.8
12768	B1	27	27	31	23		2						4	2	74.2	92.0
12768	B2	23	29	32	20		9		1					2	62.5	66.7
12768	H1	10	18	19	9		9							1	47.4	50.0
12768	H2	21	20	23	18	2	1	1						1	78.3	81.8
12768	Y2	10	11	15	5	4	3		2				1		33.3	35.7
12768	S1	28	33	40	25		10	1	1				1	2	62.5	67.6
12768	W1	40	47	51	34	4	9		1					3	66.7	70.8
12768	P1	27	23	32	18	2	4		2				1	5	56.3	69.2
12768	P3	34	35	43	25	4	7		1				2	4	58.1	67.6
12768	U1	19	17	23	13	2	3		3					1	56.5	59.1
															61.0	
14994	X3	31	34	40	25	2	6		2			1	2	2	62.5	71.4
14994	X4	19	18	22	15		3		2			1	1		68.2	75.0
14994	B3	17	22	26	13		8		1				1	3	50.0	59.1
14994	B4	26	23	28	21		2		1		1	1		2	75.0	87.5
14994	H1	15	23	24	14	2	6						2		58.3	63.6
14994	H2	23	25	30	18	2	6		2					2	60.0	64.3
14994	Y1	18	20	24	14		5		1			1	3		58.3	70.0
14994	Y2	15	13	18	10		2		1		3		1		55.6	71.4
14994	S1	27	23	29	21	2	1	2	2			1			72.4	75.0
14994	P1	18	21	23	16	2	4							1	69.6	72.7
14994	U1	10	12	16	6	2	4						4		37.5	50.0
14994	P2/S2															
															60.7	

Annex B. Glastir 2014. Sources of error and plot relocation issues

Square	Plot	T1	T2	Total	Common	A	B	C	D	J	E	F	G	I	% Agreement	% Accuracy
18367	X2	31	27	36	23	2	3		3				2	1	63.9	69.7
18367	X4	24	16	28	13		3		4			5		3	46.4	65.0
18367	B2	17	26	27	16		10		1						59.3	59.3
18367	B4	14	15	16	14		1							1	87.5	93.3
18367	H1	24	29	32	20	2	7	2	1						62.5	62.5
18367	H2	25	26	32	19	2	6	2	1					1	59.4	61.3
18367	Y2	10	13	15	8		4						3		53.3	66.7
18367	W1	14	21	27	8	2	5			11				1	29.6	30.8
18367	W2	23	23	28	18	2	4		1				1	2	64.3	72.0
18367	P3	17	18	22	13		5		2	1				1	59.1	61.9
18367	P4	13	14	17	10		4	1	1				1		58.8	62.5
18367	U1	17	26	28	16	2	9		1						57.1	57.1
															58.4	
36931	X4	21	24	28	17	2	4						2	3	60.7	73.9
36931	X5	16	22	24	13	1	5		2				2		54.2	59.1
36931	B4	18	20	27	11	4	7	1	2			2			40.7	44.0
36931	B5	22	25	29	19		6						1	3	65.5	76.0
36931	H1	14	15	15	14		1								93.3	93.3
36931	H2	16	18	22	12	2	5		1			1		2	54.5	63.2
36931	Y2	11	11	15	7		3		2				3		46.7	58.3
36931	Y3	8	9	9	8		1								88.9	88.9
36931	W1	28	33	39	22	4	8	1	1			1		1	56.4	59.5
36931	P1	24	27	34	18	2	9		1			1		3	52.9	60.0
															61.4	
41349	X3	11	14	18	7	2	5		1				1		38.9	41.2
41349	X4	2	5	6	1	2	3								16.7	16.7
41349	B3	17	17	19	15	4	2								78.9	78.9
41349	B4	12	15	18	9	2	5							2	50.0	56.3
41349	H1	17	15	21	11		4	2	3					1	52.4	55.0
41349	Y1	14	18	21	11	2	5							1	52.4	55.0
41349	Y2	17	20	23	14	1	4	1							60.9	60.9
41349	S3	26	26	29	23		3	2				1			79.3	82.1
41349	W1	15	21	22	14		7							1	63.6	66.7
41349	P2	15	15	18	12		3	1	2						66.7	66.7
41349	P3	17	19	23	13		6						2	1	56.5	65.0
41349	B2															
41349	A4	12	17	22	11		10							1	50.0	52.4
															55.5	
				1748		86	325	17	68	12	4	17	62	67		
															66.1	66.6

Annex B. Glastir 2014. Sources of error and plot relocation issues

Square	Plot	Location	adequate	How arrived at	Sketch	Photo
12334	X1	within 1m	y	Sketch and photo	Good use of nearby features	Good
12334	X3	Close	y	Sketch and photo	Good use of nearby features	Adequate
12334	Y2	Close	y	Sketch and photo	not enough local detail	Not sufficient
12334	S1	within 2m	n	Sketch and photo	Measurements didn't all tally	good
12334	S2	within 0.5m	y	Sketch and photo	lacked vital plot bearing	OK
12334	P1	Close	y	Sketch and photo	Simple but needed photo to work	OK
12334	P2	Close	y	Sketch and photo	Needed more distances/bearings	OK
12334	U5	Close	y	GPS + photo	Lacked features (but there weren't many)	Essential
12334	U9	Close	y	GPS + sketch	Photo essential combined with sketch	OK
12334	U10	Close	y	GPS + sketch	Adequate	OK
12768	X1	within 2m	y	Sketch and photos	Poor, needed careful reinterpretation	Helped
12768	X2	?	n	Sketch and photos	Distances too great for accuracy	No use
12768	B1	Within 1m	y	Sketch and photo	Poor, Misleading from X plot	OK
12768	B2	Precise	y	Sketch and photo	Good	Good
12768	H1	Precise	y	Sketch and photo	Location re B1 incorrect and not given	
12768	H2	Precise	y	Sketch and photo	Good - linked to X2 and B2	Good
12768	Y2	OK	y	Sketch and photo	Good	OK
12768	S1	Precise	y	Sketch and photo	Good	Good
12768	W1	0.5m	y	Sketch and photo	Needed photo for clarification	Good
12768	P1	Close	y	Sketch and photo	OK	Good
12768	P3	Precise	y	Sketch and photo	Good	Good
12768	U1	Good	y	Sketch and photo	Good	Good
14994	X3	Close	y	Sketch and photo	OK	OK
14994	X4	Close	y		Poor, need to key in boundary then set out X	
14994	B3	Precise	y	Sketch and photo	OK	OK
14994	B4	Precise	y		Relies on finding X from compass bearings	Needed
14994	H1	Precise	y	Sketch and photo	Fine	OK
14994	H2	Precise	y	Sketch and photo	Fine	
14994	Y1	Uncertain (within 2	n		Features too imprecise, ? Tape or range finder	
14994	Y2	Uncertain	n	Photo	Needed distance along fence then distance out	
14994	S1	Precise	y	Sketch and photo	Good	Good
14994	P1	Precise	y	Sketch and photo	Good	Good
14994	U1	within 2m	y	Sketch and photo	Good	Good
14994	P2/S2	Impossible to find	y		Needed info for access	

Annex B. Glastir 2014. Sources of error and plot relocation issues

Square	Plot	Location	adequate	How arrived at	Sketch	
18367	X2	>3m out	n	Sketch and photo	Long distances on bearings. ?Range finder or tape.	Essential
18367	X4	Close	y	Sketch and photo	Too much extra information but essentials there OK	
18367	B2	Precise	y	Sketch and photo	Distances not clear on map, 59m but 1.6m caused confusion.	Essential
18367	B4	Close	y	Sketch and photo	OK	OK
18367	H1	Close	y	Sketch and photo	OK	OK
18367	H2	Precise	y	Sketch and photo		
18367	Y2	Close	y	Sketch and photo	Measurements didn't match photo so adjusted	Essential
18367	W1	Close	y	Sketch and photo	OK but nearer features available to measure from	
18367	W2	Precise	y	Sketch and photo	Distances not clear on map, 1.6 looked like 16	Essential
18367	P3	Close	y	Sketch and photo	Out since W1 was out	
18367	P4	Close	y	Sketch and photo	Taken from outside fence as in diagram	
18367	U1	Close	n	Sketch and photo	OK	Essential
36931	X4	Approximate	n	Sketch and photo	Needs 1 actual measurement	
36931	X5	Approximate	n	Sketch and photo	OK	
36931	B4	Precise	y	Sketch and photo	Easy to refind	Good
36931	B5	Precise	y	Sketch and photo	Easy, but better features could have been used	Good
36931	H1	Precise	y	Sketch and photo	Poor. Seems H1 is at one end of D1	
36931	H2	Precise	y	Sketch and photo	OK	OK
36931	Y2	Approximate	n	Sketch and photo	Poor.	OK
36931	Y3	Precise	y	Sketch and photo	Good	Good
36931	W1	Close	y	Sketch and photo	Not precise enough re features	
36931	P1	Close	y	Sketch and photo	No bearing for orientation	
41349	X3	Close	y	Sketch and photo	Poor for finding B that it links to	
41349	X4	Close	y	Sketch and photo	Too much info! Access confusing- metal gate not accessible	
41349	B3	Close	y	Sketch and photo	No link to the H and D which are measured along the boundary	
41349	B4	Close	y	Sketch and photo	Too much info! Access confusing- metal gate not accessible	
41349	H1	Close	y	Sketch and photo	Wrong place should be 25m from B3	OK
41349	Y1	Close	n	Sketch and photo	Good	
41349	Y2	Close	y	Sketch and photo	Good	Good
41349	S3	Close	n	Sketch and photo	Too much info but not most useful!	useless
41349	W1	Precise	y	Sketch and photo	Good	Good
41349	P2	Precise	y	Sketch and photo	Good	Good
41349	P3	Close	y	Sketch and photo	Too much info but not most useful!	
41349	B2		y		Not QA'd but in a very strange place	
41349	A4		y		Doing into the crop as they did. If compared the correct crop edge the result would	

Annex B. Glastir 2014. Sources of error and plot relocation issues

Square	Plot	Orientation
12334	X1	Dubious
12334	X3	Dubious
12334	Y2	Dubious
12334	S1	Difficult water edge to follow - more comments needed
12334	S2	
12334	P1	OK
12334	P2	Bearing needed extra measurement on diagram
12334	U5	
12334	U9	
12334	U10	
12768	X1	Measurements didn't converge
12768	X2	Poor: didn't converge
12768	B1	Difficult hedge on ditch:precise position unclear
12768	B2	
12768	H1	Exact location re ditch/hedge unclear, v. difficult to access
12768	H2	
12768	Y2	Not precise
12768	S1	River low so exact bounds of plot unclear
12768	W1	
12768	P1	Compass bearing seemed wrong
12768	P3	OK
12768	U1	OK
14994	X3	Photo and compass bearings don't tally
14994	X4	Compass bearings didn't tally with measurements, had to adjust by 6m to get Urtica in cell 1 not cell 4.
14994	B3	Impenetrable nettles and brambles by September
14994	B4	? Distances using tape or range finder
14994	H1	Wrong location re X. Also at end of D not in middle
14994	H2	Again H at end not in middle of D. Not sure how it relates to an X plot.
14994	Y1	Didn't converge
14994	Y2	Too many features with range finder but not taped. Didn't converge
14994	S1	
14994	P1	
14994	U1	8 degrees out from measurement based on photo
14994	P2/S2	General comment for square is sketches don't link plots adequately and don't always provide useful measurements

Annex B. Glastir 2014. Sources of error and plot relocation issues

Square	Plot	Orientation
18367	X2	Plot didn't tally with photo, had to move plot >2m, still not a good match. Bearings didn't converge
18367	X4	Uncertain: a lot of mismatched species.
18367	B2	
18367	B4	
18367	H1	Hedge at end of D plot not in middle
18367	H2	
18367	Y2	Needed photo for relocation
18367	W1	Plot misplaced at T1 at top of bank
18367	W2	Position relative to fence suggests it straddles fence line - I would have gone entirely ditch side of fence
18367	P3	Should have had zone 0 down bank but followed their sketch all at top
18367	P4	2 zones recorded but no distances on plan
18367	U1	Measurements then adjusted from Photo.
36931	X4	Approximate distances and bearings don't allow accurate positioning
36931	X5	Not precise, measurements and bearings don't tally
36931	B4	
36931	B5	OK
36931	H1	Again, H at one end of D
36931	H2	
36931	Y2	Distances and bearings converge but plot in wrong place!
36931	Y3	Fine
36931	W1	Measurements and bearings don't tally. Adjusted to follow their sketch
36931	P1	Diffuse ditch edge, difficult to determine precise plot start
41349	X3	
41349	X4	Arable field
41349	B3	
41349	B4	
41349	H1	Again, H at end of D not in middle. Surveyors not far enough into hedge
41349	Y1	Not exact match
41349	Y2	Good
41349	S3	
41349	W1	OK
41349	P2	OK
41349	P3	No bearing
41349	B2	
41349	A4	In wrong place, 1m into the crop rather than along the ploughed margin

GMEP Bird Survey Methods

Introduction

The spring GMEP bird surveys are designed to reveal associations between breeding bird locations and Glastir management, as well as population changes in response to that management. However, there are several Glastir options that aim to enhance habitat for farmland birds in winter and that are likely to be critical for granivorous farmland birds in arable farmland. While the breeding season surveys should provide a means for testing the ultimate impacts of winter management, attribution of changes to the mechanism of winter food resource provision and success of that management per se (i.e. does it attract target species?) require specific monitoring in winter.

Currently, winter habitat effects on bird abundance are known to be important in arable farmland, but there is not such clear evidence for other habitats and no Glastir options for other habitats. Hence, winter bird surveys are a priority only in the arable parts of Wales. Surveys will therefore be conducted only on arable and mixed farms.

Specifically, the arable components of GMEP survey 1km squares (including the grassland elements of mixed farms) will be surveyed in one or more winters (resources permitting) between the first and second breeding season in which the squares are surveyed for breeding birds. Few 1km squares in Wales can be considered to be dominated by arable habitats, so an inclusive approach will be taken in which all squares with 20ha or more of arable land-use will be covered. The survey methods will follow those used in other surveys of wintering farmland birds. Analyses will investigate the use of Glastir management options by birds relative to background wintering bird populations in arable farmland.

Methods

The survey approach will consist of two visits, one in December and one in January, in which the surveyor walks a route along all field boundaries within the arable areas of each GMEP square and conducts whole-area search surveys of seed-rich habitats, including stubble fields, game cover crops and relevant Glastir options. Routes will also incorporate any grass fields present in the square that are part of the same farm as the target arable fields. Bird locations will be mapped with respect to habitat patches (fields, hedges, other habitats) and all birds seen and heard will be recorded.

Detailed methods will be as follows:

- The aim is to record all birds in the arable land in the square, or in all fields (arable and grass) in mixed farms, noting location and behaviour of all birds on each visit. A3 maps of the survey squares (use at least one per survey visit) and clipboards will be provided.
- Make two visits to each square, one in each of December and January.
- Access will be available to all arable parts of the square, or the square will be omitted from the sample.
- Visits can begin at any time, but should avoid the half hours after sunrise and before sunset. Avoid bad weather (rain, high winds) that is likely to affect counts or detection.
- Record weather conditions on each survey map: precipitation (none, intermittent, light and persistent), temperature (approximate), percentage cloud cover and Beaufort wind speed. Record conditions at the start and at the end of the survey (precipitation at the end of the survey should consider the whole survey period).

- Walk along all field boundaries, or within 50m of each point within the square (e.g. "transect" lines no more than 100m apart) in seed-rich habitats (stubbles, bird covers, Glastir option patches).
- Record all birds seen and heard using standard CBC notation, using BTO two-letter species codes and the relevant activity codes. Although we are fundamentally only interested in birds within the square boundary and only the area within the boundary needs to be covered (i.e. ideally routes do not need to pass closer than 50m of the boundary), record birds just outside the boundary as well as they are encountered.
- Most surveys should take less than three hours, but the exact time will depend on the size of the surveyable arable area and the habitat/bird density. Two-three surveys should be possible per day, depending on distances between squares.
- Record the exact survey route followed on a map and highlight areas considered poorly covered or not covered. For example, an open area of 200m across with survey routes along either edge might be considered "poorly covered" if it could be scanned from the boundaries such that large species can be seen but small ones not flushed, whereas a similarly-sized woodland with no access to the interior would probably best be considered as "not covered". Surveyors should use their judgement here as this variable will depend on subtle, local features, such as topography and vegetation height. Recording and standardizing route coverage (where surveyors actually walk) is more important than standardizing the exact order in which areas are covered.

Farmers and Local Authorities Perceptions of Glastir:

A Qualitative Evaluation of Glastir Woodland Creation and Management Schemes

[1]Kate Walker-Springett & [2]Dr Karen A. Parkhill
[1] k.walker-springett@bangor.ac.uk [2] k.parkhill@bangor.ac.uk

School of Environment, Natural Resources and Geography, Bangor University

On behalf of the Glastir Monitoring and Evaluation Project

August 2014

Llywodraeth Cymru
Welsh Government

Canolfan Ecoleg a Hydroleg
CYNGOR YMCHWIL YR AMGYLCHEDD NATURIOL
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

PRIFYSGOL BANGOR UNIVERSITY

Executive Summary

This research was commissioned to investigate and better understand the farmers' and Local Authorities perceptions of the challenges and benefits of the Glastir Woodland Creation (WC) and Woodland management schemes (WM). Qualitative methods were used in this research; focus groups with member of the farming community from a range of farm types and sizes took place at four locations across Wales. Telephone interviews with Coed Cymru officers within Welsh Local Authorities were also conducted.

Uptake of the Glastir WC and WM elements has been lower than expected triggering a concern that the Welsh Government target of 100,000 ha of new woodland to be created by 2030 might not be met. Previous research indicates that there are a number of barriers for farmers (key landowners in Wales) in terms of creating woodlands including: conflict between the land required for food production and that for woodland creation: and, a perceived division between the forestry and agricultural, particularly in terms of skills and knowledge sectors and economic disincentives. Little prior research has focussed on the engagement of Local Authorities in Glastir schemes.

This research finds little evidence to support the notion of a division between agriculture and forestry; contrary to the literature famers across Wales appear to be open to woodland creation and appreciate the numerous on and off-site benefits associated with increased tree numbers. However, significant barriers exist in the form of the Glastir scheme process. The process is perceived to undermine the scheme objectives and acts as a disincentive for potential scheme member from both the farming community and Local Authorities. It is recommended that four key elements be further investigated and adapted in order to encourage greater scheme uptake:

- The complex nature of the scheme (for example operation prescriptions for size and width of woodland, and the application process) needs to be simplified.
- The scheme is perceived as being inflexible (for example not allowing postponement of activities due to weather conditions) and therefore needs to be more flexible to take account of unexpected influences.
- The auditing process is complex and includes penalties (for example withdrawal of Glastir payments) and therefore penalties need to be clearer and the auditing process part of the scheme needs to be less threatening.
- Payment rates are obscure (for example there is confusion about what is covered and rates for contractual labour are not included) and therefore these need to be made clearer.

Table of Contents

List of Figures and Tables

Acknowledgements

This research would not have been possible without the participation of members of the farming community and Coed Cymru officers across Wales

1.0 Introduction

There is a significant amount of literature, both in the form of government documents and research outputs (e.g. reports and journal articles), which demonstrate the benefits of woodland creation (Nijnik and Bizikova 2008; Osmond and Upton 2012; Valatin and Saraev 2012; Wynne-Jones 2013a; The Woodland Trust. n.d.). It is accepted that trees provide habitat for wildlife, thereby increasing the biodiversity in a given area; this is of particular relevance in an agriculture setting where habitat heterogeneity is reduced (Altieri 1999). The Pont Bren project illustrates the benefits trees can have in improving upland hydrology, which has downstream implication for flood prevention and mitigation as well as on site benefits (The Woodland Trust. n.d.). Trees can provide a sustainable source of fuel and resources, which can in turn lead to economic gains, dependant on external factors such as market forces and size of plantation. More recently, tree planting has been increasingly prioritised as a way to sequester carbon and offset emission from carbon intensive activities (e.g. flying and agriculture – see Osmond and Upton 2012). With these benefits in mind, and in combination with the need to offset the emissions from the Welsh agricultural sector in order to meet the annual year-on-year carbon reduction target of 3%, in 2010 the Welsh Government accepted recommendation from the Welsh Land Use and Climate Change Group to increase the area of woodland in Wales by 100,000 ha (a 33% increase), by 2030.

In order to meet the 100,000 ha challenge, it was recommended that financial incentives should be put in place to encourage landowners to plant trees. One such financial mechanism is the Glastir Woodland Creation (WC) and Woodland Management (WM) schemes. Both WC and WM sit within the broader Glastir agri-environment scheme the aim of which is to continue and build upon the environmental and conservation focus of previous schemes within Wales, such as Tir Gofal (Wynne-Jones 2013a). Glastir WC and WM are stand-alone elements meaning that they are open to landowners in general and there is no requirement to be part of the larger Glastir scheme. For those within the wider Glastir element, woodland creation and management options are also available as part of the higher-level component of Glastir entitled Glastir Advanced. The Glastir scheme is funded through Axis 2 of the Rural Development Fund, as part of the EU Common Agricultural Policy.

The shift in focus from woodland creation on state owned land in the post Second World War period, to privately owned land means that incentive schemes such as Glastir are a primary method of achieving environmental goals, given that 80% of the land in Wales is farmed (Osmond and Upton 2012). However, physical (e.g. availability of land) and attitudinal (e.g. perceptions of woodland) barriers exist within the agricultural sector that leads to lower than expected uptake of woodland creation schemes (Lawrence et al. 2010). Previous research indicates that the attitudes of farmers play an important role in the decision to take up incentive scheme for woodland creation (Lawrence et al. 2010) as well as socio-demographic factors such as farm type, size and age of farmer (Lawrence et al. 2010). In addition, there is a paucity of research that investigates the efficacy of agri-environment schemes outside the agricultural sector. For example, Local Authorities (LAs) across Wales are responsible for woodland and have been also identified by Welsh Government as key participants for the Glastir WM and WC schemes. The interaction of LAs with Glastir WM or WC schemes to help finance woodland management and creation, which might not otherwise occur, is an important consideration when assessing the success of these schemes.

In Wales, Glastir and it predecessors Better Woodland Wales and Tir Gofal led to the creation of 1102.3 ha of new woodland between 2010 and 2012, representing just 1.1% of the overall 100,000 ha target (Wynne-Jones 2013a). Irrespective of the 100,000 ha target, the lack of uptake also had, and to continues to have, serious consequences on the provision of the range of environmental benefits expected as a result of the creation of new woodland and the appropriate management of existing woodland. Many stakeholders feel that the 100,000 ha target is unachievable in its current format (Wynne-Jones 2013a); if the target was number of trees rather than the area of woodland, it would perhaps be more realistic, since, for example, it would be able to take into account tree in hedgerows (Osmond and Upton 2012). Overall, greater levels of support and an integrated approach have been suggested as a way to merge farming and forestry in order to encourage the farming community to help achieve the tree planting targets (Wynne-Jones 2013a). However, integration and support can only occur if the underlying barriers and attitudes of the agricultural sector and beyond are fully understood.

The established body of research indicates that attitudes towards woodland on farms are a complex, interlinked and dominated by several key factors, which have been outlined below.

General Attitudes towards Forestry

Farming culture: Farmers hold agricultural landscapes in high regard, and social status within the farming community is achieved through good farming practice (Bell, 1999, Burton and Wilson, 2000). The conversion of productive agricultural land into woodland is seen as being morally wrong; food production takes precedence and in general woodland should be planted on land that cannot be farmed (Bell, 1999).

Timescales: The length of time taken for woodlands to mature means that land converted to woodland is less reactive to changes in markets, in comparison to crops or livestock based agriculture (Burton and Wilson, 2000; Silcock and Manley, 2008).

Socio-demographic factors

Age: Younger farmers have been shown as more likely to plant woodland (Gasson and Hill, 1990), possibly explained by the perception that land converted to woodland is a long term land use change and the increased likelihood that a younger farmer will see a financial return from his or her investment in woodland (Watkins et al., 1996).

Suitable Land: A common reason for farmers not planting trees is lack of suitable land (Watkins, 1984) and smaller farms are have been shown to be less likely to take up grants focussed on tree planting (Wavehill Consulting, 2009).

Woodland Grants

Uses: Participants in grant schemes for woodland creation have been shown to actively use their woodland, in comparison to those not involved in such schemes. The main reasons for woodland creation are: recreation, conservation and developing livestock shelters and field boundaries (Wavehill Consulting, 2009).

Efficacy: The evidence related to the efficacy of grant in encouraging woodland creation and management is not clear. It is also difficult to tell whether grants do really encourage new woodland creation or whether the landowners would have planted the trees anyway (Watkins, 1984; Sharpe et al., 2001; Church and Ravenscroft, 2008).

Uptake: Barriers exist to grant uptake which are distinct from attitudes towards forestry. These include perceived scheme bureaucracy, complex application process and lack of knowledge about available grants (Crabtree et al., 1998; Ward and Manley, 2002; Cunningham, 2009; , Wavehill Consulting, 2009).

For a more comprehensive review of the available literature, please see the Literature Review in Appendix A.

Aims and Objectives

The aim of this report is to investigate and better understand the farmers' and LAs perceptions of the challenges and benefits of the Glastir Woodland Creation and Woodland management schemes. Using qualitative methods the project has two objectives:

1. To investigate attitudes (positive and negative) towards both the Glastir Woodland Creation scheme and the Woodland Management scheme by Welsh farmers, and identify barriers to help explain the low rate of uptake, as well as possible opportunities to encourage uptake.

2. To investigate the attitudes (positive and negative) of Welsh Local Authorities to the Glastir Woodland Creation Scheme and the Woodland Management scheme, and identify barriers to uptake, as well as possible opportunities to encourage uptake.

2.0 Methods

This study incorporated two distinct methods, focus groups and interviews, to explore attitudes and opinions towards the Glastir Woodland Creation and Management Schemes within the farming community and Local Authorities across Wales. Focus groups were used to encourage reflection and discussion with members of the farming community. The aim of focus groups is not to be representative in the statistical sense, rather generalisability is possible by ensuring that range of viewpoints are captured due to the sampling techniques and criteria used to select participants, and through careful interpretations aided by research and conceptual literature. Telephone interviewing as a methodology allows a greater quantity of interviews to be carried out within the time available, given the geographic spread of interviewees. As with the focus groups, this methodology allowed a wide range of views to be captured, again allowing generalisations to be formulated. We would anticipate that the findings outlined in this report would have broad resonance with the wider farming community and Local Authorities involved in WC and WM schemes not part of this research. Prior to inviting any participants, the outline plan for the focus groups and all associated materials were approved by the Bangor University Ethics Panel. The Glastir Monitoring and Evaluation Programme Team also approved both the overarching project plan and all outgoing external communications.

2.1 Focus Groups

In order to sample as wide a range of the Welsh farming community as possible, focus groups were carried out across Wales. Priority areas were identified, with the assistance of Welsh Government, as being East Wales/Welsh Marches, East Powys, and the Severn Valley catchment due to forthcoming woodland creation geographical targets. This led to four focus groups being held in Bangor, Newtown, Abergavenny and Wrexham (Figure 1); in total, 22 individuals participated.

Figure 2.1: Map showing of the locations of the four focus groups held with members of the farming community and the 14 Welsh Local Authorities where the incumbent Coed Cymru officer was interviewed.

● = focus group locations: Bangor, Wrexham, Newtown and Abergavenny

'Demographic' criteria impacts upon peoples' worldviews, this in turn has an impact on peoples' attitudes. In this study, using previously published literature farm type and farm size were identified as being important criteria. Using the annual farm survey from June 2010 in combination with agri-environment scheme membership, farmers within 20-mile radius of each focus group location were targeted. Initial contact was made by letter and follow-up phone calls were made to confirm attendance, ensuring that a range of farm typologies (sizes and scheme memberships - i.e. current and historic agri-environment or woodland creation schemes) were included. The sample was broadly representative of the type and size of farms across Wales (Table 1).

	Focus Group			
	Bangor	Abergavenny	Newtown	Wrexham
Scheme Membership[1]				
S_NG	1	2	1	0
S_GE	2	3	1	1
S_GA	0	1	1	0
NS_NG	0	0	0	4
NS_GE	1	0	0	0
NS_GA	2	2	0	0
Farm Type[2]				
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	1	-	3
5	-	1	-	1
6	5	2	2	-
7	-	1	-	1
8	-	-	1	-
9	1	3	-	-
Farm Size (SLR)[3]				
0	-	1	-	-
1a	1	2	1	1
1b	2	-	1	1
2	1	1	1	-
3	1	2	-	-
4	-	2	-	-
5	1	-	-	3

Table 2.1: Demographics of focus group participants, obtained from June 2010 Horticultural Survey (DEFRA, 2010) and Glastir Scheme Membership data.

[1]Scheme Membership: S_NG: Previous agri-environment scheme, but not in Glastir; S_GE: Previous agri-environment scheme, currently in Glastir Entry; S_GA: Previous agri-environment scheme, currently in Glastir Advanced; NS_NG: No previous scheme, not in Glastir; NS_GE: No previous scheme, currently in Glastir Entry; NS_GA: No previous scheme, currently in Glastir Advanced.

[2]Farm Type - 1 = Cereals; 2 = General cropping; 3 = Horticulture; 4 = Specialist Pigs; 5 = Specialist Poultry; 6 = Dairy; 7 = LFA Grazing Livestock; 8 = Lowland Grazing Livestock; 9 = Mixed; 10. Other

[3]Farm Size (SLR) – Standard Labour Requirement (SLR) is a measurement of farm size, taking into account difference in the labour needed across different agricultural sectors. One SLR equates to 1900 working hours per year.
<1 SLR = Very Small
>=1 and <2 SLR = Small
>=2 and <3 SLR = Medium
>=3 and <5 SLR = Large
>5 SLR = Very Large

Each focus group began with an introduction to the project and participants were asked to sign consent forms, acknowledging the fact that the focus group was being audio recorded for the purpose of later being transcribed in preparation of thematic analysis. The main part of the focus groups were comprised of three sections. The first encouraged participants to discuss attributes of good and bad farming practice. The second explored the relationship Welsh farmers have with the environment. Finally, questions surrounding Glastir and the impact this had on perceptions of the environment were discussed, both in the context of woodland and the broader sense of general agri-environment schemes.

The discussion within section one began to identify opinions about Glastir and also gave context to explain ideas and opinions that were subsequently revealed in sections two and three. The second section used four images of different landscapes to explore perceptions of forested and un-forested scenes. Participants were encouraged to explain how they felt about each scene and discuss as to whether the scenes would fit in with their farming practices (Table 2). Using the photographs, this section probed perceptions associated with different woodland landscapes in order to identify underlying opportunities and barriers towards and uses of woodlands on agricultural land.

Agricultural Scene	Woodland Scene	Shelter Scene	Unmanaged Woodland

Table 2.2: Landscape photographs used in the focus group to compare attitudes to different woodland scenes.

Finally, the third sections used statements derived from Wynne Jones (2013a) and Osmond & Upton (2012) to explore commonly held association of farmers and forestry (Figure 2). Concepts such as the space and time needed to plant and manage woodlands, the potential uses and revenue sources and the increased need for food security where among the themes probed, as such section three concentrated the discussions on woodland on agricultural land.

> Planting woodland on my farm would have many benefits, for example: timber production, creating habitat for wildlife and helping to manage flooding. Most farmers have small pockets on unproductive land which could be converted into woodland.
>
> My choices about what to do on my land revolve around how to add value. I don't see how planting trees can really pay - the financial incentives are not large enough.
>
> I wish I had planted the woodland years ago, it's a lovely place to walk the dog, plus we coppice and use the wood for fuel at home. Planting woodland reduces the carbon footprint of the farm and stops us being so reliant on imported fuels.
>
> Farmers are farmers, not foresters - I don't feel I have the knowledge or the skills to plant and manage a woodland; I don't know who to turn to for help or advice.
>
> There is such an increased demand for food which will increase in the future, that taking land out of production for tree planting is not viable. I would not have the time to manage woodland either, with all the other demands on my time.
>
> The time period that you are tied in for with woodland creation is too long. I don't know what will happen to my farm in the future so I would prefer to be able to have more control of my land now.

Figure 2.2: Statements used in focus groups to facilitate discussion around farmer's perceptions of woodland.

2.2 Interviews

Telephone interviews were conducted with Coed Cymru officers from a range of the Welsh Local Authorities (LA) that have responsibility for woodlands. Initial contact was made through email, with follow up calls to arrange a suitable time. At the beginning of the telephone interview, a brief introduction to the project was given, and the interviewee gave verbal consent of the conversation to be recorded for transcription. The interviews then explored attitudes and opinions of the Glastir Woodland Creation and Woodland Management schemes, from the perspective of the Local Authority. In total, nine interviews were conducted covering the following Local Authorities: Anglesey; Carmarthenshire; Ceredigionshire; Conwy; Denbighshire; Gwynedd; Neath, Port Talbot and Swansea; Wrexham; and Rhondda, Bridgend and Merthyr Tydil (Figure 1).

3.0 Results and Discussion

3.1 The Glastir Scheme

This research set out to use qualitative methods to unpack the attitudes towards the woodland elements within Glastir, focussing on both the farming community and Local Authorities via Coed Cymru officers. Discussions with members of the farming community revealed that thee was little separation of the Glastir Woodland Creation and Management schemes from that of Glastir as a whole. With this in mind, the attitudes and opinions expressed reflect both the experiences participants had with Glastir in general, and it was impossible to always isolate only those attitudes that related to the WC and WM strands. Within the Local Authorities, perhaps because some of the Coed Cymru officers interviewed have been or currently are advisors for the WM and WC schemes, there was a much clearer division between the Glastir WC and WM schemes and the farm-based Glastir Entry and Advanced scheme as a whole. Therefore the opinions expressed by the Coed Cymru officers are largely based on the WC and WM sections of Glastir.

It is interesting to note that there was a high degree of similarity between the opinions expressed by the Coed Cymru officers and those from the farming community. In general, it seems that previous experiences, both good and bad, either with the All-Wales elements of Glastir or with previous woodland schemes, colour the attitudes towards the current scheme. For example, farmers who are already involved in Glastir and have had a negative experience appeared reticent about entering another Glastir scheme. Likewise, both farmers and Local Authorities compare Glastir to previous schemes and there is an expectation that Glastir should have built on previous woodland schemes (for example Better Woodland Wales) and a disappointment as this is perceived as not having happened; this was particularly acutely felt within the Local Authorities.

"To be honest most probably we hadn't really looked at the Glastir Woodland too significantly because the other requirements of Glastir processes have said you know I don't want to really go for that and it's the documentation exercise more than anything of Glastir. And we have enough paperwork as it is." **R6, Abergavenny**

"We were in the ESA which was really good scheme and you had an individual person came out, walked around the farm with you, decided what you'd do and helped you with all the paperwork when it had to go through. And it worked brilliantly and we didn't go into the last lot, Tir Gofal and then we've gone into this one but its nothing like as good as the ESA. Yes, I think the ESA was more, it was more simple wasn't it?" **R6, Bangor**

"Under Woodland Improvement Grant there was a degree of flexibility like if you know you couldn't do it this year for whatever reason you could phone them up and say look we can't do it because it was too wet or too whatever. It was a case of alright we'll just put it down for next year then and there just doesn't seem to be the opportunity to do that with Glastir." **LA1**

Figure 3.1: Quotes reflecting attitudes towards the Glastir Woodland schemes in comparison to previous schemes

3.2 Glastir Woodland Management and Creation

Concern about the finer details of the Glastir WC and WM schemes were most often expressed by Local Authorities, for example the minimum area requirement, species mix and thinning rates, reflecting a greater scheme-specific knowledge of the Coed Cymru officers. In contrast, members of the farming community talked much more generally about Glastir, and openly admitted to being strategic in terms of what land they enrolled into the scheme and which options under Glastir they would participate in. Oftentimes this reflects works that the farmers had been planning to undertake anyway, and entry into Glastir was merely a method of achieving the end result with a smaller financial burden. In both cases, dissatisfaction and unhappiness, either with scheme-specific details or more generally with the perceived complexity and bureaucracy associated with the scheme expressed by most participants undermines the overall objectives of Glastir WC and WM. This corroborates much previous research in which landowners perceptions of woodland grant schemes are described s complex and bureaucratic (Urquhart 2006; Church and Ravenscroft 2008; Cunningham 2009; Urquhart et al. 2009). Despite this, the Better Woodlands Wales (BWW) scheme examined by Wavehill Consulting (2009) was deemed to be straightforward, which perhaps explains the disappointment felt by LAs that Glastir Woodland schemes had not built on the success of BWW.

"I find that I looked through all the Glastir paperwork this morning and I thought my goodness! [Laughs] I, we were actually offered a contract and we'd already done all the work we'd suggested that we might have grants on and at the end of the day we didn't bother to fill it in, the contract was so demanding!" **R3, Wrexham**

"We're now in Glastir and will be in Glastir Advanced but we're being really cautious about which bits of the land we tie down . . . We're still trying to do it but we have been much more strategic about which bits we'll say we will commit to Glastir." **R5, Bangor**

"Well I mean if we take the reclamation woodlands you could put the reclamation woodland sites in for a thinning operation whereas you couldn't do that under Glastir because you just simply can't the 27 cubic metres volume out of there per hectare. Where if you went into Better Woodlands for Wales you could, you could thin any volume you wanted but you were paid on you know on how much volume." **LA2**

"Each grant scheme has got progressively more complex in its application process and I would say each grant scheme, because of that, has been more costly and less effective." **LA3**

Figure 3.2: Quotes reflecting attitudes towards the current Glastir Woodland schemes

3.3 Productivity versus woodland creation

There is a well-documented conflict between agricultural productivity and woodland creation (Watkins et al. 1996) where it has been shown that farmers have a tendency to see the creation of woodland on agriculturally valuable land as wrong and even immoral. In this research, the reaction to the arable scene in the photograph exercise did indicate an aesthetic preference for an arable landscape, a finding similar to that of Burton and Wilson (2000). However, the qualitative nature of the methodology used allowed an in-depth exploration of this, revealing nuances that do not quite align with the established consensus held in the literature. Whilst all but one farmer would not seriously consider planting woodland on productive land, the vast majority agreed that there were small pockets of land that could be given over to woodland creation. This contradicts previous studies that indicate a much stronger aversion to planting woodland on any farmland (Watkins et al. 1996; Burgess et al. 1998).

"I feel that a good farmer being brought up in the generation before me farming was always taught that we had to feed the nation or nowadays with the world being so small, feed the world and so that is where some moral dilemmas arise with the Glastir work." **R5, Abergavenny**

"Because like that's you've got your corridors, you've got your livestock, you've got your hedges for shelter and the hedges are growing they're tidy you know decent hedges." **R3, Abergavenny**

R1: Yeah that looks attractive, it looks well kept, it looks farmable you know practical erm…
R4: You've got trees dotted around haven't you so yeah
R3: And there are like wildlife corridors in the long hedges
Wrexham

"I think most farmers have small pockets don't we that could be converted into woodlands, I think we've all got a little bit somewhere." **R4, Wrexham**

Figure 3.3: Quotes reflecting attitudes towards the current the agricultural landscape image

Many participants were of the opinion that there is a range of more appropriate places for woodland creation than productive land, for example road verges. Osmond and Upton (2012) found that in order to meet target of new woodland creation by 2030, areas of marginal land will need to be planted; however, conservation agencies often oppose planting applications because of the ecological importance of the existing habitats (Osmond and Upton 2012).

"There's always ground at the sides of these roads and they're paying the councils just to try and cut the grass off it and you think you know there's a degree of ground there that could be planted." **R5, Wrexham**

Figure 3.4: Quote reflecting attitudes towards appropriate woodland location

Furthermore, despite the reference to a desire for tidy farms expressed by the famers in this research, which corroborates the findings of Silcock and Manley (2008), this preference for tidiness did not extend to the woodland; moreover, many of the farmers expressed an appreciation for untidy woodland in terms of its importance for biodiversity. Any reticence about creating woodlands strongly reflects the concerns about and perceived barriers of the Glastir scheme itself as opposed to an aversion to woodlands *per se*. Examples of this include concerns about the penalties and auditing or the inflexibility and lack of adaptability of Glastir such that it is perceived as being more hassle than it's worth. This mode of thinking is also apparent in the interviews with Local Authorities; whilst woodland creation on Local Authority owned land could be hampered by limited suitable space, woodland management is an on-going work stream. Again, reticence about engaging with the Glastir WM is more focussed on the perceived drawbacks, particularly the increased administrative burden and lack of flexibility of the scheme, and not a lack of impetus to manage Local Authority owned woodlands.

" . . there's not enough flexibility for individual farmers to keep control of the situation under different weather conditions and different stock conditions and so on and that's a major problem which is why with our Glastir we thought long and hard about what we wanted to do . . we were very careful about what we put in and what we didn't" **R5, Bangor**

"I think that the word that sums it all up is balance because areas like that there's nothing at all wrong with them, especially if its on the poorer ground, its being wonderful for the environment, its non-productive land, the timber doesn't even look any good for firewood, its just a balance which life has got to be all about." **R5, Abergavenny**

Figure 3.5: Quotes reflecting a desire for Glastir woodland schemes to be flexible and in balance with other farming priorities.

3.4 Relationship between farming culture and Glastir Woodland schemes

It was important to first understand the perceptions behind what makes a good and bad farmer before trying to unpack how the Glastir woodland schemes fit into the farming lifestyle, in line with the need to "create a business case for woodland creation that works with farming culture" (Wynne-Jones 2013a). The attributes of both good and bad farmers discussed by our farming participants allowed contextualisation of the attitudes towards both woodland and the Glastir schemes. In brief, 'good' farmers were considered as those who achieved a balance between productivity and caring for the environment. Both of these were seen a key contributions that the farming communities makes to society, encompassing the responsibility for land stewardship and providing food nationally and internationally. It is important to note the productivity does not necessarily equate to profitability; whilst it was acknowledged that farming is a business and profits are needed in order move forward, the importance of farming as a way of life and that the profit margins are not expected to be large was also expressed.

"So it is getting that balance and no matter how much your heart says I want to go this way, I want to protect my hay meadow which has got wonderful flowers on it, but we also have to grow grass on it and its trying to find the balance of sunflowers and lots of grass so we can feed the sheep in the winter and not have to buy in fodder." **R5, Bangor**

"Just to roll on from that of course the best thing for the environment and for the countryside is profitable farming because if farmers are making money they will repair the walls, put up new gates, look after the countryside, if we've got no brass in our pockets we're not going to be doing that. So profitable agriculture is probably the best thing, I feel, for the environment and for the countryside in general, it is vital that agriculture makes money." **R5, Abergavenny**

"You know if you take the schemes out you know to sort of put your most productive land into sort of schemes that are not going to help you make your profit is harder and harder." **R3, Abergavenny**

"And I think for me a bad farmer is somebody who doesn't care for the environment because there's that notion of sustainability that if you take no notice of what you're throwing on the fields or you know chopping down hedges and trees and all the rest of it then ultimately you're not going to be successful. I suppose you might still be successful as commercially as a farmer but in terms of the long-term view of food production you're not, you're not going to make it. **R5, Bangor**

"Some of the trouble is what are you talking a 'profitable farmer' because we're profitable because we get Single Farm Payments, there's not many farmers who actually can make a living without the Single Farm Payment, or without subsidies." **R1, Abergavenny**

Figure 3.6: Quotes reflecting the complexity of attitudes relating to farming and the environment

An interesting point raised in the Abergavenny FG was that profit-making farms are more likely to have the spare capital to invest in the environment. This connects with the perception that most of the farming community expressed, about farming being a lifestyle choice and how farming relies upon a healthy environment and embodies a duty of care towards the environment. Furthermore, the need to rely on subsidies, such as the Single Farm Payment (SFP) or indeed Glastir schemes in order to show a profit at the end of the day was also explicitly mentioned, adding weight to the idea that farming is accepted as being more of a lifestyle choice that a profit making industry.

Adaptability and resilience were also important attributes of good farmers, driven by the perception that agriculture is subject to external influences which creates uncertainty, for example climatic and political drivers. The need to be able to adapt and to be resilient in the face of changing political priorities, uncertainty over product prices and little control of the weather was seen as very important to the success of anyone within the agricultural sector. In general, most participants felt that the Glastir scheme was inflexible and overly prescriptive, an opinion also voiced strongly by the Local Authorities. In tandem, strong concerns were voiced over the penalties for not adhering to the works timetable agreed (by both farmers and Local Authorities), particularly if work was not able to be carried out due to unforeseen circumstances beyond the landowners control, for example an extremely wet winter preventing access to woodlands. Moreover, the Glastir scheme was viewed as having no mechanism whereby changes to the scheduled programme of works could be adapted following such events. The Coed Cymru officers made comparisons to the Better Woodland Wales scheme, which they believed to have had more flexibility than Glastir WM or WC, due to ability to adapt the planned operation to take account of circumstance beyond their control (i.e. weather).

"Yeah I think you have to be resilient because not only is the Government changing the rules every now and then but also we have no control over the weather and so you have to be prepared to adjust and make the best of whatever is thrown at you in terms of the weather and disease" **R5, Bangor**

"I personally haven't gone into Glastir, will not go into Glastir. Didn't go into Tir Gofal basically because they don't listen to you…when you tell them how a field, every field grows differently but they just…broad brush 'no you can't do that, you can't do that' and it doesn't work. **R3, Bangor**

"You get form after form that's like this thick within its booklet and it gets to the stage where you just think pfft [sic] you know its piles of them and then you're thinking if I get something wrong are they going to come down like a tonne of bricks. And half the time you don't even know if you've done something wrong until somebody comes and tells you. And you, you know, you end up thinking god I better not join this scheme in case I make a mistake and then I'm going to have all kinds of hassle and bother." **R2, Bangor**

"The only thing, the only thing that I'd be wary of with the Glastir Woodland Management is not to commit the Council to too much work under the scheme because of the way the scheme rules if you default on an operation then you will get fined." **LA4**

Figure 3.7: Quotes reflecting the participants' fear surrounding the auditing component of Glastir

3.5 General attitudes towards woodland

Attitudes towards woodland are intertwined with the key attributes of an effective famer; whilst the positive contributions woodland can make to land management in terms of flood management, biodiversity and shelter for livestock and crops are accepted, the idea taking productive land to plant trees on is the antithesis of the primary reason for farming i.e. to produce food. All but one farmer that participated in this research was opposed to taking productive land and converting into woodland. Moreover, there was an expectation expressed that should this happen, that farming would become more intensive in order to compensate for the loss of agricultural land. The single farmer who had converted some of his grazing pastures into woodland did so out of a belief that agriculture has become too intensive and was detrimentally impacting the environment. As such a key concern for farmers was the environmental impact of intensive farming practices. However, it was also accepted that there is a balance between profitability and caring for the environment and that farming is a business that needs to be profitable in order to survive. Concern was also expressed about whether agriculture in the Wales is economically viable if subsidies or payments for ecosystem services (i.e. Glastir) were not accounted for.

"Well if I may say I think this over-intensification of farming I mean up a level from we do. It's dreadful factory farming, these chickens in hundreds of thousands and if you're going back to profitability I think all we need to do is make a living." **R3, Newtown**

"and they could have had quarter of an acre to go with it [the other land planted for woodland] but leave me farm more intensive farming in another acre somewhere else you see." **R2 Newtown**

R7: We had, we had some very steep hillside when we went into the farm and it was completely covered in bracken and we did take out one of those schemes, it was a Forestry scheme and we planted it with trees and we found that the amount of bird life and other life that we've now got on the farm has tripled, quadrupled.
Kate: And is that something that you see as a positive feature now?
R7: Yes. **Abergavenny**

I have planted 14 odd hectares into woodland in a Glastir scheme and yeah the moral decision to plant on land that could produce food was quite a difficult one. **R5, Abergavenny**

"that's the key responsibility its not only providing our yearly income is it not but to achieve that you've got to look after the land, you keep it in good condition and these interests which you must have in the environment you must be supportive of it." **R1, Newtown**

Figure 3.8: Quotes reflecting environmental stewardship of farming and positive attitudes towards woodland creation

As previously mentioned, many participants acknowledge that there are small pockets of land on most farms that could be planted with trees, and in principle would be happy to do so, and felt confident in having the skills or knowledge to undertake such work. However, woodland creation or management would not be undertaken just for economic reasons. The length of time to maturity and the amount of work necessary during the first 10 years meant that participants believed that aside from providing wood fuel for personal use in the home, there would be little possibility for making profit from woodland; in combination there was little knowledge about whether one would be allowed to harvest wood from woodland that had been planted under the Glastir scheme. That being said, many participants expressed an affinity for woodland and several had already planted trees on their land, outside of the Glastir schemes. The delicate balance between farming the environment mentioned previously was brought up again when participants were comparing the four images of woodland; the image of a field bounded by woodland was described as being a good compromise, further highlighting the almost unanimous opinion that woodland and farming are not mutually exclusive but that farm woodlands need to be sympathetic to the food production focus of farms.

"Well we got one 18 acres, it's called the Large Wood which is mostly oak trees and they're almost like telephone poles and they want to be thinned but the cost of thinning is going to be way more than what you know just merely the price of firewood really, we can't a home to sell it." **R2, Newtown**

R4: Yeah that's what we think, best of both worlds really. You've got the wood and you've got the farmland as well.
R3: Well now then tree planting is, serious trees hardwood and so on is a long term matter. I agree the financial incentives are nowhere near large enough. I don't think we're planting for profit for use, we might be for our grandchildren . . .
R2: I have no children or grandchildren and we've planted a lot of hardwood, it is for the future, its sustainability. **Wrexham**

Figure 3.9: Quotes reflecting the financial incentives of Glastir woodland schemes.

3.6 The Glastir Process

General criticisms of the Glastir scheme itself included the relationship between the staff administering the scheme, and the administrative requirements of entry into Glastir. For those participants who had received an on-site visit, the opinions were generally positive about the member of staff who visited. However, for those that had no face-to-face contact, opinions were jaded by perceived complexity and administrative burden in placed, both on Local Authorities and farmers. The need to register all woodland within the LA was seen as a burden by the LA interviewees, due to organisational set-up within the Local Authority. More than one department have responsibility for woodland in Local Authorities, and this alongside the numerous small pockets of woodland on LA land mean that it can place an unwieldy administrative burden on LA's to document and register each patch of woodland.

The planting eligibility maps were a source of frustration across both the farming community and the LAs. This has been previously highlighted by Wynne-Jones (2013a), who found that the these maps were both a direct disincentive and an indirect barrier by attempting to encourage planting in lowland fertile regions and consequently increasing the conflict between food production and woodland creation. Planting maps continue to be perceived as inaccurate and a disincentive to express an interest in Glastir WM and WC, to both LA's and farmers. Additionally, inaccuracies on the individual farm maps were common; despite this, even when farmers corrected the maps and sent them back to Glastir, the corrections were not updated centrally and incorrect maps continued to be send out.

"Erm well yeah when you've got something as complex as that then yeah it does add an additional sort of burden on the Council to start actually looking at what they've got regards woodlands because to be honest I don't think they know themselves [laughs]" **LA1**

"each time I've had my IACS maps which are sent to you each year showing your boundaries and somebody somewhere has taken these boundaries from I presume a satellite photo. There was a small error in that a pond that was part of my field was marked as belonging to my neighbour as was a hundred metres of ditch. Now it doesn't really matter but I thought I'd better write to them and say 'look this is my ditch not his ditch' and 'that's my pond not his pond' because you know probably somebody somewhere would then say 'those aren't yours because you never said anything about it'. So I wrote I think for four years running, never got a response and then I got a response this year which was the one year I hadn't bothered writing because I'd given up" **R2, Bangor**

"The woodland creation was done on the basis of, in principle which was a good idea, but it was to plant on land where you're not going to damage an existing habitat so it was done on the All Wales Map Scheme based on Phase 1 survey data which was really quite out of date." **LA3**

Figure 3.10: Quotes reflecting the participants' perceptions of the Glastir process.

There was also the perception that the Glastir scheme was constantly changing and a feeling that the scheme was rolled out too early; moreover, experiences of the Glastir administration left some participants feeling as if there were internal conflicting opinions within Welsh Government. This finding emphasises the conclusions drawn by Wynne Jones (2013a) that contrary to accepted practises, the Glastir scheme should not reduce staff numbers and face-to-face contact with farmers and that a move towards more automated approach in not appropriate in this context. Above all, a degree of continuity was needed to allow both LA's and farmers to feel confident dealing with the schemes and to develop a sense of trust in the scheme, perceived as lacking at the current time. These comments refer to Glastir in general, but such attitudes represented a significant barrier to the uptake of Glastir WM and WC and are thus important to highlight.

"There is no communication between the Glastir Woodland Management and it doesn't come, it goes to the client and the client is who doesn't really understand woodland management but wants to do it and while I've been there you know he should be liaising with myself but doesn't do it, he just goes ahead and writes the plan. Now then the plans go away then the plans then go away and that Glastir Woodland Advisor doesn't see that plan once it's gone in-house into Welsh Government because it's another team that's building it all up. There's another mapping team in Aberystwyth who produces the maps and invariably you've got no communication, information comes out wrong, the maps are wrong and they're expected to sign you know when eventually the contracts do come through I don't know any client yet who has had a contract on time ready to sign." **LA5**

"Every other department has got a different agenda and they don't work towards the same goal, or lots of them." **R3, Bangor**

"We need a continuity of a scheme that can actually deliver you know on a, on a basis well a five review is great and it could be you know continue to be that. Because of the demise of BWW and they're starting again with Glastir I'm hoping now that Glastir can offer this kind of continuity." **LA3**

Figure 3.11: Quotes reflecting the participants' perceptions of the Glastir administration and scheme continuity

The complexity of the Glastir WC and WM schemes begins on application, when new entrants have to choose from a long list of possible options that they might want to undertake. Often, Woodland Creation Officers are met with farmers who want to undertake works that are not suitable for their land or impractical or not allowed as a result of the tree planting maps. As a result, farmers often become frustrated and less amenable to going into Glastir WC.

"I mean if you're talking about the Glastir from the point of view of the landowners well with the Council in mind from the point of view of me as a Woodland Advisor erm…you know there are certain issues with the scheme but there are with all the schemes [laughs]. Complexity, issues, the I mean you do get this its almost like a Christmas list when you turn up at a landowners who have seen the matrix of operations that they could be eligible for and what we tend to find is you turn up and they've gone through this going like we want that that that that [laughs]. You know, hang on hang on you know and you're having to sort of reign them in a bit and say no look you've only got these layers on your land and then its oh oh I don't think we're interested now if we can't get that you know its sort of disappointing really so from their point of view." **LA1**

Figure 3.12: Quote reflecting the participants' perceptions of the complexity of the Glastir

3.7 Payment Rates

Opinions about the payment rates under Glastir WC were divided; one farmer felt that the payment they receive made is economically viable for him to convert pastureland into woodland. However, many other participants felt that the payments were not in-line with the true cost of operations. The LA interviews revealed that woodland management rates, particularly for thinning, were in some cases insufficient to overcome the perceived administrative burden of entering Glastir Woodland Management. In many cases the LAs were not looking to increase their woodland holding by creating new woodland, predominately because they did not have the space (space constraints on grant uptake were also found in (Watkins 1984) or in these time if fiscal austerity, woodland creation has to compete with other priority areas for LA finances.

"They gave us loads of money for thinning the forest that's going to more or less pay for itself anyway and there's about the same amount of money for putting in the track that cost about six times that." **R6, Bangor**

"Yes I think for something like thinning or habitat restoration it's probably not actually important because we're not getting that much payment for it. For other sorts of work it really depends on the payments we're getting really I mean work like sort of fencing like access if we can get it its going to be crucial to doing the work." **LA6**

"You know when they say the 50%, there's a grant of 50% it invariably turns out to be more like 30%." **LA5**

"Because there's money going out with no you know they can maintain and upgrade footpaths etcetera at their own cost if needs be, you know where public access but where if there's no money to do the work there's no money to do the work and with regard to thinning etcetera and creating new footpaths" **LA7**

Figure 3.13: Quote reflecting the participants' perceptions of the Glastir payment rates for

A theme present across each focus group was the role of the public, both as a contributor through taxation to farming subsidies and as a driver of landscape evolution. Glastir as a novel agri-environment scheme has moved towards a payment for ecosystem services approach, with Welsh Government as the customer and the farmer as the supplier (Wynne-Jones 2013b). However it was unclear if this concept was one that the farming community engaged because Glastir and Single Farm Payments were discussed simultaneously in the discussions. The concept that woodlands would help to offset the carbon emission from agriculture was accepted as a powerful driver of woodland planting targets, but there was a concern about whether this would impact consumer choices. There was a perception that the public has a lack of understanding about the true cost, both financial and in terms of land management, of food production. There was a sense of frustration and a feeling of under appreciation for the care and management for the countryside that farmers undertake, which also manifested itself in a frustration about the fact that Glastir payments are only made on work to be done, rather than compensating work that has been already been undertaken.

"there's a great number of people who have another job and a lot of people are subsiding farming" **R1, Abergavenny**

"our food prices are just way too low, always have been, possibly always will be and until we can relate to the consumers and say 'you think its expensive but its not' because they don't realise how much money is going out in the Single Farm Payment, its almost like there a middle man giving us money to keep the consumers quiet and once we tell the consumers that they're actually not paying, very little for their food and we actually [?] payments through the back pockets through the Single Farm Payment then we might then work out whether we are profitable or now and whether people want us to be profitable or they want us to be just farm keepers really." **R1, Abergavenny**

"If you've got a nice little woodland that's well managed and well fenced in the last five years and haven't had grants on it otherwise we will pay you for that effort instead of this applying to do this and do that but lets look at people's conservation and say yes that, it would be better to reward them for what they've done." **R3, Wrexham**

Figure 3.14: Quotes highlighting the role of the public in agricultural profitability and the desire for acknowledgment of the environmental stewardship role most farmers undertake.

4.0 Conclusions

This research has highlighted the complicated nature of landowners' (farmers and Local Authorities) relationships with Glastir and how this relates to attitudes towards woodland creation and management. On the one hand, there appears to be little evidence that farmers do not want woodland on their land or that Local Authorities are not actively managing their woodland holdings. Moreover, there were positive reactions to landscape images that included woodland from the farming community. Yet on the other hand, there are significant barriers to be overcome if either publically or privately owned land is to contribute towards the Welsh Government's 100,000 ha target. A balanced, straightforward and flexible scheme needs to be created that allows woodland creation and management to be carried out in keeping with the needs of both farmers and LAs.

4.1 Compatibility of Glastir Woodland elements and farming culture

The provision for woodland creation and management within Glastir do not appear to be compatible with key attribute of farming culture, as identified by the farming community who participated in this research. The perceived lack of flexibility in the scheme means that several participants explicitly stated that they would plant woodland, but not under Glastir. The prescriptive nature of the Glastir scheme (In terms of size and widths) is also a barrier because it prevents many landowners from being allowed to create woodland on parts of their farms which best suit their needs, i.e. small disparate patches which are unused, irrespective of farm size. It is important to recognise that farming is a business and needs to be profitable; moreover, farming as a culture with strong values and attitudes means that that a focus on adapting Glastir to suit the farmers is going to have a greater chance of success, both in the short and long term, rather than trying to change farming values and attitudes. The prescriptive nature of Glastir also prevents Local Authorities for engaging with the scheme fully, and represents missed opportunities for funding woodland management above the minimum required from LA's.

4.2 Streamlined Glastir Process

Many of the general comments about Glastir related to the process of entering the scheme; although this does not directly impact Glastir Woodland Creation or Management uptake, it is nevertheless a barrier to entering into any part of the scheme, which has an indirect consequence of reducing participant numbers in the woodland schemes. Scheme complexity was detrimental to both farmers and Local Authorities and was cited by some participants as a reason not to go in Glastir schemes. A more streamline process which still uses face-to-face consultations to help landowners decide on the most appropriate operations for their land management goals would help to alleviate frustration felt as a result of excessive paperwork and time taken to apply for the scheme. Clearly outlined simple objectives, alongside an in-built evaluation process to taka the place of the current auditing element, would allow scheme entrants to feel more at ease with what they should and should not be doing, and to try to remove the fear factor when it comes to auditing and penalties. The evaluation process would also allow increased flexibility in case of situations where work has not been possible due to weather conditions or other unforeseen circumstances.

4.3 Payment Rates

The payment rates under Glastir were perceived to be incompatible with the true cost of the work involve in either creating or managing woodlands. The Glastir scheme seeks to pay for ecosystems services that it believes would not be created or maintained otherwise; perceptions were that payment rates were not sufficient to overcome the other barriers to entering Glasitr (for example the perceived inflexibility of the scheme) and encourage participation across the board. Creating and managing woodland take time away from other tasks, particularly in the case of farmers, and represents a financial pressure for LA's in challenging economic times. Greater scheme uptake could be encouraged if payment rates included costing for labour (aside from the landowner's time) as many forestry operations require specialist equipment and/or personnel.

4.4 Final Reflections

Overall, these findings demonstrate that the gulf between farming and forestry appears not to be as significant in Wales as has been found elsewhere in the UK, suggesting that the that the 100,000 ha target is not unachievable. Indeed, Welsh farmers exhibit positive attitudes towards woodland that are not based on economics; many have planted or will be planting trees on their land and agree with the major tenets of Glastir. The major barriers to entry into the Glastir woodland scheme (both WC and WM) exist within the scheme itself, and do not reflect attitudes towards woodland. Remedial action to the design and attributes of the scheme based on these findings may yield a more customer-focused scheme and consequently higher rates of scheme uptake.

5.0 References

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. *Agriculture Ecosystems & Environment* **74:**19-31.

Bell, M. (1999). A surey of 50 farmers in Lancashire to determine their attitude to woodland planting and management. Countryside Commission, Forestry Commission, Lancashire County Council.

Betts, A. and Ellis, J. (2000). What woodland wners want: an attitude survey.

Bishop, K. (1992). Britain's new forests: public dependence on private enterprise. In: Gilg, A. (ed.) *Restructuring the countryside: Environmental Policy in Practice*. London: Ashgate Publishing Ltd, p. 254.

Blackstock, P. (2000). Farm forestry needs survey. Portadown: UAOS Ltd.

Burgess, P., Goodlal, G. and Wharton-Creasey, A. (1998). Bedfordshire Farm Woodland Demonstration Project: a baseline analysis of farm woodland in mid-Bedfordshire. Cranfield, UK: Cranfield University.

Burton, R. and Wilson, O. (2000). Farmers' resistance to woodland planting in community forests: the influence of social and cultural factors DeMontfort University.

Church, A. and Ravenscroft, N. (2008). Landowner responses to financial incentive schemes for recreational access to woodlands in South East England. *Land Use Policy* **25:**1-16.

Church, A., Ravenscroft, N. and Rogers, G. (2005). Woodland owenrs attitdues to public access provision in SE England. School of Environment, Edinburgh University.

Crabtree, J., Chalmers, N. and Barron, N. (1998). Information for Policy Design; Modelling Participation in a Farm Woodland Incentive Scheme. *Journal of Agricultural Economics* **49:**306-320.

Cunningham, S. (2009). FREEwoods Survey. Woodlands Trust.

Dandy, N. (2009). Summary of Wood Fuel Work. Forestry Commission.

Gasson, R. and Hill, P. (1990). An economic evaluation of the Farm Woodland Scheme. Occasional Paper No. 17. Wye College: Department of Agricultural Economics, Farm Business Unit

Lawrence, A. and Dandy, N. (2014). Private landowners' approaches to planting and managing forests in the UK: What's the evidence? *Land Use Policy* **36:**351-360.

Lawrence, A., Dandy, N. and Urquart, J. (2010). Landowner attitudes to woodland creation and management in the UK. Farnham, UK: Forest Research.

Nijnik, M. and Bizikova, L. (2008). Responding to the Kyoto Protocol through forestry: A comparison of opportunities for several countries in Europe. *Forest Policy and Economics* **10:**257-269.

Osmond, J. and Upton, S. (2012). Growing Our Woodlands In Wales: The 100,000 Hectare Challenge. Cardiff, UK: The Institute of Welsh Affairs.

Secker Walker, J. (2009). Private landowners engagement with woodfuel production: a scoping study in Fife. Forestry Commission; Social and Economic Research Unit.

Sharpe, N., Osborn, E., Samuel, J. and Smith, R. (2001). Anglia Woodnet woodland assessment project: stage two. Summary report. Anglia Woodnet.

Silcock, P. and Manley, W. (2008). The impacts of the single payment scheme on woodland expansion. UK: Land Use Policy Group.

Sime, J., Speller, G. and Dibben, C. (1993). Research into the attitudes of owners and managers to people visiting woodlands. Surrey, UK: Jonathan Sime Associates.

The Woodland Trust. (n.d.). The Pont Bren Project. Cardiff: The Woodland Trust.

Urquhart, J. (2006). A qualitative analysis of the knowledge base of private woodland owners with respect to woodland management and public good health benefits. University of Gloucestershire.

Urquhart, J., Courtney, P. and Slee, B. (2009). Private ownership and public good provision in English woodlands. Small-scale Forestry.

Valatin, G. and Saraev, V. (2012). Natural Environment Framework: Woodland Creation Case Study. In: Sciences, C.f.H.a.E. ed. The Research Agency of the Forestry Commission.

Walker-Springett, K. (2014). Public Perceptions of Habitat Management Plans for the Freshwater Pearl Mussel in Response to Climate Driven Environmental Change. Cardiff, UK: University of Cardiff.

Ward, J. and Manley, W. (2002). New entrants to land markets: atttitudes to land management and conservation. Report to GB Wildlife and Countryside Agencies.

Watkins, C. (1984). The use of grant aid to encourage woodland planting in Great Britain. *Quarterly Journal of Forestry* **78:**213-224.

Watkins, C., Williams, D. and Lloyd, T. (1996). Constraints on farm woodland planting in England: A study of Nottinghamshire farmers. *Forestry* **69:**167-176.

Wavehill Consulting. (2009). A survey of farmers with woodland on their land. Wavehill Consulting.

Wynne-Jones, S. (2013a). Carbon blinkers and policy blindness: The difficulties of 'Growing Our Woodland in Wales'. *Land Use Policy* **32:**250-260.

Wynne-Jones, S. (2013b). Connecting payments for ecosystem services and agri-environment regulation: An analysis of the Welsh Glastir Scheme. *Journal of Rural Studies* **31:**77-86.

Appendix A: Literature Review

A-1 General attitudes towards forestry

No real tradition of farm forestry exists in in the UK, unlike other European countries (Burgess et al. 1998) and so there appears to be a tendency for farmers to see forestry as very distinct from agriculture. Moreover, some attitudes imply that using productive agricultural land for forestry is almost morally wrong (Watkins et al. 1996), as if because of productivity of the land is should only be used for agriculture and is a waste of such land (Bell 1999). Work by Walker-Springett (2014) shows that both farmers and those connected to rural locations, can have a utilitarian or anthropocentric attitude towards nature. Agriculture is perceived favourably because it produced a tangible output (i.e. food and money); the land is considered wasted if food production is limited as a result of a land use change where the services are less tangible such as flood alleviation or biodiversity enhancement. In a study in Scotland, concerns about food security were given as a reason for not planting trees on productive agricultural land (Secker Walker 2009).

Unlike crops or livestock, woodland creation takes a long time to mature and cannot be easily converted to other uses, unlike crop production which is much more reactive to market forces (Burton and Wilson 2000; Silcock and Manley 2008). Time scales are much longer and acceptance of grants means that the landowner is tied into to the scheme for a long period of time (Burton and Wilson 2000). The need for felling licences to return the land to agricultural use at the end of the scheme further compounds the belief that conversion to woodland is an irreversible decision (Bell 1999; Cunningham 2009).

The implication for agri-environmental schemes (e.g. Glastir) of this type of attitude is that those who take up grants use the least productive land. They might not be open to planting forest on the most appropriate or beneficial sites and therefore are unlikely to see benefits such as reduced runoff and erosion, which have been demonstrated by the farmers at Pont Bren (The Woodland Trust. n.d.). If farmers are not seeing the benefits of woodland creation, then there is no incentive for them to recommend the scheme to other farmers.

Attitudes towards agriculture stem predominantly from within the farming community; there is a social status achieved through good farming and the favourable aesthetics of crop management compared with the untidy appearance of woodlands (Bell 1999; Burton and Wilson 2000). Farming is evolving into the production of goods *and* services, which might subtly change attitudes toward forestry and its uses and aesthetic value. Burton and Wilson (2000) point out that to change farmers into farmer-foresters will require a change in the perception of what a good farmer actually means. The authors include the term 'leisure provider' in their farmer-forester description; this insinuates that by creating forest, farmers would then automatically become leisure providers, leading to issues such as accessibility and privacy, which have been given as reasons for landowners not to plant woodland. Farmers themselves state that they have less of a knowledge base concerning woodland (Bell 1999) thereby reinforcing the idea that farming does not include forestry. Secker and Walker (2009) suggest that this knowledge gap is a disincentive to attempt forestry management. However, in a previous study Betts and Ellis (2000) found that three-quarters of the farmers surveyed wanted more information about woodland management, suggesting that farmers have an interest in forestry management.

A-2 Socio-demographic influence on attitudes

Gasson & Hill (1999) found that younger farmers were more likely to plant woodland than older farmers. A study in the 1980s revealed that some farmers believed that the conversion of agricultural land to woodland was a long-term option, which might in part explain the reticence of older farmer to become involved in woodland creation schemes. Age is also linked to the prospective of financial returns from the woodland creation; Watkins et al. (1996) found participants felt that older farmers who planted trees were less likely to see a return on their investment. Alternatively, Silcock and Manley (2008) postulated that older famers might prefer the less labour intensive aspect of forest management, where forestry contractors can be used. In keeping with difference in attitude as a result of age, a line of succession for the farm leads to more active management of land in general, which can include woodland planting and management (Gasson and Hill 1990). If there is a clear succession then perhaps there will be a greater tendency for woodland creation, as the 'planter' would know that whilst s/he might not see the profits, his/her children would.

Public access to privately owned woodlands is seen as a barrier to woodland creation (Bishop 1992). Despite this, a study shows that only a few farmers were reluctant to allow access to their woodland (Church et al., 2005) . Whilst another study found that two thirds of respondents whose land includes pubic right of way have had no problems associated with the public access (Church and Ravenscroft 2008). Church and Ravenscroft (2008) also found that famers with woodland and allowed access, were happy to increase access provision. Sime et al. (1993) found that there was a hierarchy of groups that farmers were happy (and less happy to allow access to) for example bird watcher and local people were in the 'good' group, town dwellers were tolerated and mountain bikers and campers were discouraged.

In interview study involving Welsh Farmers by Wavehill Consulting (2009) found that the majority of participants actively use their woodland. In general a higher proportion of those who receive a grant use their woodlands for recreational purposes, as well as timber production and the enhancement of habitats for wildlife, than those who were not involved in a grant scheme (Wavehill Consulting 2009). Furthermore, a high proportion of those who receive a grant actively manage their woodland (i.e. thinning), although landowner perceptions of appropriate management is often not congruent with policy makers ideas of correct woodland management (Lawrence and Dandy 2014). Woodland is also commonly planted to provide or encourage: shelter for livestock (Burgess et al. 1998; Blackstock 2000; Wavehill Consulting 2009). Moreover, wildlife/conservation, sporting/recreation and shelter/boundaries are consistently the top aims of woodland owners who had received grants.

A-3 Efficacy of Grants

The provision of grants for woodland creation and management does not have a clear-cut effect on the quantity of woodlands created or managed. Watkins (1984) found that just under half of owners who participated in their study would have planted woodlands irrespective of grant availability. However, Sharpe et al. (2001) found that most woodland owners stated that more grants would encourage them to bring their woodland under management . But these studies focus on woodland owners who may or may not be farmers. Conflicting attitudes from participants who were and were not involved in commercial forestry were highlighted by Church and Ravenscroft (2008) who found that the majority of private owners of woodland not involved in commercial forestry felt that the grants were not relevant to their decision to plant woodlands as the woodland was not planted for financial return. However, the same study found that 60% participants who were involved in commercial forestry did state that grant were important in their decision-making. Crabtree and Appleton (1998) found that scheme payments under-compensate for direct and indirect costs of woodland creation, but in this case woodland creation was based on the conversion of high quality arable land to woodland.

Cunningham (2009) indicates that barriers to grant uptake include bureaucracy, and overly complex application process. Dandy (2009) indicates that the grants are perceived as not dependable and likely to decrease in the future. However, this would be partially nullified by the current practise of guaranteeing a fixed price for a period of time; but farmers recognise that this is still subject to the funding priorities of the EU. Conversely, a study in Wales found that 90% 0f those in receipt of Forestry Commission grants for woodland ranked the scheme as good or very good (Wavehill Consulting 2009); the most common reason for this was the financial incentives in place. Of those that had not received a grant, lack of knowledge was a key factor in determining that they not apply for a grant (Wavehill Consulting 2009). Whilst lack of knowledge about the available grants has been shown to be a barrier to uptake (Ward and

Manley 2002; Wavehill Consulting 2009), Crabtree et al. (1998) show that a lack of knowledge was strongly associated with other predictors of non-participation and concludes that is impossible to cite knowledge as the sole or main reason behind a lack of grant uptake.

Economic valuation exercises with landowners indicates that many woodland owners are not aware of the economic value of their woodland; this links with evidence from Sharpe et al .(2001) about the lack of economic incentive to manage woodlands and the perception that productive agricultural land would be wasted as forestry (Watkins et al. 1996). It is suggested that a lack of awareness of the potential revenue from woodland is a barrier to grant uptake (Lawrence et al. 2010). Revenue obtained directly through woodland (for example firewood etc.) are often not the main motivator for woodland creation (Blackstock 2000; Church and Ravenscroft 2008). Relatively few farmers use their woodland for commercial timber production (Church and Ravenscroft 2008) but this could be due to a lack of belief that woodland can offer large-scale economic returns (Burton and Wilson 2000). Conversely, Shape et al. (2001) found that 87% of woodland owners would be prepared to manage their woodland if this was a no cost to themselves (i.e. they broke even). In fact, woodlands are often unmanaged because it is not economically viable to do so (Sharpe et al. 2001). Secker Walker (2009) found that farmers do not perceive short rotation coppicing (SRC) (not eligible for Glastir payments) as giving a greater financial return than traditional agriculture and that the wood-fuel market is uncertain. The wood-fuel sector is seen as lacking a regional market structure, being complex, and having a lower long-term market viability (Dandy 2009). A report for Forestry Commission Scotland highlights the reliance of farmers in Scotland on unpaid family labour, which tends to artificially inflate farm profitability. Once this is factored out, forestry becomes more completive in comparison to more traditional agriculture.

Lack of suitable land is also a barrier to grant uptake, Watkins et al. (1984) found that the most frequent reasons given for not planting trees was not having suitable land to plant; under the Glastir scheme the smallest amount of land eligible for payment is 0.25 ha. The average size of the woodland in a grant scheme was 22 hectares compared with 5 hectares on average for woodland not in a grant scheme (Wavehill Consulting 2009). This links to general attitudes towards forestry, where spare, poor quality or less useful land is converted to forestry; smaller farms are less likely to have pockets of un-used land. The focus on the minimum entry size required by Glastir further restricts entry for those farmers who only have small pockets of land (Osmond and Upton 2012).

This also links with the previously discussed attitudes towards forestry; suitable land often means land that is not good enough for crop planting or livestock grazing (Bell 1999).

Additionally, an acceptance of grants is can be perceived as involving a loss of control over the land involved in the grant scheme (Sime et al. 1993; Urquhart 2006; Urquhart et al*.* 2009). Private woodland owners have been shown to have a strong sense of attachment to their woodland (Sime et al. 1993; Urquhart 2006) and to be against any loss of control, related to both public access and management regulations. Loss of control could be inadvertent as a consequence of environmental legislation and protection stemming from the woodland creation (Watkins et al. 1996).

Socio-economic evaluation of Glastir Efficiency Scheme

Helen Taft, Paul Cross & Dave Chadwick

afpc5c@bangor.ac.uk; Paul.Cross@bangor.ac.uk; d.chadwick@bangor.ac.uk>

School of Environment, Natural Resources and Geography, Bangor University

On behalf of the Glastir Monitoring and Evaluation Project

January 2015

JMMARY

Executive Summary

This report focuses on the Glastir Efficiency Scheme (GES), previously known as the Agricultural Carbon Reduction and Efficiency Scheme (ACRES). The GES provides grants to farmers and land managers to improve farm management, particularly to improve Slurry and Manure Efficiency (SME), Energy Efficiency (EE) and Water Efficiency measures (WE). Through these grants, GES aims to improve resource use efficiency and reduce the environmental effects of the agriculture sector, and in particular, the dairy sector. This study surveyed recipients of GES grants and evaluated the socio-economic impact of the scheme at a regional scale. We report herein on the following criteria:

- Grant allocation – the current status of approved grants, and grants in progress;
- Economic outputs and efficiency of farms;
- Labour – how employment has been impacted;
- The wider economy – farm expenditure, what money is being spent on imports and tax.

Of the 157 Glastir Efficiency Scheme participants in June 2014, 120 surveys were completed for analysis and discussion in this report. A total of 383 GES grants were approved and of these, 327 were awarded for SME, 39 for EE and 17 for WE measures.

Current status of GES grants

Of the 120 completed surveys, 59% of respondents farmed on LFA cattle and sheep farms, a further 30% on dairy farms, 7% of farms were described as ‘other’ consisting of various main farm types and 4% of farms did not specify. A total of 305 grants were approved for farms in the survey. EE grants accounted for 9.2% of total approved grants, 7.9% were assigned to dairy farms, 1.3% to ‘other’ farms and none to LFA cattle and sheep. Grants awarded to LFA cattle and sheep farms were nearly all for SME (174 of the 179 approved grants).

The total monetary value of the paid grants amounted to £1,006,490. No WE grants were in progress by July 2014. SME grants accounted for £883,000 and EE (£123,490). Lowland dairy farms received the largest grant per farm on average (£16,102), compared to £9,855 for LFA cattle and sheep farms and £8,732 for LFA dairy farms. The smallest size category of farms (0-19.9 ha) received the smallest average grant of £8,370.

Economic impacts of GES

Farm sales

As a consequence of the GES grants more than a quarter (28%) of farm businesses reported a general increase in sales with 51% reporting an increase in sales from farming specifically.

Farm expansion

The majority of members disagreed (71%) that expansion opportunities had been curtailed by GES.

Allocation of farm spending

More than 90% of respondents agreed that GES had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GES increased their scale of planned investment. Over 87% of farmers agreed that their funded project would not have happened without the grant. This suggests that GES has provided a useful tool for delivering economic development and encouraging new on-farm initiatives.

Impacts on labour

GES grants increased the annual workloads of existing employees, family members and farmers per farm per year. The workload for new employees and contractors decreased. The decrease in annual workload for contractors was greatest on LFA sheep and cattle farms. The farm type that saw the greatest increase in annual labour was lowland dairy farms.

Impacts on the wider economy

Farm expenditure

According to 77% of respondents, perceived farm viability to have increased as a consequence of receiving the grant, with 21% reporting no change. This appears to have been driven by the effect of GES grants on increased expenditure, with 52% reporting increases in expenditure. Of the 59 farms in LFA sheep and cattle, 43 reported a positive impact on changes in expenditure due to the grants.

Increased farm expenditure was spent within Welsh industries (68%), Welsh households (18%) and taxes (8%) with the remaining 6% unaccounted for due to respondent survey error.

Expenditure allocated to imports

Of the expenditure that respondents allocated to imported materials, the majority was for building materials (49%), and machinery and equipment (32%). Of these imports, 57% of spending was within the UK and Ireland; 8% reported a mixture of spending throughout the UK and European countries and 13% imported products from other European countries.

Financial effects

According to 71% of respondents, GES grants have promoted a beneficial effect on farm suppliers across all farm types. Similarly, 44% of respondents stated that farm customers and clients had experienced beneficial financial effects from the grants.

Recommendations

There were no grants in progress according to the progress report (WG, 2013). The number of WE grant types was considerably lower than for SME and EE, and it may be useful to further understand the drivers for this lack of uptake for WE grants. There were very few farms of <50 ha within the GES. There may be the potential for policy makers to consider developing grants suitable for smaller sized farms.

CONTENTS Page

1 INTRODUCTION

1.1 Background to the Glastir Efficiency Scheme

1.1.1 Background to the Glastir Scheme

The Glastir Efficiency Scheme (GES, formerly known as ACRES, the Agricultural Carbon Reduction and Efficiency Scheme) is a component of a wider Welsh Government agri-environment initiative known as Glastir. The Glastir scheme was set up as a means of merging the four existing Welsh Axis 2 agri-environment schemes (Tir Cynnal, Tir Gofal, Tir Mynydd, and the Organic Farming Scheme), into a new, single whole-farm sustainable land management initiative for farmers and land managers across Wales (WG 2014). This merger constitutes part of the Wales Rural Development Plan 2007-2013, and was made in response to the European CAP Health Check proposals (Rose 2011). The changes were driven by the need to move away from agri-environment schemes driven by paying farmers for production, to one emphasising the need for provision of environmental goods and services (known as Ecosystem Services), not usually supplied through standard market mechanisms (Wynne-Jones 2013; Reed *et al.* 2014). Under the new scheme, farmers and land managers are paid by the Welsh Government on behalf of society, for the provision of Ecosystem Services (e.g. climate change mitigation and adaptation; management of water quality and quantity; soil quality enhancement; facilitating recreational access; and strengthening social capital; (Reed *et al.* 2014). Glastir attempts to meet the need for greater integration between schemes to attain a wider and more efficient delivery of environmental services for society (Reed *et al.* 2014), whilst simultaneously improving farmers' connections to markets and strengthening rural development measures under the Welsh Rural Development Plan (WG 2014) and Axis 2 of the Common Agriculture Policy (CAP) Rural Development Pillar (Rose 2011).

1.1.1.1 Glastir objectives

The stated objectives of the Glastir scheme are (Rose 2011):

- To provide balance between the need to produce food and protect the environment;
- To be accessible to all;
- To support biodiversity, climate change and water outputs; and

- To spread money for implementing agri-environment work more widely among farmers.

1.1.1.2 Glastir scheme structure

Glastir is a five-year, whole-farm, sustainable land management scheme available to farmers and land managers across Wales. It comprises five elements: Glastir Entry, Glastir Commons, Glastir Advanced, Glastir Efficiency Grants, and Glastir Woodland Creation and Management (WG 2014). Each component is summarised below:-

Glastir Entry (All-Wales Element, AWE)

Glastir Entry is the Welsh foundation level agri-environment scheme, open to all farmers who have full management control of more than three hectares of land for the entire length of the five-year contract. Participation in the Entry level is required for eligibility to participate in all other scheme elements, with the exception of the Common Land and Woodland Creation elements. The whole-farm entry-level component is based on a points systems, where a combination of compliance with compulsory requirements, and customised choices of optional management activities, allow farmers to build up enough points to exceed the minimum eligibility threshold. It comprises three main parts: cross-compliance, the Whole Farm Code (WFC), and management options.

Cross-compliance constitutes a set of compulsory requirements that apply to all agricultural land on the farm holding. Land managers must meet standards of Good Agricultural and Environmental Condition (GAEC), concerning the protection of soil, habitats and landscape features. Additionally, cross-compliance requires farmers to meet a range of Statutory Management Requirements (SMRs) relating to the environment, public and plant health, animal health and welfare, and livestock identification and tracing. Adherence to the WFC on all land included in the contract, is a further compulsory element of Glastir Entry. The WFC comprises standards of good environmental practice, in terms of slurry spreading, manure and silage storage, rock extraction and vegetation burning. Regarding management options, farmers are required to select individual options from a list or choose from a package of options which deliver the greatest environmental benefits within a particular region.

Further to Glastir Entry, four higher level (optional) elements of the scheme are currently available:

Glastir Advanced

Glastir Advanced (previously known as the Targeted Element) was designed as an attempt to overcome reported shortcomings of previous higher-level agri-environment schemes, which were thought to have been too disparate and poorly focused to deliver significant environmental benefits (WG 2014). Candidate farms are selected for eligibility under the current Advanced scheme, on the basis of their potential for delivering environmental benefits in the key areas of soil carbon management, water quality, water quantity management, biodiversity, the historic environment, and improved access. Priority is given to applicants with the highest resulting score, based on the potential to deliver the greatest overall environmental benefit from their land.

Glastir Commons

The Glastir Commons scheme (previously named the Common Land element), was designed for farmers with Common Land rights, who are also members of a Grazing/Commoners' Association. Payments are made for adhering to either a closed grazing period over three months of the winter period (1st November to 31st March), or managing sward height throughout the year by varying stocking densities. The Glastir Commons component aims to deliver key environmental benefits relating to peatland carbon and water storage, which are important functions of Welsh Common Land.

Glastir Efficiency Scheme

Previously known as the Agricultural Carbon Reduction and Efficiency scheme (ACRES), the Glastir Efficiency Scheme (GES) provides capital grants to farmers and land managers to improve resource use efficiency and reduce the environmental imnpacts, including greenhouse gas emissions, from the agriculture sector. The scheme originally prioritised renewable energy generation outcomes, but this aspect was removed after being superseded by the UK-wide Feed in Tariffs (April 2010) and Renewable Heat Incentives (July 2013). At present, grants contributing to 40-50% of costs are available for a specific range of capital works relating to reducing on-farm energy use (Energy Efficiency), management of animal excreta and associated waste (Slurry/ Manure Efficiency), and minimising waste water generation (Water Efficiency). Grants currently available are particularly aimed at encouraging dairy farmers to take part in agri-environment schemes, in some cases for the first time.

Glastir Woodland Creation and Management

Originally functioning as a stand-alone initiative for both farmers and other woodland owners, the Glastir Woodland Creation and Management Scheme was integrated into the Glastir Scheme in January 2013. It was developed in response to the Climate Change and Land Use Report (Glastir Independent Review Group, 2011). This element of Glastir currently provides financial support to both farmers and non-farmers for managing existing continuous woodlands larger than 0.5 ha in size. Capital and multi-annual payments are provided in support of managing existing woodland and creation of new woodland, including income foregone as a result of change in land use. Payments are prioritised for delivering the following: managing soils to help conserve carbon stocks and reduce soil erosion; improving water quality; managing flood risks; conserving and enhancing wildlife and biodiversity; managing and protecting landscapes and the historic environment; and providing new opportunities to improve access and understanding of the countryside.

1.2 Socio-economical trickle down impacts in rural areas

Rural areas in Wales account for 82% of the total area and contain one third of the total population (OECD 2011). Agri-environment schemes are implicit in their support of agricultural economies, reflecting an understanding of the defining relationship between farming and the rural landscape (Davies-Jones 2011). Agriculture plays a dominant role in land-use, and in some regions it continues to play a pivotal role in the local economy (OECD 2010). Without adequate financial support, farmers may be unable to continue to farm, resulting in a loss of skills and neglected land, with subsequent environmental and socio-economic implications beyond the farm gate (e.g. less money for the local economy, movement of the young population sector to cities). Consequently, this poses a threat to the Welsh tourist industry, culture and language (Davies-Jones 2011).

Glastir seeks to move the basis of payment for farms from production-based to environmental outcome-based payments, whereby farmers are paid for providing environmental goods and services (Wynne-Jones 2013). Agricultural policies are important for those who obtain their livelihood from the agricultural sector, not only from farming but also in related upstream and downstream industries, or through activities associated with agriculture (e.g. forestry and tourism). The significance of agriculture for the rural economy can be amplified through linkages to agro-food industries and employment in these industries (OECD 2010; OECD 2011). The trickledown effect of agriculture in rural areas is important for the continuation of a sustained rural community, one which can potentially be enhanced by agricultural policies such as Glastir, by promoting 'sustainable intensification' on farms (Caballero 2011). There are many potential direct and indirect trickledown effects. A simple example offered by Glastir would be the construction of a new manure shed as a result of extra funding provided by the GES, whereby raw materials are bought locally, and local workers contracted in to construct the manure shed. On a larger scale, better land management could lead to increased biodiversity, increased tourism and increased spending in local communities. The key feature is that on-farm developments should have a beneficial trickledown effect to the wider rural community.

2 PROJECT AIMS AND OBJECTIVES

This study aimed to improve understanding of the current status of grants within GES and to evaluate the wider economic benefits to farmers and the Welsh economy.

2.1 Objectives

The key objectives of this project were:

- to summarise the current status of approved GES grants, and grants in progress;
- to assess the impact of GES grants on economic outputs and efficiency of farms;
- to determine the effect of GES grants on employment ;
- to better understand the impacts of GES grants on the wider economy.

3 METHODS

3.1 Survey structure

The survey comprised 33 questions, which aimed to assess the effect of GES grants on economic output and efficiency, farm spending, farm labour and the wider economy for each farm. To alleviate respondent burden when completing the survey, 25 Likert Scale questions were included, while the remaining eight questions were of an open-ended format. Where possible, answers to open-ended questions were grouped for the purposes of analysis. A copy of the survey is provided in Annex 1 (at the end of this report). All proportions were rounded-up to the nearest whole integer.

3.2 Data collection

All farmers from the 157 GES-participating farms were invited to complete the survey, initially by postal contact, followed by telephone calls made within a month of initial contact. Data was collected between November 2013 and July 2014.

Farms types and sizes follow the DEFRA categorisation of robust farm types (DEFRA 2010).

4 RESULTS

4.1 Participant response rate and characteristics

The survey participation rate attained 75% of the total GES member population (120 farmers agreed to complete the survey, from the original 157 Glastir Entry members invited).

4.1.1 GES-participating farms

Of the 157 farms awarded GES grant funding, the majority were LFA cattle and sheep farmers (93 farms), while the remainder were primarily dairy farmers (34 lowland dairy, and 14 LFA dairy farms). Only 16 farms were designated to other farm type categories, including 4 farms of unspecified type (Fig. 4.1).

Only three participating farms were smaller than 50 hectares. Most farms were 50 to 199.9 ha in size (92 farms), while the remainder were more than 200 ha in size (58 farms; Fig. 4.2). The average size of surveyed farms (189 ha) was larger than both the average farm size for the 2378 farms in the Glastir Entry level scheme (93 ha), and the average size of all Welsh agricultural holdings (41 ha; (WG 2014)).

4.1.2 Survey-participating farms

The distribution of survey respondents amongst both farm type and farm size categories closely matched the distribution of GES-participating farms, resulting in a robust representation of almost all classes of farms (Fig. 4.2.). In terms of farm type, LFA dairy and lowland cattle and sheep farms were slightly under-represented (approximately half of farmers from each group took part in the survey). In the farm size categories, the larger farms were slightly less well represented in percentage terms than the smallest farms (up to 19.9 ha in size).

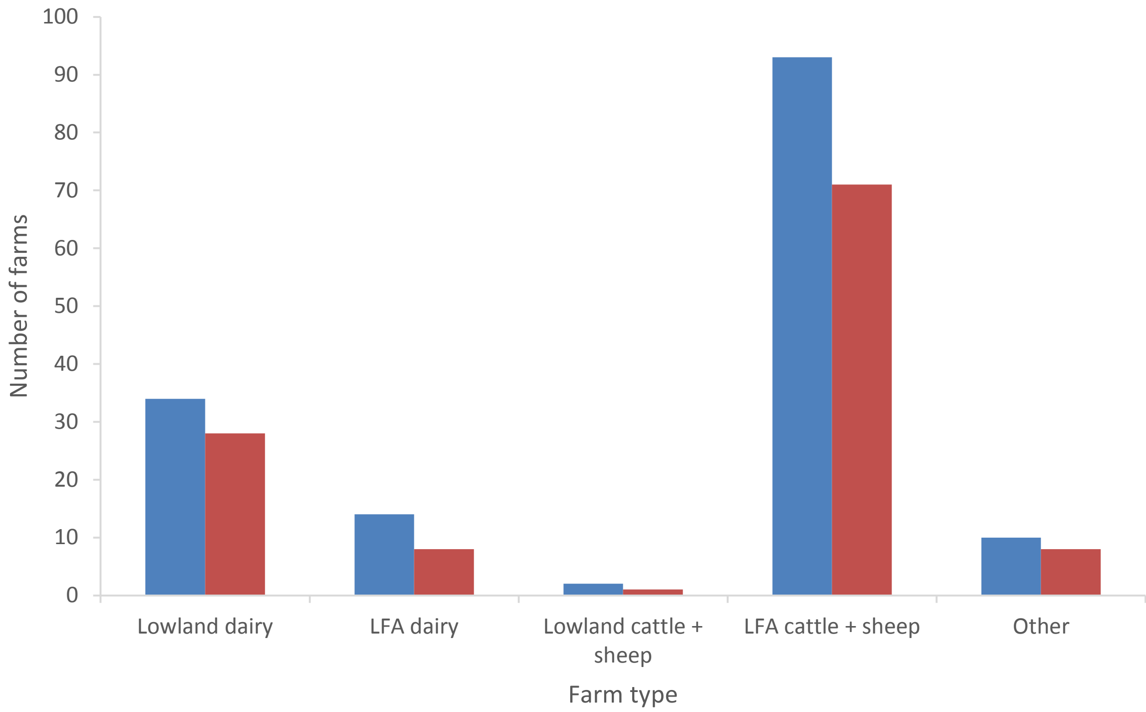


Figure 4.1. Number of participating farmers in GES (blue bars) and the survey sample (red bars), by farm type. 'Other' farm types include mixed livestock and cropping, and specialist poultry farms.

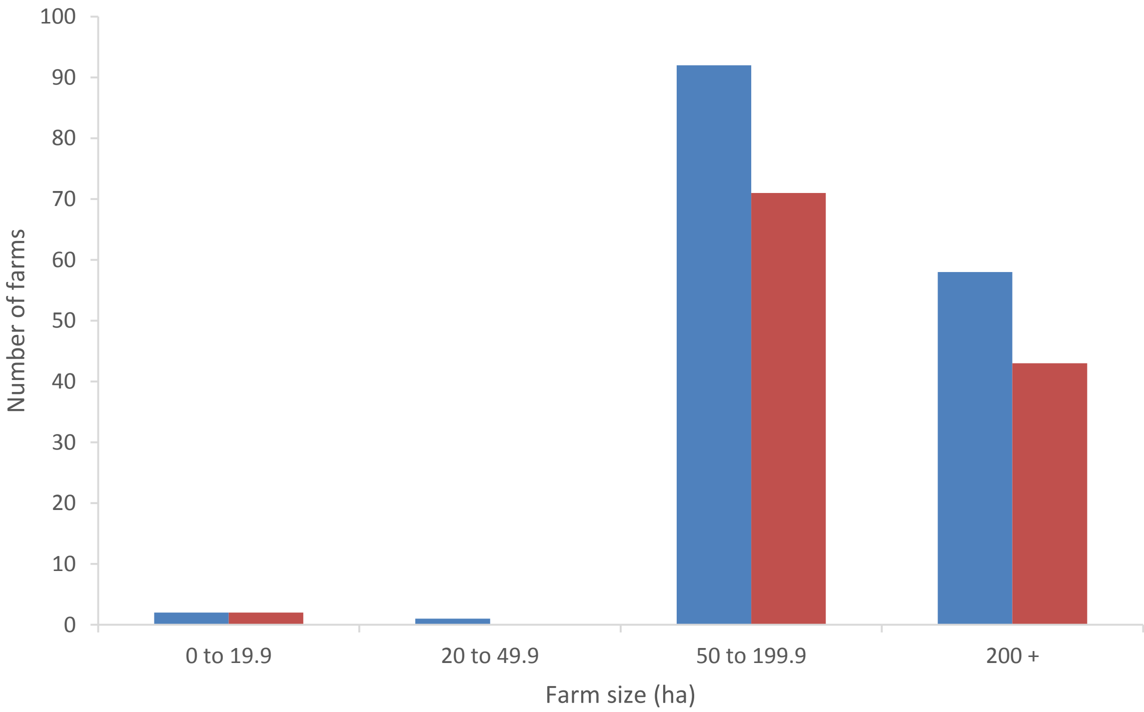


Figure 4.2. Number of participating farmers in GES (blue bars) and the survey sample (red bars), by farm size (ha).

4.2 Employment characterisation

The majority of those employed on the farms were family workers, with a strong bias towards full-time male workers (34% of all workers; Table 4.1.). Full-time male workers worked the longest average hours per week (71 hours), and were employed on the largest number of farms (113 farms). Full-time female family workers worked the second-longest hours per week (50 hours), but in lower numbers (49 workers), and on fewer farms (43 farms). In addition to family workers, many farms also employed additional (again, predominantly male) full-time and part-time workers. In contrast to family workers, female employees worked a similar number of hours per week to male employees.

Table 4.1: Proportion of workload by employee type

Employee type	Total employees	Farms with employee type	Average hours per employee per week
Full-time male family workers	181	113	71
Full-time female family workers	49	43	50
Part-time male family workers [1]	51	37	29
Part-time female family workers [1]	46	37	19
Seasonal male family workers	30	16	-
Seasonal female family workers	10	10	-
Full-time male employees	45	25	46
Full-time female employees	4	3	43
Part-time male employees [1]	71	36	18
Part-time female employees [1]	2	2	22
Seasonal male employees	34	17	-
Seasonal female employees	5	4	-

Notes: [1] *Part-time workers are assumed to work up to 30 hours per week.*

Both family and non-family seasonal workers were also employed by farms, but made up a much smaller proportion of workers than full or part-time workers.

4.3 Grant allocation

4.3.1 Approved grants

The grants allocated to farms were categorised into the following three types: Slurry and Manure Efficiency (SME); Energy Efficiency (EE) and Water Efficiency (WE). A total of 383 grant requests were approved across the 157 GES participants (Fig. 4.3 and 4.4). Of these, 327 were awarded for SME measures, 39 were awarded for EE measures, and 17 were awarded for WE measures. Most individual grants were awarded to LFA cattle and sheep farms (58.7%), with a further 23.0% awarded to lowland dairy farms (Fig. 4.3). Farms of 50 to 199.9 ha in size received the greatest number of grants (61.6%); the majority of remaining grants were allocated to farmers > 200 ha in size (33.4%; Fig 4.4).

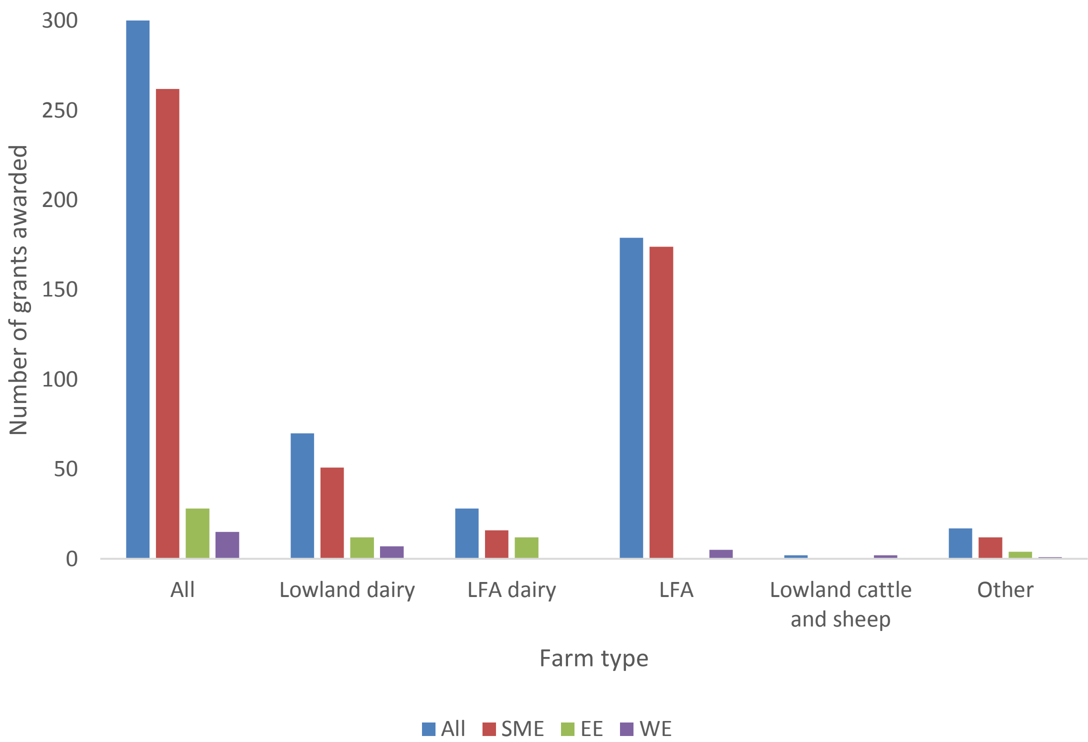


Figure 4.3. Grants approved for GES-participating farms, by farm type and grant type. Slurry and Manure Efficiency (SME); Energy Efficiency (EE) and Water Efficiency (WE)

A total of 305 grants were approved across the survey sample farms, of which the majority were SME grants (86%; Table 4.2). With respect to farm size, the largest portion of grants had been approved for larger farms, primarily in the 50 to 199.9 ha size category (62%). Most of the approved grants were allocated to LFA cattle and sheep farms (59%), while lowland dairy farms received 23% of grants.

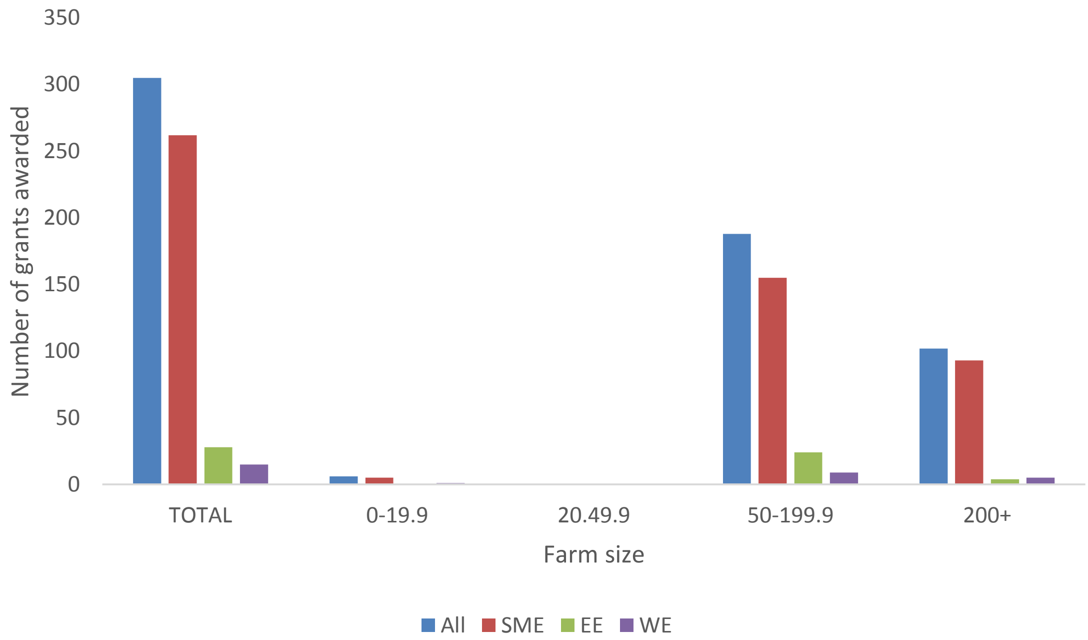


Figure 4.4. Grants approved for GES-participating farms, by farm size and grant type. Slurry and Manure Efficiency (SME); Energy Efficiency (EE) and Water Efficiency (WE)

Table 4.2. Grants approved by farm size and type (with proportion of total approved grants in parentheses)

Farm size and type	All	SME	EE	WE
TOTAL	305 *(100%)*	262 *(86%)*	28 *(9%)*	15 *(5%)*
0 to 19.9 ha	6 *(2%)*	5 *(2%)*	0 *(0%)*	1 *(0.3%)*
20 to 49.9 ha	0 *(0%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
50 to 199.9 ha	188 *(62%)*	155 *(51%)*	24 *(8%)*	9 *(3%)*
200+ ha	102 *(33%)*	93 *(30%)*	4 *(1%)*	5 *(2%)*
Unknown size	9 *(3%)*	9 *(3%)*	0 *(0%)*	0 *(0%)*
Lowland dairy	70 *(23%)*	51 *(17%)*	12 *(4%)*	7 *(2%)*
LFA dairy	28 *(9%)*	16 *(5%)*	12 *(4%)*	0 *(0%)*
LFA cattle and sheep	179 *(59%)*	174 *(57%)*	0 *(0%)*	5 *(2%)*
Lowland cattle and sheep	2 *(1%)*	0 *(0%)*	0 *(0%)*	2 *(1%)*
Other	17 *(6%)*	12 *(4%)*	4 *(1%)*	1 *(0.3%)*
Unknown type	9 *(3%)*	9 *(3%)*	0 *(0%)*	0 *(0%)*

4.3.2 Grants in progress

By October 2013, the overall percentage of grants in progress as a proportion of approved grants was 33% (Table 4.3; (WG 2013)). More than half (57%) of approved EE grants were in progress by the same date, but only 32% of approved SME grants. No approved WE grants were in progress. No EE grant money had been paid to LFA cattle and sheep farms. Overall, the majority of grants in progress were received by farms in less favoured areas (LFA) (70%), and by farms of 50 to 199.9 ha in size (68%).

Table 4.3. Grants in progress (as a proportion of category's approved grants in parentheses)

Farm size and type	All	SME	EE
TOTAL	100 *(33%)*	84 *(32%)*	16 *(57%)*
0 to 19.9 ha	2 *(33%)*	2 *(40%)*	0 *(0%)*
20 to 49.9 ha	0 *(0%)*	0 *(0%)*	0 *(0%)*
50 to 199.9 ha	68 *(36%)*	53 *(34%)*	15 *(63%)*
200+ ha	27 *(26%)*	26 *(28%)*	1 *(25%)*
Unknown size	3 *(33%)*	3 *(33%)*	0 *(0%)*
Lowland dairy	19 *(27%)*	13 *(25%)*	6 *(50%)*
LFA dairy	13 *(46%)*	6 *(38%)*	7 *(58%)*
LFA cattle and sheep	57 *(32%)*	57 *(33%)*	0 *(0%)*
Lowland cattle and sheep	0 *(0%)*	0 *(0%)*	0 *(0%)*
Other	8 *(47%)*	5 *(42%)*	3 *(75%)*
Unknown type	3 *(33%)*	3 *(33%)*	0 *(0%)*

4.3.3 Grant money received

The total monetary value of grants received by October 2013 was £1,006,490, of which £883,000 was awarded as SME grants and £123,490 as EE grants (Table 4.4.). The average grant value awarded per project was £10,988. Lowland dairy farms tended to receive larger grants, with an average of £16,103 per individual grant compared to an average grant value of £9,855 for LFA cattle and sheep farms. Farms with 50 to 199.9 ha of land received the largest average grant of £11,534, with farms of 200+ ha receiving £10,005 on average. Farms in the 0 to 19.9 ha category received the lowest average grant (£8,370).

Table 4.4. Total and average monetary values of grants by grant type, farm type and farm size

Farm size and type	Total (£)			Average per grant (£)		
	ALL	SME	EE	ALL	SME	EE
0-19.9 Ha	16, 741	16, 741	-	8, 370	8, 370	-
20.49.9 Ha	-	-	-	-	-	-
50-199.9 Ha	703, 770	583, 421	120, 348	11, 534	11, 875	8, 827
200+ Ha	258, 658	255, 515	3, 143	10, 005	10, 409	3, 143
Unknown size	27, 324	27, 324	-	10, 228	10, 228	-
Lowland dairy	257, 054	225, 848	31, 205	16, 103	19, 413	4, 775
LFA dairy	89, 759	63, 884	25, 875	8, 732	12, 942	2, 988
LFA c+s [1]	540, 459	540, 459	-	9, 855	9, 855	-
Lowland c+s [1]	-	-	-	-	-	-
Other	91, 897	25, 486	66, 411	10, 606	7, 201	20, 822
Unknown type	27, 324	27, 323	-	10, 228	10, 228	-
Total	1, 006, 493	883, 001	123, 491	10, 988	11, 298	8, 117

[1] *Less favoured area cattle and sheep.*

4.4 Economic impacts of Glastir Efficiency Scheme

By October 2013, 60 of the 120 survey farms had received approved funding for capital investments, and of the 157 farms to whom the survey was sent, a further nine farmers declined to complete the questionnaire as they had not yet received the grant. The following sections describe the impact on the Welsh economy of the Glastir Efficiency Scheme, based up on the 120 completed surveys.

4.4.1 Economic outputs and efficiency

Respondents considered that the GES grants increased the value of sales for 28% of farms, while the majority of farmers (63%) suggested that the value of sales had not changed (Fig. 4.5). Only a small proportion of farmers (3%) said that the value of their sales had decreased since obtaining grants.

When considering the overall impact of GES grants on sales from farming, most farmers reported no change (48%), while a further 33% reported 'little positive impact' and almost a fifth of respondents stated an 'important positive impact' (18.3%) (Fig. 4.6.). Very few

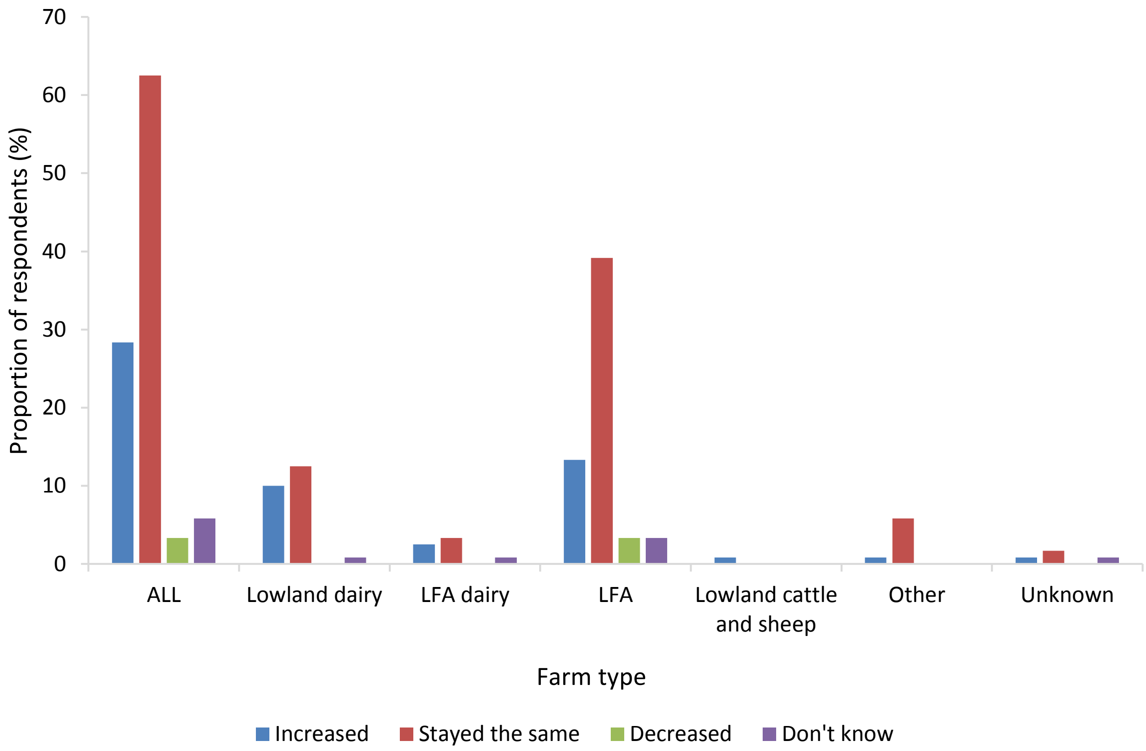


Figure 4.5. Impact of receiving GES grants on the value of sales

farmers said GES grants had had a negative impact on sales (< 1%).

4.4.2 Allocation of spending

Access to GES grants appears to have encouraged new capital investment by farmers in all farm type categories (Fig. 4.7). It was agreed by 65% and strongly agreed by 28% that the grant had encouraged them to undertake new capital investments, whilst only 5.9% of

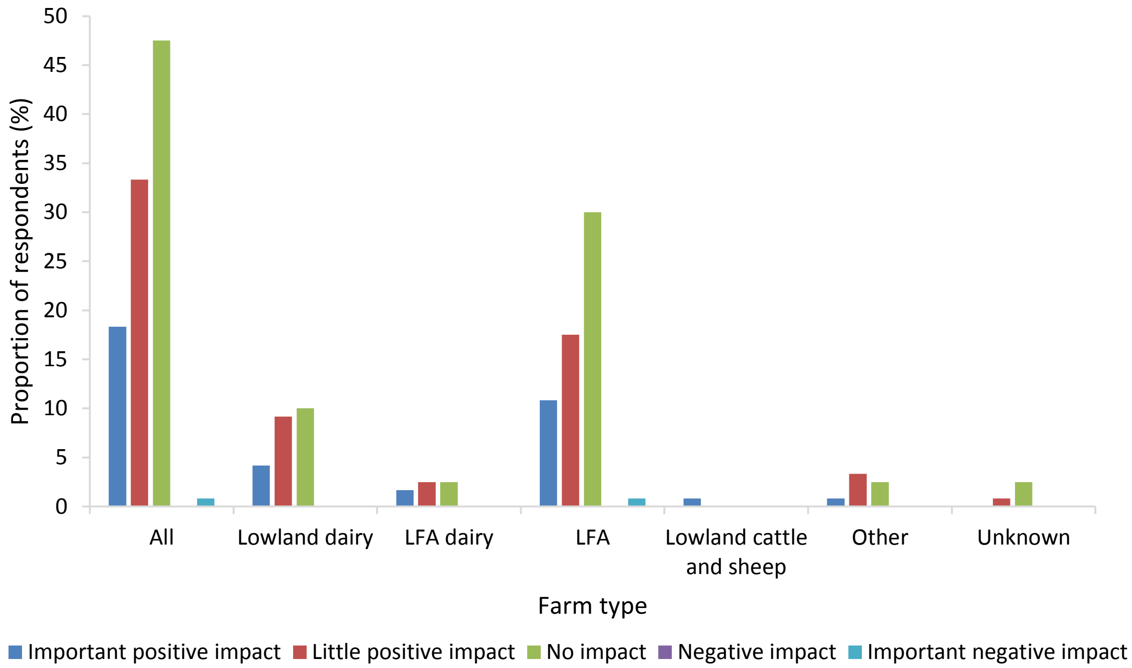


Figure 4.6. Impact of GES grants on sales from farming.

farmers disagreed with this statement.

Access to GES grants appears to have helped farmers to increase the scale of their planned investments, with 16% strongly agreeing, and 67% agreeing with the statement 'Access to the Glastir Efficiency Scheme (ACRES) grants encouraged you to increase the scale of planned investments'. Only 12% of respondents disagreed or strongly disagreed with the statement (Fig. 4.8). More than half of the respondents (55%) agreed, and one third (32%) strongly agreed that the funded project would not have happened without the grant, while

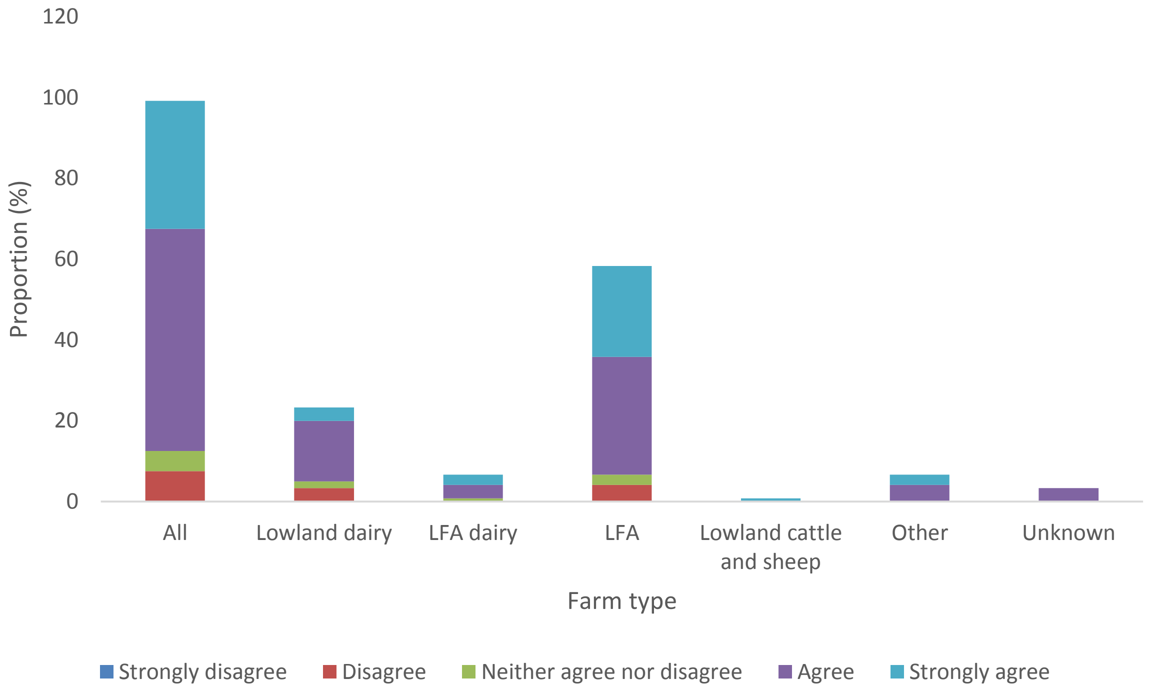


Figure 4.8. Degree of agreement that funded projects would not have happened without receiving GES grants.

only 8% of farmers disagreed with that this was the case (Fig. 4.8).

More than half of respondents reported the grants having no impact on all but two sectors of farm expenditure. Fertiliser annual expenditure was positively impacted by the grants on 75% of farms (Fig. 4.9). Labour expenditure was positively impacted in 50% of cases, and 40% of contractor expenditure. Negative impacts were reported by a minority of farmers (2-7%, depending on sector), with the largest negative impacts for contractors and building materials expenditures (7% of respondents in both cases), while the least frequently reported negative impact was on veterinary fees (2%).

Only a few respondents were able to provide monetary values for reduced expenditure. Spending on fertilisers was reduced by an average of £3,291 per farm (46 farms; range from £500-£20,000), on-farm purchases by an average of £2,375 (22 farms), and chemicals by an average of £425 per farm (4 farms).

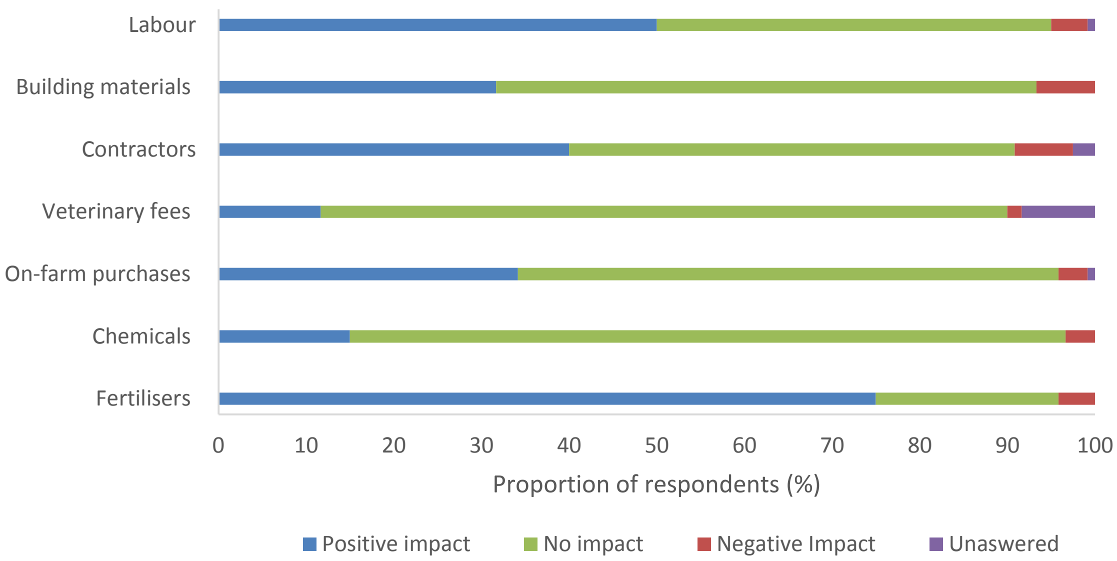


Figure 4.9. Respondents’ perception of grant impact on different sectors of on-farm expenditure.

4.4.3 Impacts on labour

On average, existing employees, family members and farmers found their annual workloads increased as a result of receiving GES grants, when aggregated across farm types (Fig. 4.10), possibly as a result of on-farm decisions to maximise the proportion of GES funding allocated to material purchases by minimising direct labour costs. In contrast, a net decrease in annual labour-days was experienced by contractors and new employees averaged across all farm types. However, an average decrease in annual labour-days was experienced on LFA cattle and sheep farms (71 farms), for contractors (3.3 labour days per farm per year), and for new employees (0.8 days per farm per year). This appeared to be countered by an annual increase of annual labour-days on lowland dairy farms (28 farms) for both existing employees (10.7 days per farm per year), and for contractors (4.3 days per

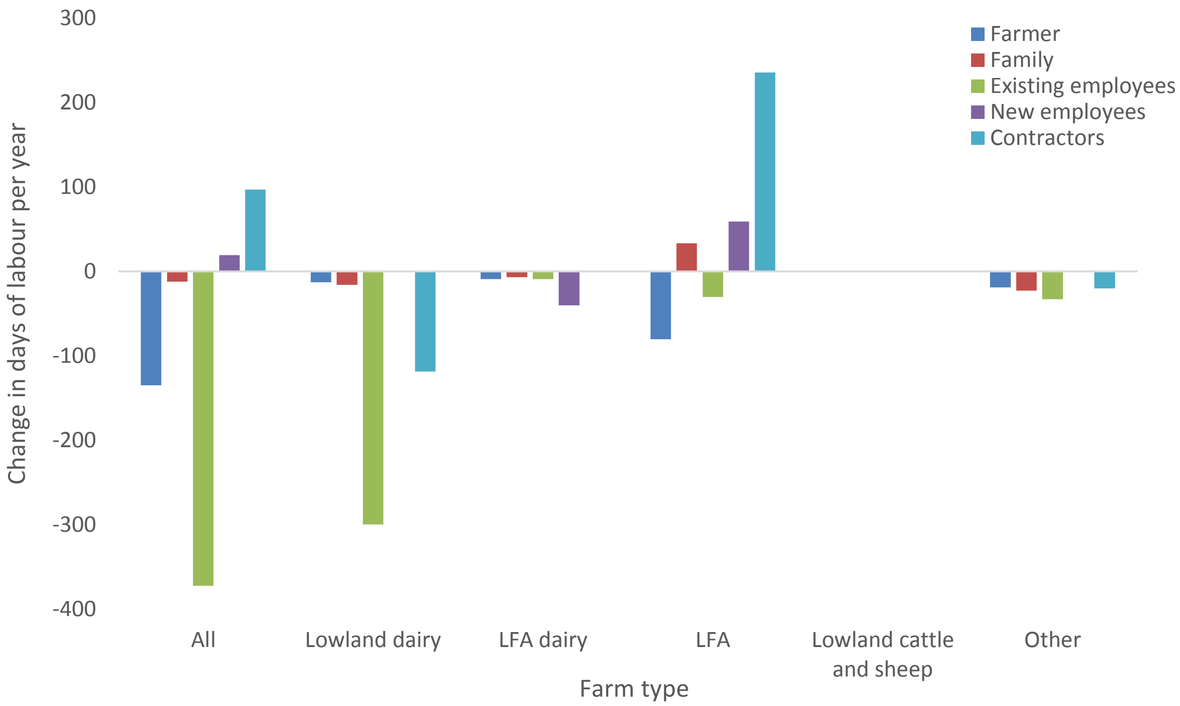


Figure 4.10. Net annual change in days of labour per year by farm type.

farm per year).

The impact of grants on labour varied across farm size categories. No change in annual labour-days worked was reported from farms of less than 50 ha in size (omitted from Fig. 4.11). Farms of 50 to 199.9 ha in size experienced an overall increase in workload, for all worker categories, and for existing employees in particular (Fig. 4.11). Conversely, farms of more than 200 ha in size showed a decrease in annual labour-days across all categories except for ‘existing employees’, with contractors losing the greatest number of additional days of labour (5 days per farm per year).

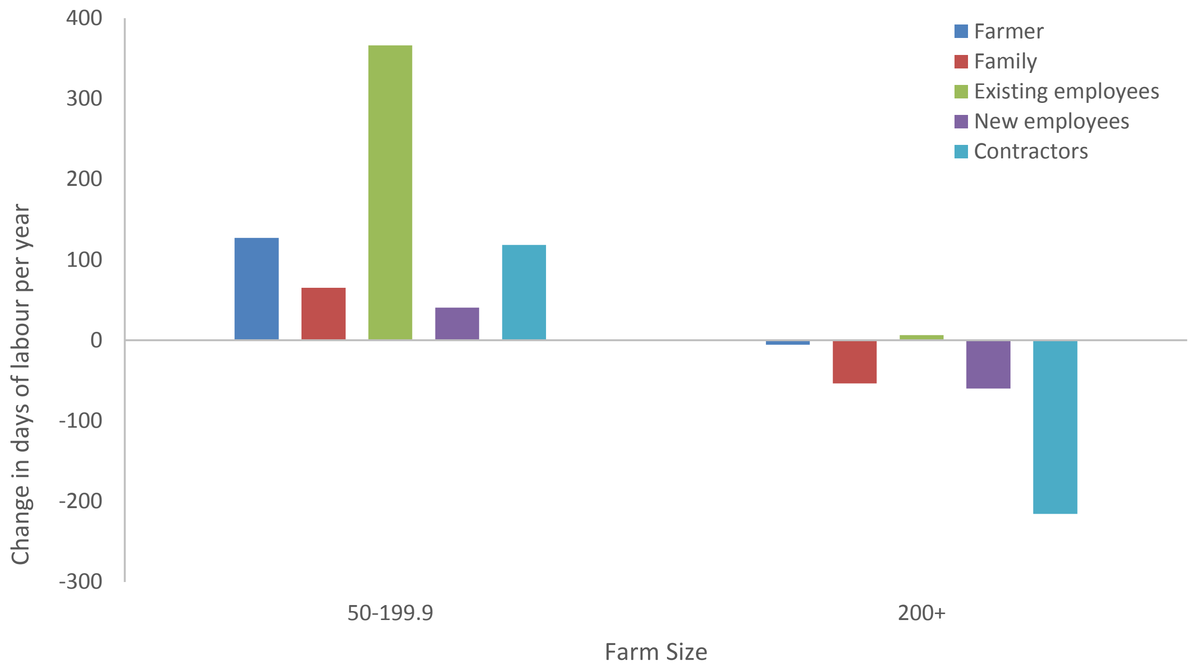


Figure 4.11. Net annual change in days of labour per year by farm size (ha).

Few respondents reported that their weekly working hours would have been different without GES grants. An increase in labour-hours worked per week on receiving grants was only experienced by 12 farmers (25.7 hours per week), while 10 farmers stated that they would have worked an additional 18.6 hours per week, had they not received GES grants.

4.4.4 Impacts on the wider economy

4.4.4.1 Farm viability

Farm viability was perceived by 77% of respondents to have increased due to GES grants, while 21% stated that farm viability remained unchanged (Fig. 4.12). As a proportion of the respondents within each farm type, lowland cattle and sheep farms and lowland dairy farms most frequently reported a perceived increase in viability (100% and 88% of respondents respectively). None of the farmers in the survey reported a perceived decrease in farm business viability after receiving GES grants.

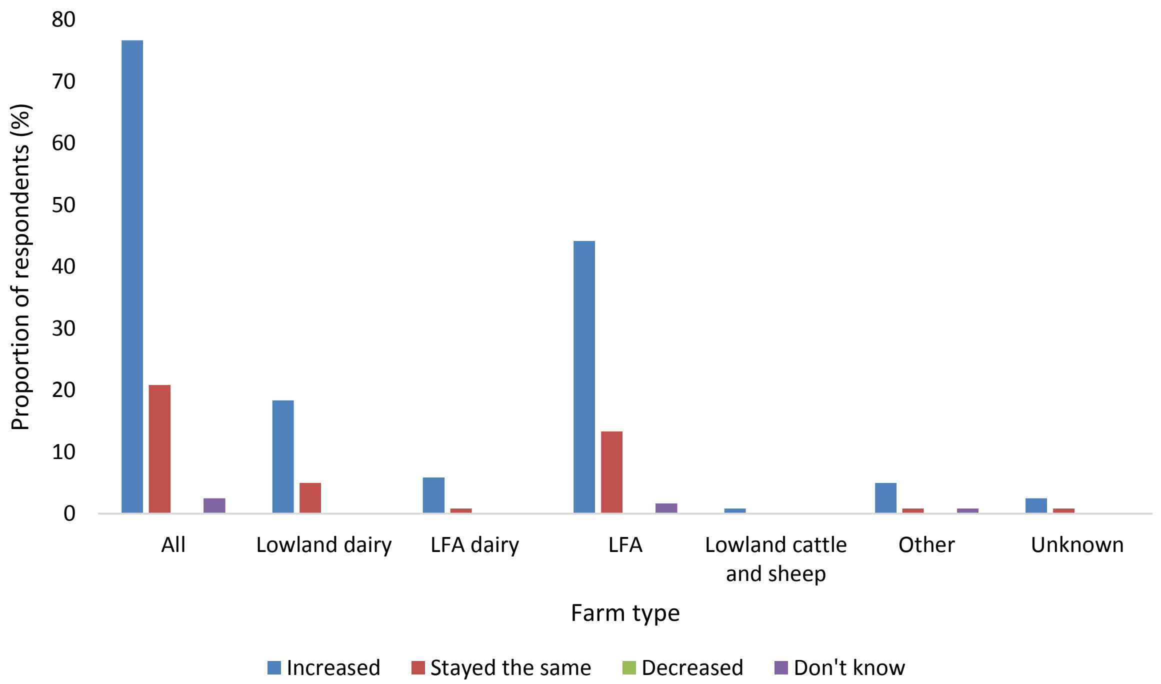


Figure 4.12. Impact of receiving GES grants on perceived farm viability

4.4.4.2 Changes in farm expenditure

Grants appear to have had a positive impact on changes in expenditure, with 68% of respondents experiencing positive impacts (i.e. improved farm infrastructure and decreased personal expenditure), and 9% strongly positive impacts (Fig. 4.13). No impact on changes in expenditure was reported by 11% of farmers. The remaining 13% of respondents reported a negative impact, but only one farmer perceived a strongly negative impact on expenditure.

Farmers were asked whether they agreed that farm expenditure had increased after receiving GES grants. Of those who answered the question (98% of survey respondents), 42% agreed, and 11% strongly agreed, whilst 42% disagreed or strongly disagreed with this statement (Fig. 4.14).

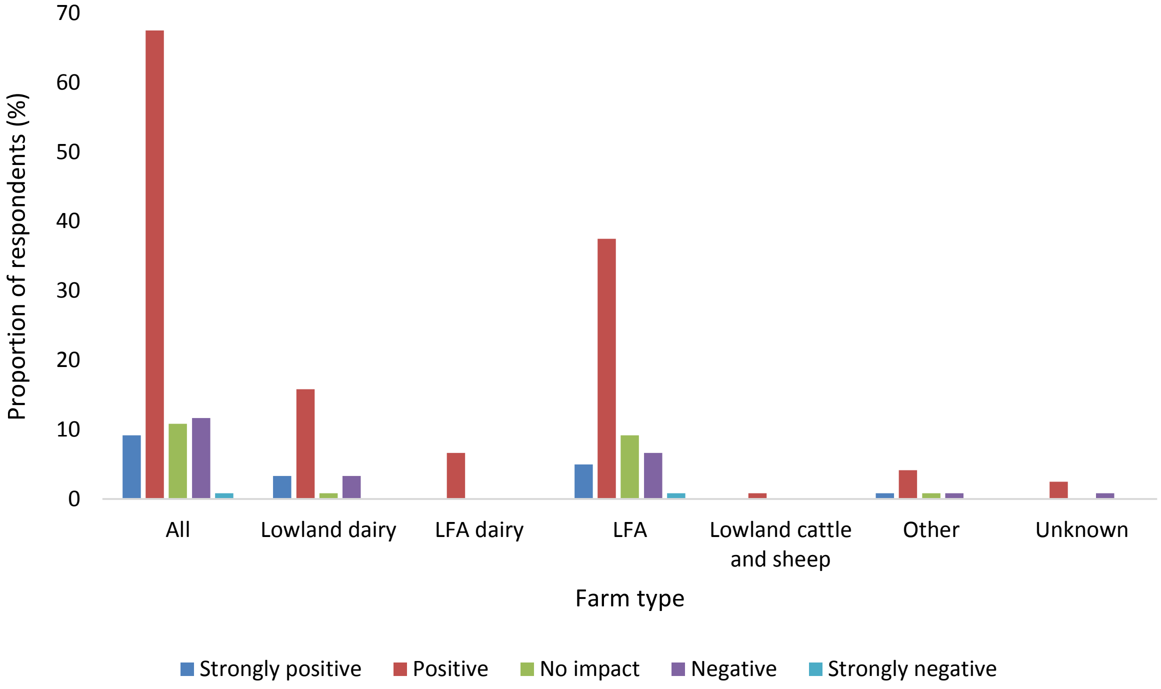


Figure 4.13. Impact of GES grants on farm expenditure.

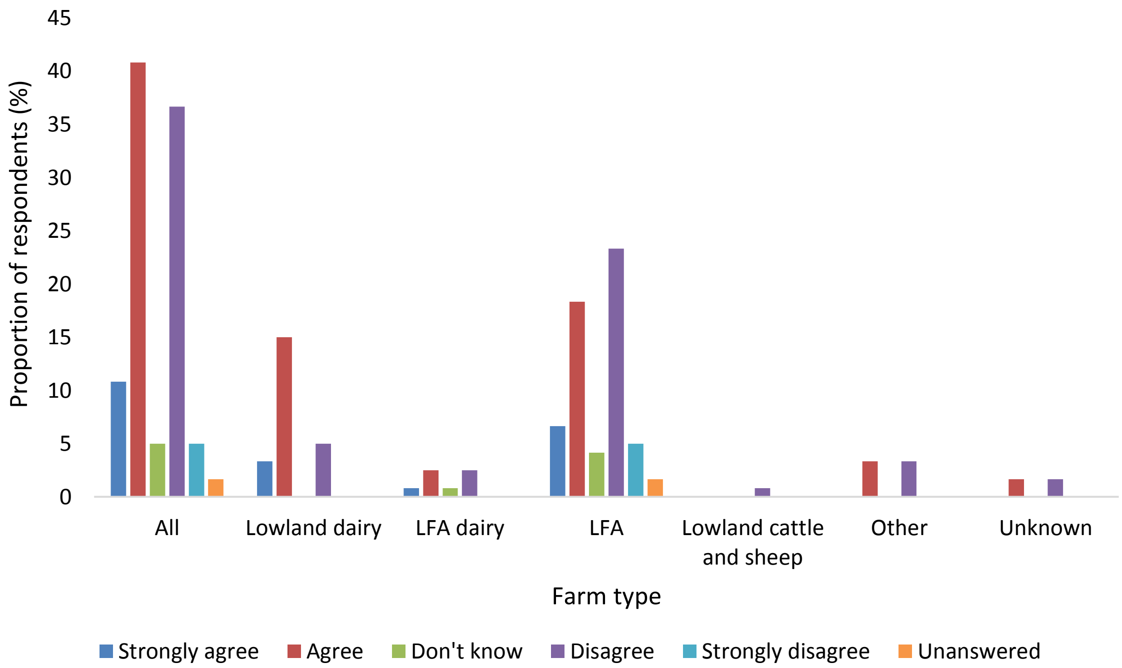


Figure 4.14. Proportion of farmers reporting an increase in expenditure after receiving GES .grants

Of the farmers reporting an increase in expenditure, 58% answered the follow-up question detailing how the additional money was spent. Increased expenditure was distributed primarily to Welsh industries (68%), Welsh households (18%) and taxes and imports (8%; Fig. 4.15). The remaining 6% of expenditure was unaccounted for[1]

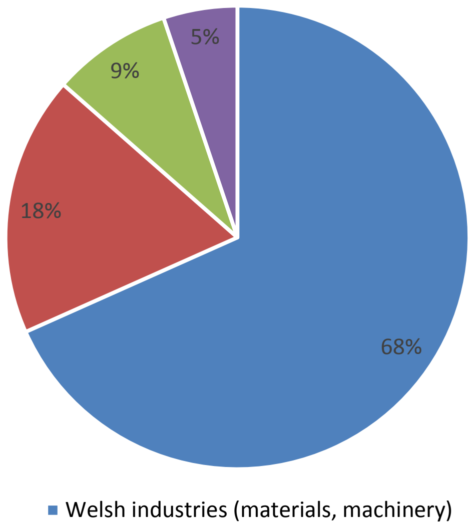


Figure 4.15. Allocation of increased expenditure following receipt of GES grants.

Of the respondents that had grants in progress (60 farms), 87% spent money on building materials (52 farms), 65% on machinery and equipment (39 farms), and 45% on labour (27 farms; Table 4.6). Only a small proportion of farms had spent money on rental and hire of equipment (13%) or repairs (5%). (Table 4.5).

Table 4.5. Total and average farm expenditure (£) across sectors, for GES-participating farms.

	Building materials	Machinery or equipment	Rental and hire	Repairs	Labour
Number of farms	52	39	8	3	27
Total expenditure	561,381	309,931	92,792	4,666	136,529
Average spent per farm	10,796	7,947	11,599	1,555	£5,057

[1] Here, 'unaccounted for' represents respondents whose answers to this question represented less than 100%, implying that some of their expenditure was allocated towards something unrepresented by the other three sectors

*4.4.4.3 Expenditure on taxes and imports*A small number of open-ended questions were included in the survey regarding expenditure allocated to taxes and imports. When asked what proportion of the expenditure was allocated specifically to taxes, 49% of participants stated 0%, with a further 17% not knowing, and 8% declining to answer (Fig. 4.16). Of those able to give an estimate, 16% recorded allocating 20% of expenditure towards taxes, and a further 5% of respondents recorded less than 20%. Five per cent of respondents reported that more than 20% of their expenditure was allocated to tax.

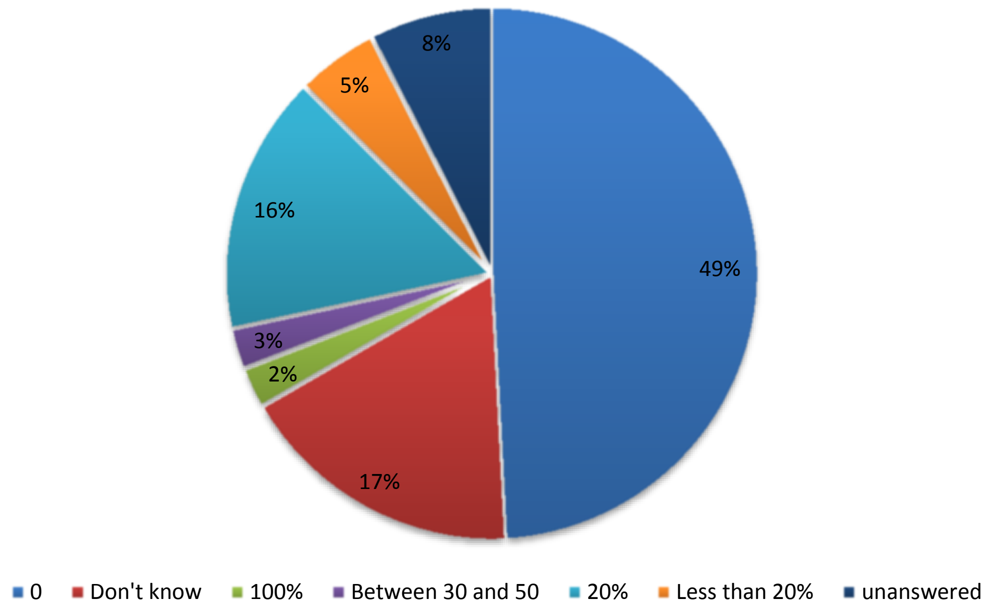


Figure 4.16. Proportion of expenditure allocated to tax per farm.

Thirty-seven respondents stated they had spent money on imports. Expenditure was primarily allocated to building materials (35% of farmers) and machinery and equipment (32% of farmers; Fig. 4.17). A small amount of expenditure was allocated to slurry equipment (14%) or animal care (feed, veterinary care; 5%). The remaining 14% of farmers

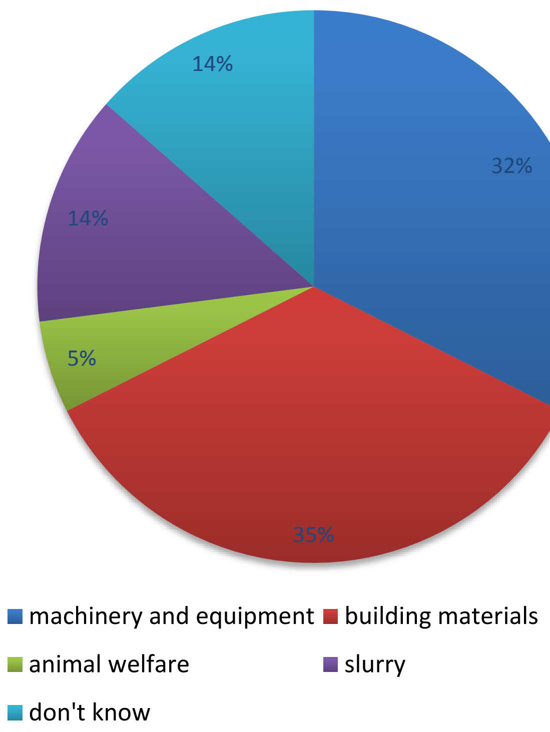


Figure 4.17. Farmer expenditure on imported products.

did not know which imported products they had spent money on.

Of the expenditure allocated to imports, 57% of respondents purchased products from within the UK and Ireland; 14% from other European countries; and 8% from within Europe including the UK. The remaining 22% of respondents did not know the origin of their imports (Fig. 4.18).

4.4.4.4 Upstream and downstream economic impacts

Overall, 71% of respondents claimed that the GES grants financially benefitted their suppliers, while only 2% of respondents reporting a perceived negative financial effect on suppliers. One fifth of respondents (19%) were unable to offer an estimate (Fig. 4.19).

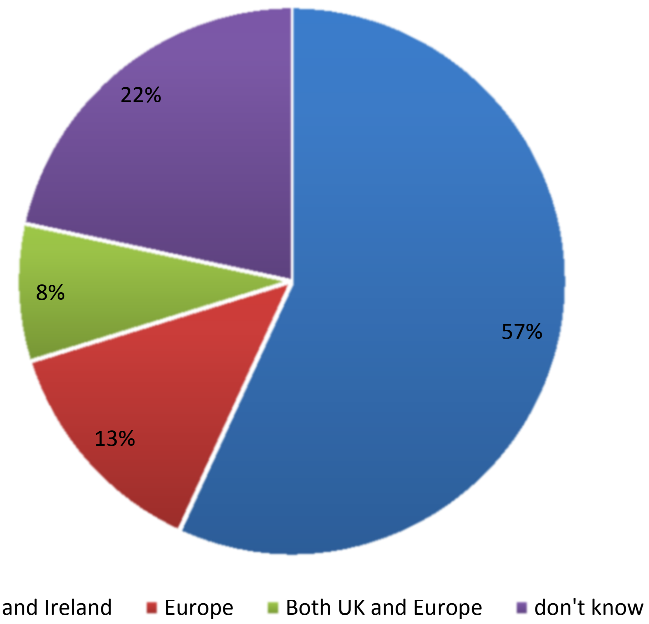


Figure 4.18. Country of origin of respondents' imported products.

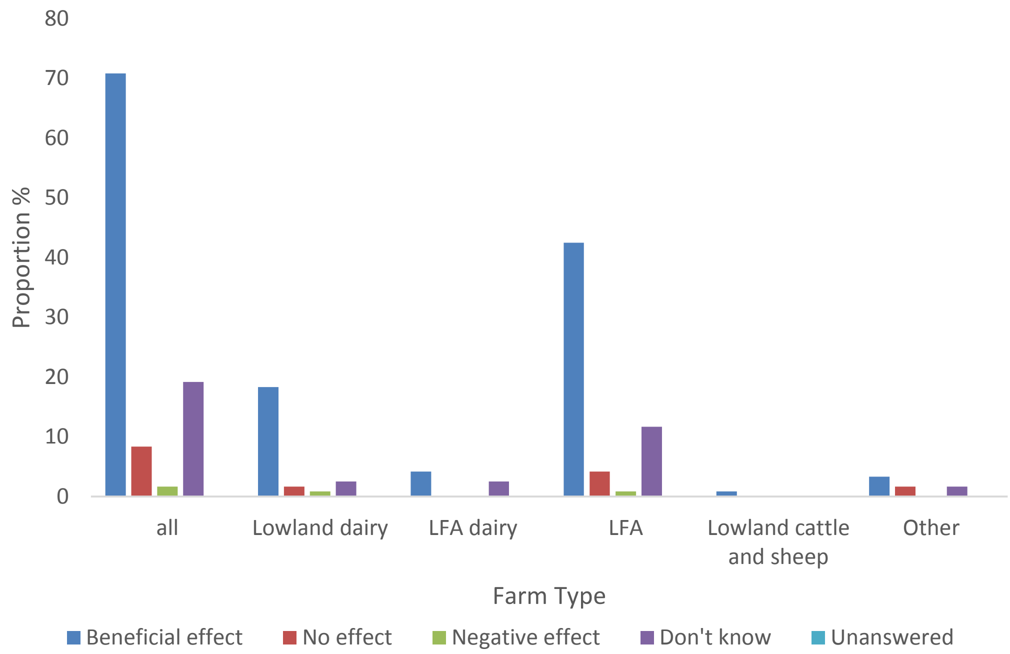


Figure 4.19. Perceived financial impact of GES grants on farm suppliers.

Most respondents reported that the financial impact of GES grants on their customers was beneficial (44%), although an almost equal proportion of respondents estimated no effect on their customers (38%; Fig. 4.20). Thirteen per cent of respondents declined to comment.

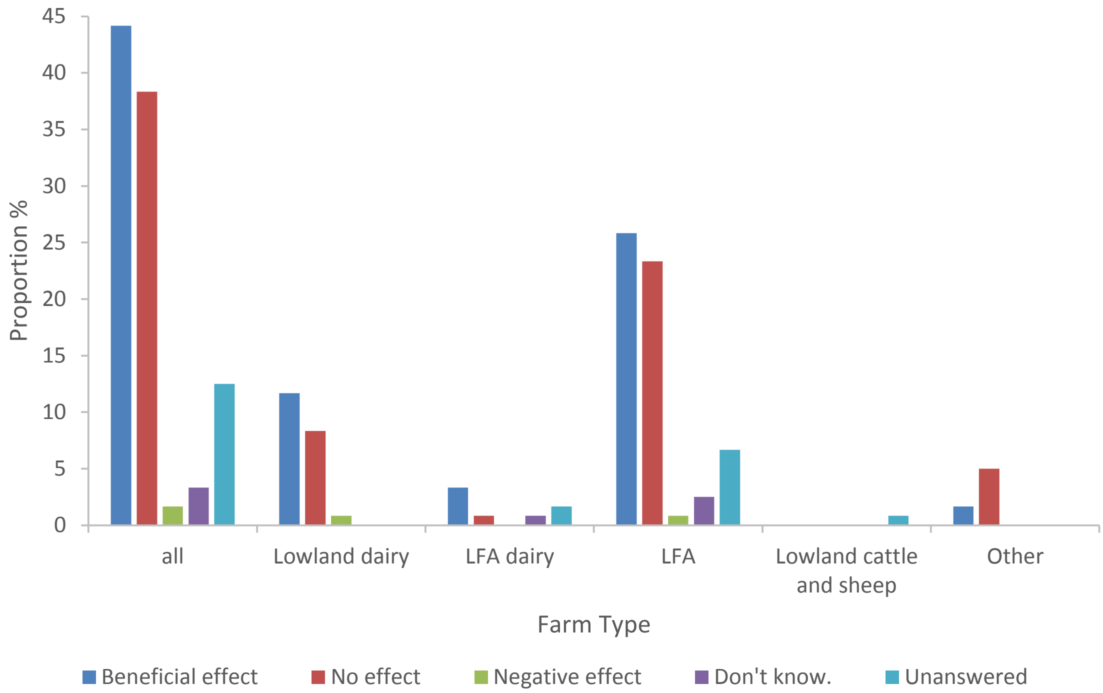


Figure 4.20. Perceived financial impact of GES grants on participating farms' customers and clients.

The perceived effect on farmers' competitors was smaller still, with only 13% of farmers claiming a beneficial effect on competitors, and the majority (54%) reporting no perceived effect (Fig. 4.21). A relatively large proportion of respondents did not answer this question (22%), while a further 8% stated they did not know the answer. Only 3% of respondents reported that GES grants had a negative effect on competitors.

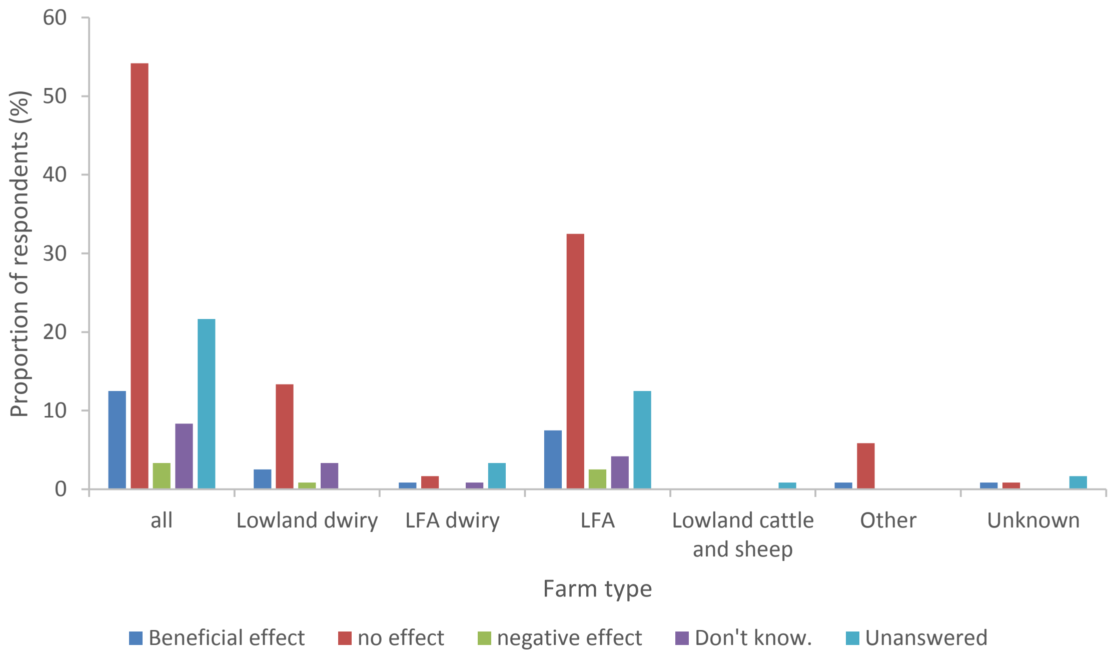


Figure 4.21. Perceived financial impact of GES grants on participating farms' competitors.

4.4.5 Farm efficiency

The majority of respondents (70%) stated that they could do more for themselves to increase efficiency on their farms, with almost a third of these (26% of all respondents) giving examples of how they could increase efficiency (Table. 4.6). The most popular specific suggestions for increasing efficiency, related to improvements in equipment (8% of respondents), land use or quality (8%), or energy and electricity use (4%), although it is possible there may be some cross-over between these categories implicit in farmers' responses. Less than a quarter of farmers (23%) reported that there was nothing more they could do, or that they did not know how to further improve efficiency on their farms. A small number of respondents (3%) claimed that financial constraints prevented them from doing anything further to improve efficiency, while 4.2% of farmers declined to answer.

Table 4.6. Farmers' responses to 'Is there anything more you could do to increase efficiency on your farms?'

Answer	Proportion of farms (%)
Yes / Probably	41
No / Not a lot / Don't think so / Already doing everything we can	18
Invest in buildings and expansion	7
Don't know / Possibly	5
Improve efficiency of grass, fertiliser and slurry use	5
Financial constraints / If I had a grant	3
We're always looking for ways to improve	3
Get equipment for handling and monitoring, especially Electronic ID	3
Renewable energy	3
Farmland or soil improvement	3
Recycling rainwater	2
Reduce electricity bill	1
Variable speed drive	1
Reduce dairy unit workload	1
Work even longer hours	1
Unanswered	4

Respondents (93%) commented that the Welsh Government could help them increase efficiency further, and three quarters of these (72% of farmers) provided examples of things that could be improved to increase efficiency on their farms (Table 4.7). Specific examples for government-facilitated improvements suggested by farmers most frequently related to providing additional financial support, and economic regulation. Only 7% of farmers were unsure whether the Welsh Government could help them further to increase efficiency on their farms, or thought that nothing more could be done by the government.

Table 4.7. Farmers' responses to whether Welsh Government could help them increase efficiency on their farms.

Response type	Proportion of farms (%)
Yes	21
No	6
‘More grants’ (often ‘More GES grants’)	15
Less bureaucracy or paperwork	8
Buildings, fencing, and walls	8
Electricity (and ‘Green energy’)	6
Don't know / Possibly	5
Pay the GES grants we've been waiting for	5
Equipment funding (e.g. Electronic ID)	5
Soil investment	3
Increase fertiliser and slurry efficiency (e.g. with a GPS grant)	3
‘Get a better agricultural minister than Carwyn Jones’	2
Farming Connect is beneficial	2
Clear TB	2
Cattle keeping and comfort	2
Support farmers under 40	2
Keep the price of beef and lamb up	2
‘We like to think the government respects that farming is among the most important industries Wales has to offer’	1
Capital items	1
Send more advisors out	1
Benchmarking	1
Not reduce Single Farm Payment as much / Use Euros	1
Give equal playing field against English farmers	1
Unanswered	1

4.4.6 Awareness of 'sustainable intensification'

More than half of respondents (55%) either did not know the meaning, or had never heard of, the term 'sustainable intensification' (Table 4.8). Of the remaining 45% of respondents, 42% offered a definition, but only 8% provided an accurate definition.

Table 4.8. Farmers' responses to the question 'Have you come across the term 'sustainable intensification' and if so what would it mean for you farm?'

Response	Proportion of farms (%)
Haven't heard of it	44
Don't know the meaning	11
An increase in intensity without harming the environment	8
An increase in efficiency / productivity	8
'A good thing'	7
'What they're trying to do with Glastir'	6
An increase in sustainability / environmental friendliness	4
For organic farms, it involves increasing farm efficiency while decreasing input	2
It would mean increasing profits	2
An increase in long-term viability for the whole of Wales	1
Optimum cropping / livestock numbers	1
'It means focusing investment on infrastructure instead of on efficiency'	1
'It would mean more livestock kept per hectare, and more work for the current area we farm; returns need to be better to pay for employees to cover the extra work'	1
'We're not very intensive anyway'	1
'Not plausible for organic farms'	1
Unanswered	4

5 DISCUSSION

5.1 Survey design

5.1.1 Sampling design

A number of caveats need to be considered before discussing the findings of the study. Both the total number of respondents, and the spread of respondents across sub-categories of farm type and size, can influence the representativeness of conclusions drawn from the resulting survey data. This socio-economic survey yielded a relatively large sample size, with 120 of the 157 (76%) farms completing the survey. Additionally, the number of surveys completed within each farm type and size category was approximately proportionate to the number of GES participants in each category. Therefore, it can be assumed that the opinions of farmers taking part in this study are representative of all farmers participating in the Glastir Efficiency Scheme.

5.1.1.2 Dissemination method

The survey data was collected through the combined use of telephone interviews and anonymous postal surveys. It is important to bear in mind that the data gathering technique can introduce potential bias into a study, such as social desirability bias and/or non-response bias (Warner 1965; Fisher 1993; Ansolabehere & Schaffner 2014).

Social desirability bias, also known as the *good subject effect* (Nichols & Maner 2008), arises when respondents wish to present a favourable image of themselves through their responses to questions, independent of the underlying validity of their responses (Furnham 1986). Such a bias tends to be more marked in face-to-face interviews where the desire to please the interviewer is at its strongest. This leads to the over-reporting of desirable behaviours and the under-reporting of undesirable items (Bowling 2005). Telephone interviews tend to minimise this effect, but the extent to which it influenced this study is difficult to determine.

By contrast, postal surveys are susceptible to non-response bias. The reliability of the survey can be undermined if the response rate becomes too low. A typically acute risk is that the non-responders may differ in some marked way from the responders. Such sample bias can invalidate attempts at population estimates (in this case, the opinions of all GES-participating farmers; (Bowling 1997; Lahaut *et al.* 2002)). All surveys that typically seek to elicit responses using data collection techniques employing postal, telephone, computer or face-to-face data collection methods are likely to suffer from non-response bias (Hill *et al.* 1997; Lahaut *et al.* 2002; Bowling 2005). Surveys that ask sensitive questions are likely to compound lower response rates as they will be further affected by social desirability bias (Tourangeau, Rips & Rasinski 2000). However, given the high response rate of this study, non-response bias is likely to be negligible.

5.1.2 Grant implementation status

Not every farm participating in the Glastir Efficiency Scheme had implemented the capital works funded by GES grants by the time the survey was conducted. This may be for a number of reasons, such as capital works being postponed due to delays in receiving grant money, or because of seasonal constraints to construction projects.

Implementation of many types of grants may have be constrained by seasonal conditions, for example, instalment of outdoor works such as slurry or manure stores would require suitable weather conditions in order to begin construction. Given that local weather conditions vary across Wales, this may have contributed to individual farms finishing projects at different times.

The relative progress of GES funded works on individual farms indicates that respondents would have experienced differing levels of benefits (or dis-benefits) from GES capital works, thereby influencing their survey responses. For example, building new slurry and manure stores would be expected to increase storage capacity for livestock manures. Approximately 40% of dairy slurry is usually applied in February-April, while only 10% is typically applied in May-July, and 25% each in August-October and November-January (Smith *et al.* 2001). Farmers completing the survey after the main period of application would have more evidence relating to the impact of GES-funded works, than those who completed it before this period. Since 78% of respondents completed the survey in July 2014 (after the main slurry application period), the data received regarding this particular grant type (SME grants) are probably more robust. This may not be the case with data relating to other grant works, particularly those that had not had time to take effect by the time the survey was completed.

5.2 Socio-economic impact of GES grants

5.2.1 Impact on Labour

The impact of the GES on labour and farm workload varied between worker categories and farm characteristics. With the provision of grants for on-farm development, a net increase in annual workload might be expected, to incorporate the additional hours required to implement construction works. An average net increase of 3.3 labour-days per farm per year was indicated when all farm and worker categories were considered together (Fig. 4.10), although this average conceals important differences in workload changes, worker categories, and the influence of farm types and sizes.

Farm type affected changes in workload, by a greater margin for some farm types than others. Most notably, an average increase in annual labour-days was seen on LFA cattle and sheep farms (3.3 labour-days per farm per year for contractors and 0.8 days per farm per year for new employees), but a large decrease was observed on lowland dairy farms (10.7 days per farm per year for existing employees and 4.3 days per farm per year for contractors). In terms of farm size, contrasts were seen between farms < 50 ha in size (no overall change), 50 to 199.9 ha in size (an overall increase), and > 200 ha in size (an overall decrease). It is important to consider the response in workload of different farm types and sizes when allocating future grant funding, and when considering the up-scaled effect on the Welsh economy as a whole.

5.2.2 Allocation of spending

Most farmers agreed that GES grants had a positive impact for capital investment and motivating project development. More than 90% of farms either agreed or strongly agreed that the grant encouraged new capital investment (Fig. 4.7). Additionally, 82% of respondents said that their project would not have happened without the grant (Fig. 4.8).

Clearly, GES grants are not intended to curtail opportunities for expansion, but in some cases, development in one area may limit development in another. However, over 70% disagreed that the grants curtailed expansion, with only 15% agreeing that it had done so.

Three out of four respondents reported a positive impact on reducing fertiliser consumption and labour costs, after receiving GES funding (Fig. 4.9). Forty-six respondents gave monetary figures for how much their farms had saved on fertilisers (an average of £3,291 per farm). This suggests that the GES has helped improve farm input costs, as well as providing additional benefits, such as reducing on-farm greenhouse gas emissions (GHG) associated with fertiliser use, and potentially wider reductions in GHG emissions associated with fertiliser production.

5.2.3 Impacts on the wider economy

Overall, 77% of respondents reported that GES grants appeared to have had a positive impact on farm viability. The majority of respondents' GES grant expenditure (68%) was allocated to Welsh industries, with a large portion of the remainder going to Welsh households (18%). This suggests that the majority of grant money is entering the local economy, although to a slightly lesser extent than that under the Tir Gofal scheme, where 73% of expenditure was directed towards Welsh industries, and 23% towards Welsh households (CEASC 2005). Imports and taxes in the present study account for approximately 8% of the increased expenditure – more than twice the proportion spent on taxes and imports under Tir Gofal (CEASC 2005). The majority of imports were sourced from the UK (57%), and all imported products were sourced from within the EU (section 4.4.4.3).

Most of the expenditure allocated to imports was spent on either building materials (87% of responding farmers) or machinery and equipment (65%; section 4.4.4.3). Less than half of the 60 farmers spent money on labour, suggesting that many farmers preferred to manage labour requirements themselves. This may explain the pronounced difference observed between the reduction in labour-days worked on smaller farms (50 to 199.9 ha in size), and the increase in labour-days worked on larger farms (> 200 ha in size) – larger may have been able to afford to subcontract work, or may have had a greater need for additional labour corresponding to larger construction projects.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study set out to generate information on the impact GES grants have had on four key themes: grant allocation, economic outputs and farm efficiency, labour and the wider economy). Each of these are taken in turn in this conclusions section.

6.1.1 Grant allocation

The results highlight an information gap regarding the number of approved grants and grants in progress. This aside, the report has observed that the number of grants have been dispersed equitably across farm types and size categories. Farmers opted primarily to improve slurry and manure efficiency and energy efficiency.

6.1.2 Economic outputs and efficiency of farms

The Glastir Efficiency Scheme had positive impacts for farm economy indicators, such as increased farm sales and the value of those sales; wider? expenditure, and increased uptake in new capital investments.

6.1.3 Labour

The impacts on labour were varied across farm types and size. The previous scheme, Tir Gofal, increased demand for labour. For GES, some farms have had an increased demand for labour and others a reduced demand, but overall there was a net decrease.

6.1.4 The wider economy

The GES grants increased perceived farm viability and had a positive effect on farm expenditure, e.g. less money spent on fertilisers. Increased grant expenditure was spent locally on Welsh industries and households. The majority of imports came from the UK and Ireland and no imports were sourced from outside of Europe. Evidently, much of the money from GES grants is being recirculated within the local economy. In rural areas this is particularly important.

6.2 RECOMMENDATIONS

6.2.1 Grants

There were no water efficiency grants in progress according to the progress report (WG 2013). The number of these grant types was considerably lower than for SME and EE, and it may be useful to further understand the drivers for this lack of uptake for WE grants. There were very few farms of <50 ha within the GES. There may be the potential for policy makers to consider developing grants suitable for smaller sized farms.

References

Ansolabehere, S. & Schaffner, B.F. (2014) Does survey mode still matter? Findings from a 2010 multi-mode comparison. *Political Analysis*, mpt025.

Bowling, A. (1997) *Measuring health: a review of quality of life measurement scales,* Second Edition edn. Open University Press, Buckingham and Philadelphia.

Bowling, A. (2005) Mode of questionnaire administration can have serious effects on data quality. *J Public Health,* **27,** 281-291.

Caballero, R. (2011) The Common Agricultural Policy (CAP) towards 2020: How can fit farming in the marginal areas of the EU. *Recent Researches in Energy, Environment, Entrepreneurship, Innovation*, 88-102.

CEASC (2005) Socio-Economic Evaluation of Tir Gofal. Agra CEAS Consulting., UK.

Davies-Jones, A. (2011) Implementing Sustainable Development for the Countryside: A Case Study of Agri-envronment Reform in Wales. *Environmental Law Review,* **13,** 9-24.

DEFRA (2010) Definition of terms used in Farm Business Managment. DEFRA publications.

Fisher, R.J. (1993) Social Desirability Bias and the Validity of Indirect Questioning. *The Journal of Consumer Research,* **20,** 303-315.

Furnham, A. (1986) Response bias, social desirability and dissimulation. *Personality and individual differences,* **7,** 385-400.

Hill, A., Roberts, J., Ewings, P. & Gunnell, D. (1997) Non-response bias in a lifestyle survey. *J Public Health,* **19,** 203-207.

Lahaut, V.M.H.C.J., Jansen, H.A.M., van de Mheen, D. & Garretsen, H.F.L. (2002) Non-response bias in a sample survey on alcohol consumption. *Alcohol & Alcoholism,* **37,** 256-260.

Nichols, A.L. & Maner, J.K. (2008) The good-subject effect: Investigating participant demand characteristics. *The Journal of general psychology,* **135,** 151-166.

OECD (2010) Agricultural Policies and Rural Development: A Synthesis of Recent OECD Work.

OECD (2011) The Role of Agriculture and Farm Household Diversification in the Rural Economy of the United Kingdom.

Reed, M.S., Moxey, A., Prager, K., Hanley, N., Skates, J., Bonn, A., Evans, C.D., Glenk, K. & Thomson, K. (2014) Improving the link between payments and the provision of ecosystem services in agri-environment schemes. *Ecosystem Services,* **9,** 44-53.

Rose, H. (2011) An introduction to Glastir and other UK agri-environment schemes. National Assembly for Wales, Cardiff, UK.

Smith, K., Brewer, A., Crabb, J. & Dauven, A. (2001) A survey of the production and use of animal manures in England and Wales. *Soil use and management,* **17,** 48-56.

Tourangeau, R., Rips, L.J. & Rasinski, K. (2000) *The psychology of survey response*. Cambridge University Press.

Warner, S.L. (1965) Randomized Response: A Survey Technique for Eliminating Evasive Answer Bias. *Journal of the American Statistical Association,* **60,** 63-69.

WG (2013) ACRES Contract and Claim Progress Report Welsh Government.

WG (2014) Proposals for the Glastir Scheme, Part of the Rural Development Plan for Wales 2014-2020. Welsh Government.

Wynne-Jones, S. (2013) Connecting payments for ecosystem services and agri-environment regulation: an analysis of the Welsh Glastir Scheme. *Journal of rural studies,* **31,** 77-86.

ACKNOWLEDGEMENTS

This research was made possible through WG funding via the GMEP project, and the kind participation of the farming community.

Annex 1

Glastir Efficiency Scheme social-economic survey

The Glastir Efficiency Scheme, previously known as ACRES, aims to increase the efficiency of Welsh farms by granting funds towards capital investments in slurry, manure and water storage and management as well as in energy efficiency.

The following questionnaire is aimed at assessing **only the Glastir Efficiency Scheme** and its impact on the Welsh economy (and not the other schemes within Glastir).

I. Economic outputs and efficiency

1. How has the value of your sales from your farming enterprise changed since obtaining a Glastir Efficiency Scheme (ACRES) grant?

- Increased
- Stayed the same
- Decreased
- Don't know

2. What impact do you think that the Glastir Efficiency Scheme (ACRES) grant has had on your sales from farming?

- Important positive impact
- Little positive impact
- No impact
- Negative impact
- Important negative impact

3. Your opportunities for expansion have been curtailed as a result of your Glastir Efficiency Scheme (ACRES) grant.

- Strongly agree
- Agree
- Don't know
- Disagree
- Strongly disagree

II. Allocation of spending

4. Access to the Glastir Efficiency Scheme (ACRES) grants encouraged you to undertake new capital investment.

- o Strongly agree
- o Agree
- o Don't know
- o Disagree
- o Strongly disagree

5. Access to the Glastir Efficiency Scheme (ACRES) grants encouraged you to increase the scale of planned investments.

- o Strongly agree
- o Agree
- o Don't know
- o Disagree
- o Strongly disagree

6. How much do you agree or disagree with the following statements?

MY FUNDED PROJECT WOULD	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
NOT HAVE HAPPENED WITHOUT THE GRANT	○	○	○	○	○
HAVE HAPPENED MORE SLOWLY WITHOUT THE GRANT	○	○	○	○	○
HAVE BEEN SMALLER WITHOUT THE GRANT	○	○	○	○	○

7. Within changes in expenditure due to Glastir Efficiency Grant (ACRES) Scheme, what were the impacts on the following sectors?

	POSITIVE IMPACT	NEGATIVE IMPACT	NO IMPACT
FERTILISERS	○	○	○
CHEMICALS	○	○	○
ON-FARM PURCHASES (FEEDSTUFF, FUEL)	○	○	○
VETERINARY FEES	○	○	○
CONTRACTORS	○	○	○
BUILDING MATERIALS	○	○	○
LABOUR	○	○	○

8. By how much were your fertiliser expenses reduced due to the Glastir Efficiency Grant (ACRES) Scheme?

=£

9. By how much were your chemical expenses reduced thanks to the Glastir Efficiency Grant (ACRES) Scheme?

=£

10. By how much were your on-farm purchases expenses reduced thanks to the Glastir Efficiency Grant (ACRES) Scheme?

=£

III. Impacts on labour

11. By how many days of labour per year was the workload on your farm **reduced** as a result of your Glastir Efficiency Grant (ACRES)?

Number of days =

12. Or, by how many days of labour per year was the workload on your farm **increased** as a result of your Glastir Efficiency Grant (ACRES)?

Number of days =

13. (*if answered to Q.11 or Q.12)* What proportion of the increased workload was devoted to the following labour sources on an annual basis :

	Proportion of reduced workload	Proportion of increased workload
Farmer		
Family		
Existing employees		
New employees		
Contractors		

Please provide answers to the following three questions (14, 15 and 16) in the table provided below.

14. How many of each of these types of people work on your farm nowadays?

15. How many hours do the workers work per week nowadays? Please differentiate hours worked and hours paid.

16. How many hours do you think they would work per week nowadays if you had not received grants from the Glastir Efficiency Grant (ACRES) Scheme?

Please place a tick in the appropriate column for each of the following

Worker type	Number	Hours worked per week	Hours paid per week	Hours per week without Glastir grant
Full-time male family workers				
Full-time female family workers				
Part-time male family workers				
Part-time female family workers				
Seasonal male family workers				
Seasonal female family workers				
Full-time male employees				
Full-time female employees				
Part-time male employees				
Part-time female employees				
Seasonal male employees				
Seasonal female employees				

part time workers = 30 hours a week.

IV. Impacts on wider economy

17. Has the grant from the Glastir Efficiency Scheme (ACRES) changed the viability of your farm enterprise?

- Increased
- Stayed the same
- Decreased
- Don’t know

18. What impact did the Glastir Efficiency Grant (ACRES) scheme have on any changes in expenditure?

- Strongly positive
- Positive
- No impact
- Negative
- Strongly negative

19. The overall annual farm expenditure has **increased** following the investment under the Glastir Efficiency Grant (ACRES) scheme.

- Strongly agree
- Agree
- Don't know
- Disagree
- Strongly disagree

20. OR **decreased** following the investment.

- Strongly agree
- Agree
- Don't know
- Disagree
- Strongly disagree

21. *(If expenditure increased)* Out of the increased spending as a result of the Glastir Efficiency Scheme grant (ACRES), what proportion was allocated to the following (answer to the best of your knowledge):

	Proportion of grant
Welsh industries (materials, machinery,…)	
Welsh households (labour, farm income,…)	
Taxes + imports	

22. If unable to answer Q19, please name purchased products and their manufacturers.

23. What proportion of the Glastir Efficiency Scheme's grants was allocated to the following sectors:

	Proportion of grant
Building materials	
Machinery/equipment	
Rental and hire	
Repairs	
Labour	

24. What proportion of the expenditure was allocated to taxes?

25. What proportion of the expenditure was allocated to wholesalers who import products from outside Wales?

26. Of the expenditure allocated to imports, for what purposes/sectors/products was the spending allocated?

27. Of the expenditure allocated to imports, towards which countries was the spending allocated?

28. What has been the financial effect of the Glastir Efficiency Grant (ACRES) scheme on your suppliers?

- Beneficial effect
- no effect negative effect
- Don't know.

29. What has been the financial effect of the Glastir Efficiency Grant (ACRES) scheme on your customers/clients/suppliers?

- Beneficial effect
- no effect
- negative effect
- Don't know.

30. What has been the financial effect of the Glastir Efficiency Grant (ACRES) scheme on your competitors?

- Beneficial effect
- no effect
- negative effect
- Don't know.

31. Is there anything more you could do to increase efficiency on your farm?

32. Is there anything more Welsh Government could do to help you increase efficiency on your farm?

33. Have you come across the term "sustainable intensification" and if so what would it mean for your farm?

Many thanks for the time and effort you have put into the completion of this survey. The information you provide is critical to our understanding and improving the scheme's objectives.

Appendix 5.1: Measuring the impact of Tir Cynnal and Tir Gofal on bird populations in Wales

Daria Dadam and Gavin Siriwardena
British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU, UK.

Introduction

Tir Gofal (TG) was the first widespread all-Wales Agri-Environment Scheme (AES) from its inception in 1999 until 2013, with over 300 farms taking part in the scheme (Medcalf *et al*. 2012). It developed from its predecessor schemes, Tir Cymen and the Welsh component of the UK Environmentally Sensitive Areas scheme, which were restricted to limited areas of Wales. TG, a competitive entry scheme, was a "deep and narrow" AES (analogous to the Higher Level element of the Environmental Stewardship scheme in England), whilst Tir Cynnal (TC), its "broad and shallow" counterpart, was introduced in 2005. TG aimed at encouraging agricultural practices that could enhance Welsh landscapes, cultural features and wildlife, and it targeted whole farms, while the main objective of TC was to protect habitats in Wales (Medcalf *et al*. 2012).

Birds are a specific target of a considerable proportion of the management options in TG and TC, they are among the aspects of the environment and nature that are valued most highly by people and are well-represented in national-scale monitoring data that facilitate investigations of management effects at the landscape scale. Therefore, responses of bird populations to management provide a good approach for the assessment of AES performance.

Previous research has investigated the effect of Environmental Stewardship (ES) in England (Davey et al. 2010, Baker *et al* 2012, Siriwardena *et al* 2014) while the potential effectiveness of TG has been considered through a literature review investigating whether the scheme could deliver the requirements of a limited number of bird species (Morris *et al* 2010). Results of the latter suggested that TG had moderate to good potential to deliver benefits to most species considered (Black Grouse *Tetrao tetrix*, Grey Partridge *Perdix perdix*, Lapwing *Vanellus vanellus*, Curlew *Numenius arquata*, Chough *Pyrrhocorax pyrrhocorax*, Tree Sparrow *Passer montanus* and Yellowhammer *Emberiza citrinella*), as the range of option prescriptions provided most of their ecological requirements (Morris *et al* 2010). A second study considered the effect of TG on Yellowhammer, Curlew and Lapwing at farm and field level over up to two years, comparing TG farms that had chosen options with the potential to benefit target species with non-scheme farms (MacDonald *et al* 2012). The authors found that Yellowhammer populations during the breeding season were higher on TG farms, but there was no evidence that Curlew and Lapwing were more abundant on land included in TG (MacDonald *et al* 2012). The same study found that suitable land in TG did not hold more lekking Black Grouse than non-TG land, and that Chough nest site productivity did not vary with the prevalence of TG within 300 metres of the nest, although a negative effect had been expected from the decreased grazing regime that many TG grassland options entail (MacDonald *et al* 2012). However, the latter study considered only habitat associations and, to date, no research has been conducted to assess whether the implementation of TG and TC schemes has benefited bird population growth.

The principal environmental threats to birds in Wales and causes of the declines that have occurred are associated with changes in agricultural practices, such as specialisation and intensification, but also with abandonment of agricultural land in some areas (Chamberlain *et al* 2000, MacDonald *et al* 2012) and the changes in upland regions to some management practices such as grazing (e.g. Bonn *et al* 2009). The TG and TC schemes therefore were designed to provide or to maintain suitable habitats for key target species in Wales, such as Black Grouse, Chough, Curlew, Grey Partridge, Lapwing, Tree Sparrow, Corn Bunting (*Emberiza calandra*) and Turtle Dove (*Streptopelia turtur*), although the last two species were rare at the inceptions of the schemes and have almost entirely disappeared from Wales in recent years (Balmer *et al* 2013).

In this study, we apply the analytical approach used by Baker et al. (2012) to survey data for birds in Wales and the available spatially explicit information on the uptake of each scheme and the options within them, with the aim of assessing the effects of management over the entire course of each scheme on bird population growth rates. The bird data are drawn from the BTO/JNCC/RSPB Breeding Bird Survey (BBS), a national, volunteer-based scheme, for 1999 to 2013 for TG and 2003 to 2013 for TC, allowing population levels before the start of each scheme to be considered.

Methods

BIRD SURVEY DATA

BBS is an annual (1994-present), UK-wide, volunteer-based survey of randomly located 1km squares and it covers c. 260 randomly selected 1km squares in Wales annually. Volunteers walk two nominally parallel 1km transects (500m apart) through each square twice during the breeding season. Each transect is divided into five 200m sections; species-specific bird counts and habitat are recorded separately in each. Annual, square-specific counts are calculated as the maximum over the two visits of the total count summed across transect sections (Harris *et al.* 2014). For this study, BBS squares were selected if they were within Wales and had been surveyed in ≥2 years between 1999 and 2013 (excluding 2001 because the survey coverage was reduced due to access restrictions introduced in response to an outbreak of Foot & Mouth Disease).

Bird species for consideration in the analyses were selected according to the potential benefits they could gain from each option group, i.e. from the habitat created from TG and TC, and subject to their being recorded in sufficient survey squares to make analyses tractable. Note that several species that would ideally have been considered could not be tested in some or all habitats, because a minimum sample size of 30 squares, a standard threshold for BBS analyses, was not reached. The only exception was Lapwing (*Vanellus vanellus*) which was retained in the analysis because of the specific interest in the species as indicated by the provision of a Lapwing-specific set of options (Table 2). Species that could not be included in the analyses, for both TG and TC, were: Barn Owl (*Tyto alba)*, Buzzard (*Buteo buteo*), Chough (*Pyrrhocorax pyrrhocorax*), Corn Bunting (*Emberiza calandra*), Dunlin (*Calidris alpina*), Dartford Warbler (*Sylvia undata*), Golden Plover (*Pluvialis apricaria*), Great-Spotted Woodpecker (*Dendrocopos major*), Hen Harrier (*Circus cyaneus*), Marsh Harrier (*Circus aeruginosus*), Marsh Tit (*Poecile palustris*), Merlin (*Falco columbarius*), Oystercatcher (*Haematopus ostralegus*), Grey Partridge (*Perdix perdix*), Kestrel (*Falco tinnunculus*), Red grouse(*Lagopus lagopus*), Redshank (*Tringa totanus*), Ring Ouzel (*Turdus torquatus*), Short-eared Owl (*Asio flammeus*), Snipe (*Gallinago gallinago*), Sparrowhawk (*Accipiter nisus*), Tree Pipit (*Anthus trivialis*), Tree Sparrow (*Passer montanus*), Wheatear (*Oenanthe oenanthe*), Whinchat (*Saxicola rubetra*), Willow Tit (*Poecile montana*), Wood Warbler (*Phylloscopus sibilatrix*) and Yellow Wagtail (*Motacilla flava*). For TC alone, data for Curlew (*Numenius arquata*), Grey Wagtail (*Motacilla cinerea*) and Pied Flycatcher (*Ficedula hypoleuca*) were also insufficient. This means that the effects of management on these species can, at most, only be inferred from those on more common, related or ecologically similar species, if these exist.

AGRI-ENVIRONMENT DATA

The AES considered here were TG and TC, which comprised agreements between land owners/managers and the government in Wales. The schemes required the implementation of particular options, chosen by farmers from specific menus available (Annex 2) and outlined in the relevant handbooks (Tir Gofal Management Plan and Tir Cynnal Scheme Rules, each as supplied to farmers by the Welsh Assembly Government), or the protection or creation of valuable habitats, for a minimum of ten and five years, respectively. Data from the entire history of each scheme were considered. The spatial boundaries and start/end dates of all agreements in both schemes were available, so informed the overlap between 1km BBS survey squares (see below) and the management that was in place in each year. The number of squares within each Scheme and for each year is listed in Table 1. TG agreement data consisted of option-specific quantities of management for each agreement whilst, for TC, only agreement boundaries were available. TC involved the protection of 5% of the agreement area as “wildlife habitat”, or the creation of such habitat if sufficient area was not already present. The habitat types that qualified as “wildlife habitat” for protection and the options available for habitat creation are listed in Table 2. Data on the types of habitat created or protected under TC in practice were not available, so analyses could only be conducted using amounts of overlap between agreement boundaries and survey squares, without considering agreement content. To refine this coarse measure, because the habitat potentially protected or created will have varied with land-use, the overlap areas were divided into arable, grassland and woodland, using the Land Cover Map 2000 provided by the Centre for Ecology and Hydrology. Thus, TC management was assessed in terms of the area under management, allowing for different influences of the restoration, enhancement or protection of different gross land-use types. Clearly, it would have been preferable to consider the real areas of management or habitat protection but, in the absence of this information, the approach taken acknowledges that different actions will have been taken in different habitats (Tir Cynnal Scheme Rules by the Welsh Assembly Government), so producing an analysis as close to management-specific as was possible and accounting for the likelihood that the types of management employed and their effectiveness will have varied with landscape. It is important to interpret the results with caution, however, because the precise management undertaken was unknown, making the details of cause and effect impossible to determine.

Spatial data containing agreement details for each holding (supplied by the Welsh Government) were used to quantify quantities of each option, for TG, or areas of gross habitat under agreement, for TC, present in each BBS square per year (Fig 1), and taking into account agreement start and end dates. All spatial analyses were undertaken using ArcMap 9.2 (ESRI 2010). Agreement boundaries were available in digital format, but the precise locations of individual management options within each TG agreement, and therefore within each 1km survey square, were unknown. Consequently, the amount of each TG option per agreement and square was estimated by assuming that the quantity of each option falling within each square was proportional to that of the whole agreement area in the square. TG options were grouped into categories (Table 3 and 4), based on the nature of the management and its expected effects on birds, in order to maximize statistical power. It would also have been of interest to investigate particular individual options but sample sizes were insufficient. Option grouping has the potential to weaken apparent relationships, if options with stronger effects are combined with those with weaker ones, but in reality this should trade off against sample sizes in terms of statistical power. TG also includes a number of options (e.g. heather burning or cutting, scrub clearance and invasive species control) that tend to support refinement of the basic option management or specific means of achieving the management goal, but are recorded simply as a duplication of the quantity of the basic option, so there is no straightforward way of quantifying their potential impact additively in combination with that of the basic option. Quantities of these options were therefore not included in the analyses to avoid undue inflation of apparent management areas under AES.

The above data processing produced total, annual quantities of management in each option category or amount of habitat within agreement for each survey square. These data then formed the predictor variables, separately for TG and TC (Table 3 and Table 4), used in the analyses described below. Management options are expected to influence population growth primarily via effects on demography, so option quantities were matched with square-specific bird counts after a one-year time lag, i.e. management needed to be in place for the breeding season before a focal year in which birds were counted.

Tests on TG data were conducted for options aimed at broad-leaved woodland, scrub, heath, unimproved grassland, wet grassland, arable land (options aimed at leaving weeds, unsprayed root crops followed by winter grazing, stubble, field margins, wildlife cover crops), and options to benefit Lapwings, grouped in option categories (Table 3) according to their targeted result in respect of habitat change. Management targeted at any given background habitat would be expected to be more common, by chance, where that habitat is more common. Hence, areas of relevant background habitat were controlled in each analysis. TC implementation was tested on areas of the following Land Cover categories that overlapped TC agreements: acid grassland, calcareous grassland, improved grassland, rough grassland, arable habitat, broadleaved woodland and heather (Table 3). Clearly, such areas may well be correlated with areas of TG uptake, so it was important also to control for TG in order to isolate, as far as possible, any effects of TC. Along, again, with the area of relevant background habitat in a focal square, the area under TG in the same background habitat was, therefore, calculated and included in the analyses as a control.
For each of these option groups, both the nominal target species for each form of management and all other species that might plausibly benefit were tested (Table 3).

STATISTICAL ANALYSIS
Analyses followed the approach for modelling variation in population growth rate with respect to environmental variables devised by Freeman & Newson (2008) and employed in an analogous analysis of agri-environment effects to that used for lowland farmland birds by Baker et al. (2012). Details of the model structures are presented in those two papers, so they are only summarized here. The method uses a log-linear approach that models the average change in expected abundance between consecutive years and can incorporate effects of spatio-temporal covariates, e.g. ES option quantities, on local growth rate. This approach allows maximum use of the available data by including observations from squares that had not been surveyed, or that had zero counts, in the previous year. Fundamentally, the analyses estimated the additional effect of management on each species' population growth rate but, importantly, growth is not thereby forced to be greatest in the years of highest management levels because annual variation in background population growth is allowed for. For each option, the models included a control for the area of the habitat in each survey square that might be confounded with the area of the option concerned. This was important because species associated with such habitats might well show more positive population trends where there is more of the habitat, while larger, habitat-specific AES management option areas would be expected by chance where there is more of the habitat concerned. Hence, spurious apparent relationships with AES management might occur if such controls are not used. The Land Cover Map controls used for each variable in the analysis are listed in Table 2. For example, for management options applicable to heather moorland, the area of heather moorland in the square (drawn from LCM2000, defined as the "Broad Habitat" named "dwarf shrub heath"), was used. Land Cover Map codes included in each habitat are illustrated in Table 5.

Models were fitted assuming a Poisson distribution for the observed BBS counts using the GENMOD procedure in SAS 9.2 (SAS Institute Inc. 2008), accounting for overdispersion using Pearson's χ^2 goodness-of-fit statistic. The significance of ES effects on population growth rates was then assessed using likelihood-ratio tests (SAS Institute Inc. 2008).
Models were run for all of the option categories and species listed in Table 2. Sample sizes varied by species because not all species were found in all survey squares in one or more years (see Results).

Results

Management of grassland

Results are shown in Table 6 for associations between population growth rate and the different forms of management of grassland under TG. There was contrasting evidence for the overall effect of grassland management options on population growth rates, with one positive significant species, Linnet (P<0.01), and one negative significant one, Skylark (P<0.01) (Table 6a). Both significant associations were related to conversion of grassland to less intensive management, whilst neither options for management of wet grassland nor specific grassland options for Lapwings led to significant population growth rates (Table 6b and 6c).

Testing for TC and controlling for TG also provided some support for an overall negative association between grassland options and population growth rates. Two of the three tests significant at P<0.05 were negative (in both cases involving Skylark, associated with acid and calcareous grass management), as were two near-significantly negative (P<0.1) results for Meadow Pipit and Starling for acid grassland options. There was only one positive, significant effect on population growth rate, for Meadow Pipit in relation to management of improved grassland (Table 7).

Management of arable land

Associations between population growth rate and management of arable land under TG are displayed in Table 8. There was evidence of a balance in favour of a positive overall effect across all species, with three species showing significant, positive effects of winter seed provision on population growth rate, Greenfinch, Yellowhammer and Stock Dove, the latter showing a strong association (P<0.001), with no negative effects (Table 8). Option groups to provide invertebrates showed a less clear overall outcome, with one positive significant population growth rate (Whitethroat), one negative association (House Sparrow) and one near-significant, positive result (P= 0.059 for Yellowhammer, Table 8).

House Sparrow showed a positive significant population growth rate in relation to arable land under TC when TG was controlled for, but no other test results were significant (Table 9).

Management of woodland

Results for associations between woodland management option groups and population growth rate of key species are presented in Table 10. Overall, there were more significant, or near-significant, positive population growth rates associated with woodland management (nine) than negative ones (two).

The option group with the most associated positive population growth rates was that considering minimization or exclusion of grazing, which showed six positive associations, of which four were significant and two almost significant (Table 10a). Three of the four significant relationships involved ground-feeding or understorey-nesting species, namely Blackbird, Robin and Wren, while Song Thrush, another ground-feeder, was near-significant (P=0.053; Table 10a). The other (near-) significant results involved Spotted Flycatcher and Blackcap (Table 10a).

The second option group category aimed at managing stock density in woodland (at higher levels than the previous category) produced a significant, positive association for just one species, Spotted Flycatcher, but no other result approached significance (Table 10b).

There was no indication of a clear direction of overall effect of options designed to encourage woodland establishment, with an equal number of positive and negative effects (two each: Table 10c). Blackcap and Chiffchaff both showed strong positive effects on growth rate of this form of management, while Robin and Blue Tit showed negative associations (Table 10c).

A contrasting overall result was achieved for TC, with one significant and one near significant negative association. Specifically, Wren showed a strong negative effect on population growth rate, whilst there was a near-significant (P<0.1) negative effect for Blackbird, each with respect to broad-leaved woodland management (Table 11).

Management of heathland
Associations between population growth rate and heather management under TG are summarized in Table 12. There was evidence for a positive effect of the management on Meadow Pipit, which showed a strong, significant, positive effect on population growth rate and Skylark, for which there was a near-significant, positive relationship (P<0.1), although Lapwing showed a near-significant, negative association (P<0.1). Results for Curlew and Stonechat were not significant. Heathland areas under TC were also associated with negative effects on both species tested, Meadow Pipit and Skylark, (Table 13), i.e. the opposite effects to those found for TG options alone.

Management of scrub
Results for population growth rate effects on key species of scrub management under TG are reported in Table 14. There was an indication of an overall positive effect of the management with two significant positive associations, Wren and Willow Warbler at P<0.05 and P<0.01 respectively, and one, Chiffchaff, reaching near significance (P=0.068). There was no management of scrub under TC.

Management of hedgerows
Associations between hedgerow management under TG and target species are reported in Table 15. There was an indication of an overall positive effect of this option on target species with five showing a significant positive population growth: Dunnock (p<0.05), Greenfinch (p<0.01), House Sparrow (p<0.001), Linnet (p=0.01) and Song Thrush (p<0.01). There was no management of hedgerows under TC.

Discussion
Across all species and option types tested, there was evidence of net positive effects of TG on the population growth rates of target species (20 significant and five near significant positive associations out of 24 significant and six near significant ones overall), but little support for the effectiveness of TC (two positive associations against five significant and three near-significant negative ones, over 10 significant or near significant population growth rates when TG was controlled for).

Management of grassland
Grassland occupies over half of the land-cover of Wales (Centre for Ecology and Hydrology 2007), so its management has the potential to be effective for wildlife proportionally. Intensification of grassland management has been associated with the decline of bird species through direct reduction in food availability for insectivores and seed-eating species as well as loss of heterogeneity and associated reduced access to prey items and nesting sites (e.g. Wilson et al 1999). Conversion or maintenance of grassland to less intensive management under TG, therefore, aimed at providing a more heterogeneous vegetation sward height, encouraging growth of native plants and increasing value for invertebrates, and results showed a positive effect on Linnet (Table 6). Research on ES in lowland England has also found a positive effect on population growth rate for grassland management in pastoral landscapes on Linnet (Baker *et al* 2012), probably showing a similar ecological response to the extensification of grassland management. However, there were no other positive effects across the six species tested and there was a surprising, negative association for Skylark with this type of grassland management (Table 6); the species requires taller vegetation in which to nest and lower vegetation where to forage, therefore it was predicted to benefit from this option group. Accordingly, Skylarks in lowland England were found to benefit from similar grassland management (Baker *et al* 2012), although more recent, analogous analyses have found less clear results: a non-significant relationship between the species and grassland management under ES in England (Siriwardena *et al* 2014).

The grassland area under TC showed a negative effect on population growth rate for the majority of species-grassland type associations, suggesting that TC was not adequate to address ecological requirements of the species and may have had unintended negative effects, and that any positive associations with AES were largely due to TG. An exception was Meadow Pipit, which showed a strong positive association with improved grassland areas overlapping with TC (Table 7). This could show a more heterogeneous sward providing the species with a preferred feeding habitat (Douglas et al 2008), but there was no evidence for such a benefit for Skylark or Starling. There was also a weak suggestion of a negative effect on population growth rate for Meadow Pipit and Starling on acid grassland under TC management, although the lack of detailed information on the TC option makes it difficult to interpret. Skylark showed a strong negative relationship with both acid and calcareous grassland under TC management. Again, this is difficult to interpret, but it may suggest that TC produced sward heights too tall for the species to forage in successfully.

Management of arable land

Management of arable land under TG provided mixed results. Arable land is rare in Wales, covering just over 3% of the land area (Centre for Ecology and Hydrology 2007), so samples of randomly selected squares are necessarily small and the power to detect effects of management in arable areas is correspondingly limited. The detection of significant relationships with TG in this study is therefore strongly suggestive of the existence of biologically important effects, even if the impact on national populations of some species is limited simply because there are few arable areas within which the species could have been affected.

Provision of winter seeds under TG through retention of stubble had a strong, significant, positive effect on population growth of Greenfinch, Stock Dove and Yellowhammer, but no significant effect on all other target species (Table 8). Previous research has shown that most granivorous farmland bird populations are limited by winter seed food availability and that reductions in this resource have driven the declines of species like Yellowhammer and prevented recoveries (e.g. Gillings et al 2005, Siriwardena et al 2007). The results here are consistent with recent work on ES in lowland England, which found analogous positive effects of winter stubble on population growth rates of Yellowhammer and Stock Dove, among numerous other species, albeit at a larger spatial scale for Stock Dove (Baker et al 2012). That more species, such as Dunnock, Skylark, Reed Bunting and House Sparrow did not show significant associations with seed provision may reflect the low power described above, a failure of the management to fill the critical resource gap (e.g. seed availability in late winter: Siriwardena et al. 2008) or different ecological or demographic pressures affecting Welsh birds as opposed to those elsewhere in the UK.

Management of arable land under TG for provision of invertebrates during the breeding season involved reduction of spraying of chemicals, creation of buffer areas between arable land and other features such as hedgerows and other wildlife habitats, and provide food plants and nectar sources for insects and other invertebrates . Increased use of pesticides in farmland has been linked to a decrease in invertebrates (e.g. Boatman et al. 2004, Chamberlain and Crick 1999), which support thrushes and warblers, for example, as well as being the principal food for chicks in the nest even of most granivorous species. While evidence is limited that breeding season food availability limits the abundance of farmland birds, it is possible that some species differ in ecology in different regions (e.g. Perkins et al 2011) and recent evidence suggests that breeding season AES management can have positive effects on species like Yellowhammer in an arable context (Siriwardena et al. 2014). The current study found a weak, positive effect on population growth rate for Yellowhammer (Table 8), suggesting an influence to add to that found for winter seed and similar to recent results for English AESs for this species (Siriwardena et al. 2014). There were no general, positive patterns, however, probably reflecting the general lack of importance of breeding season food as a limiting factor, the one exception being Whitethroat (Table 8). This migratory species nests in a wide range of field boundary habitats and invertebrate food availability is the most plausible limiting factor for abundance on the breeding grounds. As well as this positive pattern, however, there was a strong negative association with House Sparrow, which is difficult to explain. While the species might be expected to benefit from enhanced invertebrate food resources in some contexts, it is strongly associated with farm buildings and much of the relevant TG management is likely to have been located too far from nest sites to have been used. Thus, farms that featured this type of TG management may have tended to feature little positive management for sparrows closer to their nest sites and thus have been associated with declining populations.

Contrary to the TG result, House Sparrow was positively associated with arable land under TC. The broad purpose and approach behind this management were similar to those under the analogous TG options, but their effects appear to have differed. It could be that TC agreements, being simpler at the farm level, did not introduce the habitat biases that may have led to negative associations for House Sparrow with TG, as described above, but the lack of responses among the other species considered that have similar food requirements suggests that TC management failed to produce general habitat enhancements.

Management of woodland

Woodland (broadleaved, mixed and yew) covers 8.6% of Wales (Centre for Ecology and Hydrology 2007), but is probably disproportionately important in terms of biodiversity value as semi-natural habitat. Overall, there was evidence of a positive association between woodland management under TG and population growth rates of target bird species in this habitat, suggesting a significant area of success for the scheme.

Grazing of woodland understorey can lead to loss of suitable habitat for several species (Gill and Fuller 2007, Holt et al 2010); therefore, managing livestock grazing in woodland has the potential to benefit a number of species. In this study there was evidence of an overall positive association of restricting grazing pressure in woodland on species that nest or forage in the shrub layer, such as thrushes (Blackbird, Robin and Song Thrush) Wren and, to a lesser extent, Blackcap (Table 10a). Of particular interest was the population growth rate of Spotted Flycatcher, a fast-declining species (Baillie et al 2014), in relation to management that minimises or excludes grazing. The association was stronger in woodlands with some grazing (Table 10b), where it was the only significant species with respect to this management option, possibly because grazing opened up areas where the species can forage for flying insects, whilst retaining nest sites in denser vegetation. The parameter estimate for this species was, however, rather high, reflecting a small sample and suggesting that the result should be considered with caution.

Positive effects of woodland establishment were found for two species that favour open forest and scrub, although some other such species could not be tested. Blackcap and Chiffchaff showed strong positive effects on population growth rate with management aiming to establish woodland through plantation and reduced grazing (Table 10c), which should provide their preferred habitats, together with both food in the form of insects and nesting sites. The negative association of this management with Blue Tit and Robin may also reflect habitat requirements, because these species prefer denser vegetation structures and a more closed canopy or are found in hedgerows. New woodland or scrub may make habitat less favourable in the short term, or tend to have been associated with less favourable areas for these species because of landscape context, for example.

In contrast to TG, the associations between TC woodland management and population growth rates of target species tended to be negative, although only two patterns reached or approached significance (Table 11). This may reflect the focus of TC on habitat protection, as opposed to active management in TG, such that TC woodland may have been stable in quantity, but was still declining in quality, perhaps because of herbivore pressure, for example. However, while this could explain a lack of positive effects of TC woodland, it does not explain why protection under the scheme might have made the habitat worse for Wren and Blackbird.

Management of heathland

There were three significant or near-significant associations between heathland management under TG and population growth rates of the five species tested, of which the two positive ones involved non-heathland specialists, Meadow Pipit and Skylark. However, there was no evidence of an association with Curlew or Stonechat and a very weak negative association with Lapwing.

The strong positive association of Meadow Pipit with heather management may be due to the prescription to provide heather cover with some grasses and to restrict grazing, hence providing suitable habitat for the species, whereas this habitat would be less suitable for Lapwings. A previous study concluded that abundance of Meadow Pipit in upland regions was higher in landscapes which contained a mix of grass and heather than in those with only one type of vegetation (Vanhinsbergh and Chamberlain 2001). High levels of grazing have been considered generally detrimental in many upland regions in the UK (Evans *et al.* 2006) as they have been associated with loss of heather, mosaic vegetation structure and sward height (Anderson and Yalden 1981, Miles 1988, Nolan *et al*. 1995). TG management has probably therefore improved habitats for Meadow Pipits by enhancing the heather content of grass-dominated moorland. The failure to detect clear effects for the other species may partly be due to their relative rarity (Meadow Pipit is very common in upland heathland), but may also reflect weaknesses in the management, such as the generation of less than optimal vegetation structures for particular species.

Sample sizes permitted testing of TC effects in heathland for only Meadow Pipit and Skylark, but negative associations were found for both species (Table 13). As with woodland, this suggests that TC management failed to deliver the habitat enhancements for these species, perhaps because habitat protection, namely the prohibition of installing new drainage, extraction of peat and general disturbance (Welsh Assembly Government, Tyr Cynnal Scheme Rules), was insufficient to improve habitat quality. Again, however, this does not explain why TC might have had negative effects, which clearly suggests a significant conservation issue.

Management of scrub

Management of scrub under TG was positively associated with the population growth rates of two target species, Wren and Willow Warbler, with a further near-significant relationship with Chiffchaff (Table 14). All of these patterns are likely to reflect increases in vegetation density and diversity due to the management, improving both nesting cover (Ferguson-Lees et al 2011) and invertebrate food availability. There was no significant effect on seven species, however, suggesting either that the management was not effective for them or that their populations are limited by other resources.

Management of hedgerows

There was strong evidence, across species, for an overall positive association between hedgerow management under TG and population growth rates of target birds: five of the eleven species tested had significant, positive relationships (Table 15). Hedgerows provide nesting habitat for four of these species (Dunnock, Greenfinch, Linnet and Song Thrush; O' Connor and Shrubb 1986), while House Sparrows are likely to use this habitat to socialise, as they do in urban settings (Summers-Smith 1963). The House Sparrow pattern could, therefore, show a behavioural change as the birds become more detectable along BBS transects, but the other positive effects are more likely to reflect real population changes due to habitat improvement. Again, the non-significant results could reflect either management failing to deliver the precise habitat requirements of the species or limitation of abundance elsewhere, for example in open field habitats and/or in winter.

Conclusions

Baker et al. (2012) found a balance in favour of significant, positive effects of landscape-scale AES management in England, where the options concerned addressed the factors limiting target species' populations. The coverage of Wales by BBS is lower than that of England and the total sample size is smaller, so statistical power of the analyses conducted here is likely to have been lower. Moreover, many effects of AES management are likely to be small and potentially to be obscured by other environmental influences on populations, such as weather and conditions outside farmland. Hence, there are many reasons why positive effects of AES management, such as that under TG, might not be detected even if the management concerned is working locally. Conversely, when multiple statistical tests are conducted in a study like this one, a range of "significant" patterns are expected to occur by chance. However, such patterns should be evenly distributed between positive and negative associations, and the balance of effects across species and the ecological context help to inform about the reliability of apparent patterns. Overall, therefore, with the caveat that some rarer target species were not testable because of small sample sizes, the results of this study provide good evidence for broad, positive effects of several aspects of TG management, especially that concerning woodland, scrub, hedgerows and arable seed-rich habitats on target bird species. Other management under the scheme has not been so conspicuously successful.

While limited statistical power may explain some of the failure to detect positive effects of these other options, as well as for some species with respect to the option types listed above, it would be unwise to assume that sampling effects alone are responsible, or that negative or non-significant results for individual species do not reflect real patterns. First, positive effects will not occur if the management fails to address the factors limiting local or national abundance, or if the quality of the management is low and it fails to deliver the resources intended in sufficient quantities. This could be the result of problems with option design or option implementation. It is also possible that some TG options have had unintended negative effects on some species, for example by facilitating predation, competition or disease transmission (Bro et al. 2004, Siriwardena et al. 2014), that have over-ridden any positive impacts produced. There is no specific evidence that such effects have occurred in Wales, but they may be occurring in England (Siriwardena et al. 2014) and continued monitoring is essential to ensure that such issues are identified early and addressed in future AES schemes.

The results for TC in this study were much more equivocal than those for TG. This may reflect the intensity of management under the two schemes, because TG options required more tailored and more direct input from farmers, so would be expected to have greater impacts, *a priori*. It may also reflect the difference in age of the two schemes (TG being older), because management may take either some years to take effect (e.g. for grazing alleviation to influence woody vegetation structure) or require several years before positive effects are detectable statistically. However, it is important to recognize that the TC analyses here were weakened by the lack of direct data on the management undertaken or on the real changes effected in practice. Given the general lack of clear patterns across species, which would be expected among ecologically similar species if the management produced general changes in habitat quality (good or bad), it seems unlikely that the proxies employed in these analyses captured the variation in habitat management under the scheme effectively. As a result, it would be unwise to regard the results as definitive. If reliable historical data on TC uptake become available in the future, it would be valuable to repeat the analyses conducted here to derive stronger evidence as to the effectiveness of the scheme.

Overall, there is good evidence that TG has had positive effects on bird populations in Wales and, while many of those effects have been too small to reverse the declines of priority species, care may be needed to ensure that the gains that have been achieved are maintained and enhanced under Glastir. In practice, this means reviewing option design and improving it where necessary, as well as maximizing uptake, while also promoting the options that are most effective in terms of addressing the factors that limit the populations of target species. Further, the problems with the tests of TC here demonstrate that it is critical to collect accurate data about management to enable analyses of scheme effects. Nevertheless, the results of this study add further support to those from England in showing that national-scale AES management can produce positive population effects on target bird species.

References

Amar, A., Grant, M., Buchanan, G., Sim, I., Wilson, J., Pearce-Higgins, J.W. & Redpath, S. 2011. Exploring the relationships between wader declines and current land-use in the British uplands. *Bird Study*, 58, 13-26.

Anderson, P. & Yalden, D.W. 1981. Increased sheep numbers and the loss of heather in the Peak District, England. *Biological Conserv*ation, 20, 195–213.

Baillie, S.R., Marchant, J.H., Leech, D.I., Massimino, D., Eglington, S.M., Johnston, A., Noble, D.G., Barimore, C., Kew, A.J., Downie, I.S., Risely, K. & Robinson, R.A. 2014. *BirdTrends 2013: trends in numbers, breeding success and survival for UK breeding birds*. BTO Research Report No. 652. BTO, Thetford. (Available at www.bto.org/birdtrends)[Accessed 20 March 2015].

Baker, D.J., Freeman, S.N., Grice, P.V. & Siriwardena, G.M. 2012. Landscape-scale responses of birds to agri-environment management: a test of the English Environmental Stewardship scheme. *Journal of Applied Ecology*, 49, 871-882.

Balmer, D.E., Gillings, S., Caffrey, B.J., Swann, R.L., Downie, I.S. & Fuller, R.J. 2013. *Bird Atlas 2007-11: the breeding and wintering birds of Britain and Ireland*. BTO Books, Thetford.

Boatman, N.D., Brickle, N.W., Hart, J.D., Milsom, T.P., Morris, A.J., Murray,A.W.A., Murray, K.A. & Robertson, P.A. 2004. Evidence for the indirect effects of pesticides on farmland birds. *Ibis*, 146 S2, 131-143.

Bonn, A., Allott, T., Hubacek, K. & Stewart, J. 2009. Introduction: drivers of change in upland environments – concepts, threats and opportunities. *In* Bonn A, Allot T, Hubacek K, Stewart J (eds) *Drivers of Environmental Change in Uplands*. Routledge, London & New York, p 1-10.

Bro, E., Mayot, P., Corda, E. & Reitz, F. 2004. Impact of habitat management on grey partridge populations: assessing wildlife cover using a multisite BACI experiment. *Journal of Applied Ecology*, 41, 846–857

Centre for Ecology and Hydrology. 2007. *Countryside Survey: Wales Results from 2007*. Available at www.countrysidesurvey.org.uk/outputs/wales-results-2007 (Accessed 26 September 2014).

Chamberlain, D.E. & Crick, H.Q.P. 1999. Population declines and reproductive performance of skylarks *Alauda arvensis* in different regions and habitats of Great Britain. *Ibis,* 141, 38–51.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C. & Shrubb, M. 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of Applied Ecology*, 37, 771-788.

Davey, C.M., Vickery, J.A., Boatman, N.D., Chamberlain, D.E. Parry, H.R. & Siriwardena, G.M. . 2010. Assessing the impact of Entry Level Stewardship on lowland farmland birds in England. *Ibis*, **152**, 459-474.

De Leo, G., Focardi, S., Gatto, M. & Cattadori, I. 2004. The decline of the Grey Partridge in Europe: comparing demographies in traditional and modern agricultural landscapes. *Ecological Modelling,* 177, 313–335.

Douglas, D.J.T., Evans, D.M. & Redpath, S.M. 2008. Selection of foraging habitat and nestling diet by Meadow Pipits *Anthus pratensis* breeding on intensively grazed moorland: Capsule Foraging sites with low vegetation height and density, but with high arthropod biomass, are selected. *Bird Study*, 55, 290-296

Douglas, D.J.T., Vickery, J.A. & Benton, T.G. 2009. Improving the value of field margins as foraging habitat for farmland birds. *Journal of Applied Ecology*, 46, 353–362.
Durant, D., Tichit, M., Fritz, H. & Kerneis, E. 2008. Field occupancy by breeding Lapwings *Vanellus vanellus* and Redshanks*Tringa totanus* in agricultural wet grasslands. *Agriculture, Ecosystems & Environment,* 128, 146–150.

Eglington, S., Bolton, M., Smart, M., Sutherland, W., Watkinson, A. & Gill, J. 2010. Managing water levels on wet grasslands to improve foraging conditions for breeding Northern Lapwing *Vanellus vanellus*. *Journal of Applied Ecology,* 47, 451–458.

Evans, D.M., Redpath, S.M., Elston, D.A., Evans, S.A., Mitchell, R.J. & Dennis, P. 2006. To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. *Journal of Applied Ecology* , 43, 499–505.

Ferguson-Lees, J., Castell, R. & Leec H, D. 2011. *A field guide to monitoring nests.* British Trust for Ornithology, Thetford.

Freeman, S.N. & Newson, S.E. 2008.On a log-linear approach to detecting ecological interactions in monitored populations. *Ibis*, 150, 250–258.

Gill, R.M.A. & Fuller, R.J. 2007 The effects of deer browsing on woodland structure and songbirds in lowland Britain. *Ibis* ,149 S2, 119–127

Gillings, S., Newson, S.E., Noble, D.G. & Vickery, J.A. 2005. Winter availability of cereal stubbles attracts declining farmland birds and positively influences breeding population trends. *Proceedings of the Royal Society B, Biological sciences*, 272, 733–739.

Harris, S.J., Risely, K., Massimino, D., Newson, S.E., Eaton, M.A., Musgrove, A.J., Noble, D.G., Procter, D. & Baillie, S.R. 2014. The Breeding Bird Survey 2013. BTO Research Report 658. British Trust for Ornithology, Thetford.

Henderson, I.G., Fuller, R.J., Conway, G.J. & Gough, S.J. 2004. Evidence for declines in populations of grassland-associated birds in marginal upland areas of Britain. *Bird Study,* 5, 12–19.

Holt, C.A., Fuller, R.J. & Dolman, P.M. 2010. Experimental evidence that deer browsing reduces habitat suitability for breeding Common Nightingales *Luscinia megarhynchos*. *Ibis* 152: 335–346.

Medcalf, K., Whittick, E., Turton, N. & Cross, D. 2012. Welsh Agri-environment monitoring lot 1: Habitats. Final Report. Environment Systems and Thomson Ecology. [Available: wales.gov.uk/docs/drah/publications/130917report1habitatsen.pdf (Accessed 2 June 2014)].

Morris, A.J., MacDonald, M.A., Smart, J., Haysom, K.A., Rasey, A., Williams, C., Hobson, R., Dines, T., Parry, R.J. & Wilberforce, E.M. 2010. The role of desk review in assessing the potential for biodiversity delivery by the Tir Gofal agri-environment scheme in Wales. *Aspects of Applied Biology*, 100, 89-99.

MacDonald, M.A., Morris, A.J., Dodd, S., Johnstone, I., Beresford, A., Angell, R., Haysom, K., Langton, S., Tordoff, G.M., Brereton,T., Hobson, R., Shellswell, C., Hutchinson, N., Dines, T., Wilberforce, E.M., Parry, R. & Matthews, V. 2012. Welsh Assembly Government Contract 183/2007/08 to undertake Agri-environment Monitoring and Services: Lot 2 – Species Monitoring Final report: October 2012.

Miles, J. 1988. Vegetation and soil change in the uplands. In Usher, M.B. & Thompson, D.B.A. (eds) *Ecological Change in the Upland*s: 57–70. Blackwell Scientific Publications, Oxford

Nolan, A.J., Henderson, D.J. & Merrell, B.G. 1995. The vegetation dynamics of wet heaths in relation to sheep grazing intensity. In Thompson, D.B.A., Hester, A.J. & Usher, M.B. (eds) *Heaths and Moorland: Cultural Landscapes*: 174–179. HMSO, Edinburgh.

O'Connor, R.J. & Shrubb, M. 1986. *Farming and birds*. Cambridge University Press, Cambridge.

Perkins A.J., Maggs, H.E., Watson, A. & Wilson, J.D. 2011. Adaptive management and targeting of agri-environment schemes does benefit biodiversity: a case study of the Corn Bunting *Emberiza calandra.*. *Journal of Applied Ecology*, 48, 514-522.

Potts, G.R. 2012. *Partridges.* Collins, London.

Potts, G. & Aebischer, N. 1995. Population dynamics of the Grey Partridge *Perdix perdix* 1793–1993: monitoring, modelling and management. *Ibis*, 137, 29–37.

SAS Institute, Inc. 2008. Onlinedoc,Version 8.0. SAS Institute, Inc., Cary, NC.

Siriwardena, G.M., Dadam, D. & Grace, P.V. 2014. Responses of farmland birds to eight years of Environmental Stewardship. Report to Natural England.
Siriwardena, G.M. 2010. The importance of spatial and temporal scale for agri environment scheme delivery. *Ibis*, 152 , 515 525.

Siriwardena, G.M., Stevens, D.K., Anderson, G.Q.A., Vickery, J.A., Calbrade, N.A. & Dodd, S. 2007. The effect of supplementary winter seed food on breeding populations of farmland birds: evidence from two large-scale experiments. *Journal of Applied Ecology*, 44, 920–932.

Siriwardena, G.M., Calbrade, N.A. & Vickery, J.A. 2008. Farmland birds and late winter food: does seed supply fail to meet demand? *Ibis* , 150, 585-595.

Smart, J., Bolton, M., Hunter, F., Quayle, H., Thomas, G. & Gregory, R.D. 2013. Managing uplands for biodiversity: do agri-environment schemes deliver benefits for breeding lapwing *Vanellus vanellus*? *Journal of Applied Ecology,* 50, 794–804.

Summers-Smith, J.D. 1963 *The house sparrow*. Collins, London.

Vanhinsbergh D.P & Chamberlain, D.E. 2001. Habitat associations of breeding Meadow Pipits *Anthus pratensis* in the British uplands. *Bird Study*, 48, 159-172.

Vickery, J.A., Feber, R.E. & Fuller, R.J. 2009. Arable field margins managed for biodiversity conservation: a review of food resource provision for farmland birds. *Agriculture, Ecosystems and Environment*, 133, 1–13.

Wilson, J.D., Morris, A.J., Arroyo, B.E., Clark, S.C. & Bradbury, R.B. 1999. A review of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. *Agriculture, Ecosystem & Environment,* 75, 13-30.

Wilson, A.M., Vickery, J.A., Brown, A., Langston, R.H.W., Smallshire, D., Wotton, S. & Vanhinsbergh, D. 2005. Changes in the numbers of breeding waders on lowland wet grasslands in England and Wales between 1982 and 2002. *Bird Study,* 52, 55–69.

Figure 1. *Maps of the extent of all option coverage under Tir Gofal (a) and Tir Cynnal (b) and coverage of BBS squares in Wales (c).*

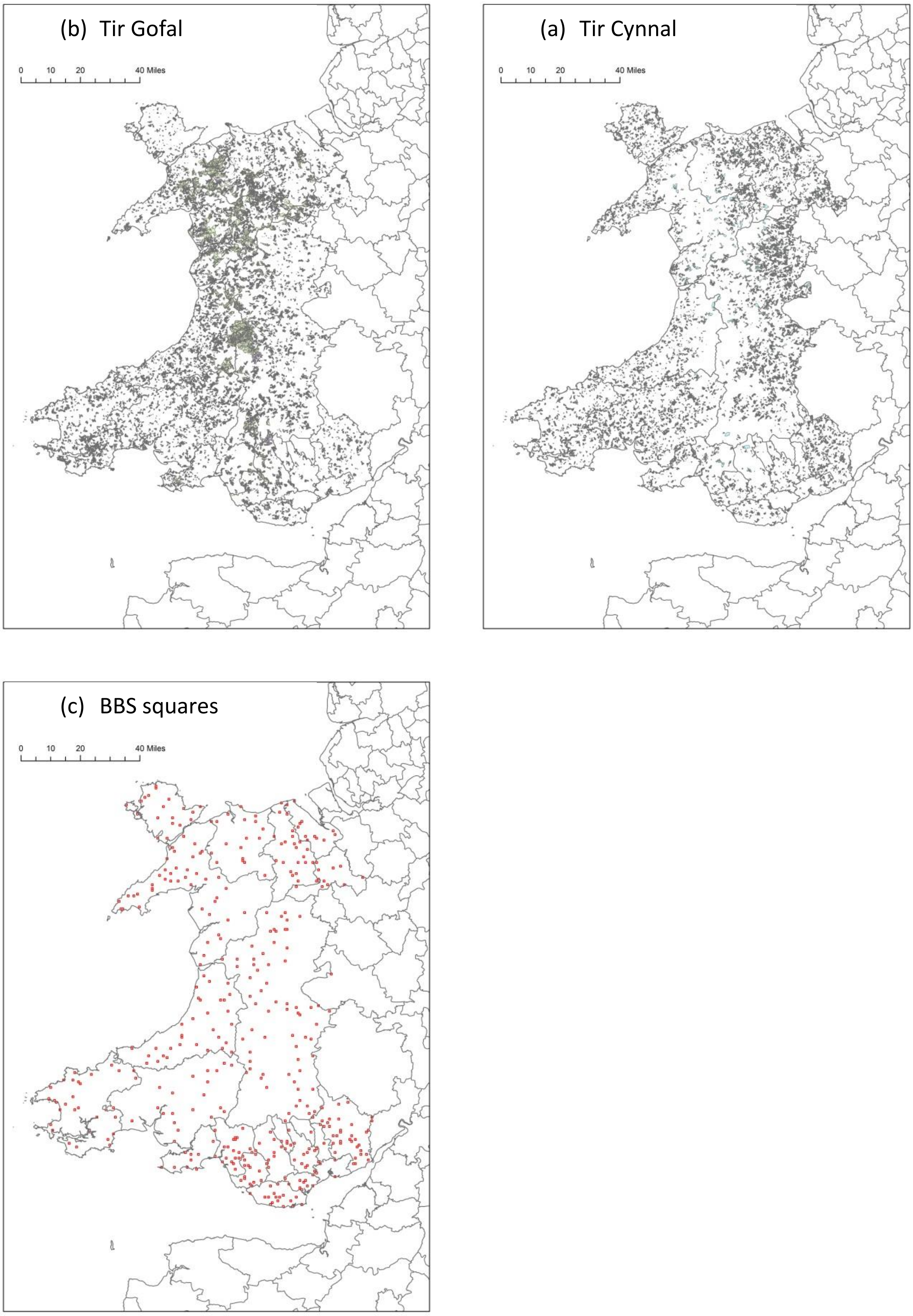


Table 1. *Sample sizes of all Welsh 1km survey squares divided between Tir Gofal and Tir Cynnal.*

Year	Number BBS squares - Tir Gofal	Number BBS squares - Tir Cynnal
1998	NA	NA
1999	NA	NA
2000	103	NA
2001	4	NA
2002	106	NA
2003	115	NA
2004	124	NA
2005	135	NA
2006	136	NA
2007	134	79
2008	113	90
2009	114	88
2010	111	93
2011	96	82
2012	135	99
2013	143	94

Table 2. *Tir Cynnal habitat creation option*

TC Habitat creation option	Description
Hedgerows	Provides a continuous strip of hedgerow at least 2 metre-wide, composed of native plants such as hazel, hawthorn, blackthorn and holly, which must be protected from livestock.
Streamside corridors	Creates a strip of at least 10 metre wide on average, protected from livestock.
Conversion of improved to semi-improved grassland	Creates semi-improved grassland that is not ploughed, and where use of inorganic fertilisers and herbicides are not permitted and wildlife habitat maintained.
Uncropped margins	Creates naturally-regenerated margins 4-12 metre wide free from molluscicides and farmyard manure and which is protected from livestock and vehicle usage.
Grass margins on cereal land	Provides a 4-12 metre wide strip of wildlife-enriching grasses which is cut or grazed once a year after middle of July and which is free from molluscicides and vehicle disturbance.
Small-scale broad-leaved tree planting	Creates a patch of native broad-leaved plants at least 3 metres apart and protected from livestock.
Wild-bird cover crop	Creates a field margins of at least 4 metre wide established by end of April and cut after mid-March of the following year containing at least two types of crop which are not sprayed by insecticides, fungicides, molluscicides or herbicides.
Unsprayed root crops	Establishes a root crop in the entire field or field margins before 1 July, which is free from insecticides, fungicides and herbicides and not grazed before mid-October or ploughed before 1 March of following year.

Table 3. *Option categories for (a) Tir Gofal and (b) Tir Cynnal with management description and list of species likely to benefit from them. Species in bold and underlined are those tested here whilst for the remaining there were insufficient data.*

(a) Tir Gofal	Description	Species likely to benefit	
Collective option name		Tested	Not-tested
Conversion/ maintenance to less intensive grassland	Creates and maintains heterogeneous sward height through reduced grazing pressure and limited application of fertilisers and herbicides.	CU, L., LI, MP, S., SG	BO, BZ, K., P., RK, SE, YW
Wet grassland	Provides marshy grassland through management of grassland species and water levels, and control of cutting and grazing pressure.	CU, L., MP, S., SG	RK, SN, MR, OC,
Lapwing-specific	Creates and maintains grazing marshes for Lapwings by managing grazing pressure to achieve a short vegetation sward and reducing grazing pressure between April and July. Water levels are also managed in winter and summer.	L.	
Rough-grass margins	Provides strips of rough grassland to entice small mammals as well as nesting and feeding sites for birds		BO., K., P.
Arable - Winter seed	Provides a supply of seeds during winter through stubble retention.	CH, D., GR, HS, LI, RB, SD, S., Y.	CB, K., TS
Arable - Invertebrates	Provides habitat for invertebrates through controlled use of herbicides and pesticides.	CH, D, HS, RB, S, SG, WH,Y.	P., TS , YW
Woodland- reduced stock grazing	Creates or maintains semi-natural broadleaved woodland with understorey, through limited grazing, and dead wood available.	B, BC, BT, CC, CH, GT, PF, R, RT, SF, ST, WO, WR, , WW	GS, MT, SH, WT
Woodland grazed by stock	Creates or maintains semi natural broadleaved woodland with grazed understorey and dead wood accompanied by sustainable timber extraction.	B, BC, BT, CC, CH, GT, PF, R, RT, SF, ST, WO, WR, WW	GS, MT, SH, WT,
Wood establishment	Provides an early succession of woodland tree species through retention of existing scattered trees, planting of species and grazing exclusion.	B., BC, BT, CC, CH, GT, R, ST, WR	G., SC, WH
Heathland	Creates or maintains upland heath by controlled grazing pressure and scrub management to encourage dwarf shrubs.	CU, MP, S., SC, L.	BK, DN, DW, HH, GP, ML, RG, RZ, SE, SN, WC
Scrub	Creates or maintains a structurally diverse scrubland with Bramble, Thorn, Gorse and Willow.	BC, CC, D., LI, R., SC, WH, WR, WW, Y.	TP, W., WC
Hedgerow	Preservation of hedgerows in fields	BF, CH, D., GO, GR, HS, LI, RB, SD, ST, WH	TS, Y.

(b) Tir Cynnal	Description	Species likely to benefit	
Collective option name		Tested	Not-tested
Acid grassland	Preserves the wildlife habitat intrinsic to this grassland type by not applying chemicals, limit vehicle disturbance and avoid exploitation of the soil.	MP., , S., SG	CU, L., RK.
Rough grassland	Preserves the wildlife habitat intrinsic to this grassland type by not applying chemicals, control grazing pressure, limit vehicle disturbance and avoid exploitation of the soil.	MP, S., SN	CU, L., RK
Calcareous grassland	Preserves the wildlife habitat intrinsic to this grassland type by not applying chemicals, avoiding overgrazing, limit vehicle disturbance and avoid exploitation of the soil.	MP, S., SG	CU, L., RK
Improved grassland	It may contain hedgerow management and conversion of improved to semi-improved grassland (see Table 4 for more details on this option).	CU, L., MP, S., SG	RK
Fen, marsh, swamp	Preserves the wildlife habitat intrinsic to this habitat by avoiding application of chemicals, limit grazing pressure, avoidance of installation of new drainage systems and clearance of ditches between 1 March and 31 August .	CU, L., RK., RW, SW, RB	
Dwarf, shrub, heath	Preserves the wildlife habitat typical heathland by avoiding overgrazing, limit vehicle disturbance and avoid exploitation of the soil including preventing peat extraction.	MP, S., SC,	BK, CU,DN, DW, HH, GP, L. , ML, RG, RK, RZ, SE, SN, WC
Broadleaved woodland	Should include small-scale broad-leaved tree planting (see Table 4 for more details on this option).	B, BC, BT, CC, CH, GT, R., RT, ST, WR, , WW	GS, MT, PF, SF, SH, WO, WT
Arable & horticultural	Likely to contain four Tir Cynnal habitat management options: wild-bird cover crop, unsprayed root crop, grass-margins on cereal land and uncropped margins (see Table 4 for more details on these options).	CH, D., HS, LI, S.	CB, K., P., RB, TS, Y.

Table 4. *Options category, group name, options codes, control variables, sample size, species list and area of option group breakdown for Tir Gofal and Tir Cynnal.*

Scheme	Option category	Grouping	Option codes	Landscape control variable	Number of survey squares with non-zero values	Mean of relevant options (ha)	Median of relevant options (ha)	Lower| upper quartiles of relevant options (ha)	
Tir Gofal	Grassland TG	Conversion/ maintenance to less intensive grassland	7A, 7B, 8, 8A, 8B, 9, 10, 10A, 10B, 32A1, 34A, 35A, 35B, 35C, 35D	General grassland	147	21.37	8.17	4.12	34.84
		Wet grassland	11,11A,42B, 36A, 36B, 36C1	No control	108	4.01	1.54	0.64	3.84
		Lapwing-specific	32B21,32B22,31D,34A,36C1,36A,36B	General grassland	7	1.85	0.86	0.54	1.92
	Arable fields TG	Winter seed	24B,25A,25B,27,29	Arable	44	4.92	2.16	0.87	5.56
		Invertebrates	24B,25A,25B,27,29, 30	Arable	42	4.58	2.67	0.93	5.56
	Woodland TG	Reduced stock grazing	1A, 1B	Broadleaved woodland	107	2.49	1.12	0.31	3.79
		Woodland grazed by stock	1C	Broadleaved woodland	63	0.81	0.48	0.23	1.06
	Heathland TG	Heathland	5, 6	Dwarf, shrub, heath	44	11.80	3.61	1.08	13.05
	Scrub TG	Scrub	2	No control	58	0.55	0.28	0.08	0.74
	Hedgerow	Hedgerow	18	Arable & horticultural +	108	633.39 metres	410.39 metres	144.55	1042.1

				calcareous grassland + improved grassland				metres	metres
Tir Cynnal	Acid grassland	Acid grassland	n/a	Acid grassland	38	6.35	2.15	0.37	7.12
	Calcareous grassland	Calcareous grassland	n/a	Calcareous grassland	52	1.80	1.08	0.51	2.11
	Improved grassland	Improved grassland	n/a	Improved grassland	127	10.11	6.25	1.09	12.88
	Woodland	Woodland (broad-leaved)	n/a	Woodland (broad-leaved)	91	2.31	0.78	0.20	2.37
	Arable & horticultural	Arable & horticultural	n/a	Arable & horticultural	60	3.23	1.07	0.12	3.61

Table 5. *Land Cover Map 2000 subclass habitat codes (Fuller et al 2002) included in each habitat category used as controls.*

Habitat	BH class		
	Codes	Names	Variants
Acid grassland	8	Acid grass and bracken	Acid, acid (rough), acid with Juncus, acid with *Nardus/Festuca/Molinia*
Neutral grassland	6	Neutral /semi-improved/rough grassland	Grass set-aside, rough grass (unmanaged), grass (neutral unimproved)
Calcareous grassland	7	Calcareous	Calcareous (managed), calcareous (rough)
Improved grassland	5	Improved grassland	intensive, grass (hay/ silage cut), grazing marsh
General grassland	n/a	Combination of acid, calcareous, neutral and rough, and improved grassland	n/a
Fen, marsh, swamp	11	Fen, marsh, swamp	swamp, fen/marsh, fen willow
Dwarf, shrub, heath	10	Dense dwarf shrub heath and open dwarf shrub heath	Dense or open ericaceous, gorse
Broadleaved woodland	1	Broad-leaved/mixed woodland	Deciduous, mixed, open birch, scrub
Arable & horticultural	4	Arable and horticultural	cereal, arable bare ground, root vegetables, horticulture, non-cereal , unknown, orchard, arable grass (ley), setaside

Table 6. *Population growth rate for grassland management options under Tir Gofal. Conversion to less intensive grassland management, management of wet grassland and management of grassland for Lapwing under Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant results are highlighted in bold, near-significant results (P<0.1) are underlined, n/a indicates insufficient data to run the analysis. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

		Conversion to less intensive grassland				Wet grassland				(c) Lapwing-management grassland			
Species	N	Est	SE	χ^2	P	Est	SE	χ^2	P	Est	SE	χ^2	P
CU	50	0.145	0.154	0.88	0.347	0.113	0.105	1.14	0.285	n/a	n/a	n/a	n/a
L.	20	-1.198	1.197	1.69	0.193	0.047	1.246	0.00	0.970	0.700	0.800	0.66	0.416
LI	120	0.472	0.162	9.29	**0.002**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	119					-				n/a	n/a	n/a	n/a
MP		-0.043	0.076	0.32	0.571	0.011	0.031	0.13	0.717				
	133					-				n/a	n/a	n/a	n/a
S.		-0.297	0.055	31.55	**0.000**	0.048	0.044	1.21	0.271				
SG	104	-0.227	0.177	1.80	0.180	0.020	0.705	0.00	0.977	n/a	n/a	n/a	n/a

Table 7. *Population growth rate for management of grassland under Tir Cynnal controlled for Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels. Types of grassland where a species would not usually occur were not tested. I=Improved, A= Acid , C = Calcareous.* Statistically significant results are highlighted in bold, near-significant results (P<0.1) are underlined. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

			Grassland (habitat and Tir Gofal controlled)			
Species	N	Grassland type	Est	SE	χ^2	P
MP	56	I	0.131	0.148	828.63	**0.004**
S.	71	I	-0.212	0.112	10.46	0.746
SG	51	I	0.133	0.154	49.88	0.480
MP	56	A	-0.356	0.290	348.42	<u>0.062</u>
S.	71	A	-1.061	0.340	1983.44	**0.000**
SG	51	A	-1.436	1.296	286.31	<u>0.091</u>
MP	56	C	2.494	1.608	16.43	0.685
S.	71	C	-3.402	1.659	885.88	**0.003**
SG	51	C	-1.620	1.260	13.47	0.714

Table 8. *Population growth rate for arable land managed under Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant results are highlighted in bold, near-significant results (P<0.1) are underlined. W= winter food options, I= provision of invertebrates options; N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

Species	N	Arable management	Est	SE	χ^2	P
CH	259	W	-0.027	0.059	0.21	0.650
D.	204	W	0.060	0.075	0.65	0.420
GR	155	W	0.255	0.128	398.75	**0.045**
HS	167	W	-0.048	0.081	0.35	0.556
LI	120	W	0.244	0.156	2.42	0.120
RB	41	W	-1.422	1.506	0.87	0.351
S.	133	W	0.084	0.123	0.46	0.497
SD	43	W	0.895	0.186	28.19	**0.000**
Y.	42	W	0.249	0.120	4.39	**0.036**
CH	259	I	0.008	0.076	0.01	0.921
D.	204	I	-0.003	0.103	0.00	0.975
HS	167	I	-0.241	0.105	5.32	**0.021**
RB	41	I	-0.860	1.190	0.53	0.468
S.	133	I	0.098	0.124	0.63	0.428
SG	104	I	-0.460	0.324	2.18	0.140
WH	107	I	0.158	0.081	388.62	**0.048**
Y.	42	I	0.240	0.129	3.56	<u>0.059</u>

Table 9. *Population growth rate for management of arable land under Tir Cynnal controlled for Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant are highlighted in bold. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

		Arable (habitat and Tir Gofal controlled)			
Species	N	Est	SE	χ^2	P
CH	148	0.296	0.120	24.01	0.624
D.	104	0.090	1.555	252.00	0.112
HS	86	0.084	0.180	459.73	**0.032**
LI	66	1.560	0.179	9.47	0.758
S.	71	0.048	0.332	122.63	0.268

Table 10. *Population growth rate for woodland management: (a) options to minimise or exclude grazing, (b) managed grazing and (c) woodland establishment management under Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant are highlighted in bold, near-significant results are underlined, n/a indicates insufficient data to run the analysis. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

		Minimise/exclude stock grazing				Managed stock grazing				Woodland establishment			
Species	N	Est	SE	χ^2	P	Est	SE	χ^2	P	Est	SE	χ^2	P
B.	258	0.215	0.089	5.77	**0.016**	0.543	0.352	2.41	0.121	0.560	0.377	2.24	0.134
BC	181	0.259	0.137	3.54	<u>0.060</u>	0.698	0.506	2.00	0.157	1.776	0.574	10.76	**0.001**
BT	233	-0.036	0.103	0.12	0.727	-0.595	0.471	1.68	0.195	-0.829	0.364	5.20	**0.023**
CC	199	0.071	0.135	0.27	0.601	0.045	0.987	0.00	0.964	5.355	1.501	18.34	**0.000**
CH	259	0.069	0.100	0.48	0.488	0.117	0.256	0.21	0.650	0.380	0.311	1.51	0.220
GT	224	-0.091	0.126	0.52	0.472	0.761	0.476	2.67	0.102	0.197	0.471	0.18	0.675
PF	31	0.305	0.297	1.03	0.309	0.417	0.881	0.22	0.641	n/a	n/a	n/a	n/a
R.	252	0.200	0.095	4.43	**0.035**	-0.082	0.298	0.08	0.782	-0.967	0.319	9.37	**0.002**
RT	94	-0.029	0.194	0.02	0.879	-0.290	0.314	0.88	0.350	n/a	n/a	n/a	n/a
SF	33	1.237	0.539	5.53	**0.019**	11.637	4.281	7.95	**0.005**	n/a	n/a	n/a	n/a
ST	226	0.249	0.128	3.75	<u>0.053</u>	-0.093	0.504	0.03	0.853	-0.560	0.628	0.80	0.372
WO	29	-0.005	0.327	0.00	0.989	0.271	1.263	0.05	0.832	n/a	n/a	n/a	n/a
WR	255	0.465	0.086	28.36	**0.000**	-0.164	0.282	0.35	0.556	0.283	0.296	0.92	0.338
WW	191	-0.011	0.115	0.01	0.924	-0.049	0.257	0.04	0.850	n/a	n/a	n/a	n/a

Table 11. *Population growth rate for management of broad-leaved woodland under Tir Cynnal controlled for Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant results are highlighted in bold, near-significant ones (P<0.1) are underlined. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

		Broad-leaved woodland (habitat and Tir Gofal controlled)			
Species	N	Est	SE	χ^2	P
B.	132	-0.213	0.147	373.41	<u>0.053</u>
BC	93	0.390	0.275	17.34	0.677
BT	128	-0.428	0.183	4.01	0.841
CC	100	-0.250	0.250	42.04	0.517
CH	148	-0.264	0.177	93.44	0.334
GT	112	-0.631	0.230	36.38	0.546
R.	134	-0.427	0.166	38.11	0.537
RT	50	0.007	0.301	132.81	0.249
ST	114	-0.592	0.228	136.09	0.243
WR	135	-0.210	0.175	787.34	**0.005**
WW	101	-0.121	0.239	204.72	0.152

Table 12. *Population growth rate for heathland management under Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant results are highlighted in bold, near-significant ones (P<0.1) are underlined. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1for definitions of the species codes.

		Lowland and upland heathland combined			
Species	N	Est	SE	χ^2	P
CU	50	-0.404	0.421	98.31	0.321
L.	20	-2.982	2.228	277.96	<u>0.095</u>
MP	119	0.090	0.025	1278.71	**0.000**
S.	133	0.083	0.047	307.86	<u>0.079</u>
SC	62	0.064	0.072	78.78	0.375

Table 13. *Population growth rate for management of heathland under Tir Cynnal controlled for Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant results are highlighted in bold, near-significant ones (P<0.1) are underlined, n/a indicates insufficient data to run the analysis. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1 for definitions of the species codes.

		Heathland (habitat and Tir Gofal controlled)			
Species	N	Est	SE	χ^2	P
MP	56	-0.504	0.364	578.07	**0.016**
S.	71	-0.317	0.384	581.84	**0.016**
SC	31	n/a	n/a	n/a	n/a

Table 14. *Population growth rate for scrub management under Tir Gofal. Scrub Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.*
Statistically significant results are highlighted in bold, near-significant ones (P<0.1) are underlined. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1 for definitions of the species codes.

		Scrub			
Species	N	Est	SE	χ^2	P
BC	181	1.254	1.536	0.67	0.413
CC	199	2.641	1.461	3.32	<u>0.068</u>
D.	204	1.840	1.163	2.52	0.112
LI	120	2.901	1.772	2.68	0.102
R.	252	-0.062	0.737	0.01	0.933
SC	62	-8.521	5.309	2.71	0.100
WH	108	0.964	1.295	0.56	0.456
WR	255	1.575	0.731	4.65	**0.031**
WW	191	3.099	0.955	10.72	**0.001**
Y.	42	-0.378	3.920	0.01	0.923

Table 15. *Population growth rate for hedgerow management under Tir Gofal, displayed as parameter estimates ("Est") for the effects of option quantity on population growth rate, their standard errors (each multiplied by 100 for presentation purposes) and significance levels.* Statistically significant results are highlighted in bold. N shows the number of BBS squares with non-zero management in which the species was recorded. See Annex 1 for definitions of the species codes

		Hedgerow			
Species	N	Est	SE	χ^2	P
BF	90	0.003	0.003	77.15	0.380
CH	236	0.001	0.001	130.14	0.254
D.	191	0.002	0.001	483.74	**0.028**
GO	178	-0.001	0.002	51.50	0.473
GR	121	0.006	0.002	976.09	**0.002**
HS	164	0.005	0.001	1657.47	**0.000**
LI	98	0.009	0.003	1208.90	**0.001**
RB	35	0.001	0.006	4.84	0.826
SD	46	0.000	0.002	3.25	0.857
ST	193	0.003	0.001	676.62	**0.009**
WH	107	0.001	0.002	16.96	0.680

Annex 1 English and scientific names of BBS species code.

BBS code	English name	Scientific name	BBS code	English name	Scientific name
B.	Blackbird	*Turdus merula*	P.	Grey Partridge	*Perdix perdix*
BC	Blackcap	*Sylvia atricapilla*	PF	Pied Flycatcher	*Ficedula hypoleuca*
BO	Barn Owl	*Tyto alba*	R.	Robin	*Erithacus rubecula*
BK	Black Grouse	*Tetrao tetrix*	RB	Reed Bunting	*Emberiza schoeniclus*
BT	Blue Tit	*Cyanistes caeruleus*	RG	Red Grouse	*Lagopus lagopus*
BZ	Buzzard	*Buteo buteo*	RK	Redshank	*Tringa totanus*
CB	Corn Bunting	*Emberiza calandra*	RT	Redstart	Phoenicurus phoenicurus
CC	Chiffchaff	*Phylloscopus collybita*	RZ	Ring Ouzel	*Turdus torquatus*
CF	Chough	*Pyrrhocorax Pyrrhocorax*	S.	Skylark	*Alauda arvensis*
CH	Chaffinch	*Fringilla coelebs*	SC	Stonechat	Saxicola rubicola
CU	Curlew	*Numenius arquata*	SD	Stock Dove	*Columba oenas*
D.	Dunnock	*Prunella modularis*	SE	Short-eared Owl	*Asio flammeus*
DN	Dunlin	*Calidris alpina*	SF	Spotted Flycatcher	*Muscicapa striata*
DW	Dartford Warbler	*Sylvia undata*	SG	Starling	*Sturnus vulgaris*
GO	Goldfinch	*Carduelis carduelis*	SH	Sparrowhawk	*Accipiter nisus*
GR	Greenfinch	*Chloris chloris*	SN	Snipe	*Gallinago europeo*
GL	Grey Wagtail	*Motacilla cinerea*	ST	Song Thrush	*Turdus philomelos*
GP	Golden Plover	*Pluvialis apricaria*	TS	Tree Sparrow	*Passer montanus*
GS	Great-Spotted Woodpecker	*Dendrocopos major*	W.	Wheatear	*Oenanthe oenanthe*
HH	Hen Harrier	*Circus cyaneus*	WC	Whinchat	*Saxicola rubetra*
HS	House Sparrow	*Passer domesticus*	WH	Whitethroat	*Sylvia communis*
K.	Kestrel	*Falco tinnunculus*	WO	Wood Warbler	*Phylloscopus sibilatrix*
KF	Kingfisher	*Alcedo atthis*	WP	Woodpigeon	*Columba palumbus*
L.	Lapwing	*Vanellus vanellus*	WR	Wren	*Troglodytes troglodytes*
LI	Linnet	*Carduelis cannabina*	WT	Willow Tit	*Poecile montana*
ML	Merlin	*Falco columbarius*	WW	Willow Warbler	*Phylloscopus trochilus*
MP	Meadow Pipit	*Anthus pratensis*	Y.	Yellowhammer	*Emberiza citrinella*
MR	Marsh Harrier	*Circus aeruginosus*			
MT	Marsh Tit	*Poecile palustris*			
OC	Oystercatcher	*Haematopus ostralegus*			

Annex 2 Tir Gofal options and option names.

Option code	Option name
1A	*SEMI-NATURAL BROADLEAVED WOODLAND: Ungrazed*
1B	*SEMI-NATURAL BROADLEAVED WOODLAND: Lightly Grazed by Livestock*
1C	*SEMI-NATURAL BROADLEAVED WOODLAND: Grazed By Livestock*
2	*SCRUB*
5	*UPLAND HEATH (includes High Mountain Heath)*
6	*LOWLAND AND COASTAL HEATH*
7A	*UNIMPROVED ACID GRASSLAND: Enclosed Lowland*
7B	*UNIMPROVED ACID GRASSLAND: Unenclosed, 200 ha or less*
8	*UNIMPROVED NEUTRAL GRASSLAND*
8A	*UNIMPROVED NEUTRAL GRASSLAND: Haymeadow*
8B	*UNIMPROVED NEUTRAL GRASSLAND:Grazed*
9	*UNIMPROVED LIMESTONE GRASSLAND*
10	*SEMI-IMPROVED GRASSLANDS*
10A	*SEMI-IMPROVED GRASSLANDS: Haymeadow*
10B	*SEMI-IMPROVED GRASSLANDS: Grazed*
11	*MARSHY GRASSLAND*
11A	*MARSHY GRASSLAND: Unenclosed*
18	HEDGEROW RESTORATION
24B	*UNSPRAYED CEREAL, RAPE AND LINSEED CROPS FOLLOWED BY THE RETENTION OF WINTER STUBBLES: Conversion from improved grassland*
25A	*RETENTION OF WINTER STUBBLES IN CEREAL, RAPE AND LINSEED CROPS: After a Conventionally Grown Crop*
25B	*RETENTION OF WINTER STUBBLES IN CEREAL, RAPE AND LINSEED CROPS: After an Unsprayed Crop*
27	*UNSPRAYED ROOTS FOLLOWED BY WINTER GRAZING*
29	*UNCROPPED FALLOW MARGINS ALONGSIDE ARABLE AND ROOT CROPS*
30	*ESTABLISHMENT OF WILDLIFE COVER CROPS*
31D	*CONVERT ARABLE LAND TO GRASSLAND: Improved Coastal Grazing Marsh*
32A1	*CONVERSION OF IMPROVED GRASSLAND TO SEMI-IMPROVED GRASSLAND: Parkland to Semi-improved Haymeadow*
32B2.1	*CONVERSION OF IMPROVED GRASSLAND TO SEMI-IMPROVED GRASSLAND: Grazing Marsh for Lapwing*
32B2.2	*CONVERSION OF IMPROVED GRASSLAND TO SEMI-IMPROVED GRASSLAND:* Grazing Marsh / Lapwing and Wildfowl
34A	*MANAGE IMPROVED GRASSLAND FOR BREEDING LAPWING*
35A	*CONVERSION OF SEMI-IMPROVED GRASSLAND TO UNIMPROVED GRASSLAND: Neutral Grazed*
35B	*CONVERSION OF SEMI-IMPROVED GRASSLAND TO UNIMPROVED GRASSLAND:Acid/Limestone Grazed*
35C	*CONVERSION OF SEMI-IMPROVED GRASSLAND TO UNIMPROVED GRASSLAND: Acid/Limestone Restored by Haycropping*
35D	*CONVERSION OF SEMI-IMPROVED GRASSLAND TO UNIMPROVED GRASSLAND:Neutral Grassland*
36A	*INCREASE WATER LEVELS ON SUITABLE HABITATS AND FEATURES: Improved Land Managed for Conversion to Semi-improved*
36B	*INCREASE WATER LEVELS ON SUITABLE HABITATS AND FEATURES: Marshy Grassland*
36C1	*INCREASE WATER LEVELS ON SUITABLE HABITATS AND FEATURES :Improved Grazing Marsh for Lapwing*
42B	*ESTABLISH NEW SALTMARSHES AND REEDBEDS: New Saltmarsh on Improved land and New Reedbeds on Saltmarshes*

Appendix 5.2: Preliminary analysis of GMEP vegetation plots: can we detect a legacy effect of Tir Gofal on baseline habitat condition?

Introduction

One of the future aims of GMEP is to assess the impact of Glastir on species and habitats. To do this we need to evaluate the baseline condition and any existing variation in habitat condition. One possible source of existing variation is the legacy effects of previous agri-environment schemes. Schemes such as Tir Cynnal and Tir Gofal were the predecessors of Glastir and the prescriptions applied may have affected the habitat condition recorded in the baseline GMEP survey. For example if habitats in Tir Gofal entered the scheme with relatively higher quality or changed positively as a result of managed enhancement this could either limit scope for further enhancement or stimulate further positive change. Either way a significant effect of scheme legacy would need to be included to more fully explain responses to Glastir.

To investigate and quantify legacy effects we analysed differences in vegetation between plots that were on land that had previously been under the Tir Gofal scheme and plots that had never been under Tir Gofal. Tir Gofal was a higher level agri-environment scheme with a focus on enhancing existing habitats. The scheme ran from 1999 to 2012 and had components for both maintenance of existing habitats ("maintain" options) and for conversion or extensification of improved land ("enhance" options) (Medcalf *et al*. 2012). The evidence for a legacy effect on current performance indicators as a result of previous Tir Gofal prescriptions was evaluated from vegetation plot data from the Year 1 and 2 GMEP surveys.

Increased statistical power will arise when Years 3 and 4 of the first GMEP roll are included and so the results of this analysis should be considered preliminary.

Methods

Whether a GMEP survey plot was in land previously under Tir Gofal was assessed using spatial data provided by Welsh Government for the extent for Tir Gofal options. Because the Tir Gofal spatial data has information on which parcels of land were under which options, it was possible to assess whether a GMEP plot had been in land under a specific Tir Gofal option. In the spatial data linear options, such as hedgerow management, are mapped as line features with no width information. To account for inaccuracies in spatial mapping and the potential width of linear features each was assumed to be 10 metres wide. This will allow the effects of linear features to be assessed in plots that are not directly on top of the features e.g. plots next to hedges.

Initial investigation showed that 1043 out of 4135 (25%) of year 1 and 2 GMEP plots were in land that had previously been under a Tir Gofal option. Of these, most had been under options to maintain unenclosed grassland, wet grasslands, raised and blanket bog (Table 16). The 10 options present in more than 40 GMEP squares were investigated further, with the exception of the capital option for funding stock netting. The effect of stock netting is difficult to evaluate as it not possible to know exactly where stock were excluded from.

For each option, or combination of options, in Table 17 differences in a number of habitat condition indicators were evaluated between plots on land that had been under the relevant Tir Gofal option and plots on land where the option had never been applied. Each Tir Gofal option only applies to a certain number of habitats, for example marshy grassland maintenance option (11) only applies to habitat already containing marshy grassland (broad habitat classification fen, marsh and swamp). Therefore, when comparing plots in land that had been in Tir Gofal to land never in Tir Gofal, it is important to only use comparable habitat types. For example, to look at the effect of option 11 on maintaining marshy grassland only plots in fen, marsh and swamp that had never been under Tir Gofal option 11 would be used as the counterfactual. The same process was used to determine counterfactual datasets for other options: the habitat and landscape location (area of habitat or linear feature) impacted by the option were used as criteria to select equivalent plots sampling the same kind of habitat and feature but never subject to Tir Gofal options according to the spatial data layers provided.

The GMEP survey makes use of several different plot types which can be targeted in analyses to ensure only relevant parts of the landscape are assessed. For example, we are only interested in the effects of hedgerow restoration on vegetation recorded in hedgerows and we can use the GMEP plot type to filter the selection to the appropriate plot types (in the case of hedgerow restoration this is D plots). Table 17 shows the plot types included for analysis of each option.

Table 16. *Number of GMEP plots occurring on land that has previously been under Tir Gofal. Each Tir Gofal option is listed separately.*

Option code	Type	Description	Number of GMEP plots
7B	Maintain	Grassland (unenclosed)	121
88A1A	Capital works	Supplement for stock netting	111
11	Maintain	Marshy grassland	93
12	Maintain	Raised and blanket bog	71
40A	Enhance	Establish heathland on acid grassland	63
18	Capital works	Hedgerow restoration	62
7A	Maintain	Grassland (enclosed unimproved acid)	54
5	Maintain	Heaths (upland)	47
1A	Maintain	Ungrazed broadleaf woodland	42
10	Maintain	Semi-improved grassland	38
13	Maintain	Reedbeds, swamps and fens	34
10B	Maintain	Grazed semi-improved grassland	26
1B	Maintain	Lightly grazed broadleaf woodland	23
3BP	Maintain	Improved parkland	23
6	Maintain	Heaths (lowland including coastal)	17
2	Maintain	Scrub management	14
1C	Maintain	Grazed broadleaf woodland	14
32A2	Enhance	Conversion of improved grassland to semi-improved grassland: other improved land to semi-improved haymeadow	13
88A1	Capital works	Timber post and wire fencing	13
12A	Maintain	Blanket bog	12
19A	Capital works	Wall restoration	10
25B	Enhance	Retention of winter stubbles in cereal, rape and linseed crops after an unsprayed crop	10
7C	Maintain	Commons grassland	10

24A	Enhance	Unsprayed cereal, rape and linseed crops	9
8	Maintain	Unimproved neutral grassland	8
45C	Capital works	Heather management (cutting)	8
14A	Maintain	Coastal grazing marsh (improved grassland)	7
8B	Maintain	Unimproved grazed neutral grassland	7
29	Enhance	Uncropped fallow margins alongside arable and root crops	6
38	Enhance	Establishment of streamside corridors	6
10A	Maintain	Semi-improved grassland (haymeadow)	5
16A	Maintain	Grazed maritime cliff and slope	5
31C1	Enhance	Convert arable land to grassland: semi-improved grazed pasture	5
27	Enhance	Unsprayed roots followed by winter grazing	4
24B	Enhance	Unsprayed cereal, rape and linseed crops followed by the retention of winter stubbles	4
53A	Capital works	Scrub clearance (mechanical)	4
50.2	Capital works	Bracken control (chemical)	3
25A	Enhance	Retention of winter stubbles in cereal, rape and linseed crops after a conventionally grown crop	3
32B3	Enhance	Conversion of improved grassland to semi-improved grassland: other improved land to pasture	3
34B	Enhance	Manage improved grassland for over wintering wildfowl	3
26	Enhance	Spring sown cereals undersown with grasses and legumes	2
50.1	Capital works	Bracken control (mechanical)	2
60	Linear	Piping for water supply	2
14/10B	Maintain	Coastal grazing marsh (semi-improved grassland)	2
14/15A	Maintain	Coastal grazing marsh (floodplain grassland scrub)	2
35D	Enhance	Conversion of semi-improved grassland to unimproved grassland: neutral restored by haycropping	2
3CP	Maintain	Arable parkland	2
30	Enhance	Establishment of wildlife cover crops	1

33	Enhance	Create water feature buffer zone on arable	1
14/1A	Maintain	Coastal grazing marsh (improved grassland)	1
15C	Maintain	Saltmarsh (existing un-grazed marsh)	1
16B	Maintain	Maritime cliff and slope (ungrazed)	1
37A	Enhance	Establish new broadleaved woodlands and scrub: establish payment	1
37C	Enhance	Establish new broadleaved woodlands and scrub: plant new woodland	1
3AP	Maintain	Semi-improved parkland	1
Grand Total			**1043**

Table 17. *Options, or combinations of options, for which Tir Gofal legacy effects on habitat condition indicators were evaluated. X and U plots are randomly placed in areas of habitat away from linear features with U plots targeting unenclosed habitats. D plots sample woody linear features including hedgerows. B plots sample field boundaries.*

Option code	Description	Applicable broad habitat	Applicable plot types
1A	Maintain ungrazed broadleaved woodland	Broadleaved woodland	X, Y
5	Maintain upland heath	Dwarf shrub heath, bog	U, X
7A/7B	Maintain unenclosed grassland or enclosed unimproved acid grassland	Acid grassland	U, X
7B/12	Maintain unenclosed grassland or raised and blanket bogs	Bog	U, X, Y
11	Maintain marshy grassland	Fen, marsh, swamp	X, Y, U
18	Hedgerow restoration	Arable and horticulture, improved grassland, neutral grassland	D
40A	Establish heath on acid grassland	Acid grassland	U, X
IMP(B56)	Maintain improved grassland	Improved grassland, neutral grassland	B

The indicators chosen to report on the impacts of each option are shown in Table 18. Indicators were chosen based on both the performance indicators used in Tir Gofal monitoring (Natural Resources Wales 2001) and on the vegetation plot data available from the GMEP survey. Several of the performance indicators used in the Tir Gofal monitoring were not recorded in the GMEP survey and could not be used. Additional indicators were included to aid detection of the expected ecological impact of the option (Table 18).

Table 18. *Indicators used to assess impact of legacy schemes on habitat condition. Where the indicator has an asterisk this indicates an exact or very close match to the performance indicators used in the Tir Gofal Monitoring Report for that option.*

	Tir Gofal option						
Indicator	**1A**	**5**	**7A/7B**	**7B/12**	**11**	**18**	**40A**[a]
AWI richness	x						
Bracken cover			x*	x*			x*
Conifer cover	x						
Dwarf shrub cover		x*		x*			x*
Ellenberg F			x	x	x		x
Ellenberg N	x	x	x	x	x		x
Eriophorum vaginatum cover				x			
Grass : forb ratio		x	x	x	x		x
Non-native cover	x*						
Rush cover			x	x	x*		x
Sphagnum cover				x*	x		x
Total richness	x					x	
Understorey height	x						
Woody cover	x			x			x

[a] Compared to Tir Gofal performance indicators for heathland reversion

The Tir Gofal scheme ran between 1999 and 2012, with new entrants only accepted until 2009. Plots that entered in the first half of the scheme (1999 to 2006) had therefore been under options for longer, and might be expected to show more change, than plots which only entered in the latter half of the scheme (2006-2012). To account for this, differences were investigated between three groups of plots: Never in Tir Gofal, Entered Tir Gofal post-2006 and Entered Tir Gofal pre-2006. Differences in performance indicators between these groups were assessed using linear mixed models where Tir Gofal group (Never in Tir Gofal, entered post-2006, entered pre-2006) was a fixed effect and survey square was a random effect. Where the indicator was a count variable (e.g. total richness) generalised linear mixed models with a Poisson distribution were used. The expectation was for greater differences to be present between counterfactual plots and Tir Gofal plots that had entered earlier rather than later. Without more intensive time series monitoring it is not possible to say however whether such effects are evidence of a positive change over time or better targeting of habitat that entered the scheme earlier.

Results

For the vast majority of indicators (42 out of 45) there was no evidence that plots occurring on land previously subjected to Tir Gofal prescriptions had different values to plots on land which had never been under Tir Gofal (Annex 3). In three cases a significant difference was observed between the Tir Gofal groups (Table 19). For one of these cases, a difference in bracken cover under options 7A and 7B, there was very little data available and therefore the confidence in this result is low. For the other cases where a significant difference was seen, one (total species richness under option 1A) only showed significant differences between the two time periods of Tir Gofal application and no difference from land where Tir Gofal was never applied. This is due to the larger variation in richness in land where Tir Gofal never occurred, even after filtering for habitat and plot type (Figure 2 a). For option 1A (Ungrazed broadleaved woodland) species richness was higher in plots that had entered Tir Gofal before 2006. In one case there were significant differences between plots in land that had entered Tir Gofal before 2006 and plots that had never been under Tir Gofal. Plots that had entered option 5 (maintain upland heath) before 2006 had lower grass:forb ratio in 2013/’14 than plots never in Tir Gofal (Figure Y1 b).

Table 19. *Tests of the difference between each indicator variable in groups of plots that came into Tir Gofal earlier (pre-2006) or later (post-2006) versus counterfactual plots never in Tir Gofal but in equivalent habitat type.*

Option	Indicator	Comparison	Estimated difference	P value
1A	Total species richness	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.39215	0.027227
5	Grass : forb ratio	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-1.82549	0.007668
7A/7B	Bracken cover	Entered Tir Gofal pre-2006 - Never in Tir Gofal	1.544481	0.042537†

† There was very little data to support this result so it is not discussed further.

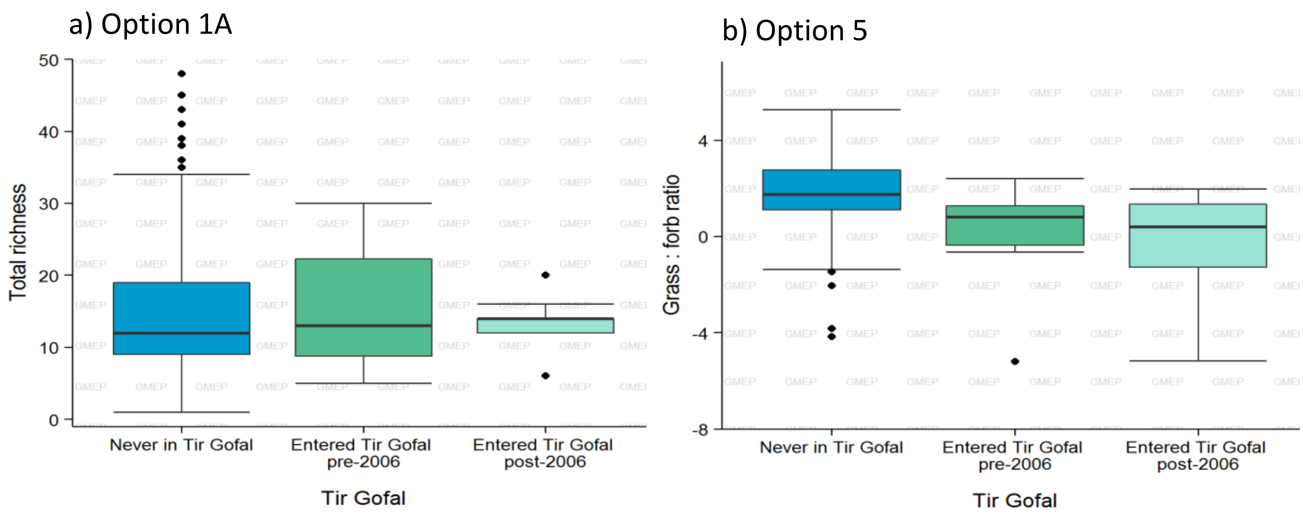


Figure 2. *Significant differences in indicator variables between plots in land that entered Tir Gofal in two different time periods (before or after 2006) and plots that had never been in Tir Gofal.* Corresponding significance tests are presented in Table 19 and total numbers of plots in each analysis in Table 20.

Table 20. *Number of GMEP vegetation plots from the year 1 and 2 surveys that coincided with Tir Gofal options and counterfactual plots never in Tir Gofal.*

Option code	Number of plots in option	Number of plots in counterfactual
11	28	183
18	33	534
1A	21	221

40A	28	170
5	19	217
7A/7B	55	143
7B/12	38	156

Discussion

In interpreting the impacts of legacy schemes on the baseline conditions observed in GMEP squares it is important to note that the GMEP survey was not designed to evaluate legacy scheme effects and therefore our results may differ from the monitoring conducted by past agri-environment schemes. In particular, we only attempted to detect the signal of Tir Gofal in the first two years of Gmep survey data. Our sample sizes were therefore small compared to previous more intensive evaluation of Tir Gofal in which a wider range of scheme effects were detected (Medcalf et al 2012). In addition, we have only evaluated one past scheme and our sample size is small for most Tir Gofal options, therefore caution should be used in evaluating the results. However, despite these concerns, it is important to consider the potential effects of previous agri-environment schemes on the baseline conditions recorded by the GMEP survey. If there was evidence that Tir Gofal was responsible for differences in the baseline levels of indicators recorded then it would be important to account for this effect in future analyses of Glastir impact to avoid incorrectly attributing change. Our analysis suggests that, within the first and second years of GMEP recording, there was little evidence that Tir Gofal had led to lasting changes in the indicators measured. Only three out of 47 option-indicator combinations showed any influence of Tir Gofal occurrence or duration and only two of these showed differences between plots that had been in Tir Gofal and those that had not which were well supported by the data (i.e. excluding the difference in bracken cover in option 7A/7B).

Grass : forb ratio was found to be significantly lower in upland heathlands that had been maintained under Tir Gofal option 5 than in heathlands that had never been in Tir Gofal. Low grass:forb ratio is considered to be indicative of better ecological condition, as a high proportion of graminoids is often a result of excessive nutrient enrichment or over-grazing. Unfortunately, grass : forb ratio was not used as a performance indicator in the Tir Gofal monitoring surveys and therefore a direct comparison with this evaluation cannot be made. However, the Tir Gofal monitoring report (Medcalf et al 2012) did conclude that heathland sites were generally being well protected by Tir Gofal, with 45% of sites improving in ecological condition. The report also concluded that changes in condition in heathland were likely to occur in the long term as most changes were observed in only the second of two resurveys, eight years after the start of Tir Gofal. Our results support this conclusion, with only plots that entered Tir Gofal before 2006 having a significantly lower grass:forb ratio.

Overall our results suggest that, in most cases, there is no evidence that Tir Gofal has led to long term changes in the indicators assessed which would need to be accounted for in any analysis of change due to Glastir measures. However, this result does not necessarily mean that the Tir Gofal scheme did not have any long term impacts. At this stage it is more likely to reflect our inability to detect effects given the small sample size available. Hence, based on just years 1 and 2, we do not have enough coincidence between GMEP plots and past Tir Gofal option land to adequately test whether the positive changes seen in grasslands, woodland and blanket bog in Medcalf et al (2012) are reflected in the GMEP sample. These analyses will have greater power when all four years of data have been accumulated. At that point we will re-run these analyses in preparation for analysing change in time once the second roll starts to yield repeat data.

References

Natural Resources Wales. 2001. Performance Indicators for Tir Gofal Habitat Management Prescriptions. Draft 4. January 2001.

Medcalf K., Whittick E., Turton, N., Cross, D. 2012. Wales Agri-Environment Monitoring Lot 1: Habitats. Final Report. Welsh Government.

Annex 3. Predicted indicator values and significance tests for all 47 indicator/option combinations between three Tir Gofal groups: Never in Tir Gofal, Entered Tir Gofal pre-2006 and Entered Tir Gofal post-2006. Rush cover comprises cover *of J.effusus, maritima, inflexus, conglomeratus, acutiflorus*. Woody cover comprises trees and shrubs including Bramble and Roses but excluding dwarf shrubs.

Option code	Indicator	Estimate of indicator in each Tir Gofal group				Differences in indicators between Tir Gofal groups		
11	Ellenberg N	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	3.939	3.735	4.144	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.245	0.675
		Entered Tir Gofal pre-2006	3.694	3.139	4.249	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.612	0.188
		Entered Tir Gofal post-2006	3.327	2.635	4.020	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.367	0.662
11	Grass : forb ratio	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	-0.031	-0.338	0.275	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.034	0.997
		Entered Tir Gofal pre-2006	0.003	-0.910	0.915	Entered Tir Gofal post-2006 - Never in Tir Gofal	1.025	0.278
		Entered Tir Gofal post-2006	0.993	-0.321	2.307	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.991	0.423
11	Rush cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	2.673	2.252	3.094	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-1.011	0.297
		Entered Tir Gofal pre-2006	1.662	0.372	2.952	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.869	0.642
		Entered Tir Gofal post-2006	1.804	-0.091	3.700	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.143	0.991
11	*Sphagnum* cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.589	1.117	2.062	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.439	0.815
		Entered Tir Gofal pre-2006	1.150	-0.222	2.523	Entered Tir Gofal post-2006 - Never in Tir Gofal	1.324	0.357
		Entered Tir Gofal post-2006	2.913	1.013	4.814	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	1.763	0.276
11	Ellenberg F	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	7.207	7.112	7.302	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.250	0.239
		Entered Tir Gofal pre-2006	7.457	7.164	7.751	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.130	0.825
		Entered Tir Gofal post-2006	7.337	6.907	7.766	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.121	0.888
18	Total richness	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	5.300	4.230	6.370	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.062	0.815
		Entered Tir Gofal pre-2006	5.639	4.408	6.870	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.066	0.859
		Entered Tir Gofal post-2006	4.961	3.670	6.253	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.128	0.696

1A	AWI richness	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	2.590	1.439	3.740	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.377	0.070
		Entered Tir Gofal pre-2006	3.776	2.360	5.192	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.176	0.723
		Entered Tir Gofal post-2006	2.171	0.569	3.774	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.553	0.128
1A	Conifer cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.335	0.173	0.496	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.065	0.982
		Entered Tir Gofal pre-2006	0.270	-0.424	0.963	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.335	0.691
		Entered Tir Gofal post-2006	0.000	-0.801	0.801	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.270	0.867
1A	Ellenberg N	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	5.183	5.045	5.320	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.049	0.972
		Entered Tir Gofal pre-2006	5.133	4.700	5.567	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.089	0.933
		Entered Tir Gofal post-2006	5.272	4.765	5.778	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.138	0.907
1A	Non-native cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.148	0.766	1.530	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.348	0.890
		Entered Tir Gofal pre-2006	1.495	0.005	2.986	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.285	0.944
		Entered Tir Gofal post-2006	0.862	-0.875	2.600	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.633	0.844
1A	Total richness	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	13.609	12.534	14.683	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.127	0.374
		Entered Tir Gofal pre-2006	15.459	14.245	16.672	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.265	0.065
		Entered Tir Gofal post-2006	10.444	9.173	11.715	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.392	0.027
1A	Understorey height	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.861	1.691	2.032	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.063	0.980
		Entered Tir Gofal pre-2006	1.799	1.146	2.451	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.336	0.658
		Entered Tir Gofal post-2006	2.197	1.436	2.959	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.399	0.704
1A	Woody cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	10.093	9.629	10.557	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.145	0.989
		Entered Tir Gofal pre-2006	10.237	8.255	12.220	Entered Tir Gofal post-2006 - Never in Tir Gofal	1.431	0.440
		Entered Tir Gofal post-2006	11.524	9.234	13.815	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	1.287	0.672

40A	Bracken cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.478	0.176	0.780	Entered Tir Gofal pre-2006 - Never in Tir Gofal	1.099	0.327
		Entered Tir Gofal pre-2006	1.577	0.050	3.103	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.684	0.253
		Entered Tir Gofal post-2006	1.162	0.324	2.001	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.414	0.881
40A	Ellenberg N	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	3.079	2.926	3.232	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.089	0.933
		Entered Tir Gofal pre-2006	2.990	2.473	3.507	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.142	0.626
		Entered Tir Gofal post-2006	3.221	2.893	3.549	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.231	0.711
40A	Grass : forb ratio	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.874	1.604	2.143	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.167	0.953
		Entered Tir Gofal pre-2006	2.040	0.900	3.180	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.270	0.705
		Entered Tir Gofal post-2006	2.144	1.458	2.829	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.103	0.986
40A	Rush cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.872	0.633	1.110	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.472	0.779
		Entered Tir Gofal pre-2006	0.400	-0.991	1.791	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.185	0.852
		Entered Tir Gofal post-2006	0.687	0.038	1.335	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.287	0.925
40A	*Sphagnum* cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.654	0.411	0.897	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.592	0.617
		Entered Tir Gofal pre-2006	0.062	-1.192	1.316	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.276	0.707
		Entered Tir Gofal post-2006	0.377	-0.299	1.054	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.315	0.896
40A	Dwarf shrub cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.483	1.149	1.816	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.322	0.911
		Entered Tir Gofal pre-2006	1.161	-0.406	2.728	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.448	0.589
		Entered Tir Gofal post-2006	1.035	0.131	1.938	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.126	0.989
40A	Woody cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.406	0.193	0.619	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.924	0.172
		Entered Tir Gofal pre-2006	-0.518	-1.538	0.503	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.030	0.994
		Entered Tir Gofal post-2006	0.436	-0.146	1.018	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.953	0.233

40A	Ellenberg F	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	6.116	6.001	6.231	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.180	0.740
		Entered Tir Gofal pre-2006	5.936	5.446	6.426	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.210	0.320
		Entered Tir Gofal post-2006	5.906	5.612	6.200	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.030	0.994
5	Ellenberg N	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	2.291	2.170	2.412	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.099	0.917
		Entered Tir Gofal pre-2006	2.192	1.690	2.693	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.012	0.998
		Entered Tir Gofal post-2006	2.279	1.867	2.690	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.087	0.959
5	Grass : forb ratio	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.858	1.527	2.190	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-1.825	0.008
		Entered Tir Gofal pre-2006	0.033	-1.181	1.246	Entered Tir Gofal post-2006 - Never in Tir Gofal	-1.141	0.100
		Entered Tir Gofal post-2006	0.717	-0.396	1.830	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.684	0.661
5	Dwarf shrub cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	5.284	4.645	5.924	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.852	0.760
		Entered Tir Gofal pre-2006	6.136	3.707	8.566	Entered Tir Gofal post-2006 - Never in Tir Gofal	1.479	0.300
		Entered Tir Gofal post-2006	6.763	4.740	8.786	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.626	0.910
7A/7B	Bracken cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.397	0.086	0.709	Entered Tir Gofal pre-2006 - Never in Tir Gofal	1.544	0.043
		Entered Tir Gofal pre-2006	1.942	0.687	3.197	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.533	0.169
		Entered Tir Gofal post-2006	0.931	0.389	1.473	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-1.011	0.290
7A/7B	Ellenberg N	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	3.067	2.910	3.224	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.101	0.869
		Entered Tir Gofal pre-2006	2.965	2.549	3.382	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.125	0.442
		Entered Tir Gofal post-2006	3.192	2.966	3.417	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.226	0.548
7A/7B	Grass : forb ratio	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.865	1.585	2.146	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.086	0.981
		Entered Tir Gofal pre-2006	1.951	1.022	2.881	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.154	0.776
		Entered Tir Gofal post-2006	2.019	1.566	2.472	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.068	0.990

7A/7B	Rush cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.802	0.541	1.062	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.180	0.951
		Entered Tir Gofal pre-2006	0.982	-0.195	2.159	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.125	0.879
		Entered Tir Gofal post-2006	0.926	0.477	1.376	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.056	0.996
7A/7B	Ellenberg F	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	6.125	6.005	6.246	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.017	0.996
		Entered Tir Gofal pre-2006	6.142	5.743	6.541	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.160	0.230
		Entered Tir Gofal post-2006	5.965	5.770	6.159	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.177	0.681
7B/12	Bracken cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.092	-0.006	0.191	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.081	0.959
		Entered Tir Gofal pre-2006	0.011	-0.580	0.602	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.083	0.705
		Entered Tir Gofal post-2006	0.010	-0.182	0.202	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.001	1.000
7B/12	*Eriophorum vaginatum* cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	2.932	2.423	3.441	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.929	0.780
		Entered Tir Gofal pre-2006	3.861	1.083	6.639	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.223	0.900
		Entered Tir Gofal post-2006	2.709	1.758	3.660	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-1.152	0.705
7B/12	Ellenberg N	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.934	1.847	2.021	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.039	0.989
		Entered Tir Gofal pre-2006	1.973	1.407	2.539	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.028	0.953
		Entered Tir Gofal post-2006	1.906	1.731	2.081	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.067	0.971
7B/12	Grass : forb ratio	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	1.912	1.564	2.259	Entered Tir Gofal pre-2006 - Never in Tir Gofal	1.283	0.283
		Entered Tir Gofal pre-2006	3.195	1.505	4.885	Entered Tir Gofal post-2006 - Never in Tir Gofal	0.556	0.219
		Entered Tir Gofal post-2006	2.467	1.845	3.090	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.728	0.691
7B/12	Rush cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.561	0.281	0.841	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.195	0.974
		Entered Tir Gofal pre-2006	0.367	-1.429	2.162	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.144	0.885
		Entered Tir Gofal post-2006	0.418	-0.144	0.979	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.051	0.998

7B/12	*Sphagnum* cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	5.304	4.711	5.897	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-1.032	0.822
		Entered Tir Gofal pre-2006	4.272	0.795	7.749	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.996	0.246
		Entered Tir Gofal post-2006	4.308	3.164	5.452	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	0.036	1.000
7B/12	Dwarf shrub cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	3.922	3.132	4.712	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.539	0.946
		Entered Tir Gofal pre-2006	3.383	-0.063	6.829	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.583	0.666
		Entered Tir Gofal post-2006	3.339	2.024	4.654	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.044	1.000
7B/12	Woody cover	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	0.109	0.013	0.206	Entered Tir Gofal pre-2006 - Never in Tir Gofal	0.264	0.544
		Entered Tir Gofal pre-2006	0.373	-0.130	0.875	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.086	0.632
		Entered Tir Gofal post-2006	0.023	-0.153	0.199	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.350	0.379
7B/12	Ellenberg F	Tir Gofal group	Estimated value	Lower estimate	Upper estimate	Test	Estimated difference	P value
		Never in Tir Gofal	7.198	7.087	7.309	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-0.057	0.986
		Entered Tir Gofal pre-2006	7.141	6.431	7.851	Entered Tir Gofal post-2006 - Never in Tir Gofal	-0.100	0.686
		Entered Tir Gofal post-2006	7.098	6.876	7.321	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.043	0.992

Appendix 5.3: Long-term Population Trends of Birds in Wales

Gavin M. Siriwardena and Daria Dadam
British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2LW.
Updated May 2015

Introduction
Annual breeding bird monitoring occurs in Wales independently of GMEP, under the BTO/JNCC/RSPB Breeding Bird Survey (BBS), a scheme using volunteer survey effort to cover a random selection of 1km squares every year. This survey is designed to provide long-term, large-scale monitoring of bird and larger mammal populations, and it can be used to test for signals of management, such as agri-environment schemes, at large temporal and spatial scales (e.g. Davey et al. 2010, Baker et al. 2012). However, the survey method is not intensive and it does not provide reliable information on absolute annual population sizes in local survey squares, or of the locations of bird with respect to fine-scale habitat patches, so the bespoke surveys under GMEP are essential for testing Glastir effectiveness. Nevertheless, the national coverage of BBS monitoring makes it ideal for revealing broad population changes of widespread species.

Here, up-to-date background population changes for the whole of Wales are presented for the life of the BBS to date, i.e. from 1994 to 2013. Data typically take around a year to be processed and made ready for analysis, but it is intended that this document be kept up to date throughout GMEP as a source of reference for all-Wales population trends among bird species of interest. The population trends shown are estimates of changes in relative abundance across the whole of Wales, so are appropriate for assessing progress towards statutory conservation targets.

The population trends shown are mostly taken from the BTO's annual Bird Trends Report (http://www.bto.org/about-birds/birdtrends), with the addition of data on some species that are recorded less commonly than is required for the standards of that report and data from other sources for very rare species (see below). Details of the BBS survey methods and of the analytical techniques used can be found there (http://www.bto.org/about-birds/birdtrends/2014/methods/breeding-bird-survey). In brief, however, the survey is based on a random sample of 1km squares, stratified by observer density, which are visited twice each year. On each visit, 2km of transect is walked and maximum counts per square per year are used to estimate annual indices of relative abundance, which are the back-transformed year effects from a log-linear Poisson model of count as a function of categorical site and year effects. Most conservation applications are concerned with long-term, underlying population trends, rather than short-term changes driven by weather (for example). Changes are therefore presented both as annual index values (blue squares) and as smoothed trends (green lines). Confidence intervals (green shaded areas) are estimated by bootstrapping by survey square.

The species shown are those that are of general interest for conservation or specific interest for potential effects of Glastir, together with as many other Section 42 priority species as possible. For the Bird Trends report, species present in fewer than 30 BBS squares are excluded because small sample sizes provide less reliable results. This is particularly the case in a survey like the BBS, where turnover of squares in the sample can lead to rapid changes in pattern between years if squares with contrasting local populations of a rare species drop in and out. However, the choice of a 30-square threshold is arbitrary and a lot of the uncertainty associated with small samples is reflected in increases in the breadth of the confidence intervals around the smoothed trends. For the purposes of reporting the maximum amount of information on trends in Wales, therefore, species of interest with smaller sample sizes but for which the calculation of annual index values was still tractable are included below. Nevertheless, indices for species for which samples fell below the 30-square threshold are less reliable and these species are flagged; the trends indicated for them should be interpreted with caution.

Even after including the rarer species in BBS, no national monitoring data are available for a number of priority species for conservation in Wales. Intensive surveys are conducted annually for Chough (A. Cross & A. Stratford, pers. comm.) and these data will be summarized here in due course. Data are available for some further species from bespoke surveys; where these results are published, they are incorporated below (for Hen Harrier and Golden Plover), while unpublished data will be added when provided by the data holders (notably RSPB). For other key species not effectively extinct in Wales, but sufficiently uncommon to be noteworthy species for recreational birdwatchers, informal count records are collated by county in the annual Birds in Wales report produced by the Welsh Ornithological Society. The species considered are Twite, Golden Plover, Hawfinch, Hen Harrier, Ring Ouzel, Tree Sparrow, Turtle Dove and Yellow Wagtail. These data are not standardized and are likely to incorporate considerable variation in effective sampling effort. However, it is likely that birdwatchers visit the same sites each year and those who are regular contributors to bird reports probably have reasonably regular habits from year to year. Overall, it would be unwise to interpret the fine details of changes in these counts between years as reliable, but gross changes in abundance within very small populations should be apparent, provided that coverage by county is reasonably consistent over time and all relevant counties appear in the annual data fairly frequently. Hence, data were extracted from the Birds in Wales reports from 1995 to 2012 (excluding 2001, when countryside closure due to foot-and-mouth disease restricted access for birdwatchers) for birds likely to be breeding in Welsh counties. The biology and phenology of movement of each species were used to decide whether an entry in a report referred to a breeding bird. Only entries with a defined number of individuals were included and reports of “pairs” or “territories” were interpreted as representing two birds each. If a range of counts was provided, the maximum was taken as the annual number for the location concerned. A reporting bias was present in some years and/or locations in which, due to birds being numerous, numbers of individuals were not reported. Another possible bias was due to lack of confirmed zero counts: a species that had not been reported from a location was treated as missing value rather than as confirmed absence, unless absence was reported explicitly. Only counties reporting counts in two or more years were included. This may result in an apparent downturn in population which is, in fact, an artefact of the reporting methodology of the Bird Reports used. The impact of this problem was minimized by the statistical approach that was used, assuming that population changes were uniform in direction across the counties from which counts were reported and that the major centres of population were covered in some years at least. Nevertheless, it is important to recognize that the report data are no substitute for structured sampling or population censuses and it would be unwise to use them as more than a general guide to population trajectories, as opposed to definitive information about (relative) population size. In the future, these analyses should be replaced by more standardized monitoring if it becomes possible, or by analyses of data gathered within BirdTrack (www.birdtrack.net).

Annual county-specific numbers of birds were modelled as a function of year and county identity, as categorical factors, specifying Poisson errors and a log link function, weighting by the number of counties contributing data in each year. Back-transformed annual year effect estimates were then plotted against year to show temporal trends in abundance. This method is the same as that normally used for population index generation using national survey data such as from the BBS. To summarize population trends over time, linear trends were fitted through the annual index values using least squares regression, once again weighting by the number of counties contributing data in each year as an index of annual data quality. For Twite, data were present from only one county; therefore the trend shows the raw number of birds plotted against year.

Trends from the best available of the sources described above are shown for each species, using data from across the whole of Wales, together with BBS trends for the whole of the UK if they are appreciably different from the Wales ones. The vertical lines on each graph show the periods used to produce trend summaries in GMEP reporting. The text simply then describes the broad patterns seen; for more detail and information on variation in demographic parameters where available, please see the BTO Bird Trends report website (follow links for each species accounts). In addition, summaries of range change revealed from Bird Atlas 2007-2011 (Balmer et al. 2013), which considered distributions at the 10km square scale across the whole of Wales and how these have changed over four decades, are summarized for the rarest species.

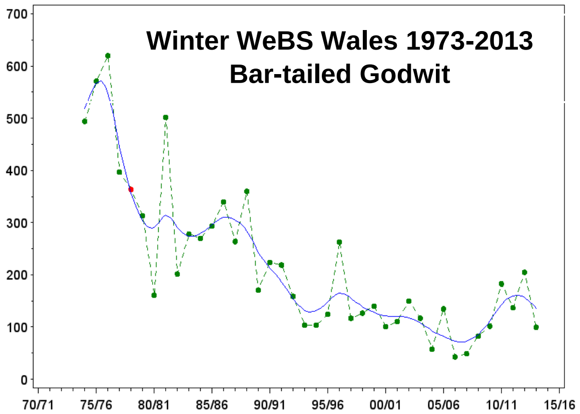
All of the above relates to breeding bird populations. However, eight Section 42 priority species are so designated because of the wintering populations. These species (Bar-tailed Godwit, Bewick's Swan, Black-headed Gull, Common Scoter, Dark-bellied Brent Goose, Greenland Greater White-fronted Goose, Herring Gull and Ringed Plover) are all surveyed annually by the BTO/JNCC Wetland Bird Survey (WeBS) in coastal and inland wetland habitats. Details of WeBS methodology can be found at http://www.bto.org/volunteer-surveys/webs, but it is a volunteer survey that operates throughout the year, aiming to provide total population counts for coastal habitats and to cover a representative sample of inland stillwaters. Counts are made monthly and the winter data presented here collate records from October-March each year for sites in Wales.

Three of the wetland Section 42 species also breed in Wales, but are not monitored effectively by the BBS. For these species (Black-headed Gull, Herring Gull and Ringed Plover), breeding season WeBS trends (derived from counts from April to June) are also presented.

All WeBS trends are shown for the maximum run of data collected under the scheme for each species, but discussion of the trends focuses on the periods from 1994, as for the other trends. Dots and dashed lines show inter-annual changes, while solid lines show smoothed trends. Green dots are drawn entirely from empirical data, while red dots show where an appreciable portion of the sample has been imputed due to gaps in survey coverage.

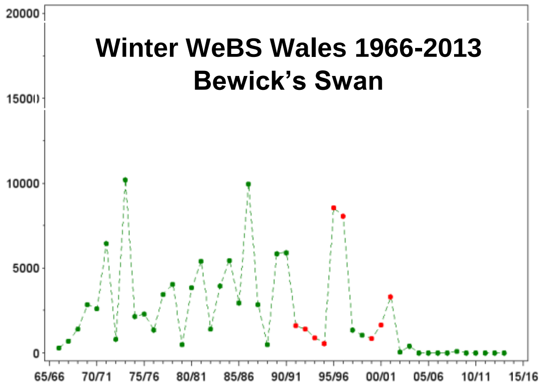
Species accounts (in alphabetical order)

BAR-TAILED GODWIT (Limosa lapponica)



The Bar-tailed Godwit population wintering in Wales has been rather stable overall since the mid-1990s, but this follows a sustained period of decline. Recent changes may show the beginning of a recovery of the population, but this is currently unclear.

BEWICK'S SWAN (Cygnus columbianus bewickii)

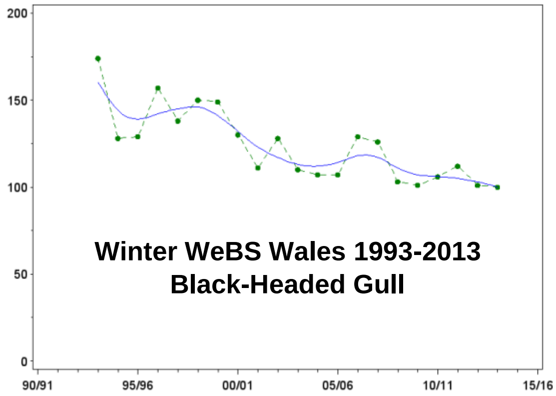


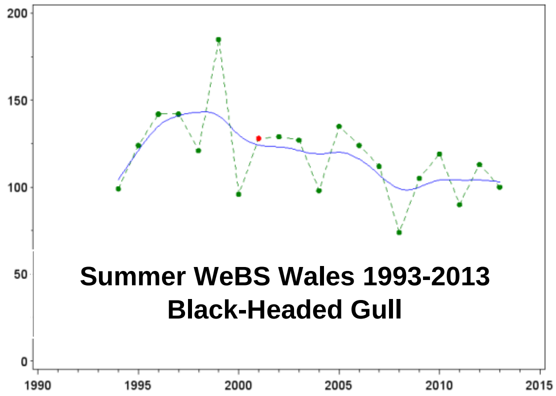
The global population of Bewick's Swan has declined by 27% and there may also have been a tendency for the species to winter further east than was the case historically (Balmer et al. 2013). Wales is at the western edge of the wintering range and the broad scale changes have been reflected in the species' almost total disappearance as a significant wintering bird: only scattered records were reported for the 2007-11 Bird Atlas (Balmer et al. 2013). The winter WeBS trend also reflects this pattern, with counts effectively being zero since 2002-03. Note that the latter means that the species cannot contribute to the summary population trend indicator in the GMEP reporting.

BLACK GROUSE (Tetrao tetrix)

The Black Grouse distribution in Wales has contracted considerably since 1970, with the species having been lost from more southerly upland areas now to be concentrated in Snowdonia and the Clywdian Hills, although the latter area has seen some gains in abundance (Balmer et al. 2013). There are too few Bird Report records for this species to allow any analyses of incidental data, but RSPB have conducted periodic surveys that inform about population changes in Wales and the aim is to incorporate these data here in due course.

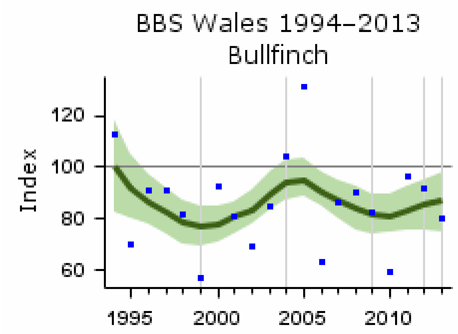
BLACK-HEADED GULL (Larus ridibundus)





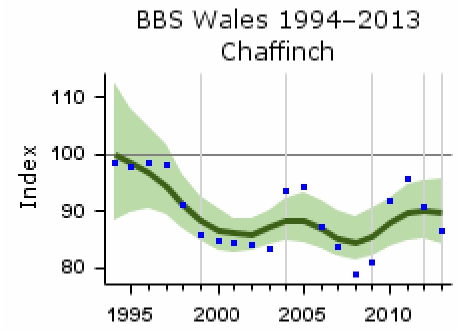
Both the breeding and wintering Black-Headed Gull populations in Wales have declined since the mid-1990s, although the pattern is clearer and stronger, being subject to smaller fluctuations, in wintering numbers. This may be the result of sampling error, with colonies either being somewhat mobile, or sites with differently sized colonies dropping in and out of the survey sample over time.

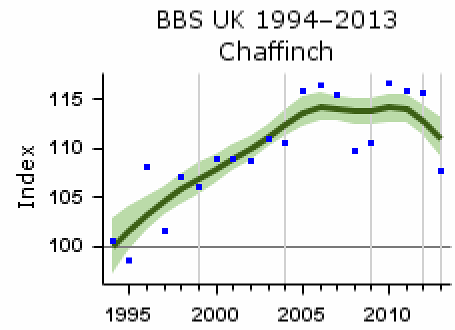
BULLFINCH (Pyrrhula pyrrhula)



The Bullfinch population trend in Wales reflects trends in the wider UK. In England at least, there was a steep decline that started before the inception of BBS; in Wales, as in England, populations may now be increasing, or perhaps fluctuating around a stable level. [More detail]

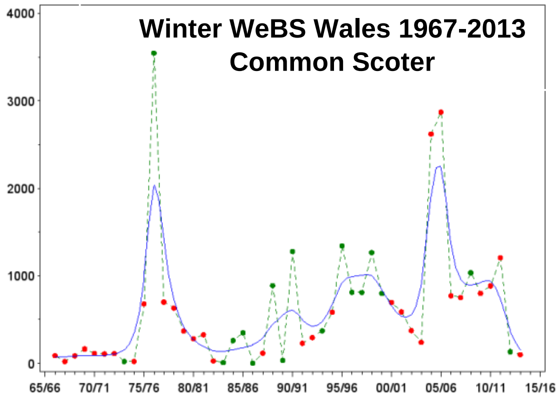
CHAFFINCH (*Fringilla coelebs*)





The species has been showing a fluctuating population trend in Wales, in contrast with the upward UK trend. [More detail]

COMMON SCOTER (Melanitta nigra)



There has been some uncertainty over wintering Common Scoter numbers around Wales, as shown by the large number of imputed counts in the time series (red dots). The data suggest that numbers have fluctuated considerably over time, but with a tendency to increase since the early 1990s, notwithstanding low counts in the most recent two winters.

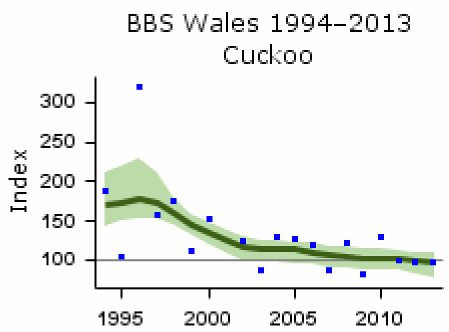
CORN BUNTING (Emberiza calandra)

There is no BBS trend for Corn Bunting produced for Wales and it is now extinct as a breeding species, reflecting the long-term trend across the UK, which has shown a steep decline during the BBS period and before. [More detail] Bird Atlas 2007-11 (Balmer et al. 2013) shows the losses of (already sparse) pockets of breeding Corn Buntings during the 1970s and 1980s, with the final breeding locations being lost between 1991 and 2011. Occasional birds are recorded in Wales, near the English border, so recolonization is possible given appropriate habitat management.

CHOUGH (Pyrrhocorax pyrrhocorax)

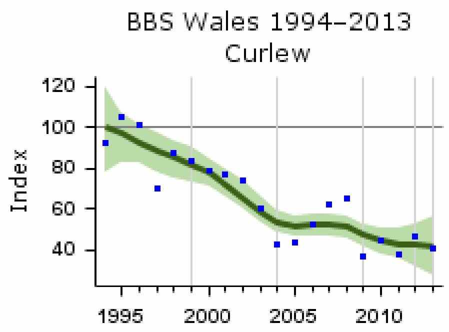
No BBS trend can be produced for chough in Wales because the species is too localized. Survey data may be available from independent volunteer surveyors, which it is hoped will be available here for Ceredigion and northwards in Spring 2015, with data to be added for Dyfed in due course, pending negotiation. Bird Atlas 2007-11 (Balmer et al. 2013) shows increases in the Chough breeding range, especially since 1991, with newly recorded locations on the south coast in particular. The bulk of the population is found in Snowdonia and on the west coast, particularly in Gwynedd and Pembrokeshire.

CUCKOO (Cuculus canorus)



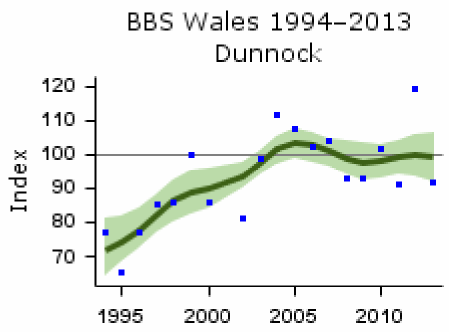
The UK Cuckoo population has been in decline since the mid-1980s and the Welsh population shows a consistent pattern since the inception of BBS. [More detail]

CURLEW (Numenius arquata)



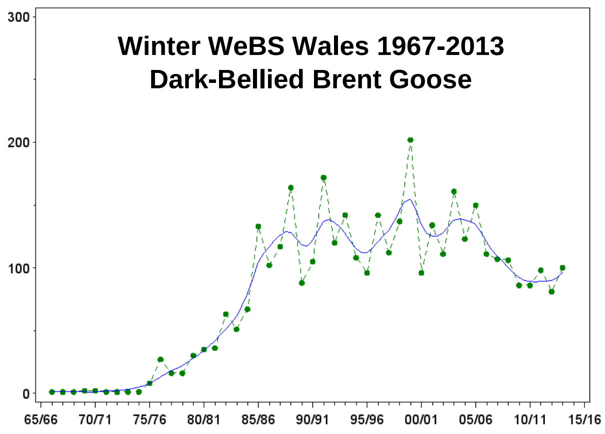
Curlew in Wales has been in long-term decline throughout the BBS period, in line with the pattern seen across the whole of the UK. [More detail]

DUNNOCK (Prunella modularis)



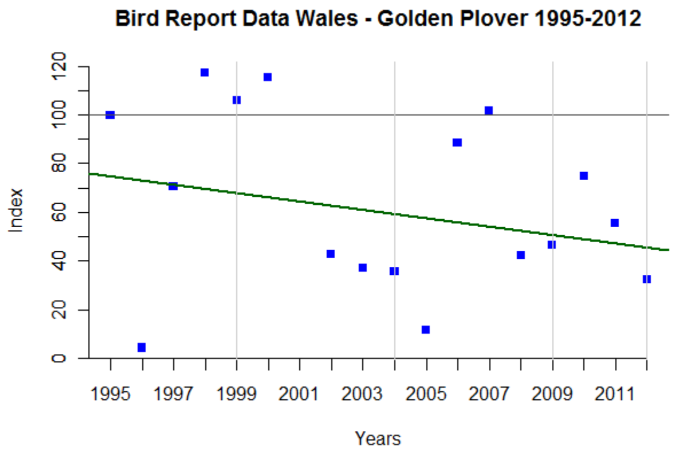
The Dunnock population trend in Wales has matched the wider UK one, showing an increase during the 1990s and early 2000s, followed by a period of stability. All of this follows a steep population decline from the mid-1970s.

DARK-BELLIED BRENT GOOSE (Branta bernicla bernicla)



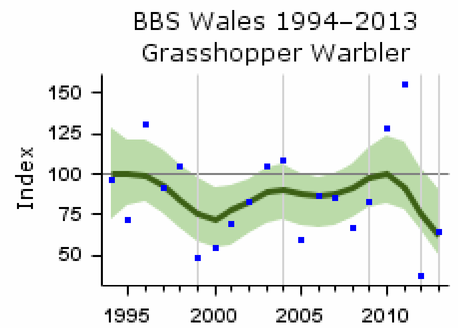
The Dark-Bellied Brent Goose population in Wales has fallen over the last ten years, following a pronounced increase in the 1970s and 1980s that was shared by a number of arctic-breeding goose populations and a subsequent period of stability.

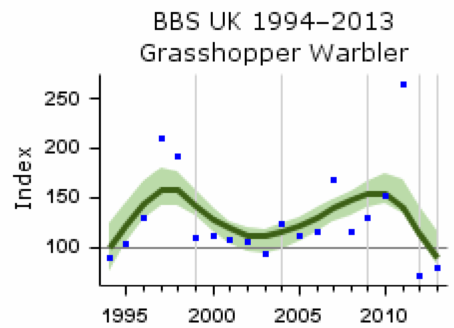
GOLDEN PLOVER (Pluvialis apricaria)



Golden Plover breeding densities are lower in suitable habitat in Wales than in the species' core areas in the UK in Scotland, but long-term changes show little clear gross change in abundance or in range (Balmer et al. 2013). However, an RSPB survey in 2007 found just 36 pairs in Wales, which was interpreted as a decline of c. 80% from the late 1970s (although a true baseline was not available for comparison, Johnstone et al. 2008). Bird Report data also suggest a possible general population decline between 1995 and 2012, which reflects the trend for UK (Baillie et al 2014) [More detail], but the pattern is not strong. Nine vice counties contributed to the Bird Report trend and, whilst none of them had reports in all years, three (Brecon, Radnor and Meirionnydd) contributed with at least nine years and Carmarthen contributed with six years, while the remaining five vice counties had records for four or fewer years. No data were available for 2001, due to the foot-and-mouth disease outbreak preventing countryside access. The outlier in 1995 is due to a large count in one of the vice counties in that year; without such large initial index the decline would appear shallower.

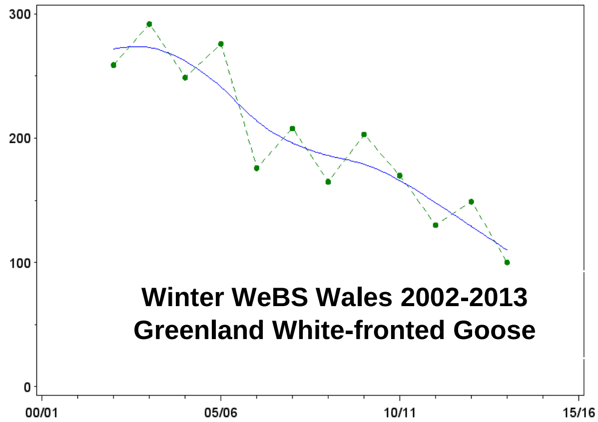
GRASSHOPPER WARBLER (Locustella naevia)





There has been no clear trend in Grasshopper Warbler numbers in Wales. Note that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares), so the apparent detailed changes should be interpreted with caution. However, the broad similarity to the wider UK pattern suggests that there trend has not been strongly affected by sampling bias. [More detail]

GREENLAND GREATER WHITE-FRONTED GOOSE (Anser albifrons flavirostris)

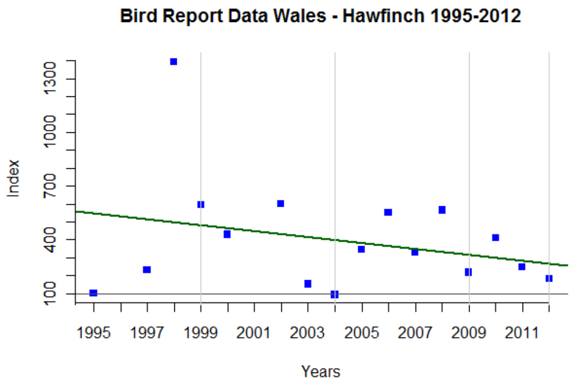


The wintering Greenland Greater White-Fronted Goose population in Wales has shown a sustained decline in Wales since 2000, when annual monitoring became possible. This reflects a broader decline throughout the subspecies' wintering range over this period, although it follows a period of increase. [More detail]

GREY PARTRIDGE (Perdix perdix)

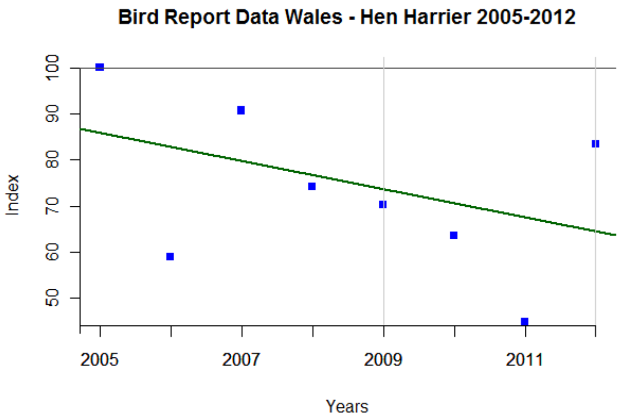
Grey partridge is too rare in Wales to be monitored by the BBS, having largely disappeared in the 1970s and 1980s, mirroring the long-term decline across the UK as a whole. [More detail] Bird Atlas 2007-11 (Balmer et al. 2013) shows continuing losses of breeding locations throughout Wales since 1972, with the remaining strongholds being Anglesey, the far south-east and along the English border. Insufficient records are available in Bird Reports to allow analysis.

HAWFINCH (Coccothraustes coccothraustes)



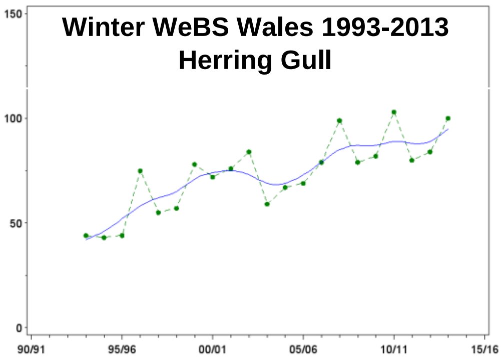
Hawfinch has a patchy distribution in Wales (Balmer et al. 2013), following an irregular pattern of gains and losses of breeding locations since 1972. It is too rare to be monitored by the BBS, but is now mostly found in south Gwynedd, with other, isolated records coming from sites in mid-Wales and the far south-east (Balmer et al. 2013). The trend from bird report data for Hawfinch shown suggests a declining population between 1995 and 2012, but is influenced by an outlier year in 1998, when a high index value appears to have been driven by high numbers reported birds in one vice-county. The amount of data available varied between vice-counties but the species was recorded during the breeding months in twelve of them. While none of the vice-counties had reported the species for all of years considered, Gwent had records for 11 of the 18 years considered, and Glamorgan and Meirionnydd for eight and seven, respectively. All years were represented in the dataset but only a maximum of four vice-counties provided data each year.

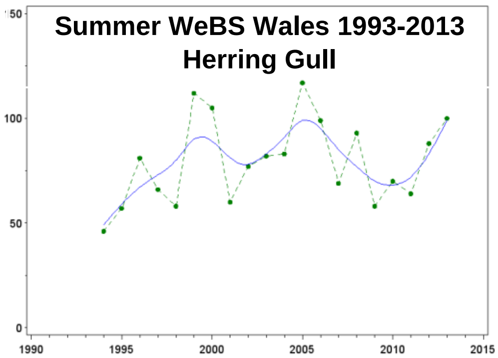
HEN HARRIER (Circus cyaneus)



Bird report data suggest that the Hen Harrier population in Wales has declined between 2005 and 2012. This contrasts with recent findings of a survey in the UK that showed an increase by almost 33% in Wales between 2004 and 2010 (Hayhow et al. 2013). The number of proven and possible pairs in the aforementioned survey was 57 (Hayhow et al. 2013), and data from the 2010 Welsh Bird Report also suggest approximately 51 pairs. Since the Bird Report records are unstandardized and unstructured, they are less reliable than the targeted surveys, so should be treated with caution. However, they may be the only source of annual data in the future. Six vice-counties contributed to the trend reported above and two of them, Meirionnydd and Montgomeryshire, contributed with all years. All years were represented in the dataset, and data for four years (2007, 2009, 2010 and 2012) came from at least five vice-counties. [More detail].

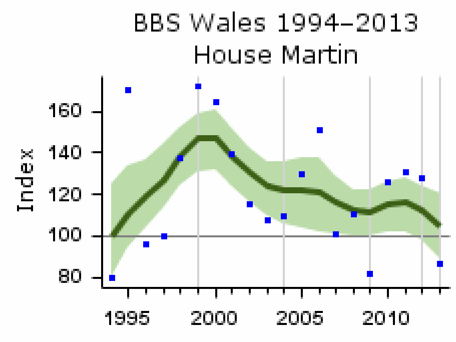
HERRING GULL (Larus argentatus)

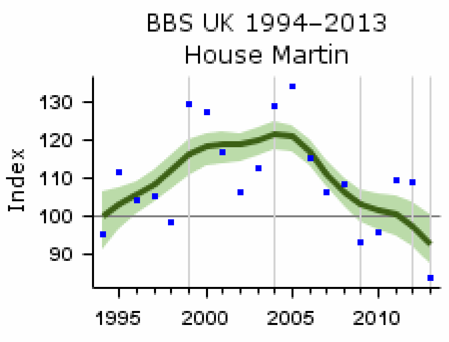




The wintering Herring Gull population in Wales has shown a steady increase since the mid-1990s, but breeding numbers have tended to fluctuate, with less of a clear, long-term pattern.

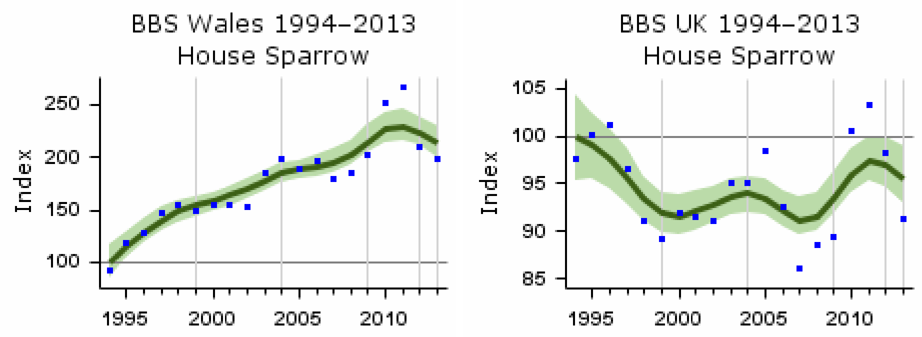
HOUSE MARTIN (Delichon urbicum)





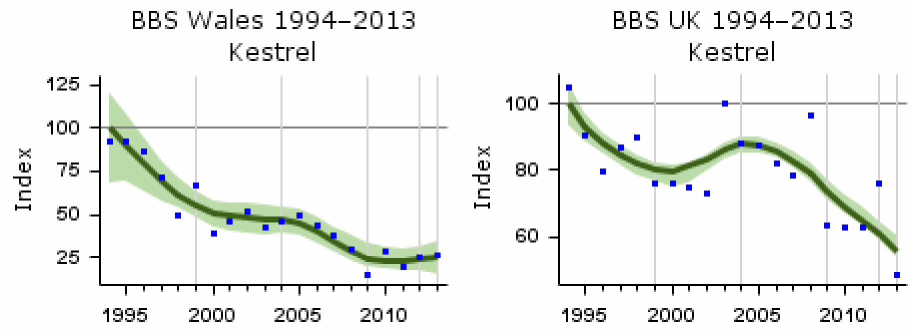
The House Martin trend in Wales has fluctuated over time, broadly in line with the wider UK pattern, but with differences in the height or depth of peaks and troughs. The patterns therefore suggest that broad-scale changes have been driven by factors common to birds at very large spatial scales, such as wintering conditions, but that factors specific to Wales may have influenced variations within these broad changes. [More detail] A specific UK House Martin survey will be run by the BTO in 2015.

HOUSE SPARROW (Passer domesticus)



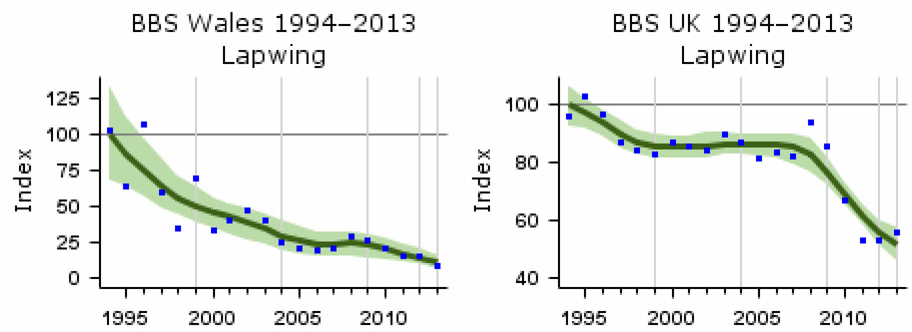
The population trend of House Sparrow in Wales is in contrast with that elsewhere in the UK, as the species has been increasing consistently through the period of BBS monitoring, although it may now be levelling off. [More detail]

KESTREL (Falco tinninculus)



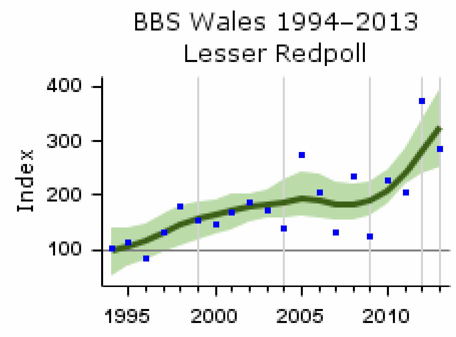
The Kestrel has shown a steady decline in Wales during the BBS period, a pattern that appears both more severe and more consistent than the decline seen at the wider UK scale. [More detail] Note, however, that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares); therefore, the apparent details of the trend should be interpreted with caution.

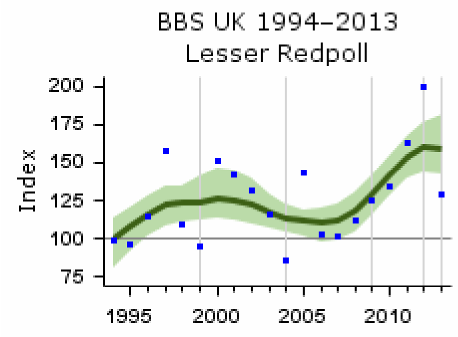
LAPWING (Vanellus vanellus)



The Lapwing has shown a steady decline in Wales during the BBS period, a pattern that appears both more severe and more consistent than the decline seen at the wider UK scale. [More detail] Note, however, that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares); therefore, the apparent details of the trend should be interpreted with caution.

LESSER REDPOLL (Acanthis cabaret)



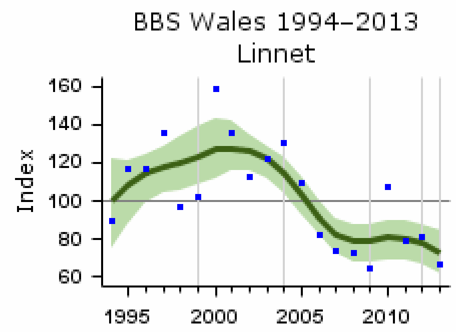


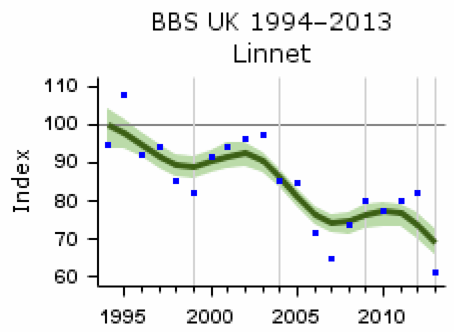
The Lesser Redpoll has shown a sustained, large increase in Wales since the inception of the BBS. This change has been larger (in percentage terms) and subject to fewer fluctuations, than the pattern across the wider UK, although the latter has also been positive overall. [More detail]

LESSER SPOTTED WOODPECKER (Dendrocopos minor)

A rather rare and localized species that can also be difficult to detect, the Lesser Spotted Woodpecker is not monitored effectively by BBS in Wales and is also too irregularly recorded in Bird Reports to allow annual trend data to be extracted. There has been a large-scale fall in abundance and loss of range across Britain and this has also been seen in Wales (Balmer et al. 2013). The species remains reasonably widespread, however, albeit at low densities (Balmer et al. 2013), which will make any putative bespoke survey activity difficult.

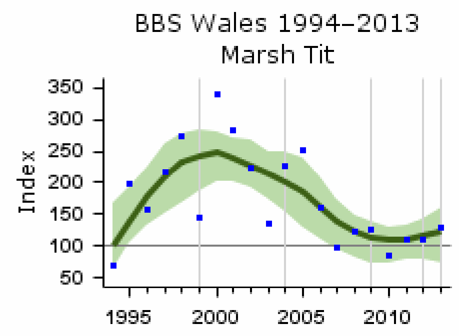
LINNET (Linaria cannabina)

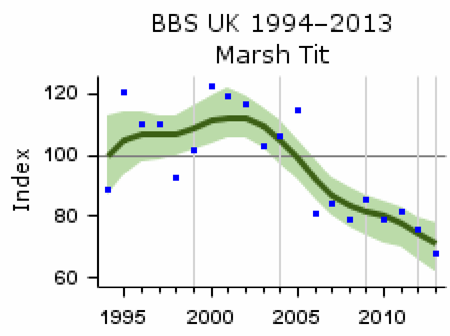




The trend for Linnet in Wales shares a clear period pf decline during the 2000s with the wider UK trends that was both followed and preceded by periods of stability, or at least less steep change. However, the details of the trend through the rest of the time series differ, suggesting that there are differences in the drivers of population change between Wales and elsewhere in the UK. [More detail]

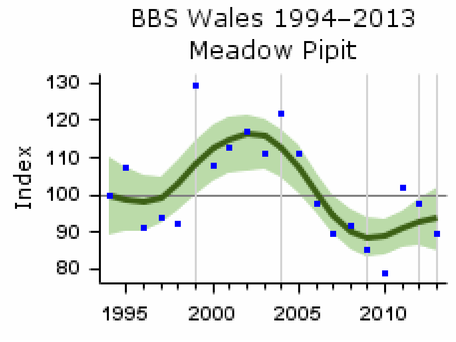
MARSH TIT (Poecile palustris)

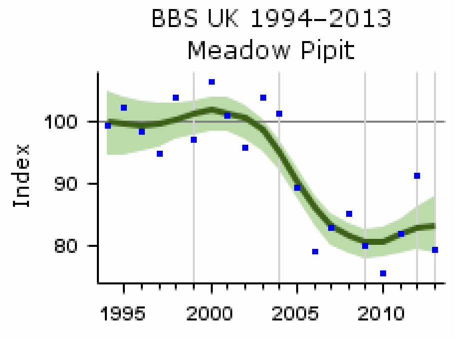




Following a long-term decline in the 1970s and 1980s, the UK Marsh Tit population has fallen further since the mid-2000s. Welsh birds have shown a similar pattern, but with larger fluctuations, and may now be relatively stable. [More detail]

MEADOW PIPIT (Anthus pratensis)



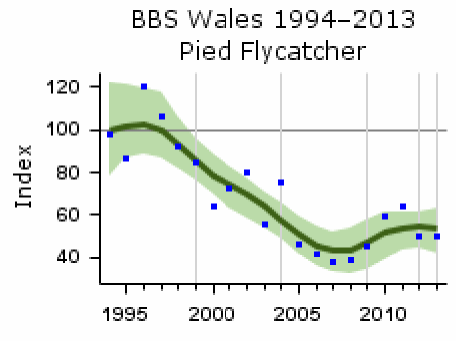


The UK Meadow Pipit population declined in the 2000s, a pattern seen also in Wales; however, this seems to have followed a transient population increase in Wales, as opposed to a period of relative stability in the wider UK. Recent population trends show signs of levelling off, or perhaps the beginning of a recovery. [More detail]

NIGHTJAR (Caprimulgus europaeus)

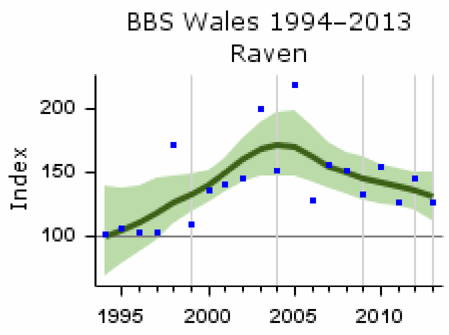
Nightjars are nocturnal habitat specialists in a rare, geographically restricted habitat (heathland and young plantation forestry), which makes them poorly suited for monitoring by the randomized, diurnal BBS and also limits casual records of the species for Bird Reports. Bird Atlas 2007-11 included specific night visits to potentially suitable habitat and recorded a general spread of the Nightjar distribution in Wales since 1990, although some locations where the species had been recorded in 1970 no longer have these birds. It is likely that there has been a general population increase, but that the suitability of some areas has changed over a timescale of several decades as forestry plantations have matured.

PIED FLYCATCHER (Ficedula hypoleuca)



The Pied Flycatcher trend in Wales is derived from a small sample of BBS squares (less than 30 squares), so the apparent details of the trend should be interpreted with caution. However, the pattern of a steep decline until the late 2000s, followed by signs of population stability, is similar to the wider UK trend, so there is no evidence that the apparent pattern of change is influenced by bias due to small sample sizes. [More detail]

RAVEN (Corvus corax)

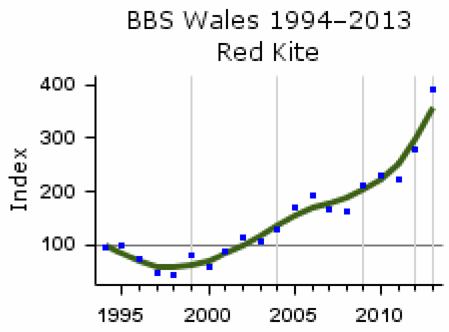


Raven populations in Wales, reflecting the wider UK population trend, have been fairly stable over time, albeit with what appears to have been a transient peak in abundance in the mid-2000s. It is likely that population changes in this species will be slow because it is long-lived and a slow breeder. [More detail]

RED GROUSE (Lagopus lagopus)

The Red Grouse remains widespread in upland Wales, although it has declined considerably since 1970 and again since 1990, leading to range losses, especially from the southern Cambrian Mountains (Balmer et al. 2013). Annual monitoring data are lacking, however, and the species is poorly recorded in Bird Reports.

RED KITE (Milvus milvus)

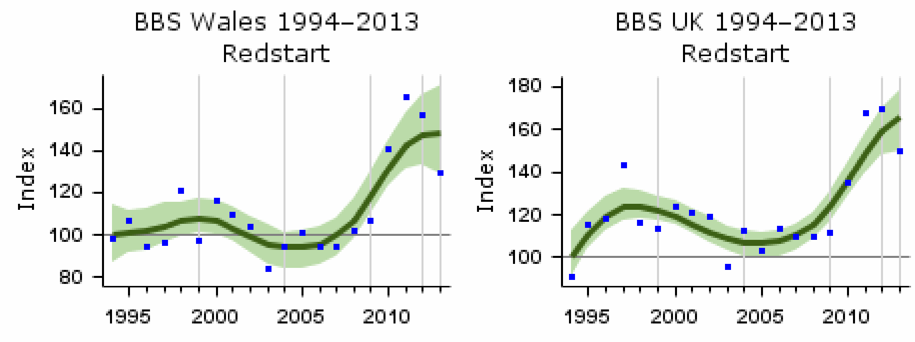


Red Kites have increased rapidly across Wales, as in the wider UK, although the changes in Wales stem from intensive conservation activity around an historical population, while those elsewhere have been seeded by large-scale re-introduction programmes. Note that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares), so the apparent details of the trend should be interpreted with caution. Moreover, there is a technical issue with calculating bootstrapped confidence intervals for this species because of very small samples and stochastically variable records in the early years. However, the long-term trend for this species is unequivocally upward, so inference about long-term population changes is unaffected. [More detail]

REDSHANK (Tringa totanus)

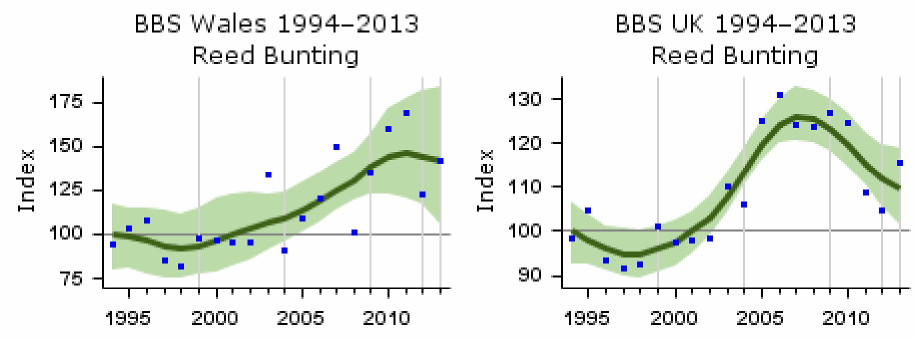
Redshank are too rare in Wales to be monitored effectively by BBS, but the UK trends from both this survey and the Waterways Breeding Bird Survey both show clear declines since the mid-1990s [More detail]. Wintering Redshank numbers have been stable in the long-term in Wales (http://www.bto.org/volunteer-surveys/webs/publications/webs-annual-report), but reflect coastal records that are likely to involve different breeding populations as well as (or completely excluding) those birds that breed in Wales, so the relevance of this pattern to breeding Welsh redshank numbers is questionable.

REDSTART (Phoenicurus phoenicurus)



Redstart populations have fluctuated over time, but have shown a sharp increase since 2006, both in Wales and in the wider UK. The drivers of this pattern are probably, therefore, common to birds from across the UK, such as conditions on the wintering grounds, although it is possible that more variable ecological or demographic relationships underlie the earlier population changes. [More detail]

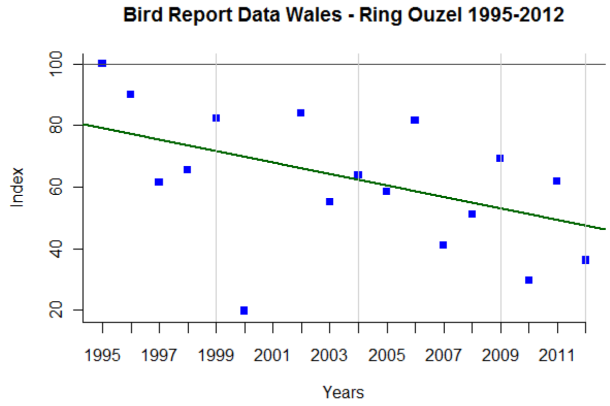
REED BUNTING (Emberiza schoeniclus)



Reed Bunting abundance has shown an increasing trend in Wales that is not dissimilar to the pattern seen in the wider UK, although the latter averages over variable regional trends. [More detail] Note, however, that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares) and that the confidence intervals are broad; therefore, the details of the trend are uncertain and the apparent changes, especially short-term fluctuations, should be interpreted with caution.

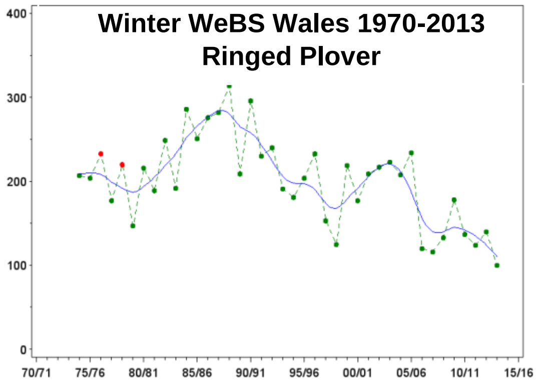
RING OUZEL (Turdus torquatus)

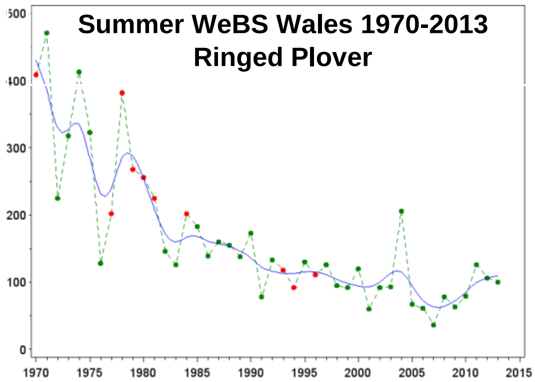
The Ring Ouzel is too rare in Wales to be monitored by BBS, but is believed to have declined in Wales, as across the UK, as reflected in range contractions since the early 1970s and late 1980s (Balmer et al. 2013). Losses since 1972 have occurred particularly from mid-Wales and the major population centres are now in Snowdonia and the Brecon Beacons. It is likely that fewer than 50 breeding pairs remain in Wales, unless significant populations are unrecorded by causal observers (Pritchard 2013).



Bird report data suggest that the Welsh Ring Ouzel population declined between 1995 and 2012. Eleven counties contributed to the trend, and whilst none of them provided entries for every year, Brecon contributed with all but one (2002), whilst Meirionnydd, Caernarfon and Montgomeryshire contributed with 10 or more years. All years were represented in the dataset, and data for six years (1999, 2003, 2006, 2008, 2009 and 2010) came from at least five counties. This species was particularly prone to entries of unspecified numbers of birds in the Welsh Bird Reports, so the trend should be interpreted with particular caution as high counts from some vice-counties were not be quantified in the dataset compiled and so the analysis assumes that trends in these counties reflected those elsewhere. This tended to be more common earlier in the time series, so the apparent decline may actually under-estimate the true changes in the population. The low, outlier index value in 2000 was due to fewer vice-counties reporting birds and low numbers being reported where counts were found.

RINGED PLOVER (Charadrius hiaticula)



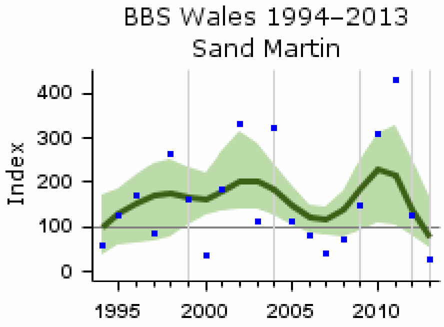


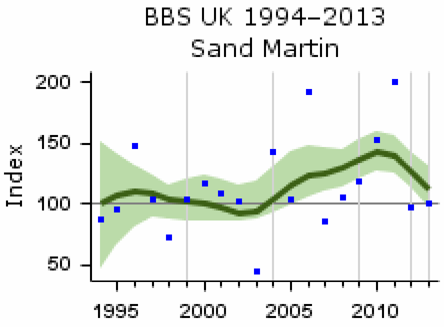
Both wintering and breeding Ringed Plover populations in Wales have tended to decline since the mid-1990s, although the winter pattern has shown both larger fluctuations and a more pronounced reduction in abundance.

ROSEATE TERN (Sterna dougalli)

Roseate Tern has a very localized breeding distribution in the UK and has only recently been recorded on Anglesey in Wales, where the isolated records in Bird Atlas 2007-11 relate to individual birds paired with Common Terns.

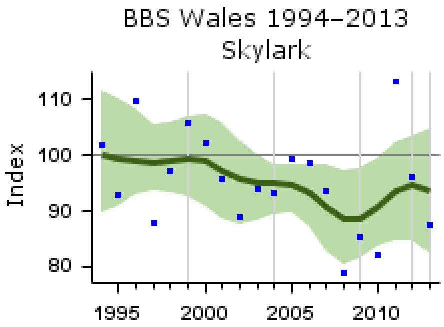
SAND MARTIN (Riparia riparia)

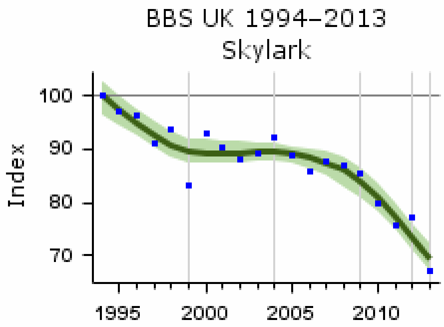




Sand Martins have shown fluctuating, but overall rather stable long-term changes in both Wales and the wider UK, although a period of decline may have begun in 2010 [More detail]. Note, however, that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares) and is associated with wide confidence intervals, so the apparent details of the trend should be interpreted with caution. In addition, colonies of this species are known relocate rather rapidly in some instances, so large stochastic variations in local abundance can occur and influence apparent trends.

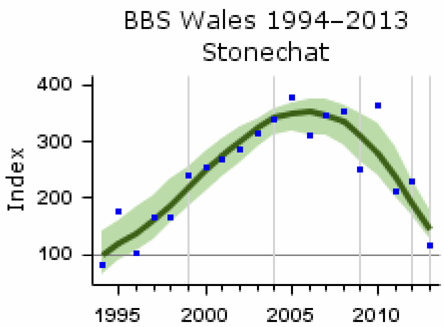
SKYLARK (Alauda arvensis)





The long-term decline in Skylark populations that has occurred throughout the UK has continued during the BBS period and is also seen to some extent in Wales alone, although the magnitude of change has been smaller. [More detail] It is worth noting that the confidence intervals for Wales are larger than those for the UK because the sample size is much smaller. This makes the details of the temporal trend less reliable for Wales, but it is likely that similar ecological factors underlie the changes because the gross patterns are common across the regions of the UK.

STONECHAT (Saxicola rubicola)

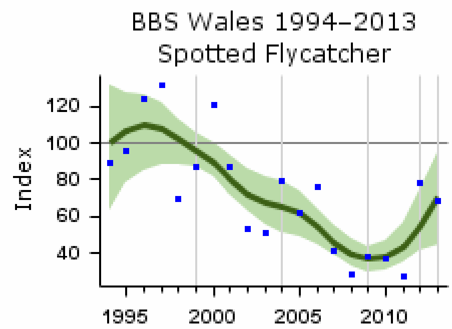


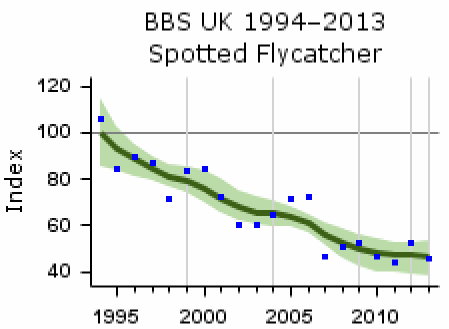
The Stonechat population trend shows a remarkable pattern of smooth, steady increase up to 2005, followed by a rapid decline, which is seen at both the UK and Wales levels. [More detail] This suggests that large, ongoing ecological changes have occurred, but the evidence on this species is limited. A recent BTO volunteer survey of chats in Wales is elucidating both current population status and relationships with habitat, and will report in 2015.

SNIPE (Gallinago gallinago)

Snipe are too rare in Wales to be monitored effectively by BBS; the survey method is also not ideally suited to the species because of its crepuscular habits, so there is likely to be more uncertainty associated with square-level counts than there is for most species. However, BBS and Waterways Breeding Bird Survey trends at the UK level show declines in Snipe abundance since 2000 (and probably earlier) [More detail], while there have been considerable losses in the breeding range in Wales in the long term (Balmer et al. 2013).

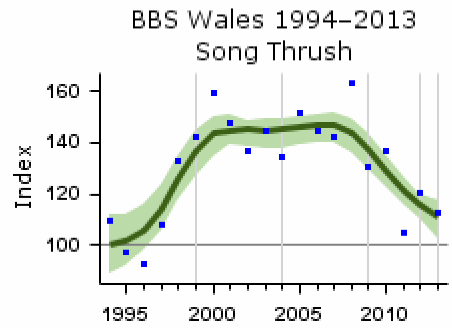
SPOTTED FLYCATCHER (Muscicapa striata)





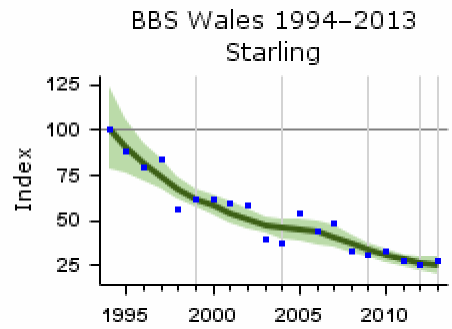
Spotted Flycatchers have been in long-term decline at the UK level and this pattern is seen in Wales alone, as well. [More detail] There is an indication, however, that the Welsh population may be in recovery, but the trend in Wales is derived from a small sample of BBS squares (fewer than 30), so this pattern should be interpreted with caution.

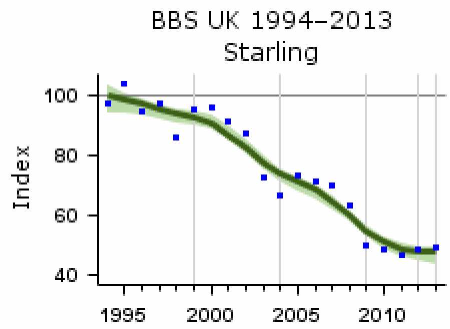
SONG THRUSH (Turdus philomelos)



Song Thrush abundance in Wales has fluctuated during the BBS period, reflecting the UK-level trend. These changes are in the context of larger, long-term declines, however. [More detail]

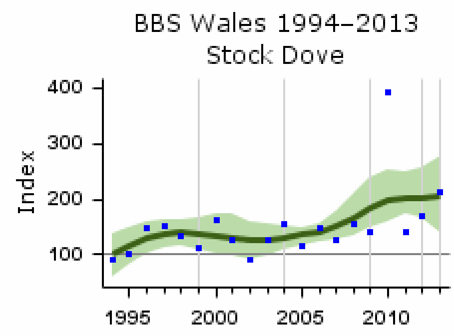
STARLING (Sturnus vulgaris)

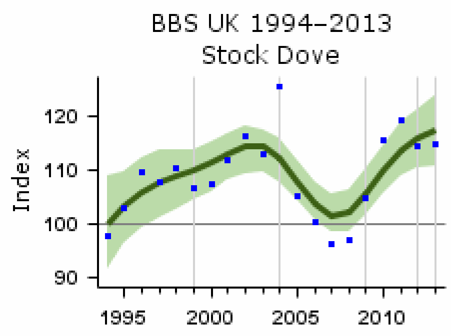




Rapid declines have occurred in breeding Starling abundance at the both the Wales and wider UK levels, although the Welsh decline may be slowing, while the wider UK one has tended to increase in rate over time, at least until 2010. [More detail] It is noteworthy that much of the public experience of Starlings involves large, roosting, winter flocks; these flocks typically consist of winter migrants from northern Europe as well as local breeding birds, so their presence and size is not closely related to UK breeding population trends.

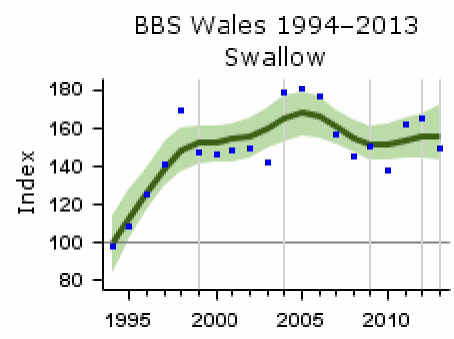
STOCK DOVE (Columba oenas)

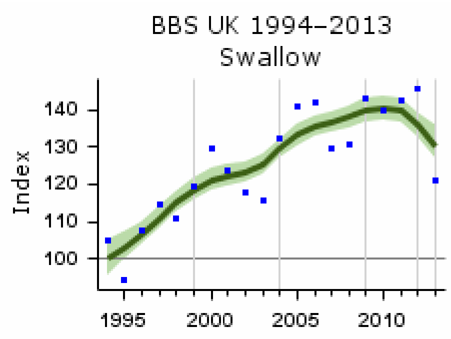




The long-term pattern in UK Stock Dove abundance is for a sustained increase following strong negative effects of organochlorine pesticides up to the early 1960s, with the increase tending to level off since the 1990s. [More detail] A general pattern for a shallow population increase during the BBS period is then apparent at both the Wales and wider UK levels, with the increase being rather smoother in Wales alone. It is likely that the increases will cease as the available habitat is saturated.

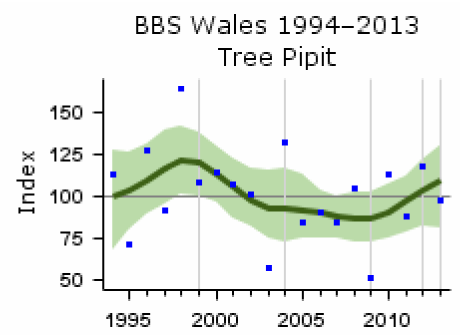
SWALLOW (Hirundo rustica)

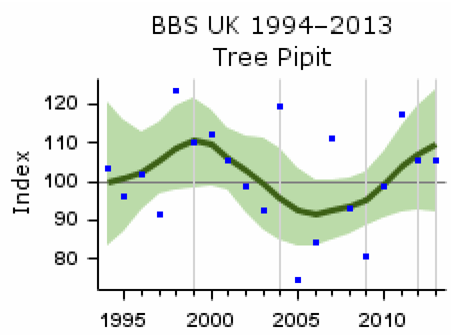




The Swallow population in Wales has been rather stable since the late 1990s, whereas the wider UK population has tended to increase during this period, at least until 2012. [More detail] This followed a rapid increase at the beginning of the BBS period and suggests that the population may be at carrying capacity, or constrained by another factor that has shown little variation in recent years.

TREE PIPIT (Anthus trivialis)

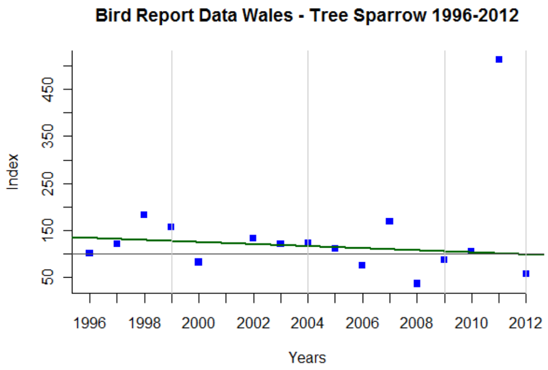




Tree Pipit numbers are stable in Wales; there have some fluctuations in the trend since 1994, but no clear long-term increase or decline. The fluctuations have mirrored those in the wider UK, albeit being smaller in magnitude, suggesting that they have been driven by factors operating at large spatial scales, as opposed to specific to Wales. [More detail]

TREE SPARROW (Passer montanus)

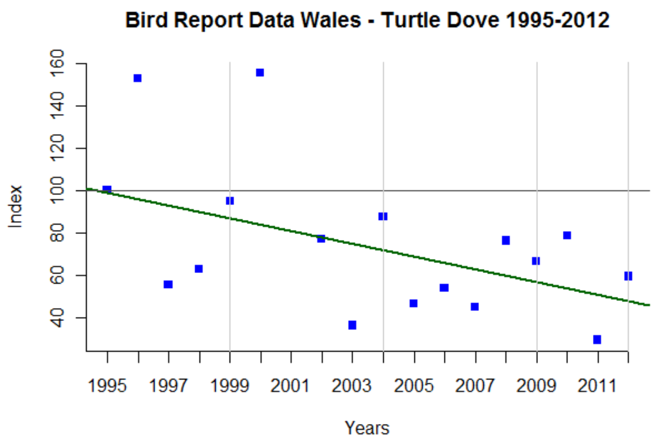
Tree Sparrows are too rare in Wales to be monitored by BBS, but are now showing a shallow, sustained increase at the UK level, following a precipitous decline before the BBS period began [More detail]. However, they are believed still to be declining in Wales. Bird Atlas 2007-11 shows range losses throughout Wales since 1972, with Tree Sparrow now being found mostly only in Clwyd and south-east Dyfed (Balmer et al. 2013).



Bird Report data for Tree Sparrow show little evidence of a clear trend between 1996 and 2012, with a pattern perhaps for a slight decline over time, although the data for the last two years in the time series are sparse, with just one (different) county with records in each year. Eleven vice-counties contributed to the trend, and whilst none of them provided records for all years, five of them (Brecon, Montgomeryshire, Pembrokeshire, Gwent, Glamorgan) contributed with at least nine years and one more, Carmarthen, with at least five; all other counties contributed with less than five years and all years, apart from 1995, were represented. [More detail]

TURTLE DOVE (Streptopelia turtur)

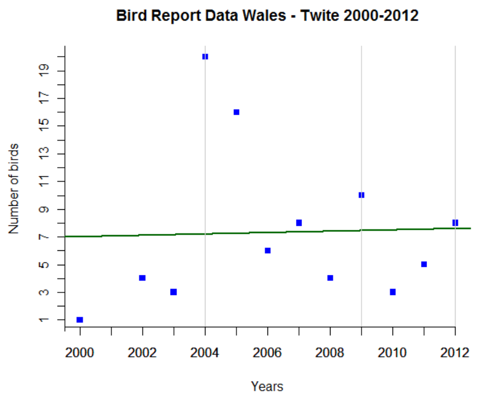
Turtle Doves are now too rare in Wales to be monitored by BBS and are declining precipitously at the UK level [More detail]. It is likely that they are declining further in Wales as well. They have also declined further in Wales, as reflected in Bird Atlas 2007-11 (Balmer et al. 2013), which showed major range losses, particularly between 1972 and 1991. After further losses before 2007, there were breeding records from a few locations along the English border only.



Bird Report data for Turtle Dove show a steep decline between 1995 and 2012, mirroring the overall decline observed in the UK overall (Baillie et al 2014). Note, however, the trend reported above may not reflect the population of breeding birds because passage birds may have contributed to the counts in some years. Ten vice counties contributed to the trend, although none with data for all years. Five vice-counties (Carmarthen, Caernarfon, Pembrokeshire, Gwent and Glamorgan) provided records for at least nine years, while a further three (Denbigh, Cardiganshire and Anglesey) contributed with at least five and the rest with four or fewer years. All years were represented in the dataset, apart from 2001, reflecting countryside access restrictions after the foot-and-mouth disease outbreak. The outlier in 2000 is due to a high count for one of only two vice-counties contributing that year.

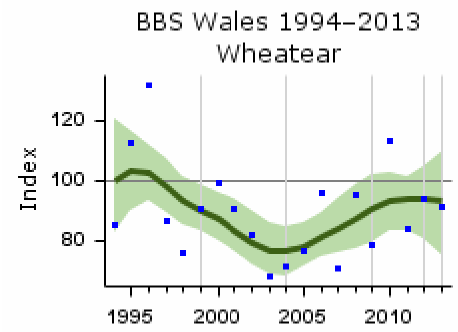
TWITE (Carduelis flavirostris)

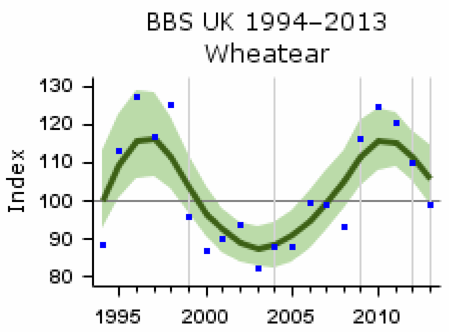
Twite are too rare in Wales to be monitored by BBS, but are the subject of specific, periodic surveys by RSPB and others. The breeding population in Wales, although small and highly range-restricted, appears to have increased considerably in recent decades, particularly in Snowdonia and upland Clywd (Balmer et al. 2013).



Bird report data for Twite were available from only one vice-county, Caernarfon, from 2000 to 2012 (excluding 2001); records from other counties were available from only one year, so were not included in the analysis (see Introduction). There was no clear trend in the Caernafon counts, but they were low and only a small fraction of the Welsh population.

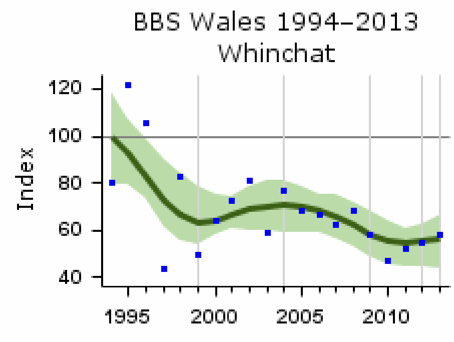
WHEATEAR (Oenanthe oenanthe)

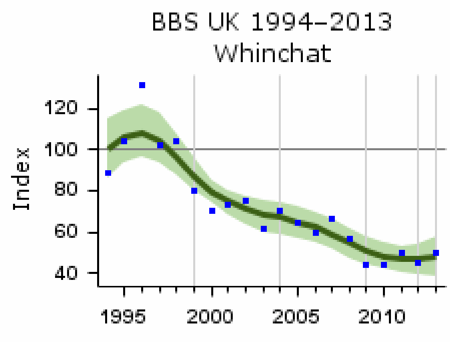




The Welsh population of Wheatear has fluctuated during the BBS period, broadly reflecting the pattern seen across the wider UK. [More detail] This broad-scale pattern is suggestive of a role for broadly influential factors such as conditions on the wintering grounds or on migration, rather than specific to Wales, driving population change. A recent BTO volunteer survey of chats in Wales is elucidating both current population status and relationships with habitat, and will report in 2015.

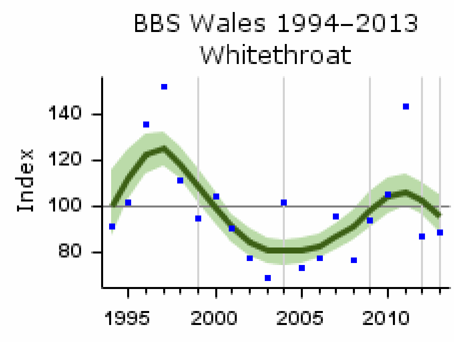
WHINCHAT (Saxicola rubetra)

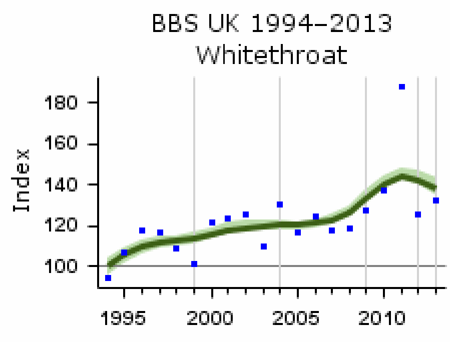




Whinchats have declined in Wales during the BBS period, although at a variable rate-of-change. The pattern is also slightly different to that seen across the wider UK (although the UK-wide population has declined even more, proportionally). [More detail] Note, however, that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares); therefore, the apparent details of the trend should be interpreted with caution. A recent BTO volunteer survey of chats in Wales is elucidating both current population status and relationships with habitat, and will report in 2015.

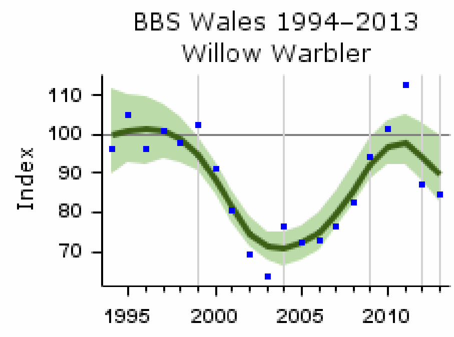
WHITETHROAT (Sylvia communis)

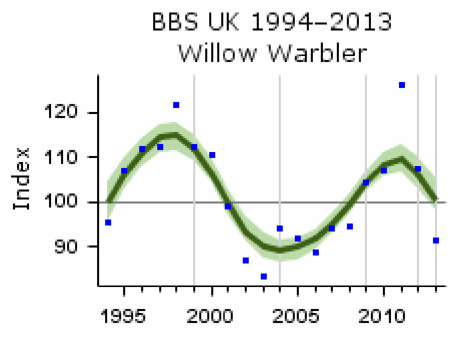




Following an historical decline in the 1970s due to weather effects on the wintering grounds, the UK-wide Whitethroat population has been slowly increasing. In Wales alone, however, the population trend has fluctuated much more. [More detail] This suggests a role for local factors driving changes that are not important for birds breeding elsewhere in the UK.

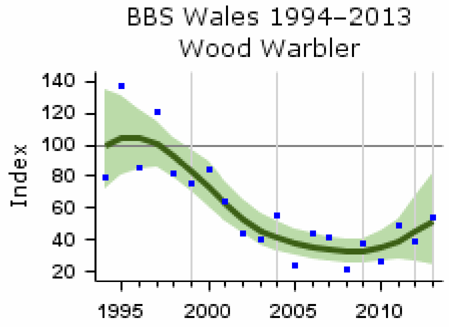
WILLOW WARBLER (Phylloscopus trochilus)

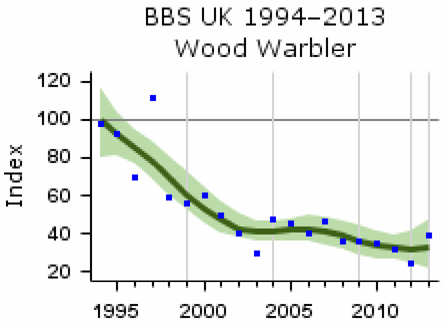




The oscillating long-term population trend of Willow Warbler in Wales is mostly similar to the wider UK trend, suggesting influences of factors that operate at large scales or that affect birds on their wintering grounds or on migration. [More detail]

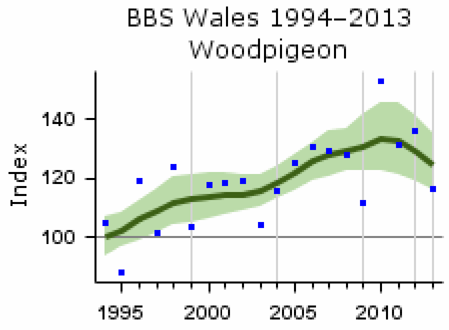
WOOD WARBLER (Phylloscopus sibilatrix)

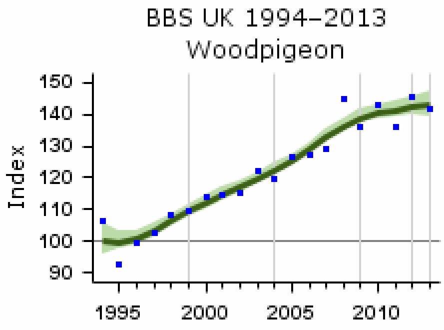




Wood Warblers have declined in Wales during the BBS period, although the trend may have turned upward since 2008. The pattern is also slightly different to that seen across the wider UK. [More detail] Note, however, that the trend in Wales is derived from a small sample of BBS squares (less than 30 squares); therefore, the apparent details of the trend should be interpreted with caution.

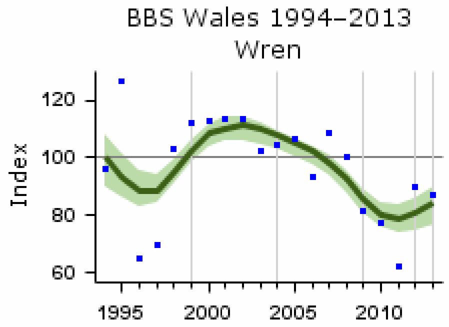
WOODPIGEON (Columba palumbus)

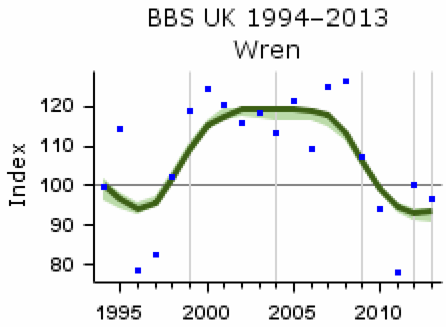




Woodpigeon numbers have increased historically across the UK and Wales is no exception. Similarly, signs of stabilization in abundance have appeared since the late 2000s, perhaps showing saturation of the available habitat or resource limitation. [More detail]

WREN (Troglodytes troglodytes)

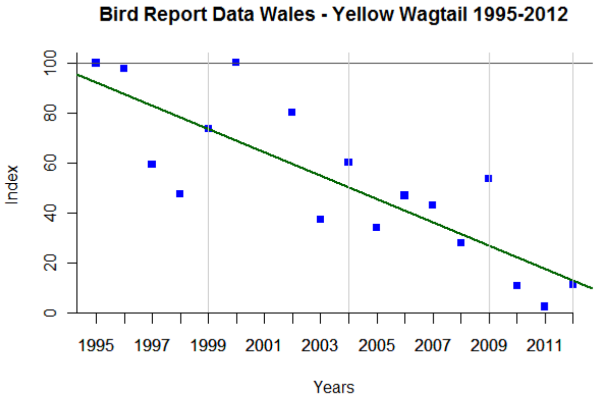




Wren abundance is often highly variable between years because the species is vulnerable to cold winter weather. Nevertheless, long-term trends in the Welsh population are broadly similar to those in the wider UK, albeit with some evidence for a slight, long-term decline that is not apparent across the whole of the UK. [More detail]

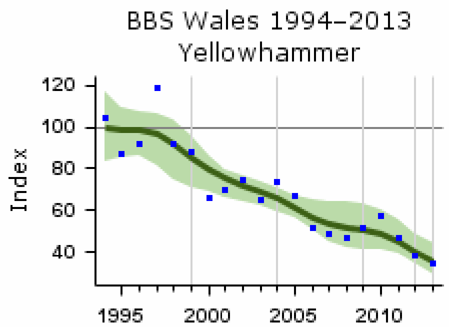
YELLOW WAGTAIL (Motacilla flava)

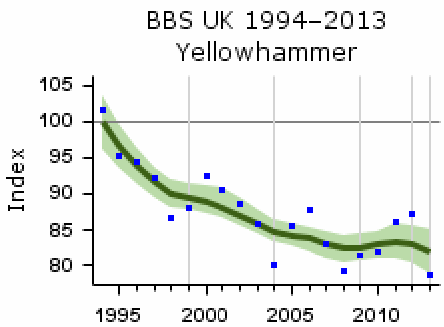
The Yellow Wagtail is now too rare in Wales to be monitored by BBS. Following a long-term decline across the UK, mirrored in marked range contractions throughout Wales since 1972, the species now breeds only in isolated locations and along the English border (Balmer et al. 2013). [More detail]



The available bird report data for Yellow Wagtail show a steep, negative trend between 1995 and 2012. Data were available for all counties, although only one, Brecon, provided a complete list for every year. One other county, former Montgomeryshire, contributed with 10 years, from 1995 to 2015, while all other counties contributed with five or fewer years. Only in 2009 reports were submitted from at least 10 counties while all other years saw records from four or fewer counties. The high index value for 2000 is due to relatively high counts in all three counties that contributed to the total for that year.

YELLOWHAMMER (*Emberiza citrinella*)





Yellowhammer abundance began to decline on farmland across the UK in the mid-1980s. Proportional declines have been steeper in Wales than elsewhere during the BBS period, with an additional recent downturn being the opposite of recent changes in England, which may be the result of agri-environment management. [More detail]

References

Baillie, S.R., Marchant, J.H., Leech, D.I., Massimino, D., Sullivan, M.J.P., Eglington, S.M., Barimore, C., Dadam, D., Downie, I.S., Harris, S.J., Kew, A.J., Newson, S.E., Noble, D.G., Risely, K. & Robinson, R.A. (2014) BirdTrends 2014: trends in numbers, breeding success and survival for UK breeding birds. Research Report 662. BTO, Thetford. http://www.bto.org/birdtrends

Baker, D.J., Freeman, S.N., Grice, P.V. & Siriwardena, G.M. (2012) Landscape scale responses of birds to agri-environment management: a test of the English Environmental Stewardship scheme. Journal of Applied Ecology 49: 871-882.

Balmer, D.E., Gillings, S., Caffrey, B.J., Swann, R.L., Downie, I.S. & Fuller, R.J.
2013. Bird Atlas 2007-11: the breeding and wintering birds of Britain and Ireland. BTO Books, Thetford.

Davey, C.M., Vickery, J.A., Boatman, N.D., Chamberlain, D.E. Parry, H.R. & Siriwardena, G.M. 2010. Assessing the impact of Entry Level Stewardship on lowland farmland birds in England. Ibis, 152: 459-474.

Hayhow, D. B., Eaton, M. A., Bladwell, S., Etheridge, B., Ewing, S. R., Ruddock, M., & Stevenson, A. (2013). The status of the Hen Harrier, Circus cyaneus, in the UK and Isle of Man in 2010. Bird Study, 60: 446-458.

Johnstone, G.I., Dyda, J. & Lindley, P. 2008. The population status of breeding Golden Plover and Dunlin in Wales in 2007. Welsh Birds 5: 300-310.
Pritchard, R. 2013. Welsh Bird Report 26 (2012). Birds in Wales 10: 2-178.

Annex 4. Matrix of population trend scores in five-year blocks derived from the trends shown in Appendix 5.3 and used to derive the population summary indicator (Section 5.2.1.3.4).

Species	Data source	Time Periods and Scores								Notes
		1994-1999	Score	2000-2004	Score	2005-2009	Score	2010-2014	Score	
Aquatic Warbler	NA									globally endangered, not in Wales
Bar-tailed Godwit	WeBS	=	1	-	0	+	1	=	1	winter - WeBS
Common Bullfinch	BBS	-	0	+	1	-	0	=	1	
Black-headed Gull	WeBS	+	1	=	1	-	0	=	1	colonial - will always be in a small number of locations; Summer WeBS
Great Bittern	NA		FALSE		FALSE		FALSE		FALSE	extinct?
Black Grouse	RSPB		FALSE		FALSE		FALSE		FALSE	surveyed regularly by RSPB
Tundra Swan	WeBS	=	1	-	0	0	FALSE	0	FALSE	winter - WeBS; population approximately zero since 02-03
Corn Bunting	NA		FALSE		FALSE		FALSE		FALSE	extinct
Corn Crake	NA		FALSE		FALSE		FALSE		FALSE	extinct
Chough	Independent data		FALSE		FALSE		FALSE		FALSE	Surveyed annually independently
Common Cuckoo	BBS	-	0	-	0	-	0	-	0	
Eurasian Curlew	BBS	-	0	-	0	=	1	-	0	
Common Scoter	WeBS	=	1	=	1	=	1	=	1	winter - WeBS; very variable with many imputed counts
Dunnock	BBS	+	1	+	1	=	1	=	1	
Dark-bellied Brent Goose	WeBS	+	1	=	1	-	0	=	1	winter - WeBS
Red-backed Shrike	NA		FALSE		FALSE		FALSE		FALSE	extinct
Common Grasshopper Warbler	BBS	-	0	+	1	=	1	-	0	14 BBS squares; UK long-term stable
Golden Plover	Reports	-	0	-	0	-	0	-	0	
Hawfinch	Reports	=	1	=	1	=	1	=	1	trend extracted from bird reports
Herring Gull	WeBS	+	1	=	1	-	0	+	1	Summer WeBS
Hen Harrier	RSPB/rare	ND	FALSE	ND	FALSE	+	1	ND	FALSE	Reliable data available for 2004-10 only
House Sparrow	BBS	+	1	+	1	=	1	-	0	

Kestrel	BBS	-	0	=	1	-	0	=	1	
Northern Lapwing	BBS	-	0	-	0	=	1	-	0	
Common Linnet	BBS	=	1	=	1	-	0	=	1	
Lesser Redpoll	BBS	+	1	=	1	=	1	+	1	23 BBS squares; UK stable during BBS period
Lesser Spotted Woodpecker	Rare		FALSE		FALSE		FALSE		FALSE	now very rare; insufficient bird report data
Marsh Tit	BBS	=	1	=	1	-	0	=	1	12 BBS squares; UK declining
European Nightjar	Nocturnal; Atlas		FALSE		FALSE		FALSE		FALSE	nocturnal
Greenland Greater White-fronted Goose	WeBS	ND	FALSE	=	1	-	0	-	0	winter - WeBS
Grey Partridge	Rare		FALSE		FALSE		FALSE		FALSE	insufficient bird report data
Pied Flycatcher	BBS	=	1	-	0	=	1	=	1	
Reed Bunting	BBS	=	1	=	1	+	1	=	1	
Red Grouse	Rare		FALSE		FALSE		FALSE		FALSE	insufficient bird report data
Ringed Plover	WeBS	=	1	=	1	-	0	=	1	
Ring Ouzel	Reports	-	0	-	0	-	0	-	0	trend extracted from bird reports
Roseate Tern	Rare		FALSE		FALSE		FALSE		FALSE	very rare, only odd breeding records
Sky Lark	BBS	=	1	=	1	-	0	=	1	
Spotted Flycatcher	BBS	=	1	-	0	-	0	+	1	
Common Starling	BBS	-	0	-	0	-	0	-	0	
Song Thrush	BBS	+	1	=	1	=	1	+	1	
European Turtle Dove	Reports	-	0	-	0	-	0	-	0	now very rare
Tree Pipit	BBS	=	1	=	1	=	1	=	1	
Eurasian Tree Sparrow	Reports	=	1	=	1	=	1	=	1	now very rare
Twite	Reports	=	1	=	1	=	1	=	1	surveyed regularly by RSPB; trend extracted from bird reports here
Wood Lark	NA		FALSE		FALSE		FALSE		FALSE	extinct
Wood Warbler	BBS	=	1	-	0	=	1	=	1	
Willow Tit	Rare		FALSE		FALSE		FALSE		FALSE	now very rare; insufficient bird report data
Yellowhammer	BBS	=	1	-	0	-	0	-	0	
Yellow Wagtail	Reports	-	0	-	0	-	0	-	0	now rare in Wales, only near English border

Appendix 5.4: Comparison of Phase 1 habitat map and satellite Land Cover Map

A comparison exercise was carried out to determine whether the CCW Phase 1 dataset and the LCM2007 data would give similar estimates of the proportion of semi-natural habitat. Maps of % SN habitat for each 1 km^2 across Wales, were produced using both datasets (Figure 3). Overall the maps show a similar spatial pattern, but some differences are visible. A difference map was also produced to highlight the spatial dependence in the agreement between the two datasets.

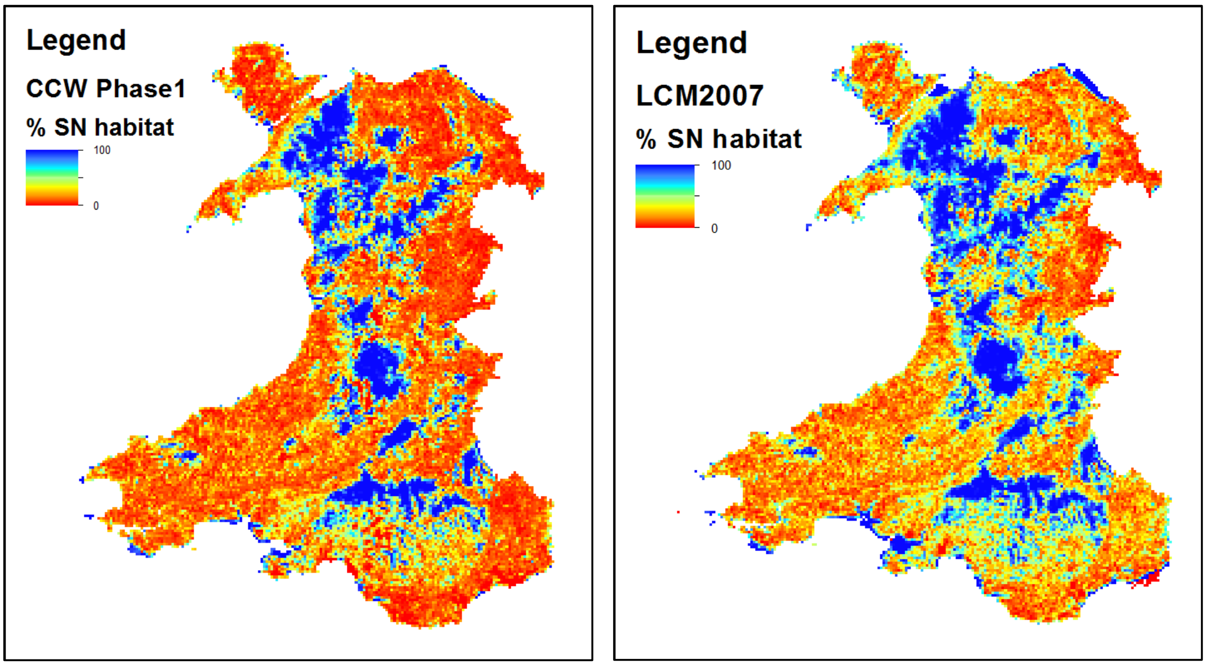


Figure 3. *Map of proportion of semi-natural habitat (%) estimated using CCW Phase 1 data (left) and LCM2007 (right).*

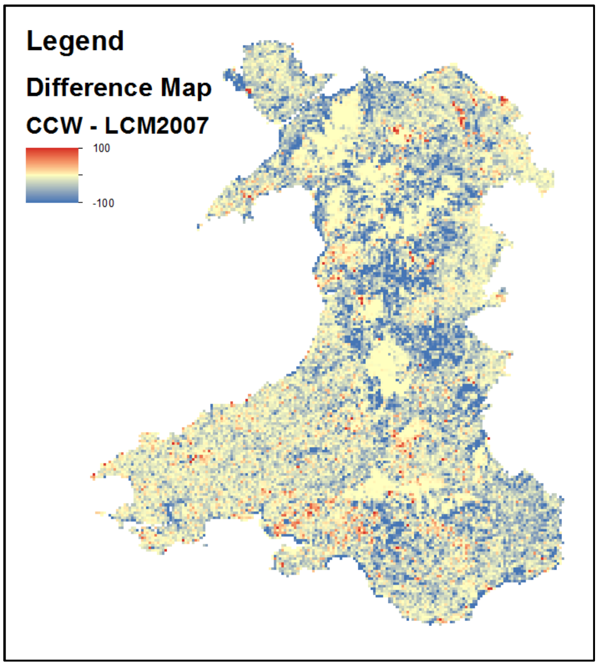


Figure 4. *Map to show the percentage difference between the proportion of semi-natural habitat (PSN) estimated using CCW Phase 1 data and that estimated using LCM2007. Red areas show where CCW Phase 1 had a higher PSN estimate than LCM2007 and blue areas show where LCM2007 gave a higher PSN estimate than CCW Phase 1.*

Scatter plots of the relationship between the % SN habitat estimates from the two datasets showed a good level of agreement, with most points being distributed around the 1:1 line (Figure 5). However, LCM2007 had a tendency to give a higher % SN habitat estimate than CCW Phase 1. The scatter plots for each of the case study areas exhibited a similar pattern (Figure 6).

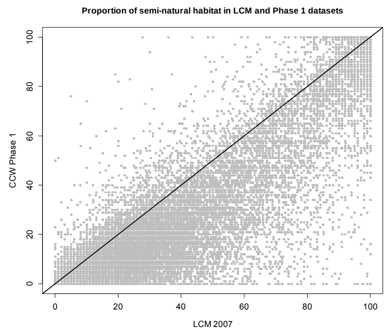


Figure 5. *Scatter plots showing the proportion of semi-natural habitat (%) estimated from LCM2007 and CCW Phase 1 datasets, for each 1km² across Wales.*

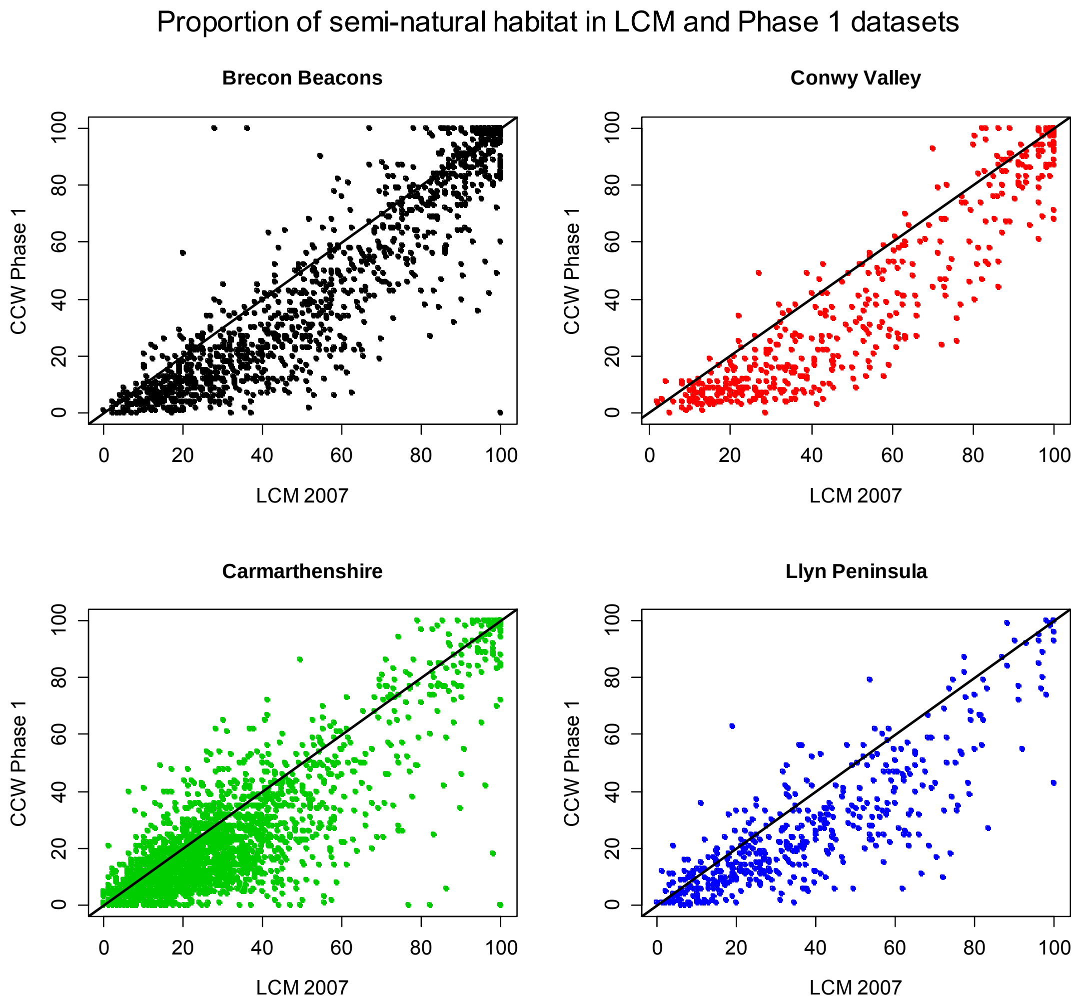


Figure 6. *Scatter plots showing the proportion of semi-natural habitat (%) estimated from LCM2007 and CCW Phase 1 datasets, for each 1km², for the four case study areas.*

Appendix 5.5: Habitats used in calculating semi-natural or modified land cover

Table 21. *List of LCM2007 classes categorised as either semi-natural or modified land cover.*

LCM2007 Class		Semi-natural or modified
1	Broadleaved woodland	Semi-natural
2	Coniferous Woodland	Modified
3	Arable and Horticulture	Modified
4	Improved Grassland	Modified
5	Rough grassland	Semi-natural
6	Neutral Grassland	Semi-natural
7	Calcareous Grassland	Semi-natural
8	Acid grassland	Semi-natural
9	Fen, Marsh and Swamp	Semi-natural
10	Heather	Semi-natural
11	Heather grassland	Semi-natural
12	Bog	Semi-natural
13	Montane Habitats	Semi-natural
14	Inland Rock	Semi-natural
15	Saltwater	Semi-natural
16	Freshwater	Semi-natural
17	Supra-littoral Rock	Semi-natural
18	Supra-littoral Sediment	Semi-natural
19	Littoral Rock	Semi-natural
20	Littoral sediment	Semi-natural
21	Saltmarsh	Semi-natural
22	Suburban	Modified
23	Urban	Modified

Appendix 5.6: Calculating Monad (1km square) species pools for vascular plants

To determine the monad species pools we first extracted records from the BSBI plant database between 1970 and 2013. We ran Frescalo to identify species pools at the hectad scale while accounting for recorder effort (corrected hectad pools). We then looped through each monad and identified a set of “missing species”. These were determined as those species present in the corrected (frescalo) species pool for the associated hectad but missing from the monad in question. For each missing species, we used a Bernoulli coin flip to estimate presence (1) or absence (0) within the monad. The coin flip was weighted so that the probability of being present (1) was a combination of the proportion of suitable habitat and probability of presence at the hectad level. The proportion of suitable habitat was estimated as the cumulative proportions of all suitable habitat types (LCM 2007) given the species habitat associations in plantatt. This was multiplied by the probability of presence at the hectad level, which was estimated from frescalo (bounded between 1 and 0, with 1 being 100% present).

Appendix 5.7: Characterising soils of national importance in Wales

In Scotland work has been undertaken to identify, soils of national conservation importance (Towers et al., 2005; 2008); soils are assessed based on conservation and functional importance. Abundance was one of the criteria used (Towers et al., 2005), and they tested 3 methods of assessing abundance:

a) *Soil landscape method: All 580 Soil Map Units were allocated to a 'soil landscape' type, based on the predominant Major Soil Sub-Group and their associated soil types within different landscapes. In this way, Soil Map Units with similar assemblages of soil types (based on the dominant and secondary Major Soil Sub-Groups) were grouped together, termed 'Aggregated Soil Map Units'. This method therefore does not assess the rarity of individual Major Soil Sub-Groups, but rather the rarity of different soil assemblages.*
b) *Dominant soil sub-group method: Each soil map unit is allocated to the predominant Major Soil Sub-Group within it. In some Soil Map Units, the dominant Major Soil Sub-Group comprises 100 of the unit, whereas in many of the complex units, it can be as low as 40.*
c) *Estimated area of soil series method: The percentage cover of each Major Soil Sub-Group within each Soil Map Unit is assessed so that the total area of each map unit is apportioned to its component Major Soil Sub-Group based on this percentage. The total area of each Major Soil Sub-Group is then calculated by summing the contribution from each Soil Map Unit.*

They used the first method, but commented that all three methods gave similar results. In later work they used an alternative method fixing the value for rarity, rather than trying to define an inflexion point on the frequency distribution they aggregated soil map units and defined as rare those whose area, when summed, occupied less than 5 of the study area.

Appendix 5.8: Spatial modelling of plant species occurrence at multiple scales

Pete Henrys[1], Janine Illian[2] and Charlotte Todd-Jones[2]

[1] CEH Lancaster, [2] Department of Statistics, University of StAndrews

The ultimate aim of this work is to model and estimate plant species occurrence probabilities over the whole of Wales using the species data recorded from the GMEP vegetation plots. We do this by assuming that these probabilities are a realisation of a Gaussian random field – essentially a random spatial process covering the wholes of Wales from which any species occurrence data is a realisation. Modelling in this way ensures that we preserve the spatial properties inherent in the species data.

We have two key data sets available from which to build the model. The first is the vegetation data recorded as part of the main GMEP field survey in the vegetation "X" plots. This detailed, quality assured quadrat data consists of species presence absence data due to the census approach of monitoring the full quadrat. Additional data from the GMEP survey, such as soil pH and land cover, also allows us to include predictor variables in our model for a more detailed assessment of spatial heterogeneity. The second species data set available is the volunteer collected data from the BSBI (Botanical society of the British Isles) coordinated and stored by the BRC (Biological Records Centre). This data has complete spatial coverage of Wales at 10km, but has presence only data and suffers from uneven recorder effort. As the two species records contain complimentary species, we can assume that they are independent realisations of the same underlying process, albeit at different scales and hence with different variance. This is the Gaussian random field we wish to estimate.
The initial model we have developed was therefore a simple latent Gaussian model that contains a Gaussian Random field to account for spatial autocorrelation in the response and additional variance components corresponding to the differing scales of the species data: GMEP field data 1km square and the BRC 10km square. Specifically, the Gaussian field is a Matèrn field, approximated by a solution to an SPDE (stochastic partial differential equation) as described in Lindgren et al. (2011). This approximation is based on a constrained Delauney triangulation (the "mesh") of the spatial domain of interest. The model is then fitted using INLA (integrated nested Laplace approximation, Rue et al., 2009) for computational efficiency.

We model the GMEP vegetation data, including the wider 10km presence only species pool data from BRC as a spatial predictor. As our species data from the GMEP squares is presence/absence, the model assumes a binomial response, where measurements are assumed to be independent conditional on the latent field. The latent field contains both the Matèrn field and spatial covariates (currently pH, BRC species pool data and land cover, but factors and other covariates can be easily added).
Extensions will include:

- accounting for the uncertainty in the spatial predictors;
- accounting for varying effort in the species pool data;
- including other ecological predictors associated with the climatic and other habitat preferences of the species.

Initial Runs

Initial model runs show that the structure of the model works well and that computational efficiency is optimised by use of the SPDE and INLA approaches. The model described above has currently been run for one species (*Agrostis capillaris*) using the limited range of spatial covariates (Figure 7). We intend to run the current model on more species before extending the set of predictors used to estimate relationships and the species' spatial distribution.

The map below shows the estimated surface of occurrence probabilities for *Agrostis capillaris* and the table shows the relationship between the GMEP vegetation data modelled and the spatial predictors. Note that these are both preliminary outputs to show the model running rather than conclusive results.

The mapped species probabilities are plotted at 1km^2 resolution, this being the finest resolution across all the predictor variables. Although the model was built at the 200m^2 plot level, 1km^2 probabilities were obtained by repeatedly sampling from the fitted model: within each 1km cell, 5000 estimates of species probability were obtained representing the 5000 200m^2 plots within the 1km square. From these 5000 probabilities a realized set of 5000 species presence/absence records were estimated. The proportion of presences was then taken as the species occurrence probability within the 1km square.

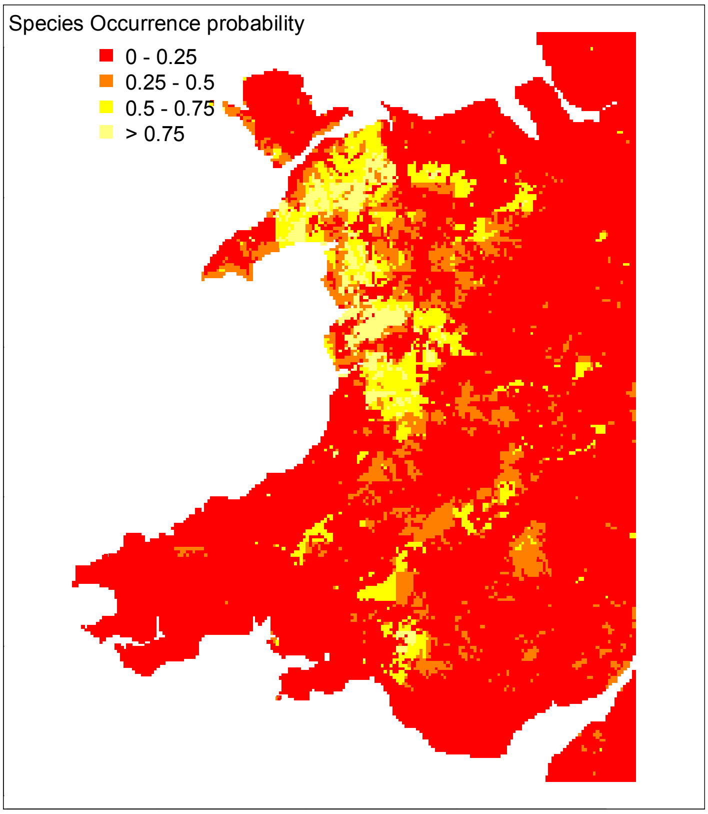


Figure 7: *Map showing the estimated probability of Agrostis capillaris occurring in each 1km grid cell, based on the fitted model.*

	Coefficient Estimates		
	Lower	Median	Upper
Intercept	-62.21	-26.38	14.62
ph	-4.10	0.29	5.37
BRC 10km Species Pool	0.04	3.71	9.05
Broadleaved Woodland	-40.65	-1.46	23.85
Coniferous Woodland	-6.86	21.34	45.89
Improved Grassland	-126.06	-60.39	-19.28
Rough Grassland	-53.80	-11.10	12.68
Neutral Grassland	-80.39	-40.24	-10.66
Calcareous Grassland	-12.99	17.37	40.84
Fen, Marsh and Swamp	-83.43	-12.38	30.55
Heather	-12.20	23.77	49.83
Heather Grassland	-14.65	14.53	37.48
Bog	-3.72	28.20	54.29
Supra-littoral Rock	-48.91	9.83	98.14
Supra-littoral sediment	-18.10	22.22	64.15
Saltmarsh	-89.78	-40.16	-11.72
Urban	-41.49	25.67	111.82

Table 22: *Estimated coefficients (median) together with credible intervals (lower and upper) for each parameter in the fitted model. Highlighted rows show significant variables.*

From the modelling approach taken it is also possible to extract the mean and standard deviation of the fitted random spatial field and plot across Wales to visualise the spatial correlation and uncertainty in the data. This spatial field shows where we are most uncertain in the probability estimates, either because of lack of data or weak covariate relationships and as such is a valuable output from the analysis to draw robust conclusions.

Figure 8 shows the standard deviation in the fitted random field and the lowest variation (blue spots) occur where we have a high number of observations and strong covariate relationships as defined in Table 22. It is clear that this uncertainty varies in space and clearly demonstrates the advantage of including this form of spatial heterogeneity in the model.

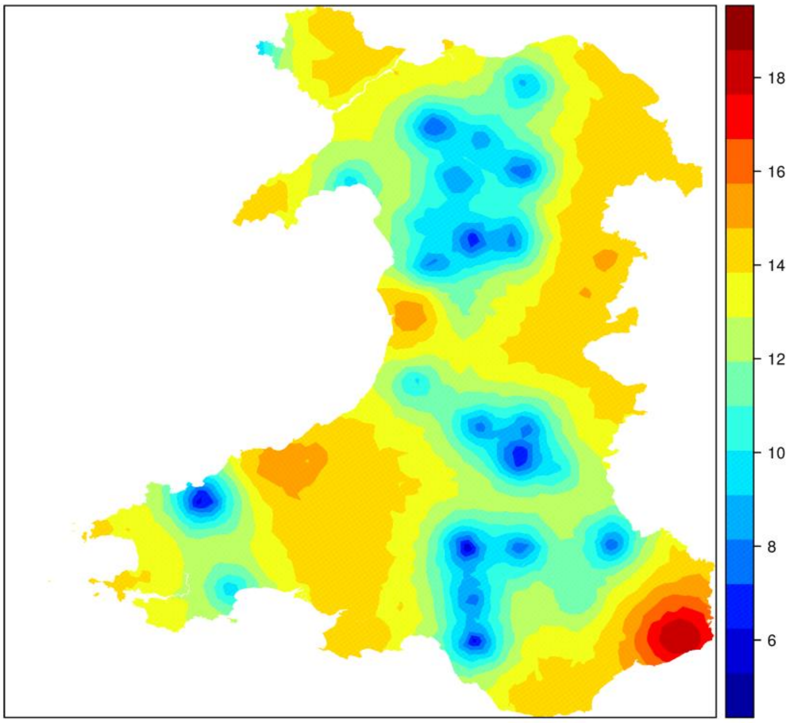


Figure 8: Estimates standard deviation of the fitted spatial random field in the model. The legend is in standard deviations and as such has no units. Areas with low uncertainty (deep blue hotspots) correspond to areas with a high number of observations and strong covariate relationships.

Conclusions

Although there have been previous attempts to model and map species occurrence probabilities over large spatial areas, few have regarded the data in its true spatial form and hence account for the differing sources of variation present in the data. The modelling approach adopted here has taken account of spatial autocorrelation present in the data and the spatial un-evenness in the observation locations. This is often ignored when building species distribution models as the focus is often on covariate relationships, but including this is key to ensure that inference made from the model and predictions based on the model are robust. The INLA approach described, not only accounts for this spatial correlation but does so in a fast efficient way meaning that multiple species runs, which have previously been computationally infeasible, are possible.

The flexible model has also allowed us to work at various spatial scales. We have included key random effects such that 10km BRC data and 200m GMEP data can be combined into the same model and we have utilised the Bayesian nature of the model to draw realisations and produce 1km predictions from a model built using 200m2 plot data. This unique approach has ensure we have maximised the use of all available data.

Further extension to this modelling technique such as those previously mentioned as well as incorporating a temporal element to account for changes over time, will enable us to realise a uniquely robust, informative, novel and scale-variant species modelling capability.

References:

Lindgren, F. & Rue, H., Lindström, J. (2011) An explicit link between Gaussian fields and Gaussian Markov random fields : the SPDE approach (with discussion). *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 73, 423–498.

Rue, H., Martino, S. & Chopin, N. (2009) Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. *J. R. Stat. Soc. Ser. B (Statistical Methodology)*, 71, 319–392.

Appendix 5.9: Future developments for the Wales-only Priority Invertebrate Species indicator

Bayesian vs WSS approach

The Priority Invertebrate Species Indictaor is an example of the "*trends in occurrence indicators*". These are based on semi-structured biological records that were collected by a vast network of volunteers. Such data tend to contain various forms of noise and bias that can inhibit their use in trend estimation (Tingley & Beissinger, 2009; Hassall & Thompson, 2010; (Isaac *et al.*, 2014b). Recent analytical developments have highlighted several approaches that produce robust trend estimates while accounting for such bias (Isaac *et al.*, 2014b). The priority species indicator was based on the "well-sampled sites" mixed effects modelling approach of Roy *et al.* (2012) and Isaac *et al.* (2014a). A key aspect of this approach is the two-stage filtering process that ensure the models are only based on a "well-sampled" subset of the data. First, those visits (unique combination of site and date) with species lists shorter than the median list length recorded across all sites were excluded, then sites with less than 3 years of data (records) were removed. For each species, a generalised linear mixed effects model with binomial error structure was fitted to the well-sampled data subset, with year as the fixed effect and site as a random effect (Roy *et al.,* 2012). The yearly fitted occupancy values were extracted from the models and formed the annual occupancy index for each species. These species-specific annual occupancy estimates were then combined to form the annual priority species indicator that was calculated as the geometric mean across all species, each year. Confidence intervals surrounding the geometric mean were estimated by bootstrapping (Buckland *et al.*, 2005). A key assumption of the well-sampled sites model is that species' detectability has not changed over time. However, in many cases this assumption is not met, for example, new survey techniques (e.g. the invention bat detectors), the publication of new identification keys, variation in the time of year of survey, or focussing recording onto targeted species (e.g. the harlequin ladybird survey - http://www.harlequin-survey.org/) can all alter detectability.

Recent studies have highlighted the value of Bayesian occupancy models for estimating species occurrence in the presence of imperfect detection (van Strien *et al.*, 2013; Isaac *et al.*, 2014). This approach uses two hierarchically coupled sub-models, one, the state model, governs the true presence/absence of a species at a site in a given year, the second, the observation model, governs the probably of detecting that species given its presence or absence, and is therefore conditional on the state model (Equation 1). For each site year combination the model estimates presence or absence for the species in question (Z_{it}), which is linked to the observed data (y_{jtv}), given variation in detection probability (p_{jtv}). These Z_{it} values are then combined to create an annual estimate of the proportion of occupied sites.

Equation 1: The Bayesian occupancy model used to estimate annual proportion of occupied sites.

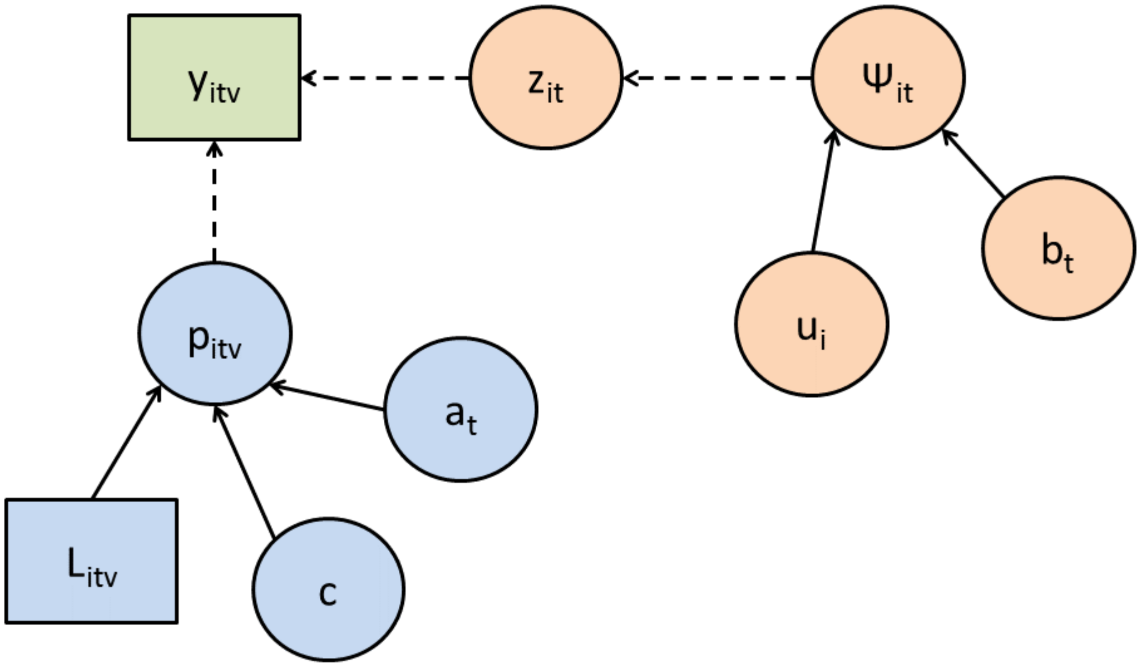
State model - $z_{jt} \sim \text{Bernoulli}(\psi_{jt})$; $\text{logit}(\psi_{jt}) = b_t + u_j$

Observation model - $y_{jtv} | z_{jt} \sim \text{Bernoulli}(z_{jt} * p_{jtv})$; $\text{logit}(p_{jtv}) = a_t + c.\log(L_{jtv})$

Z_{it} = True occupancy of site (i) in year (t). Can be a 1 or 0, present or absent.
ψ_{jt} = The probability that site (i) is occupied in year (t)
b_t = Year effect (categorical)
u_j = Site effect (categorical)
y_{jtv} = Observed presence/absence at site (i) at year (t) on visit (v)
p_{jtv} = The probability of detection at site (i) at year (t) on visit (v), conditional on Z_{it} that is the species true presence or absence.

a_t = Year level random effect (categorical)
L_{jtv} = List length at site (i) in year (t) on visit (v)
c = Change in the log-odds of detectability associated with an increasing list length by a factor of *e.*

Figure 9 *Directed acyclic graph illustrating the occupancy model structure. Orange shading represents the state model, blue shading represents the observation model, and the green box represents the observed data.*



The occupancy model approach requires repeated visits within a closure period (a year, in this case) from which the detection probability is estimated following capture-recapture theory (MacKenzie, 2006; van Strien *et al.*, 2013). Detectability is also informed by the number of species recorded on a given visit (L_{itv}), a proxy for recorder effort.

Where the WSS indicator was based on fitted values, here we use the species-specific annual occupancy estimates. Again the annual index for the priority species indicator can be calculated as the geometric mean of these annual occupancy estimates across all species. Each species is given equal weighting when calculating the geometric mean and the 95% confidence intervals can be calculated via bootstrapping (Buckland *et al.*, 2005). As the WSS indicator was based on fitted values from linear models, the 95% confidence intervals tend to increase overtime reflecting the gradual divergence of the species-specific trend lines from the fixed origin of 100 in the initial year. In contrast, the species-specific annual occupancy estimates used in the Bayesian indicator are not restricted to follow a linear pattern, and as a result the 95% CIs are not expected to follow the temporal increasing pattern as seen in the WSS indicator. An additional benefit of the occupancy model approach is that results for past years will not be affected by the addition of data for future years, which is not the case for the WSS model.

Modelling the impact of covariates including Glastir

The indicators were developed as a metric of the ongoing trends in priority species. An area for future study would be to further develop the indicator to monitor the effectiveness of conservation strategies aimed at halting biodiversity loss. Such a development may be applied to the Welsh indicator with the aim of improving our understanding of the impact of Tir Gofal on priority species. An initial approach would be to run the models on separate subsets of the data, one subset consisting of 1km grid squares that have received targeted conservation management, while the other subset consists of those without. Each subset of data would be represented by its own indicator (inter-annual variation in occupancy), and when plotted together would illustrate the difference in the average trend across priority species in regions with and without targeted conservation management. There are several limitations of this approach, firstly, variation in the conservation management approach, and in the time-frame of their implication will create noise in this metric. For example, we are less likely to detect the impact of conservation management after just one year, compared to several years of implementation. Furthermore, species' responses to conservation management is likely to lag behind its implementation. Additionally, species will respond in a variety of ways to conservation management (e.g. some may benefit and increase while others decline) such variation would be missed in a composite indicator. Finally, separating the impact of conservation management on the indicator from the impact of inter-annual variation in environmental factors (such as weather) presents a challenge that is likely to be amplified when using coarser resolution data.

An alternative approach would be to include a conservation management covariate into the occupancy model (see *extensions to the model* section of MacKenzie *et al.* 2002). In its simplest form, this would be the addition of a binary explanatory variable (*managed* vs *non-managed*) to the state model, therefore, ψ_{jt} (the probability that site *i* is occupied in time *t*) would be related to a site-year conservation management term (1/0). Rather than being a simple binary variable (*managed* vs *non-managed*), this management variable could take a number of other forms. For example, it could be a categorical variable based on the different conservation management options (e.g. the various agri-environment scheme options), or alternatively it could be a continuous variable based on the proportion of land cover within the grid cell devoted to conservation management. By adding a management term into the occupancy model we would produce a coefficient for the impact of management on the probability of occupancy for each species. These values could then be combined (in a similar way to the species-specific annual occupancy estimates for the indicator) to give a single value for impact of conservation management across all priority species. A key advantage of this approach is that the flexibility of the model and that the models estimate the impact of management on a site-year basis means that the majority of the limitations listed in the paragraph above do not apply.

References

Buckland, S.T., Magurran, a E., Green, R.E. & Fewster, R.M. (2005) Monitoring change in biodiversity through composite indices. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, **360**, 243–54.

Hassall, C. & Thompson, D.J. (2010) Accounting for recorder effort in the detection of range shifts from historical data. *Methods in Ecology and Evolution*, **1**, 343–350.

Isaac, N.J.B., van Strien, A.J., August, T.A., de Zeeuw, M.P. & Roy, D.B. (2014a) Extracting robust trends in species' distributions from unstructured opportunistic data: a comparison of methods. *BioRXiv*.

Isaac, N.J.B., van Strien, A.J., August, T.A., de Zeeuw, M.P. & Roy, D.B. (2014b) Statistics for citizen science: extracting signals of change from noisy ecological data. *Methods in Ecology and Evolution*, **5**, 1052–1060.

MacKenzie, D.I. (2006) *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*, Academic Press, Burlington, Massachusetts, USA.

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege J, S., Royle, A. & Langtimm, C.A. (2002) Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, **83**, 2248–2255.

Roy, H.E., Adriaens, T., Isaac, N.J.B., Kenis, M., Onkelinx, T., Martin, G.S., Brown, P.M.J., Hautier, L., Poland, R., Roy, D.B., Comont, R., Eschen, R., Frost, R., Zindel, R., Van Vlaenderen, J., Nedvěd, O., Ravn, H.P., Grégoire, J.-C., de Biseau, J.-C. & Maes, D. (2012) Invasive alien predator causes rapid declines of native European ladybirds. *Diversity and Distributions*, **18**, 717–725.

Van Strien, A.J., van Swaay, C.A.M. & Termaat, T. (2013) Opportunistic citizen science data of animal species produce reliable estimates of distribution trends if analysed with occupancy models. *Journal of Applied Ecology*, **50**, 1450–1458.

Tingley, M.W. & Beissinger, S.R. (2009) Detecting range shifts from historical species occurrences: new perspectives on old data. *Trends in Ecology & Evolution*, **24**, 625–633.

Appendix 5.10: Biodiversity - data portal entries

Headline question: What are the long term trends in biodiversity in Wales?

Priority Species Indicator for Wales

Target: *Biodiversity*

Question type: *Long term trends*

Question: *What are the long-term trends in occupancy of well-recorded priority invertebrate species in Wales?*

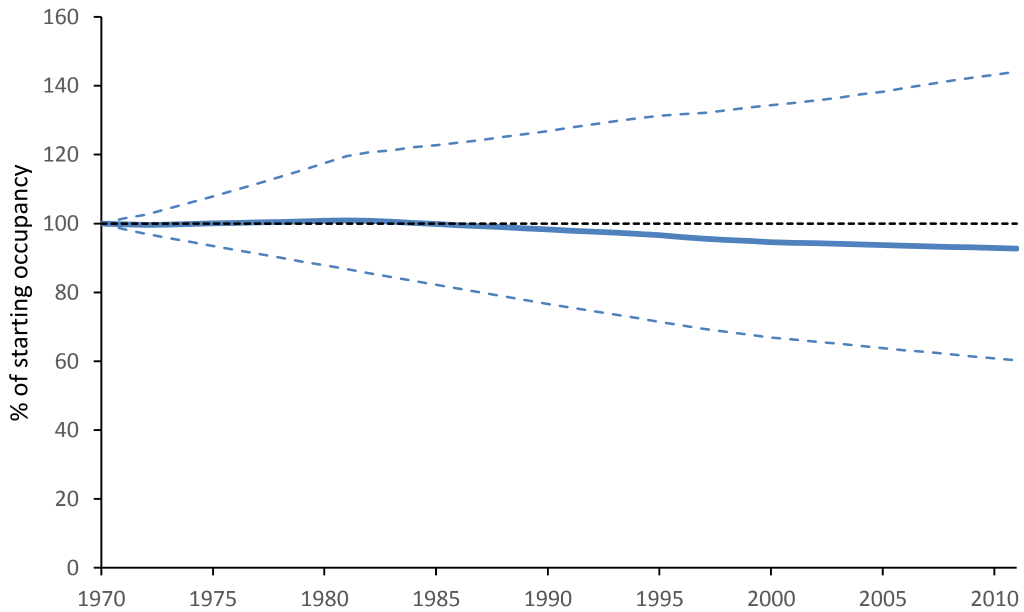
Background to question:

Given the many threats to biodiversity (e.g. habitat loss, invasive species, climate change, etc.) and the need to report on progress towards Strategic Goal D "*Enhance the benefits to all from biodiversity and ecosystem services*" of the Aichi Targets from the Convention on Biological Diversity (http://www.cbd.int/sp/targets/), there is a need to develop an accurate metric of biodiversity status. Temporal trends in such a metric can be used to monitor long-term change, and can assess the effectiveness of conservation strategies aimed at halting biodiversity loss. Here we use an indicator that utilises opportunistic biological records to examine the long-term trends in priority invertebrate species in Wales. The derivation of the indicator mirrors the approach applied at UK level (http://jncc.defra.gov.uk/page-6850) hence the two are directly comparable. Species covered by other established recording schemes – birds, bats, plants - or where reliable data does not exist for the time period were excluded.

Evidence:

The priority invertebrate species indicator (Figure 1) illustrates the change in frequency of occurrence of well-recorded priority species in Wales between 1970 and 2010. The indicator was created by combining the annual frequency of occurrence estimates of 87 species, the majority of which are moths (81 moths, 1 dragonfly and 6 bee species). The indicator shows a marginal decline across all species, however the 95% confidence intervals surrounding the trend are large and span zero. Consequently we cannot decisively say that the trend across priority species is anything other than stable.

Figure 1. Change in the frequency of occurrence of priority invertebrate species in Wales between 1970 and 2011. The dashed lines represent 95% confidence intervals for mean annual occupancy estimate.



Data:
We provide the annual index values and their associated 95% confidence intervals (Table 1). The annual index is the geometric mean of the annual frequency of occurrence estimates across all 87 species included in the analysis. The confidence intervals of the geometric mean were identified via bootstrapping (see methods below for further detail).

Table 1 The annual frequency of occurrence estimate across all species (Index) is shown alongside the 95% confidence intervals

Year	Index	2.5% CI	97.5% CI
1970	100.00	100.00	100.00
1971	99.78	98.39	101.40
1972	99.57	96.99	102.59
1973	99.72	95.82	104.31
1974	99.86	94.65	106.08
1975	100.01	93.49	107.85
1976	100.16	92.34	109.69
1977	100.30	91.22	111.55
1978	100.45	90.09	113.54
1979	100.60	88.94	115.52
1980	100.75	87.85	117.51
1981	100.89	86.73	119.56
1982	100.80	85.57	120.73
1983	100.48	84.42	121.27
1984	100.16	83.34	122.18
1985	99.84	82.21	122.70
1986	99.53	81.07	123.47
1987	99.21	79.97	124.24
1988	98.90	78.87	125.17
1989	98.58	77.75	126.02
1990	98.27	76.66	126.79
1991	97.95	75.61	127.88
1992	97.64	74.55	128.76
1993	97.33	73.52	129.66
1994	97.02	72.49	130.58
1995	96.61	71.46	131.32
1996	96.07	70.37	131.71
1997	95.58	69.38	132.14
1998	95.24	68.57	132.89
1999	94.90	67.72	133.71
2000	94.59	66.89	134.33
2001	94.42	66.30	135.04
2002	94.25	65.66	135.79
2003	94.08	65.13	136.47
2004	93.90	64.49	137.49
2005	93.73	63.78	138.23
2006	93.56	63.19	139.39

2007	93.39	62.64	140.35
2008	93.21	62.04	141.45
2009	93.04	61.40	142.30
2010	92.87	60.80	143.20
2011	92.71	60.27	144.13

Methodology:
The priority invertebrate species indicator was produced by following the methodology of the *C4b: Status of priority species – frequency of occurrence – insects* section within the UK biodiversity indicators 2014 report (http://jncc.defra.gov.uk/page-4229).

Biological records were extracted at the 1 km grid square scale from data held within the Biological Records Centre, the Bee, Wasps and Ants (BWARS) recording database and the records database of the British Dragonfly Society. Only data between 1970 and 2011 were included in the analysis; time lags in data collation prevented the inclusion of more recent records. Such biological records tend to contain many forms of sampling bias (for example between-year variation in recorder effort), making it hard to detect genuine signals of change. To account for this, we utilised the "well-sampled sites" mixed effects model approach of Roy *et al*. 2012 (see GMEP year 2 report). The annual index for each species was based on the fitted annual occupancy estimates from each species-specific models. Each species' time-series was expressed as the proportion of the first year which was set to 100. The overall annual indicator was then estimated as the geometric mean of the annual index values across all species. Confidence intervals were calculated via bootstrapping (n = 10,000). For each iteration, a random sample of species were selected with replication and the geometric mean recalculated.

Long-term trends in section 42 butterfly species

Target: *Biodiversity*

Question type: *Long term trends*

Question: *What are the long-term trends in section 42 butterfly species abundance across Wales?*

Background to question:
Section 42 of the Natural Environment & Rural Communities Act 2006 lists 189 invertebrate species of principal importance for conservation of biological diversity in Wales. Fifteen are butterflies. Evidence to date has shown that the combined effects of land-use change and climate have been responsible for changes in population size and range of many species. Those characteristic of less productive semi-natural habitats have fared the worst while rare species are additionally vulnerable because of their small and dispersed populations. Groups of Glastir measures are targeted at particular habitats and species, including three section 42 butterflies. By implementing habitat restoration and appropriate grazing and cutting regimes, these measures should favour butterfly larval foodplants and appropriate vegetation structure. The impact of these measures on butterfly abundance is best assessed against the backdrop of past and current trends in numbers. Here, long-term trend results are presented for section 42 butterflies in Wales based on UK Butterfly Monitoring Scheme (UKBMS) recording, as a context for interpreting further changes that may be attributed to Glastir.

Evidence:
Six of the 15 section 42 butterfly species had enough Welsh records to calculate changes in population indices. Trends over 38 years (1976-2013) and the past 10 years are consistent with the total abundance indices for Habitat Specialists (see BD009.2). Over the longer period most species declined showing more stability in the past 10 years. The last two columns show counts in the GMEP squares in 2013 and 2014 combined. The three species targeted by specific bundles of interventions in Glastir are highlighted in red and were rare or unrecorded in the Gmep transect surveys in 2013 and 2014.

Data:

SPECIES	No. years used in trend	No. sites 2013	% change in index 2012-2013	Series trend (38-yrs)	10-yr trend	No. GMEP sites 2013-14	% GMEP sites 2013-14
Dingy Skipper	N/A	5	N/A	N/A	N/A	0	0
Grizzled Skipper	N/A	0	N/A	N/A	N/A	0	0
Wood White	N/A	0	N/A	N/A	N/A	0	0
Brown Hairstreak	N/A	1	N/A	N/A	N/A	1	1
White-letter Hairstreak	N/A	2	N/A	N/A	N/A	2	1
Small Blue	N/A	2	N/A	N/A	N/A	0	0
Silver-studded Blue	N/A	1	N/A	N/A	N/A	0	0
White Admiral	N/A	0	N/A	N/A	N/A	0	0
Small Pearl-bordered Fritillary	15	7	-9	-24	89	6	4
Pearl-bordered Fritillary	16	12	74	171*	72	0	0
High Brown Fritillary	10	9	990	-8	-33	1	1
Marsh Fritillary	21	20	272	-79**	-44	0	0
Wall Brown	38	36	476	-38	39	24	16

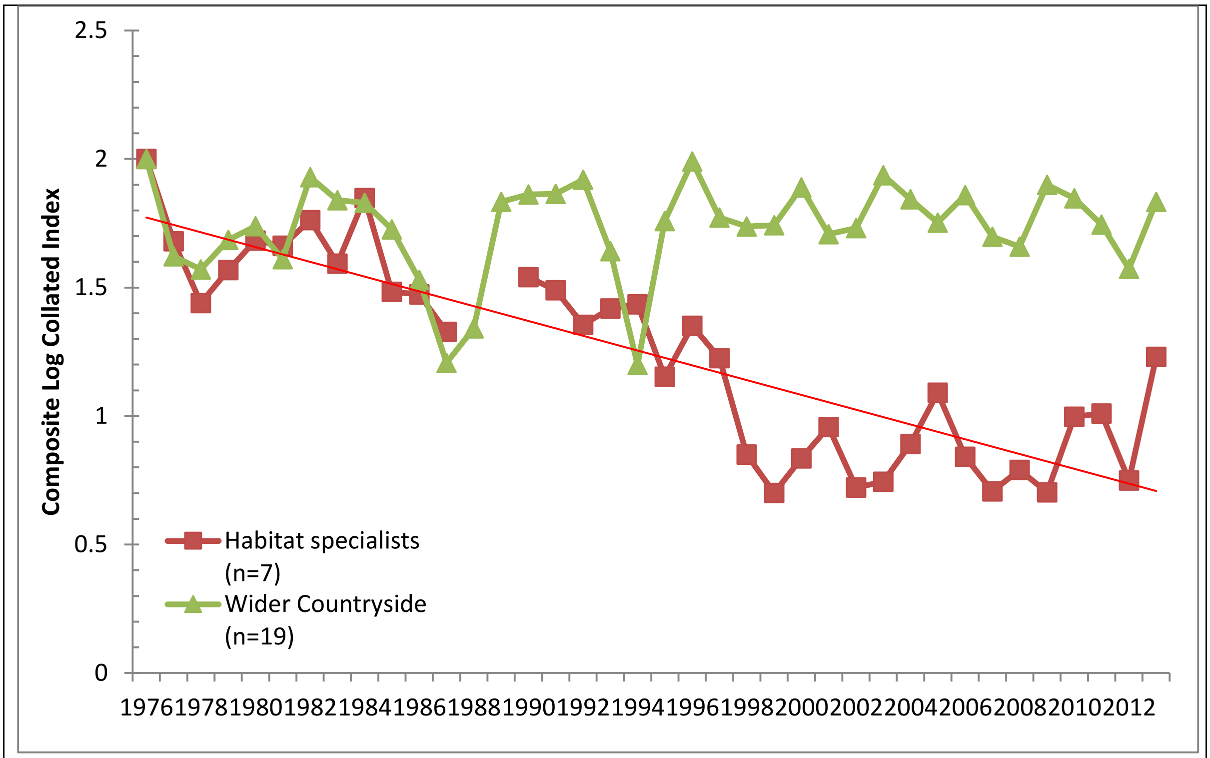
Grayling	32	7	447	-84***	257*	3	2
Large Heath	N/A	0	N/A	N/A	N/A	2	1

Methodology:

Data are based on occupancy of Welsh UKBMS 1km squares. Because the species are rare, records are limited in number and so trends in the data, particularly those ranging back to 1976, should be interpreted with caution. Counts of presence in GMEP 1km squares were derived from pollinator surveys (see Pollinator survey results portal pages for further details).

Long-term trends in butterflies

Target: *Biodiversity*
Question type: *Long term national trends*
Question: *What are the long-term trends in butterfly abundance across Wales?*
Background to question: Butterfly numbers have declined at least since the 1970's as a result of habitat loss through land converted to agriculture and subsequent intensification. Because insect populations fluctuate annually in response to weather, parasitism, predation and other factors, it is essential to determine patterns over long-time series to see how populations are changing when these other effects are accounted for. Butterflies are important for a number of reasons; they are pollinators, prey for many other taxa, particularly birds, and are of cultural significance having a positive effect on people's well being. Whilst other invertebrate groups are also important for these and other ecosystem services we often lack sufficient data to determine patterns in abundance, whereas for butterflies we have a comprehensive dataset going back to 1976. In addition, analyses to date have revealed that other taxa are showing similar patterns across the UK, and butterflies have been shown not only to be good indicators of the general health of the countryside, but also good indicators of how other taxonomic groups are responding.
Evidence: UK Butterfly Monitoring Scheme (UKBMS) data is shown for Wales going back to 1976 (Fig 1). Butterfly species abundance in 324 1km squares has been collated and trend lines are shown for two groups: Wider Countryside species include generalists such as Meadow Brown (*Maniola jurtina*), Large White (*Pieris brassicae*) and Peacock (*Aglais io*), whose larvae feed on forbs and grasses abundant in productive farmland. These species are therefore able to survive better in the modern countryside and show a stable pattern with fluctuations reflecting the influence of the weather on population size. Habitat specialist species such as Pearl-bordered (*Boloria euphrosyne*) , High Brown (*Argynnis adippe*) Fritillaries, and the Grayling (*Hipparchia semele*) show greater restriction to less productive semi-natural habitats such as heathland and fen. The index for these species shows a rapid and highly significant decline in Wales since 1976, and appearing to stabilise at a lower abundance after 1998. Figure 1: Long term trends in butterfly abundance in Wales.



	No. species	Series trend (%)	Series trend description	10-yr trend (%)	10-yr trend description
All species	*26*	*-3*	*Stable*	*-7*	*Stable*
Wider Countrsyide species	*19*	*25*	*Stable*	*-16*	*Stable*
Habitat specialists	*7*	*-91****	*Rapid decline*	*38*	*Stable*

Methodology:
The UKBMS is a volunteer-based scheme that has been running since 1976 with well over 3,000 sites to date. Data on the population status of butterflies is derived from a national-scale programme of site-based monitoring and sampling in randomly selected 1km squares (Wider Countryside Butterfly Survey – WCBS). The majority of sites are monitored by butterfly transects involving weekly counts along fixed routes throughout the season. Counts are converted to a site index that accounts for both the size of the colony and the time in the season when the count was made. The WCBS was established in 2009 to improve data on national population status of butterflies across the countryside as a whole. For wider countryside species, data from the two main survey types are combined to create national indices for these species, whilst for habitat specialists which are more reliant on reduced effort monitoring, only BMS data is used. General Additive Models are used to calculate site-level indices for each recorded species. Following this a log-linear model is used to calculate a national collated index for each species. These indices are combined to calculate composite indices for each butterfly group. See http://www.ukbms.org/ for further details.

Nectar plant abundance on arable land

Target: *Biodiversity*

Question type: *Long term trends*

Question: Are nectar plants declining in Welsh arable land?

Background to question:

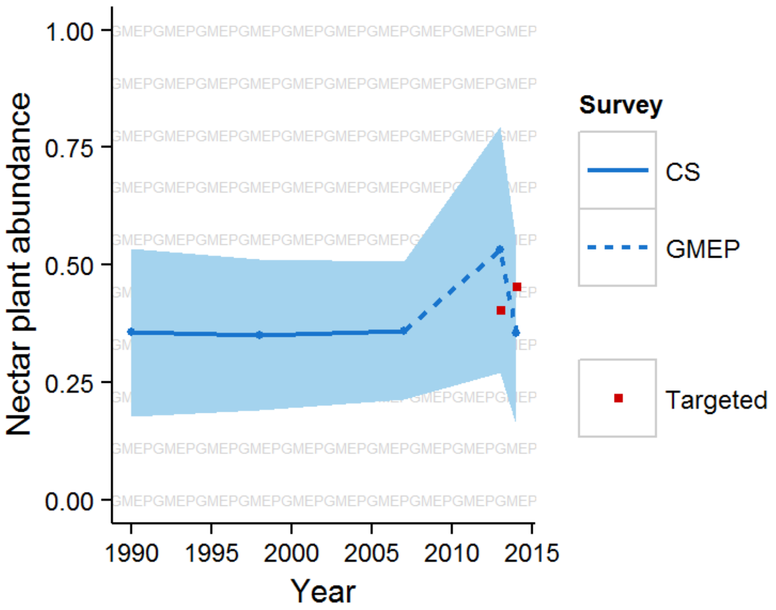
Pollinating invertebrates and their wild nectar plants have been declining across NW Europe since the 1950s. In many places this has led to a pollinator deficit reducing potential supply of the ecosystem service of crop pollination and reducing the biodiversity of nectar plants and their pollinating insects. Over time GMEP surveys can be used to quantify jointly recorded changes in abundance of preferred nectar plants and pollinating insects and estimate how they are impacted by Glastir. To interpret these future patterns it is essential to understand what has happened in the past. To do this GMEP survey data can be linked up with longer term records from Countryside Survey. Three examples are presented that quantify changes in the abundance of the most common nectar-providing plants since 1990. Some habitats are more important than others in supporting these plant species. Here we focus on data from the Arable & Horticultural Broad Habitat. This habitat is however, less extensive in Wales than other parts of the UK hence sample sizes were small (11 area and 20 linear plots in 2013; 19 and 26 respectively in 2014).

Evidence:

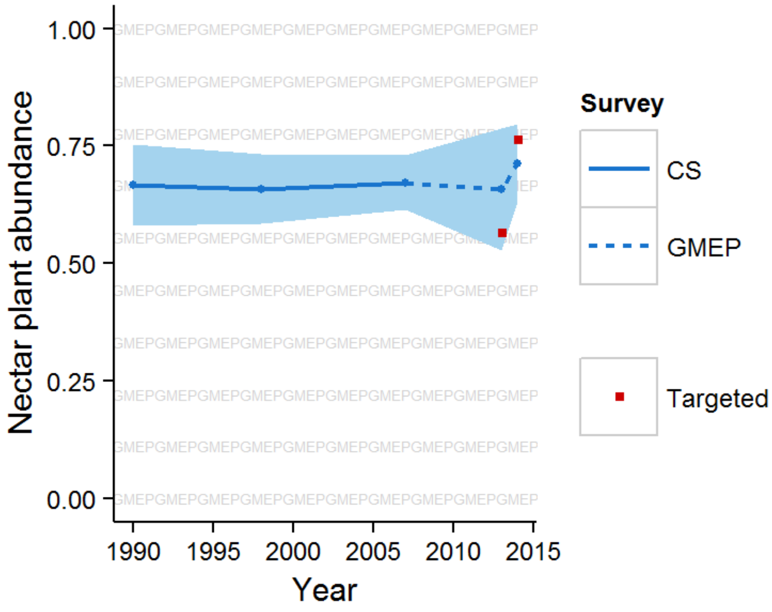
There were no significant differences in abundance of important nectar plants between any pair of years. Mean nectar plant abundance was roughly 30% higher in linear plots than in plots sampling the interior of arable fields (Fig 1a,b).

Figure 1: Mean cover-weighted abundance of nectar plants in a) plots that randomly sample areas of arable land, b) plots from linear features associated with arable land.

a)



b)



Data:
CSV supplied.

Methodology:
GMEP survey datasets:
Plots that randomly sampled areas of habitat or linear features associated with the arable land (field boundaries, adjacent watercourses and hedgerows) were selected from Countryside Survey and GMEP where every plot was linked to a mapped area of Arable & Horticultural Broad Habitat. Because of sample size differences and reflecting the unique importance of linear features, particularly adjacent to arable fields, area and linear plots were analysed separately.

Indicators:
The indicator was calculated by first ranking the preferred foodplants listed in Dyer, R et al (2014). *The Identification of Preferential Foodplants for Pollinator Species of Concern in the UK. Report to Natural England*. The attribute used to rank each species was the total number of observed pollinator-plant interactions. The highest ranking species were Bramble (*Rubus fruticosus* agg.), Ragwort (*Senecio jacobaea*) and Hogweed (*Heracleum sphondylium*). Rank importance of each species was scaled to between 0 (least important) and 1 (most important). The mean rank of the species in each GMEP plot was then derived and the importance of the species additionally weighted by its observed cover so that high ranking plants with greater cover result in values of the indicator closer to 1.

Nectar plant abundance in Neutral Grassland

Target: *Biodiversity*

Question type: *Long term trends*

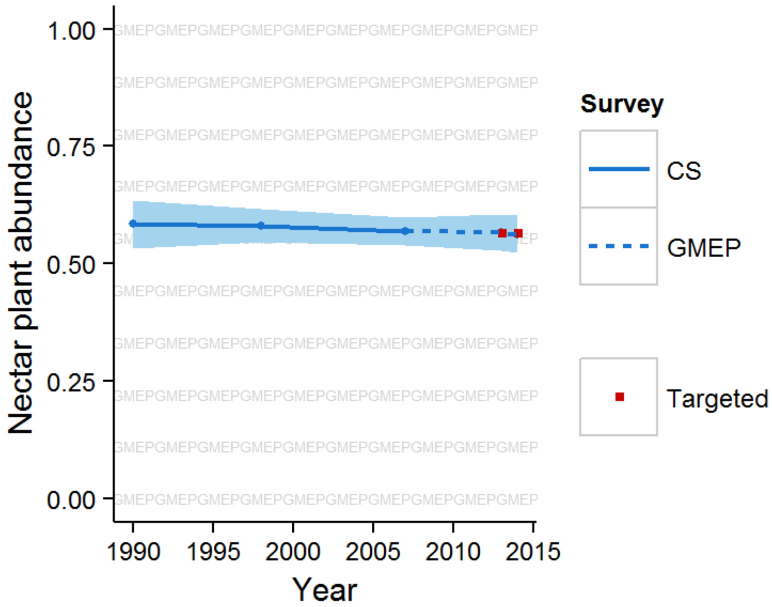
Question: Are nectar plants declining in Welsh Neutral Grassland?

Background to question:
Pollinating invertebrates and their wild nectar plants have declined across NW Europe since about the 1950s. In many places this has led to a pollinator deficit reducing potential supply of the ecosystem service of crop pollination and reducing the biodiversity of nectar plants and their pollinating insects. Over time GMEP survey data can be used to quantify jointly recorded changes in abundance of preferred nectar plants and pollinating insects and estimate how they are impacted by Glastir. To interpret these future patterns it is essential to understand what has happened in the past. To do this GMEP surveys can be linked up with longer term records from Countryside Survey. Three examples are presented that quantify changes in the abundance of the most common nectar-providing plants since 1990. Some habitats are more important than others in supporting these plant species. Here, data is presented from the Neutral Grassland Broad Habitat.

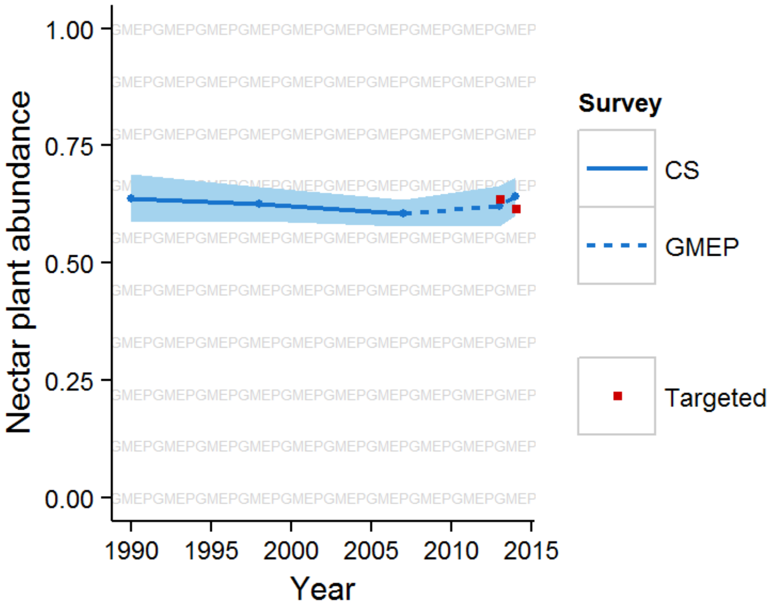
Evidence:
There were no significant differences in abundance of important nectar plants between any pair of years.

Figure 1: Mean cover-weighted abundance of nectar plants in a) plots that randomly sample areas of Neutral Grassland, b) plots from linear features associated with Neutral Grassland.

a)



b)

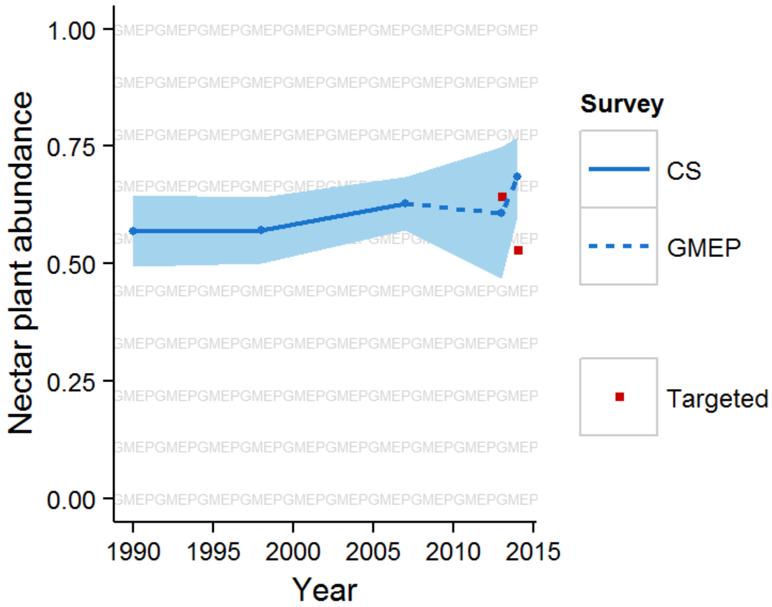


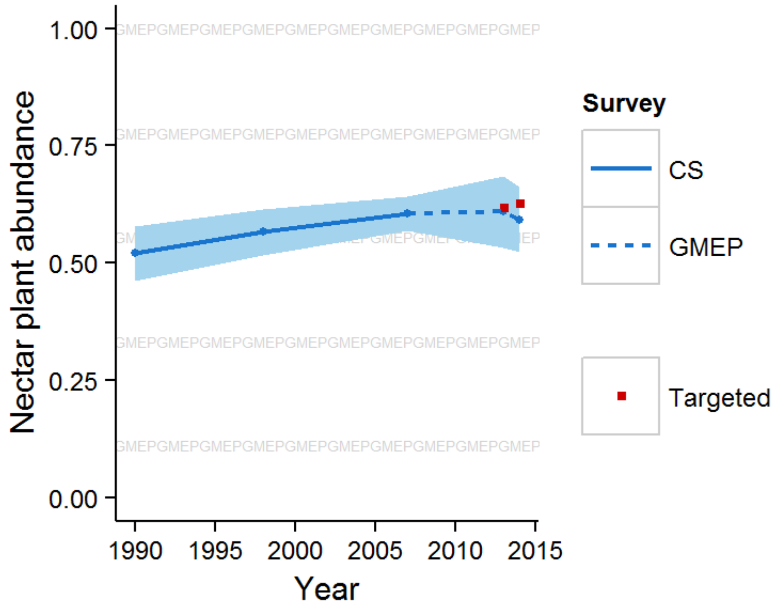
Data:
CSV supplied.

Methodology:
GMEP survey datasets:
Plots that randomly sampled areas of habitat or linear features associated with Neutral Grassland (field boundaries, adjacent watercourses and hedgerows) were selected from Countryside Survey and GMEP where every plot was linked to a mapped area of Neutral Grassland. Because of sample size differences and reflecting the unique importance of linear features, area and linear plots were analysed separately.

Indicators:
The indicator was calculated by first ranking the preferred foodplants listed in Dyer, R et al (2014). *The Identification of Preferential Foodplants for Pollinator Species of Concern in the UK. Report to Natural England*. The attribute used to rank each species was the total number of observed pollinator-plant interactions. The highest ranking species were Bramble (*Rubus fruticosus* agg.), Ragwort (*Senecio jacobaea*) and Hogweed (*Heracleum sphondylium*). Rank importance of each species was scaled to between 0 (least important) and 1 (most important). The mean rank of the species in each GMEP plot was then derived and the importance of the species additionally weighted by its observed cover so that high ranking plants with greater cover result in values of the indicator closer to 1.

Nectar plant abundance in Broadleaved woodland

Target: *Biodiversity*
Question type: *Long term trends*
Question: Are nectar plants declining in Welsh broadleaved woodland?
Background to question: Pollinating invertebrates and their wild nectar plants have declined across NW Europe since about the 1950s. In many places this has led to a pollinator deficit reducing potential supply of the ecosystem service of crop pollination and reducing the biodiversity of nectar plants and their pollinating insects. Over time GMEP survey data can be used to quantify jointly recorded changes in abundance of preferred nectar plants and pollinating insects and estimate how they are impacted by Glastir. To interpret these future patterns it is essential to understand what has happened in the past. To do this GMEP field survey data can be linked up with longer term records from Countryside Survey. Three examples are presented that quantify changes in the abundance of the most common nectar-providing plants since 1990. Some habitats are more important than others in supporting these plant species. Here we focus on data from the Broadleaved, Mixed & Yew woodland Broad Habitat. The other indicators present data from the Neutral Grassland and Arable & Horticultural Broad Habitats.
Evidence: There were no significant differences in abundance of important nectar plants between any pair of years. Figure 1: Mean cover-weighted abundance of nectar plants in a) plots that randomly sample areas of woodland, b) plots from linear features inside or on the edge of woodlands. a)  b)



Data:
CSV supplied.

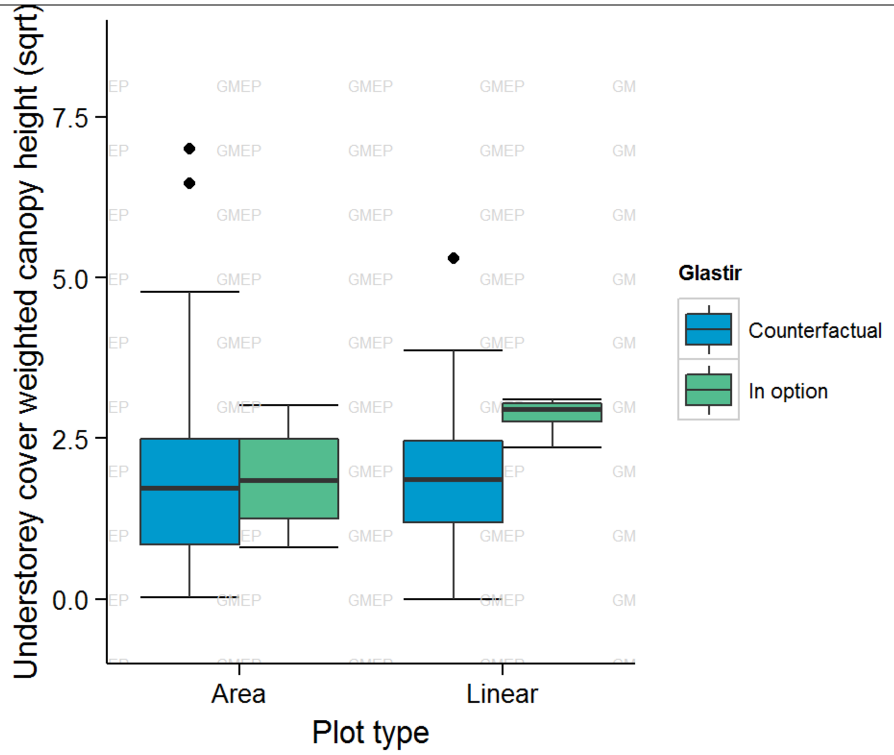
Methodology:
GMEP survey datasets:
Plots that randomly sampled areas of woodland or linear features associated with woodland (woodland boundaries, adjacent watercourses and hedgerows) were selected from Countryside Survey and GMEP where every plot was linked to a mapped area of woodland. Because of sample size differences and reflecting the unique importance of linear features, area and linear plots were analysed separately.

Indicators:
The indicator was calculated by first ranking the preferred foodplants listed in Dyer, R et al (2014). *The Identification of Preferential Foodplants for Pollinator Species of Concern in the UK. Report to Natural England*. The attribute used to rank each species was the total number of observed pollinator-plant interactions. The highest ranking species were Bramble (*Rubus fruticosus* agg.), Ragwort (*Senecio jacobaea*) and Hogweed (*Heracleum sphondylium*). Rank importance of each species was scaled to between 0 (least important) and 1 (most important). The mean rank of the species in each GMEP plot was then derived and the importance of the species additionally weighted by its observed cover so that high ranking plants with greater cover result in values of the indicator closer to 1.

Headline question: What are the impacts of Glastir options on conditions associated with section 42 species?

Dormouse; habitat condition indicators

Target: *Biodiversity*
Question type: *Benefit of Glastir options*
Question: What is the impact of the Glastir options on ecological conditions associated with Dormouse?
Background to question: Glastir targets management on named rare species. These are listed in Section 42 of the Natural Environment & Rural Communities Act 2006. The targeting mechanism involves funding bundles of options within areas known to encompass target species populations. Most options are however not species-specific and can be funded in any eligible area of habitat because of the wider benefits they bring. While no benefit is likely to arise for the species in areas where it is absent or unlikely to establish in the future it is useful to determine whether the option results in the desired impact on ecological condition (vegetation and habitat structure, plant species composition, soils and waters) that would directly favour the target species if the option land coincided with species occurrence. This question can be answered using all areas of in-option land without the rare species being present. In most cases Gmep does not measure rare species' performance but focusses on assessing the impact of the option on ecological conditions. In parallel current distribution data is used to say how many recent records for the species coincide with GMEP squares with relevant option uptake.
Evidence: <u>Glastir uptake:</u> Of 20 Dormouse options 9 have been taken up in at least one Gmep square. The most common options focus on hedgerow management (5, 6, 6b) and stock exclusion in woodlands (100). Example indicators were generated to measure changes in shrub species composition and the structure of the woodland understorey, as well as species richness of shrubs in trees in hedgerows. . <u>Coincidence with target species:</u> Available distribution data for Dormouse indicated no post-1970 records in any of the 27 Gmep squares containing Dormouse options. This is likely to be an underestimate since it was not possible to access a large proportion of known Dormouse records for Wales. <u>Indicators:</u> In woodlands, understorey canopy height did not differ significantly between in-option and out of scheme plots but Bramble cover was higher within in-option plots because of much higher values on linear features (Fig 1b). In hedgerows, in-option and out of scheme plots did not differ in total tree and shrub species richness (Fig 2). Figure 1: Plots in option 100 (woodland stock exclusion) compared to out of scheme plots in broadleaved woodland. Mean cover-weighted canopy height per plot a) where canopy height per species was classified as follows: *1.* foliage <100mm in height; *2.* 101-299mm; *3.* 300-599mm; *4.* 600-999mm; *5.* 1.0-3.0m; *6.* 3.1-6.0m; *7.* 6. 1-15.0m; *8.* >15m. Cover of Bramble b). a)



b)

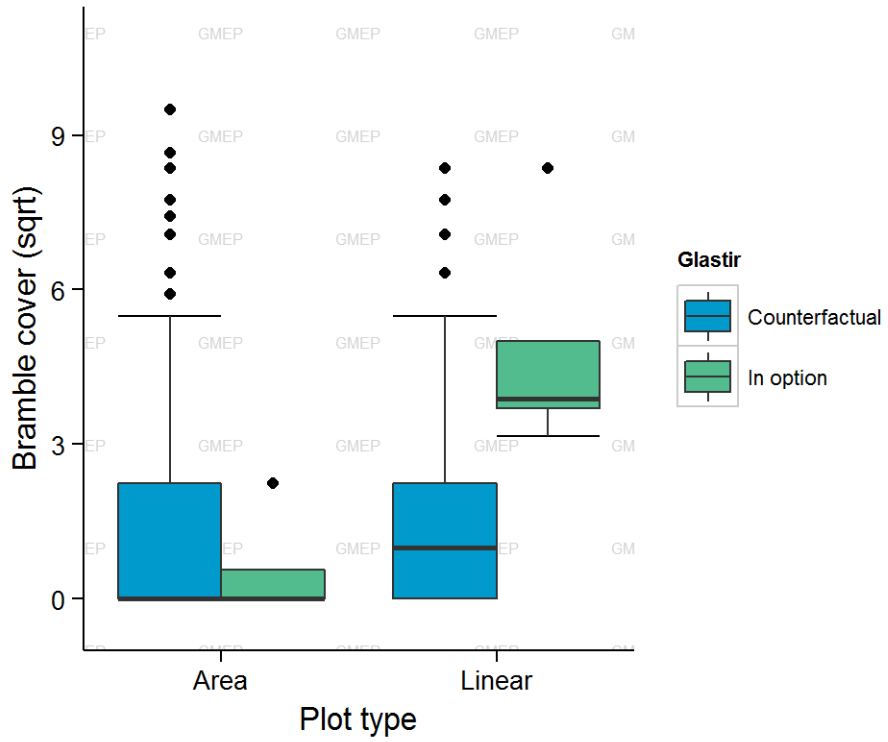
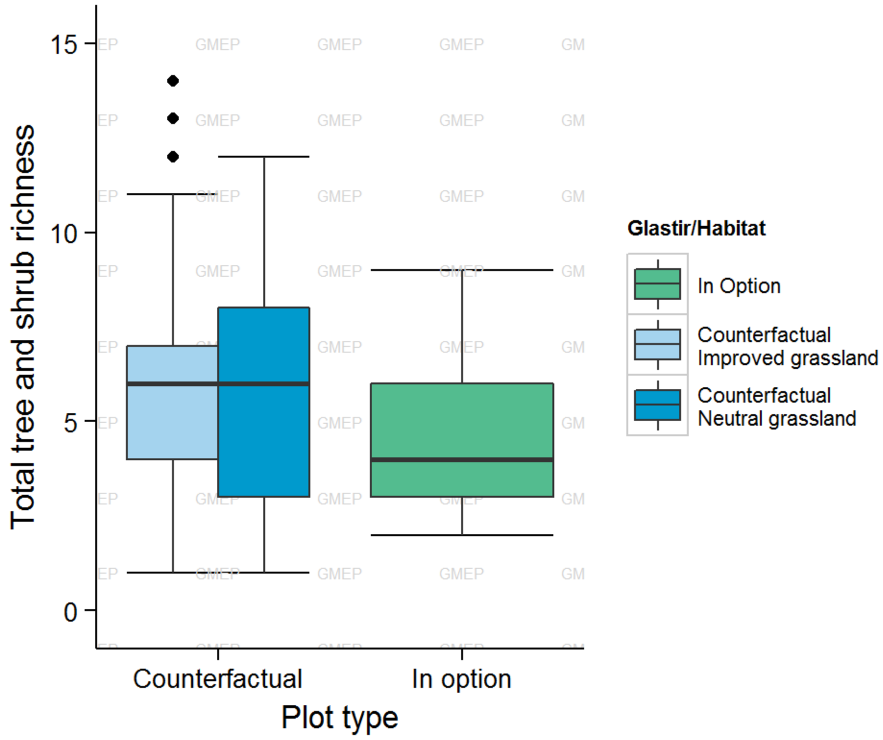


Figure 2: Total tree and shrub richness in 30m long hedgerow plots contrasting those in hedgerow management options with out of scheme hedgerows. Note that in-option plots were either adjacent to Improved (7 plots) or Neutral grassland (2 plots) but were too few in number to analyse by broad habitat. Hence counterfactual hedgerow plots next to either habitat type are shown separately for comparison.



Data:

CSV supplied.

Methodology:

Gmep field survey datasets:

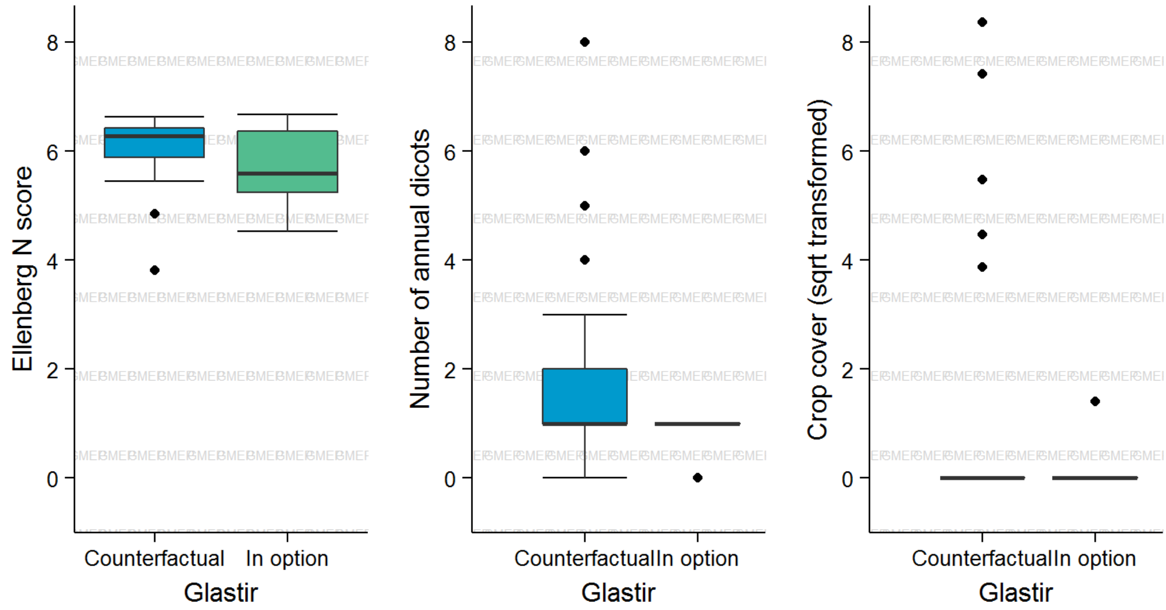
Uptake of Dormouse options was sufficient to support a comparison of plots in hedgerows and woodlands both in-option and out of scheme. Dataset size for hedgerows was very small. More coverage of options will be available following the year 3 and 4 surveys, which will also involve better targeting of options.

Indicators:

Indicator variables were selected as those best able to convey the impact of the options on ecological conditions important for the target species. Dormice benefit from a taller understorey that should develop and persist following exclusion of stock. Hence, cover-weighted canopy height was calculated based on the known average foliage heights of the species recorded. Cover of major foodplants – Bramble and Honeysuckle - were also extracted. Honeysuckle was too rare to analyse. As Gmep encounters increasing levels of uptake, analysis of more indicator variables will be possible, for example data relating to hedgerow structure, dimensions and condition.

Rare arable plants; habitat condition indicators

Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question: *What is the impact of the Glastir options on ecological conditions associated with Rare Arable Plants (RAP)?*
Background to question: Glastir targets management on named rare species. These are listed in Section 42 of the Natural Environment & Rural Communities Act 2006. The targeting mechanism involves funding bundles of options within areas known to encompass target species populations. Most options are however not species-specific and can be funded in any eligible area of habitat because of the wider benefits they bring. While no benefit is likely to arise for the species in areas where it is absent or unlikely to establish in the future it is useful to determine whether the option results in the desired impact on ecological condition (vegetation and habitat structure, plant species composition, soils and waters) that would directly favour the target species if the option land coincided with species occurrence. This question can be answered using all areas of in-option land without the rare species being present. In most cases Gmep does not measure rare species' performance but focusses on assessing the impact of the option on ecological conditions. In parallel current distribution data is used to say how many recent records for the species coincide with Gmep squares with relevant option uptake.
Evidence: <u>Glastir uptake:</u> Of 9 RAP options, 5 occur in Gmep squares but only 3 (30,33 and 32b) had enough plot data (n=5) to evaluate ecological differences between in-option and out of scheme land. This is a very small sample size. The number should increase with the addition of yr 3 and 4 squares and a shift to better targeting of option land. <u>Coincidence with target species:</u> Of 16 Gmep 2013/'14 squares where RAP options were present, none had recent recorded occurrences of rare Arable Plants (Plantlife data) and none were recorded in any of the squares during the 2013 and '14 Gmep field surveys. <u>Indicators:</u> Annual dicot richness was significantly higher in the counterfactual plots. This is certainly because the small number of plots in RAP options were still improved grassland at the time of survey. As the ground experiences low intensity cultivation associated with the requirements of the options, then all three indicators should change. In comparison with cultivated cropland out of scheme the expectation would be for a reduction in fertility score over time, an increase in crop cover and an increase in annual dicot richness in response to the three options but note that fertilisers are allowed under options 30 and 32b. Figure 1: Comparison of plots in RAP options in Gmep squares (2013/'14) with out of scheme arable plots. Three variables are shown indicating fertility levels, richness of non-crop forbs and cover of crop.



Data:
CSV supplied.

Methodology:
Gmep field survey datasets:
Low uptake of RAP options in Gmep squares reflected low uptake in Wales as a whole. This resulted in only 5 vegetation plots being in-option in the Gmep field surveys of 2013/'14. These plots were contrasted with the same types of plots selected on out of scheme arable land as the counterfactual.

Caveats:
While Gmep field survey explicitly targets the interior and edges of arable fields, rare arable plants have a localised distribution in Wales and are rare and ephemeral in occurrence where they do occur. Hence it is unlikely that Gmep field survey will ever accumulate enough records of these species to be able to directly evaluate their abundance in terms of the effects of Glatrir options.

Curlew; habitat condition indicators

Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question: What is the impact of the Glastir options on ecological conditions associated with Curlew?
Background to question: Glastir targets management on named rare species. These are listed in Section 42 of the Natural Environment & Rural Communities Act 2006. The targeting mechanism involves funding bundles of options within areas known to support target species' populations. Most options are however not species-specific and can be funded in any eligible area of habitat because of the wider benefits they bring. While no benefit is likely to arise for the species in areas where it is absent or unlikely to establish in the future, it is useful to determine whether the option results in the desired impact on ecological condition (vegetation and habitat structure, plant species composition, soils and waters) that would directly favour the target species if the option land coincided with species occurrence. This question can be answered using all areas of in-option land without the rare species being present. In most cases Gmep does not measure rare species' performance but focusses on assessing the impact of the option on ecological conditions. In parallel current distribution data is used to say how many recent records for the species coincide with Gmep squares with relevant option uptake.
Evidence: Glastir uptake: Of 17 Curlew options 5 have been taken up in at least one Gmep square. The most common options focused on grazing of open country (41a,b) and upland grassland (18) . Enough plots coincided with these options to allow assembly of in-option and out of scheme data. Of the 17 Curlew options all but one were taken up somewhere in Wales up to the end of 2014. Coincidence with target species: Curlew were recorded in 2 of the 29 Gmep 2013 and '14 squares with sufficient option area to be analysed. Overall, Curlew were recorded in 22 of the 150 Gmep squares. Indicators: In both Bog and Acid grassland, vegetation was most often between 15 and 40cm in height (Fig 1). None of the indicators differed significantly between in-option and out of scheme land (Fig 2). Figure 1: Measured vegetation heights in Gmep area plots in option (41a,b,18) or out of scheme in 2013/14 field survey. 1; None, 2; 0-7cm, 3; 7-15cm, 4; 15-40cm, 5; 40cm-1m, 6; >1m.

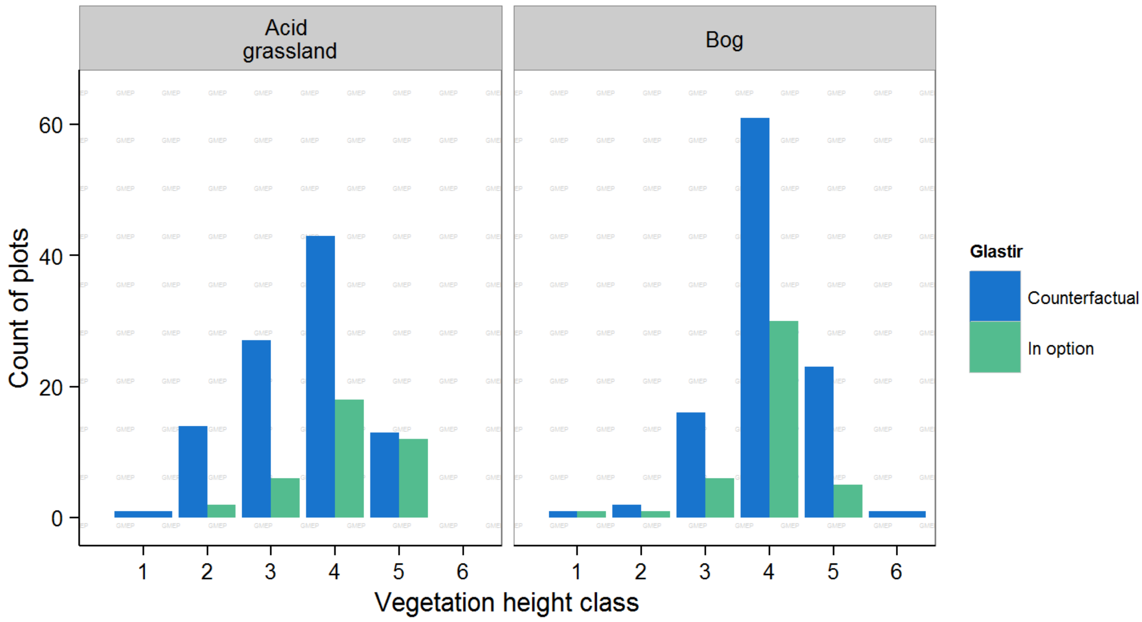
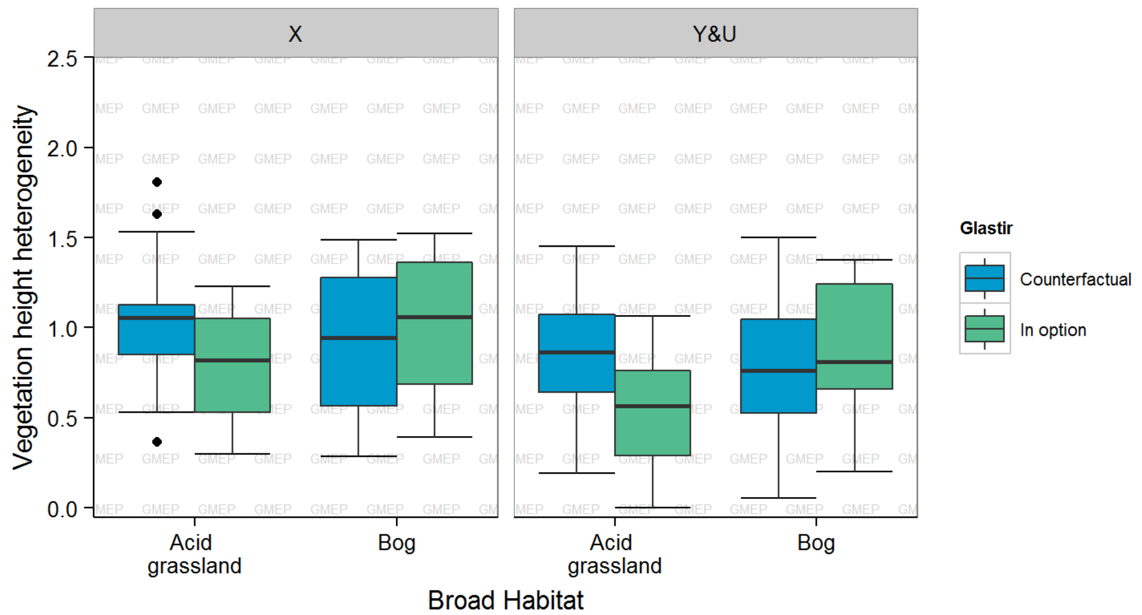
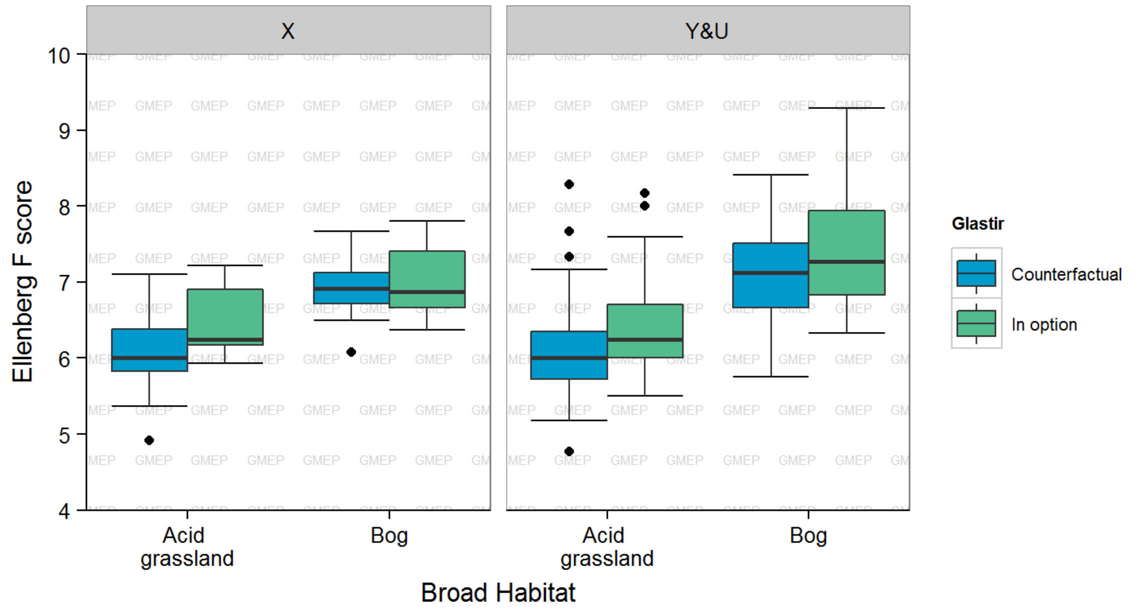


Figure 2: Indicators derived from the plant species composition of random X plots versus plots targeted on priority habitats (Y) or 'open country' broad habitats (U). Vegetation heterogeneity a), wetness index b) and rush cover c).

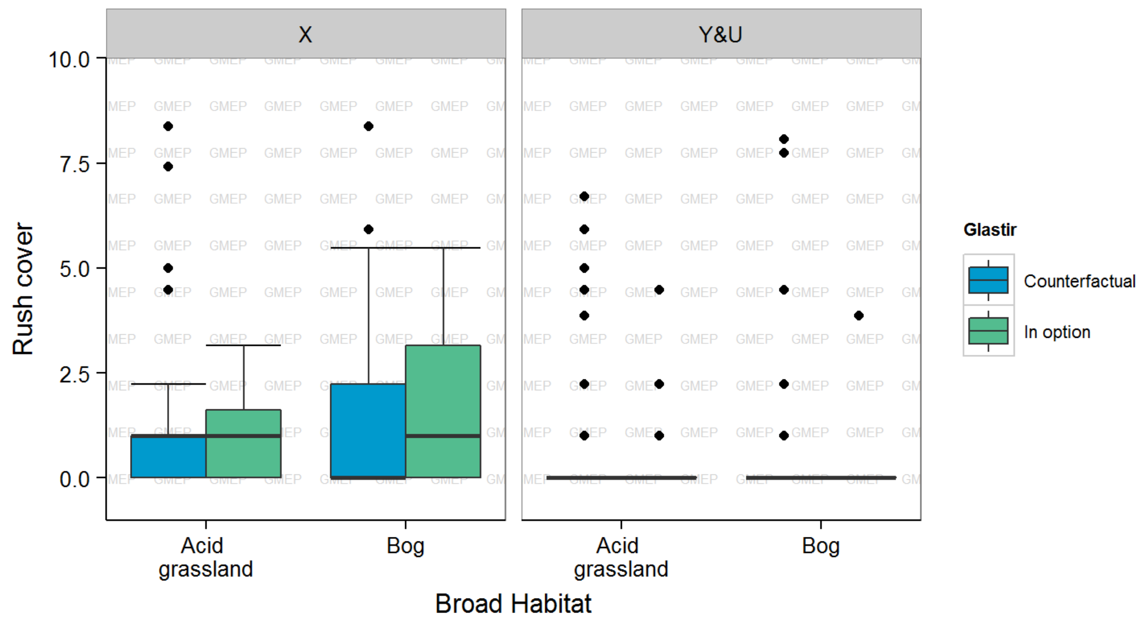
a)



c)



b)



Data:
CSV supplied.

Methodology:
Gmep field survey datasets:
Since Curlew nest in open land away from field boundaries, area plots only were selected for analysis. Enough data were available for comparison of in-option versus out of scheme plots in Acid grassland and Bog broad habitats. The dataset was split into two groups; 200m^2 X plots that randomly sample all land, and 4m^2 plots targeted onto priority habitats (Y) or 'open country' habitats.

Indicators:
Indicators measured changes in rush cover (*Juncus* spp.), observed vegetation height and presence of moisture-loving plants; the higher the wetness index the greater the cover of plants

indicating wet conditions. Since Curlews tend to select breeding habitat where vegetation varies in height forming a mosaic structure, a measure of vegetation heterogeneity was also calculated. Plant species with the same average foliage height class were grouped and their total cover summed. A diversity index was then calculated on the variation in cover-weighted height classes in each plot. Higher values indicate cover of a wider range of plant heights. The distributions of vegetation heights recorded in plots during the field survey were also extracted. Over time the expectation would be for appropriate grazing under Curlew options to maintain or reduce vegetation height, maintain or create vegetation mosaic structure, maintain or reduce rush cover where dominant and maintain or increase vegetation wetness relative to out of scheme land.

Lapwing; habitat condition indicators

Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question: *What is the impact of the Glastir options on ecological conditions associated with Lapwing?*
Background to question: Glastir targets management on named rare species. These are listed in Section 42 of the Natural Environment & Rural Communities Act 2006. The targeting mechanism involves funding bundles of options within areas known to support target species' populations. Most options are however not species-specific and can be funded in any eligible area of habitat because of the wider benefits they bring. While no benefit is likely to arise for the species in areas where it is absent or unlikely to establish in the future it is useful to determine whether the option results in the desired impact on ecological condition (vegetation and habitat structure, plant species composition, soils and waters) that would directly favour the target species if the option land coincided with species occurrence. This question can be answered using all areas of in-option land without the rare species being present. In most cases Gmep does not measure rare species' presence but focusses on assessing the impact of the option on ecological conditions. In parallel current distribution data is used to say how many recent records for the species coincide with Gmep squares with relevant option uptake.
Evidence: <u>Glastir uptake:</u> Of 14 Lapwing options 4 have been taken up in at least one Gmep square. The most common options focused on grazing of open country (41a,b). Enough plots coincided with these options to allow assembly of in-option and out of scheme data. <u>Coincidence with target species:</u> Lapwing were recorded in 2 of the 27 Gmep 2013 and '14 squares with enough option land for analysis. <u>Indicators:</u> In both Bog and Acid grassland, vegetation was most often between 15 and 40cm in height based on measurements in 200m^2 plots (Fig 1). None of the indicators differed significantly between in-option and out of scheme land (Fig 2). Figure 1: Measured vegetation heights in Gmep 200m^2 plots in option (41a,b) or out of scheme in 2013/14 field survey. 1; None, 2; 0-7cm, 3; 7-15cm, 4; 15-40cm, 5; 40cm-1m, 6; >1m.

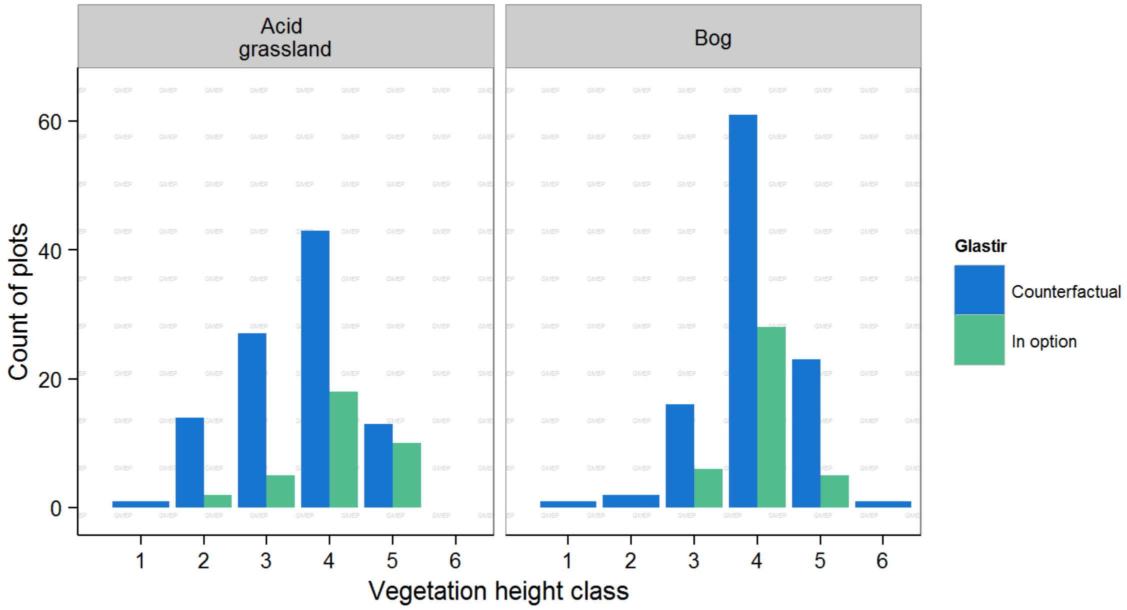
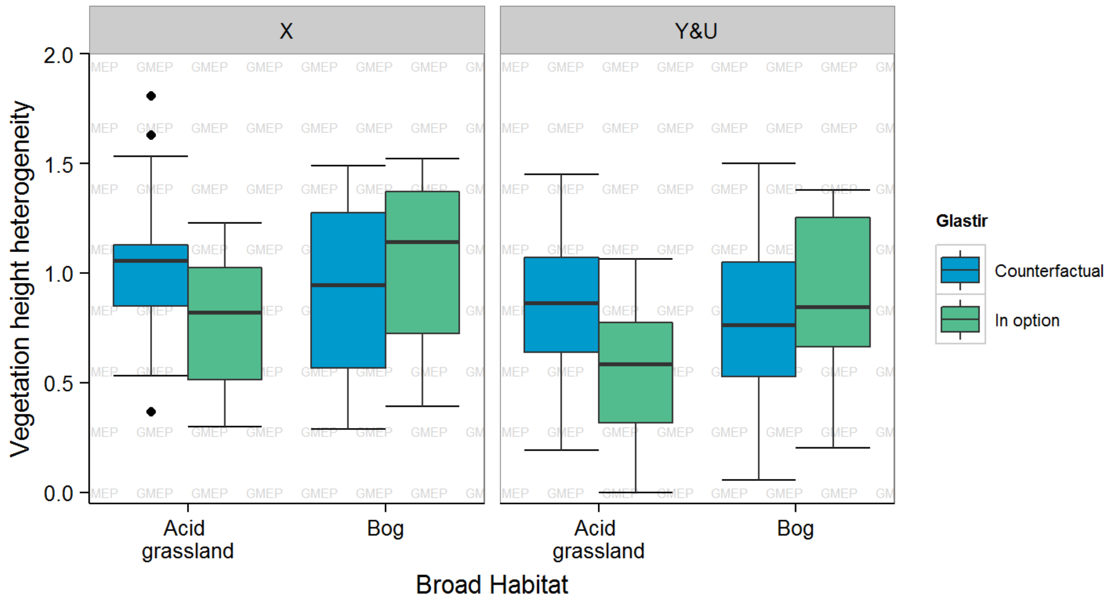
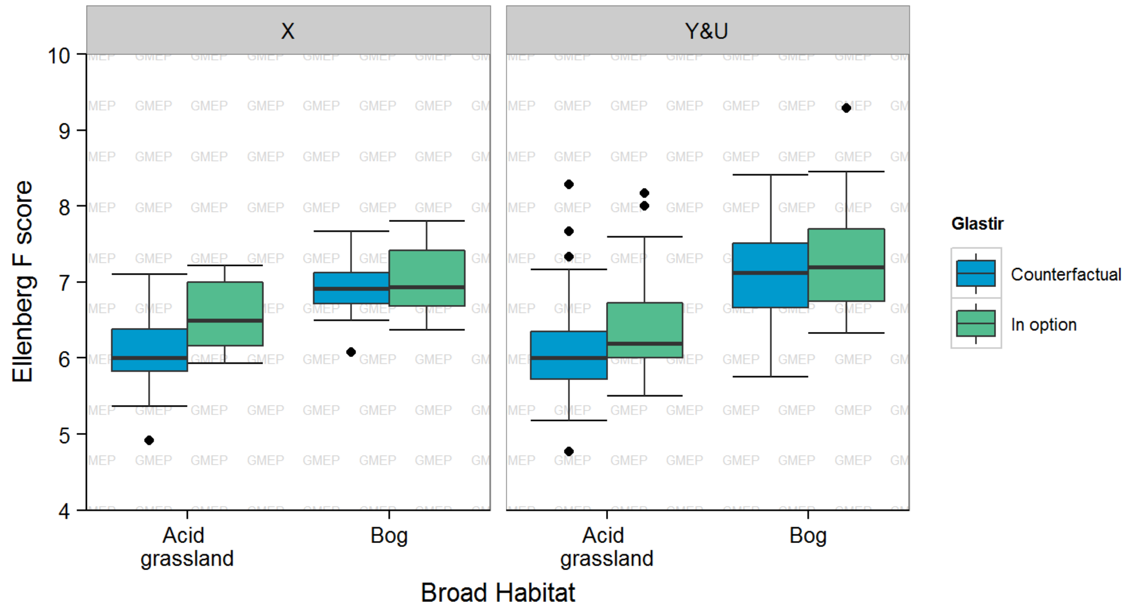


Figure 2: Indicators derived from the plant species composition of random X plots versus plots targeted on priority habitats (Y) or 'open country' broad habitats (U). Vegetation heterogeneity a), wetness index b) and rush cover c).

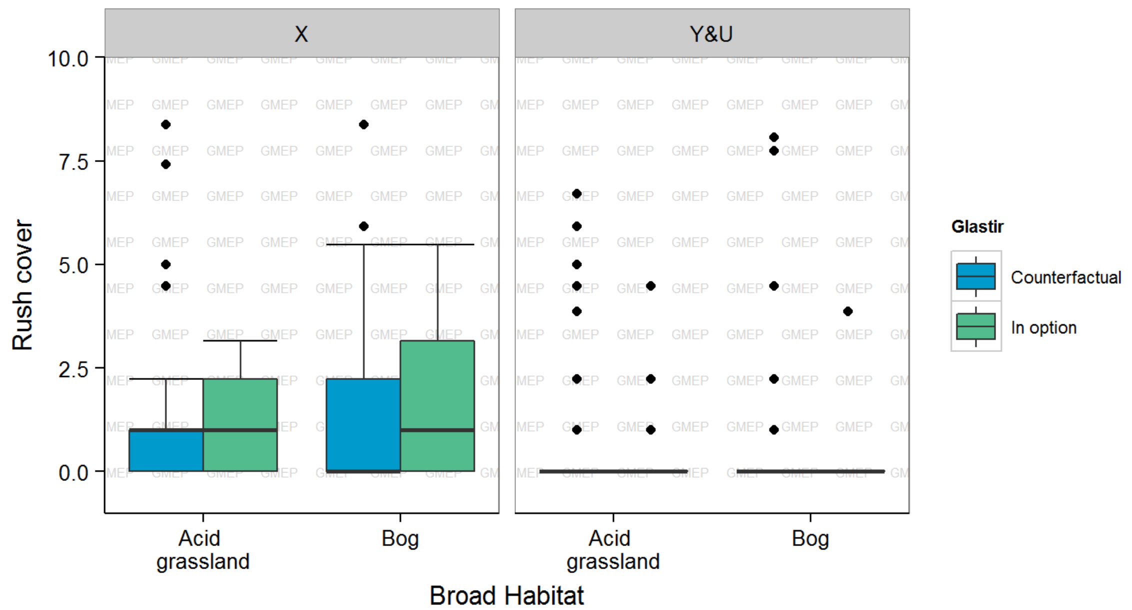
a)



b)



c)



Data:
CSV supplied.

Methodology:
Gmep field survey datasets:
Since Lapwing nest in open land away from field boundaries, area plots only were selected for analysis. Enough data was available for comparison of in-option versus out of scheme plots in Acid grassland and Bog broad habitats so as to achieve like with like comparison. The dataset was split into two groups, 200m^2 X plots that randomly sample all land, and 4m^2 plots targeted onto priority habitats (Y) or 'open country' habitats (U).

Indicators:
Indicators measured changes in rush cover (*Juncus* spp.), observed vegetation height and presence of moisture-loving plants; the higher the wetness index the greater the cover of plants

indicating wet conditions. Since Lapwing select nesting habitat where vegetation varies in height forming a mosaic structure, a measure of vegetation heterogeneity was also calculated. Plant species with the same average foliage height class were grouped and their total cover summed. A diversity index was then calculated on the variation in cover-weighted height classes in each plot. Higher values indicate cover from a wider range of plant heights. The distributions of vegetation heights recorded in plots during the field survey were also extracted. Over time the expectation would be for appropriate grazing under Lapwing options to maintain or reduce vegetation height, maintain or create vegetation mosaic structure, maintain or reduce rush cover where dominant and maintain or increase vegetation wetness relative to out of scheme land.

Lesser Horsehoe Bat; habitat condition indicators

Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question: *What is the impact of the Glastir options on ecological conditions associated with Lesser Horseshoe Bat (LHB)?*
Background to question: Glastir targets management on named rare species. These are listed in Section 42 of the Natural Environment & Rural Communities Act 2006. The targeting mechanism involves funding bundles of options within areas known to encompass target species populations. Most options are however not species-specific and can be funded in any eligible area of habitat because of the wider benefits they bring. While no benefit is likely to arise for the species in areas where it is absent or unlikely to establish in the future it is useful to determine whether the option results in the desired impact on ecological condition (vegetation and habitat structure, plant species composition, soils and waters) that would directly favour the target species if the option land coincided with species occurrence. This question can be answered using all areas of in-option land without the rare species being present. In most cases Gmep does not measure rare species' performance but focusses on assessing the impact of the option on ecological conditions. In parallel current distribution data is used to say how many recent records for the species coincide with Gmep squares with relevant option uptake.
Evidence: <u>Glastir uptake:</u> Of 91 LHB Glastir options, 32 occur in Gmep squares but only 10 (133, 134, 15c, 19, 19b, 22, 15b, 15, 15d, 41a) had enough plot data (n=157) to evaluate ecological differences between in-option and out of scheme land. This number will increase with the addition of yr 3 and 4 squares and a shift to better targeting of option land. <u>Coincidence with target species:</u> Of 81 Gmep 2013/'14 squares where LHB options are present, 5 have post-2000 recorded occurrences of LHB (Bat Conservation Trust data). <u>Indicators:</u> Out of scheme land was broadly similar to in-option land across the four broad habitats. Ellenberg fertility score was significantly higher in the out of scheme counterfactual plots in Fen, marsh & swamp and Acid grassland. Since all options stipulate appropriate grazing and low or zero fertiliser inputs we would expect indicator values to be maintained relative to out of scheme land or to change consistent with reduced fertility, more wetland species and higher plant species richness. Figure 1: Plots in Acid grassland in option versus out of scheme.

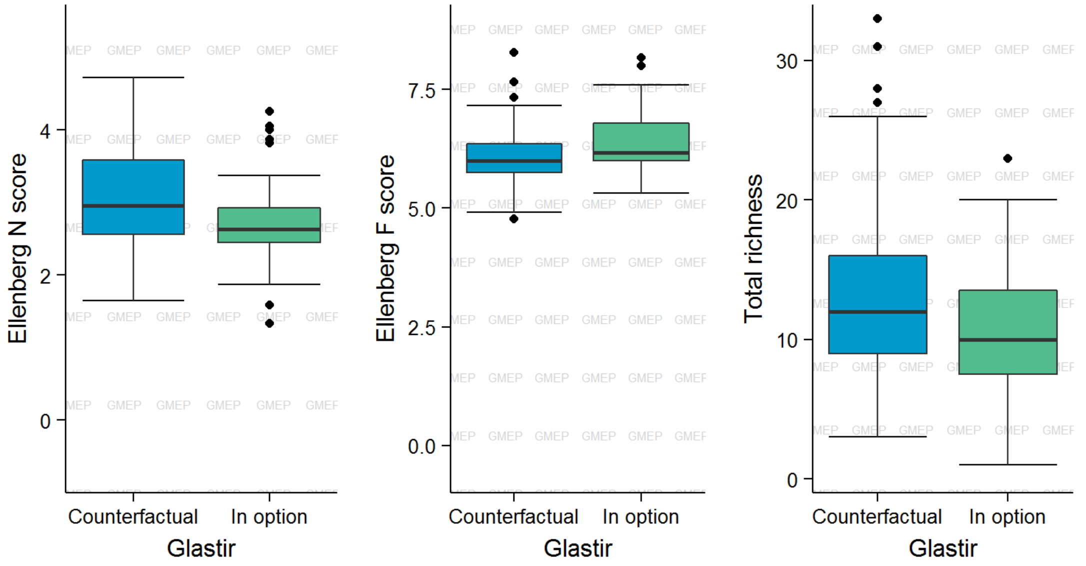


Figure 2: Bog in option versus out of scheme.

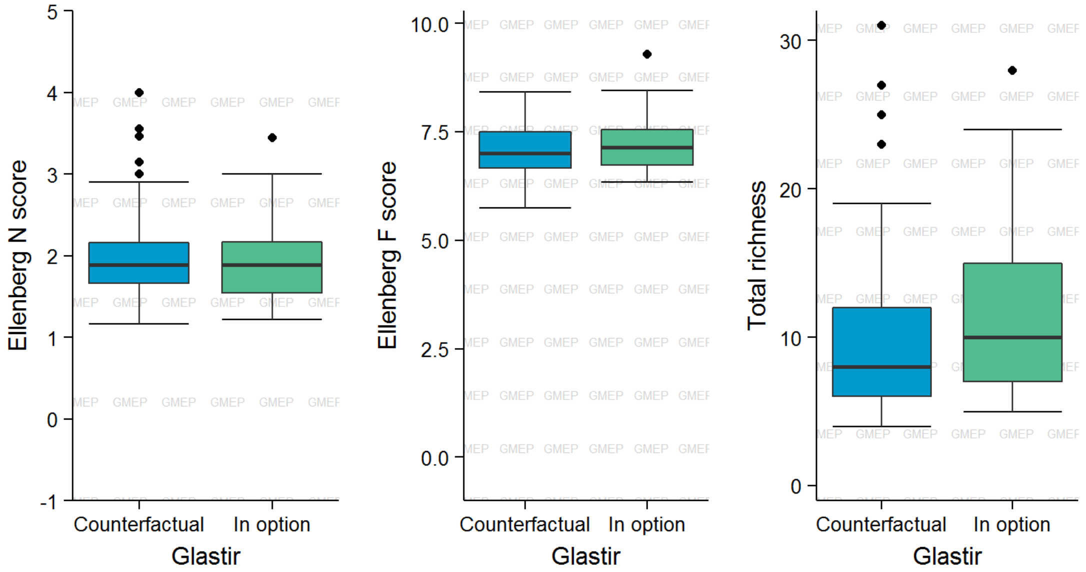


Figure 3: Bracken in option versus out of scheme.

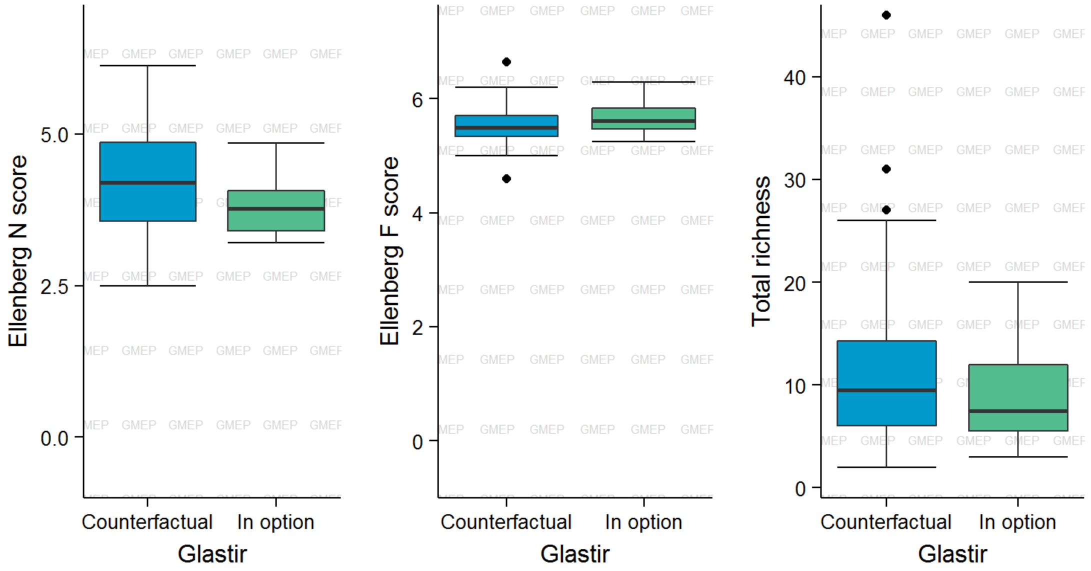


Figure 4: Fen, Marsh & Swamp in option versus out of scheme.

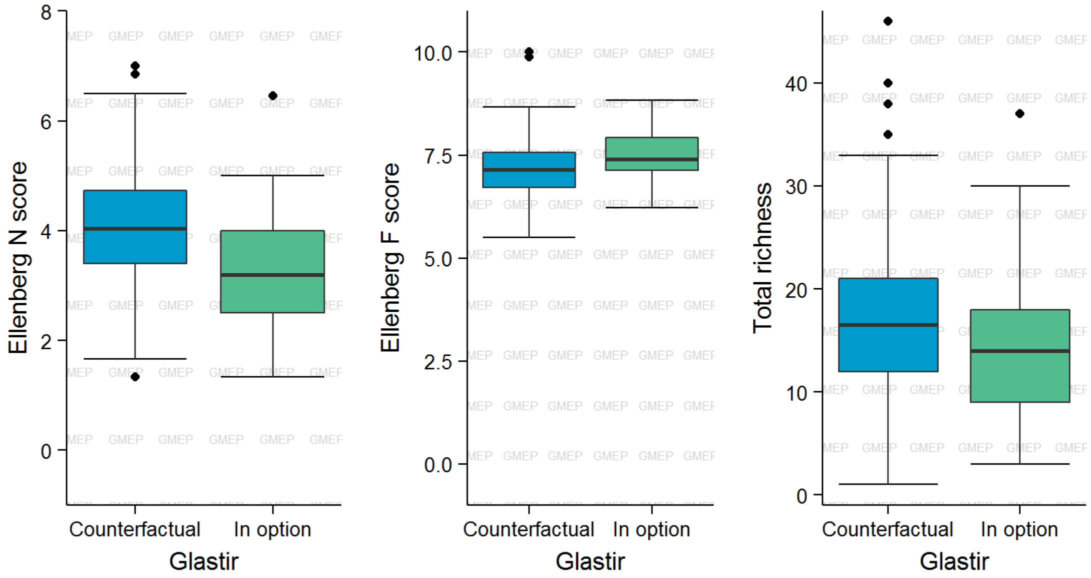
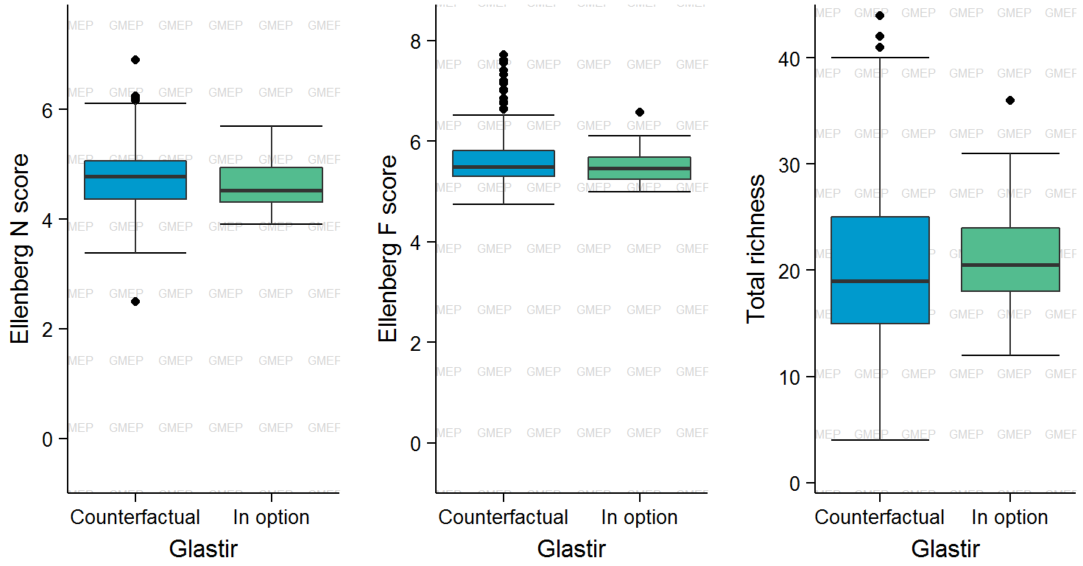


Figure 5: Neutral grassland in option versus out of scheme.



Data:
CSV supplied.

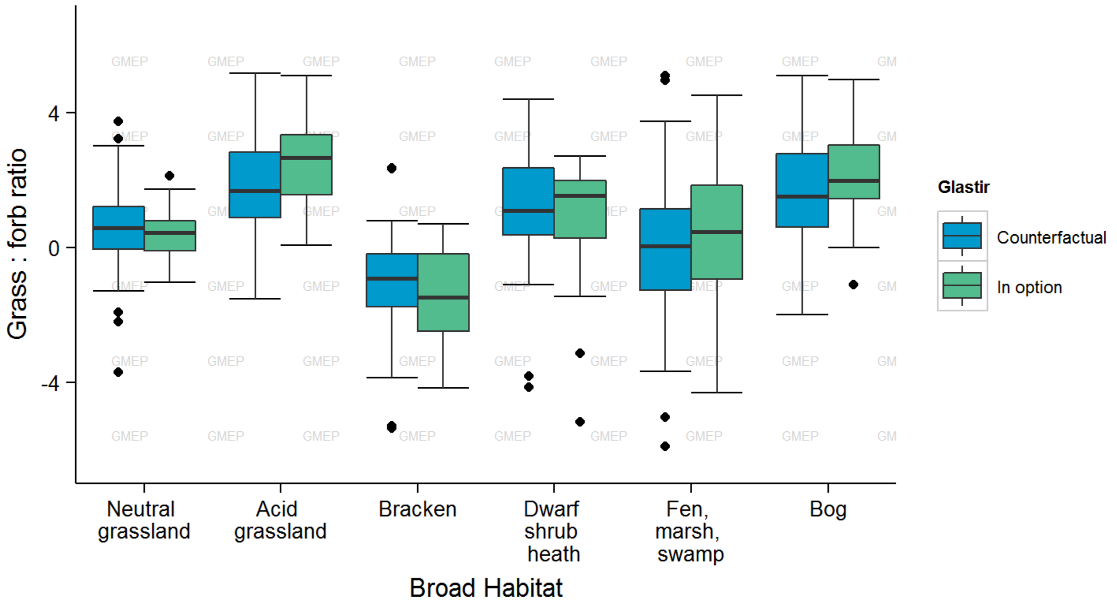
Methodology:
Gmep field survey datasets:
Options with sufficient coincident vegetation plot data for analysis all focussed on management of semi-natural habitats including grazed permanent pasture (15) existing hay-meadow (22), lowland marshy grassland (19) and open country (41a). Plots were assembled from in-option and out of scheme land and grouped by broad habitat for like-with-like comparison.

Indicators:
Mean Ellenberg N score and Ellenberg F score were used as plant species-based indicators of fertility and soil wetness respectively.

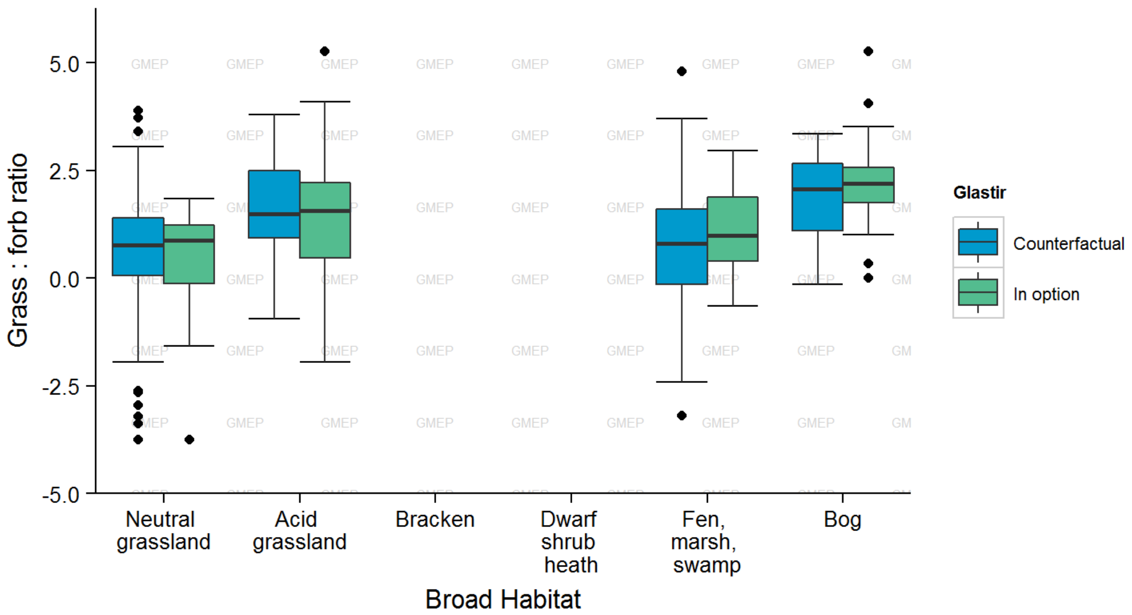
Caveats:
Gmep does not record bats. In addition bat populations coincide with few of the Gmep squares. Analysis therefore focusses on detecting the expected impact of options linked to LHB on ecological conditions within each habitat rather than impacts on the target species.

Marsh Fritillary; habitat condition indicators

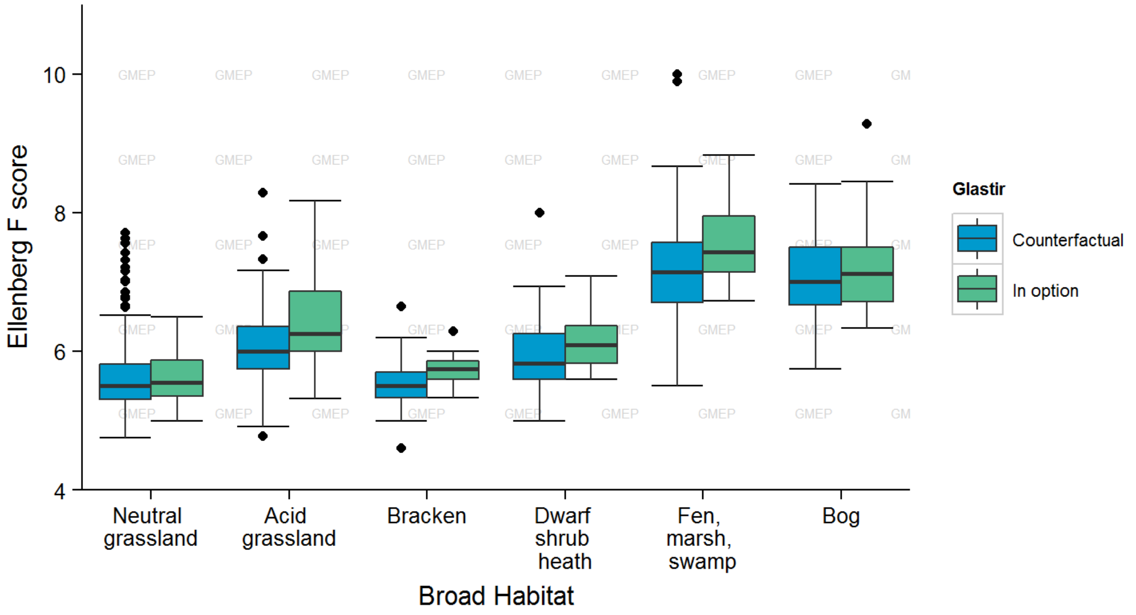
Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question: *What is the impact of the Glastir options on ecological conditions associated with the Marsh Fritillary butterfly (MF)?*
Background to question: Glastir targets management on named rare species. These are listed in Section 42 of the Natural Environment & Rural Communities Act 2006. The targeting mechanism involves funding bundles of options within areas known to encompass target species populations. Most options are however not species-specific and can be funded in any eligible area of habitat because of the wider benefits they bring. While no benefit is likely to arise for the species in areas where it is absent or unlikely to establish in the future it is useful to determine whether the option results in the desired impact on ecological condition (vegetation and habitat structure, plant species composition, soils and waters) that would directly favour the target species if the option land coincided with species occurrence. This question can be answered using all areas of in-option land without the rare species being present. In most cases Gmep does not measure rare species' performance but focusses on assessing the impact of the option on ecological conditions. In parallel current distribution data is used to say how many recent records for the species coincide with Gmep squares with relevant option uptake.
Evidence: <u>Glastir uptake:</u> Of 27 MF options 12 occur in Gmep squares. The most common options focus on zero or low input grazing of open country, permanent pasture and lowland marshy grassland. Because these option are relatively extensive, a satisfactorily large number of vegetation plots were selected for comparing in-option (n=238) and out of scheme (n=874) land. <u>Coincidence with target species:</u> In the 69 Gmep squares with MF options present, 6 had a post-2000 recorded occurrence of Marsh Fritillary (UKBMS data). MF was not recorded in any Gmep square during the 2013/'14 pollinator surveys. <u>Indicators:</u> Occurrences of the MF larval foodplant Devil's-bit Scabious (*Succisa pratensis*) were too few to analyse. Plants of wet conditions were significantly more common in Fen, Marsh & Swamp in-option land in area plots away from linear features (Fig1a). Linear plots within the in-option Bog broad habitat were significantly grassier than out of scheme (Fig 1b). Over time the wetness indicator and butterfly foodplant cover would be expected to increase or remain stable and the grass:forb ratio to remain stable or decrease in comparison with out of scheme habitat. Figure 1: Comparison of area plots (a,c) and linear plots (b,d) in MF options in Gmep squares (2013/'14) with out of scheme plots. Two variables are shown indicating the ratio of cover of grasses to forbs (a,b) and the presence of moisture-loving plants (c,d). a)


Grass : forb ratio
4
0
-4
Neutral grassland
Acid grassland
Bracken
Dwarf shrub heath
Fen, marsh, swamp
Bog
Broad Habitat
Glastir
Counterfactual
In option

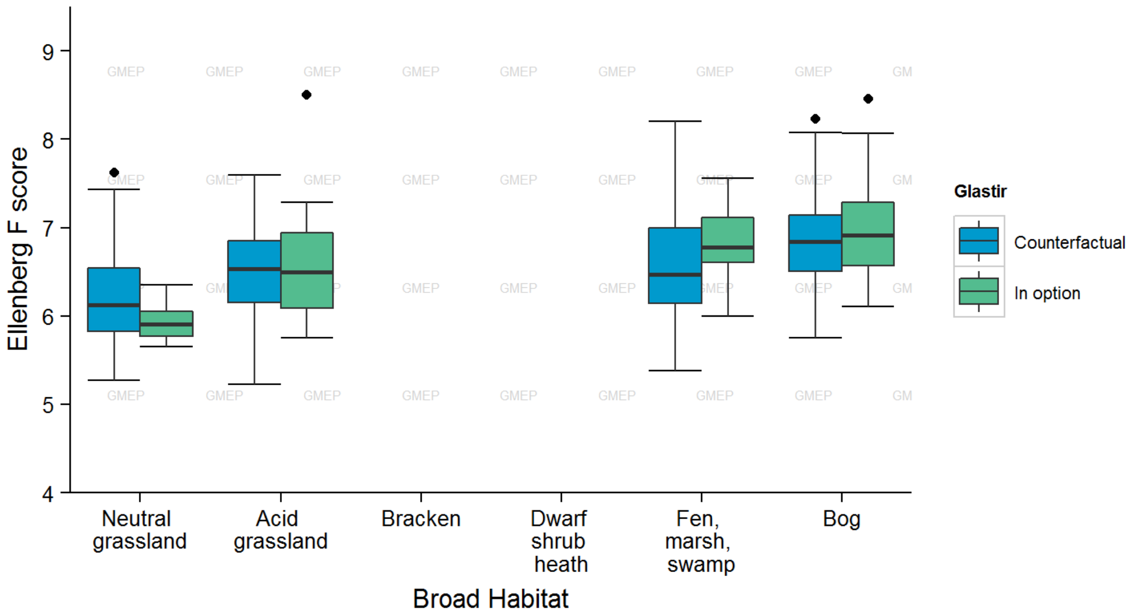
b)


Grass : forb ratio
5.0
2.5
0.0
-2.5
-5.0
Neutral grassland
Acid grassland
Bracken
Dwarf shrub heath
Fen, marsh, swamp
Bog
Broad Habitat
Glastir
Counterfactual
In option

c)



d)



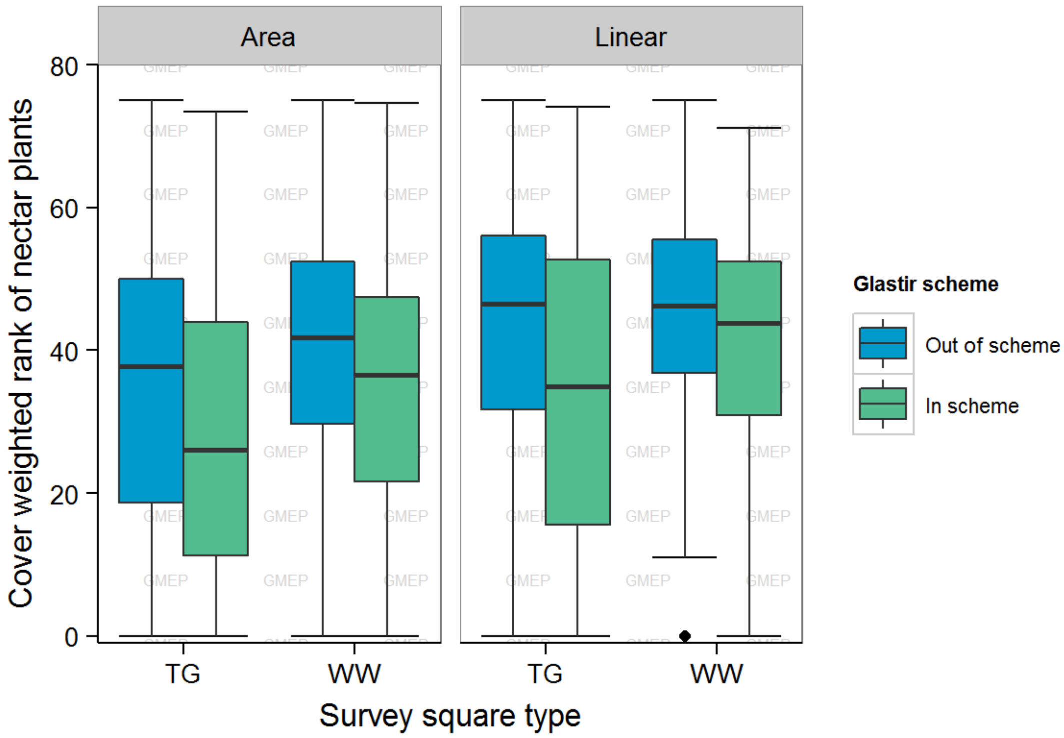
Data:
CSV supplied.

Methodology:
Gmep field survey datasets:
Relatively large numbers of in-option plots allowed analysis by plot type (areal versus linear) and broad habitat thus allowing a like with like comparison between in-option and out of scheme habitat.

Indicators:

Indicator variables were selected as those best able to convey the impact of the options on ecological conditions important for the target species; in this case foodplant abundance, wet conditions and no increase in grass dominance relative to forbs.

Nectar plant abundance

Target: *Biodiversity*	
Question type: *Benefit of Glastir measures*	
Question: *What is the impact of Glastir on the cover of preferred nectar plants?*	
Background to question: Pollinating invertebrates and their wild nectar plants have declined across NW Europe since around the 1950s. In many places this has led to a pollinator deficit reducing potential supply of the ecosystem service of crop pollination and reducing the biodiversity of nectar plants and their pollinating insects. Over time GMEP survey data can be used to quantify changes in abundance of preferred nectar plants and pollinating insects. However, to correctly interpret observed ecological changes over time it is important to characterise baseline differences between land in and out of Glastir. Therefore differences are presented for cover of preferred nectar plants either in or out of agreement land and by Wider-Wales (WW) and Targeted (TG) squares.	
Evidence: Cover-weighted values of nectar plant importance ranged widely reflecting the inclusion of the full range of habitat types surveyed. The indicator did not differ significantly between in-Glastir and out-of-Glastir land. Over time the broadly extensifying effect of Glastir might be expected to increase values of the indicator. However, the nectar plant list includes species that vary greatly in terms of their preference for disturbance levels and productivity. Therefore in future, separation by habitat could prove a more effective means of discriminating Glastir effects on nectar plants that differ in susceptibility to land management change. Figure 1: Cover-weighted importance index of preferred nectar plants in GMEP plots combining 2013/'14 field survey data. All broad habitats are included. Plots were divided into those sampling linear features and fields, woods and unenclosed land away from linear features. 	

Data:

CSV supplied.

Methodology:

GMEP survey datasets:

To provide the broadest possible picture of the baseline, GMEP vegetation plots were selected from all habitat types surveyed in 2013 and ’14. Plots were divided into an area group that sample fields, woodlands and unenclosed land and a linear group sampling hedgerows, watercourse banks and field boundaries.

Indicators:

The indicator was calculated by first ranking the preferred foodplants listed in Dyer, R et al (2014). *The Identification of Preferential Foodplants for Pollinator Species of Concern in the UK. Report to Natural England*. The attribute used to rank each species was the total number of observed pollinator-plant interactions. The highest ranking species were Bramble (*Rubus fruticosus* agg.), Ragwort (*Senecio jacobaea*) and Hogweed (*Heracleum sphondylium*). The mean rank of the species in each GMEP plot was then derived and the importance of the species additionally weighted by its observed cover so that high ranking plants with greater cover result in higher values of the indicator.

Indicators of high and low habitat quality; Common Standards Monitoring plant species

Target: *Biodiversity*

Question type: *Benefit of Glastir measures*

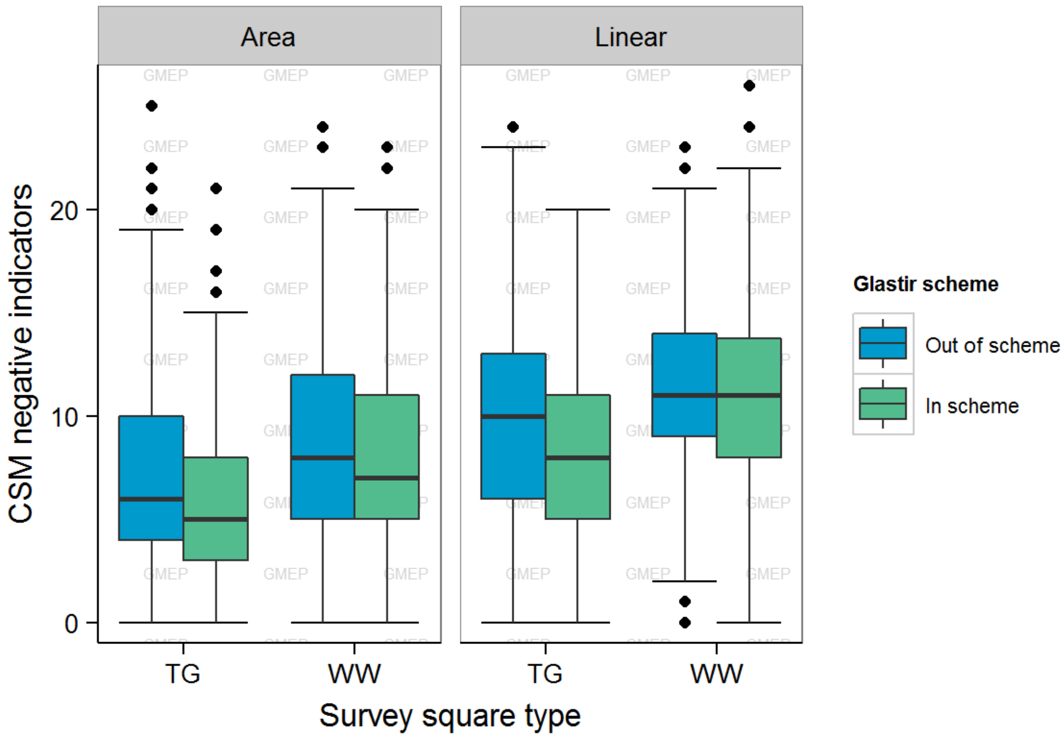
Question: *What is the impact of Glastir on the diversity of species indicating high or low quality habitat?*

Background to question:
The ecological condition and extent of most semi-natural habitats has declined in Britain since the 1950s. Since the late 1980s, agri-environment schemes have become an important mechanism for restoration and maintenance of agriculturally managed habitats. The Glastir scheme pays land owners for production foregone as a result of implementing a broadly extensifying series of management options. As a result, biodiversity of species associated with 'good' habitat condition, as defined by the statutory conservation agencies, should be maintained or increase in number. Over time GMEP survey data can be used to measure such changes. To correctly interpret observed ecological changes over time it is important to first characterise baseline differences between land in and out of Glastir agreement land. Counts of JNCC Common Standards Monitoring (CSM) species per vegetation plot are used as an overall indicator of conservation value. Differences are also presented by Wider-Wales (WW) and Targeted (TG) squares.

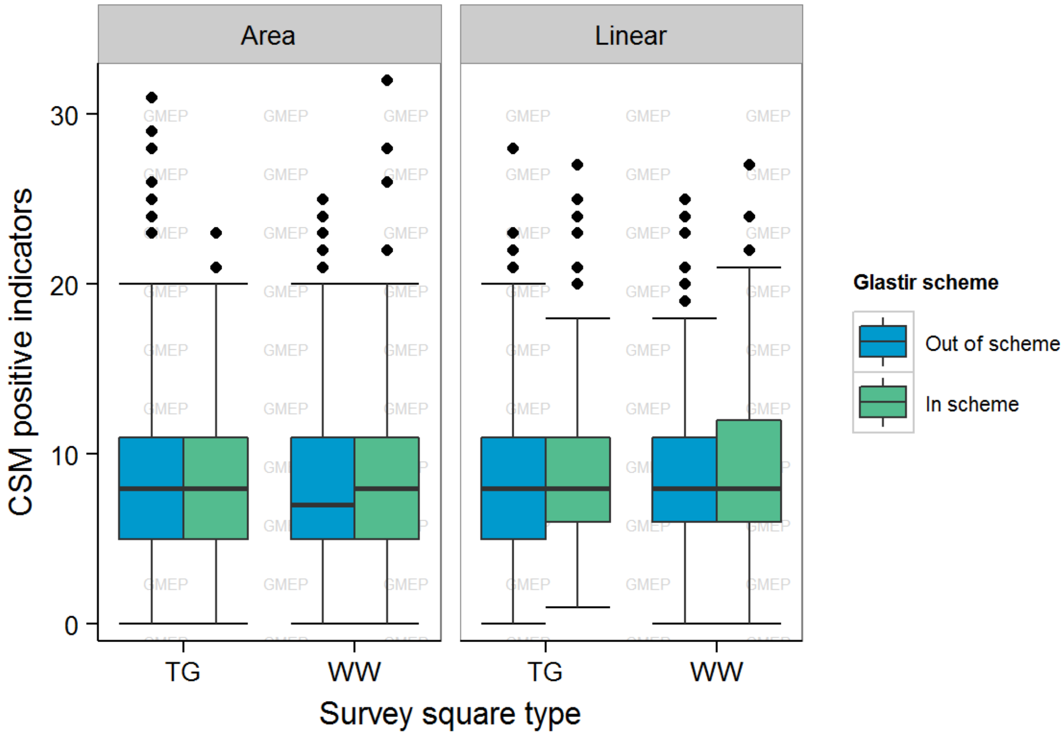
Evidence:
CSM species richness did not differ between land in and out of Glastir in 2013 and '14.

Figure 1: Count of a) negative and b) positive CSM indicator species per vegetation plot. Data for 2013 and '14 were combined and all broad habitats are included. Plots were divided into linear plots sampling linear features and area plots sampling fields, woods and unenclosed land away from linear features.

a)



b)



Data:

CSV supplied.

Methodology:

GMEP field survey datasets:

To provide the broadest possible picture of the baseline, plots were selected from all habitat types and divided into an area group sampling fields, woodlands and unenclosed land and a linear group sampling hedgerows, watercourse banks and field boundaries.

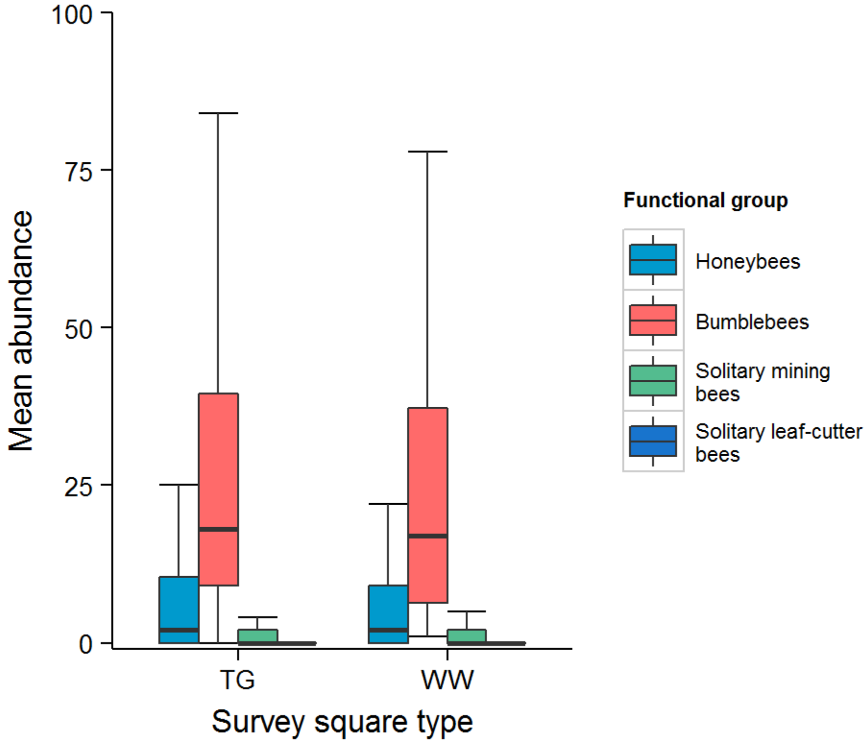
Indicator:

The total number of CSM indicators in each vegetation plot was counted. Negative indicators (poor condition) were counted separately from positive indicators (good condition). Species were extracted from a list compiled from JNCC CSM Guidance documents by the Botanical Society of the British Isles in March 2014.

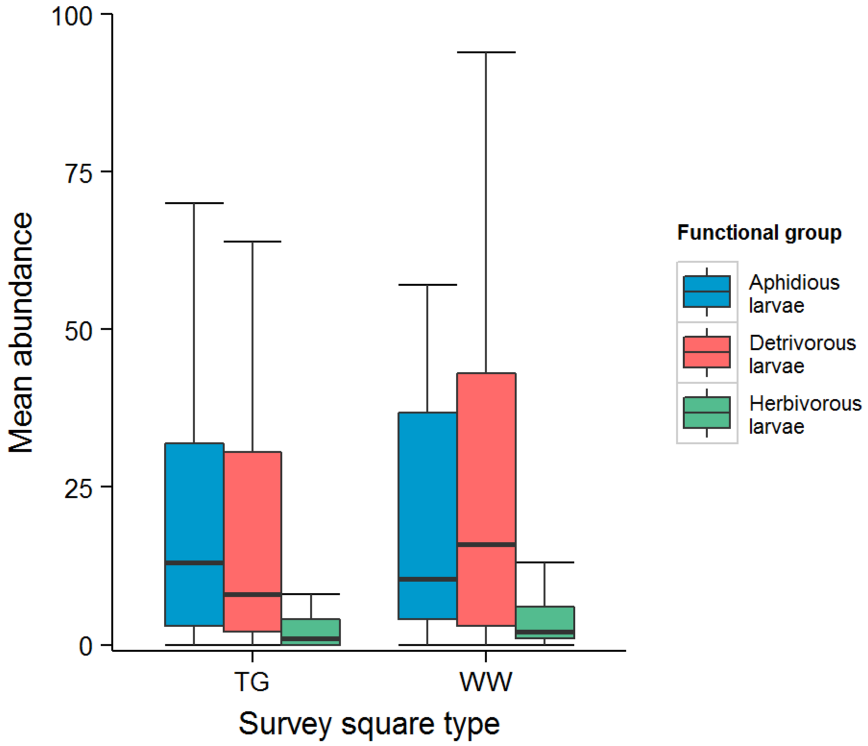
CSM indicator counts in each plot were **not** restricted to those applying just to the sampled habitat type. For example if a plot sampled neutral grassland then all species were counted not just those applying to neutral grassland habitats. This approach has several merits; it is consistent with deriving an overall indicator of the biodiversity of conservation indicator species in the countryside, it allows the indicator to be expressed for habitats without published lists such as linear features and woodlands, it is independent of decisions about the allocation of the plot to habitat type.

Bee and Hoverfly abundance

Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question*: How does the baseline distribution of bees and hoverfly species differ between Targeted (TG) and Wider Wales (WW) 1km squares in GMEP?*
Background to question: GMEP is designed to detect the impacts of the Glastir scheme and so a sample of 1km squares is weighted toward land prioritised under the scheme. This results in a Targeted sample of squares that are analysed alongside a Wider Wales set of squares representing an unbiased sample of the 'average' countryside for comparison. To correctly interpret observed ecological changes over time it is important to characterise baseline differences between the two sub-samples. The differences between Targeted and Wider Wales squares are shown for mean abundance of functional groups of hoverflies and bees. These groups are recorded in the GMEP pollinator surveys and differ in the ecosystem services they help to provide. Hoverfly groups are differentiated based on the ecosystem services provided by their larvae: Group1 = pest control, group2 = organic matter decomposition, group 3 = herbivores. Bees are split into 4 functional groups determined by the way in which the females collect pollen, which affects their efficiency as pollinators. Honeybees and bumblebees collect it on specialised hairs on their hind legs, but wet the pollen so its sticks and is less likely to fall off. Bumblebees are much more hairy so pick up more pollen on body hair. Solitary bees all collect dry pollen which is much more likely to fall off and many are hairy. Mining bees collect the pollen on their legs, whilst leaf-cutters collect it on their abdomen.
Evidence: Bee groups were similarly abundant in Targeted (TG) and Wider Wales (WW) squares with bumblebees being by far the most abundant bee group recorded across all squares. Hoverfly groups were generally more abundant in Wider Wales 1km squares, particularly those with detritivorous larvae (group 2). Those with predatory larvae feeding on aphids were more similar in abundance in Targeted and Wider Wales squares. Figure 1. Baseline differences in total counts of pollinating invertebrates per Gmep 1km square in 2013 and 2014; a) Bees, b) Hoverflies. a)



b)



Methodology:
The GMEP pollinator surveys are based on the Wider Countryside Butterfly Survey and suited to recording common and widespread (wider countryside) species. Pollinator surveys focused on three main pollinator groups: butterflies, bees and hoverflies. Butterflies were recorded to species

level, whilst bees and hoverflies were recorded as groups based on broad differences morphological and ecological differences. Surveys were split into two independent parts: a standardised 2km transect route through each square followed by a timed search in a 150m^2 flower-rich area within the square. Two visits per square per year are carried out; one in July and a second in August. In total, 60 1km squares were visited in 2013 and 90 in 2014. Surveys were only conducted between 10:00 and 16:00, or between 09:30 and 16:30 if >75% of the survey area was un-shaded and weather conditions were suitable for insect activity. The criteria for suitable weather were: temperature between 11 and 17^{o}C with at least 60% sunshine or above 17^{o}C regardless of sunshine, and with a wind speed below 5 on the Beaufort scale (small trees in leaf sway).

Butterfly diversity and abundance

Target: *Biodiversity*

Question type:*Benefit of Glastir measures*

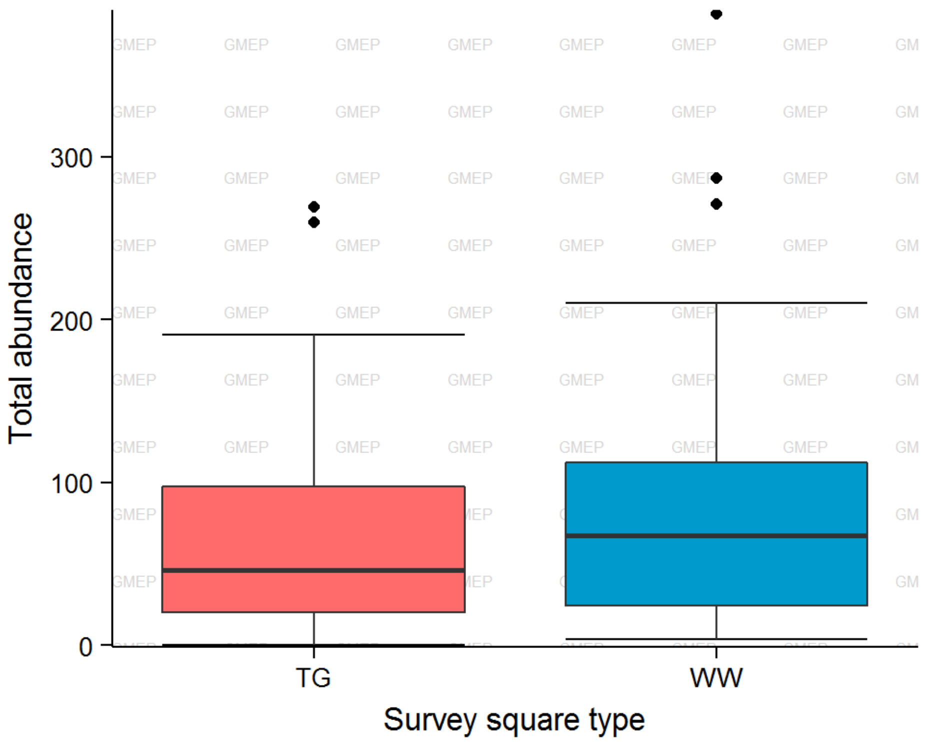
Question*: How does the baseline distribution of butterfly species differ between Targeted and Wider Wales 1km squares in GMEP?*

Background to question:
Welsh Government target Glastir funding according to a system of environmental priorities. Currently the focus is on diffuse pollution and climate change and so land that is targeted under these priorities will receive greater funding and therefore greater levels of management intervention. Since the job of GMEP is to detect Glastir impacts, the sample of 1km squares is weighted toward prioritised land resulting in a Targeted (TG) sample of squares that are analysed alongside a Wider Wales (WW) set of squares that represent an unbiased sample of the 'average' countryside for comparison. To correctly interpret changes over time it is important to characterise baseline differences between the two sub-samples. For example the Targeted squares will receive greater levels of funding and so more change is expected to be attributable to Glastir but differences in starting values of biodiversity, soil conditions and land cover will also influence the responsiveness of the two samples over and above differences in intervention. More sophisticated ways of accounting for these differences will be applied as the time series grows and change over time becomes quantifiable. At present it is useful simply to describe the differences between the two sub-samples.

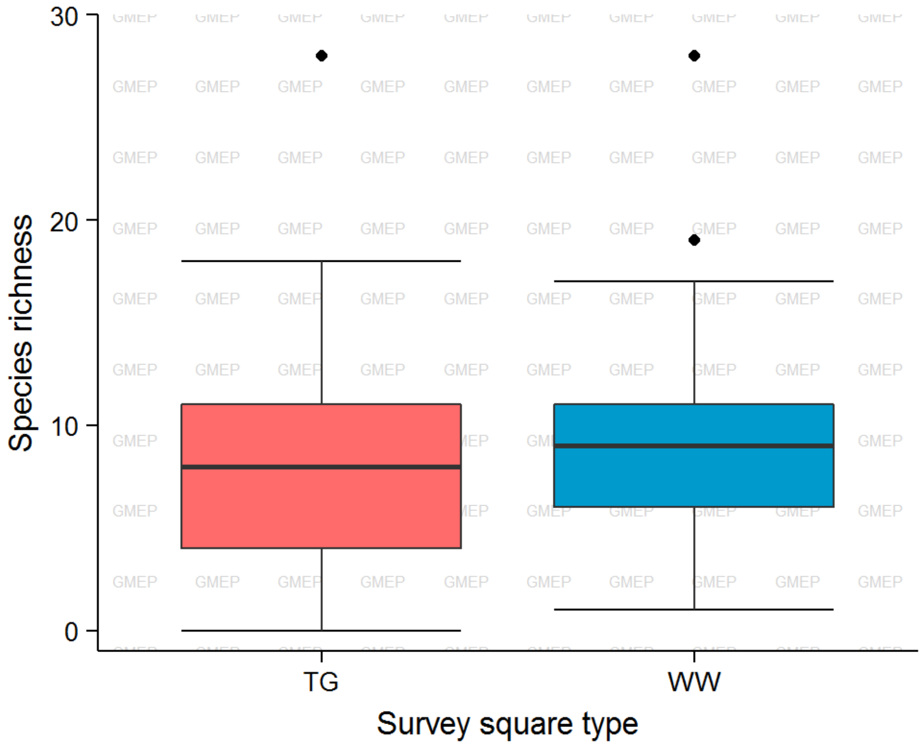
Evidence:
Total counts of butterflies per square (Fig 1a) and butterfly species richness (Fig 1b) were lower in the Targeted sample. This is likely to reflect the more unenclosed and upland nature of the habitats in the sample, which was weighted toward bog and heath.

Figure 1. Total counts of butterflies (a) and butterfly species richness (b) in GMEP Targeted (TG) or Wider Wales (WW) squares from pollinator surveys carried out in 2013 and 2014.

a)



b)



Methodology:
The GMEP pollinator surveys are based on the Wider Countryside Butterfly Survey (WCBS) and are suited to recording common and widespread (wider countryside) species. Pollinator surveys focused on three main pollinator groups: butterflies, bees and hoverflies. Butterflies were recorded to species level, whilst bees and hoverflies were recorded as groups based on broad morphological and ecological differences. Surveys were split into two independent parts: a standardised 2km transect route through each 1km^2 followed by a timed search in a 150m^2 flower-rich area within the square. Two visits per square per year are carried out; one in July and a second in August. In total, 60 1km squares were visited in 2013 and 90 in 2014. Weather criterion: surveys were only conducted between 10:00 and 16:00, or between 09:30 and 16:30 if >75% of the survey area was un-shaded and weather conditions were suitable for insect activity. The criteria for suitable weather were: temperature between 11 and 17°C with at least 60% sunshine or above 17°C regardless of sunshine, and with a wind speed below 5 on the Beaufort scale (small trees in leaf sway).

Whole Farm Code and eutrophication indicators on agreement land

Target: *Biodiversity*
Question type: *Benefit of Glastir measures*
Question: *Has the Whole Farm code prevented eutrophication of semi-natural habitats on agreement land?*
Background to question: Farms in the Glastir scheme are subject to the Whole Farm Code. This includes rules applicable to so-called 'habitat land' that has not been subject to agricultural improvement. The application of fertilisers is prohibited on such land under the code. The objective is to "..help retain our native Welsh vegetation types, plants and animals." A large body of evidence shows that improvement from increased fertiliser application favours a smaller number of agriculturally favoured species, often grasses, at the expense of a larger number of native species more suited to less productive conditions, often forbs. The successful prevention of improvement on existing 'habitat land' under the Whole Farm Code should therefore result in maintenance or increased abundance of typical forbs relative to grasses and no long-term decline in plant species associated with higher conservation value of unimproved habitats. A series of plant and soil indicators are used for this purpose. In order to best interpret expected future changes it is important to show how these indicators vary between lands in and out of Glastir at the start of the scheme.
Evidence: Phosphorus in soil: High available levels of this nutrient are associated with agricultural grasslands. The higher Olsen's P on agreement land in Wider Wales squares may simply reflect the greater targeting of Glastir on grassland-dominated farmland while lower P levels on agreement land in Targeted squares probably reflect the greater abundance of peaty upland habitats targeted for Glastir options (Fig 1). Plant species composition: Indicators of qood quality habitat were equally common in and out of scheme and in Targeted and Wider-Wales (Fig 3). However, in-scheme 'habitat land' is associated with vegetation indicating lower productivity and with fewer negative conservation indicator species (Fig 4) despite being grassier, although not significantly so (Fig 5). Targeted squares are separated again from Wider Wales being more likely to include low productivity peaty habitats, and hence having lower fertility scores (Fig 5), and supporting fewer agriculturally favoured species that indicate lower conservation value of 'habitat land' (Fig 4). Figure 1: Olsens P in soil sampled from 'habitat land' in or out of Glastir agreement in 2013 and '14.

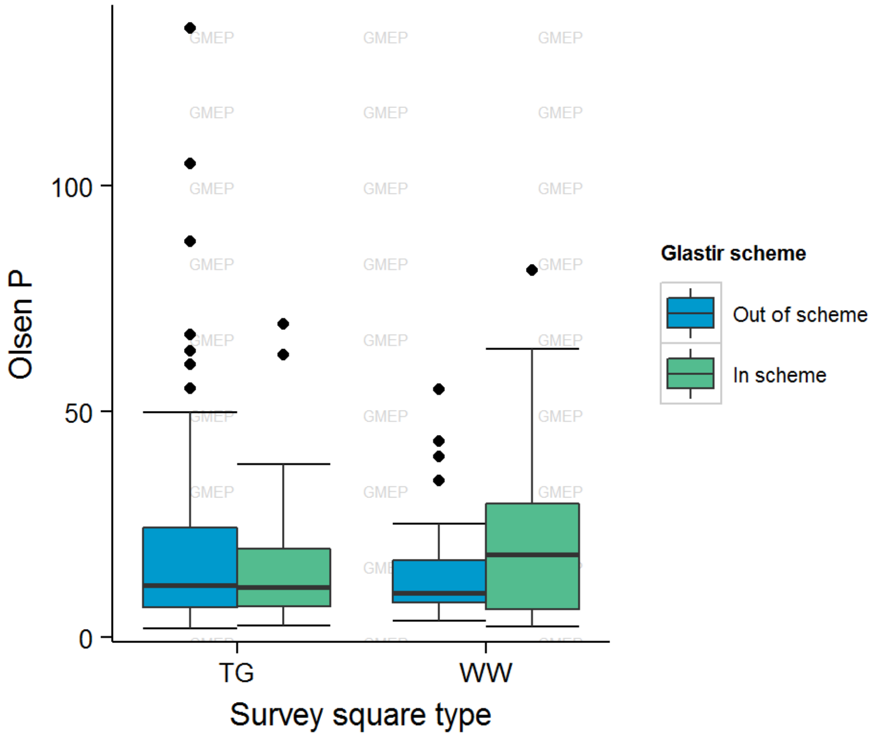


Figure 2: Count of Common Standards Monitoring (-ve) plant species in plots in 'habitat land'.

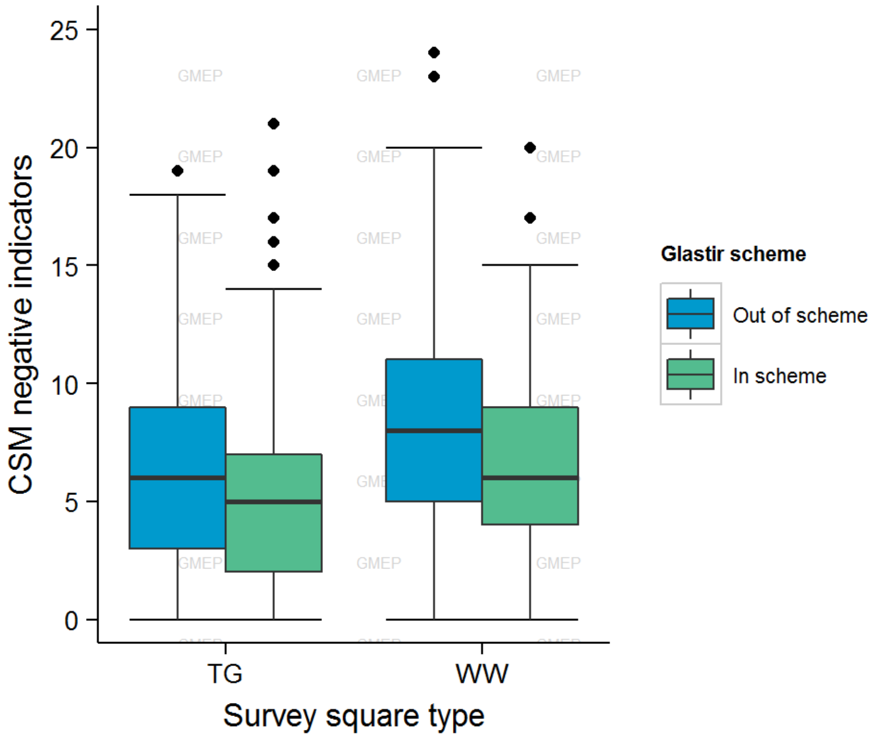


Figure 3: Count of Common Standards Monitoring (+ve) plant species in plots in 'habitat land'.

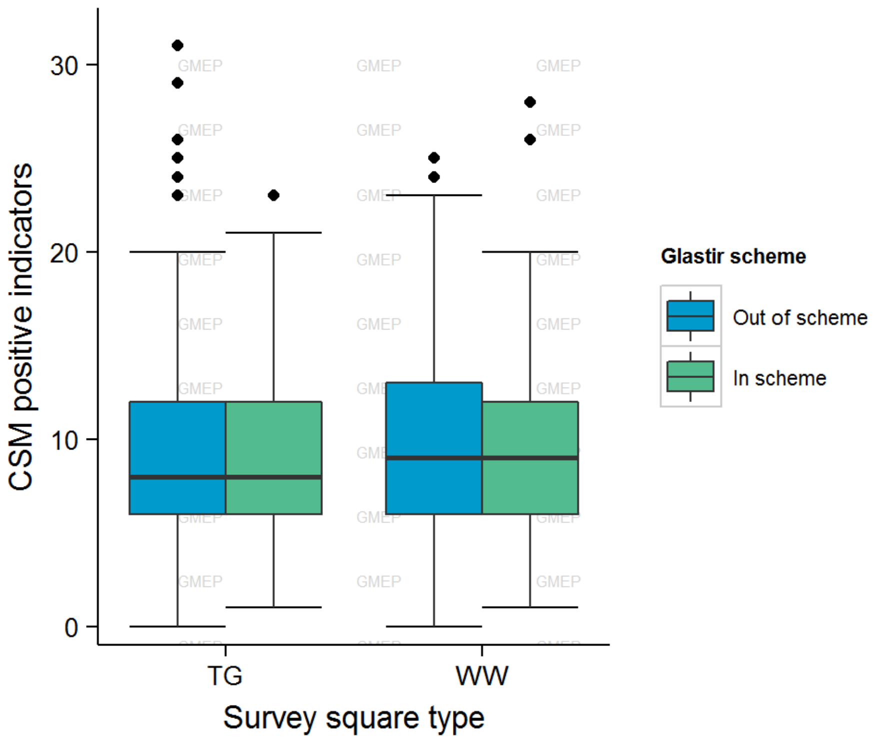


Figure 4: Ratio of grass to forb cover in plots in 'habitat land'.

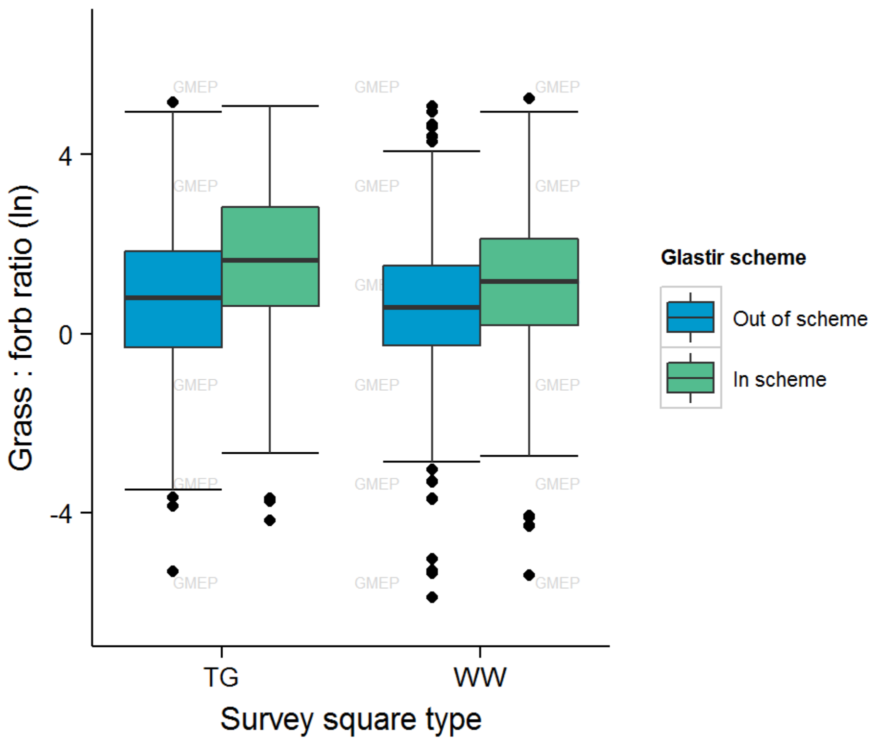
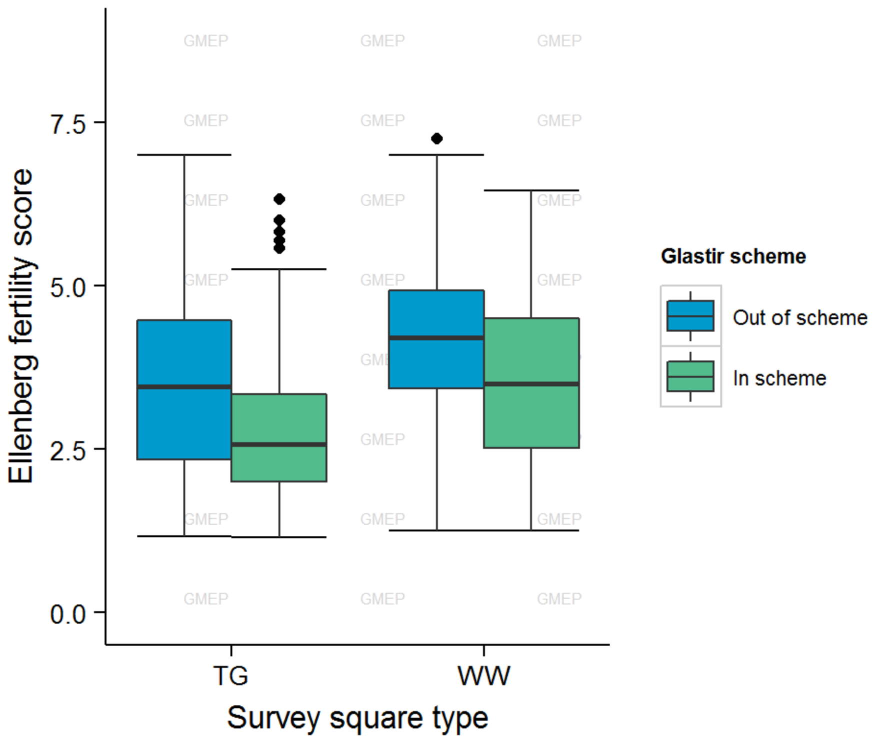


Figure 5: Index of vegetation fertility based on plant species in plots in 'habitat land'.



Data:
Significant differences between in and out-scheme land applied to count of negative CSM indicator species only.

CSV supplied.

Methodology:
<u>Gmep field survey datasets:</u>
'Habitat land' was defined as all plots with <25% combined cover of *Lolium* spp and *Trifolium repens*. Woodland, arable, urban, open water and littoral broad habitats were excluded. Vegetation plots were selected focussing on areal habitat only; linear features were excluded. Plots were defined as 'in-scheme' if they fell within Glastir agreement boundaries provided by WG. All data for 2013 and 2014 were combined.

<u>Derived indicators:</u>
See soils portal pages for soil sampling protocols. Plant species-based indicators were all derived from the species composition and cover recorded in each vegetation sampling plot. Common Standards Monitoring indicators were extracted from a list compiled by the Botanical Society of the British Isles in March 2014 from published agency guidance notes. Mean Ellenberg fertility and grass:forb ratio were calculated using methods from Countryside Survey (www.countrysidesurvey.org.uk).

Whole Farm Code; abundance of Invasive Non-Native Species and Injurious Weeds

Target: *Biodiversity*

Question type: *Benefit of Glastir measures*

Question: *What is the impact of the Glastir Whole Farm Code on abundance of Invasive Non-Native Species (INNS) and Injurious Weeds?*

Background to question:

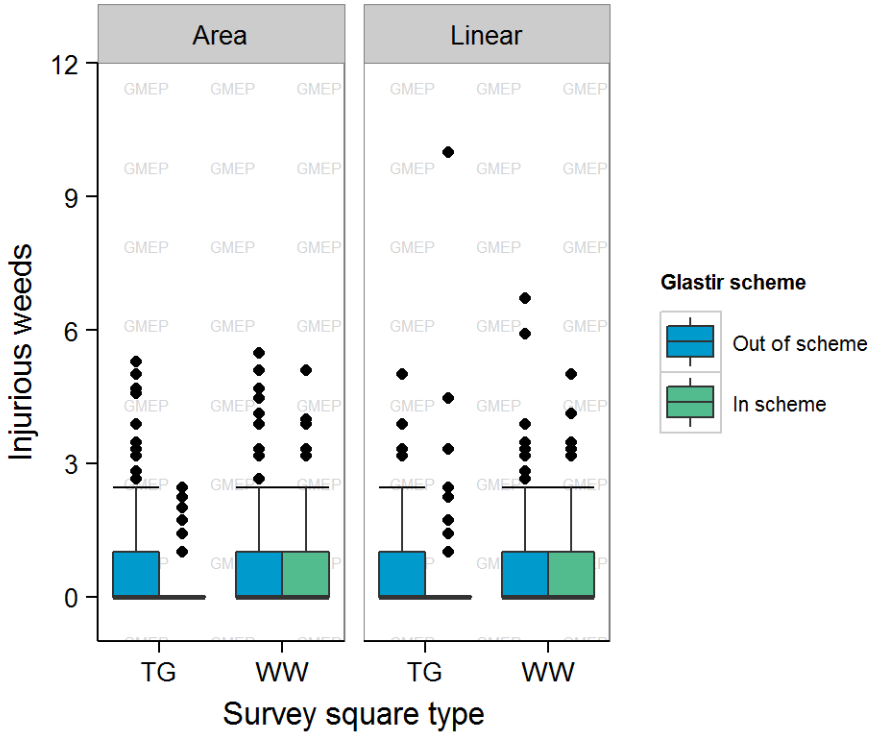
Farms in the Glastir scheme are subject to the Whole Farm Code. The application of herbicides is prohibited except for spot treatment of invasive plants and injurious weeds. These species are important to control because they can reduce agricultural productivity, act as sources for dispersal to surrounding land, damage buildings and ancient monuments, and invade habitats and waterways to the detriment of native wildlife. The Whole Farm Code restricts herbicide use but in doing so should not favour weed establishment and dispersal.

Results show the baseline cover of INNS and Injurious Weed species in vegetation plots in or out of agreement land and covering all areal habitats and linear features in the 2013/’14 surveys.

Evidence:

INNS records were too few in Gmep plots to support plotting and analysis. Injurious Weed cover did not differ significantly between in and out-scheme land (Fig 1).

Figure 1: Summed square-root transformed cover of Injurious Weeds in Gmep plots from all surveyed habitat areas and linear features in Gmep squares.



Data:

CSV supplied.

Methodology:

<u>GMEP field survey datasets:</u>

Linear and areal plots were selected from Gmep 1km square field survey data covering all habitats surveyed.

Indicators:
Recorded cover was summed in each plot for the INNS species Japanese Knotweed, Himalayan Balsam and Giant Hogweed. A separate indicator was similarly derived for the notifiable Injurious Weeds Creeping Thistle (*Cirsium arvense*), Spear Thistle (*Cirsium vulgare*), Broad-leaved Dock (*Rumex obtusifolius*), Curled Dock (*Rumex crispus*) and Ragwort (*Senecio jacobaea*) (see Defra Report WC1042 (2013)).

Appendix 5.11: Biodiversity – data portal entries

Headline question: What are the long term trends in the condition of priority (section 42) habitats?

Blanket Bog

Background

Blanket bogs are a section 42/priority habitat consisting of rain-fed extensive bog communities or landscapes with poor surface drainage typically forming in upland areas with high rainfall. They are waterlogged peat forming habitats, containing peat-forming plants e.g. heather, Sphagnum, cotton grasses, sundews that are adapted to wet environments. Peat depths can be quite variable ranging from 0.5m- 3m. There are extensive areas of Blanket Bog in the Welsh uplands and they are important habitats for characteristic and rare species (e.g. cloudberry) and for carbon sequestration and storage. Threats to Blanket Bogs include drainage, burning, overgrazing and cutting peat for fuel or garden uses, climate change and atmospheric pollutants. The condition of Blanket Bog can be measured in a number of different ways. Here we show changes in the number of characteristic bog species, total plant species richness, plant preference scores for moisture and soil Carbon. There are other measurements taken in GMEP that could also be used.

Methodology

As part of the field survey in 2013 and 2014 permanent vegetation plots were established. These include random plots (200^2m) and 2m x 2m plots in Blanket Bog. Within the plots all higher plants were recorded to species level and a limited number of lower plants. Using the vegetation plot data a number of indicators have been calculated to report on habitat condition. The total number of species within a plot has been calculated. The number of Common Standard Monitoring indicator species was calculated by taking species identified in the guidance for the priority habitat (JNCC) and in discussions with the Botanical Society of the British Isles and identifying characteristic Bog indicators. The number of CSM species within a plot was then calculated. Data from Countryside Survey in 1990, 1998 and 2007 has been used for the long term trend. Soil data from soil cores taken at the 200m^2 plots has also been used to calculate an indicator for soil carbon. A better indicator for carbon content of blanket bog soils might be topsoil bulk density, however, we only have data back to CS2007 for this measure.
There has been a slight decrease in the number of characteristic Bog species (CSM indicators) between 1990 and 1998 (Figure 1, Table 1), the GMEP Wider Wales sample has a higher number of indicators to CS in 2007 with slightly more in the targeted squares.
There has been a decline in overall species richness in Blanket Bogs since 1990 in 2m x 2m and 200m2 plots (Figure 2, Table 2); however the GMEP sample is not significantly different than in 2007.
The only significant difference between years in changes in sphagnum cover is between 2007 and the GMEP sample in 2m x 2m plots.
There was a significant increase in Eriophorum vaginatum cover in 200m2 plots between 1990 and 2007
There was a significant increase in the cover of Dwarf Shrubs between 1998 and 2014 in 2m x 2m plots, changes between other years were not significant.
There were no significant changes in Ellenberg Moisture values.
The trend in concentration of topsoil carbon is for a slight increase since 1978 which can be seen in Figure 3 and Table 3.

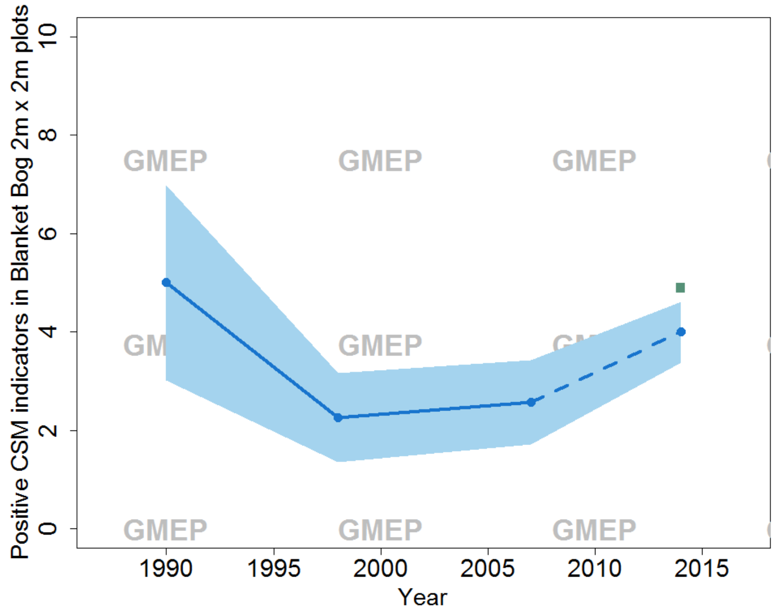


Figure 1: Trends in the mean number of characteristic Blanket Bog species (CSM) in 2m x 2m plots (same pattern in 200m2 plots)

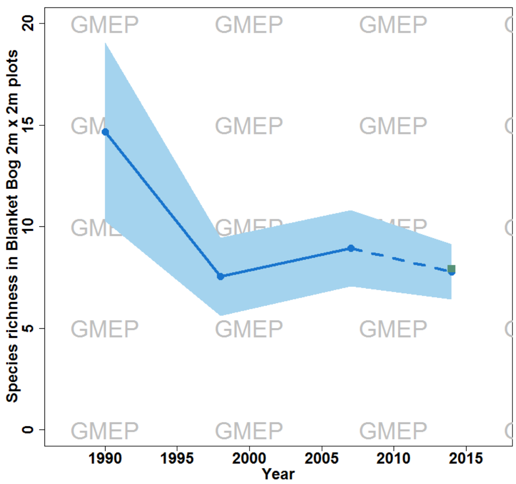


Figure 2a: Trends in the mean Total plant species richness in 2m x 2m plots

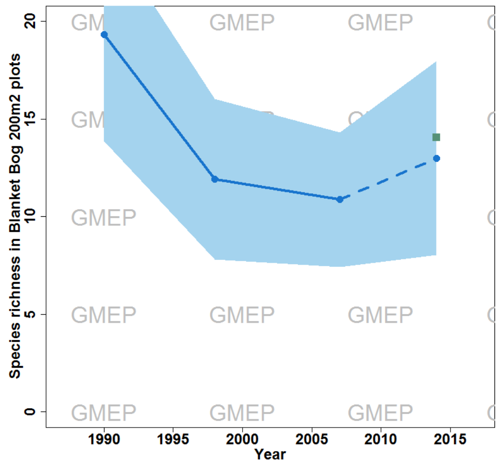


Figure 2b: Trends in the mean Total plant species richness in 200m2plots

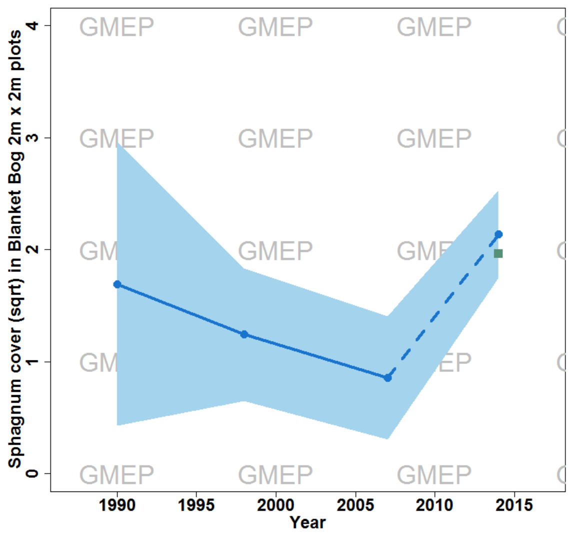


Figure 3a: Trends in the mean cover of Sphagnum in 2m x 2m plots

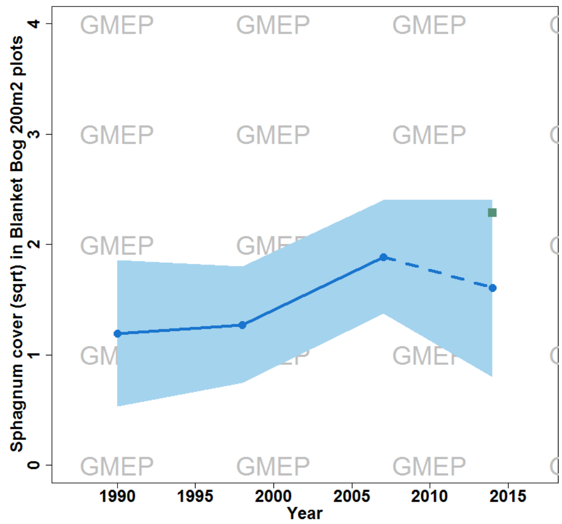


Figure 3b: Trends in the mean cover of Sphagnum in 200m2 plots

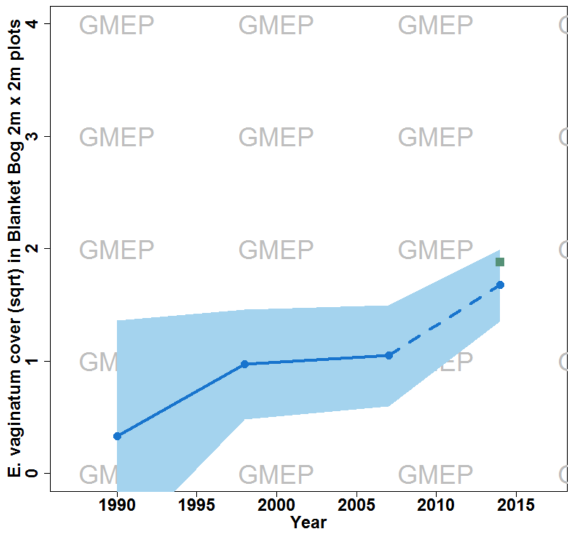


Figure 4a: Trends in the mean cover of *E.vaginatum* in 2m x 2m plots

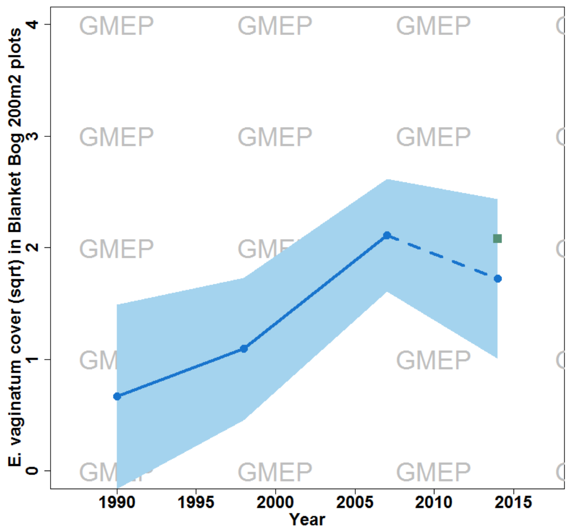


Figure 4b: Trends in the mean cover of *E.vaginatum* in 200m2 plots

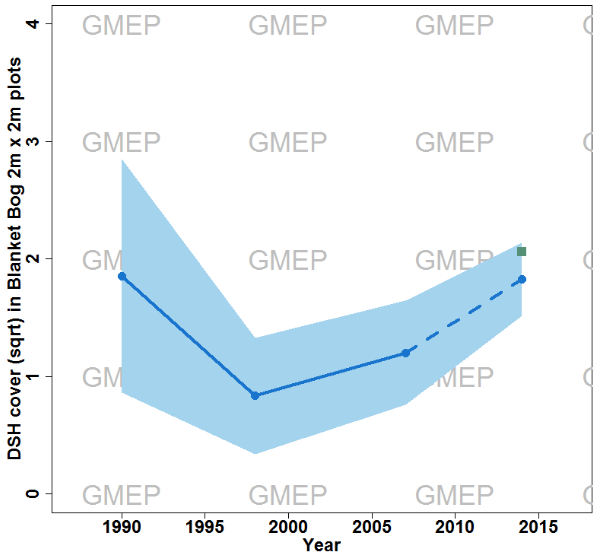


Figure 5a: Trends in the mean cover of *Dwarf Shrubs* in 2m x 2m plots

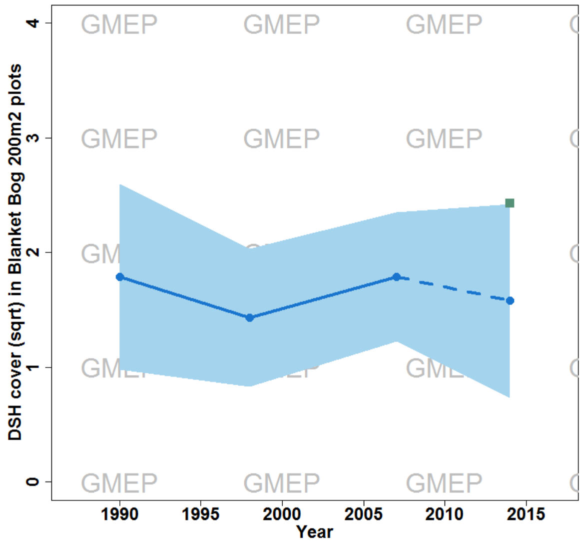


Figure 5b: Trends in the mean cover of *Dwarf Shrubs* in 200m2 plots

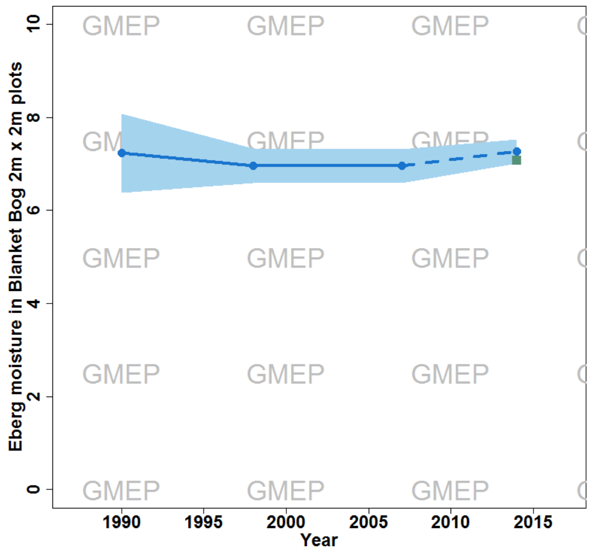


Figure 6a: Trends in Ellenberg moisture score in 2m x 2m plots

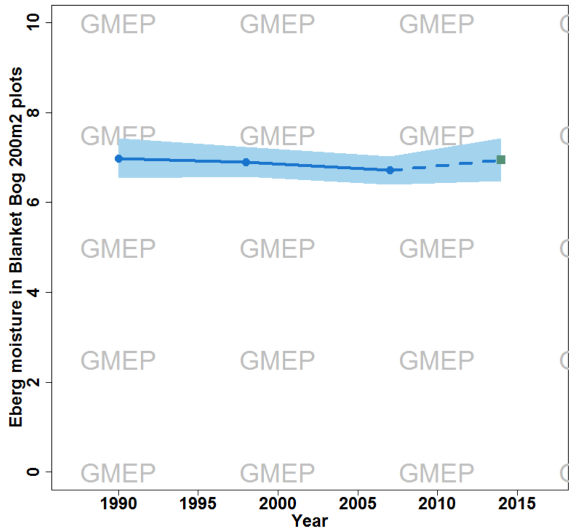


Figure 6b: Trends in Ellenberg moisture score in 200m2 plots

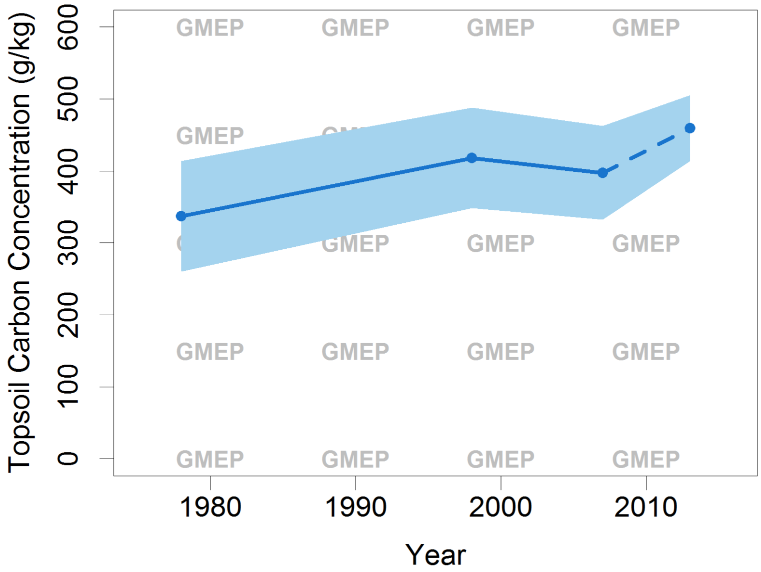


Figure 7: Changes in Topsoil carbon concentration

Table 1: Trends in the mean number of Characteristic Bog species (CSM) in 2m x 2m plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990: CS	5.00	3.02	6.98
1998: CS	2.26	1.36	3.17
2007: CS	2.57	1.72	3.43
2013/14: GMEP	4.00	3.39	4.61

There has been a slight decline between 1990 and 1998 and a significant difference between 2007 and 2013/14

Table 2a: Trends in the mean total species richness per 2m x 2m plot

Year	Estimated_Value	Lower_est.	Upper_est.
1990	14.67	10.28	19.05
1998	7.54	5.62	9.46
2007	8.94	7.07	10.80
2013/14: GMEP	7.77	6.41	9.14

Changes between 1990, 1998 and 2007 are significant; however there are no significant differences between 2007 and 2014.

Table 2b: Changes in species richness in 200m2 plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	19.32	13.86	24.79
1998	11.92	7.82	16.02
2007	10.88	7.43	14.33
2014	13.00	8.04	17.96

There is a sig decrease between 1990 and 2007

Table 3a: Changes in Sphagnum cover in 2m x 2m plots

Year	N	Estimated_Value	Lower_est.	Upper_est.
1990	3	4.33	0.50	8.16
1998	12	3.07	1.28	4.86
2007	15	2.09	0.42	3.75
2013/14: GMEP	97	5.55	4.36	6.74

There is a significant difference between 2007 and 2013/14 GMEP sample

Table 3b: Changes in Sphagnum cover in 200m2 plots

Year	N	Estimated_Value	Lower_est.	Upper_est.
1990	3	1.85	-0.34	4.05
1998	5	2.16	0.50	3.82
2007	8	3.66	2.09	5.24
2014	39	3.64	1.24	6.04

There are no significant differences

Table 4a: Changes in *E. vaginatum* in 2m x 2m plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	0.33	-0.69	1.36
1998	0.97	0.48	1.46
2007	1.05	0.60	1.50
2014	1.68	1.36	2.00

There are no significant differences between years

Table 4b: Changes in *E.vaginatum* in 200m2 plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	0.67	-0.16	1.49
1998	1.09	0.45	1.73
2007	2.11	1.61	2.62
2014	1.72	1.01	2.44

There is a significant difference between 1990 and 2007

Table 5a: Changes in Dwarf Shrubs in 2m x 2m plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	1.86	0.86	2.85
1998	0.84	0.34	1.33
2007	1.20	0.76	1.65
2014	1.83	1.52	2.14

There is a significant difference between 1998 and 2014, changes between other years are not significant

Table 5b: Changes in DSH in 200m2 plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	1.79	0.98	2.59
1998	1.43	0.83	2.03
2007	1.79	1.23	2.35
2014	1.58	0.73	2.42

There are no significant differences between years

Table 6a: Changes in Ellenberg moisture values in 2m x 2m plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	7.23	6.39	8.07
1998	6.96	6.59	7.33
2007	6.95	6.60	7.31
2014	7.27	7.01	7.54

There are no significant differences between years

Table 6b: Changes in Ellenberg moisture values in 200m2 plots

Year	Estimated_Value	Lower_est.	Upper_est.
1990	6.98	6.54	7.43
1998	6.90	6.57	7.24
2007	6.71	6.40	7.03
2014	6.95	6.48	7.43

There are no significant differences between years

Headline question: How is the ecological condition of section 42 (priority) habitats related to Glastir?

Blanket Bog

Background
Glastir options that are likely to affect the Blanket Bog habitat include 41a and 41b grazing management of open country with set maximum stocking rates, additional management options for re-wetting or stock reduction and the capital works for Grip blocking. Improving habitat condition is important for reducing the loss of Green House Gases; degraded blanket bog is more likely to be a source for carbon release into the atmosphere rather than a sink. Increasing the water levels and reducing the stocking rate are the main restoration objectives with a number of other activities that may be required e.g. re-seeding, gully stabilisation. In recent years there has been considerable activity in Wales to restore degraded blanket bog with a number of LIFE projects.

Methodology
As part of the field survey in 2013 and 2014 permanent vegetation plots were established. These include random plots (2002m) and 2m x 2m plots in Blanket Bog. Within the plots all higher plants were recorded to species level and a limited number of lower plants. Using the vegetation plot data a number of indicators have been calculated to report on habitat condition. The total number of species within a plot has been calculated. The number of Common Standard Monitoring indicator species was calculated by taking species identified in the guidance for the priority habitat (JNCC) and in discussions with the BSBI and calculating the number of them within a plot. Soil data from soil cores taken at the 200m plots has also been used to calculate an indicator for soil carbon within the plot. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the square was under Glastir management was used as a factor in the analysis. In future it will be possible to look at specific options spatially (allowing for suitable sample sizes) to assess whether a particular option is having an effect.

Results
The only significant result from comparing land under Glastir management with land outside of Glastir management is that there is a higher species richness in blanket Bog in a square subject to Glastir management.
This will reflect the baseline quality of the land entering the scheme rather than current Glastir management prescriptions as it takes such habitats some time to change (hydrology can change within a couple of years but vegetation and GHG emissions can take up to ten years to recover after restoration).

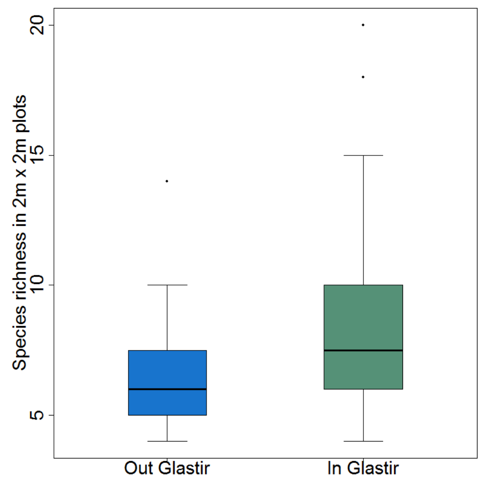


Figure 1: Species richness in 2m x 2m plots in Blanket Bog

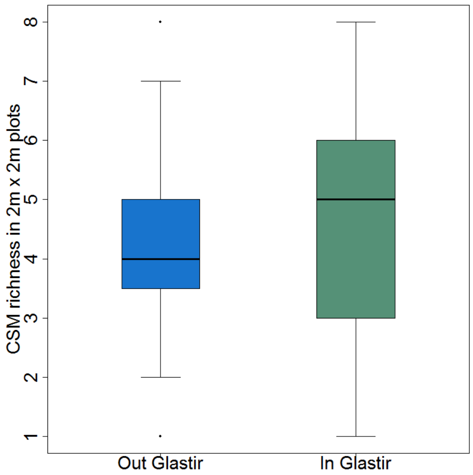


Figure 2: CSM richness in 2m x 2m plots in Blanket Bog

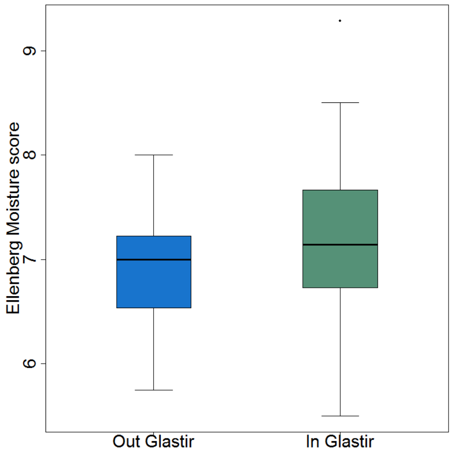


Figure 3: Ellenberg Moisture score in 2m x 2m plots in Blanket Bog

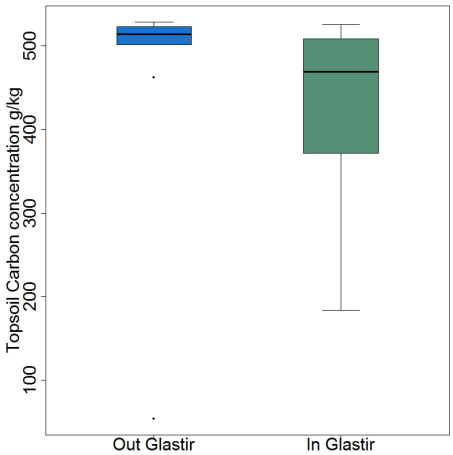


Figure 4: Topsoil Carbon concentration g/kg in Blanket Bog

Table 1: Species richness in 2m x 2m plots in Blanket Bog

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	6.39	4.35	8.43
1	9.17	8.05	10.30

There is a significant difference between land in Glastir and land outside Glastir

Table 2: CSM richness in 2m x 2m plots in Blanket Bog

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	4.05	3.16	4.95
1	4.84	4.31	5.37

There is no significant difference between land in Glastir and land outside Glastir

Table 3: Ellenberg Moisture score in 2m x 2m plots in Blanket Bog

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	7.02	6.69	7.35
1	7.26	7.07	7.46

There is no significant difference between land in Glastir and land outside Glastir

Table 4: Topsoil Carbon concentration g/kg in Blanket Bog

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	364.15	166.35	561.95
1	441.11	286.27	595.96

There is no significant difference between land in Glastir and land outside Glastir

What are the long term trends in the condition of priority (section 42) habitats? Purple Moor grass and Rush Pasture

Background

Purple moor grass and rush pastures occur on poorly drained, usually acidic soils in lowland areas of high rainfall. Purple moor grass *Molinia caerulea,* and rushes, especially sharp-flowered rush *Juncus acutiflorus*, are usually abundant. Acid indicators may be present but especially notable are uncommon assemblages of rich fen species such as *Juncus subnodulosus (*blunt flowered rush*), Carex pulicaris* (flea sedge), *Carex hostiana* (Tawny sedge*), Cirsium dissectum* (meadow thistle), *Epipactis palustris* (marsh helleborine)*, Gymnadenea conopsea (*fragrant orchid) and *Serratula tinctoria* (saw-wort).It is a reasonably common habitat type in Wales and composed 5% of the area of GMEP survey squares. It is classified as marshy grassland under Glastir (NVC M22-26) and subject to marshy grassland Glastir options. The condition of Purple Moor grass can be measured in a number of ways, Some indicators from GMEP include plant species richness, plant preference score for moisture

Methods

As part of the field survey in 2013 and 2014 permanent vegetation plots were established. These include random plots (200^2m) and 2m x 2m plots in Purple Moor grass rush pasture. Within the plots all higher plants were recorded to species level and a limited number of lower plants. Using the vegetation plot data a number of indicators have been calculated to report on habitat condition. The total number of species within a plot has been calculated. The number of Common Standard Monitoring indicator species was calculated by taking species identified in the guidance for the priority habitat (JNCC) and in discussions with the BSBI and identifying characteristic Purple Moor grass indicators. The number of characteristic (CSM) species within a plot was then calculated. Scores indicating plant preferences for moisture (Ellenberg wetness index) have also been calculated, each plant has an individual wetness score and an average is then taken for a plot, higher scores indicate wetter conditions. Data from Countryside Survey has been used for the long term trend but Purple Moor grass rush pasture was surveyed for the first time in 2007 so the trend only goes back to there.

Results

Purple Moor grass Rush pasture was recorded for the first time as a distinct habitat type in 2007 Countryside Survey so the trend only goes from 2007.

There were no significant differences in the number of characteristic plant species (CSM), Total plant species richness or plant moisture (Ellenberg) scores in 2m x 2m plots between 2007 and the GMEP 2013/2014 sample. This suggests that there has been no significant change in the condition of Purple Moor grass rush pasture.

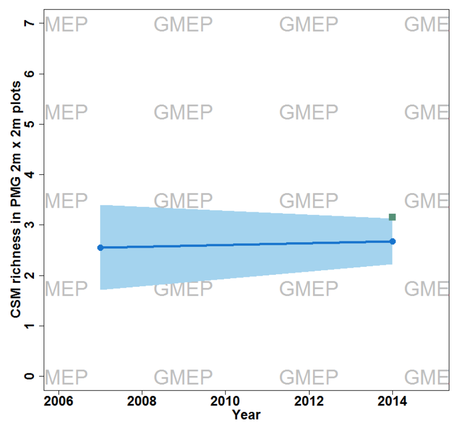


Figure 1: The trend in the characteristic species (CSM) richness in a 2m x 2m plot

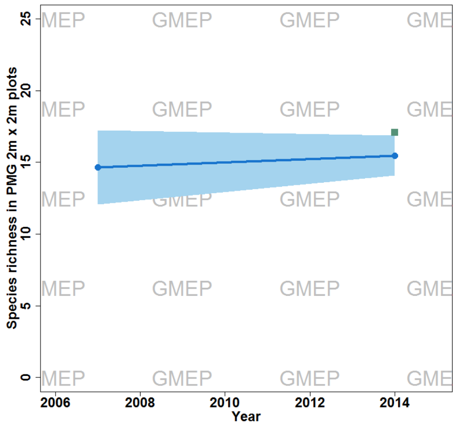


Figure 2: The trend in the Total plant species richness in a 2m x 2m plot

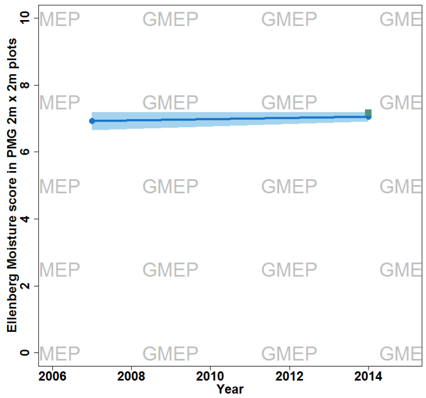


Figure 3: The trend in Ellenberg moisture score in a 2m x 2m plot

Table 1 The trend in the characteristic (CSM)plant species richness in a 2m x 2m plot

Year	Estimated_Value	Lower_est.	Upper_est.
2007	2.56	1.71	3.40
2014	2.68	2.22	3.13

There is no significant difference in characteristic (CSM) species richness between 2007 and 2013/14

Table 2: The trend in total plant species richness in 2m x 2m plots

Year	Estimated_Value	Lower_est.	Upper_est.
2007	14.67	12.07	17.26
2014	15.48	14.09	16.88

There is no significant difference in Total species richness between 2007 and 2013/14

Table 3: The trend in mean Ellenberg Moisture score in 2m x 2m plots

Year	Estimated_Value	Lower_est.	Upper_est.
2007	6.93	6.73	7.12
2014	7.07	6.93	7.21

There is no significant difference in plant moisture score (Ellenberg) between 2007 and 2013/14.

Appendix 5.12: What are the long term trends in Habitat diversity?

Background

Habitat diversity can be a good thing in that a mixture of habitats provides variety in abiotic conditions, food and shelter and is preferable to a species-poor monoculture. High habitat diversity should provide resilience from changing environmental conditions (e.g. climate change) enabling species to move between habitats when conditions change. However, high habitat diversity can also be a sign of increasing fragmentation and it is important that larger continuous areas of habitat are also maintained for example, in unenclosed upland environments. Habitat diversity and connectivity (reported elsewhere) can both contribute to the creation of ecological networks which have an important role to play in the conservation of habitats and species in an increasingly fragmented landscape.

Methods

Habitat diversity and the mean area of a habitat patch within a 1km square have been calculated from field survey data. All Habitats are mapped within a 1km square to Broad and Priority habitat classification by surveyors in the field using a computer with bespoke GIS technology. This classification has been applied continuously from 1984 to 2014. The Shannon diversity index (H´) following the formula - Σ p_i ln $p_{i,}$ was used to calculate habitat diversity where $p_{i,}$ is the proportion of habitat $_{i.}$. Habitats were substituted for species and 1km squares for quadrats. Urban areas were excluded and all Priority Habitat types were included as separate habitats. The mean patch size was calculated from the area data as a mean per 1km square.

Results

There has been no significant change in habitat diversity between 1984 and 2014.
Although Figure 2 does suggest an increasing trend in mean patch size the There has been no significant change in mean patch size between 1984 and 2014.

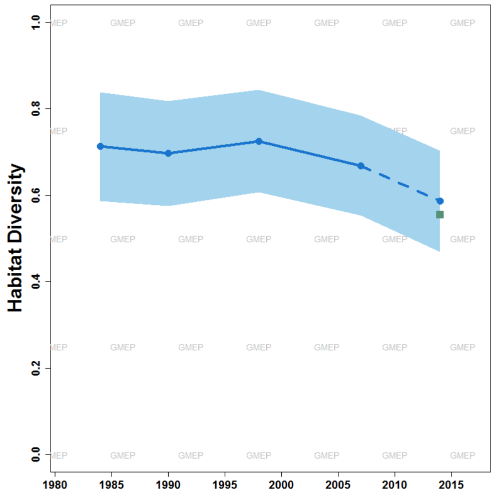


Figure 1: Trends in habitat diversity (Shannon diversity index) between 1984 and 2014

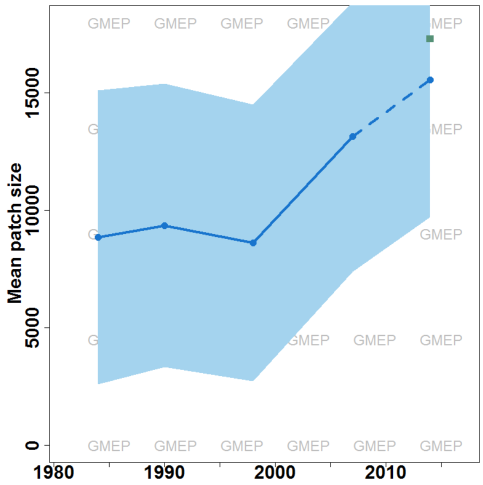


Figure 2: Trends in mean habitat patch size between 1984 and 2014

Table 1: Mean Habitat Diversity over Time

Year	Estimated_Value	Lower_est.	Upper_est.
1984	0.71	0.59	0.84
1990	0.70	0.58	0.82
1998	0.73	0.61	0.84
2007	0.67	0.55	0.78
2013/14 GMEP	0.59	0.47	0.70

There are no significant differences between years

Table 2: Changes in mean patch size over time

Year	Estimated_Value	Lower_est.	Upper_est.
1984	8860.33	2609.50	15111.17
1990	9364.52	3339.38	15389.67
1998	8619.06	2725.65	14512.47
2007	13142.26	7398.74	18885.77
2013/14 GMEP	15554.23	9715.08	21393.38

There are no significant differences between years

Does habitat diversity vary according to whether land is in Glastir?
Within Glastir high habitat diversity as such is not an objective of the scheme but maintaining areas of habitat land in good condition is important. It is a useful measure to assess whether land in and out of Glastir consist of higher habitat diversity at this stage of the scheme.

Methods
Habitat diversity was calculated as described above. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the square was under Glastir management was used as a factor in the analysis. In future it will be possible to look at specific options spatially (allowing for suitable sample sizes) to assess whether a particular option is having an effect.

Results
Habitat Diversity is higher in 1km squares that are subject to Glastir management.

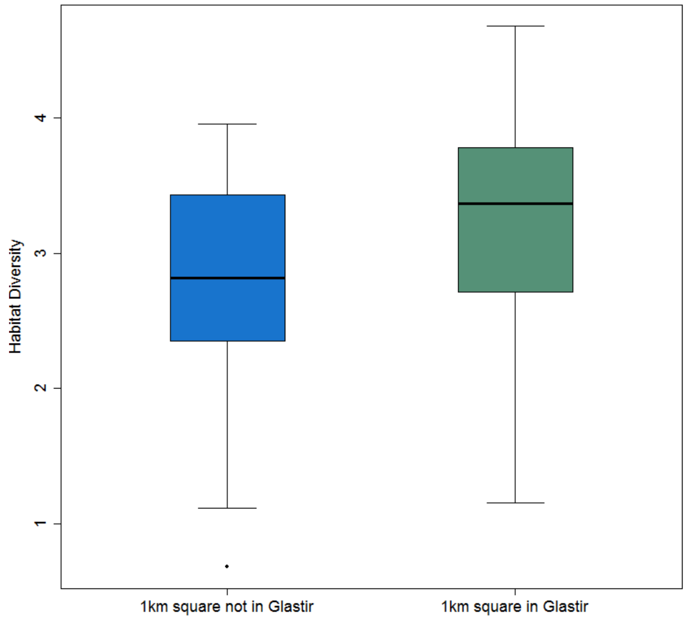


Figure 3: Mean Habitat diversity per 1km square where land is managed under Glastir and is not in Glastir.

Table 1: Mean Habitat diversity per 1km2 in a 1km square where land is in Glastir and land is not in Glastir

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	2.815193	2.549823	3.080562
1	3.185736	3.042068	3.329405

There is a significant difference between squares where the land owner is in Glastir and squares where the land owner is not in Glastir

Appendix 5.13 How many priority habitats are sampled in the GMEP field survey and how many Priority habitats coincide with Glastir agreement maps by the end of year 2?

Background

There are a number of habitats of principle importance to conservation in Wales which are known as 'Priority' habitats or section 42 habitats. The production of a section 42 list is a requirement of the Natural Environment and Rural Communities Act 2006, and is used to guide and prioritise future conservation action in Wales. Some of these priority habitats are specifically mentioned as targets in Glastir e.g. Lowland heathland, wetland and there are options in the scheme designed to optimise management to ensure that they are in good condition. Many of these habitats are important to priority and section 42 species and management and creation options in Glastir are designed to benefit them. In GMEP, priority and broad habitats are mapped in every 1km square, this includes large areas of habitat e.g. blanket bog but also linear features such as streamsides, hedgerows and belts of trees. This question addresses the number and type of habitats surveyed in GMEP but also goes wider to look at the habitats covered by Glastir uptake to date.

Methodology

In the GMEP field survey the habitats and features of every 1km square are mapped using a bespoke GIS software system on field computers. As well as classifying each habitat type using a vegetation key many detailed attributes are recorded such as the height of the vegetation, the species composition, the management and use and the condition. This gives us a detailed complex database that can be queried to determine how habitats and features vary spatially and how they are changing and how they are influenced by management actions. It is also valuable information to contribute to studies of priority species.

Results

Figure 1 shows the % of the GMEP square area attributed to different habitat types.
The most commonly surveyed habitats are the Broad habitats improved, neutral and acid grasslands and coniferous and Broadleaved woodland. These make up a large proportion of the Welsh countryside. The most frequently surveyed priority habitats include Purple Moor Grass rush pasture, upland heath, Blanket Bog and some of the woodland priority habitats wet woodland and Lowland mixed deciduous. Most of the priority habitat types are recorded in the GMEP survey but some make up a very low percentage of the survey. Upland habitats are better represented in the targeted squares which is to be expected as these were chosen to reflect the Welsh Government priorities in the first two years of Carbon and water.
Figure 2 shows the percentage of the total area of different habitats in Wales that are currently under a Glastir scheme. Acid, calcareous and marshy grassland (includes Purple Moor grass Rush pasture) are well covered by Glastir agreements as are bogs, mires and heathlands. Woodland habitats are less well covered with only 22.7 % of semi-natural broadleaved woodland being under Glastir agreement.

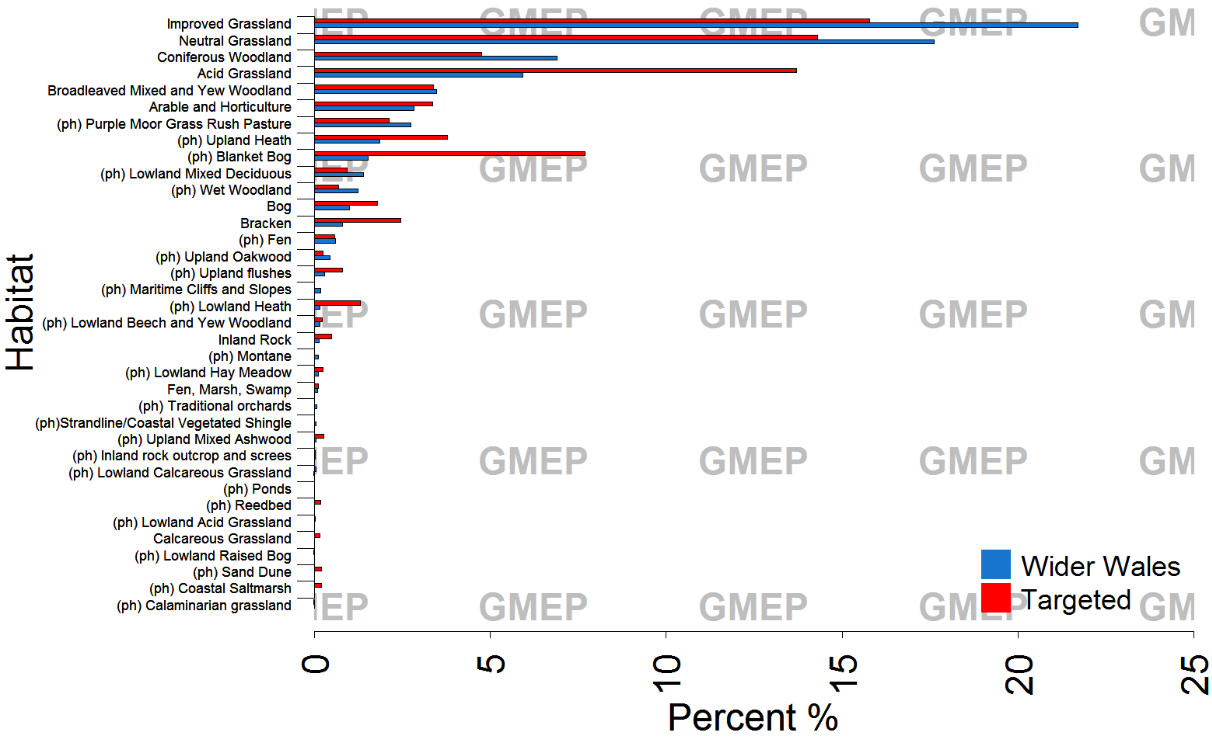


Figure 1: Percentage of habitats surveyed in the GMEP field survey, the broad habitat figures do not include those areas also identified as priority habitat.

Table 1: Data from GMEP field survey showing coverage of different Broad and Priority habitats within the field survey

Habitat	%WW	%TG
Improved Grassland	21.7	15.77
Neutral Grassland	17.61	14.29
Coniferous Woodland	6.91	4.76
Acid Grassland	5.93	13.7
Broadleaved Mixed and Yew Woodland	3.47	3.38
Arable and Horticulture	2.83	3.37
(ph) Purple Moor Grass Rush Pasture	2.74	2.13
(ph) Upland Heath	1.86	3.79
(ph) Blanket Bog	1.53	7.7
(ph) Lowland Mixed Deciduous	1.4	0.93
(ph) Wet Woodland	1.25	0.7
Bog	1.01	1.79
Bracken	0.81	2.47
(ph) Fen	0.61	0.58
(ph) Upland Oakwood	0.45	0.25
(ph) Upland flushes	0.3	0.81
Standing Open Waters and Canals	0.2	1.32
(ph) Maritime Cliffs and Slopes	0.19	0.01
(ph) Lowland Heath	0.16	1.31
(ph) Lowland Beech and Yew Woodland	0.16	0.23

Inland Rock	0.15	0.5
Rivers and Streams	0.14	0.19
(ph) Montane	0.13	0
(ph) Lowland Hay Meadow	0.12	0.26
Fen, Marsh, Swamp	0.1	0.12
(ph) Traditional orchards	0.07	0.01
(ph)Strandline/Coastal Vegetated Shingle	0.05	0.01
(ph) Upland Mixed Ashwood	0.05	0.27
(ph) Inland rock outcrop and screes	0.03	0.03
(ph) Lowland Calcareous Grassland	0.02	0.05
(ph) Ponds	0.01	0.01
(ph) Reedbed	0	0.19
(ph) Lowland Acid Grassland	0	0.04
Calcareous Grassland	0	0.16
ph) Lowland Raised Bog	0	0.02
ph) Sand Dune	0	0.2
(ph) Coastal Saltmarsh	0	0.22
(ph) Calaminarian grassland	0	0.02

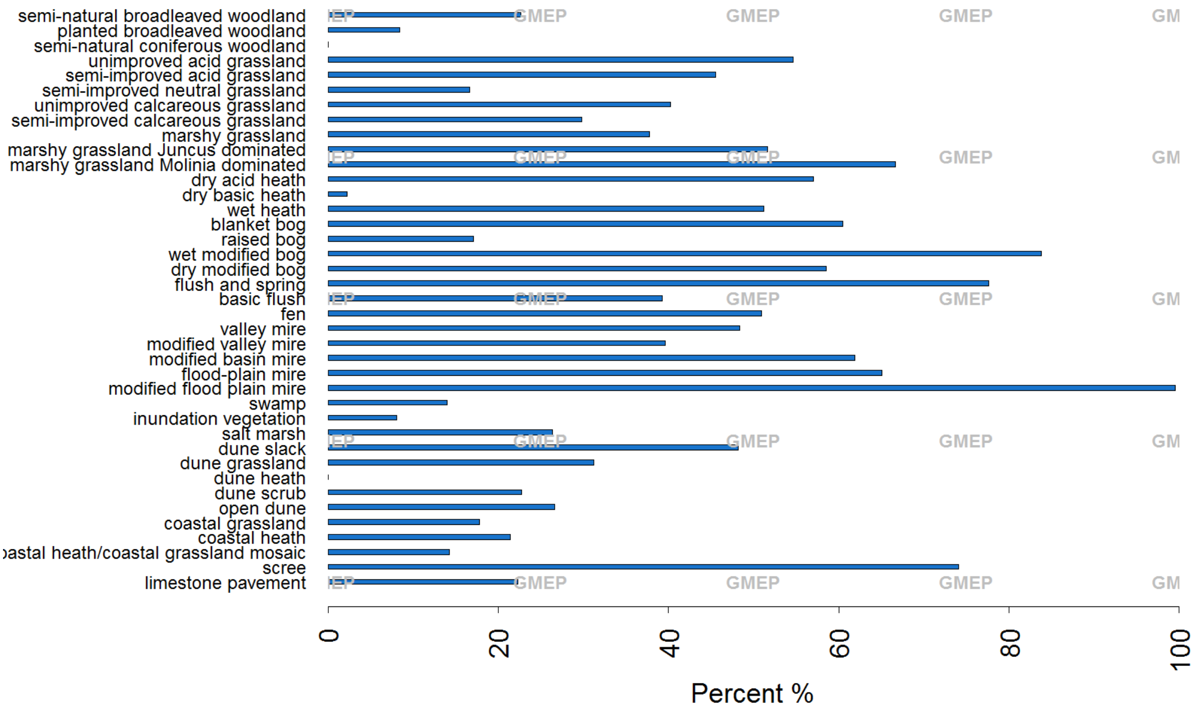


Figure 2: Percentage of total area of each habitat in Wales covered by a Glastir scheme (includes all schemes, entry, advanced, Woodland element, commons, GEG) and uses NRW Phase 1 survey data to represent habitat coverage

Table 2: Data from NRW Phase 1 Habitat map overlaying land under Glastir scheme to determine approximate percentage of different habitat types under Glastir management across the whole of Wales.

	Code	Habitat	Glastir ENTRY	Glastir ADVANCED	Glastir Woodland Management	Glastir COMMONS	Glastir GEG	Glastir Total
Woodland and scrub	A.1.1.1	semi-natural broadleaved woodland	21.11	1.98	1.44	0.18	0.88	22.70
	A.1.1.2	planted broadleaved woodland	7.11	0.63	1.17	0.07	0.27	8.42
	A.1.2.1	semi-natural coniferous woodland	0.00	0.00	0.00	0.00	0.00	0.00
	A.1.3.1	semi-natural mixed woodland	6.03	0.72	1.67	0.00	0.00	6.03
	A.1.3.2	planted mixed woodland	8.77	0.61	3.79	0.02	1.28	12.04
Grassland and marsh	B.1.1	unimproved acid grassland	40.62	9.70	0.03	13.97	0.55	54.67
	B.1.2	semi-improved acid grassland	43.20	7.14	0.06	1.93	1.39	45.53
	B.2.2	semi-improved neutral grassland	15.94	1.65	0.08	0.49	0.31	16.62
	B.3.1	unimproved calcareous grassland	15.98	1.70	0.00	24.25	0.02	40.23
	B.3.2	semi-improved calcareous grassland	7.88	1.02	0.00	21.98	0.41	29.85
	B.5	marshy grassland	35.64	7.14	0.06	1.91	0.88	37.77
	B.5.1	marshy grassland Juncus dominated	30.56	4.71	0.00	21.11	0.18	51.67
	B.5.2	marshy grassland Molinia dominated	41.70	8.35	0.00	24.97	0.11	66.69
Heathland	D.1.1	dry acid heath	33.23	7.64	0.09	23.67	0.28	57.02
	D.1.2	dry basic heath	1.35	0.00	0.00	0.89	0.00	2.25
	D.2	wet heath	35.24	11.22	0.07	15.62	0.56	51.15
	D.3	lichen/bryophyte heath	54.28	0.00	0.00	9.22	0.00	63.49
	D.5	dry heath/acid grassland mosaic	32.85	6.67	0.09	24.77	0.27	57.87
	D.6	wet heath/acid grassland mosaic	54.10	23.96	0.00	4.99	0.64	59.55
	D.7	basic dry heath/calcareous grassland mosaic	0.55	0.00	0.00	0.00	0.00	0.55
Mire	E.1.6.1	blanket bog	50.45	19.57	0.00	10.03	0.76	60.49
	E.1.6.2	raised bog	14.29	7.40	0.00	2.82	0.00	17.12
	E.1.7	wet modified bog	65.45	44.11	0.01	18.35	0.37	83.82
	E.1.8	dry modified bog	22.89	4.32	0.00	35.69	0.41	58.54
	E.2	flush and spring	70.39	61.67	0.00	7.26	7.06	77.65
	E.2.1	acid/neutral flush	38.75	9.92	0.01	16.11	0.31	54.90
	E.2.2	basic flush	19.79	16.09	0.00	19.48	0.04	39.27
	E.3	fen	46.41	11.01	0.01	4.33	0.51	50.93
	E.3.1	valley mire	26.85	8.99	0.00	21.05	0.01	48.33
	E.3.1.1	modified valley mire	37.94	7.14	0.05	1.59	0.00	39.59

	E.3.2	basin mire	38.92	14.62	0.21	12.55	5.33	52.01
	E.3.2.1	modified basin mire	49.85	48.74	0.00	12.00	0.00	61.85
	E.3.3	flood-plain mire	65.09	57.71	0.00	0.00	0.00	65.09
	E.3.3.1	modified flood plain mire	99.49	99.49	0.00	0.00	0.00	99.49
Swamp, marginal and inundation	F.1	swamp	12.07	3.64	0.73	1.26	0.35	14.00
	F.2.2	inundation vegetation	5.83	0.17	1.06	1.18	0.00	8.07
Coastland	H.2.6	salt marsh	26.29	8.90	0.00	0.09	0.00	26.38
	H.6.4	dune slack	44.13	13.17	0.00	4.07	0.00	48.20
	H.6.5	dune grassland	25.95	0.42	0.00	5.29	0.00	31.25
	H.6.6	dune heath	0.00	0.00	0.00	0.00	0.00	0.00
	H.6.7	dune scrub	22.64	10.29	0.00	0.09	0.00	22.73
	H.6.8	open dune	22.78	1.74	0.00	3.86	0.00	26.64
	H.8.1	hard cliff	8.61	0.47	0.00	0.38	0.00	8.99
	H.8.2	soft cliff	9.15	0.01	0.00	0.00	0.00	9.15
	H.8.4	coastal grassland	17.06	4.70	0.01	0.74	0.77	17.84
	H.8.5	coastal heath	21.45	4.82	0.00	0.00	0.00	21.45
	H.8.6	coastal heath/coastal grassland mosaic	14.26	0.82	0.00	0.00	0.00	14.26
Rock	I.1.2	scree	64.73	21.28	0.00	9.30	0.00	74.03
	I.1.2.1	acid/neutral scree	43.25	4.98	0.00	5.25	0.06	48.72
	I.1.2.2	basic scree	3.52	0.00	0.00	0.00	0.00	3.52
	I.1.3	limestone pavement	22.32	6.22	0.00	0.02	0.00	22.34

Appendix 5.14: Extending beyond field squares: Net Primary Productivity (NPP) mapping

Introduction

Traditional land cover mapping focusses on determining a single land cover type for a particular pixel or parcel of land. However, this rarely captures the complexity of the landscape, so methods have been developed that aim to capture the heterogeneity by identifying a number of classes for each pixel or parcel using fuzzy classification methods. This enables a more sophisticated description of the between-class variation in the landscape, but fails to capture the within-class variation of the different classes. Users are increasingly demanding a more nuanced picture of the landscape to enable remote sensing to routinely be used to monitor change in land cover/habitat, and changes in condition. To meet these new user requirements requires new methods and products to be developed to enhance traditional land cover mapping products.

The Normalised Difference Vegetation Index (NDVI), derived from remotely sensed imagery, can be used as an indicator for vegetation productivity. The exact form of the relationship between NDVI and productivity depends on several factors including the satellite sensor and the habitat type; therefore, *in situ* data is required to calibrate the relationship. The advantage of continuous biophysical products is that they: (i) Capture sub-polygon and within class variability, so gradients in grassland productivity across a specific field will be mapped, as will the wider variations across a region, or across different regions; (ii) Are a key requirement of condition monitoring and early detection of land cover change; (iii) Enable more sophisticated-modelling – by quantifying differences in different pixels/parcels of the same land-cover type. For example, by identifying both areas of grassland (from the categorical data) and areas of higher and lower productivity grassland (from the continuous data).
The aim here was to combine detailed field survey data and broad scale remote sensing data to produce a map of Net Primary Productivity (NPP) for the whole of Wales.

Method

The overall approach was to use ANPP values derived from GMEP field survey data in combination with remotely sensed NDVI imagery to derive a relationship between ANPP and NDVI, which could then be used to extrapolate beyond the survey squares and produce a map of NPP for Wales.
In situ Specific Leaf Area (SLA) measurements from 707 x-plots within 150 1 km squares across Wales, surveyed over 2013 and 2014, were used to estimate Annual NPP (ANPP) values based on the method described in Stevens *et al*. (In prep.). Landsat 8 imagery for Wales was downloaded for the years 2013 and 2014. The raw digital numbers were calibrated to TOA reflectance and clouds and cloud shadows were masked out of the imagery. The red and NIR bands were used to produce NDVI images, NDVI = (NIR-red)/(NIR+red), and NDVI values for each x-plot were extracted from the imagery using the plot coordinates. Cloud free Landsat 5 TM surface reflectance NDVI imagery from 2011 was also used to illustrate what is possible under cloud free conditions.
Least squares linear regression was used to determine the strength and form of the image-specific relationship between ANPP and NDVI. This was initially done for grassland habitats, as these were expected to give the strongest relationships, and then for all habitat types. The derived relationships were then applied to the NDVI imagery to produce maps of ANPP for all grasslands across Wales. Land Cover Map 2007 was used to produce a mask of all non-grassland habitats in order to exclude these areas from the resulting map.

Results

Relationship between ANPP and NDVI for grassland habitats
Results showed that the relationship between ANPP and NDVI for grassland habitats had a seasonal dependence. The strongest relationship was seen in the spring and autumn (e.g. Figure 1), while in the summer and winter months, the correlation was very weak (e.g. Figure 2). Variation in the slope

and the R^2 value for the relationship between ANPP and NDVI is shown in Figure 3. The strong correlations observed for spring images is likely to be due to differences in the 'greening up' times of the different plots, i.e. the more productive grasslands will green up earlier in the year than less productive ones. Similarly, in the autumn, the highly productive grasslands will continue to grow later into the season than the low productivity grasslands. In the summer and winter images all grasslands have reached a similar level of 'greenness' and hence, there is very little variation in NDVI across the productivity gradient.

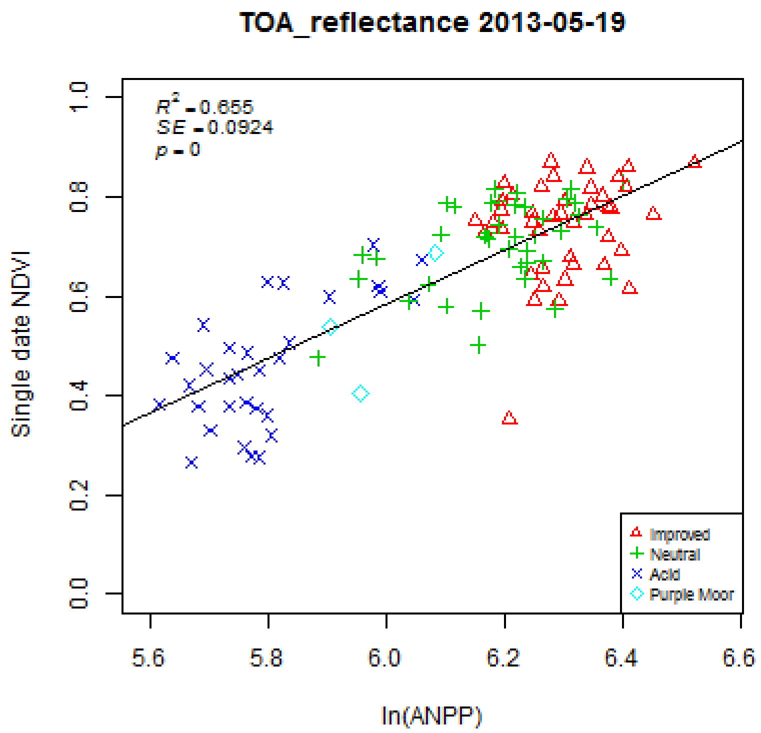


Figure 1. Scatter plot showing the relationship between NDVI and ln(ANPP) for grassland habitat based on a spring image, 2013-05-19.

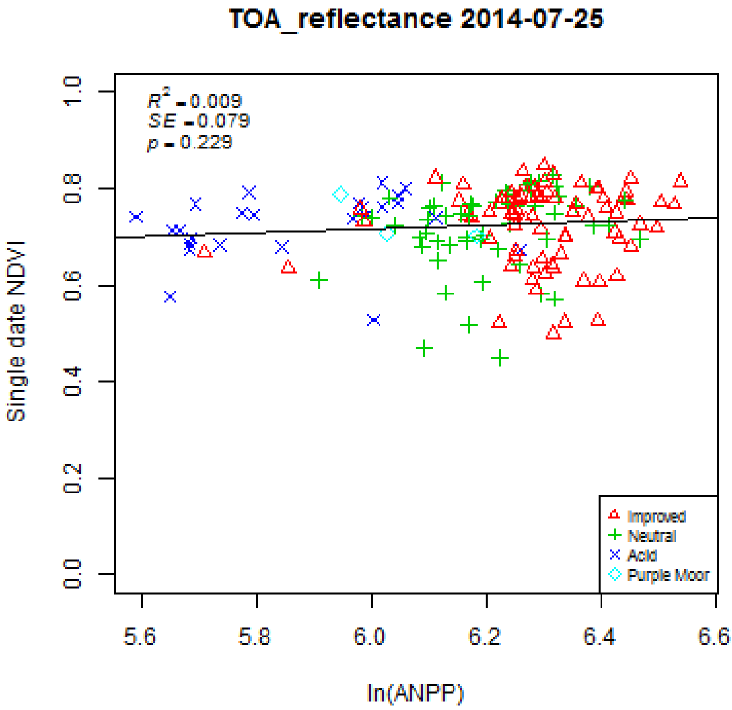


Figure 2. Scatter plot showing the relationship between NDVI and ln(ANPP) for grassland habitats based on a summer image, 2014-07-25.

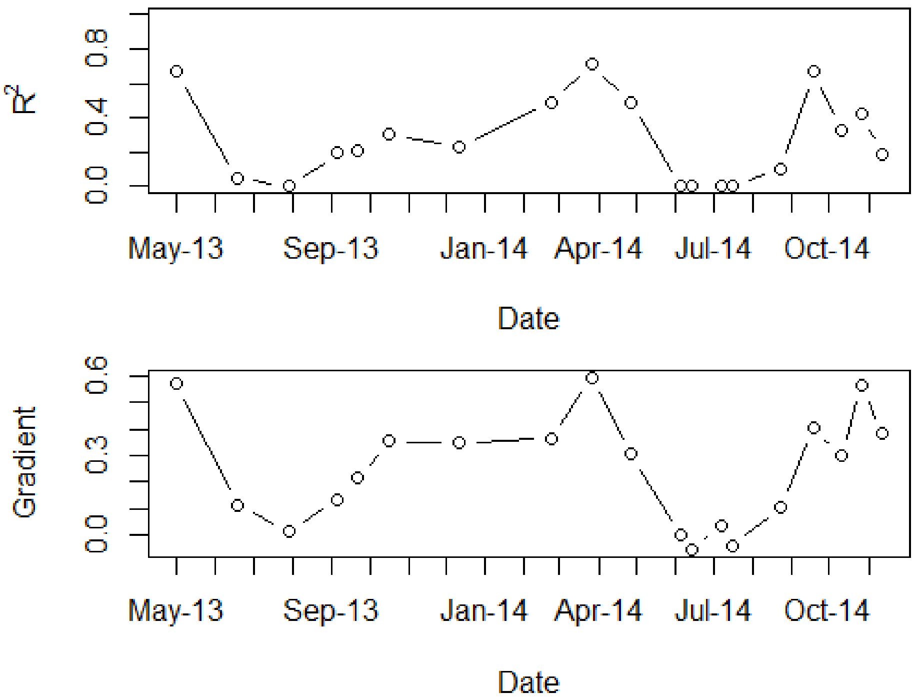


Figure 3. Time series of gradient and R^2 values for the relationship between ANPP and NDVI for grassland habitats.

Relationship between ANPP and NDVI for all habitat types

When all habitat types were considered, a similar seasonal dependence in the relationship between ANPP and NDVI was observed, with the strongest relationship occurring in the spring (Figure 4) and the weakest in summer and winter (Figure 5). The R^2 values were lower when all habitat types were included as there was more scatter in the relationship. Arable, dwarf shrub heath and coniferous habitats did not fit in well with the relationship shown by the other habitat types. In some scatter plots, broadleaved woodland appeared to be anomalous. Arable was expected to give anomalous results since the observed NDVI value is very sensitive to the timing of the image relative to time of planting and harvest. Hence, the methodology presented here is not suitable for estimating the productivity of arable land. For dwarf shrub heath, coniferous and deciduous the deviation from the trend observed for the other habitat types is likely to be due to problems with the trait based model used to estimate the *in situ* ANPP values. These issues are expected to be improved in a future version of the model which is currently being developed.

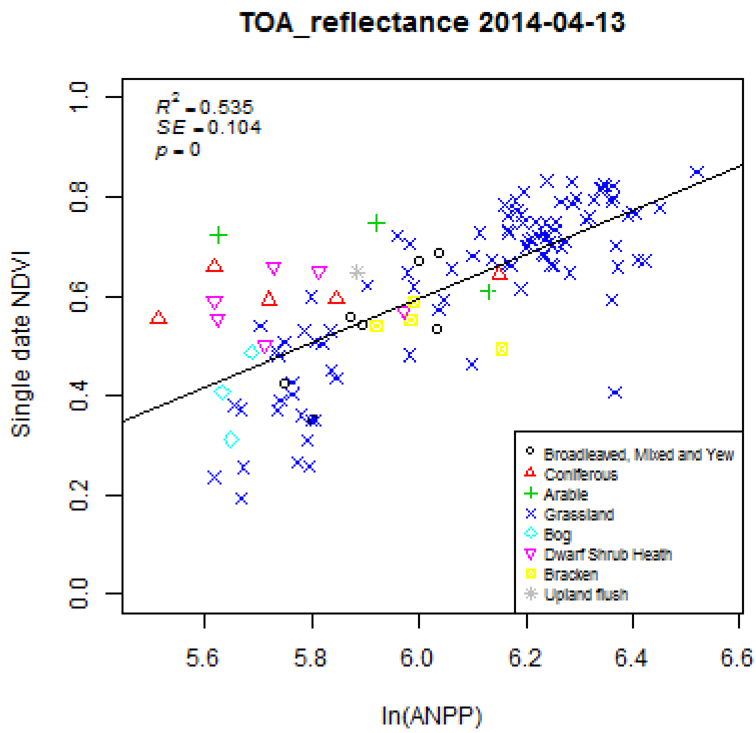


Figure 4. Scatter plot of ln(ANPP) versus NDVI for a spring image, 2014-04-13, for all habitat types

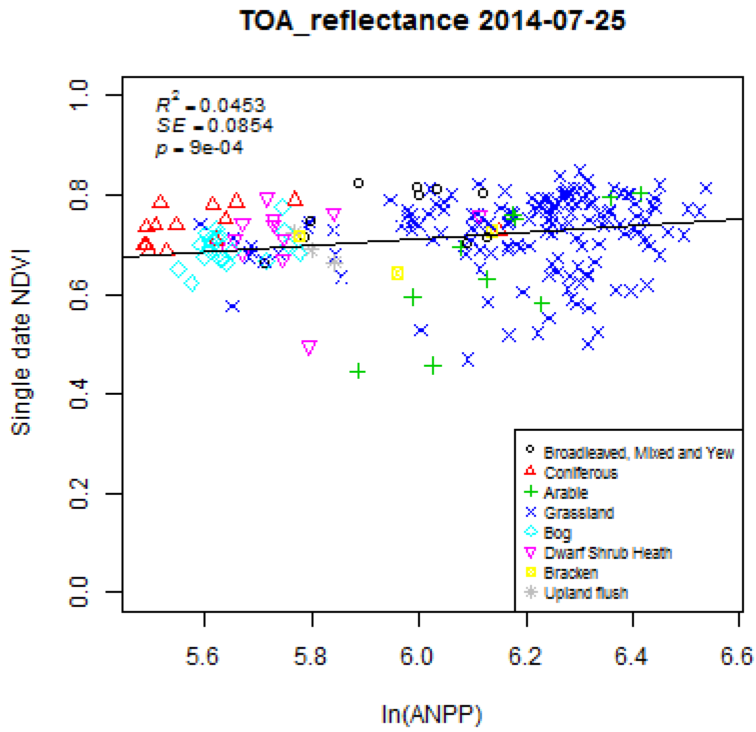


Figure 5. Scatter plot of ln(ANPP) versus NDVI for a summer image, 2014-07-25, for all habitat types.

ANPP maps

The Landsat 8 NDVI image captured on 2014-04-13 gave the highest correlation with *in situ* ANPP measurements (R^2 = 0.714; Figure 6). The relationship between NDVI and ln(ANPP), derived using least squares linear regression, for this image was:

$$\ln(ANPP) = 1.21 \times NDVI_{\text{L8 TOA}} + 5.35$$

where $NDVI_{\text{L8 TOA}}$ is the NDVI value calculated from Landsat 8 top-of-atmosphere reflectance. Figure 7 shows the ANPP map which was produced by applying this equation to the NDVI, after first masking out cloud and non-grassland habitats. The map illustrates the problem of cloud cover, as large portions of the image were obscured by cloud.

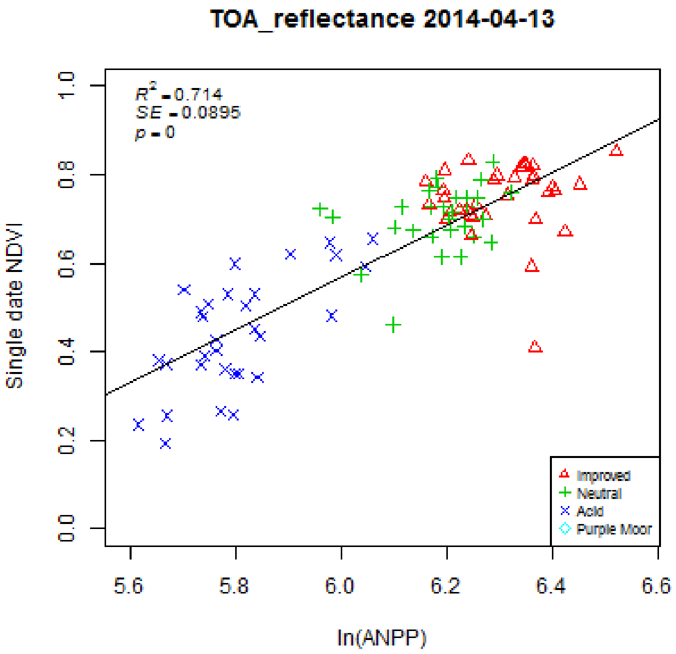


Figure 6. Scatter plot showing the relationship between NDVI and ln(ANPP) for grassland habitat based on a Landsat 8 image captured on 2014-04-13.

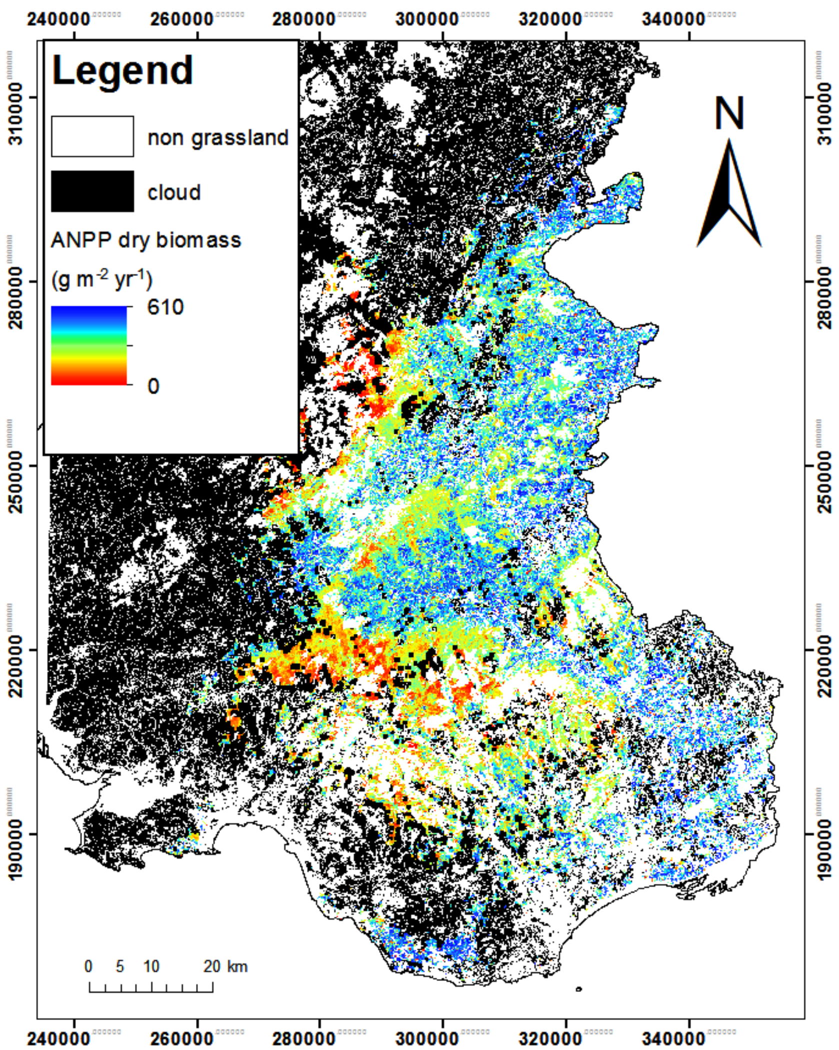


Figure 7. Map of ANPP for south-east Wales produced using a Landsat 8 image captured on 2014-04-13.

To illustrate what is possible with good cloud free imagery, two cloud free Landsat 5 TM images from 2011-04-28 were downloaded. The two images covered almost the whole of Wales, apart from a small strip of south east Wales. Figure 8 shows the scatter plot produced using these two Landsat scenes. The R^2 value for the relationship is lower than for the Landsat 8 imagery, and there is more scatter in the relationship. This could be due to the temporal separation of the satellite image (2011) and the *in situ* data (2013 and 2014), which could have led to phenological differences or changes land cover type some plots. Alternatively the weaker relationship could be due to limitations of the Landsat TM 5 sensor. Despite the weaker relationship, the correlation was still significant and therefore it was reasonable to use the model to predict ANPP value beyond the survey squares.

The relationship between In(ANPP) and NDVI for these images, derived using least squares linear regression, had the form:

$$\ln(ANPP) = 0.888 \times NDVI_{LT5} + 5.50$$

where $NDVI_{LT5}$ is the NDVI value derived from Landsat 5 TM surface reflectance. Figure 9 shows the ANPP map produced by applying this equation to two Landsat 5 TM scenes.

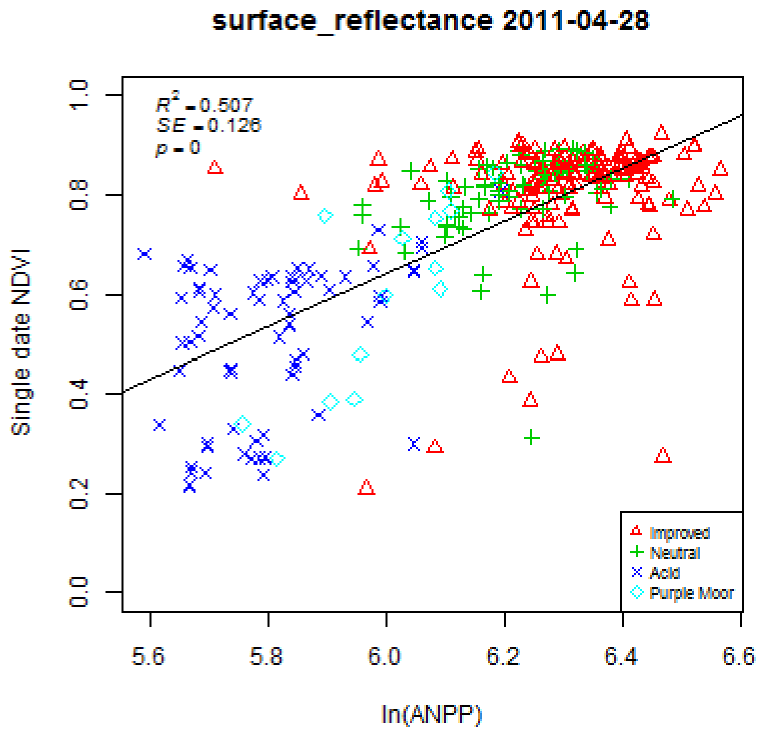


Figure 8. Scatter plot showing the relationship between NDVI and ln(ANPP) for grassland habitat based on a Landsat 5 TM image captured on 2011-04-28.

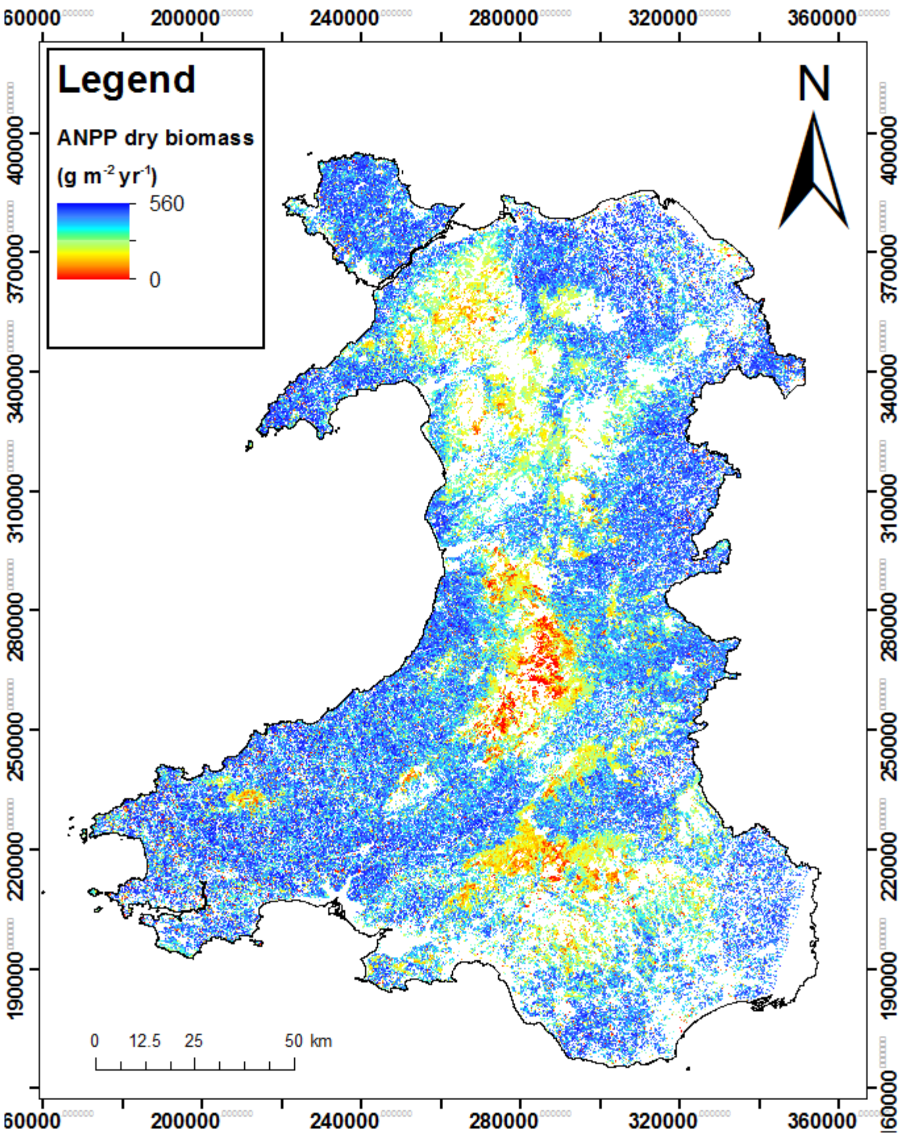


Figure 9. ANPP map for Wales produced using Landsat 5 TM imagery from 2011

Conclusions

A method has been demonstrated for extrapolating variables calculated from field measurements beyond the survey squares to produce maps of biophysical parameters at a national scale. In this example, maps of vegetation productivity were produced, but the method could also be applied to other variables, e.g. moisture content. It provides an alternative to traditional land cover mapping which divides the landscape up into discrete habitat types.

The results have shown the potential for using satellite data to extrapolate ANPP values spatially beyond the GMEP x-plots to produce ANPP maps for Wales. The correlations observed between the NDVI imagery and the ANPP values were reasonably strong, particularly considering that the *in situ* data were not designed specifically for validation of remotely sensed data. The plots are located randomly within each habitat patch so some plots may be at the edge of a land parcel and influenced by neighbouring land use or field margins/boundaries (for arable land plots are always located near the edge of the land parcel). The relationships derived are image-specific and hence, must be calibrated for each image using available *in situ* data. Furthermore, the method is dependent on cloud free imagery acquired in the spring or autumn, in order to give a relationship which is strong enough to justify extrapolating outside the survey squares and producing a product with a reasonable level of accuracy.

This method could potentially be used for monitoring changes in vegetation productivity over time. To do this would require obtaining sufficient cloud free imagery in the spring or autumn to produce a map of the whole of Wales. Currently, the availability of suitable cloud free imagery is limited; however, with the launch of the planned Sentinel-2 satellite, suitable optical imagery will become much more frequently collected, thereby increasing the probability that cloud free imagery will be acquired. Hence, it is conceivable that national scale vegetation productivity maps could be produced and updated every few years.

References

Stevens, C.J., T. Ceulemans, J.G. Hodgson, S. Jarvis, J.P. Grime & S.M. Smart. (In prep.). 'Changes in indicators of natural capital and ecosystem services across temperate grasslands; vegetation change in grasslands of the Sheffield region between 1965 and 2012/3'.

BARBASTELLE BAT

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Trees in unmanaged deciduous woodland (ancient or semi-natural) are favoured as roost trees, particularly dead or mature trees with splits, cracks and lose bark (Russo et al. 2004; Greenaway, 2001). As such this species is reliant on woodland managers to retain old or damaged trees necessary for roosting (Schofield & Fitzsimmons, 2004). The loose bark of dead oak trees is particularly used by both sexes of barbastelle bat for roosting (Greenaway, 2005). A study by Howorth (2009) found that woodland which has potential to be used by barbastelle was principally comprised of oak. Furthermore, a dense understorey/well developed shrub layer will aid humidity around roost trees and lower wind speeds; this is especially important for nursery roosts, as well as helping to maintain insect abundance and availability (Greenaway, 2004). Scrub and woodland understorey are the larval food of many small moths (Greenaway 2005); a rich shrub layer could be important in providing prey diversity (Sierro, 1999). A study in Italy showed barbastelles had a preference for oaks with a large circumference. This was thought to indicate the preference for old woodland with high diversity (Sierro, 1999). Barbastelles are specialist moth predators. The retention of woodland edges is beneficial as this enhances moth abundance and diversity (Zeale et al. 2012).	100. Woodland - stock exclusion 24. Allow woodland edge to develop out into adjoining improved land	• Length of new stock-proof fencing bordering existing woodland • Stock excluded from woodland • Area of existing woodland • New area of scrub/woodland on improved land next to existing woodland • New length and location of stock proof fence • <u>% cover of shrub in deciduous woodland</u> • <u>% cover of oak in deciduous woodland</u> • <u>Moth numbers (woodland)</u>	Linears & Fence Condition Habitat mapping Habitat mapping - polygons Habitat mapping Linears and Fence condition Habitat mapping; X & Y plot Habitat mapping; X & Y plot Invertebrate surveys?

Barbastelles benefit from rich hedges and have been seen frequently hunting along these features as they support high densities of moths (Zeale et al. 2012). Tree lines close to woodland roost sites provide connectivity and cover beyond woodland borders. This cover is particularly needed at dusk when leaving woodland roosting sites to forage (Zeale et al. 2012). As such, the larger hedges are left to grow, the more shade is provided and the better the flight line cover is for movement to foraging sites (Greenaway 2004, 2005). In particular, continuous double hedge lines are ideal (i.e. second line of trees are shrubs planted parallel to existing hedgerow) where woodland connectivity breaks down into hedgerows (Greenaway, 2004).	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; ≥ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots
	2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land	• New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; ≥ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthron	Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots
	3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; ≥ 5 woody species • ≤ 25% native conifers	Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots
	5 Enhanced Hedgerow Management On Both Sides	• WLF maintained at least 2m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Habitat mapping; B & D plots B & D plots
	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre	• New stock proof, double fencing around existing hedges	Linears & Fence condition

	width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness	D plots D plots
	43A/43B. Double Fence and Restore Hedge Banks With/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • WLF connectivity • WLF – Woodland connectivity • Moth numbers • Hedge height ideally 3- 4m • Mature Double hedges	Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots CONEFOR CONEFOR Invertebrate surveys Linears & D plots Linears
A study by Zeale et al. (2012) found that barbastelles had a significant preference to hunt along vegetation at the edge of water bodies (Zeale et al. 2012). Linear features like stream corridors are vital to link habitats and barbastelles will feed in woodlands before following a stream to feed over water meadows (Forestry Commission, 2005). Water meadows are	7A/B Create a streamside corridor on improved land on one/both side of a watercourse 9A/9B. Create a new streamside corridor on improved land with tree planting on one/both sides of a watercourse	• New stream side corridor on improved land • New stock proof fence adjacent to stream corridor • Removal of Japanese knotweed and Himalayan balsam	Habitat mapping – linears Linears & Fence condition B, D & S plots Linears & Fence condition

highly productive of insect biomass (Greenaway, 2005) and bats foraging over wet meadows mainly prey on micromoths (Bat Conservation Trust, 2010a). A line of trees on both sides of a small stream with canopies touching creates the ideal flight line; but as a stream becomes wider, a wide line of trees on one side of the bank is more preferable (Greenaway, 2005). Tree lines should be left alongside watercourse, with only light selective felling to ensure understory remains intact (Greenaway 2005).	8 Continued management of an existing streamside corridor 173. Streamside corridor management	• Fencing maintained to exclude stock • Removal of Japanese knotweed and Himalayan balsam No guidance • <u>Presence of woodland stream or river</u> • <u>Stream corridor – Woodland connectivity</u> • <u>Tree lined streams connected to water meadows</u> • <u>Moth numbers (stream corridors & water meadows)</u>	B, D & S plots Habitat mapping CONEFOR Habitat mapping Invertebrate surveys
Light grazing has little effect on moth biomass. Old established unfertilised grasslands and water meadows are naturally highly productive of insect biomass (Greenway, 2004).	123 Lowland unimproved neutral grassland – pasture 125 Lowland unimproved neutral grassland - reversion (pasture) 134 Lowland marshy grassland - reversion (pasture)	• Sheep grazing on unimproved neutral grassland • Sheep & Cattle grazing on unimproved neutral grassland • Sward height between 10cm – 20cm • Sward height between 5cm – 20cm when not grazed by sheep • Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm	Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping, X, U & Y plots
'Series of isolated trees, such as spreading willows, can be highly effective in slowing wind speeds and increasing insect availability' (Greenaway, 2005).	104 Wood pasture 13 Plant individual native trees on improved land	• Isolated trees on improved or grazed grassland • New wood pasture/isolated trees • Tree guards	Habitat mapping – points Habitat mapping Habitat mapping

	106 Historic parks and gardens	• Maintained grazing on grassland	Habitat mapping
'Freshwater is important for drinking and foraging. New ponds and pond complexes created for bats should be located in areas near to, or with good connectivity to, other important habitats for bats, such as woodlands, river corridors and wetlands.' (Pond Conservation, 2011). Pond Conservation (2011) suggest ponds should be located within 1km of woodland, river corridors, hedgerows and tree-lines.	35 Create a wildlife pond on enclosed improved land 35B Create a wildlife pond on enclosed improved land – variable size 36 Buffer existing unfenced in-field ponds	No guidance • New Ponds with an area > 25m^2 and < 1000m^2 • Stock proof fenced ≥10m from pond edge • New area of rough grass around pond ≥10m from pond edge • New stock proof fencing around existing ponds • <u>Ponds within 1km from Woodlands, hedges and stream/river corridors</u>	 Habitat mapping Linears and Fence condition Habitat mapping & Y plots Habitat mapping – linears Habitat mapping
Entwistle et al. (2001) suggest that old orchards should be retained as these provide bats with additional feeding opportunities. According to Entwistle et al. (2001), barbastelles have also been recorded in parks and orchards.	11 Restore a traditional orchard 12 Create a new orchard on improved land Option 172 - Orchard Management	• Area of new orchard adjacent to existing orchard • Tree protectors • Orchard grazing • Area of new orchard on improved land • Tree protectors • Varied sward -80% of grasses between 7cm & 20cm • 5-10% left uncut every year • <u>Old orchards – tree maturity</u>	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping, X & Y plots Habitat mapping Habitat mapping
Study of barbastelle bats at Pengeli forest found that over grown scrub (mainly bramble) in the near vicinity of roosts was an important feeding ground for the bats (Billington, 2003).	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub	• New area of rough grassland in field corner (Max size 0.35ha) • New length and location of stock proof	Habitat mapping Linears and fence condition

	101 Trees and scrub - establishment by Planting / 102 Trees and scrub - establishment by natural regeneration 103 Scrub - stock exclusion	• Newly established trees and scrub • New length of stock proof fence • Existing area of scrub • New stock proof fencing around areas of scrub	Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition
Field margins helps to provide a buffer against pesticide spray drift. Adding margin to arable land also helps to increase insect availability (Entwistle et al, 2001). Particularly of use of arable margins are situated next to hedgerows (English Nature, 2003).	174 Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	• New rough grass margin on arable land • Livestock excluded	Habitat mapping Habitat mapping
Hay cutting greatly and suddenly alters local insect availability at a very susceptible time of year for pregnant barbastelle bats (Greenaway, 2005).	124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion (hay cutting) 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Grassland maintained by grazing and hay cutting • Between 5-10% left uncut each year • 80% of grasses between 5-15cm high after cutting • Grassland maintained by grazing and hay cutting • Between 5-10% left uncut each year • 80% of grasses between 5-15cm high after cutting • Fields shut off to livestock by 1 May	Habitat mapping Habitat mapping Habitat mapping; X & Y plot Habitat mapping Habitat mapping Habitat mapping; X ploy Habitat mapping
Unable to find evidence	Option 175 - Management of rough grassland; enclosed land	• Minimal or no scrub on grassland • At least 75% of grasses >20cm high	Habitat mapping, X plots Habitat mapping, X plots

BECHSTEIN'S BAT

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Bechstein's bat is a woodland species as deciduous woodland provides most of their habitat needs (Entwistle et al. 2001). Compositional analysis of broad habitat classes ranked broadleaved woodland and water significantly over pasture, tree-lines hedgerows and conifer plantations. Furthermore areas of broadleaved woodland with a closed canopy and well developed understorey were preferred (Schofield and Fitzsimmons, 2004). The UK wide Bechstein project found that Breeding female Bechstein's bats are predominantly found in woodlands that meet three or four of the following model criteria devised by Hill and Greenaway (2006): Broadleaf woodland particularly that dominated by oak and/or ash: At least 75% canopy cover: Native understorey present, particularly hazel and hawthorn: At least 50% understorey cover. Understorey is a key feature of woodland used by Bechstein's, particularly as understorey gives some degree of cover (Greenaway, 2004). Native understorey of hawthorn and hazel is particularly important and should be retained where possible (Miller, 2012; Kerth et al. 2001). Foraging by British Bechstein's bats largely takes place in the crowns of mature oak trees, but foraging areas are small and colony sizes are being limited due to fragmentation of suitable woodland (Durrant et al. 2009). In agreement with this, Greenaway suggests about 50 hectares of mature oak with a good understory and small streams are ideal foraging habitat	100. Woodland - stock exclusion 24. Allow woodland edge to develop out into adjoining improved land	• Length of new stock-proof fencing bordering existing (deciduous) woodland • Stock excluded from woodland • Area of existing (deciduous) woodland • Area of new scrub/woodland on improved land next to existing woodland • New length and location of stock proof fence • <u>Insect numbers (woodland)</u> • <u>At least 75% canopy cover and 50% understorey cover</u> • <u>Hazel and hawthorn in woodland understory</u> • <u>Ash and/or oak dominated woodland</u> • <u>50ha of mature oak woodland</u> • <u>Woodland – woodland connectivity</u>	Linears & Fence Condition Habitat mapping Habitat mapping - polygons Habitat mapping Linears and Fence condition Invertebrate surveys Habitat Mapping, X & Y plots Habitat Mapping, X & Y plots Habitat mapping, X & Y plots Habitat mapping CONEFOR

for both juvenile and adult Bechstein's. Colony size and success is thought to be greatest when oak is the dominant woodland species (Greenaway, 2004). Roosting occurs within hollow, dead branches, rot holes or old woodpecker holes in old deciduous trees (Quine et al, 2004). The majority of roost trees have been found on the edge of the woodland close to open fields (Fitzsimons et al. 2002).			
Hedges that are similarly structured to favoured woodland (i.e tree lines) are particularly important as these provide connectivity between foraging areas (Palmer et al. 2013). Radio tracking projects in the UK have tracked individual bats foraging along hedgerows and in small woodland areas. Bats will follow hedgerows to access other woodland within a few hundred metres. Mature, large hedgerows are most favourable. Hedges should therefore be sympathetically managed and allowed to grow large if possible (Merrett 2012).	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land 2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land 3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m • New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; $\geq$ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthron • New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; $\geq$ 5 woody species • $\leq$ 25% native conifers	Habitat Mapping – linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots Habitat mapping - linears Linears & Fence condition B & D plots B & D plots

			B & D plots
	5 Enhanced Hedgerow Management On Both Sides	• WLF maintained at least 2m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Habitat mapping; B & D plots B & D plots
	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Linears & Fence condition Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness	D plots D plots
	43A/43B. Double Fence and Restore Hedge Banks <u>With</u>/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • <u>WLF connectivity</u> • <u>WLF – Woodland connectivity</u> • <u>Moth numbers</u> • <u>Hedge height ideally 3- 4m</u>	Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots CONEFOR CONEFOR Invertebrate surveys Linears & D plots

		• <u>Mature Double hedges</u>	Linears
Foraging woodland areas are normally associated with streams (Fitzsimons et al. 2002) and Bechstein's maternity roosts in the UK have been found to usually be located within 1km of a water body (Miller, 2012). Radio-tacked bats have been found to forage along tree lined rivers within close proximity to woodland (few hundred metres). This has been shown to benefit Bechstein's when commuting and foraging outside of woodland (Merrett 2012). A study by Palmer et al. (2013) found four roost trees lined along a small river and all were situated within 550m of woodland.	7A/B Create a streamside corridor on improved land on one/both side of a watercourse 9A/9B. Create a new streamside corridor on improved land with tree planting on one/both sides of a watercourse 8 Continued management of an existing streamside corridor 173. Streamside corridor management	• New stream side corridor on improved land • New stock proof fence adjacent to stream corridor • Removal of Japanese knotweed and Himalayan balsam • Fencing maintained to exclude stock • Removal of Japanese knotweed and Himalayan balsam No guidance • <u>Stream corridor –woodland connectivity</u> • <u>High species richness</u> • <u>Tall and wide corridors</u>	Habitat mapping – linears Linears & Fence condition B, D & S plots Linears & Fence condition B, D & S plots <u>CONEFOR</u> B, D & S plots Habitat mapping
Orchards found in close proximity to Bechstein bat woodland should be retained and positively managed for insects. This could be beneficial as male Bechstein's have been found at a wider range of sites, including small woodland. In addition, a male has been recorded in bat box on the edge of a small patch of orchard in Wiltshire (Merrett, 2012).	11 Restore a traditional orchard 12 Create a new orchard on improved land Option 172 - Orchard Management	• Area of new orchard adjacent to existing orchard • Tree protectors • Orchard grazing • Area of new orchard on improved land • Tree protectors • Varied sward -80% of grasses between 7cm & 20cm • 5-10% left uncut every year	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping, X & Y plots Habitat mapping

'Series of isolated trees, such as spreading willows, can be highly effective in slowing wind speeds and increasing insect availability' (Greenaway, 2005).	104 Wood pasture 13 Plant individual native trees on improved land 106 Historic parks and gardens	• Isolated trees on improved or grazed grassland • New wood pasture/isolated trees • Tree guards • Maintained grazing on grassland	Habitat mapping – points Habitat mapping Habitat mapping Habitat mapping
Unable to find evidence	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub 101 Trees and scrub -establishment by Planting / 102 Trees and scrub - establishment by natural regeneration 103 Scrub - stock exclusion	• New area of rough grassland and scrub in field corner (Max size 0.35ha) • New area of scrub in field corner • New length and location of stock proof • New area of trees and scrub • New length of stock proof fence • Existing area of scrub • New stock proof fencing around areas of scrub	Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition
Unable to find evidence	123 Lowland unimproved neutral grassland – pasture / 125 Lowland unimproved neutral grassland - reversion (pasture) 134 Lowland marshy grassland - reversion (pasture) / 133 Lowland marshy grassland	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm – 20cm • Sward height between 5cm – 20cm when not grazed by sheep • Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm	Habitat mapping Habitat mapping Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping, X, Y & U plots

Unable to find evidence	124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion (hay cutting) 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Grassland maintained by grazing and hay cutting • Between 5-10% left uncut each year • 80% of grasses between 5-15cm high after cutting • Grassland maintained by grazing and hay cutting • Between 5-10% left uncut each year • 80% of grasses between 5-15cm high after cutting • Fields shut off to livestock by 1 May	Habitat mapping Habitat mapping Habitat mapping; X & Y plot Habitat mapping Habitat mapping Habitat mapping; X ploy Habitat mapping
Unable to find evidence	405 Additional Management Payment - Grazing management for dung invertebrates	Minimal guidance – additional payment	

GREATER HORSESHOE BAT

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Ancient woodland is one of the key habitats for this species and has been proven to be valuable foraging habitat as well as being used key flight paths Requirement of prey items reflects the selection of favoured habitat i.e. cock chafers feed on deciduous tree leaves (Billington & Rawlinson, 2006). Wet woodland is also a major foraging habitat for lesser horseshoes as this habitat supports particularly diverse and high insect numbers (Entwistle, 2001).	100. Woodland - stock exclusion 24. Allow woodland edge to develop out into adjoining improved land	• Length of new stock-proof fencing bordering existing (deciduous) woodland • Stock excluded from woodland • Area of existing (deciduous) woodland • New area of scrub/woodland on improved land next to existing woodland • New length and location of stock proof fence • <u>Insect numbers (woodland)</u> • <u>Canopy closure/cover</u> • <u>Presence of wet woodland</u>	Linears & Fence Condition Habitat mapping Habitat mapping Habitat mapping Linears and Fence condition Invertebrate surveys Habitat Mapping, X & Y plots Habitat mapping
Tall, thick Woody linear features (WLF) at least 2m high are efficient at providing a linear feature with a large abundance of insect prey using just a small area of land. Furthermore they accumulate high concentrations of insects during high winds (Longley, 2003; Ransome & Hutson, 2000). Thick hedgerows or scrub adjacent to cattle grazed pasture are also highly suitability for greater horseshoe bats as manure provides one of main source of food – dung beetles (Billington & Rawlinson, 2006). Greater horseshoes primarily forage along the edge of tree lines, woodland edges and hedgerows (Longley, 2003). For the conservation of greater horseshoes, Natural England (2003) advise that tree lines and	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land 2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m • New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots Habitat mapping – linears Habitat mapping; B & D plots

hedges are planted across large, open areas of permanent pasture to help create smaller fields which are well linked with existing hedges and woodland blocks to improve flight path connectivity. Hedges should be broad, ideally 3-6m across and 3m high to provide sheltered flight paths before dark. Finally, young saplings should be left in hedges to provide shelter and feeding perches.		• New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; ≥ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthron	Linears & Fence condition Habitat mapping – linears B & D plots B & D plots
	3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; ≥ 5 woody species • ≤ 25% native conifers	Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots
	5 Enhanced Hedgerow Management On Both Sides	• WLF maintained at least 2m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Habitat mapping; B & D plots B & D plots
	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Linears & Fence condition Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness	D plots D plots

	43A/43B. Double Fence and Restore Hedge Banks <u>With</u>/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • <u>WLF connectivity</u> • <u>WLF – Woodland block connectivity</u> • <u>Hedge height: >2m</u> • <u>Hedge width: >3m</u> • <u>Mature hedgerows adjacent to cattle grazed pasture</u> • <u>Invertebrate numbers (WLF)</u>	Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots CONEFOR CONEFOR Linears & D plots Linears & D plots Habitat mapping Invertebrate surveys?
Greater horseshoes prefer to fly close to scrambling tall-herb and scrub. River and stream corridors are key flight paths used for commuting and navigation (Entwistle et al, 2001; Billington and Rawlinson, 2006).	7A/B Create a streamside corridor on improved land on one/both side of a watercourse 9A/9B. Create a new streamside corridor on improved land with tree planting on one/both sides of a watercourse 8 Continued management of an existing streamside corridor 173. Streamside corridor management	• New stream side corridor on improved land • New stock proof fence adjacent to stream corridor • Removal of Japanese knotweed and Himalayan balsam • Fencing maintained to exclude stock • Removal of Japanese knotweed and Himalayan balsam No guidance • <u>Stream corridor connectivity</u>	Habitat mapping – linears Linears & Fence condition B, D & S plots Linears & Fence condition B, D & S plots CONEFOR

		• Stream corridor – roost connectivity • Tall and wide corridors	CONEFOR Habitat mapping
'Freshwater is important for drinking and foraging. New ponds and pond complexes created for bats should be located in areas near to, or with good connectivity to, other important habitats for bats, such as woodlands, river corridors and wetlands.' (Pond Conservation, 2011). Pond conservation (2011) suggest ponds should be located within 1km woodland, river corridors, hedgerows and tree-lines.	35 Create a wildlife pond on enclosed improved land 35B Create a wildlife pond on enclosed improved land – variable size 36 Buffer existing unfenced in-field ponds	No guidance • New Ponds with an area > 25m^2 and < 1000m^2 • Stock proof fenced >10m from pond edge • New area of rough grass around pond >10m from pond edge • New stock proof fencing around existing ponds • Ponds within 1km from Woodlands, hedges and Stream/river corridors	 Habitat mapping Linears and Fence condition Habitat mapping & Y plots Habitat mapping - linears Habitat mapping
Old orchards (mature fruit trees) with a grazed understory can be used a hunting area by greater horseshoes particularly if use of pesticides are avoided (English Nature, 2003). Retaining old orchards, particularly adjacent to grazed pasture is beneficial as this provides additional foraging opportunities (Entwistle, 2001).	11 Restore a traditional orchard 12 Create a new orchard on improved land Option 172 - Orchard Management	• Area of new orchard adjacent to existing orchard • Tree protectors • Orchard grazing • Area of new orchard on improved land • Tree protectors • Varied sward -80% of grasses between 7cm & 20cm • 5-10% left uncut every year • Old orchards - tree maturity • Orchards adjacent to grazed pasture	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping, X & Y plots Habitat mapping Habitat mapping Habitat mapping

'Series of isolated trees, such as spreading willows, can be highly effective in slowing wind speeds and increasing insect availability' (Greenaway, 2004).	104 Wood pasture 13 Plant individual native trees on improved land 106 Historic parks and gardens	• Isolated trees on improved or grazed grassland • New wood pasture/isolated trees • Tree guards • Maintained grazing on grassland	Habitat mapping – points Habitat mapping Habitat mapping Habitat mapping
Field margins helps to provide a buffer against pesticide spray drift. Adding margin to arable land also helps to increase insect availability (Entwistle et al, 2001). This is particularly useful when arable margins are situated next to hedgerows (English Nature, 2003).	26 Fixed rough grass margins on arable land 26B Rotational rough grass margin on arable land 174 Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	• New rough grass margin • Width of 2-8m on arable land • No grazing once established • Mix of tussock forming grasses • Cannot be rotated • New rough grass margin adjacent to cereal, rape, linseed or root crop • Between 2-8m wide • Mix of tussock forming grasses • No grazing once established • Can be rotated • New rough grass margin on arable land • Livestock excluded	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping
Light grazing has little effect on moth biomass and so should be encouraged to maintain vegetation structure, arrest succession and foster species-rich grassland. Old established unfertilised grasslands and water meadows are naturally highly productive of insect biomass (Greenway, 2004). Cattle dung is used by the Night-flying Dung beetle (*Aphodius rufipes)* to lay eggs, as well as being a food source for the adults. *Aphodius rufipes* is key prey item for lactating females and juveniles. Hence cattle grazed pasture is a valuable foraging habitat for greater	15 Grazed permanent pasture with no inputs. / 15C Grazed permanent pasture with no inputs and mixed grazing Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture)	• Permanent pasture maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm • Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & U plots

horseshoe bats (Billington & Rawlison, 2006; Bat Conservation Trust, 2010). A mosaic of grazed permanent pasture and botanically diverse pasture helps to promote high densities of insects. This coupled with an abundance of tall bushy hedges, is the ideal habitat for greater horseshoe bats (English Nature, 2003)	123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture) 128 Lowland unimproved calcareous grassland / 129 Lowland unimproved calcareous grassland - reversion (pasture) 131 Conversion from arable to grassland (no inputs) 133 Lowland marshy grassland / 134 Lowland marshy grassland; reversion (pasture)	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep • Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm • Area of new grassland • Grassland grazed once established • Sward height at least 5cm • Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm • <u>Numbers of dung beetles particularly Aphodius rufipes</u> • <u>Permanent pasture bordered by mature hedges</u> • <u>Cattle grazed pasture</u>	Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping Habitat mapping, X plot Habitat mapping Habitat mapping, X, U & Y plots Invertebrate Survey Habitat mapping Habitat mapping
Hay meadows provide good foraging areas for preying on insects during the summer. Leaving an uncut area allows more invertebrates to survive once the hay is cut. Furthermore, grazing after a cut benefits invertebrates as they create patches of bare or disturbed ground with dung (Bug life, n.d; Vincent wildlife trust, 2014)	22 Existing hay meadows	• Field shut off from livestock before 15 May and closed for at least 10 weeks • Aftermath sward height - 80% of the grasses between 5- 15cm high • Grassland maintained by grazing and hay cutting	Habitat mapping Habitat mapping; X & Y plots Habitat mapping

	122 Lowland unimproved acid grassland - reversion (hay cutting) / 124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion (hay cutting) / 130 Lowland unimproved calcareous grassland - reversion (hay cutting) / 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Field shut off from livestock by 1 May every year • Between 5%-10% left uncut • Aftermath sward height - 80% of the grasses between 5- 15cm high	Habitat mapping Habitat mapping Habitat mapping; X & Y plots
Wetland supports insect rich feeding habitat. An abundance of insect prey key for the survival of greater horseshoe bats. As such, loss of feeding areas is often due to loss of wetlands and hedges and conversion to arable land (Townsend, 2005). Marshy grassland should be retained as this habitat supports good populations of preferred insects such as crane fly (English Nature, 2003).	19 Lowland marshy grassland 19B Management of lowland marshy grassland with mixed grazing Option 143 - Lowland fen / 145 Lowland fen; reversion (pasture)	• Sward height (excluding rushes) between 5-30cm on enclosed land • Mixed grazing • Sward height (excluding rushes) between 5-30cm on enclosed land • Grazing on Lowland fen • Sward height between 10cm-80cm (except patches of moss)	Habitat mapping, X, Y & U plots Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping Habitat mapping, X & Y plots
Unable to find evidence	20. Management of Coastal and Lowland Heath / 20B. Management of Coastal and Lowland Heath With Mixed Grazing	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • ≥25% dwarf-shrub species on coastal heath • ≤25% of heath burnt over 5 years	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping
Unable to find evidence	33 Establish a wildlife cover crop on improved land	• On improved land only • 4m wide seed bed established for crop • Crop cover to be at least 80% cereals with at least one of the following; mustard, rape or linseed.	Habitat mapping Habitat mapping Habitat mapping; A & M plot

		• No maize	Habitat mapping
Unable to find evidence	Option 148 - Coastal grassland (maritime cliff and slope)	• Grassland maintained by grazing • Varied sward height	Habitat mapping
Unable to find evidence	46 - Reedbed; stock exclusion 147 - Reedbed; creation	• New stock proof fencing around reedbed • New area of reedbed	Linears and Fence condition Habitat mapping
Unable to find evidence	149 - Saltmarsh; restoration (no grazing) 150 - Saltmarsh; creation	• Livestock exclusion on existing marsh	Habitat mapping
Unable to find evidence	153 - Red clover ley	• 80% of sward is red clover	Habitat mapping, X plot
Unable to find evidence	175 Management of rough grassland; enclosed land	• Minimal or no scrub • At least 75% of grasses >20cm high	Habitat mapping, X plots Habitat mapping, X plots
Unable to find evidence	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub 101. Trees and scrub - establishment by Planting 102. Trees and scrub - establishment by natural regeneration 103 Scrub - stock exclusion	• New area of rough grassland and scrub in field corner (Max size 0.35ha) • New length and location of stock proof • New area of trees and scrub • New length of stock proof fence • Existing area of scrub • New stock proof fencing around areas of scrub	Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition
Unable to find evidence	31 Unsprayed spring sown cereals retaining winter stubbles 115 Lowland dry heath with less than 50% western gorse / 116 Lowland dry heath with more than 50% western gorse	Minimal guidance	

	117 Lowland wet heath with less than 60% purple moor- grass / 118 Lowland wet heath with more than 60% purple moor-grass 119 Lowland heath habitat expansion - establishment on grassland 139 Lowland bog and other acid mires with less than 50% purple moor-grass 140 Lowland bog and other acid mires with more than 50% purple moor-grass 141 Lowland bog and other acid mires - restoration (no grazing) 142 Lowland bog and other acid mires - reversion (pasture)		

LEESER HORSESHOE BAT			
Evidence obtained from Literature	**Target Species and Glastir Measures**	**Specific Response Variables**	**GMEP Survey Data That Captures Measure or Target**
Studies of Lesser Horseshoe maternity roosts found that their roosts are chosen on basis of well-connected foraging area. Whilst blocks of mixed woodland are highly selected, hedgerows and tree lines were also important as these provided connectivity to the maternity roost and other foraging areas (Knight, 2006; Motte & Libois, 2002; Schofield, 1996). Woodland edges can act as shelter from the wind, thus reducing wind speeds. Not only does this aid economical hunting flight but edges also accumulate high concentrations of insects (Billington & Rawlinson 2006). Lesser horseshoe bats echolocation method suggests the species prefers to forage close to cluttered habitats (Billington & Rawlinson, 2006; Bontadina et al. 2002; Schofield, 1996). Numerous radio-tracking studies have shown that mixed broadleaved woodland and woodland edges are the preferred foraging habitat for this species (Knight, 2006; Motte & Libois, 2002; Schofield, 1996). Foraging by lesser horseshoes has been observed foraging in dense vegetation such as canopy of hawthorn or hazel trees, or close to the canopy of trees or hedgerows (Schofield, 1996). It is thought oak, ash, hawthorn and hazel are the main deciduous woodland species used by lesser horseshoes as sources of insect prey from (Motte & Libois, 2002; Schofield 1996). As such, protecting understorey from stock grazing protects insect availability.	100. Woodland - stock exclusion 24. Allow woodland edge to develop out into adjoining improved land	• Length of new stock-proof fencing bordering existing (mixed deciduous) woodland • Stock excluded from woodland • Area of existing (mixed deciduous) woodland • New area of scrub/woodland on improved land next to existing woodland • New length and location of stock proof fence • <u>% cover of shrub in deciduous woodland</u> • <u>% cover of oak & ash in deciduous woodland</u> • <u>Insect numbers (woodland)</u> • <u>Presence of wet woodland</u>	Linears & Fence Condition Habitat mapping Habitat mapping - polygons Habitat mapping Linears and Fence condition X & Y plots Habitat mapping, X & Y plots Invertebrate surveys Habitat mapping

Wet woodland is a foraging habitat also used by lesser horseshoes as this habitat supports particularly diverse and high insect numbers (Entwistle et al. 2001; Schofield & Bontadina, 1999).			
Lesser horseshoe bats actively avoid open areas and instead rely on woody linear features lines (WLF) to move between roosts and woodland feeding areas. Studies of lesser horseshoe maternity roosts found that their roosts are chosen on basis of well-connected foraging area. Whilst blocks of mixed woodland are highly selected, hedgerows and tree lines were also important as these provided connectivity to the maternity roost and other foraging areas. These woody features and appropriate herbaceous vegetation were foraged within 2-3 km of the maternity roost (Knight, 2006; Motte & Libois, 2002; Schofield, 1996). In uplands and lowland, tall unmanaged hedges adjacent to semi or unimproved wet pasture fields, improved damp or wet ground are of greater significance when within 1-3km from roost (Billington & Rawlinson, 2006; Knight 2006; Schofield, 1996). Linear features not only important for connectivity and foraging, but are also important for predator avoidance (Schofield, 1996). Studies by Knight (2006) and Schofield (1996) found Improved fields with tall unkempt hedges on one or more sides of the boundaries were significantly selected for when foraging. Hedges also act as shelters from the wind, reducing wind speeds which aids economical hunting flight, as well as being able to accumulate high concentrations of insects (Billington & Rawlinson 2006). Managed hedges have also been found to be used by lesser horseshoe bats mainly for	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land 2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land 3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m • New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; $\geq$ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthorn • New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; $\geq$ 5 woody species • $\leq$ 25% native conifers	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots

commuting, albeit at a low level (Knight, 2006; Schofield, 1996).	5 Enhanced Hedgerow Management On Both Sides	• WLF maintained at least 2m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Habitat mapping; B & D plots B & D plots
	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Linears & Fence condition Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness	D plots D plots
	43A/43B. Double Fence and Restore Hedge Banks With/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots
		• WLF connectivity • WLF – Woodland connectivity – • Insects numbers (WLF's) • WLF's bordering wet pastures	CONEFOR CONEFOR Invertebrate survey? Habitat mapping

‘Vegetated streams banks and bank side trees are used to move between roosts and woodland feeding areas as these provide connectivity (Billington & Rawlinson, 2006). Numerous studies have shown that lesser horseshoes forage and commute along structurally diverse vegetated riparian strips and river bank edges. However these habitat features are least selected for when there is woodland within the foraging areas (Bontadina et al. 2002; Motte & Libois, 2002).	7A/B Create a streamside corridor on improved land on one/both side of a watercourse 9A/9B. Create a new streamside corridor on improved land with tree planting on one/both sides of a watercourse 8 Continued management of an existing streamside corridor 173. Streamside corridor management	• New stream side corridor on improved land • New stock proof fence adjacent to stream corridor • Removal of Japanese knotweed and Himalayan balsam • Fencing maintained to exclude stock • Removal of Japanese knotweed and Himalayan balsam No guidance • Stream corridor connectivity • Stream corridor – woodland connectivity • Species rich • Structural diversity	Habitat mapping – linears Linears & Fence condition B, D & S plots Linears & Fence condition B, D & S plots CONEFOR CONEFOR S & P plots S & P plots
‘Freshwater is important for drinking and foraging. New ponds and pond complexes created for bats should be located in areas near to, or with good connectivity to other important habitats for bats, such as woodlands, river corridors and wetlands.’ (Pond Conservation, 2011). Pond conservation (2011) suggests ponds should be located within 1km woodland, river corridors, hedgerows and tree-lines.	35 Create a wildlife pond on enclosed improved land 35B Create a wildlife pond on enclosed improved land – variable size 36 Buffer existing unfenced in-field ponds	No guidance • New Ponds with an area > 25m^2 and < 1000m^2 • Stock proof fenced ≥10m from pond edge • New area of rough grass around pond ≥10m from pond edge • New stock proof fencing around existing ponds • Ponds within 1km from Woodlands, hedges and Stream/river corridors	Habitat mapping Linears and Fence condition Habitat mapping & Y plots Habitat mapping - linears Habitat mapping

Management practises recommended by Knight (2006) & Entwistle et al. (2001) suggest that old orchards should be retained as these provide additional feeding opportunities.	11 Restore a traditional orchard 12 Create a new orchard on improved land Option 172 - Orchard Management	• Area of new orchard adjacent to existing orchard • Tree protectors • Orchard grazing • Area of new orchard on improved land • Tree protectors • Varied sward -80% of grasses between 7cm & 20cm • 5-10% left uncut every year	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping, X & Y plots Habitat mapping
'Series of isolated trees, such as spreading willows, can be highly effective in slowing wind speeds and increasing insect availability' (Greenaway, 2004).	104 Wood pasture 13 Plant individual native trees on improved land 106 Historic parks and gardens	• Isolated trees on improved or grazed grassland • New wood pasture/isolated trees • Tree guards • Maintained grazing on grassland	Habitat mapping – points Habitat mapping Habitat mapping Habitat mapping
Light grazing has little effect on moth biomass and should be encouraged to maintain vegetation structure, species richness and arrest succession. Old established unfertilised grasslands and water meadows are naturally highly productive of insect biomass (Greenway, 2004). A study of lesser horseshoe bats found pastures were the preferred foraging habitat compared to arable fields. It is therefore suggested that permanent pasture is retained or created within the near vicinity of a roost, particularly if associated with woodyland (Knight, 2006).	15 Grazed permanent pasture with no inputs / 15C Grazed permanent pasture with no inputs and mixed grazing 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture) 123. Lowland unimproved neutral grassland – pasture / 125. Lowland	• Permanent pasture maintained • Grazing/ Mixed grazing • Grassland maintained by grazing • 75% grasses and herbs between 3cm-20cm in height between May and September • Grassland maintained by grazing	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping;

	unimproved neutral grassland - reversion (pasture) 128 - Lowland unimproved calcareous grassland / 129. Lowland unimproved calcareous grassland - reversion (pasture) 131 - Conversion from arable to grassland (no inputs) 133 - Lowland marshy grassland / 134 Lowland marshy grassland; reversion (pasture)	• In sheep grazed areas, varied sward height maintained between 10cm – 20cm • In none sheep grazed areas, varied sward height maintained between 5cm – 20cm • Grassland maintained by grazing • 75% grasses and herbs between 3cm-50cm in height between May and September • Establishment of new grassland • Grassland maintained by grazing • Sward height at least 5cm • Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm • <u>Pasture associated with hedges and/ or woodland</u>	Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping Habitat mapping; X plots Habitat mapping Habitat mapping, X, U & Y plots Habitat mapping
Field margins helps to provide a buffer against pesticide spray drift. Adding margin to arable land also helps to increase insect availability (Entwistle et al, 2001), particularly arable margins which are situated next to hedgerows (English Nature, 2003).	26 Fixed rough grass margins on arable land 26B Rotational rough grass margin on arable land	• New rough grass margin • Width of 2-8m on arable land • No grazing once established • Mix of tussock forming grasses • Cannot be rotated • New rough grass margin adjacent to cereal, rape, linseed or root crop • Between 2-8m wide • Mix of tussock forming grasses	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping

	174 Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	• No grazing once established • Can be rotated • New rough grass margin on arable land • Livestock excluded	Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping
Well-developed field boundaries such as areas of trees and scrub can provide links between roosts and foraging areas provided they are connected to a network of hedges and woodland (Billington & Rawlinson, 2006). Scrub and overhanding vegetation also provides a source of insects for foraging bats (Entwistle, 2001).	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub 101 Trees and scrub - establishment by Planting / 102 Trees and scrub - establishment by natural regeneration 103 Scrub - stock exclusion	• New area of rough grassland and scrub in field corner (Max size 0.35ha) • New length and location of stock proof • New area of trees and scrub • New length of stock proof fence • Existing area of scrub • New stock proof fencing around areas of scrub • <u>Scrub/tree connectivity to hedges and woodland</u>	Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition
Unable to find evidence	22 Existing hay meadows	• Field shut off from livestock before 15 May and closed for at least 10 weeks • Aftermath sward height - 80% of the grasses between 5- 15cm high	Habitat mapping Habitat mapping; X & Y plots
Unable to find evidence	Option 143 - Lowland fen / 145 – Lowland fen; reversion (pasture)	• Grazing on Lowland fen • Sward height between 10cm-80cm (except patches of moss)	Habitat mapping Habitat mapping, X & U plots
Unable to find evidence	146 - Reedbed; stock exclusion 147 - Reedbed; creation	• New stock proof fencing around reedbed • New area of reedbed	Linears and Fence condition Habitat mapping

Unable to find evidence	21. Management of grazed saltmarsh 21B. Management of grazed saltmarsh with mixed grazing 149. Saltmarsh; restoration (no grazing) 150. Saltmarsh; creation	• Saltmarsh grazing by cattle, sheep, goats or ponies • Saltmarsh grazing by cattle, sheep, goats or ponies • Livestock exclusion on existing marsh • Area of new saltmarsh	Habitat mapping Habitat mapping Habitat mapping Habitat mapping
Unable to find evidence	153 - Red clover ley	• 80% of sward is red clover	Habitat mapping, X plot
Unable to find evidence	175 Management of rough grassland; enclosed land	• Minimal or no scrub • At least 75% of grasses >20cm high	Habitat mapping, X plots Habitat mapping, X plots
Unable to find evidence	20. Management of Coastal and Lowland Heath / 20B. Management of Coastal and Lowland Heath With Mixed Grazing	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • ≥ 25% dwarf-shrub species on coastal heath • ≤25% of heath burnt over 5 years	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping
Unable to find evidence	19 Lowland marshy grassland 19B Management of lowland marshy grassland with mixed grazing	• Sward height (excluding rushes) between 5-30cm on enclosed land • Sheep & Cattle grazing on marshy grs (enclosed land) • Sward height (excluding rushes) between 5-30cm on enclosed land	Habitat mapping, X, Y & u plots Habitat mapping Habitat mapping, X, Y & u plots
Unable to find evidence	31 Unsprayed spring sown cereals retaining winter stubbles	• On improved land only • Natural regeneration of grass and broadleaved plants after harvest • No grazing between harvest and 1st January	Habitat mapping A & M plots Habitat mapping Unlikely to be mapped

		• Can be rotated	
Unable to find evidence	115 Lowland dry heath with less than 50% western gorse / 116 Lowland dry heath with more than 50% western gorse 117 Lowland wet heath with less than 60% purple moor- grass / 118 Lowland wet heath with more than 60% purple moor-grass 119 Lowland heath habitat expansion - establishment on grassland 139 Lowland bog and other acid mires with less than 50% purple moor-grass 140 Lowland bog and other acid mires with more than 50% purple moor-grass 141 Lowland bog and other acid mires - restoration (no grazing) 142 Lowland bog and other acid mires - reversion (pasture)	Minimal guidance	

DORMOUSE			
Evidence obtained from Literature	**Target Species and Glastir Measures**	**Specific Response Variables**	**GMEP Survey Data That Captures Measure or Target**
Dormice are highly arboreal (Bright, 1998) and are largely associated with diverse deciduous woodland and scrub with a diverse and abundant understorey. It is therefore important that dormice can freely move from tree to tree and tree to understory without having to go to the ground (Bright et al. 2006). Dormouse abundance is often highest in mid-aged coppice, 6–10 years of re-growth (Bright and Morris, 1990). Best canopy trees are oaks with hazel and bramble providing the best understory providing they are not too heavily shading to prevent fruiting. The larger the woodland size, the higher the possibility of dormouse being present within a woodland, particularly if over 50ha in size (Bright et al, 2006). Coppice woodland is thought to be optimal habitat for dormice as this provides glades of open canopy, re-growth and a places to hibernate after an arboreal summer. Cessation of coppicing is thought to be one of the reasons for dormouse population decline as this ultimately results in suppression of re-growth in the understory due to heavy shading (Bright and Morris, 1990; Bright et al, 2006). Dormouse feed on largely ephemeral food sources i.e. tree/shrub flowers, fruits and phytophagous insects. Hazel is the principle food source providing insects and hazel nuts, used to fatten up dormice for hibernation. However, different species provide different food source throughout the year, therefore dormice require a large variety of tree and shrub species to provide	100. Woodland - stock exclusion 24. Allow woodland edge to develop out into adjoining improved land	• Length of new stock-proof fencing bordering existing (deciduous) woodland • Stock excluded from woodland • Area of existing deciduous woodland • Area of new scrub/woodland on improved land next to existing woodland • New length and location of stock proof fence • <u>% oak – canopy</u> • <u>% hazel and bramble – understory</u> • <u>Woodland (deciduous& coniferous) between 20ha and >50ha</u> • <u>Coppice woodland</u> • <u>Species rich</u>	Linears & Fence Condition Habitat mapping Habitat mapping - polygons Habitat mapping Linears and Fence condition Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping

them with a continuous food supply throughout the year. Trees of value include hornbeam, yew, ash, sycamore, oak, wayfairing tree, birch, sweet chestnut, birch, blackthorn and hawthorn. Shrubs of value include bramble, broom and honeysuckle (Bright & Morris, 1990; Bright et al, 2006). Browsing by stock suppresses vegetation regeneration and fruiting, stock should therefore be excluded from woodland with dormice to ensure sufficient food sources (Forest research, 2007; Bright et al. 2006).			
Woody linear features (WLF) may be important in facilitating dispersal between woodlands and maintaining the integrity of dormouse (meta) populations, particularly in small, fragmented habitats (Bright, 1998). Dormice are known to breed and nest in species rich hedges, particularly where they provide connectively to large woodlands (Bright et al. 2006; Hedgelink n.d). Connectivity is key as well connected hedges, woodland and patches of scrub facilitate movement through the landscape and also allows adults to forage and nest with ease (Hedgelink, n.d). Shrub diversity is linked to dormouse abundance, as such, hedgerows need to species rich particularly as dormice tend to travel less than 70m from their nests and need a diverse and constant food source throughout the seasons (Bright et al. 2006). Dormouse shown to be averse to crossing gaps (even narrow 1m-3m gaps) in hedgerows and gaps in hedges likely to constrain movement (Bright, 1998). Hedges need to be thick and wide to provide habitat connections. Laying, coppicing and the use of fencing to prevent stock damage seen as best management practise to restore hedges for gappy hedges for dormice (Bright et al. 2006).	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land 2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land 3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m • New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; $\geq$ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthorn • New WLF on improved land • WLF between 5-15m wide • New stock proof fencing	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots Habitat mapping - linears Linears & Fence condition B & D plots

As part of good hedgerow management, Bright et al. (2006) suggest hedges should be maintained at a height of 3m, but probably 4m.		• Species richness ; $\geq$ 5 woody species	B & D plots
		• $\leq$ 25% native conifers	B & D plots
	5 Enhanced Hedgerow Management On Both Sides	• WLF maintained at least 2m high and 1.5m wide	Habitat mapping; B & D plots
		• Hedgerow saplings/trees at intervals of 20-70m	B & D plots
	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New stock proof, double fencing around existing hedges	Linears & Fence condition
		• New margin between hedge and fence	Habitat mapping - Linears
		• Decrease in vertical gappiness	B & D plots
		• WLF maintained at least 1.5m high and 1.5m wide	Habitat mapping; B & D plots
		• Hedgerow saplings/trees at intervals of 20-70m	B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m	D plots
		• Decrease in vertical gappiness	D plots
	43A/43B. Double Fence and Restore Hedge Banks <u>With</u>/without Planting	• New stock proof, double fencing around existing hedges	Linears & Fence condition
		• New margin between hedge and fence	Habitat mapping - Linears
		• Decrease in vertical gappiness	Habitat mapping - Linears
		• WLF restored to a minimum of 0.5m high and 0.5m wide	Habitat mapping; B & D plots
		• Hedgerow saplings/trees at intervals of 20-70m	B & D plots
		• <u>WLF connectivity</u>	CONEFOR

		• WLF – Woodland Connectivity • % Hazel • % Bramble, honeysuckle, blackthorn, hawthorn & broom • WLF height 3m-4m	CONEFOR Habitat mapping; B & D plots Habitat mapping; B & D plots Habitat mapping
Scrub, being made up of woody species is a favourable habitat of dormice. Scrub can allow dormice to inhabit small areas of Ancient woodland and PAWS sites as they provide connectivity. Young growth stands are considered good habitat for dormice, particularly if species rich. The long term aim is for scrub to develop into woodland which is largely achieved by removing access to grazing stock (Bright et al, 2006).	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub 101 Trees and scrub - establishment by Planting / 102 Trees and scrub - establishment by natural regeneration 103 Scrub - stock exclusion	• New area of rough grassland and scrub in field corner (Max size 0.35ha) • New length and location of stock proof • New area of trees and scrub • New length of stock proof fence • New stock proof fencing around existing areas of scrub • Scrub – WLF connectivity • Scrub – woodland connectivity	Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition Habitat mapping CONEFOR CONEFOR

GREAT CRESTED NEWT

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Great crested newts (GCN) prefer deciduous woodland with vegetated or shrubby ground cover and a considerable amount of leaf litter. Dead wood is also valuable as this provides a refuge in hot/dry conditions or when overwintering and foraging outside of breeding season. (Malmgren, 2002; Mullner, 2001). Deciduous woodland appears to support higher densities of newts compared to coniferous woodland (Langton et al. 2001). Numerous studies have shown that GCN have a preference for moving to woodland when leaving a close-by pond in the summer (Malmgren, 2002; Mullner, 2001). The value of woodland is maximised when it occurs together as a mosaic with semi-natural grassland and ponds (Langton et al, 2001).	100. Woodland - stock exclusion 24. Allow woodland edge to develop out into adjoining improved land	• Length of new stock-proof fencing bordering existing (deciduous) woodland • Stock excluded from woodland • Area of existing (deciduous) woodland • Area of new woodland on improved land • New length and location of stock proof fence • <u>Pond-Woodland connectivity</u> • <u>Pond, woodland, grassland mosaic</u> • <u>Woodland litter</u> • <u>Woodland understory cover</u>	Linears & Fence Condition Habitat mapping Habitat mapping - polygons Habitat mapping Linears and Fence condition Habitat mapping Habitat mapping X & Y plots X & Y plots
'Hedges provide additional foraging and dispersal habitat, particularly on agricultural intensive land. Hedge banks also increase the surface area of land, provide a sheltered microclimate, and often have mammal burrows that newts may share.' (Langton et al, 2001). A study by Joly et al. (2001) found a negative relationship between hedgerow length and newt abundance thus suggesting hedgerows do not provide a substitute for terrestrial habitat. Instead, hedges act as corridors between ponds providing additional foraging and dispersal habitat particularly on agricultural intensive land (Langton et al, 2001).	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land 2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m • New earth bank at least 0.75m high and 0.75m wide	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots Habitat mapping – linears Habitat mapping; B & D plots

	3 Create a wildlife corridor – established woody strip Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing 42B. Hedgerow restoration without fencing 43A/43B. Double Fence and Restore Hedge Banks <u>With</u>/without Planting	• WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; ≥ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthorn • New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; ≥ 5 woody species • ≤ 25% native conifers • New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m • Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness • New stock proof, double fencing around existing hedges	Linears & Fence condition Habitat mapping – linears B & D plots B & D plots Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots Linears & Fence condition Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots D plots D plots Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots

		• New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • <u>WLF adjacent to rough grassland</u> • <u>Pond-Rough grassland -WLF – Woodland connectivity</u>	B & D plots Habitat mapping Habitat mapping
Great crested newts mainly rely on ponds for breeding, although slow-running streams may be used (Forestry commission, 2013; Edgar & Bird, 2006). River banks/riparian strips can be used as habitat corridors between ponds, thus providing connectivity through the landscape, and preventing isolation of metapopulations (Langton et al. 2001).	7A/B Create a streamside corridor on improved land on one/both side of a watercourse 9A/9B. Create a new streamside corridor on improved land with tree planting on one/both sides of a watercourse 8 Continued management of an existing streamside corridor 173. Streamside corridor management	• New stream side corridor on improved land • New stock proof fence adjacent to stream corridor • Removal of Japanese knotweed and Himalayan balsam • Fencing maintained to exclude stock • Removal of Japanese knotweed and Himalayan balsam No guidance	Habitat mapping – linears Linears & Fence condition B, D & S plots Linears & Fence condition B, D & S plots
Ponds are essential for most newts as pond is where they congregate more or less every year for breeding (Mullner, 2001). Courtship and display by adult newts happens in open pond margins. Egg larvae are laid on floating and submerged marginal vegetation, and larvae develop and feed for invertebrates in all zones of the pond (Langton et al. 2001). The closer the new pond is from an existing colonised pond (ideally <500m), the more likely a new pond will be colonised (Langton et al. 2001; Oldham et al. 2000). Optimum pond size is between 500 and 750m^2 (Oldham	35 Create a wildlife pond on enclosed improved land 35B Create a wildlife pond on enclosed improved land – variable size 36 Buffer existing unfenced in-field ponds	No guidance • New Ponds with an area > 25m^2 and < 1000m^2 • Stock proof fenced $\geq$10m from pond edge • New area of rough grass around pond $\geq$10m from pond edge	 Habitat mapping Linears and Fence condition Habitat mapping & Y plots Habitat mapping - linears

et al. 2000). Key feature of pastoral farmland to provide best chance for GCN is that inter-pond distances should low (Langton et al. 2001). Great crested newt exhibit metapopulation dynamics. Good terrestrial habitat (i.e. rough grassland) which allows newts to readily disperse, particularly to surrounding pond is essential to ensure genetic diversity (Oldham et al. 2000; Wright, 2007). Good quality habitat around a new pond (allowed to development as result of fencing) also gives newts a choice of direction when leaving the water (Langton et al. 2001). Water bodies which support submerged and emergent vegetation as well as an abundant and diverse invertebrate community (i.e. may fly larvae and water shrimp) are seen to be of good quality for GCN larvae (Oldham et al. 2000).		• New stock proof fencing around existing ponds • <u>Pond-pond distance (<500m)</u> • <u>Pond-Rough grassland -WLF – Woodland- Connectivity</u> • <u>Ideal Pond size; 500 - 750m^2</u> • <u>Presence of submerged & emergent macrophytes around pond edge</u> • <u>Good water quality</u> • <u>No pond fish</u> • <u>Pond Invertebrates</u>	 Habitat mapping Habitat mapping Habitat mapping RHS survey RHS survey RHS survey RHS survey
Arable land imposes foraging and distribution restrictions due to use of pesticide use and intensive farming practises such as ploughing and harrowing. However, rough grassland with dense tussocks provide areas for movement, cover and food (Langton et al, 2001). Grass margins increase floral diversity and therefore enhance insect prey (Wright, 2007). Rough grass buffers can also help to protect watercourses and ponds from the effects of run-off and spray drift (Wright, 2007). Threats to GCN include eutrophication of ponds (Edgar & bird, 2006). Rough grass buffers can help to protect watercourses and ponds from the effects of run-off and spray drift (Wright, 2007). Natural England is currently funding research on the use of buffer strips in their agri-scheme. Whilst buffers could provide cover/foraging areas for newts around edges of fields and connectivity, there management timing is an issue,	26 Fixed rough grass margins on arable land 26B Rotational rough grass margin on arable land 27 Fallow margins	• New rough grass margin • Width of 2-8m on arable land • No grazing once established • Mix of tussock forming grasses • Cannot be rotated • New rough grass margin adjacent to cereal, rape, linseed or root crop • Between 2-8m wide • Mix of tussock forming grasses • No grazing once established • Can be rotated • New fallow crop margin adjacent to cereals, oil seed rape, linseed, maize or roots • Between 2-8m wide	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Unlikely to be measured

particularly if buffer zones are rotational and not permanent (Liz Howe Pers. comm).		• Can be rotated • <u>Pond – rough grass connectivity</u> • <u>Tussocky vegetation</u> • <u>Vegetation height</u>	 Habitat mapping Habitat mapping; A or M plot Habitat mapping; A or M plot
Good terrestrial habitat (i.e. rough grassland) which allows newts to readily disperse, particularly to surrounding ponds is essential to ensure genetic diversity (Oldham et al. 2000; Wright, 2007). Adults usually occupied surrounding habitat within 250-500m of ponds (Edgar & Bird, 2006; Langton et al. 2001). Grassland management should aim to provide floristically-rich, invertebrate-rich and structurally varied habitat. To be maintained as grassland the sward needs to be cut or lightly grazed at least annually (Langton et al. 2001). Permanent rough/rank (especially tussocky) grassland is particularly suitable as this provides refuge throughout the year (Edgar & Bird, 2006; Langton et al. 2001)	15 Grazed permanent pasture with no inputs. / 15C Grazed permanent pasture with no inputs and mixed grazing Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture) 123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture) 128 Lowland unimproved calcareous grassland / 129 Lowland unimproved calcareous grassland - reversion (pasture) 131 Conversion from arable to grassland (no inputs)	• Permanent pasture maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm • Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm • Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep • Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm • Area of new grassland • Grassland grazed once established • Sward height at least 5cm	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping Habitat mapping, X plot

	133 Lowland marshy grassland / 134 Lowland marshy grassland; reversion (pasture)	• Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm • <u>Tussocky grassland</u>	Habitat mapping Habitat mapping, X, U & Y plots Habitat mapping
Scrub is important on farms where little or no woodland exists in the near vicinity of ponds (Wright, 2007).	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub 101. Trees and scrub - establishment by Planting / 102. Trees and scrub - establishment by natural regeneration 103 Scrub - stock exclusion	• New area of rough grassland and scrub in field corner (Max size 0.35ha) • New length and location of stock proof • New area of trees and scrub • New length of stock proof fence • Existing area of scrub • New stock proof fencing around areas of scrub	Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition Habitat mapping Linears and fence condition
Good terrestrial habitat (i.e rough and tussocky grassland) allows newts to readily disperse, particularly to surrounding ponds which is essential to ensure genetic diversity (Oldham et al. 2000). Rough, tussocky grassland also provides food and may be used as refuge in hot, dry conditions.	Option 175 - Management of rough grassland; enclosed land	• Sward height >20cm • <u>Tussocky grassland</u> • <u>Rough grs-pond connectivity</u>	Habitat mapping, X plots Habitat mapping
Morecambe Bay and Glan-traeth, Isle of Anglesey both have coastal sand dune systems and waterbodies. Both are designated as SAC's partly due to the presence of great crested newts. Light grazing at Glan-traeth helps to maintain open terrestrial habitat for GCN adults.	25 Management of sand dunes / 25B Management of sand dunes with mixed grazing	• Grazing with cattle, sheep, goats or ponies • Varied sward height	Habitat mapping
Grassland management should aim to provide floristically-rich, invertebrate-rich and structurally varied habitat. To be maintained as grassland the sward	104 Wood pasture 106 Historic parks and gardens	• Isolated trees on improved or grazed grassland • Maintained grazing on grassland	Habitat mapping – points & polygons Habitat mapping

need to be cut or lightly grazed at least annually (Langton et al. 2001).		• <u>Ponds in parkland</u>	Habitat mapping
Permanent rough/rank (especially tussocky) grassland particularly suitable as this provides refuge throughout the year (Edgar & Bird, 2006; Langton et al. 2001) Good terrestrial habitat (i.e rough and tussocky grassland) allows newts to readily disperse, particularly to surrounding ponds which is essential to ensure genetic diversity (Oldham et al. 2000).	19 Lowland marshy grassland 19B Management of lowland marshy grassland with mixed grazing	• Sward height (excluding rushes) between 5-30cm on enclosed land • Sheep & Cattle grazing on marshy grs (enclosed land) • Sward height (excluding rushes) between 5-30cm on enclosed land • <u>Presence of marshy grassland</u> • <u>Tussocky grassland</u>	Habitat mapping, X, Y & Uplots Habitat mapping Habitat mapping, X, Y & U plots
Unable to find evidence	109 Calaminarian grassland	• Grazing • Sward height between 2cm – 5cm	Habitat mapping Habitat mapping, X & Y plots
Unable to find evidence	143 Lowland fen 145 Lowland fen - reversion (pasture 144 Lowland fen - restoration (no grazing)	• Sheep/Cattle grazing on Lowland fen • Sward height between 10cm-80cm • New stock proof fence around fence	Habitat mapping Habitat mapping, X & U plots Linears and Fence condition
Unable to find evidence	Option 146 - Reedbed; stock exclusion Option 147 - Reedbed; creation	• New stock proof fencing around reedbed • New area of reedbed	Linears and Fence condition Habitat mapping
Unable to find evidence	14 Commit to 100% slurry injection 14B Commit to 75% slurry injection 17 Blanket Bog 157 Buffer zones to prevent erosion and run-off from grassland - ditch landscapes / 158 Buffer zones to prevent erosion and run-off from land under arable cropping 403/404 Add’ Management Payment - Re- wetting / 405 Additional Management Payment - Grazing management for dung invertebrates	Minimal guidance	

RED SQUIRREL

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Study of woodland fragmentation in Sweden showed in years with low densities of red squirrel, the species occurred mainly in larger woods with a preference towards large areas of coniferous trees (30ha). Whilst smaller and/or low quality woods tend to be occupied when situated close to permanently inhabited woodland and, connected by hedgerows within 200-600m (Van Apeldoorn et al. 1994). In Belgium it was found (through radio telemetry data) that tree rows and hedgerows bordering meadows and fields were used by juveniles to disperse from one small, fragmented woodland patch to another. Furthermore, during late summer-autumn, mainly adult males were found to move between nearby small woods (<350m apart) using hedgerows and tree lines not only for movement, but also to forage due to the abundance of hazelnuts, berries and acorns (Wauters et al. 1994). Verboom & Van Apeldoorn (1990) suggest red squirrel occurrence significantly increases when the amount of surrounding woods and/or hedgerows increase.	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land 2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land 3 Create a wildlife corridor – established woody strip Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m • New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; $\geq$ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthron • New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; $\geq$ 5 woody species • $\leq$ 25% native conifers	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots Linears & Fence condition Habitat mapping - Linears

	width (1 metre from centre) / 42A Hedgerow Restoration With Fencing 42B. Hedgerow restoration without fencing 43A/43B. Double Fence and Restore Hedge Banks <u>With</u>/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m • Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness • New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • <u>WLF – small coniferous woodland block connectivity</u>	B & D plots Habitat mapping; B & D plots B & D plots D plots D plots Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots CONEFOR connectivity modelling.
The probability of red squirrel occurrence significantly increases when a woodland is situated close to a large, permanently inhabited wood (Verboom & van Apeldoorn, 1990). Ideally, the shape of a red squirrel forest should be round, rather than long a thin to minimise the movement of grey squirrels. Furthermore, boundary areas of at least 3km comprised of coniferous forest or	100. Woodland - stock exclusion 24 Allow woodland edge to develop out into adjoining improved land	• Length of stock-proof fencing bordering existing (coniferous) woodland • Stock excluded from woodland • Area of existing (coniferous) woodland	Linears & Fence Condition Habitat mapping Habitat mapping - polygons Habitat mapping

open land should be established around woodland to act as a buffer to greys (Lurz et al, 2004). The population ecology of red squirrels is driven by sufficient food resources, largely the temporal and spatial availability of tree seeds (Gurnell et al, 2002; Lurz et al, 1997). A radio-tracking study at Theftford forest showed that mixed conifer plantations >34 years old were preferred the habitat for red squirrels, whilst mixed conifers <25yrs were significantly avoided. Thinned, open stands of trees were also avoided. The study therefore highlighted that forests becomes more suitable for red squirrels with age. (Gurnell et al. 2002). Newly planted trees will not produce significant seed crops for at least 30 years after planting (Pepper & Patterson, 1998). Tree species to be planted as part of prescription are not specified. Oak, beech, sycamore, chestnut and hazel (large seeded species) should not be planted as these are the food plants of the grey squirrel (Wales squirrel Forum, 2009; Pepper and Patterson, 1998). If broadleaves are planted this should be confined to willow, aspen, birch and rowan (small seeded species). Seed-producing areas should be connected by continuous strips of trees to prevent isolation and facilitate movement between them (Lurz et al, 2004).	40 Management of existing fence on stock excluded woodland	• New area of scrub/woodland on improved land next to existing woodland • New length and location of stock proof fence • Existing stock proof fence maintained • Stock excluded from woodland • <u>Presence of grey squirrel</u> • <u>Existing area of mixed coniferous woodland</u> • <u>Woodland shape (round)</u> • <u>Small seeded trees – conifers, willow, aspen, birch and rowan</u>	Linears and Fence condition Linears and fence condition Habitat mapping Not measured Habitat mapping Habitat mapping Habitat mapping, X plots

WATER VOLE

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Change in both land use and riparian habitat management has resulted in habitat loss and fragmentation causing isolation of water vole populations (Strachen & Moorhouse, 2006). In the UK, lowland water voles have a preference wide swaths of dense riparian vegetation growing from soft banks alongside water courses; rocky banks are generally avoided. Riparian vegetation represents both shelter and food for water voles; thus increasing the width over a given length may lead to lower predation risk, increased survival rate and increased food abundance (Moorhouse et al. 2009; Strachen & Moorhouse, 2006). Water voles are known to eat over 200 different types of plants (particularly sedges, grasses and rushes) and do not tend to move more than 1-2m from the water edge (Gwent Wildlife Trust; Stoddart, 1970). A study by Moorhouse et al. (2009) found an increase in the abundance of suitable vegetation (e.g. riparian vegetation) of up to 300cm^2 per m of can increase water vole survival rate (Moorhouse et al. 2009). Riparian vegetation should be allowed to grow tall, particularly as voles tends to select sites with grass tussocks and emergent plants. As such, lowland river systems and riparian habitats which support water vole colonies should be protected from excessive grazing. The erection of stock proof fencing either side of a water course will therefore prevent trampling by stock and allow buffer strips either side of the water course to develop. (Strachen & Moorhouse, 2006).	7A/B Create a streamside corridor on improved land on one/both side of a watercourse	• New stream side corridor on improved land • New stock proof fence adjacent to stream corridor • Removal of Japanese knotweed and Himalayan balsam	Habitat mapping – linears Linears & Fence condition B, D, S & P plots
	8 Continued management of an existing streamside corridor	• Fencing maintained to exclude stock • Removal of Japanese knotweed and Himalayan balsam	Linears & Fence condition B, D, S & P plots
	173. Streamside corridor management	No guidance • Continuous length of riparian vegetation • Species rich • Tall, tussocky, non-woody, riparian vegetation • 1-2m wide riparian corridor • Mature willows adjacent to watercourse (mink indicator) • Low cover of streamside bramble (mink indicator)	 Habitat mapping S & P plots S & P plots Habitat mapping Habitat mapping – points Habitat mapping; S & P plots

Mink are often associated with dense scrub and woodland adjacent to water courses. Furthermore, hollow, mature trees, especially willow are used as breeding/nursery dens and bramble thickets along water courses are used by minks for cover when foraging (Strachen & Moorhouse, 2006; Carter & Bright, 2003).			
A small number of ponds in close proximity is favourable for water voles (Strachen & Moorhouse, 2006). Ideally, new ponds should be located as near as possible (up 1km) from existing water vole colonies, particularly as ponds help to link and extend wetland complexes. Furthermore, ponds created for water voles should be 1m deep and no wider than 10m largely because water voles do not like to swim more than 10m across open water. Around the edges, pond margins need to be at least 2m wide and well covered with tall grasses and herbs (Pond conservation, 2010). However, management IS needed every few years to ensure trees are not over shading the pond and out competing more favourable vegetation (Pond conservation, 2010). Off-stream ponds with marginal vegetation along waterways may be particularly valuable for water voles as these can provide a refuge area during flooding, as well as providing linkage between isolateD populations (Strachen & Moorhouse, 2006).	35 Create a wildlife pond on enclosed improved land 35B Create a wildlife pond on enclosed improved land – variable size 36 Buffer existing unfenced in-field ponds	No guidance • New Ponds with an area > 25m^2 and < 1000m^2 • Stock proof fenced ≥10m from pond edge • New area of rough grass around pond ≥10m from pond edge • New stock proof fencing around existing ponds • <u>Ponds within 1km from Woodlands, hedges and Stream & river corridors</u>	Habitat mapping Linears and Fence condition Habitat mapping & Y plots Habitat mapping - linears Habitat mapping
Carter & Bright (2003) found predation rates of water vole by American mink (a major threat to water vole populations) strongly declined with increasing distance of burrows from main water channels (>10m wide). Reed beds therefore appeared to be an effective refuge from predation as they provide habitat away from features associated with mink such as scrub and ditches. Reedbeds may also support source populations	146 - Reedbed; stock exclusion 147 - Reedbed; creation	• New stock proof fencing around reedbed • New area of reedbed • <u>Area of reedbed >10m wide</u>	Linears and Fence condition Habitat mapping Habitat mapping

that are likely to help increase the size and viability of metapopulations in the surrounding landscape (Hardman & Harris, 2010; Carter & Bright, 2003). In Stodmash NNR, Kent; water voles still thrive in the large reedbeds even though mink are thought to have been resident for 30 years (Birght & Carter, 2000).			
Water pollution is one of the main threats to water voles (White et al. 1997). However rough grass buffer strips have ability to intercept run-off and spray drift before it reaches water courses and other habitats (Wright, 2007). A water vole scheme working with farmers in Chichester created 61km of six-metre wide buffer strips as part of the English agri-envrionment scheme. Many of the buffers were targeted beside ditches and watercourses which not only helps protect riparian strips, as well as creating links for water voles between farms (Strachen & Moorhouse, 2006).	26 Fixed rough grass margins on arable land 26B Rotational rough grass margin on arable land 174 Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	• New rough grass margin between 2-8m on arable land • No grazing once established • Cannot be rotated • New rough grass margin between 2-8m on arable land • No grazing once established • Can be rotated • New rough grass margin on arable land • Livestock excluded	Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping
An extensive area of marsh (584ha) studied in Somerset found that grazed marshes can provide refuge for water voles from mink predation. This was thought to be due to the avoidance of open terrestrial habitat by mink when attempting to access channels and ditches. Furthermore, the narrow ditches which run through the marsh may also not provide sufficient enough water depth for mink to escape by diving when attacked by predators (Macpherson & Bright, 2010).	19 Lowland marshy grassland 19B Management of lowland marshy grassland with mixed grazing	• Sward height (excluding rushes) between 5-30cm on enclosed land • Mixed grazing • Sward height (excluding rushes) between 5-30cm on enclosed land • <u>Presence of marshy grassland</u> • <u>Presence of narrow, water filled ditches</u>	Habitat mapping, X, Y & u plots Habitat mapping Habitat mapping, X, Y & U plots

Unable to find evidence	15 Grazed permanent pasture with no inputs. / 15C Grazed permanent pasture with no inputs and mixed grazing Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture)	• Permanent pasture maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm • Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & U plots
	123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture)	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep	Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots
	128 Lowland unimproved calcareous grassland / 129 Lowland unimproved calcareous grassland - reversion (pasture)	• Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm	Habitat mapping Habitat mapping; X & U plots
	131 Conversion from arable to grassland (no inputs)	• Area of new grassland • Grassland grazed once established • Sward height at least 5cm	Habitat mapping Habitat mapping Habitat mapping, X plot
	133 Lowland marshy grassland / 134 Lowland marshy grassland; reversion (pasture)	• Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm	Habitat mapping Habitat mapping, X, U & Y plots

Unable to find evidence	104 Wood pasture 106 Historic parks and gardens	• Isolated trees on improved or grazed grassland • Maintained grazing on grassland	Habitat mapping – points & polygons Habitat mapping
Unable to find evidence	20. Management of Coastal and Lowland Heath / 20B. Management of Coastal and Lowland Heath With Mixed Grazing	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • ≥25% dwarf-shrub species on coastal heath • ≤25% of heath burnt over 5 years	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping
Unable to find evidence	143 - Lowland fen / 145 - Lowland fen; reversion (pasture)	• Grazing on Lowland fen • Sward height between 10cm-80cm (except patches of moss)	Habitat mapping Habitat mapping, X & U plots
Unable to find evidence	122 Lowland unimproved acid grassland - reversion (hay cutting) / 124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion (hay cutting) / 130 Lowland unimproved calcareous grassland - reversion (hay cutting) / 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Grassland maintained by grazing and hay cutting • Field shut off from livestock by 1 May every year • Between 5%-10% left uncut • Aftermath sward height - 80% of the grasses between 5- 15cm high	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & Y plots
Unable to find evidence	22 Existing hay meadows	• Field shut off from livestock before 15 May and closed for at least 10 weeks • Aftermath sward height - 80% of the grasses between 5- 15cm high	Habitat mapping Habitat mapping; X & Y plots

Unable to find evidence	41A Grazing management of open country 41B Grazing management of open country with mixed grazing	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed	Habitat mapping Habitat mapping
Unable to find evidence	14 Commit to 100% slurry injection 14B Commit to 75% slurry injection 16 Upland heath 17 Blanket Bog 18 Upland grassland 117 Lowland wet heath with less than 60% purple moor grass / 118 Lowland wet heath with more than 60% purple moor-grass 119 Lowland heath habitat expansion - establishment on grassland 139 Lowland bog and other acid mires with less than 50% purple moor-grass 140 Lowland bog and other acid mires with more than 50% purple moor-grass 141 Lowland bog and other acid mires - restoration (no grazing) 142 Lowland bog and other acid mires - reversion (pasture)	Minimal or no guidance	

BAT CONSERVATION TRUST. 2010. Bat Conservation Trust, Barbastelle bat - Barbastella barbastellus [Online]. Available: file:///C:/Users/amwin/Downloads/barbastelle%20(1).pdf [Accessed 2014].

BAT CONSERVATION TRUST. 2010. Bat Conservation Trust, Greater horseshoe - Rhinolophus ferrumequinum [Online]. Available: file:///C:/Users/amwin/Downloads/greaterhorseshoe%20(1).pdf [Accessed 2014].

BILLINGTON, G. 2003. Report of further research of Barbastelle bats associated with Pengelli Forest National Nature Reserve. Countryside Council for Wales, Report Number 591.

BILLINGTON, G. & RAWLINSON, M. 2006. A review of horseshoe bats flight lines and feeding areas. Countryside Council for Wales, Sciecne Report No. 755. Bangor.

BONTADINA, F., SCHOFIELD, H. & NAEF-DAENZER, B. 1999. Habitat preferences in lesser horseshoe bats as revealed by radio-tracking. Bat Research News, 40, 110-111.

BONTADINA, F., SCHOFIELD, H. & NAEF-DAENZER, B. 2002. Radio-tracking reveals that lesser horseshoe bats (Rhinolophus hipposideros) forage in woodland. Journal of Zoology, 258, 281-290.

BRIGHT, P., CARTER, S. & NATURE, E. 2000. Halting the decline: Refuges and national Key sites for water voles, English Nature.

BRIGHT, P. & MORRIS, P. 1995. A review of the dormouse (Muscardinus avellanarius) in England and a conservation programme to safeguard its future. Hystrix, the Italian Journal of Mammalogy, 6.

BRIGHT, P., MORRIS, P., MITCHELL-JONES, A. J. & NATURE, E. 2006. The dormouse conservation handbook.

BRIGHT, P. W. 1998. Behaviour of specialist species in habitat corridors: arboreal dormice avoid corridor gaps. Animal behaviour, 56, 1485-1490.

BRIGHT, P. W. & MORRIS, P. A. 1990. Habitat requirements of dormice Muscardinus avellanarius in relation to woodland management in Southwest England. Biological Conservation, 54, 307-326.

BUG LIFE. 2013. Lowland meadows [Online]. Available: https://www.buglife.org.uk/advice-and-publications/advice-on-managing-bap-habitats/lowland-meadows [Accessed 2014].

CAPIZZI, D., BATTISTINI, M. & AMORI, G. 2002. Analysis of the hazel dormouse, Muscardinus avellanarius, distribution in a Mediterranean fragmented woodland. Italian Journal of Zoology, 69, 25-31.

CARTER, S. & BRIGHT, P. 2003. Reedbeds as refuges for water voles (Arvicola terrestris) from predation by introduced mink (Mustela vison). Biological Conservation, 111, 371-376.

DURRANT, C., BEEBEE, T. C., GREENAWAY, F. & HILL, D. 2009. Evidence of recent population bottlenecks and inbreeding in British populations of Bechstein’s bat, Myotis bechsteinii. Conservation Genetics, 10, 489-496.

EDGAR, P. & BIRD, D. R. 2006. Action plan for the conservation of the crested newt Triturus cristatus species complex in Europe. Council of the European Union, Strassbourg, Germany, 1-33.

ENTWISTLE, A. C., HARRIS, S., HUTSON, A.M., RACEY, P.A., WALSH, A., GIBSON, S.D., HEPBURN, I. & JOHNSTON, J. 2001. Habitat management for bats – a guide for land managers, land owners and their advisors. Joint Nature Conservation Committee, Peterborough.

FEBER, R., FIRBANK, L., JOHNSON, P. & MACDONALD, D. 1997. The effects of organic farming on pest and non-pest butterfly abundance. Agriculture, ecosystems & environment, 64, 133-139.

FITZSIMONS, P., HILL, D. & GREENAWAY, F. 2002. Patterns of habitat use by female Bechstein's bats (Myotis bechsteinii) from a maternity colony in a British woodland. School of Biological Sciences, University of Sussex, 22pp.

FORDER, V. 2006. Ecology and Conservation. The water vole Arvicola terrestris amphibius. Wildwood Trust.

FOREST RESEARCH. 2007. Guidance on managing woodlands with dormice in England [Online]. Forestry Commission. Available: http://www.forestry.gov.uk/pdf/england-protectedspecies-dormouse.pdf/$file/england-protectedspecies-dormouse.pdf [Accessed 2014].

GLENDELL, M. & VAUGHAN, N. 2002. Foraging activity of bats in historic landscape parks in relation to habitat composition and park management. Animal Conservation, 5, 309-316.

GREATOREX-DAVIES, J. N., HALL, M. L. & MARRS, R. H. 1992. The conservation of the pearl-bordered fritillary butterfly (Boloria euphrosyne L.): preliminary studies on the creation and management of glades in conifer plantations. Forest Ecology and Management, 53, 1-14.

GREENAWAY 2005. Advice for the management of flightlines and foraging habitats of the barbastelle bat Barbastella barbastellus.

GREENAWAY, F. 2001. The barbastelle in Britain. British Wildlife, 12, 327-334.

GREENAWAY, F. 2004. Woodland management advice for Bechstein's bat and barbastelle bat. English Nature Research reports, Report Number 658, Peterborough.

GREENAWAY, F. & NATURE, E. 2005. Advice for the management of flightlines and foraging habitats of the barbastelle bat Barbastella barbastellus. English Nature Research reports, Report Number 658, Peterborough.

GURNELL, J., CLARK, M. J., LURZ, P. W., SHIRLEY, M. D. & RUSHTON, S. P. 2002. Conserving red squirrels (Sciurus vulgaris): mapping and forecasting habitat suitability using a Geographic Information Systems Approach. Biological Conservation, 105, 53-64.

GURNELL, J., CLARK, M. J., LURZ, P. W., SHIRLEY, M. D. & RUSHTON, S. P. 2002. Conserving red squirrels (Sciurus vulgaris): mapping and forecasting habitat suitability using a Geographic Information Systems Approach. Biological Conservation, 105, 53-64.

GWENT WILDLIFE TRUST. No date. What is a water vole? [Online]. Available: http://www.gwentwildlife.org/what-we-do/projects/water-vole-project/what-water-vole [Accessed 2014].

HARDMAN, C. & HARRIS, D. 2010. RSPB/NE Countdown 2010: Bringing Reedbeds to Life Project Wildlife surveys, Chapter 10: Water Vole and Mink Surveys.

HEDGELINK. No date. How to manage you hedges for dormice [Online]. Available: http://www.hedgelink.org.uk/documents/Dormice%20%26%20Hedges%20Leaflet.pdf [Accessed 2014].

HILL, D. A., & GREENAWAY, F. 2006. Putting Bechstein's bat on the map. Final Report to Mammals Trust UK. London.

JOLY, P., MIAUD, C., LEHMANN, A. & GROLET, O. 2001. Habitat Matrix Effects on Pond Occupancy in Newts

Efecto de la Matriz del Hábitat en la Ocupación de Estanques por Tritones. Conservation Biology, 15, 239-248.

JONES, G. & RAYNER, J. M. 1989. Foraging behavior and echolocation of wild horseshoe bats Rhinolophus ferrumequinum and R. hipposideros (Chiroptera, Rhinolophidae). Behavioral Ecology and Sociobiology, 25, 183-191.

KERTH, G. & MELBER, M. 2009. Species-specific barrier effects of a motorway on the habitat use of two threatened forest-living bat species. Biological Conservation, 142, 270-279.

KNIGHT, T. 2006. The use of landscape features and habitats by the lesser horseshoe bat (Rhinolophus hipposideros). PhD thesis, University of Bristol.

LANGTON, T., BECKETT, C. & FOSTER, J. 2001. Great crested newt conservation handbook, Froglife.

LONGLEY, M. 2003. Greater horseshoe bat project 1998–2003. English Nature Research Reports Number 532. English Nature, Peterborough.

LURZ, P., GARSON, P. & WAUTERS, L. 1997. Effects of temporal and spatial variation in habitat quality on red squirrel dispersal behaviour. Animal Behaviour, 54, 427-435.

LURZ, P., GURNELL, J. & RUSHTON, S. 2004. Managing forests for red squirrels. (Quine, C., Shore, R. & Trout, R., Eds.): proceedings of a symposium organised jointly by the Mammal Society and the Forestry Commission. Foresty Commission, Edinburgh.

MACPHERSON, J. L. & BRIGHT, P. W. 2010. Movements of radio-tracked American mink (Neovison vison) in extensive wetland in the UK, and the implications for threatened prey species such as the water vole (Arvicola amphibius). European Journal of Wildlife Research, 56, 855-859.

MALMGREN, J. C. 2002. How does a newt find its way from a pond? Migration patterns after breeding and metamorphosis in great crested newts (Triturus cristatus) and smooth newts (T. vulgaris). Herpetological Journal, 12, 29-36.

MILLER, H. 2012. Bechstein's Bat Survey final report. Report. Bat Conservation Trust, London, UK [Online]. Available: http://www.bats.org.uk/pages/bechsteins_bat_project.html. [Accessed 2014].

MOORHOUSE, T., GELLING, M. & MACDONALD, D. 2009. Effects of habitat quality upon reintroduction success in water voles: evidence from a replicated experiment. Biological Conservation, 142, 53-60.

MOTTE, G. & LIBOIS, R. 2002. Conservation of the lesser horseshoe bat (Rhinolophus hipposideros Bechstein, 1800)(Mammalia: Chiroptera) in Belgium. A case study of feeding habitat requirements. Belgian Journal of Zoology, 132, 49-54.

MÜLLNER, A. 2001. Spatial patterns of migrating Great Crested Newts and Smooth Newts: The importance of the terrestrial habitat surrounding the breeding pond. Rana, Sonderheft, 4, 279-293.

NATURE, E. 2003. Managing landscapes for the greater horseshoe bat [Online]. English nautre, Peterborough. Available: http://warksbats.co.uk/pdf/GHSManagingLandscapes.pdf [Accessed 2014].

OLDHAM, R., KEEBLE, J., SWAN, M. & JEFFCOTE, M. 2000. Evaluating the suitability of habitat for the great crested newt (Triturus cristatus). Herpetological Journal, 10, 143-156.

PALMER, E., PIMLEY, E., SUTTON, G. & BIRKS, J. 2013. A study on the population size, foraging range and roosting ecology of Bechstein's bats at Grafton wood SSSI, Worcestershire. A report to The People's Trust for Endangered Species & Worcester Wildlife Trust. Link Ecology and Swift Ecology, Worcestershire, England.

PEPPER, H. W. & PATTERSON, G. S. 1998. Red squirrel conservation, Forestry Authority.

PEPPER, H. W., PATTERSON, G. S. & BRITAIN, G. 1998. Red squirrel conservation, Forestry Authority.

POND CONSERVATION. 2010. Creating ponds for water voles. A 50 year project to create a network of clean water ponds for freshwater wildlife. [Online]. Available: http://www.freshwaterhabitats.org.uk/wordpress/wp-content/uploads/2013/09/watervole-dossier-2013.pdf [Accessed 2014].

POND CONSERVATION. 2011. Creating ponds for bats. A 50 year project to create a network of clean water ponds for freshwater wildlife. [Online]. Available: http://www.freshwaterhabitats.org.uk/wordpress/wp-content/uploads/2013/09/Bat-dossier.pdf 2014].

RANSOME, R. & HUTSON, A. M. 2000. Action plan for the conservation of the greater horseshoe bat in Europe (Rhinolophus ferrumequinum), Council of Europe.

RANSOME, R. & HUTSON, A. M. 2000. Action plan for the conservation of the greater horseshoe bat in Europe (Rhinolophus ferrumequinum). No. 18-104, Council of Europe.

RODRÍGUEZ, A. & ANDRÉN, H. 1999. A comparison of Eurasian red squirrel distribution in different fragmented landscapes. Journal of Applied Ecology, 36, 649-662.

RUSSO, D., CISTRONE, L., JONES, G. & MAZZOLENI, S. 2004. Roost selection by barbastelle bats (Barbastella barbastellus, Chiroptera: Vespertilionidae) in beech woodlands of central Italy: consequences for conservation. Biological Conservation, 117, 73-81.

SCHOFIELD, H. & FITZSIMMONS, P. 2004. The importance of woodlands for bats in managing woodlands and their mammals (Quine, C., Shore, R. & Trout, R., Eds.): proceedings of a symposium organised jointly by the Mammal Society and the Forestry Commission. Foresty Commission, Edinburgh.

SCHOFIELD, H. W. 1996. The ecology and conservation biology of Rhinolophus hipposideros, the lesser horseshoe bat. PhD thesis, University of Aberdeen.

SHUTTLEWORTH, C. M., LURZ, P. W., GEDDES, N. & BROWNE, J. 2012. Integrating red squirrel (< i> Sciurus vulgaris</i>) habitat requirements with the management of pathogenic tree disease in commercial forests in the UK. Forest Ecology and Management, 279, 167-175.

SIERRO, A. 1999. Habitat selection by barbastelle bats (Barbastella barbastellus) in the Swiss Alps (Valais). Journal of Zoology, 248, 429-432.

STODDART, D. M. 1970. Individual range, dispersion and dispersal in a population of water voles (Arvicola terrestris (L.)). The Journal of Animal Ecology, 403-425.

STRACHEN, R. & MOORHOUSE, T. 2006. Water Vole Conservation Handbook. Wildlife Conservation Research Unit, University of Oxford, Oxford.

THE VINCENT WILDLIFE TRUST. 2014. Horseshoe bats. The Vincent Wildlife Trust, Herefordshire.

TRUST, B. C. 2010. Barbastelle bat - Barbastella barbastellus [Online]. Bat Conservation Trust, London. Available: file:///C:/Users/amwin/Downloads/barbastelle.pdf [2014].

VAN APELDOORN, R., CELADA, C. & NIEUWENHUIZEN, W. 1994. Distribution and dynamics of the red squirrel (Sciurus vulgaris L.) in a landscape with fragmented habitat. Landscape Ecology, 9, 227-235.

VERBOOM, B. & VAN APELDOORN, R. 1990. Effects of habitat fragmentation on the red squirrel, Sciurus vulgaris L. Landscape Ecology, 4, 171-176.

WAUTERS, L., CASALE, P. & DHONDT, A. A. 1994. Space Use and Dispersal of Red Squirrels in Fragmented Habitats. Oikos, 69, 140-146.

WAUTERS, L. A., HUTCHINSON, Y., PARKIN, D. T. & DHONDT, A. A. 1994. The effects of habitat fragmentation on demography and on the loss of genetic variation in the red squirrel. Proceedings of the Royal Society of London. Series B: Biological Sciences, 255, 107-111.

WHITE, P. C. L., GREGORY, K. W., LINDLEY, P. J. & RICHARDS, G. 1997. Economic values of threatened mammals in Britain: A case study of the otter Lutra lutra and the water vole Arvicola terrestris. Biological Conservation, 82, 345-354.

WICKRAMASINGHE, L. P., HARRIS, S., JONES, G. & VAUGHAN JENNINGS, N. 2004. Abundance and Species Richness of Nocturnal Insects on Organic and Conventional Farms: Effects of Agricultural Intensification on Bat Foraging Abundancia y Riqueza de Especies de Insectos Nocturnos en Granjas Orgánicas y Convencionales: Efectos de la Intensificación Agrícola sobre el Forrajeo de Murciélagos. Conservation Biology, 18, 1283-1292.

WRIGHT, D. 2007. Environmental Stewardship. How great crested newts can earn points for your farm. Entry Level Stewardship (ELS) and Higher Level Stewardship (HLS) options. Herpetological Conservation Trust, Bournemouth.

ZEALE, M. R. K., DAVIDSON-WATTS, I. & JONES, G. 2012. Home range use and habitat selection by barbastelle bats (Barbastella barbastellus): implications for conservation. Journal of Mammalogy, 93, 1110-1118.

BROWN BANDED CARDER BEE – *Bombus humilis*

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Bombus humilis one of the long-tongued bumblebee species that emerges relatively late in the season (May) and is associated with tall but open flower –rich grasslands where it establishes nests on the surface of the ground (Claire Carvell pers comms). Hedges can be an important part of the landscape; providing hedges are not intensively managed or degraded by herbicides. Uncropped areas of farmland i.e. hedgerows bases may provide flowers throughout the season for foraging bees. (Goulson, 2010). Carvell et al .(2006) also suggest that sympathetic management of vegetation along hedgerows edges could also encourage plants such as *Ajuga reptans* and *Lamium album*, both of which provide spring forage. However these are not likely to be required by this species until May. Bumblebee working group (2002) similarly recognised that hedge-bottom plants such as labiates in less intensive agricultural situations are important forage components for long-tongue bumblebee species.	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; ≥ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots
	2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land	• New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; ≥ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthorn	Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots
	3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; ≥ 5 woody species • ≤ 25% native conifers	Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots

	5 Enhanced Hedgerow Management On Both Sides	• WLF maintained at least 2m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Habitat mapping; B & D plots B & D plots
	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Linears & Fence condition Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness	D plots D plots
	43A/43B. Double Fence and Restore Hedge Banks <u>With</u>/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • <u>Presence of Labiates in hedgerows</u> • <u>Connectivity to flower rich grassland</u>	Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots
One of the major agricultural changes in Britain is the loss of red clover leys (Goulson, 2010), yet red clover is	153 - Red clover ley	• Area of new red clover ley • $\geq$ 80% of sward is red clover	Habitat mapping, X plot

one of the most important food plants of *B.humilis* & B. *sylvarum* (Hymettus ltd, 2006). It has also been found that the Fabaceae family is disproportionally favoured as forage plants (Goulson, 2010; Connop, 2008; Saunders, 2008). Knowing this, the creation of red clover leys therefore has the potential to encourage the expansion of this species, particularly as red clover often flowers late into the summer (Bumblebee conservation trust, n.d).			
B. humilis has undergone a major decline in its distribution, most remaining populations being on extensive areas of coastal grassland along the southern and western coasts of England and Wales (Bwars, 2014). Recent national records have found the remaining populations of *B humilis* & *B.sylvarum* have a coastal distribution (Connop 2007; Buglife, n.d). Main habitat *of B.humilis* is in Devon and Cornwall. Thought to be due to the extensive area of semi-natural heath / grassland on the northern coastal cliff tops which are kept from the succession of scrub by the exposed climate and thin soils. Where there is heath, it is generally more open with mosaics of grassland species including Betony *Stachys officinalis*, Saw-wort *Serratula tinctoria* and Knapweed *Centaurea nigra* (Saunders 2008). Although this habitat in some cases becomes very narrow, it does form a long, continuous strip which fulfils the requirement for the species to have large areas of high quality forage (Saunders, 2008). Grazing plays a key role in maintaining the abundance and species richness associated with bumblebee forage plants. Cattle are particularly suitable for bee conservation as their grazing creates a more structurally and floristically diverse sward that also benefits other invertebrates (Carvell, 2002).	20. Management of Coastal and Lowland Heath / 20B. Management of Coastal and Lowland Heath With Mixed Grazing Option 148 Coastal grassland (maritime cliff and slope)	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • ≥ 25% dwarf-shrub species on coastal heath • ≤25% of heath burnt over 5 years • Sheep/cattle grazing on coastal grassland • Presence of coastal heath and grassland • High species richness • Cattle grazing	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping Habitat mapping Habitat mapping X, Y & U plots Habitat mapping

The loss of unimproved grasslands coupled with the narrow diet of carder bees compared to the common bee species is thought to be one of main causes of carder bee decline (Goulson, 2010). *B. sylvarum* and *B. humilis* utilise a network of forage sources over site- and landscape-scales therefore conservation of a single site might not be sufficient to support populations. A network of forage and nesting habitat at a site- and landscape-scale is required to support viable metapopulations and to buffer colonies against the effects of forage patch losses (Connop et al. 2011). *B.humilis* need areas of large, fairly tall, open grasslands with small, but widely distributed patches of long-tubed flowers preferred for foraging (Carvell, 2002; buglife, n.d). Study by Carvell (2002) showed that *B .humilis* numbers were significantly related to increased vegetation structure, height and total flower abundance. The bumblebee working group (2002) also consider that foraging habitat is dependent upon the structure of the grassland (i.e mosaic of vegetation structure, tall and open) as much as the exact composition of the flora. However numerous studies have observed that there is obvious preference towards some plant species. Flower families most favoured and visited by *B. humilis* include Lamiaceae, Scrophulariaceae, Asteraceae and particularly Fabaceae (Connop, 2010; Connop, 2008; Carvell, 2002; Buglife n.d). *B. humilis* emerge late from hibernation in comparison to other bees, as such workers require relatively late forage (Goulson, 2010) and have been recorded foraging in late September and even into early October in this study (Connop 2008). As such it is vital that sites	15 Grazed permanent pasture with no inputs. / 15C Grazed permanent pasture with no inputs and mixed grazing	• Permanent pasture maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm	Habitat mapping Habitat mapping
	Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture)	• Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm	Habitat mapping Habitat mapping; X & U plots
	123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture)	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep	Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots
	128 Lowland unimproved calcareous grassland / 129 Lowland unimproved calcareous grassland - reversion (pasture)	• Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm	Habitat mapping Habitat mapping; X & U plots
	131 Conversion from arable to grassland (no inputs)	• Area of new grassland • Grassland grazed once established • Sward height at least 5cm	Habitat mapping Habitat mapping Habitat mapping, X plot
	133 Lowland marshy grassland / 134 Lowland marshy grassland; reversion (pasture)	• Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm	Habitat mapping Habitat mapping, X, U & Y plots

have a continuum of flowers from late May to late September (Saunders 2008; Bumblebee Conservation Trust, n.d (a)). Buglife (n.d) suggests that stands of flowering knapweed, burdock and thistle should be protected as these provide food for foraging Queens. Grazing plays a key role in maintaining the abundance and species richness preferred bumblebee forage plants such as C. nigra and T. pratense. Recently sheep and cattle grazed grassland found to support B. humilis. Cattle are particularly suitable for bee conservation as their grazing creates a more structurally and floristically diverse sward than grazing by sheep; this also benefits other invertebrates (Carvell, 2002). The importance of undisturbed grassland becomes particularly clear with the understanding of nesting preferences. Generally they nest on the surface of the ground (surface nesting species) at the base of long vegetation, often under accumulated dried plant litter or moss at the base of the vegetation. Sunlight provides warmth to the surface of the nests, but they are also known to utilise old nests of small mammals (Hymettus, 2002; Natural Museum & Galleries of Wales, n.d).		• <u>High % of Scrophulariaceae, Orobanchaceae, Asteraceae, Lamiaceae and particularly Fabaceae flowering plants in grassland</u> • <u>Tall vegetation</u> • <u>Stands of knapweed, burdock & thistles</u> • <u>Litter</u> • <u>Bryophytes</u> • <u>Tussocky vegetation</u> • <u>Mosaic of unimproved flower rich grassland</u>	X, Y or U plots Habitat mapping; X, Y or U plots Habitat mapping X, Y or U plots X, Y or U plots X, Y or U plots Habitat mapping
Carder bees are reliant on tall, undisturbed grassland, particularly tussocky grassland (Connop 2008). Sowing non-crop field margins with wildlife seed mixtures has the potential for providing the best foraging habitat for bumblebees through the season, so long as preferred forage species are introduced such *as Trifolium pratense, Lotus corniculatus* and *Centaurea nigra* (Goulson 2010; Carvell et al. 2006; Pwyll, 2005).	26 Fixed rough grass margins on arable land 26B Rotational rough grass margin on arable land	• New rough grass margin • Width of 2-8m on arable land • No grazing once established • Mix of tussock forming grasses • Cannot be rotated • New rough grass margin adjacent to cereal, rape, linseed or root crop	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping

Glastir prescriptions suggest a tussock-forming grass mixture should be sown. In support of this, a study by Carvell (2004) created 6m wide arable field margin sown with 'tussocky grasses'. After three years, (having being left uncut after year one), the margin had developed into the expected tussocky structure thought to be ideal for nest seeking queen's. Most favoured plant families include Fabaceae, Lamiaceae, Asteraceae and Scrophulariaceae (Bug life n.d). Study in Salisbury plain mostly recorded *B. humilis* within the taller less intensively managed, reverting arable grasslands due to their structural suitability as nesting habitat, as well as the availability of forage plants (Carvell, 2002). The importance of undisturbed grassland becomes particularly clear with the understanding of nesting preferences. Generally carder bees nest on the surface of the ground at the base of long, tussocky vegetation, often under accumulated dried plant litter or moss at the base of the vegetation. Sunlight provides warmth to the surface of the nests, but they are also known to utilise old nests of small mammals such as voles (Bumblebee Working Group, 2002; Natural Museum & Galleries of Wales, n.d.)	27 Fallow margins 174 Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	• Between 2-8m wide • Mix of tussock forming grasses • No grazing once established • Can be rotated • New fallow crop margin adjacent to cereals, oil seed rape, linseed, maize or roots • Between 2-8m wide • Can be rotated • New rough grass margin on arable land • Livestock excluded • <u>Tussocky vegetation</u> • <u>High % of Scrophulariaceae, Orobanchaceae, Asteraceae, Lamiaceae and particularly Fabaceae flowering plants in grassland</u> • <u>% litter</u> • <u>% bryophytes</u>	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping
Carder bees are reliant on tall, undisturbed grassland, particularly tussocky grassland (Connop 2008) as well as smaller patches that are widely distributed. A study by Carvell (2002) also showed that *B .humilis* numbers were significantly related to increased vegetation structure, height and total flower abundance.	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub 175 - Management of rough grassland; enclosed land	• New area of rough grassland in field corner (Max size 0.35ha) • New length and location of stock proof • No/Minimal scrub on rough grs (enclosed land) • Varied sward height >20cm	Habitat mapping Linears and fence condition Habitat mapping Habitat mapping

		• Tussocky grassland • Tall vegetation	
Habitats peripheral to the cliffs are also important, such as dunes (Saunders, 2008). In the past, national records have found the remaining populations of *B humilis* & *B.sylvarum* have a coastal distribution (Connop 2008; Buglife, n.d).	25 Management of sand dunes 25B Management of sand dunes with mixed grazing 151 Coastal vegetated shingle and sand dunes - creation	• Grazing by cattle, sheep, goats or ponies • Managed by grazing • At least 20% <5cm and at least 40% <10cm • Grass cover <70% in wet hollows	Habitat mapping
B. humilis emerge late from hibernation in comparison to other bees, as such workers require relatively late forage (Goulson, 2010). Carvell (2000) and bumblebee conservation trust (n.d) recommend cutting should be delayed until mid-July to August or if a farm has numerous hay meadows then a field (rotating each year) should be late in September. A later cut therefore maintains forage flowers into late season. Hay cutting prescriptions recommend that hay is cut after 8th July. No other specification for cutting, as such this may detrimental for bees.	22 Existing haymeadows 122 Lowland unimproved acid grassland - reversion (hay cutting) / 124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion (hay cutting) / 130 Lowland unimproved calcareous grassland - reversion (hay cutting) / 132 Conversion from improved grassland to semi- improved grassland (hay cutting) 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Field shut off from livestock before 15 May and closed for at least 10 weeks • Aftermath sward height - 80% of the grasses between 5- 15cm high • Grassland maintained by grazing and hay cutting • Field shut off from livestock by 1 May every year • Between 5-10% left uncut • Aftermath sward height - 80% of the grasses between 5- 15cm high • Change from improve grassland to semi-improved grassland • Grassland maintained by grazing and hay cutting • Between 5-10% left uncut	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & Y plots Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & Y plots

		• Aftermath sward height - 80% of the grasses between 5- 15cm high	
Unable to find evidence; however Claire Carvell (pers comm.) suggest these measures have the potential to provide forage resources depending on seedbank.	19 Lowland marshy grassland 19B Management of lowland marshy grassland with mixed grazing	• Sward height (excluding rushes) between 5-30cm on enclosed land • Sheep & Cattle grazing on marshy grs (enclosed land) • Sward height (excluding rushes) between 5-30cm on enclosed land • Presence of marshy grassland	Habitat mapping, X, Y & u plots Habitat mapping Habitat mapping, X, Y & u plots Habitat mapping
Unable to find evidence; however Claire Carvell (pers comm.) suggest these measures have the potential to provide forage resources depending on cover crop chosen i.e. nectar/pollen rich.	33 Establish a wildlife cover crop on improved land 34 Unharvested cereal headland 34B Unfertilised and unsprayed cereal headland	• On improved land only • 4m wide seed bed established for crop • Crop cover to be at least 80% cereals with at least one of the following; mustard, rape or linseed. • No maize • Only on improved land • 3-6m wide cereal headland established along edge of crop • Only on improved land • 3-6m wide cereal headland established along edge of crop Can be rotated	Habitat mapping Habitat mapping M plot M plot Habitat mapping Habitat mapping Habitat mapping Habitat mapping
Unable to find evidence	41A Grazing management of open country 41B Grazing management of open country with mixed grazing	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed	Habitat mapping Habitat mapping

Unable to find evidence	115 Lowland dry heath with less than 50% western gorse / 116 Lowland dry heath with more than 50% western gorse 117 Lowland wet heath with less than 60% purple moor- grass / 118 Lowland wet heath with more than 60% purple moor-grass 119 Lowland heath habitat expansion - establishment on grassland	Minimal guidance	

SHRILL CARDER BEE – *Bombus sylvarum*

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Bombus sylvarum one of the longer-tongued bumblebee species that emerges relatively late in the season, in May (Bumblebee Conservation Trust, n.d (b)). Providing hedges are not intensively managed or degraded by herbicides, uncropped areas of farmland such as hedgerows may provide flowers throughout the season for foraging bumblebees. (Goulson, 2010). Carvell et al (2006) also suggest that sympathetic management of vegetation along hedgerows edges could also encourage plants such as *Ajuga reptans* and *Lamium album*, both of which provide spring forage. Hymettus (2002) similarly recognised that hedge-bottom plants such as labiates in less intensive agricultural situations were important forage components for long-tongue bumblebee species.	1/1B Create a 3m or 2m corridor to include tree and shrub planting on improved land	• New WLF on improved land • WLF to grow at least 2m wide • New stock proof, double fence • Species richness; $\geq$ 5 woody species • Rough grass margin between hedge and fence • Hedgerow saplings/trees at intervals of 20-70m	Habitat Mapping –linears Habitat mapping; B & D plots Linears & Fence condition B & D plots Habitat mapping – linears B & D plots
	2/2B Create a 3m or 2m corridor to include earth bank and tree and shrub planting on improved land	• New earth bank at least 0.75m high and 0.75m wide • WLF to grow at least 2m wide • New stock proof, double fence • New rough grass margin between fence and WLF • Species richness; $\geq$ 5 woody species • Up to 75% of plants may be hawthorn and/or blackthron	Habitat mapping – linears Habitat mapping; B & D plots Linears & Fence condition Habitat mapping – linears B & D plots B & D plots
	3 Create a wildlife corridor – established woody strip	• New WLF on improved land • WLF between 5-15m wide • New stock proof fencing • Species richness ; $\geq$ 5 woody species • $\leq$ 25% native conifers	Habitat mapping - linears Linears & Fence condition B & D plots B & D plots B & D plots

	6 Double fence gappy hedges / 6B Double fence gappy hedgerows at a 2 metre width (1 metre from centre) / 42A Hedgerow Restoration With Fencing	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF maintained at least 1.5m high and 1.5m wide • Hedgerow saplings/trees at intervals of 20-70m	Linears & Fence condition Habitat mapping - Linears B & D plots Habitat mapping; B & D plots B & D plots
	42B. Hedgerow restoration without fencing	• Hedgerow trees at intervals of 20-70m • Decrease in vertical gappiness	D plots D plots
	43A/43B. Double Fence and Restore Hedge Banks With/without Planting	• New stock proof, double fencing around existing hedges • New margin between hedge and fence • Decrease in vertical gappiness • WLF restored to a minimum of 0.5m high and 0.5m wide • Hedgerow saplings/trees at intervals of 20-70m • <u>Presence of Labiates in hedgerows</u> • <u>Connectivity to flower rich grassland</u>	Linears & Fence condition Habitat mapping - Linears Habitat mapping - Linears Habitat mapping; B & D plots B & D plots
One of the major agricultural changes in Britain is the loss of red clover leys (Goulson, 2010), yet red clover is one of the most important food plants of *B.humilis* & B. *sylvarum* (Hymettus, 2006; Bug life n.d). It has also been found that the Fabaceae family is disproportionally favoured as forage plants (Goulson, 2010; Connop, 2007; Saunders, 2008). Knowing this, the creation of red clover leys theredore has the potential to encourage the expansion of this	153 - Red clover ley	• Area of new red clover ley • $\geq$ 80% of sward is red clover	Habitat mapping, X plot

species, particularly as red clover often flowers late into the summer (Bumblebee conservation trust, n.d).			
Recent national records have found the remaining populations of *B humilis* & *B.sylvarum* have a coastal distribution (Connop 2008; Buglife, n.d.a). Grazing plays a key role in maintaining the abundance and species richness preferred bumblebee forage plants. Cattle are particularly suitable for bee conservation as their grazing creates a more structurally and floristically diverse sward that also benefits other invertebrates (Carvell, 2002).	20. Management of Coastal and Lowland Heath 20B. Management of Coastal and Lowland Heath With Mixed Grazing Option 148 - Coastal grassland (maritime cliff and slope)	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • $\geq$25% dwarf-shrub species on coastal heath • $\leq$25% of heath burnt over 5 years • Sheep/cattle grazing on coastal grassland • High species diversity • Cattle grazing	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping Habitat mapping
The loss of unimproved grasslands coupled with the narrow diet of carder bees compared to the common bee species is thought to be one of main causes of carder bee decline (Goulson, 2010). *B. sylvarum* and *B. humilis* utilise a network of forage sources over site- and landscape-scales therefore conservation of a single site might not be sufficient to support populations. A network of forage and nesting habitat at a site- and landscape-scale is required to support viable metapopulations and to buffer colonies against the effects of forage patch losses (Connop et al. 2011). Shrill carder bee needs large, continuous patches of flowering plants (buglife, n.d). Flower families preferred by *B.sylvarum* workers include Lamiaceae, Orobanchaceae, Scrophulariaceae and Fabaceae, all of which are visited roughly equally (Connop, 2008; Buglife n.d). Connop (2008) found B.sylvarum preferred to forage on Odontites verna and points out this plant has been consistently recorded as a favourite forage plant in other previous studies including Edwards(1999), Harvey (1999);	15 Grazed permanent pasture with no inputs. / 15C Grazed permanent pasture with no inputs and mixed grazing Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture) 123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture)	• Permanent pasture maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm • Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm • Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots

and Harvey (2000). In a separate study, the Hymettus (2002) also identified a strong association with Odontites verna. However the bumblebee working group (2002) felt that foraging habitat was dependent upon the structure of the grassland (tall and open) as much as the exact composition of the flora, although it was obvious that some plants were favoured. Also been suggested that density of suitable flower resources seems to be the decisive factor (Hymettus, 2006). Horsley et al (2013) suggest that management should be to maintain large expanses of unimproved, flower-rich habitat using traditional management i.e. grazing or cutting. Bug life (n.d) suggests that stands of flowering knapweed, burdock and thistle should be protected to provide food for foraging Queens. Grazing plays a key role in maintaining the abundance and species richness preferred bumblebee forage plants such as C. nigra and T. pratense. Cattle are particularly suitable for bee conservation as their grazing creates a more structurally and floristically diverse sward that also benefits other invertebrates (Carvell, 2002). B. humilis and B. sylvarum emerge late from hibernation in comparison to other bees, as such workers require relatively late forage (Harvey, 2000) and have been recorded foraging in late September and even into early October in this study (Connop 2008). As such it is vital that sites have a continuum of flowers stretching from late May to late September (Saunders 2008; Bumblebee conservation trust, n.d).	128 Lowland unimproved calcareous grassland / 129 Lowland unimproved calcareous grassland - reversion (pasture) 131 Conversion from arable to grassland (no inputs) 133 Lowland marshy grassland / 134 Lowland marshy grassland; reversion (pasture) .	• Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm • Area of new grassland • Grassland grazed once established • Sward height at least 5cm • Grazing of Marshy grassland • Varied sward – 80% of grasses (excluding rushes) between 10 & 30cm • High % of Scrophulariaceae, Orobanchaceae, Asteraceae, Lamiaceae and particularly Fabaceae flowering plants in grassland • Presence of *Odontites verna* • Tall vegetation • Stands of knapweed, burdock & thistles • Litter • Bryophytes • Tussocky vegetation • Large expanse of unimproved flower rich grassland • Cattle grazing	Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping Habitat mapping, X plot Habitat mapping Habitat mapping, X, U & Y plots X, Y or U plots X, Y or U plots Habitat mapping; X, Y or U plots Habitat mapping X, Y or U plots X, Y or U plots X, Y or U plots Habitat mapping Habitat mapping
Carder bees are reliant on tall, undisturbed grassland, particularly tussocky grassland (Connop 2008). Sowing non-crop field margins with wildlife seed mixtures has the potential for providing the best foraging habitat for	26 Fixed rough grass margins on arable land	• New rough grass margin • Width of 2-8m on arable land • No grazing once established	Habitat mapping Habitat mapping Habitat mapping

bumblebees through the season, so long as preferred forage species are introduced such as Trifolium pratense, Lotus corniculatus and Centaurea nigra (Goulson 2010; Carvell et al. 2006; Pwyll, 2005). Glastir prescriptions suggest a tussock-forming grass mixture should be sown. In support of this, a study by Carvell (2004) created 6m wide arable field margin sown with 'tussocky grasses'. After three years, (having being left uncut after year one), the margin had developed into the expected tussocky structure thought to be ideal for nest seeking queen's. Most favoured plant families include Fabaceae, Lamiaceae, Asteraceae and Scrophulariaceae (Bug life n.d). Study in Salisbury plain mostly recorded B. humilis within the taller less intensively managed, reverting arable grasslands due to their structural suitability as nesting habitat, as well as the availability of forage plants (Carvell, 2002). The importance of undisturbed grassland becomes particularly clear with the understanding of nesting preferences. Generally carder bees nest on the surface of the ground at the base of long, tussocky vegetation, often under accumulated dried plant litter or moss at the base of the vegetation. Sunlight provides warmth to the surface of the nests, but they are also known to utilise old nests of small mammals such as voles (Hymettus, 2002; Natural Museum & Galleries of Wales, n.d.) Management recommendations from Horsley et al (2013) include retained isolated patches of coarse vegetation to provide nesting opportunities for the species.	26B Rotational rough grass margin on arable land 27 Fallow margins 174 Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	• Mix of tussock forming grasses • Cannot be rotated • New rough grass margin adjacent to cereal, rape, linseed or root crop • Between 2-8m wide • Mix of tussock forming grasses • No grazing once established • Can be rotated • New fallow crop margin adjacent to cereals, oil seed rape, linseed, maize or roots • Between 2-8m wide • Can be rotated • New rough grass margin on arable land • Livestock excluded • <u>Tussocky vegetation</u> • <u>High % of Scrophulariaceae, Orobanchaceae, Asteraceae, Lamiaceae and particularly Fabaceae flowering plants in grassland</u> • <u>% litter</u> • <u>% bryophytes</u>	Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping
Carder bees are reliant on tall, undisturbed grassland, particularly tussocky grassland (Connop 2008) as well as smaller patches that are widely distributed. A study by Carvell (2002) also showed that B .humilis numbers were significantly related to increased vegetation structure, height and total flower abundance. Generally	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub	• New area of rough grassland in field corner (Max size 0.35ha) • New length and location of stock proof	Habitat mapping Linears and fence condition

carder bees nest on the surface of the ground at the base of long, tussocky vegetation, often under accumulated dried plant litter or moss at the base of the vegetation. Sunlight provides warmth to the surface of the nests, but they are also known to utilise old nests of small mammals such as voles (Hymettus, 2002; Natural Museum & Galleries of Wales). Management recommendations from Horsley et al (2013) include retaining isolated patches of coarse vegetation to provide nesting opportunities for the species.	175 - Management of rough grassland; enclosed land	• No/Minimal scrub on rough grs (enclosed land) • Varied sward height >20cm • <u>Tussocky grassland</u> • <u>Tall vegetation</u>	Habitat mapping Habitat mapping
Habitats peripheral to the cliffs are also important, such as dunes (Saunders, 2008). In the past, national records have found the remaining populations of *B humilis* & *B.sylvarum* have a coastal distribution (Connop 2008; Buglife, n.d).	25 Management of sand dunes 25B Management of sand dunes with mixed grazing 151 Coastal vegetated shingle and sand dunes - creation	• Grazing by cattle, sheep, goats or ponies • Managed by grazing • At least 20% <5cm and at least 40% <10cm • Grass cover <70% in wet hollows	Habitat mapping
B. humilis and B. sylvarum emerge late from hibernation in comparison to other bees, as such workers require relatively late forage (Goulson, 2010). Carvell (2000) and bumblebee conservation trust (n.d) recommend cutting should be delayed until mid-July to August or if a farm has numerous hay meadows then a field (rotating each year) should be late in September. A later cut therefore maintains forage flowers into late season. Hay cutting prescriptions recommend that hay is cut after 8th July. No other specification for cutting, as such this may detrimental for bees.	22 Existing haymeadows 122 Lowland unimproved acid grassland - reversion (hay cutting) / 124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion (hay cutting) / 130 Lowland unimproved calcareous grassland - reversion (hay cutting) / 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Field shut off from livestock before 15 May and closed for at least 10 weeks • Aftermath sward height - 80% of the grasses between 5- 15cm high • Grassland maintained by grazing and hay cutting • Field shut off from livestock by 1 May every year • Between 5-10% left uncut • Aftermath sward height - 80% of the grasses between 5- 15cm high	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & Y plots

	132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Change from improve grassland to semi-improved grassland • Grassland maintained by grazing and hay cutting • Between 5-10% left uncut • Aftermath sward height - 80% of the grasses between 5- 15cm high	Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & Y plots
Unable to find evidence; however Claire Carvell (pers comm.) suggest these measures have the potential to provide forage resources depending on seedbank.	19 Lowland marshy grassland 19B Management of lowland marshy grassland with mixed grazing	• Sward height (excluding rushes) between 5-30cm on enclosed land • Sheep & Cattle grazing on marshy grs (enclosed land) • Sward height (excluding rushes) between 5-30cm on enclosed land • Presence of marshy grassland	Habitat mapping, X, Y & u plots Habitat mapping Habitat mapping, X, Y & u plots Habitat mapping
Unable to find evidence; however Claire Carvell (pers comm.) suggest these measures have the potential to provide forage resources depending on cover crop chosen i.e. nectar/pollen rich.	33 Establish a wildlife cover crop on improved land 34 Unharvested cereal headland 34B Unfertilised and unsprayed cereal headland	• On improved land only • 4m wide seed bed established for crop • Crop cover to be at least 80% cereals with at least one of the following; mustard, rape or linseed. • No maize • Only on improved land • 3-6m wide cereal headland established along edge of crop • Only on improved land • 3-6m wide cereal headland established along edge of crop Can be rotated	Habitat mapping Habitat mapping M plot M plot Habitat mapping Habitat mapping Habitat mapping Habitat mapping

No evidence	41A Grazing management of open country 41B Grazing management of open country with mixed grazing	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed	Habitat mapping Habitat mapping
Unable to find evidence	115 Lowland dry heath with less than 50% western gorse / 116 Lowland dry heath with more than 50% western gorse 117 Lowland wet heath with less than 60% purple moor- grass / 118 Lowland wet heath with more than 60% purple moor-grass 119 Lowland heath habitat expansion - establishment on grassland	Minimal guidance	

HIGH BROWN FRITILLARY

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Grass/bracken mosaics below 300m, situated on south-facing slopes are most likely to support high brown fritillaries. Breeding areas are characterised by short sparse vegetation with little grass cover as well as violets growing through a shallow layer of bracken litter (<15cm). Females lay their eggs individually on the leaves and stems of dead bracken. Once the caterpillars emerge, long periods of time are spent basking on bracken litter. Time is also spent feeding on the leaves of Common Dog-violet (Bulman et al, 2005; Ellis et al, 2012). Extensive grazing by cattle and ponies is ideal to create/maintain ideal habitats for this species is they help to break up the dense trash, thus opening up the canopy for violets (Warren & Wigglesworth, n.d (a)). * As detailed by Barnett & Warren (1995), adults will feed on; Bramble (*Rubus fruticosus*) blossom Common Knapweed (*Centaurea nigra*) Thistle species (*Cirsium* spp.) Ragwort (*Senecio jacobaea*) Betony (*Stachys officinalis*) Field scabious (*Knautia arvensis*) And hawkbits	15 Grazed permanent pasture with no inputs. / 15C Grazed permanent pasture with no inputs and mixed grazing	• Permanent pasture maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm	Habitat mapping Habitat mapping
	Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture)	• Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm	Habitat mapping Habitat mapping; X & U plots
	123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture)	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep	Habitat mapping Habitat mapping; Habitat mapping; X & Y plots Habitat mapping; X & Y plots
	128 Lowland unimproved calcareous grassland / 129 Lowland unimproved calcareous grassland - reversion (pasture)	• Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm	Habitat mapping Habitat mapping; X & U plots
	122 Lowland unimproved acid grassland - reversion (hay cutting) / 124 Lowland unimproved neutral grassland – haymeadow / 126 Lowland unimproved neutral grassland - reversion	• Grassland maintained by grazing and hay cutting • Field shut off from livestock by 1 May every year • Between 5%-10% left uncut	Habitat mapping Habitat mapping Habitat mapping

	(hay cutting) / 130 Lowland unimproved calcareous grassland - reversion (hay cutting) / 132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Aftermath sward height - 80% of the grasses between 5- 15cm high • Bracken stands or grass/bracken mosaics on south facing slopes (below 300m) • Grazing by cattle or ponies • Presence of * species	Habitat mapping; X & Y plots Habitat mapping, X & U plots Habitat mapping Habitat mapping' X & Y plots
Grass/bracken mosaics below 300m, situated on south-facing slopes are most likely to support fritillaries. Breeding areas are characterised by short sparse vegetation with little grass cover as well as violets growing through a shallow layer of bracken litter (<15cm). Females lay their eggs individually on the leaves and stems of dead bracken. Once the caterpillars emerge, long periods of time are spent basking on bracken litter. Time is also spent feeding on the leaves of Common Dog-violet (Bulman et al, 2005; Ellis et al. 2012). Feeding also occasionally occurs on Hairy Violet (*Viola hirta*), Heath Dog-violet (*Viola canina*) and Pale Dog-violet (*Viola lactea*) (Warren & Barnett, 1995). Extensive grazing by cattle and ponies is ideal to create/maintain ideal habitats for this species is they help to break up the dense trash, thus opening up the canopy for violets (Warren & Wigglesworth, n.d). Breeding requirements of the high brown fritillary defined by Warren & Key (1991) and Warren (1992). • Dense bracken stand with a canopy between 30-70% cover •Bracken height between 40-110cm	44 Mechanical bracken control	• Areas of Bracken • Change in bracken height • Bracken stands or grass/bracken mosaics on south facing slopes (below 300m) • Bracken height between 40 - 110cm • Bracken Litter • Short vegetation growing through bracken litter • 10-25% cover of Common-Dog violet in bracken understory • <30% grass cover • Grazing by cattle or ponies	Habitat mapping Habitat mapping Habitat mapping, U plots Habitat mapping, U plot U plots U plots Habitat mapping, U plots Habitat mapping, U plots Habitat mapping

•The larval food plant, common dog violet is abundant (10- 25% cover) amongst a sparse ground vegetation under bracken • Bracken litter 5-l0cm with low grass cover 30%) and low levels of bracken "thatch" (accumulation of dead bracken litter in the sub-canopy) •Sites are on sheltered, south-facing below 300m altitude Stands of bracken on uplands are moorlands are unsuitable because they are too acidic and do not contain violets (Warren & Wigglesworth, n.d).			
(CRoW Act definition of 'open country' – mountain, moor, heath and downland). Extensive grazing by cattle and ponies is ideal to create/maintain ideal habitats for this species is they help to break up the dense trash, thus opening up the canopy for violets (Warren & Wigglesworth, n.d (a)).	41A Grazing management of open country 41B Grazing management of open country with mixed grazing	• Gazing of 'open country' • Mixed grazing of 'open country' • <u>Grazing by cattle and ponies</u>	Habitat mapping Habitat mapping Habitat mapping
As detailed by Barnett & Warren (1995), adults will feed on Bramble (*Rubus fruticosus*) blossom.	103 Scrub - stock exclusion	• Existing area of scrub • New stock proof fencing around areas of scrub • <u>Areas of bramble</u>	Habitat mapping Linears and fence condition

MARSH FRITILLARY

Evidence obtained from Literature	**Target Species and Glastir Measures**	**Specific Response Variables**	**GMEP Survey Data That Captures Measure or Target**
Devil's bit scabious (*Succisa pratensis*) is the larval food plant of the marsh fritillary. When egg-laying, females lay their eggs on the underside of the plant's leaves and have a tenancy to choose the largest leaves for this purpose; field scabious and small scabious are also occasionally used (Gaywood, n.d; Warren & Wigglesworth, n.d (b)). Devil's bit scabious leaves used for egg laying are typically found in swards of 8-25cm, or shorter swards of 5-15cm when the food plant is abundant. (Warren & Wigglesworth, n.d (b)). Damp, acid or healthy grassland, where devil's-bit scabious is abundant, is one of the two main types of habitat which support marsh fritillary. These habitats are normally open, unshaded and dominated by tussock-forming grass such as *Molinea caerulea* on more acidic soils or *Deschampsia caespitosa* on more neutral soils (Warren, 1994; Butterfly Conservation, n.d). Dry, calcareous grassland is the second of the two major habitats, but this is predominately found in central, southern Britain, usually on west or south facing slopes (Warren, 1994). In Wales, marsh fritillaries will also breed in unimproved neutral grassland (Fowles & Smith, 2006). The marsh fritillary exhibits metapopulation dynamics as there is regular turnover of colonies causing high rates of extinction but also some colonisation of new sites due to their ability to dispersal. Since colonies are interconnected, the long term survival of the species is	19 Lowland marshy grassland	• Sward height (excluding rushes) between 5-30cm on enclosed land	Habitat mapping, X, Y & u plots
	19B Management of lowland marshy grassland with mixed grazing	• Mixed grazing • Sward height (excluding rushes) between 5-30cm on enclosed land	Habitat mapping Habitat mapping, X, Y & u plots
	123. Lowland unimproved neutral grassland – pasture	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs	Habitat mapping Habitat mapping
	133. Lowland marshy grassland 134. Lowland marshy grassland; reversion (pasture)	• Sward height between 10cm – 20cm • Sward height between 5cm – 20cm when not grazed by sheep	Habitat mapping; X & Y plots Habitat mapping; X & Y plots
	117 Lowland wet heath with less than 60% purple moor- grass	• Grazing of Marshy grassland • Sward height between 10cm-30cm	Habitat mapping Habitat mapping, X, Y & u plots
	118 Lowland wet heath with more than 60% purple moor-grass	• Area of lowland wet heath with <60% purple moor-grass	Habitat mapping
	139 Lowland bog and other acid mires with less than 50% purple moor-grass	• Area of lowland wet heath with >60% purple moor-grass	Habitat mapping
	140 Lowland bog and other acid mires with more than 50% purple moor-grass	• Area of lowland bog/acid mire with <50% purple moor-grass	Habitat mapping

dependent on the protection of a mosaic of suitable, large habitat patches in close proximity. This therefore allows successful dispersal at times of high population levels, but also compensates for the periodic local extinctions to which local populations are prone (Warren 1994). A study by Schtickzelle et al. (2005) suggests the restoration or enlargement of existing habitat patches, as well as the creation of new habitat patches will help to improve metapopulation viability and the larger the habitat area, the better. Ideally, scrub more than 0.5 m tall) should covers no more than 5% of area (Fowles, 2003). Populations can fluctuate from year to year due to food supply, bad weather and caterpillar parasitism by *Cotesia melitaearum* and *Cotesia bignellii* (Barnett & Warren, 1995; Gaywood, n.d). Bulman (2001) studied parasitoid attack and found that *Cotesia bignelli* appears to have metapopulation dynamics. The presence of parasitoids may therefore be a major cause of variation and metapopulation dynamics of the marsh fritillary, and may help to explain the butterfly's requirement of large habitat patches.	141 Lowland bog and other acid mires - restoration (no grazing)	• Area of lowland bog/acid mire with <50% purple moor-grass • Area of lowland bog/acid mire • <u>High % of *Succisa pratensis*</u> • <u>Tussocky sward</u> • <u>Sward height 12-25cm</u> • <u>Cattle or horse grazing only</u> • <u>Presence of *Cotesia melitaearum* and *Cotesia bignelli* (parasitic wasps)</u> • <u>Scrub >0.5m tall covers <5% area within habitat patches</u> • <u>Species rich</u> • <u>Closely connected, large habitat patches together exceeding 2ha*</u>	Habitat mapping Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping Habitat mapping Habitat mapping, Invertebrate survey Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping
Unable to find evidence	20. Management of Coastal and Lowland Heath / 20B. Management of Coastal and Lowland Heath With Mixed Grazing	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • ≥ 25% dwarf-shrub species on coastal heath • ≤25% of heath burnt over 5 years	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping
Unable to find evidence	Option 143 - Lowland fen 145 - Lowland fen; reversion (pasture) 144 Lowland fen - restoration (no grazing)	• Grazing on Lowland fen • Sward height between 10cm-80cm (except patches of moss) • Area of restored/new lowland fen	Habitat mapping Habitat mapping, X & U plots Habitat mapping

Unable to find evidence	400 Additional Management Payment - Stock management 403 Additional Management Payment Re-wetting	Minimal guidance, additional payment.	

PEARL BORDEDED FRITILLARY

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
To the west of Britain, the main breeding habitat of the pearl bordered fritillary is rough grassland, hillside bracken stands with violets growing through a shallow (<15cm) layer of bracken litter and/ or scattered scrub, often gorse and blackthorn (Barnett & Warren, 1995b; Warren & Wiggleworth n.d). The key larval food-plant throughout its range is Common Dog-Violet (*Viola riviniana*) but further north Marsh Violet (*V. palustris*) can be used, and other species such as Heath Dog-Violet *Viola canina* may be used in some habitats. A mosaic of bracken and grassy patches as well as abundant violets growing through the bracken litter is an ideally suited habitat. The mosaic is typically 1/3 grass to 2/3 bracken. To create this type of habitat, extensive grazing by cattle and ponies is ideal, particularly as trampling by animals helps to break up the bracken trash and opens up the bracken canopy to provide germination sites for violets (Warren & Wigglesworth, n.d (c)). Adults feed in areas where there are plenty of spring flowers, like bugle and thistle (Barnett & Warren, 1995; Warren & Wigglesworth, n.d (c)). Sheep are the least appropriate grazing animal as they do not trample bracken beds sufficiently, and may also eliminate nectar plants (Brereton, n.d).	Option 120 - Lowland unimproved acid grassland / 121. Lowland unimproved acid grassland - reversion (pasture)	• Grassland maintained by grazing • Varied sward - 20% of grasses >7cm and 20% of grasses <7cm • Grassland maintained by grazing • At least 75% of grasses and herbs between 3cm-20cm	Habitat mapping Habitat mapping; X & U plots Habitat mapping Habitat mapping; X & U plots
	123. Lowland unimproved neutral grassland – pasture / 125. Lowland unimproved neutral grassland - reversion (pasture)	• Sheep grazing on unimproved neutral grs • Sheep & Cattle grazing on unimproved neutral grs • Sward height between 10cm & 20cm • Sward height between 5cm & 20cm when not grazed by sheep	Habitat mapping Habitat mapping Habitat mapping; X & Y plots Habitat mapping; X & Y plots
	128 Lowland unimproved calcareous grassland	• Grassland maintained by grazing • Varied sward – at least 75% of grasses and herbs between 3cm & 50cm	Habitat mapping Habitat mapping; X & U plots
	41A Grazing management of open country	• Gazing of ‘open country’	Habitat mapping
	41B Grazing management of open country with mixed grazing	• Mixed grazing of ‘open country’	Habitat mapping

		• Hillside bracken stands on rough grassland • Violets growing through bracken litter • Grassland mosaic (30% grass to 60% bracken) • Scattered scrub particularly gorse and blackthorn on grassland • Grazing by cattle and ponies • Presence of spring flowers i.e. Bugle & thistle	
To the west of Britain, the main breeding habitat of the pearl bordered fritillary is rough grassland, hillside bracken stands with violets growing through a shallow (<15cm) layer of bracken litter and/ or scattered scrub, often gorse and blackthorn (Barnett & Warren, 1995; Warren & Wiggleworth n.d). The female butterflies lay their eggs singly on dead bracken litter near to violets and once hatched, the caterpillars feed intermittently on common dog violet, particularly the young leaves which grow through the shallow stands of bracken litter. (Bulman et al. 2005; Brereton, n.d; Warren & Barnett, 1995; Warren & Wigglesworth, n.d (c)). Cutting should not be seen a replacement for grazing. If cutting is the only option, areas of Bracken (0.5 to 1ha) should be cut during late May or early June over a 3 to 10 year period (Bulman et al. 2005).	44 Mechanical bracken control	• Cutting between 1st May & 15th August • Hillside bracken stands on rough grassland • Violets growing through bracken litter • Grazing by cattle and ponies	Habitat mapping Habitat mapping Habitat mapping, U plots Habitat mappin
To the west of Britain, the main breeding habitat of the pearl bordered fritillary is rough grassland, hillside bracken stands with violets growing through a shallow (<15cm) layer of bracken litter and/ or scattered scrub (Barnett & Warren, 1995; Warren & Wiggleworth n.d).	103 Scrub - stock exclusion	• Existing area of scrub • New stock proof fencing around areas of scrub	Habitat mapping Linears and fence condition Habitat mapping

As well as bracken litter, other leaf litter, (including bramble) is important because it provides a place for the caterpillars to hibernate during the winter months (Bulman et al, 2005; Warren & Barnett, 1995).		• Scattered scrub in grassland • Presence of leaf litter	Unlikely to be recorded
Extensive grazing by cattle and ponies is ideal, particularly as trampling by animals helps to break up the bracken trash and opens up the bracken canopy to provide germination sites for violets (Warren & Wigglesworth, n.d (c)).	400 Additional Management Payment - Stock management 401 Additional Management Payment - Mixed grazing 411 Additional Management Payment - Reduce stocking	Minimal guidance	Unlikely to be measured
Unable to find evidence	20. Management of Coastal and Lowland Heath 20B. Management of Coastal and Lowland Heath With Mixed Grazing	• Grazing by cattle, sheep, goats or ponies • >50% dwarf shrub species on lowland heath • ≥ 25% dwarf-shrub species on coastal heath • ≤25% of heath burnt over 5 years	Habitat mapping Habitat mapping, X, Y & U plots Habitat mapping, X, Y & U plots Habitat mapping
Unable to find evidence	148 Coastal grassland (maritime cliff and slope)	• Sheep/cattle grazing on coastal grassland	Habitat mapping
Unable to find evidence	15 Grazed permanent pasture with no inputs. 15C Grazed permanent pasture with no inputs and mixed grazing	• Permanent pasture maintained • Grazing/ Mixed grazing	Habitat mapping Habitat mapping

WELSH CLEARWING

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Welsh Clearwing females lay their eggs in the bark crevices of mature, often isolated/scattered birch trees, over 40-50 years old, in open situations with sunlit trunks. Both Silver Birch Betula pendula and Downy Birch Betula pubescens are used. The caterpillars feed and grow within the inner bark of the trees for up to 2-3 years until pupation takes place (Butterfly Conservation Wales, n.d; Knowler, n.d). If the trees are not currently used by the moth, it is advised that all existing, old birch trees should be retained, as these may be colonised in future (Butterfly Conservation Wales). A study in England and Wales using known records of the species found almost 60% of the pupae emergent holes occur at high altitude on the warmer South side of the host tree (Bevan & Forman, 2013). Very little is known the ecology of the Welsh clearwing other than the preference for rearing larva in the trunks of Birches. Furthermore, there is little known reason why the species is not more wide spread in Wales (Bevan & Forman, 2013).	13 Plant individual native trees on improved land 104 Wood pasture	• New individual broadleaved native trees on improved land • Tree guards or fencing around new trees • No new ash trees • Area of wood pasture • Grazed grass understory • Presence of existing, mature Silver and/or downy birch trees • Scattered or isolated birch trees	Habitat mapping – Points Habitat mapping – Points Habitat mapping – Points Habitat mapping Habitat mapping Habitat mapping – Points Habitat mapping - Points

"In even aged stands, where trees could die at the same time, ensure the establishment of new trees to provide continually maturing trees for the future" (Butterfly Conservation Wales, n.d).	101. Trees and scrub - establishment by Planting 102. Trees and scrub - establishment by natural regeneration	• New area of trees and scrub • New length of stock proof fence	Habitat mapping Linears and fence condition assessment
	103 Scrub - stock exclusion	• Existing area of scrub • New stock proof fencing around areas of scrub	Habitat mapping Linears and fence condition assessment

BARNETT, L., WARREN, M. S. & CONSERVATION, B. 1995. Marsh Fritillary: Eurodryas Aurinia, Butterfly Conservation.

BARNETT, L. K. & WARREN, M. S. 1995. Species Action Plan: High brown fritillary Argynnis adippe. Butterfly Conservation, Dorset.

BARNETT, L. K. W., M. S. S BUTTERFLY CONSERVATION, DORSET. 1995. Species Action Plan: Pearl-bordered fritillary Boloria euphrosyne. Butterfly Conservation, Dorset.

BARNETT, L. K. W., M. S. 1995. Species action plan: Pearl-bordered fritillary Boloria euphrosyne. Butterfly Conservation, Dorset.

BETZHOLTZ, P. E., EHRIG, A., LINDEBORG, M. & DINNÉTZ, P. 2007. Food plant density, patch isolation and vegetation height determine occurrence in a Swedish metapopulation of the marsh fritillary Euphydryas aurinia (Rottemburg, 1775) (Lepidoptera, Nymphalidae). Journal of Insect Conservation, 11, 343-350.

BEVAN, R. & FORMAN, D. 2013. A mysterious moth: The Welsh clearwing. Natur Cymru.

BRERETON, T. No date. The distribution, ecology and conservation of the pearl-bordered fritiilary butterfly Boloria euphrosyne in Scotland [Online]. Scottish Natural Heritage, Edinburgh. Available: http://www.snh.org.uk/publications/on-line/advisorynotes/114/114.htm.

BUGLIFE. No date. Species management sheet. Shrill carder bee (Bombus sylvarum) and Brown-banded carder bee (Bombus humilis) [Online]. Available: https://www.buglife.org.uk/sites/default/files/Shrill%20and%20Brown-banded%20carder%20bee%20species%20management%20sheet.pdf [Accessed 22/09/2014].

BULMAN, C., JOY, J. & BOURN, N. 2005. How to identify suitable Bracken habitats for Fritillaries. Butterfly Conservation. Butterfly Conservation, Dorset.

BULMAN, C. R. 2001. Conservation biology of the marsh fritillary butterfly Euphydryas aurinia. PhD Thesis, Unicersity of Leeds.

BUMBLEBEE CONSERVATION TRUST. No date (a). Managing wildflower meadow for bumblebees Bumblebee Conservation Trust. Hampshire. [Online]. Available: http://bumblebeeconservation.org/images/uploads/BBCT_Land_Factsheet_2_WELSH.pdf [Accessed 2014]

BUMBLEBEE CONSERVATION TRUST No date (b). Shrill carder bee factsheet. Bumblebee Conservation Trust. Hampshire.

BUTTERFLY CONSERVATION WALES. No date. Welsh Clearwing Synanthedon scoliaeformis. Swansea. [Online]. Available: http://butterfly-conservation.org/files/bcw_welsh-clearwing_eng.pdf [Accessed 10/03/2015].

CARVELL, C. 2002. Habitat use and conservation of bumblebees (Bombus spp.) under different grassland management regimes. Biological Conservation, 103, 33-49.

CARVELL, C., MEEK, W. R., PYWELL, R. F. & NOWAKOWSKI, M. 2004. The response of foraging bumblebees to successional change in newly created arable field margins. Biological Conservation, 118, 327-339.

CARVELL, C., ROY, D. B., SMART, S. M., PYWELL, R. F., PRESTON, C. D. & GOULSON, D. 2006. Declines in forage availability for bumblebees at a national scale. Biological Conservation, 132, 481-489.

CONNOP, S. 2007. Habitat and habitat management requirements of the shrill carder bee (bombus sylvarum) and the brown-banded carder bee (bombus humilis) in South Essex. University of East London.

CONNOP, S., HILL, T., STEER, J. & SHAW, P. 2010. The role of dietary breadth in national bumblebee (Bombus) declines: Simple correlation? Biological Conservation, 143, 2739-2746.

CONNOP, S., HILL, T., STEER, J. & SHAW, P. 2011. Microsatellite analysis reveals the spatial dynamics of Bombus humilis and Bombus sylvarum. Insect Conservation and Diversity, 4, 212-221.

EDWARDS, M. 1999. UK BAP Bumblebee Working Group Report, 1999. Midhurst.

ELLIS, S., BOURN, N. & BULMAN, C. 2012. Landscape-scale conservation for butterflies and moths. Lessons from the UK. Butterfly Conservation, Dorset.

FOWLES, A. P. & SMITH, R. G. 2006. Mapping the Habitat Quality of Patch Networks for the Marsh Fritillary Euphydryas aurinia (Rottemburg, 1775) (Lepidoptera, Nymphalidae) in Wales. Journal of Insect Conservation, 10, 161-177.

GAYWOOD, M. No date. The distribution, ecology and conservation of the marsh fritillary butterfly (Eurodryas aurinia) [Online]. Scottish national heritage, Edinburgh. Available: http://www.snh.org.uk/publications/on-line/advisorynotes/9/9.htm [Accessed 01/10/14].

GOULSON, D. 2010. Bumblebees: behaviour, ecology, and conservation, Oxford University Press.

GOULSON, D., HANLEY, M. E., DARVILL, B., ELLIS, J. & KNIGHT, M. E. 2005. Causes of rarity in bumblebees. Biological Conservation, 122, 1-8.

HARVEY, P. 2000. Shrill Carder Bee: Essex 2000. Report Produced for English Nature, Colchester Essex.

HORSLEY, C., WHITEHOUSE, A. & FALK, S. 2013. South West Bees Project. A report on the status of threatened bees in the region with recommendations for conservation action. Buglife.

HYMETTUS. 2002. Bumblebee working group report - Summary of report. [Online]. Available: http://hymettus.org.uk/downloads/2002_BWG_Report.pdf [Accessed 2014].

HYMETTUS. 2006. Bumblebees, Bombus species, associated with open grassland [Online]. Available: http://hymettus.org.uk/downloads/Grassland_Bumblebee_info_sheet.pdf [Accessed 2014].

KNOWLER, J. T. No date. The Welsh clearwing in The Trossachs. Milngavie, Glasgow.

MASON, C. F. & MACDONALD, S. M. 2000. Corn Bunting Miliaria calandra populations, landscape and land-use in an arable district of eastern England. Bird Conservation International, 10, 169-186.

NATURAL, MUSEUM, &, GALLERIES, OF & WALES. No date. Bombus humilis [Online]. Available: http://naturalhistory.museumwales.ac.uk/corespecies/CMS/Resources/pdfs/Bombus_humilis/Bombus_humilis_1.pdf [Accessed 2014].

PYWELL, R. F., WARMAN, E. A., CARVELL, C., SPARKS, T. H., DICKS, L. V., BENNETT, D., WRIGHT, A., CRITCHLEY, C. N. R. & SHERWOOD, A. 2005. Providing foraging resources for bumblebees in intensively farmed landscapes. Biological Conservation, 121, 479-494.

SAUNDERS, P. 2008. Bombus muscorum and Bombus humilis in the South West in 2008. Hymettus Ltd [Privately published pamphlet, Hymettus ltd, Lea-Side, Carron Lane, Midhurst, West Sussex.

SCHTICKZELLE, N., CHOUTT, J., GOFFART, P., FICHEFET, V. & BAGUETTE, M. 2005. Metapopulation dynamics and conservation of the marsh fritillary butterfly: population viability analysis and management options for a critically endangered species in Western Europe. Biological Conservation, 126, 569-581.

SMITH, M. N. 2010. The status and distribution of the shrill carder bee Bombus sylvarum on Magor & Undy SSSI and Whitson SSSI on the Gwent Levels and on the Newport Wetlands National Nature Reserve in 2009. CCW Contract Science, No. 919. Countrysdie Council for Wales.

WAHLBERG, N., KLEMETTI, T., SELONEN, V. & HANSKI, I. 2002. Metapopulation structure and movements in five species of checkerspot butterflies. Oecologia, 130, 33-43.

WALES, B. C. No date. Welsh Clearwing Synanthedon scoliaeformis. Butterfly Conservation, Dorset.

WARREN, M. 1994. The UK status and suspected metapopulation structure of a threatened European butterfly, the marsh fritillary Eurodryas aurinia. Biological Conservation, 67, 239-249.

WARREN, M. & WIGGLESWORTH, T. No date. High Brown Fritillary Argynnis adippe. Butterfly Conservation, Dorset.

WARREN, M. S. 1992. The High Brown Fritillary - Britain's most endangered butterfly. Butterfly Conservation New, 50, 26-30.

WARREN, M. S. 1995. Managing local microclimates for the high brown fritillary, Argynnis adippe. In: PULLIN, A. (ed.) Ecology and Conservation of Butterflies. Springer Netherlands.

WARREN, M. S. & WIGGLESWORTH, T. No date (a). High Brown Fritillary Argynnis adippe. Butterfly Conservation, Dorset.

WARREN, M. S. & WIGGLESWORTH, T. No date (b). Marsh Fritillary Euphydryas aurinia. Butterfly Conservation, Dorset.

WARREN, M. S. & WIGGLESWORTH, T. No date (c). Pearl-bordered Fritillary Boloria euphrosyne. Butterfly Conservation, Dorset.

BLACK GROUSE

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
(CRoW Act definition of 'open country' – mountain, moor, heath and downland)	41A Grazing management of open country	• Grazing of 'open country'	Habitat mapping
Black grouse require a mosaic of upland habitats because they are depend on different type of vegetation to support their yearly lifecycle (RSPB, n,d. (a)).	41B Grazing management of open country with mixed grazing	• Mixed grazing of 'open country'. Cattle and sheep must be grazed	Habitat mapping
	16 Upland heath	No guidance	
A study in Wales (Cayford, 1990) and studies in the Northern Pennines (Baines, 1994; Starling-Westeberg, 2001) have all found heather and bilberry to form a considerable part of the black grouse diet throughout the year. Whilst this is true, the black grouse diet also closely reflects seasonal plant availability. During the spring cotton grass buds are a large part of their diet, whilst during the summer herbs, grasses, sedge and rushes are consumed. In the Autumn and winter months, heather makes up almost their entire diet, particularly for males. Yet, as noted by Black Grouse UK (2007) and Natural England (2010), winter berries found on shrubs and small trees such as hawthorn and rowan can also provide food in the winter. Any grazing occurring on these areas should aim to allow vegetation to flower and set seed (Adamson, 2007).	17 Blanket Bog	No guidance	
	18 Upland grassland	No guidance	
		• Light grazing	Habitat mapping
		• Mosaic of suitable upland habitats including heather moor, bog, rough/damp grassland and scattered trees	Habitat mapping
		• Presence of heather and bilberry	Habitat mapping, X, Y or U plots
		• Areas of tall (>40cm) rush or heather cover	X, Y or u Plots
		• Short grazed pasture on moorland edge	Habitat mapping

During the breeding season, hens require long heather or tall areas of rush (>40cm) for nesting and cover (Adamson, 2007; RSPB, n.d. (a)). Both Baines (1994) and Starling-Westeberg, (2001) found habitats such as damp/marshy grassland were particularly important as these provided rich, tall rushes ideal for nesting and rearing chicks. Lek sites tend to be on relatively flat, open pasture on moorland edges (or forest edges, glades and tracks). Most importantly these sites are characterised by short vegetation which is usually grazed (Adamson, 2007).			
Extensive heather blocks can be a barrier to chick movement and feeding (RSPB, n.d. (a)). As such, burning of heather is important to provide/maintain a mosaic of different patch ages which encourages the growth of young shoots (which black grouse feed on), as well as create structural diversity (Adamson, 2007; RSPB, n.d. (a)).	402 Additional Management Payment - Control burning	• Patches of burnt heather • Patch size between 0.25 and 1ha • Burning should not occur next to bracken or where juniper has been recorded • Burning should not occur where sphagnum capillifolium is present • <u>Mosaic of different heather patch ages and heights</u>	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping
On heather moorland, light grazing helps to maintain a varied structural mosaic of heather and rough grass (RSPB, n.d. (a)).	400 Additional Management Payment - Stock management 401 Additional Management Payment - Mixed grazing 411 Additional Management Payment - Reduce stocking	Minimal guidance	Unlikely to be measured

CHOUGH

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Good chough feeding sites must have short vegetation and bare ground whichs allows accessible foaraging for invertebrates. As such, short-grazed rough pastures are ideal due to having minimal vegetation cover and plentiful invertebrates. (Bullock et al. 1983; RSPB, 2014). In line with previous studies, one of the most recent studies by Whistehead et al. (2005) found choughs had a preference for habitats with a sward height of around 2cm with associated grazing (Whitehead et al. 2005). Choughs take invertebrates just below the surface of the ground and are reliant on short pasture (less than 5cm in height), soft soil and bare areas for feeding (Poole, 2003; RSPB, 2014). Removal of livestock is thought to be one of the main reasons for population decline as this has led to once close cropped sward becoming too tall or scrubbed over for the birds to feed (RSPB, n.d). Fuller & Ausden (2008) also recognise the issue of scrub expansion whcih causes a loss of habitat for choughs. Choughs tend to nest on coastal cliffs. In Wales. Whitehead et al. (2005) found choughs showed strongest slection for grazed habitats i.e coastal pasture during the breeding season. As such the provision of short pasture on on cliff tops and coastal slopes are particualarly important. Maintainance or	15 Grazed permanent pasture with no inputs 15 Grazed permanent pasture with no inputs	• Grassland maintained by grazing • Grassland maintained with a range of sward heights • At least 20% of the grassland must be less then 7 centimetres high and at least 20% of the grassland must be more than 7 centimetres high. • Pasture or improved land maintained by grazing • Grassland maintained with a range of sward heights • At least 20% of the grassland must be less then 7 centimetres high and at least 20% of the grassland must be more than 7 centimetres high. • <u>Coastal/cliff slope grazed pasture</u> • <u>Presence of animal dung (particularly cattle)</u> • <u>Short sward height (0-5cm)</u>	Habitat mapping Habitat mapping, X plot Habitat mapping Habitat mapping Habitat mapping, X plot Habitat mapping Habitat mapping X plot Habitat mapping, X Habitat mapping Habitat mapping plot

restoration of these area are therefore thought to be a priority. Numerous studies (e.g. McCracken & Foster, 1994 & Mackay, 1996) have observed grazing to be an additional benefit to feeding choughs because animal dung provides an important source of invertebrates throughout the year.			
Low intensity, maritime heath is important for choughs as this provides a rich source of invertebrates as well as short turf or bare ground vital for feeding just below the surface. Maritime heathland which Is periodically burnt is also thought to be ideal, whilst grazing by livestock is vital in maintaining suitable feeding habitat (Bullock, 1983; Wildlife trust, n.d). Choughs breeding on Ramsay off the coast of Pembrokehshire have been observed to also feed in areas where the turf is very short; such areas of which were found amongst the coastal heather. The vegetation is kept close-cropped by constant grazing, trampling by visitors and rabbit grazing (Cowdy, 1973). The coast of Holyhead has suffered from a lack of heather grazing over the decades and this had led to tall leggy heather stands and a profusion of gorse. As a reuslt, the once diverse heathland community has dwindled which has further led to the loss of foraging choughs. Ideally patches of dry heath, short sward and grazed pasture is needed to provide both short and long vegegtation suitable to support invertebrates and foraging choughs (Ratcliffe & Bateson, 2014).	115 Lowland dry heath with less than 50% western gorse 116 Lowland dry heath with more than 50% western gorse	• Whole Farm Code apply to all the land within this option. • Light grazing • No newly planted trees • Whole Farm Code apply to all the land within this option. • Light grazing • No newly planted trees • <u>Mosaic of short vegetation and dry heath</u>	 Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping
Choughs largely breed on the west coast of Wales, and need enclosed nest sites and well grazed cliff slopes or hillside to feed on. Choughs take invertebrates just below the surface of the ground and are reliant on	161 Grassland management for chough (feeding)	• Whole Farm Code apply to all the land within this option. • Grassland maintained by grazing	 Habitat mapping Habitat mapping, x plots

short turf, with bare areas for feeding (Poole, 2003; RSPB, n.d). Removal of livestock is thought to be the one of the main reasons for population decline as this has led to once close cropped sward becoming too tall or scrubbed over for the birds to feed (RSPB, n.d). Fuller & Ausden (2008) also recognise the issue of scrub expansion which causes a loss of habitat for choughs. Choughs utilise cliff faces and cliff tops with grazed, cliff-slope grassland being one of their preferred feeding area (Poole, 2003). A study by Ausden & Bateson (2005) studied the introduction of year round cattle grazing on 26ha area of formerly ungazed, semi-improved grassland at South Stack RSPB reserve, Anglesey. After 1 year of grazing, the estimated sward height was reduced from over 10cm to between 0-5cm in height. Consequently, the use of the area by feeding choughs increased by over 40% during the late winter and just under 30% in the early spring. The study therefore highlights the importance of cattle grazing. Not only does it show how suitable grazing management of an area can increase opportunites for feeding choughs during the breeding season, but it further demonstrates that choughs are reliant on short, open vegetation. Numerous studies (e.g. McCracken & Foster, 1994 & Mackay, 1996) have observed grazing have a beneifical to choughs becuase animal dung provides an important source of invertebrates throughout the year.		• 80% Sward between 3cm to 5cm throughout the year • Coastal/cliff slope grazed grassland • Low % scrub cover • Presence of animal dung, (particularly cattle)	Habitat mapping Habitat mapping, x plot X or Y plots
(CRoW Act definition of 'open country' – mountain, moor, heath and downland) Holyoak (1972) observed choughs breeding inland on hills and mountains in North Wales, some of which built their sheep wool, cupped nests on heather stems. Feeding was observed on boggy areas, grassland and	41A Grazing management of open country 41B Grazing management of open country with mixed grazing 16 Upland heath	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed No guidance	Habitat mapping Habitat mapping

hill pastures. On the Calf, Isle of Man choughs were also observed feeding in bare earth and rocky places around the heather. Numerous studies (e.g. McCracken & Foster, 1994 & Mackay, 1996) have observed grazing have a beneifical to choughs becuase animal dung provides an important source of invertebrates throughout the year.	18 Upland grassland	No guidance • Presence of animal dung, (particularly cattle)	X, Y & U plots
Suitable grazing management of an area can increase opportunites for feeding choughs during the breeding season (Ausden & Bateson, 2005). Furthermore, numerous studies (e.g. McCracken & Foster, 1994 & Mackay, 1996) have observed grazing have a beneifical to choughs becuase animal dung provides an important source of invertebrates throughout the year.	401 Additional Management Payment - Mixed grazing 411 Additional Management Payment - Reduce stocking	Minimal guidance	Unlikely to be measured
Unable to find evidence	117 Lowland wet heath with less than 60% purple moor- grass 118 Lowland wet heath with more than 60% purple moor-grass	Minimal guidance	
Unable to find evidence	401 Additional Management Payment - Mixed grazing 411 Additional Management Payment - Reduce stocking	Minimal guidance	

CORN BUNTING

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
During the summer, adult birds collect insects to feed their chicks. Grass margins at the edge of cereal fields are suitable for this purpose because, in comparison to the adjacent crop; margins support higher invertebrate numbers (Brickle et al. 2000; Vickery et al. 2002). Grass margins sown with cocksfoot are particularly effective as these create a tussocky sward which typically support relatively high invertebrate numbers (Brickle et al. 2000; Vickery et al. 2002; RSPB, n.d). Corn buntings prefer large, open arable and mixed farming (RPSB, n.d). Mason & Macdonald (2000) found corns buntings has a strong preference for selecting territories without hedges, as well as generally avoiding hedges particularly hedges over 1.5m tall. Furthermore, the RSBP (n.d) suggests margins should be created in arable fields away from tall hedges and treelines.	26 Fixed rough grass margins on arable land 26B Rotational rough grass margin on arable land 27 Fallow margins	• New rough grass margin • Width of 2-8m on arable land • No grazing once established • Mix of tussock forming grasses • Cannot be rotated • New rough grass margin adjacent to cereal, rape, linseed or root crop • Between 2-8m wide • Mix of tussock forming grasses • No grazing once established • Can be rotated • New fallow crop margin adjacent to cereals, oil seed rape, linseed, maize or roots • Between 2-8m wide • Can be rotated • <u>Open arable and mixed farmland</u> • <u>Margins away from tall hedges and treelines</u> • <u>Tussocky grassland</u>	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping, A & M plots
Corn buntings prefer large, open arable and mixed farming. During the breeding season, adult corn buntings nest in cereal crops and feed on seeds and grain, whilst the chicks are reared mainly on insects (RSPB, n.d). During the	28 Retain winter stubbles	• Light grazing • No maize • Natural regeneration of grass and broadleaved plants after harvest • No undersown stubble • Can be rotated	Habitat mapping Habitat mapping; A & M plots A & M plots A & M plots

summer, adult birds take insects from crops to feed their chicks; spring-sown barley is one of the habitats predominantly used. During the winter, the retention of stubble after harvest, particularly from unsprayed crop provides essential winter food in the form of broadleaved seeds (Brickle et al. 2000; RSPB, n.d). Study by Perkins et al. (2012) found weed abundance is strong predictor of nesting territory. Weeds provide ground cover at the base of crops which helps to conceal nesting chicks. Furthermore, weeds host a range of invertebrates which are vital chick-food. Areas which are heavily sprayed with insecticide and herbicide are less used as foraging areas because these eliminate invertebrates and broadleaved weeds (Brickle et al. 2000; RSPB, n.d). As such, breeding productivity is suppressed due to the reduction of nests concealment and chick food (Perkins et al. 2012).	31 Unsprayed spring sown cereals retaining winter stubbles 163 Unsprayed spring sown barley crop for corn bunting (nesting & feeding) 32B Plant unsprayed root crops on improved land	• On improved land only • Natural regeneration of grass and broadleaved plants after harvest • No grazing between harvest and 1st January • Can be rotated • Spring sown barley crop established between 15 March – 15 April each year • Barely to cover at least 2ha and be at least 75m wide • Only on improved land • White turnips, soft yellow turnips, hardy yellow turnips, swedes or fodder beets established before 1 July • Invasive or alien weeds to be spot treated I.e. spear thistle, creeping thistle, curled dock, broad-leaved dock, ragwort, Japanese knotweed or Himalayan balsam. • Grass buffer, minimum of 2m wide established if crop is situated next to watercourse • Weeds in crop understory • Open arable and mixed farmland	Unlikely to be measured Habitat mapping A & M plots Habitat mapping Unlikely to be mapped Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping; A, M & X plot Habitat mapping A, M & X plot Habitat mapping
During the summer, adult birds take insects from crops to feed their chicks; areas of set-aside are one of the habitats predominantly used for this purpose (Brickle et al. 2000; RSPB, n.d).	33 Establish a wildlife cover crop on improved land	• On improved land only • 4m wide seed bed established for crop • Crop cover to be at least 80% cereals with at least one of the following; mustard, rape or linseed.	Habitat mapping Habitat mapping Habitat mapping; A & M plot

In winter, birds flock together and mainly feed on seeds (particularly cereal grain) in areas with plenty of food such as cover crops and winter stubble (RSPB, n.d).	34 Unharvested cereal headland 34B Unfertilised and unsprayed cereal headland	• No maize • Only on improved land • 3-6m wide cereal headland established along edge of crop • Only on improved land • 3-6m wide cereal headland established along edge of crop • Can be rotated	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured
Corn Bunting declines have been linked previously to changes in cropping, notably localized reductions in the area of cereals grown (Donald et al. 1994) and the increasing trend for autumn sowing of cereals (Brickle & Harper 2002). Because winter cereals are harvested 3-4 weeks earlier than spring cereals, late-summer nesting habitats are often removed in the modern farming landscape, restricting female Corn Buntings to just one brood (Brickle & Harper 2002). Autumn-sowing also removes the opportunity for overwinter stubbles, which are important foraging habitats for Corn Buntings outside the breeding season (Perkins et al. 2008).	162 Unsprayed autumn sown cereal crop for corn bunting (nesting & feeding)	• Plots to cover at least 2ha and be at least 75m wide • Sown crop established before 31 October • <u>Numerous studies suggest autumn sowing is unsuitable</u>	Habitat mapping Unlikely to be measured
Corn buntings prefer large, open arable and mixed farming (RPSB, n.d). Insects for chicks during the summer can be found in rough, tussocky grassland (RSPB, n.d).	175 Management of rough grassland; enclosed land	• Minimal or no scrub • At least 75% of grasses >20cm high • <u>Open arable and mixed farmland</u> • <u>Tussocky grassland</u>	Habitat mapping, X plots Habitat mapping, X plots Habitat mapping Habitat mapping, X plot

CURLEW

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
CRoW Act definition of 'open country' – mountain, moor, heath and downland. Curlew are associated with low disturbance and breed in upland areas of open moorland, rough and damp pastures and boggy ground. Nesting occurs in wide variety of vegetation types but usually select relatively tall vegetation withn a tussock of rough pasture (Haworth & Thompson, 1990*;* RSPB, n.d. (c)). A study by Pearce-Higgins & Grant (2006) found curlew abundance tended to be greater on plots where vegetation structure was relatively heterogeneous. A further report by Pearce-Higgins et al. (2006) found curlews in the Peak district had an association with intermediate vegetation heights, with the highest densities of curlews being found in areas where mean vegetation height was approx' 30cm; a height of which reflects the vegetation found in structurally diverse moorland. Grazing, inparticular mixed grazing of moorland helps to achieve a mosaic of taller,tussocky vegetation and shorter grassy areas ideal for breeding (RSPB, n.d (c)). Whilst breeding occurs on moorland, curlews instead prefer to feed on large surrounding agricultral fields. No curlew without chicks was observed feeding on the moorland and curlews with chicks preferred to fly short distances to feed in fields closest to the moors i.e. at the edge of the moor. The choice to feed in large fields was linked to increased visibility when looking out for	41A Grazing management of open Country 41B Grazing management of open country with mixed grazing 16 Upland heath 17 Blanket Bog 18 Upland grassland	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed No guidance No guidance No guidance • <u>Heterogeneous vegetation structure</u> • <u>Damp soil</u> • <u>Moorland with marginal, large agricultural fields</u>	Habitat mapping Habitat mapping X, Y & U plots Soil cores Habitat mapping

predators; pastures were the main field type utilised (Glenn, 1998).			
Studies on the east coast have focussed on changes in bird numbers on sites experiencing saltmarsh reclamation (Goss-custard & Yates, 1992) and salt marsh managed realignment (Atkinson et al. 2004), both of which have recorded curlews using saltmarsh sites.	21 Grazed saltmarsh 21B Management of grazed saltmarsh with mixed grazing	• Grazing by cattle, sheep, goats or ponies • Grazed marshes: at least 20% of the sward should be under 10 centimetres and at least 20% over 10 centimetres in height. • Grazing by cattle, sheep, goats or ponies • Grazed marshes: at least 20% of the sward should be under 10 centimetres and at least 20% over 10 centimetres in height.	Habitat mapping Habitat mapping, X plots Habitat mapping Habitat mapping, X plots
In 2007, a five year project at the RSPB's Lake Vyrnwy reserve saw the reintroduction of grazing to rush-dominated moor, as well as the installation of fencing to prevent the trampling of nests by livestock (Jonhstone et al. 2012).	164 Grassland management for curlew (nesting & chick feeding)	• Grassland maintained by grazing • From 1 April to 15 July 25% of the sward must be less than 5cm in height, 25% of the sward must be between 20cm and 30 cm in height, the remaining 50% of the sward must be < 20cm in height. • Maintain thinly scattered rush cover at no more than 30% of the area, • No large dense blocks of rush • No tree planting	Habitat mapping Habitat mapping; X plot Habitat mapping; X & Y plot Habitat mapping Habitat mapping

Adult curlews have been observed foraging on permanent pastures, rough grazing and hay meadows. But importantly, curlews have a preference towards large fields close to moorland (Glenn, 1998).	165 Grassland management for curlew (adult feeding)	• Grassland maintained by grazing • From 1 April to 15 July 80% of the sward must be less than 5cm in height • From 31 July to 15 March of the following year at least 20% of the sward must be less than 7cm in height and 20% of the sward must be more than 7cm in height • Maintain thinly scattered rush cover no more than 30% of the area • No large dense blocks of rush • Large fields at the margin of moorland	Habitat mapping Habitat mapping; X plot Habitat mapping; X plot Habitat mapping; X plot Habitat mapping Habitat mapping
Nesting occurs in a wide variety of vegetation types, but in unimproved haycrops tall, sparse vegetation is slected for nesting. Late cut meadows (mid July onwards) can be important for nesting birds. Furthermore, leaving damp corners of the meadow uncut is beneficial as these can provide a feeding area for the unfledged chicks (RSPB, n.d. (c)). Curlews prefer open, undisturbed areas and generally aovid nesting close to trees, hedgerows and shrub cover (RSPB, n.d (c)); Wilson et al, 2004). In Finland, curlews showed an preference for tall vegetation (25-45cm), especially haymeadows. This was expected as taller vegetation can provide both good areas to forage as well as shelter for chicks and nest from predation (Valkama et al. 1998).	166 Haymeadow management for curlew (nesting)	• Grassland maintained by grazing and hay cutting • Between 5% & 10% left uncut every year after July • 80% of aftermath sward height of the grasses between 5cm and 15cm high • Sward should never be cut below 2cm • No tree planting	Habitat mapping Habitat mapping Habitat mapping; X plot Habitat mapping; X plot Habitat mapping

GOLDEN PLOVER

Evidence obtained from Literature	**Target Species and Glastir Measures**	**Specific Response Variables**	**GMEP Survey Data That Captures Measure or Target**
Rank, tall heather >12cm in height is thought to impede movement and foraging, as such these areas are avoided both by adults and chicks. Instead, during the summer months, a mosaic of short, open vegetation such as, short heath, wet flushes and blanket bog is ideal for breeding (Whittingham et al. 2000; Whittingham et al. 2001; RSPB, n.d. (d). Furthermore vegetation associated with these habitats including heather, bilberry, crowberry and cotton grass all provide invertebrates essential for feeding chicks (Pearce-Higgins & Yalden, 2004). Furthermore this is a tendency for chicks to use marshy patches of *Juncus effusus* for cover (Percival & Smith, 1992; Whittingham et al. 2001). Golden plovers require moorland for nesting and rearing chicks. However, since habitat selection is partly driven by availability of food, breeding adult golden plovers (particularly during the incubation period) prefer to forage in enclosed fields situated at the moorland boundary. Due to grazing and enrichment of enclosed agricultural fields (e.g. short pasture and grassland), these have higher earthworm and tipulid larvae densities in comparison to upland habitats (Ratcliffe, 1976; Whittingham et al. 2001; Pearce-Higgins & Yalden, 2003). To maintain structural variability extensive gazing of moorland is suggested. Not only will this retain an open habitat structure by preventing the colonisation of trees, but it will also break up patches of uniform heather stands (Whittingham et al. 2000).	16 Upland heath 17 Blanket Bog 18 Upland grassland 41A Grazing management of open country 41B Grazing management of open country with mixed grazing	No guidance No guidance No guidance • Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed • Mosaic of short heath, blanket bog, marsh and wet flushes on Moorland • Key upland species – *Calluna vulgaris, Eriophorum vaginatum*, Empetrum nigrum, Vaccinium myrtillus and *Juncus effuses* • Enclosed grassland at the moorland edge	 Habitat mapping Habitat mapping Habitat mapping X, Y & U plots Habitat mapping

Grazing of grassland maintains a short sward; not only does this aid movement and makes foraging more efficient (Ratcliffe, 1976), whilst enrichment of grassland, (partly from manure) results in higher earthworm and tipulid larvae densities in comparison to upland habitats (Ratcliffe, 1976; Whittingham et al. 2001; Pearce-Higgins & Yalden, 2004). Since habitat selection is partly driven by availability of food, breeding adult golden plovers (particularly during the incubation period) prefer to forage in enclosed fields situated at the moorland boundary. Due to grazing and enrichment of enclosed agricultural fields such and improved grassland and pasture, these have higher earthworm and tipulid larvae densities in comparison to upland habitats (Ratcliffe, 1976; Whittingham et al. 2001; Pearce-Higgins & Yalden, 2003).	167 Grassland management for golden plover (feeding)	• Grassland maintained by grazing • At least 80% of sward must be <5cm in height between March and June • Maintain thinly scattered rush no more than 10% of the area • No dense blocks of rush • <u>Enclosed grassland fields at the moorland edge</u>	Habitat mapping Habitat mapping; X plot Habitat mapping; X plot Habitat mapping Habitat mapping

LAPWING

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
CRoW Act definition of open country – mountain, moor, heath and downland. Grazing helps maintain short sward and sparse tussocky structure ideal for lapwings (RSPB, n.d).	41A Grazing management of open country 41B Grazing management of open country with mixed grazing	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed	Habitat mapping Habitat mapping
Lapwings are known to breed on grassland with low stocking densities, yet it is vital that the sward is short with some bare ground patches for feeding, as well as tussocks of taller vegetation (i.e rush) to provide cover for the chicks (Natural England, 2011; RSPB, n.d). This is refelcted in a study by Galbraith (1988) which found choice of nesting habitat was not influenced by food availability in the immediate vicinity of the nest site, but instead by the amount of vegetation cover to favour concealment of the incubating adult and eggs. However vegetation which is too tall and rank hinders the movement of chicks in search of food. The preference for large fields and the avoidance of close trees or tall woody linear features (WLF) which support predators is thought likely to be a predator-avoidance strategy (Galbraith, 1988). Findings by MacDonald & Bolton (2008) and Sheldon et al. (2007) both found that predation rates decreased the further nests were from the field boundaries. As such both suggest that lapwing management shoud be targeted in the centre of the largest field to ensure suitable nesting habitat is created as far as possible	168 Grassland management for lapwing (nesting & feeding)	• Grassland maintained by grazing • By 31 March at least 80% of the sward must be less than 5 centimetres high. • From 1 May to 15 July at least 50% of the sward must be less than 7 centimetres in height, and at least 10% of the sward must be over 10 centimetres high. • Maintain thinly scattered rush cover at no more than 30% of the area. • No large dense blocks of rush • Between 5% and 10% of the area should be bare ground • No newly planted tree • <u>Large, open fields with centre away from WLF and woodland edges</u> • <u>Light grazing</u> • <u>Shallow pools (scrapes) and shallow linear wet features (drains)</u> *(creating scrapes is part of capital works)*	Habitat mapping Will not be captured Habitat mapping, X plots Habitat mapping, X plots Habitat mapping, X plots Habitat mapping, X plots Habitat mapping Habitat mapping Habitat mapping Habitat mapping?

from field boundaires, thus helping to minimise predation rates. Recent efforts to re-create wet grassland and improve wader breeding success has foccussed on reinstalling wet features.Damp areas or shallow muddy water margins (i.e. scrapes) provide an abundane of food. They are therefore important feeding areas for lapwings in early spring before the breeding season, and later on, for their chicks. (Eglington et al. 2010; Natural England, 2011; RSPB, n.d). Providing sufficeint invertebrate prey can be sustained during the pre-fledging period, chicks with access to wet features are able to grow rapidly and maintain body condition thus enhancing chances of survival (Eglington et al. 2010). Linear wet features are an increasingly widely used tool for re- wetting grassland and research has shown waders prefer nesting close to linear features wet features. Furthermore, linear wet features do not elevate the risk of predation of nests or checks (Eglington et al. 2009).		Very similar to above prescription, Natural England (2011) suggests the ideal sward structure to have; • Little dead plant litter. • Scattered bare ground covers up to 10% of the area. • Short sward, less than 5 cm tall covers more than 70% of the area. • Scattered clumps 10-15 cm, or occasional taller tussocks make up about 20% of the sward.	X plots Habitat mapping, X plots Habitat mapping, X plots Habitat mapping, X plots
Lapwings prefer to nest in large, open fields with short but variable vegetation structure on spring-tilled arable land (RSPB, n.d). Galbraith (1988) reported on the difficulties of finding nests when located on the bare soil of spring cereal fields due to lack of features to help pin-point the nest location. It was therefore thought that visual hunters/predators such as crows may suffer the same difficulty. Numerous studies have found the success of lapwing nesting appears to be strongly influenced by predators. As such lapwings prefer to nest away from boundary features such as hedgerows, trees and woodland edges as these support predators (Sheldon et al. 2007;	169 Unsprayed spring sown cereals, oil seed rape, linseed or mustard crop for lapwing (nesting)	• New area of unsprayed spring sown cereals • Crop established in a cultivated seed bed • No under sowing of crop • Bare ground • Large, open field situated areas away from WLF and woodland edges • Spring sown cereal field adjacent to pasture or grassland	Habitat mapping Habitat mapping Habitat mapping, X plot Habitat mapping, X plot Habitat mapping Habitat mapping

Chamberlain et al. 2009). Findings by Sheldon et al. (2007) and Macdonald & Bolton (2008) both suggest that lapwing management shoud be targeted in the centre of the largest field, as such suitable nesting habitat is created as far as possible from field boundaires which would help to minimise predation rates. Whilst lapwings tend to nest in arable fields, parents will often walk their chicks onto grazed pasture to feed (RSPB, n.d). Galbraith (1988) observed that food supply within the immediate vicinty of the nest was not seen an important factor for nesting lapwings. Hay fields and pastures supported significantly higher number and biomass of invertebrates than cereal fields. As such birds preferred to nest in cereal fields close to pasture.			
Sheldon et al. (2007) assessed the effectiveness of an agri-environment prescription, option 1B (overwinter cereal or linseed stubble followed by a spring/summer fallow –<u>similar to glastir</u>) designed to provide rough bare ground that lapwings prefer as nesting habitat. 85% of the 34 lapwing nests successfully hatched at least one chick on cultivated fields. This could be maximised by locating plots a sufficient distance from field boundaries to reduce predation. Nests >50m away from the nearest field boundary were found to have a higher daily survival rate. Finally, since the option stipulates that all agriculutral operations should be completed by the 20th March, no nests were lost because agricultural operations. Lapwings start nesting from mid-March, prescription possibly encouraging mechanical operations to occur too late in the month.	170 Uncropped fallow plot for lapwing (nesting)	• Establishment of fallow plot before 14 April each year • New plot left as bare ground • Plot allowed to regenerate naturally • <u>Large, open fields</u> • <u>Fallow plots situated in open areas away from WLF's and woodland edges</u> • <u>Cereal field adjacent to pasture or grassland</u>	Habitat mapping Habitat mapping, X plot X plot Habitat mapping Habitat mapping Habitat mapping

Chamberlain et al. (2009) similarily studied the use of fallow plot options within two English agri-envrionment schemes.Lapwings occured on about 40% of the 212 fallow plots studied and plots with >50% bare ground had 14% higher occupancy rate than plots with <50% bare ground. Lapwing occurrence decreased if there was woodland adjacent, as such it's thought that nesting occurrence could be increased through better management and placement of plots i.e. situated in open areas away from woody boundary features. Galbraith (1988) observed that food supply within the immediate vicinty of the nest was not seen as an important factor for nesting lapwings. Hay fields and pastures supported significantly higher number and biomass of invertebrates than cereal fields. As such birds preferred to nest in cereal fields close to pasture/grassland and ulitmately move their chicks.			
Declines in wader populations in the UK are thought to be driven primarily by changes in agricultural grassland management, particularly decrease in wetness due to improvement of drainage (Bolton et al. 2007). Linear wet features are an increasingly widely used tool for re- wetting grassland and research has shown waders prefer nesting close to linear features wet features. Furthermore, linear wet features do not elevate the risk of predation of nests or checks (Eglington et al. 2009). A further study by Eglington et al. (2010) identified wet features on managed wet grassland. In comparison to the wet grassland, wet footdrains and wet pools supported the highest invertebrate biomass. Furthermore chicks observed feeding in these wet	403 Additional Management Payment - Re-wetting 404 Additional Management Payment - Re-wetting (improved land)	• Re-wetting of agricultural land • Re-wetting of improved land • Shallow pools (scrapes) and shallow linear wet features (drains)	Vegetation composition change – X plots or Y plots Vegetation composition change – X plots or Y plots Habitat mapping

features were also found to have higher foraging rates and biomass intake. The creation of shallow wet features appeared to be highly effective at providing neccessary food needed to sustain foraging chicks and enhancing chick growth, particulalry later in the season. As such reinstalling of wet features in grassland is thought likely to improve breeding success.			

RING OUZEL

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Ring ouzels primarily breed in mature/tall heather (40-50cm in height) on steep slopes, gullies and crags (RSPB, n.d. (e)). The decline in ring ouzel abundance was more likely if grass-heather mosaics were initially extensive; the loss of heather for nesting is thought to affect predation risk and be a critical factor leading to breeding site desertion, particularly at lower altitudes (Buchanan et al. 2003). A study by Sim et al. (2013) found juveniles used grass-heather mosaics; short grass provided suitable foraging means whilst being in close proximity to heather which provided cover from predators. However, during the late summer, juveniles moved to taller, heather-dominated, berry-rich areas to satisfy their foraging needs. Bilberries, crowberries and rowan were particularly favoured when foraging and are an important food source in the late summer as birds stock up on food before migrating (Sim et al. 2013; RSPB, n.d. (e)). Bracken patches provide ring ouzels with cover when foraging and are sometimes used for nesting (RSPB, n.d (e))	16 Upland heath	No guidance • <u>Heather 40-50cm in height on steep slopes, gullies or crags</u> • <u>Grass-heather-bracken mosaic</u> • <u>Presence of Bilberry, crowberry and rowan</u>	 Habitat mapping Habitat mapping X, Y or U plots
(CRoW Act definition of 'open country' – mountain, moor, heath and downland) Ring ouzels are summer visitors and are usually found above 250m altitude. Ring ouzels breed on moorland and establish their home ranges in areas dominated by patches of their preferred vegetation types. An 'ideal	41A Grazing management of open country 41B Grazing management of open country with mixed grazing	• Grazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed • <u>Moorland</u> • <u>Grass-heather-bracken mosaic</u>	Habitat mapping Habitat mapping Habitat mapping Habitat mapping

home range mosaic' might involve 10-15 discrete habitat patches in an area of 5-10 ha, comprising 50% grazed grass, 15% heather, 10% bilberry, 5% rock/bare ground, 5% bracken, 5% moss, 5% rough grass and 5% other (Burfield, 2002). Bracken patches provide ring ouzels with cover when foraging and are sometimes used for nesting (RSPB, n.d. (e)). Bird shift from foraging for invertebrates in grassland during nesting to forage at higher altitudes on heather-rich moorland berries, particularly bilberry, crowberry and rowan (Sim et al. 2013; RSPB, n.d. (e)).		• Heather 40-50cm in height on steep slopes, gullies or crags • Presence of Bilberry, crowberry and rowan	Habitat mapping X, Y or U plots
Similarly to choughs, the presence of livestock is essential to prevent the growth of tall rank vegetation which reduces habitat suitability for feeding. Ring ouzels select short, grazed grassland for foraging during the nesting period due to the high availability of earthworms (favoured food). Foraging occurs within 450m of the nest during this period. Furthermore the short sward is thought to increase predator avoidance and facilitate the movement of birds along the ground (Burfield, 2002).	161 Grassland management for chough (feeding)	• Whole Farm Code apply to all the land within this option. • Grassland maintained by grazing • 80% Sward between 3cm to 5cm throughout the year	 Habitat mapping Habitat mapping; X plot
Ring ouzels select open, short, grazed grassland for foraging during the nesting period due to the high availability of earthworms (favoured food). Foraging occurs within 450m of the nest during this period. Furthermore the short sward is thought to increase predator avoidance and facilitate the movement birds along the ground (Burfield, 2002).	171 Grassland management for ring ouzel (feeding)	• Grassland maintained by grazing • From April to July the sward must be <5cm in height • From August to March at least 20% of sward must be <7cm in height and at least 20% must be >7cm in height • Thinly scattered rush cover no more than 30% of the area • No dense blocks of rush • No new trees planted	Habitat mapping Habitat mapping Habitat mapping; X plot Habitat mapping; X plot Habitat mapping Habitat mapping

TURTLE DOVE

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Decrease in turtle dove numbers in the UK is thought to be due to degradation of habitat quality, rather than solely habitat loss; particularly as management techniques are more intense and damaging (Browne et al. 2004). Turtle doves primarily nest in hedges or scrub over 4m tall (RSPB, 2008). Tall, overgrown thorny scrub (principally hawthorn and blackthorn) are the preferred species used by nesting turtle doves (Brown & Aebischer, 2004; Browne, 2005). Nestling turtle doves have a preferred hedge height and width of 4.5m and 3m. As such, sympathetic management should allow for this (Browne & Aebischer, 2001). In comparison to areas of scrub and woodland, both Mason & Macdonald (2000) and Browne (2005) found hedges tended to be the least favoured habitat. Yet, Browne et al. (2004) found turtle density was positively related to increases (per unit area) of hedgerow and woodland.	3 Create a wildlife corridor – Establish wooded strip on improved ground	• New WLF on improved land • WLF width between 5-15m • New stock proof fencing • Species richness ; $\geq$ 5 woody species • $\leq$ 25% native conifers • <u>Thorny species - blackthorn and hawthorn</u>	Habitat Mapping –Linears D plots Linears & Fence condition B & D plots B & D plots Habitat mapping; B, D & H plots
Turtle doves primarily nest in hedges or scrub over 4m tall (RSPB, 2008). Tall, overgrown thorny scrub (principally hawthorn and blackthorn) are the	23 Allow small areas of improved land in corners of fields to revert to rough grassland and scrub	• New area of rough grassland in field corner (Max size 0.35ha) • New length and location of stock proof fence	Habitat mapping Linears and fence condition

preferred species used by nesting turtle doves (Brown & Aebischer, 2004; Browne, 2005). Mason & Macdonald (2000) found turtle doves had a stronger preference towards scrub habitats than woodland.		• Thorny species - blackthorn and hawthorn • Scrub >4m in height	Habitat mapping; B, D & H plots Habitat mapping
Turtle doves have been recorded in crop fields but found mainly feeding on weed strips around the edge of the field. (Mason & Macdonald, 2000; Browne & Aebischer, 2001). Evidence from plant surveys suggest unmanaged areas such as set-aside and other rough ground adjacent to crop is more suited as a foraging area, particularly as these areas can support short, open and weed rich cover (Browne & Aebischer, 2001; Browne, 2002). Browne (2002) found feeding generally took place on short (average 12cm in height) and sparse (average 40%) vegetation cover. Turtle doves have also been observed feeding on short vegetation (<10cm), and sparse (<20%) vegetation. Adult diets have been determined through faecal samples; cultivated seeds principally wheat and oil-seed rape, formed 60% of their diet with the remainder being made up by a mixture of Common Fumitory, Knotgrass and Common Chickweed. Nestling diets are similar in that 74% of seeds eaten where from cultivated plants, with the rest being made up of weeds (Browne,	27 Fallow margins	• New fallow crop margin • 2-8m wide margin on improved land; must be situated next to cereals, oil seed rape, linseed, maize or roots • Can be rotated • Short vegetation; average 12cm or less • Sparse vegetation; average 40% cover or less • Weed rich fallow margin • Key weed species - Common Fumitory, Knotgrass and Common Chickweed	Habitat mapping Habitat mapping Unlikely to be measured Habitat mapping; A or M plot Habitat mapping; A or M plot A & M plot A & M plot

2002).Similar results were found by Browne & Aebicher (2001).			
Turtle doves feed on stubble after harvest to pick at the fallen grain fallen from the crop. As such, leaving stubble uncultivated until the end of August provides seed food (Browne, 2002; RSPB, 2008). Key feeding areas visited by turtle doves receive no application of herbicide. Herbicides remove broad leaf weeds that provide seed food for turtle doves, as such intensively farmed landscape are not suitable for foraging (Browne, 2002; RSPB, 2008).	31 Unsprayed spring sown cereals retaining winter stubbles	• On improved land only • Natural regeneration of grass and broadleaved plants after harvest • Light grazing after 1 January • Can be rotated	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured
Both adult and juvenile turtle doves feed exclusively on seeds, particularly cultivated seeds such wheat and oil-seed rape (Browne, 2002). Establishing a wildlife crop corner is thought to be a good way of introducing seed-rich habitat into grassland. Using a low seed rate helps to create an open crop which not allows weeds to germinate and seed, whilst also allowing ground access (Browne & Aebicher, 2001; RSPB, 2008). Optimal feeding areas visited by turtle doves receive no application of herbicide because these remove broad leaf weeds that provide seed food for turtle doves. As such intensively farmed landscape are not suitable for foraging (Browne, 2002; RSPB, n.d).	33 Establish a wildlife cover crop on improved land 34 Unharvested cereal headland 34B Unfertilised and unsprayed cereal headland	• On improved land only • 4m wide seed bed established for crop • Crop cover to be at least 80% cereals with at least one of the following; mustard, rape or linseed. • No maize • Only on improved land • 3-6m wide cereal headland established along edge of crop • Only on improved land • 3-6m wide cereal headland established along edge of crop Can be rotated • <u>Sparse vegetation; average 40% cover or less</u>	Habitat mapping Habitat mapping A &M plot A & M plot Habitat mapping Habitat mapping Habitat mapping Habitat mapping A &M plot

		• Short vegetation; average 12cm or less • Weed In understorey • Key weed species - Common Fumitory, Knotgrass and Common Chickweed	A & M plot A& M plot
Study by (Murton et al. 1964) observed a small percentage of turtle doves feeding in root crop fields with weeds.	32B Plant unsprayed root crops on improved land	• On improved land only • Crop established could be white turnips, soft yellow turnips, hardy yellow turnips, swedes or fodder beets • Grass buffer (minimum 2m) if option located next to a watercourse • Key weed species - Common Fumitory, Knotgrass and Common Chickweed	Habitat mapping Habitat mapping; X plot Habitat mapping X plot
Unable to find evidence	30 Unsprayed spring sown cereals or legumes	• On improved land only • No clover in crop understorey • Can be rotated	Habitat mapping X plot Unlikely to be measured

TWITE

Evidence obtained from Literature	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Reed (1995) studied habitat uses of twites during and after breeding; post-breeding twites would switch to foraging in in lightly grazed pastures once the chicks had fledged around July. Study by Reine (2006) also found that twites preferred improved fields without livestock or fields with low stocking rates. This was because flower cover was greatest in these fields.	15 Grazed permanent pasture with no inputs 15C Grazed permanent pasture with no inputs and mixed grazing	• Grassland maintained by grazing • Grassland maintained with a range of sward heights • At least 20% of the grassland to be less then 7 centimetres high and at least 20% of the grassland to be more than 7 centimetres high. • Maintained by grazing • Grassland maintained with a range of sward heights • At least 20% of the grassland to be less then 7 centimetres high and at least 20% of the grassland to be more than 7 centimetres high. • <u>Pasture close to moorland edge</u>	Habitat mapping Habitat mapping Habitat mapping; X plot Habitat mapping Habitat mapping; X plot Habitat mapping; X plot Habitat mapping
CRoW Act definition of 'open country' – mountain, moor, heath and downland. In Britain, twite are typically found in upland areas and nest on the moorland edge (Brown et al. 1995). They have a strong preference for nesting in the litter under patches of bracken or in tall heather on steep sloping ground McGhie et al. 1994; Brown, 1995; Reine, 2006). Nests have also been found in rocky areas such as cliffs and quarries (Reine, 2006).	41A Grazing management of open country 41B Grazing management of open country with mixed grazing 16 Upland heath 17 Blanket Bog 18 Upland grassland	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed No guidance No guidance No guidance	Habitat mapping Habitat mapping

Moorland is rarely used to collect seed food (Wilson & Wilkinson, 2010), however twite will use burnt Molina grassland where they feed on fallen Molina seeds (Orford, 1973; Raine, 2006). Moorland heterogeneity is needed for twites to breed successfully; extensive patches of upland grasses through over grazing and burning should be avoided (Raine, 2006). Over-grazing, particularly by sheep can quickly cause a loss of heterogeneity on heath moorland, as grasses will tend to dominate. Presence of twite has been shown to be negatively related to the presence of livestock (Raine, 2006). However light grazing (ideally cattle or mixed) is needed to prevent succession of moorland in scrub or woodland, as well as to maintain different heather heights (Raine, 2006; RSPB, n.d. (f)).		• <u>Moorland edge</u> • <u>Large patches of heather</u> • <u>Bracken patches on steep slopes</u> • <u>Burnt Molinia patches</u>	Habitat mapping Habitat mapping Habitat mapping Habitat mapping
Twites have a strong preference for foraging in hay meadows with a high density of dandelion (*Taraxacum*) and sorrel (*Rumex acetosa*) flowers (McGhie et al. 1994; Raine, 2006). The birds feed almost exclusively on unripened dandelion seeds until the food source runs out, after which they switch to feeding almost entirely on sorrel. However, once the meadows are cut, the fields are no longer visited (McGhie et al. 1994).	22 Existing hay meadows 126 Lowland unimproved neutral grassland - reversion (hay cutting)	• Field shut off from livestock before 15 May and closed for at least 10 weeks • Aftermath sward height - 80% of the grasses between 5- 15cm high • Grassland maintained by grazing and hay cutting • Between 5-10% left uncut each year • 80% of grasses between 5-15cm high after cutting • Grassland maintained by grazing and hay cutting	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Habitat mapping; X & Y plot Habitat mapping

In later studies, both Raine (2006) and Wilson & Wilkinson (2010) found annual meadow grass, dandelion, sorrel, autumn hawkbit and thistles each in turn make up a significant part of an adult and chick's diet from May to August. Seed-rich areas, particularly late-cut upland hay meadows should be provided within 2km of the moorland edge (Raine, 2006; RSPB, n.d. (f)).	132 Conversion from improved grassland to semi- improved grassland (hay cutting)	• Between 5-10% left uncut each year • 80% of grasses between 5-15cm high after cutting • Fields shut off to livestock by 1 May • <u>Upland hay meadows close to moorland edge</u> • <u>Key Species – Annual meadow grass, Dandelion, sorrel, autumn hawkbit and thistles</u>	Habitat mapping Habitat mapping; X ploy Habitat mapping Habitat mapping Habitat mapping; X & U plots
RSPB (n.d. (f).) suggests leaving 2m field margins as these can provide seed food for chicks throughout the summer.	26 Fixed rough grass margins on arable land	• New rough grass margin • Width of 2-8m on arable land • No grazing once established • Mix of tussock forming grasses • Cannot be rotated	Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured
	26B Rotational rough grass margin on arable land	• New rough grass margin adjacent to cereal, rape, linseed or root crop • Between 2-8m wide • Mix of tussock forming grasses • No grazing once established • Can be rotated	Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured
	27 Fallow margins	• New fallow crop margin adjacent to cereals, oil seed rape, linseed, maize or roots • Between 2-8m wide • Can be rotated	Habitat mapping Habitat mapping Unlikely to be measured
In Scotland, crop stubble, particularly from oil-seed rape and turnips are used as winter feeding ground for flocks of twite (Hancock & Wilson, 2003).	28 Retain winter stubbles	• Light grazing • No maize • Natural regeneration of grass and broadleaved plants after harvest • No undersown stubble	Habitat mapping Habitat mapping; A & M plots A & M plots A & M plots

		• Can be rotated	Unlikely to be measured
Since twites feed predominately on small-seeds of ruderal plants throughout the year (even when feeding their chicks), they are susceptible to land use change, particularly reduced seed availability (Wilkinson & Wilson, 2010). As a result of agricultural intensification, both cereal and root crops in the uplands have declined. This is thought to have removed key weed species needed to sustain twite (Raine, 2006). Extensive farmland surveys in Scotland found root crops (such as turnips) and their associated weed species have been shown to be an important winter food resource for Twite (Hancock & Wilson, 2003).	30 Unsprayed spring sown cereals or legumes 31 Unsprayed spring sown cereals retaining winter stubbles 32B Plant unsprayed root crops on improved land	• On improved land only • No clover in crop understorey • Can be rotated • On improved land only • Natural regeneration of grass and broadleaved plants after harvest • No grazing between harvest and 1st January • Can be rotated • On improved land only • Crop established could be white turnips, soft yellow turnips, hardy yellow turnips, swedes or fodder beets • Upland cereal and root crops close to moorland • Weeds in crop understorey – dandelion and sorrel	Habitat mapping X plot Unlikely to be measured Habitat mapping A & M plots Habitat mapping Unlikely to be mapped Habitat mapping Habitat mapping; A & M plots Habitat mapping Habitat mapping, A & M plots
Wildlife crop cover can provide a mix of seed-bearing plants needed for foraging twites (RSPB, n.d. (f)).	33 Establish a wildlife cover crop on improved land	• On improved land only • New ≥ 4m wide seed bed on improved land • New cover crop have ≥ 80% cereals including either mustard, linseed or rape • No maize	Habitat mapping Habitat mapping Habitat mapping; A & M plots Habitat mapping
Unable to find evidence	34 Unharvested cereal headland	• Only on improved land • 3-6m wide cereal headland established along edge of crop • Only on improved land	Habitat mapping Habitat mapping Habitat mapping Habitat mapping

	34B Unfertilised and unsprayed cereal headland	• 3-6m wide cereal headland established along edge of crop • Can be rotated • 3-6m wide cereal headland established along edge of crop • Only on improved land • 3-6m wide cereal headland established along edge of crop • Can be rotated	Unlikely to be measured Habitat mapping Habitat mapping Habitat mapping Habitat mapping Unlikely to be measured
Unable to find evidence	Option 120 - Lowland unimproved acid grassland / 121 Lowland unimproved acid grassland - reversion (pasture) 123. Lowland unimproved neutral grassland – pasture / 125 Lowland unimproved neutral grassland - reversion (pasture) 133 - Lowland marshy grassland /134 Lowland marshy grassland; reversion (pasture)	• Grassland maintained by grazing • 75% grasses and herbs between 3cm-20cm in height between May and September • Grassland maintained by grazing • In sheep grazed areas, varied sward height maintained between 10cm – 20cm • In none sheep grazed areas, varied sward height maintained between 5cm – 20cm • Grazing of Marshy grassland • 80% of grasses (excluding rushes) between 10cm-30cm in height	Habitat mapping Habitat mapping; X & U plot Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping; X & Y plots Habitat mapping Habitat mapping; X, Y & U plots
Unable to find evidence	159 Grassland managed with no inputs between 15 October and 31 January	• Grassland maintained by grazing • Sward height at least 5cm	Habitat mapping Habitat mapping; X plot
Unable to find evidence	175 Management of rough grassland - enclosed land	• Minimal or no scrub on grassland • At least 75% of grasses >20cm high	Habitat mapping X plot Habitat mapping; X plot

ADAMSON 2007. Southern uplands partnership. Black grouse project report.

ATKINSON, P. W., CROOKS, S., DREWITT, A., GRANT, A., REHFISCH, M. M., SHARPE, J. & TYAS, C. J. 2004. Managed realignment in the UK – the first 5 years of colonization by birds. Ibis, 146, 101-110.

AUSDEN, M. & BATESON, D. 2005. Winter cattle grazing to create foraging habitat for Choughs Pyrrhocorax pyrrhocorax at South Stack RSPB Reserve, Anglesey, Wales. Conservation Evidence, 2, 26-27.

BAINES, D. 1994. Seasonal differences in habitat selection by Black Grouse Tetrao tetrix in the northern Pennines, England. Ibis, 136, 39-43.

BLACK GROUSE UK. 2007. Black Grouse UK. Published in support of the UK Biodiversity Action Plan for black grouse [Online]. Available: http://www.blackgrouse.info/ [Accessed 02/02/2015].

BOLTON, M., TYLER, G., SMITH, K. E. N. & BAMFORD, R. O. Y. 2007. The impact of predator control on lapwing Vanellus vanellus breeding success on wet grassland nature reserves. Journal of Applied Ecology, 44, 534-544.

BRICKLE, N. W. & HARPER, D. G. C. 2002. Agricultural intensification and the timing of breeding of Corn Buntings Miliaria calandra: In an intensively managed agricultural landscape, few females attempted a second brood. Bird Study, 49, 219-228.

BRICKLE, N. W., HARPER, D. G. C., AEBISCHER, N. J. & COCKAYNE, S. H. 2000. Effects of agricultural intensification on the breeding success of corn buntings Miliaria calandra. Journal of Applied Ecology, 37, 742-755.

BROWN, A. & CRICK, H. 1995. The distribution, numbers and breeding ecology of twite Acanthis flavirostris in the South Pennines of England. Bird Study, 42, 107-121.

BROWNE, S. J. 2002. The breeding ecology of a declining farmland bird: The turtle dove Streptopelia turtur. PhD Thesis, De Montfort University.

BROWNE, S. J. & AEBISCHER, N. J. 2004. Temporal changes in the breeding ecology of European Turtle Doves Streptopelia turtur in Britain, and implications for conservation. Ibis, 146, 125-137.

BROWNE, S. J., AEBISCHER, N. J. & CRICK, H. Q. P. 2005. Breeding ecology of Turtle Doves Streptopelia turtur in Britain during the period 1941–2000: an analysis of BTO nest record cards: Capsule No trends over time were detected in any aspect of Turtle Dove breeding ecology and only slight regional variation, based on individual nesting attempts recorded. Bird Study, 52, 1-9.

BROWNE, S. J., AEBISCHER, N. J., YFANTIS, G. & MARCHANT, J. H. 2004. Habitat availability and use by Turtle Doves Streptopelia turtur between 1965 and 1995: an analysis of Common Birds Census data: Capsule Breeding density on long-term CBC plots fell in proportion to loss of nesting rather than feeding habitat. Bird Study, 51, 1-11.

BROWNE, S. J. A., N. J. 2004. The role of agricultural intensification in the decline of the turtle dove Streptopelia turtur. English Nature Research Report, No. 421. English Nature. Peterborough.

BUCHANAN, G. M., PEARCE-HIGGINS, J. W., WOTTON, S. R., GRANT, M. C. & WHITFIELD, D. P. 2003. Correlates of the change in Ring Ouzel Turdus torquatus abundance in Scotland from 1988–91 to 1999: The change was correlated with environmental, habitat and management variables. Bird Study, 50, 97-105.

BULLOCK, I., DREWETT, D. & MICKLEBURG, S. 1983. The chough in Britain and Ireland. British Birds, 76, 377-401.

BURFILED, I. J. 2002. The breeding ecology and conservation of the Ring Ouzel Turdus torquatus in Britain. PhD Thesis, University of Cambridge.

CAYFORD, J. T. 1990. The distribution and habitat preferences of black grouse in commercial forests in Wales: Conservation and management implications. Union of Game Biologists Congress 19, 435–447.

CHAMBERLAIN, D., GOUGH, S., ANDERSON, G., MACDONALD, M., GRICE, P. & VICKERY, J. 2009. Bird use of cultivated fallow 'Lapwing plots' within English agri-environment schemes. Bird Study, 56, 289-297.

COWDY, S. 1973. Ants as a major food source of the chough. Bird Study, 20, 117-120.

DONALD, P. F. & EVANS, A. D. 1994. Habitat selection by Corn Buntings Miliaria calandra in winter. Bird Study, 41, 199-210.

EGLINGTON, S. M., BOLTON, M., SMART, M. A., SUTHERLAND, W. J., WATKINSON, A. R. & GILL, J. A. 2010. Managing water levels on wet grasslands to improve foraging conditions for breeding northern lapwing Vanellus vanellus. Journal of Applied Ecology, 47, 451-458.

EGLINGTON, S. M., GILL, J. A., SMART, M. A., SUTHERLAND, W. J., WATKINSON, A. R. & BOLTON, M. 2009. Habitat management and patterns of predation of Northern Lapwings on wet grasslands: the influence of linear habitat structures at different spatial scales. Biological Conservation, 142, 314-324.

FULLER, R. J. & AUSDEN, M. 2008. Birds and habitat change in Britain: a review of losses and gains in the twentieth century. British Birds 101, 644–675.

GALBRAITH, H. 1988. Effects of agriculture on the breeding ecology of lapwings Vanellus vanellus. Journal of Applied Ecology, 487-503.

GOSS-CUSTARD, J. & YATES, M. 1992. Towards predicting the effect of salt-marsh reclamation on feeding bird numbers on the Wash. Journal of Applied Ecology, 330-340.

HAWORTH, P. & THOMPSON, D. 1990. Factors associated with the breeding distribution of upland birds in the South Pennines, England. Journal of Applied Ecology, 562-577.

HOLYOAK, D. 1972. Behaviour and ecology of the Chough and the Alpine Chough. Bird Study, 19, 215-227.

JOHNSTONE, I. G., THORPE, R. I., TAYLOR, R. & LAMBART, D. 2012. The State of Birds in Wales 2012. RSPB Cymru, Cardiff.

MACDONALD, M. A. & BOLTON, M. 2008. Predation of Lapwing Vanellus vanellus nests on lowland wet grassland in England and Wales: effects of nest density, habitat and predator abundance. Journal of Ornithology, 149, 555-563.

MASON, C. F. & MACDONALD, S. M. 2000. Corn Bunting Miliaria calandra populations, landscape and land-use in an arable district of eastern England. Bird Conservation International, 10, 169-186.

MASON, C. F. & MACDONALD, S. M. 2000. Influence of landscape and land-use on the distribution of breeding birds in farmland in eastern England. Journal of Zoology, 251, 339-348.

MCGHIE, H. A., BROWN, A. F., REED, S. & BATESON, D. 1994. Aspects of the breeding ecology of twite in the south Pennines. English Nature Research Report, No.118. English Nature. Peterborough.

MCKAY, C. R. 1996. Conservation and ecology of the red-billed chough Pyrrhocorax pyrrhocorax. PhD Thesis, University of Glasgow.

MURTON, R., WESTWOOD, N. & ISAACSON, A. 1964. The feeding habits of the Woodpigeon Columba palumbus, Stock Dove C. oenas and Turtle Dove Streptopelia turtur. Ibis, 106, 174-188.

NATURAL ENGLAND. 2010. Natural England Technical Information Note TIN087. Illustrated guide to black grouse. Sheffield: Natural England.

NATURAL ENGLAND. 2011. Natural England Technical Information Note TIN090. Illustrated guide to managing farmland for lapwings. Sheffield: Natural England.

ORFORD, N. 1973. Breeding distribution of the twite in central Britain. Bird Study, 20, 51-62.

PEARCE-HIGGINS, J., BEALE, C., WILSON, J. & BONN, A. 2006. Analysis of moorland breeding bird distribution and change in the Peak District. Unpublished report to Moors for the Future (report no. 11).

PEARCE-HIGGINS, J. W. & YALDEN, D. W. 2003. Variation in the use of pasture by breeding European Golden Plovers Pluvialis apricaria in relation to prey availability. Ibis, 145, 365-381.

PEARCE-HIGGINS, J. W. & YALDEN, D. W. 2004. Habitat selection, diet, arthropod availability and growth of a moorland wader: the ecology of European Golden Plover Pluvialis apricaria chicks. Ibis, 146, 335-346.

PERCIVAL, S. & SMITH., C. 1992. Habitat requirements of golden plover. A pilot Study. English Nature Research Report, No. 1. English Nature. Peterborough.

PERKINS, A. J., MAGGS, H. E., WATSON, A. & WILSON, J. D. 2011. Adaptive management and targeting of agri-environment schemes does benefit biodiversity: a case study of the corn bunting Emberiza calandra. Journal of Applied Ecology, 48, 514-522.

PERKINS, A. J., MAGGS, H. E. & WILSON, J. D. 2008. Winter bird use of seed-rich habitats in agri-environment schemes. Agriculture, Ecosystems & Environment, 126, 189-194.

PERKINS, A. J., WATSON, A., MAGGS, H. E. & WILSON, J. D. 2012. Conservation insights from changing associations between habitat, territory distribution and mating system of Corn Buntings Emberiza calandra over a 20-year population decline. Ibis, 154, 601-615.

POOLE, A. 2003. Analysis of Chough productivity and recreational use in Pembrokeshire. CCW contract science, Report No. 553. Country side council for Wales.

RAINE, A. F. 2006. The breeding ecology of Twite Carduelis flavirostris and the effects of upland agricultural intensification. PhD thesis, University of East Anglia.

RATCHLIFFE, D. A. 1976. Observations on the breeding of the Golden Plover in Great Britain. Bird Study, 23, 63-116.

RATCLIFFE, J. & BATESON, D. 2014. Holy Island coast, Anglesey: a review of conservation management, issues and solutions. Journal of Coastal Conservation, 1-9.

RATCLIFFE, J. & BATESON, D. 2014. Holy Island coast, Anglesey: a review of conservation management, issues and solutions. Journal of Coastal Conservation, 1-9.

REED, S. 1995. Factors limiting the distribution and population size of twite (Carduelis flavirostris) in the Pennines. Naturalist, 120, 93-102.

RSPB. 2008. Turtle dove [Online]. Available: http://www.rspb.org.uk/forprofessionals/farming/advice/details.aspx?id=204060 [Accessed 07/02/2015.

RSPB. 2014. Birds by name. Chough [Online]. Available: http://www.rspb.org.uk/discoverandenjoynature/discoverandlearn/birdguide/name/c/chough/nesting.aspx [02/02/2015].

RSPB. No date. (a). Black grouse. Habitats and land management [Online]. Royal Society for the Protection of Birds. Available: http://www.rspb.org.uk/Images/black_grouse_leaflet_tcm9-214926.pdf [Accessed 04/02/2015.

RSPB. No date. (b). Farming and crofting for birds. Corn Bunting [Online]. Available: http://www.rspb.org.uk/Images/Corn%20bunting_tcm9-133202.pdf [Accessed 13/02/15].

RSPB. No date. (c). Farming for birds in Wales. Curlew [Online]. Available: http://www.rspb.org.uk/Images/Englishcurlews1_tcm9-133250.pdf [Accessed 29/02/2015].

RSPB. No date. (d). Farming for birds in Wales. Golden plover [Online]. Available: http://www.rspb.org.uk/Images/Englishgoldenplover_tcm9-133252.pdf [Accessed 09/02/2015.

RSPB. No date. (e). Farming for birds in Wales. Ring Ouzel. [Online]. Available: http://www.rspb.org.uk/Images/Englishringouze1_tcm9-133260.pdf [Accessed 03/02/2015].

RSPB. No date. (f). Farming for birds in Wales. Twite. [Online]. Available: http://www.rspb.org.uk/Images/Englishtwite1_tcm9-133266.pdf [Accessed 16/02/2015].

RSPB. No date. Lifeline to recovery – the RSPB's species recovery success in the UK [Online]. Available: http://www.rspb.org.uk/Images/lifeline_tcm9-132660.pdf.

SHELDON, R. D., CHANEY, K. & TYLER, G. A. 2007. Factors affecting nest survival of Northern Lapwings Vanellus vanellus in arable farmland: an agri-environment scheme prescription can enhance nest survival: Capsule A spring/summer fallow agri-environment prescription improved Lapwing nest survival. Bird Study, 54, 168-175.

SIM, I. M., LUDWIG, S. C., GRANT, M. C., LOUGHREY, J. L., REBECCA, G. W. & REDPATH, S. 2013. Seasonal variation in foraging conditions for Ring Ouzels Turdus torquatus in upland habitats and their effects on juvenile habitat selection. Ibis, 155, 42-54.

SIM, I. M., LUDWIG, S. C., GRANT, M. C., LOUGHREY, J. L., REBECCA, G. W. & REDPATH, S. 2013. Seasonal variation in foraging conditions for Ring Ouzels Turdus torquatus in upland habitats and their effects on juvenile habitat selection. Ibis, 155, 42-54.

STARLING-WESTERBERG, A. 2001. The habitat use and diet of Black Grouse Tetrao tetrix in the Pennine hills of northern England. Bird Study, 48, 76-89.

VALKAMA, J. & CURRIE, D. 1999. Low productivity of curlews Numenius arquata on farmland in southern Finland: causes and consequences. Ornis Fennica, 76, 65-70.

WARREN, P. K. & BAINES, D. 2002. Dispersal, survival and causes of mortality in black grouse Tetrao tetrix in northern England. Wildlife biology, 8, 91-97.

WHITEHEAD, S., JOHNSTONE, I. & WILSON, J. 2005. Choughs Pyrrhocorax pyrrhocorax breeding in Wales select foraging habitat at different spatial scales: Capsule At coarse spatial resolution breeding Choughs showed strongest selection for grazed habitats, while at a finer resolution they selected areas with shorter swards and more friable soils. Bird Study, 52, 193-203.

WHITTINGHAM, M. J., PERCIVAL, S. M. & BROWN, A. F. 2000. Time budgets and foraging of breeding golden plover Pluvialis apricaria. Journal of Applied Ecology, 37, 632-646.

WHITTINGHAM, M. J., PERCIVAL, S. M. & BROWN, A. F. 2001. Habitat selection by golden plover Pluvialis apricaria chicks. Basic and Applied Ecology, 2, 177-191.

WILKINSON, N. I. & WILSON, J. D. 2010. Breeding ecology of Twite Carduelis flavirostris in a crofting landscape. Bird Study, 57, 142-155.

WILSON, A. M., AUSDEN, M. & MILSOM, T. P. 2004. Changes in breeding wader populations on lowland wet grasslands in England and Wales: causes and potential solutions. Ibis, 146, 32-40.

Annual Knawel

<table>
<tr><th>Indicators Obtained from Evidence</th><th>Target Species and Glastir Measures</th><th>Specific Response Variables</th><th>GMEP Survey Data That Captures Measure or Target</th></tr>
<tr><td rowspan="2"><u>Agricultural Crops</u>

Scleranthus annuus can grow as an annual or biennial plant and occurs on dry sandy grounds both in arable habitats as well as on disturbed soil in dry heathland, commons, waste places, and occasionally river or coastal shingle (Preston et al. 2002). It main occurrence is on sandy acidic soils but it can also occasionally be found on soils containing carbonates (Salisbury 1961). It is a very small-statured species with low levels of competitiveness and is mainly found under conditions of low fertility, as expressed by its Ellenberg N score of 4 (Hill et al. 2004).
As S. annuus germinates over winter (Muller 1978), autumn cultivation is recommended. Because of its lack of competitiveness, un-cropped cultivated margins and unfertilised conservation headlands sown with winter cereals may be a good strategy to provide optimal conditions for this species. Flowering time is from June to August (Fitter & Peat 1994).
S. annuus tends to form a long-term persistent seed bank (Thompson et al. 1997), and can thus persist locally during periods of unsuitable management.</td><td>27. Fallow margins</td><td>• New fallow crop margin on improved land
• Situated next to cereals, OSR, linseed, maize or root crops
• Fallow margin width of 2m to 8m
• Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops)
• Not cut before 1 August or until 14 weeks after sowing (whichever is later)
• No fertiliser applied
• Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming
• May be rotated</td><td>Habitat mapping, A & M plots</td></tr>
<tr><td>28. Retain winter stubbles</td><td>• New winter stubble on improved land following a cereal crop
• Straw removed within two weeks of harvest
• Any grazing not to exceed 0.4 LU × ha^{-1} at any one time
• No maize and no undersowing of the stubble
• Any cut no earlier than 15 February</td><td>Habitat mapping & X plots</td></tr>
</table>

		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	

N.B. Anything highlighted in red in the 'Specific response variable' column is thought to contradict the highlighted evidence obtained from the literature.

Broad-fruited Cornsalad

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Agricultural Crops *Valerianella rimosa* is an annual species that almost exclusively grows in arable habitats (Wilson 2008). It is found on a range of soils, often as part of species-rich communities, and tends to be associated with other rare arable spp. such as *Scandix pecten-veneris*, *Ranunculus arvensis*, and *Silene gallica* (Wilson 2008). Little is known about its seed bank persistence, but its seed is likely to be moderately long-lived when buried in soil (Wilson 2008). *V. rimosa* germinates both in autumn and in spring, and accordingly, it is found both in autumn crops and in spring crops (Wilson 2008). Its July-August flowering time (Fitter & Peat 1994) is relatively late. Early harvest dates should thus be avoided, to enable *V. rimosa* to complete its life cycle. Being very uncompetitive, *V. rimosa* does best in nutrient-poor (field margin) situations with an open crop canopy (Wilson 2008), which is also reflected in its high Ellenberg L (=light) value of 8, and its low Ellenberg N value of 3 (Hill et al. 2004). Accordingly, management of fields as conservation headlands may benefit the species. Nitrogen fertilization, on the other hand, via enhancing competition from the crop canopy, tends to have detrimental effects on its performance, e.g. in winter wheat (Wilson 1999). No information is available about its susceptibility to herbicides, but it is likely to	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

be affected by the majority of broad-spectrum herbicides (Wilson & King 2003).		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated • <u>Stubble left after crop harvest</u> (to allow comnpletion of life cycle) • <u>Arable dicot richness</u> • <u>Occurrence of other rare arable spp.</u>	

Chamomile

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Heathland *C. nobile* is a perennial growing on moderately acidic soils in short grassy vegetation, usually on relatively acid, sandy or gley soils that are seasonally wet, usually in winter (Winship 1994; Winship & Chatters 1994. Its habitats include herb-rich grassland, e.g. on commons and pastures, turf, and more recently also on sports fields (Winship 1994). It requires sufficient disturbance, e.g. through grazing, mowing or trampling, to keep vegetation short and open (Winship & Chatters 1994). Under close trampling, it can achieve more than 50% cover, due to its ability to spread vegetatively under such conditions (Kay & John 1994). It is uncompetitive, as indicated by a high Ellenberg L value of 8 (Hill et al. 2004), but can persist in moderately nutrient-rich sites, as long as disturbance keeps competitive species in check. It is also found in maritime grassland, e.g. on cliffs, where exposure and salt spray keep the sward short (Winship & Chatters 1994). In addition to reproducing via seed, the species is well-adapted to spread clonally via creeping stems, particularly in situations where grazing pressure is very high (Winship & Chatters 1994). Little is known about its seed longevity. While it is assumed that it can persist as seed in the soil at least for limited periods (Plantlife 2013), no seed was detected in samples from underneath several populations (Kay & John 1994). Threats include the cessation of grazing, as well as the drainage of suitable habitats (Winship & Chatters 1994). Suitable restoration measures include the	41A Grazing management of open country 41B Grazing management of open country with mixed grazing 119 Lowland heath habitat expansion - establishment on grassland	• Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed • Adhere to permitted range of seasonal grazing levels: 1 April – 30 June: 0.00-0.10 LU/ha 1 July – 30 Sept.: 0.00-0.05 LU/ha 1 Oct. – 31 Mar.: 0.00*-0.01 LU/ha	Habitat mapping Habitat mapping (Specifics of grazing won't be captured)

reinstatement of cattle and/or pony grazing on heathland, targeted scrub control in overgrown habitat, and the reversion of pasture to heathland (Plantlife2013). Sheep and rabbit grazing, on the other hand, do not usually produce the poached ground preferred by this species (Winship 1994). Where grazing is impractical, mowing may help to maintain existing populations of *C. nobile*, but not necessarily those of rarer species that may be associated in herb-rich grassland (Winship 1994).			
C. nobile is a perennial usually growing on relatively acid, sandy or gley soils that are seasonally wet, usually in winter (Winship 1994; Winship & Chatters 1994. Threats include the drainage of suitable habitats (Winship & Chatters 1994).	403 Additional Management Payment - Re-wetting	• <u>Mean Ellenberg F moisture score</u>	
Unable to find evidence	20 Management of lowland and coastal heath 20B Management of lowland and coastal heath with mixed grazing 44 Mechanical bracken control 115 Lowland dry heath with less than 50% western gorse 116 Lowland dry heath with more than 50% western gorse 117 Lowland wet heath with less than 60% purple moor- grass 118 Lowland wet heath with more than 60% purple moor-grass 139 Lowland bog and other acid mires with <50% purple moor-grass 140 Lowland bog and other acid mires with >50% purple moor-grass 141 Lowland bog and other acid mires; restoration (no grazing)	<u>N/A</u>	N/A

	142 Lowland bog and other acid mires; reversion (pasture) 400 Additional Management Payment - Stock management 401 Additional Management Payment - Mixed grazing 402 Additional Management Payment - Control burning 411 Additional Management Payment - Reduce stocking		

Corn Buttercup

Indicators Obtained from Evidence	**Target Species and Glastir Measures**	**Specific Response Variables**	**GMEP Survey Data That Captures Measure or Target**
<u>Agricultural Crops</u> *Ranunculus arvensis* is an annual species of arable land on a wide range of soil types including loams, sands, clays, and chalk (Preston et al. 2002). It is often found with other rare weeds such as *Scandix pecten-veneris* and *Valerianella rimosa* (Smith 1994). *R. arvensis* is susceptible to many broad-spectrum herbicides and has experienced a rapid decline from the 1940s onwards in response to the spread of synthetic herbicides (Potts & Vickerman 1974). Improved cleaning of crop seed has also played a role in its decline (Salisbury 1961). It has been suggested that traditionally, seed dispersal occurred through grazing of the stubble by lifestock (Schneider et al. 1994). While Salisbury (1961) suggested that buried fruits can remain viable for many years, studies of soil seed banks (Thompson et al. 1997) and burial experiments (e.g. Wilson 1990) suggest that the species may only have a short-term persistent seed bank. Germination takes place in autumn and winter (Wilson & King), and for this reason, autumn-sown crops are more suitable than spring-sown crops (Schneider et al. 1994). Crop rotations with a strong focus on spring-sown crops should thus be avoided at sites where the species is present (Schneider et al. 1994). *R. arvensis* tends to be suppressed at high cereal tiller densities (Schneider et al. 1994). Its rather shallow root system (Kutschera 1960) enables it to tolerate saturated soil conditions in late winter and spring.	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

Flowering occurs from June to July (Fitter & Peat 1994). A late harvest will promote self-seeding, as fully ripened fruits detach from the plant more easily, whereas an early harvest tends to result in seed removal from the site (Schneider et al. 1994). If there is sufficient soil moisture after harvest, re-growth can occur from subsidiary branches, and for this reason, it may be beneficial to leave the stubble after harvest (Schneider et al. 1994).		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated • Stubble left after crop harvest (to allow re-growth) • Arable dicot richness • Occurrence of other rare arable spp.	

N.B. Anything highlighted in red in the ‘Specific response variable’ column is thought to contradict the highlighted evidence obtained from the literature.

Cornflower

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Agricultural Crops *Centaurea cyanus* used to be an annual weed mostly of arable land, particularly on sandy and rather acidic soils (Smith in Stewart et al. 1994, growing mainly in crops of rye (Smith 1994). Now, it occurs more often in waste places and other disturbed sites, either as garden escape or sown as part of wildflower mixes (Preston et al. 2002). Its true distribution as naturally-occurring species is now obscured by widespread introduction and colonisation from introduced populations (Wilson 2007). Main germination season is September to October, with some further germination after spring cultivations (Wilson & King 2003). Acccordingly, it is found both in winter crops as well as in spring crops, but autumn-germinated plants in winter crops are usually bigger and produce more seed than plants in spring crops (Schneider et al. 1994). Its decline is linked to a range of factors, including seed cleaning, habitat loss (Wilson 2007), and a poor ability to compete with cereal crops sown at high densities (Svensson & Wigren 1982). C. cyanus also is sensitive to a range of herbicides (Preston et al. 2002), but due to its ability to emerge from greater depths, it is less sensitive to pre-emergence herbicides (Schneider et al. 1994). Seed is short-lived under field conditions, and usually, only a small fraction of seeds remains viable for more than one year (e.g. Svensson & Wigren 1985; Barralis et al. 1988). Accordingly, the species does best in crop	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

rotations with a strong focus on winter crops (Schneider et al. 1994) which boost its re-seeding. Re-seeding is further promoted by late harvest dates (Schneider et al. 1994).		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	

Large-flowered Hemp-nettle

Indicators Obtained from Evidence	**Target Species and Glastir Measures**	**Specific Response Variables**	**GMEP Survey Data That Captures Measure or Target**
<u>Agricultural Crops</u> Summer annual weed of cultivated, marginal and waste ground (Preston et al. 2002). In the British Isles, *Galeopsis speciosa* is often found within root crops, especially potatoes, on peaty soils (Preston et al. 2002). The seeds require cold stratification (Karlsson et al. 2006) prior to seedling emergence in spring, which usually occurs around late April (Salisbury 1961). Information on seed bank persistence is scarce, but short-term persistence of up to five years appears likely (Thompson et al. 1997) Flowering is relatively late, between July and September (Fitter & Peat 1994), and the species is likely to benefit from leaving stubbles after harvest. *G. speciosa* is considered to be one of the more vigorously growing species of arable weed that can hold its own relatively well in competitive arable crops (Hakansson 2003). This is also reflected in the species having been assigned a relatively high Ellenberg N value of 7 (Hill et al. 2004). While there is no published evidence from UK studies on its response to various cultivation practices, in eastern Europe, *G. speciosa* has been found to be negatively affected by stubble removal after harvesting, as well as by early pre-winter ploughing, by inter-row cultivation of tilled crops, and by herbicide application (Sokolova 2009).	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated • <u>Stubble left after crop harvest</u> (to allow completion of life cycle) • <u>Autumn cultivation not too early</u> (to allow completion of life cycle)	

N.B. Anything highlighted in red in the 'Specific response variable' column is thought to contradict the highlighted evidence obtained from the literature.

Marsh Clubmoss

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
<u>Heathland</u> *Lycopodiella inundata* is usually found on bare peaty, or occasionally sandy or silty areas, usually with a bare ground cover of about 30-60% (Headley 1994; Byfield & Stewart 2007). The margins of lakes are its natural habitat, where it grows in or immediately adjacent to the inundation zone (Byfield & Stewart 2007). Its most important semi-natural habitat are bare patches within extensively grazed heathland, and in Wales, sheep-grazed moorland represents one of the strongholds of the species (Byfield & Stewart 2007). In terms of substrate, it is mostly found on very acidic and oligotrophic, moist to wet soils in fully exposed situations (Rasmussen & Lawesson 2002). In wet heathland, it is often associated with *Rhynchospora alba* and with *Rhynchospora fusca*, which along with the purplish alga *Zygogonium ericetorum* may be good indicators of habitat suitability for *L. inundata* (Byfield & Stewart 2007). As *L. inundata* is a pteridophyte, its life cycle is formed of two independent stages, including a free-living gametophyte stage in addition to the much more conspicuous sporophyte stage. The gametophyte is superficial and green and requires a several years to reach maturity (Headley 1994). The sporophyte is a short-lived prostrate perennial plant that grows at the tips of evergreen branches whose older sections fragment after about two years, resulting in clonal reproduction (Headley 1994; Byfield & Stewart 2007). According to Headley (1994). The species often occurs as a pioneer (Rasmussen & Lawesson 2002) and can rapidly	119 Lowland heath habitat expansion - establishment on grassland 140 Lowland bog and other acid mires with more than 50% purple moor-grass	• Adhere to permitted range of seasonal grazing levels: Option 119: 1 April – 30 June: 0.00-0.10 LU/ha 1 July – 30 Sept.: 0.00-0.05 LU/ha 1 Oct. – 31 Mar.: 0.00*-0.01 LU/ha Option 140: 1 April – 30 Sept.: 0.20-0.30 LU/ha 1 Oct. – 31 Mar.: 0.00-0.10 LU/ha	Habitat mapping (specifics of grazing won't be captured)

colonise bare patches created by winter inundation, cattle poaching, peat cutting, or vehicle activity (Preston et al. 2002). It has been suggested that *L. inundata* reaches new sites through highly efficient dispersal of spores (Øllgaard 1985). In already-established populations, the main means of dispersal likely is clonal spread by fragmentation (Rasmussen & Lawesson 2002). Due to its slow, prostrate growth, with stems typically only growing about 3-6 cm per year (Byfield & Stewart 2007), *L. inundata* is a very poor competitor as succession proceeds (Rasmussen & Lawesson 2002). Repeated disturbance and erosion are key for its continued persistence at a site (Rasmussen & Lawesson 2002; Byfield & Stewart 2007). Threats include eutrophication and the cessation of suitable grazing regimes, as well as destruction of wetlands, e.g. due to drainage (Headley 1994; Rasmussen & Lawesson 2002). Traditionally, the practice of turf-cutting was beneficial to *L. inundata* (Byfield & Stewart), and accordingly, the use of sod cutting in wet heath restoration tends to positively affect *L. inundata* populations (Dorland et al. 2005). On sites where it already grows, protracted periods of uninterrupted traditional management, e.g. via extensive grazing, have been recommended (Byfield & Stewart 2007).			

Pillwort

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Heathland *Pilularia globulifera* is a perennial fern of silty or peaty lake or pond margins and shallow, seasonally-dry ditches and pools, e.g. within heathland and upland grassland, but can also survive in deep water where it is occasionally found as a submerged aquatic (Jermy 1994; Scott et al. 1999). It is also occasionally found in man-made habitats such as old clay-pit workings and gravel extraction sites (Scott et al. 1999). Suitable waterbodies tend to be moderately acid and nutrient-poor, as also expressed by Ellenberg R - and N-values of 4 and 2, respectively (Hill et al. 2004). In a survey of Welsh upland pools, *Pilularia globulifera* was not found in pools with more than 0.005 mg/l nitrate or with a water pH of lower than 5.2 (Slater et al. 1991). A re-analysis of Slater et al.'s (1991) dataset by Wilkinson (1998) demonstrates that *P. globulifera* is predominantly found in pools where species richness of emergent plants is high. As a pioneer, *P. globulifera* requires bare ground, usually created by fluctuating water levels or disturbance, e.g. by cattle or horse trampling (Preston et al. 2002; Jermy 1994). It temporarily occupies such patches of bare ground until it is being ousted by competitive late-successional species (Jermy 1994). Colonization can occur locally through creeping rhizomes or across larger distances via the spreading of sporocarps on the feet of lifestock and waterfowl (Scott et al. 1999; Szczęśniak & Szlachetka 2008; Plantlife 2010). According to Jermy (1994), the gametophyte generation is only short-lived, and new sporophytes can emerge within 17 days of	20 Management of lowland and coastal heath 20B Management of lowland and coastal heath with mixed grazing 41A Grazing management of open country 41B Grazing management of open country with mixed grazing 119 Lowland heath habitat expansion - establishment on grassland 140 Lowland bog and other acid mires with more than 50% purple moor-grass	• Grazing by cattle, sheep, goats or ponies • ≥50% dwarf shrub species on lowland heath • ≥25% dwarf shrub species on coastal heath • ≤25% of heath burnt over 5 years • Gazing of 'open country' • Mixed grazing of 'open country'. Cattle and sheep must be grazed • Adhere to permitted range of seasonal grazing levels: Option 119: 1 April – 30 June: 0.00-0.10 LU/ha 1 July – 30 Sept.: 0.00-0.05 LU/ha 1 Oct. – 31 Mar.: 0.00*-0.01 LU/ha Option 140: 1 April – 30 Sept.: 0.20-0.30 LU/ha 1 Oct. – 31 Mar.: 0.00-0.10 LU/ha	Habitat mapping, X & U plots Habitat mapping Habitat mapping (specifics of grazing won't be captured)

spore germination. It has been suggested that sporocarps can persist at the bottom of pools or ponds (Plantlife 2010). While no direct evidence exists, Szczęśniak & Szlachetka (2008) have found that some of the sporocarps they collected did remain hard and closed for extended periods, which may facilitate sporocarp burial in the mud. Threats include habitat deterioration (e.g. due to the infilling of ponds, eutrophication, drainage, and the cessation of grazing) and destruction (e.g. due to the loss of ponds or heathland) (Scott et al. 1999; Plantlife 2010). At some sites, the spread of invasive alien species such as *Crassula helmsii* may pose a threat (Scott et al. 1999). Preservation of existing populations depends crucially on the maintenance of open site conditions, e.g. where suitable via grazing by cattle and horses (Plantlife 2010). Restoration efforts might include reinstatement of suiutable grazing regimes, and, in the case of ponds, dredging to the original profile (Plantlife 2010).			

Purple-ramping Fumitory

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Agricultural Crops *Fumaria purpurea*, first described in 1902, is endemic to the British Isles (Pearman & Preston 1994). It is difficult to identify and its current mapped distribution may not accurately reflect its actual distribution (Lockton 2003). Literature describing its ecological requirements is scarce (Lockton 2003). The species is found across a range of habitats that are either disturbed or opened up by summer drought (Pearman & Preston 1994). In Wales, it is found in arable fields, as well as in gardens and allotments, on waste ground, in hedge banks, and earthy shore habitats (Lockton 2003). F*. purpurea* occurs mostly in spring-sown crops (Preston et al. 2002). The reason for this is likely a combination of *F. purpurea*, like the related *Fumaria officinalis* (Roberts & Feast 1973), being a spring-germinating species, and/or of it being too uncompetitive to do well underneath the canopy of autumn-sown crops, which would be in agreement with its relatively low Ellenberg N value of 5 (Hill et al. 2004). Nothing is known about its seed bank persistence, but it seems likely that like the closely related *F. officinalis* (Thompson et al. 1997), it may have seeds that remain viable for a long time when buried in soil. Flowering is relatively late, between July and October (Fitter & Peat 1994), suggesting that this species may benefit from leaving stubbles after harvest.	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated •	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated • Stubble left after crop harvest (to allow completion of life cycle)	

Red Hemp-nettle

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
<u>Agricultural Crops</u> *Galeopsis angustifolia* is an annual species of arable fields that also occurs on coastal sands and shingle (Smith & Wilson 1994). In arable situations it is confined to light chalky soils that are well-drained (Wilson & King 2003). Its germination occurs entirely in the spring, and accordingly, *G. angustifolia* is restricted to spring crops (Wilson & King 2003). Its decline is partly due to a move away in agriculture from spring crops to winter crops (Preston et al. 2002), but also due to its susceptibility to many herbicides, and the increased use of N fertilizer and of nitrogen-demanding crop varieties (Wilson & King 2003). Little is known about its seed bank persistence, but according to Wilson & King (2003), its seeds are likely to be long-lived. *G. angustifolia* is late-flowering from July to October (Wilson & King 2003), and tends to grow rapidly after crop harvest, setting much seed in stubbles if these are left in late summer (Smith & Wilson in Stewart et al. 1994). It is therefore essential to leave the stubble after harvest. Arable populations have been shown to benefit from management of fields as conservation headlands (Sotherton 1990).	27. Fallow margins	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated	Habitat mapping, A & M plots
	28. Retain winter stubbles	• New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping & X plots

		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated • Stubble left after crop harvest (to allow completion of life cycle) • Autumn cultivation not too early (to allow completion of life cycle)	

Shepherd's Needle

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Agricultural Crops *Scandix pecten-veneris* is an annual species of arable land and only rarely found in other habitats (Preston et al. 2002). The majority of populations is now found on heavy calcareous clays (Wilson 2006), but historically, the species occurred on a wide range of soil types (Brenchley 1920). Germination occurs mainly in the autumn (October-November), with a small amount of germination in spring (Brenchley & Warington 1936; Wilson 1990). Accordingly, *S. pecten-veneris* is typically found in fields sown with winter cereals (Wilson 2006). Its flowering time of April to July (Fitter & Peat) is relatively early compared to other rare arable species, although spring-germinated individuals can be expected to flower much later than autumn—germinated individuals. This species is more competitive than other rare arable weed species and can cope better than these with more fertile conditions and enhanced levels of competition by the crop canopy. Accordingly, it can tolerate a certain amount of fertilizer application; however, experimental N applications in a winter wheat crop did nonetheless reduce plant densities (Wilson 1999). The species has been found to benefit from management of fields as conservation headlands (Sotherton 1990). Due to its relative competitiveness, it is not just found in species-rich vegetation in extensively managed crops where it co-occurs with other rare arable species, but	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

also in species-poor vegetation in which other rare species cannot persist (Wilson 2006). *S. pecten-veneris* is susceptible to a wide range of broad-spectrum herbicides (Wilson 1990, 2006), but at the same time has shown resistance to a few herbicides (Wilson & King 2003). Its seeds are short-lived, and few seeds tend to persist for more than one year (Brenchley & Warington 1936; Wilson 1990). Accordingly, crop rotations with a strong focus on spring-sown crops should be avoided where the species is present. Ideal management for the species includes annual autumn cultivation, and crop harvesting only after *S. pecten-veneris* has set seed. A risk of *Scandix* seedlings being eliminated by pre-sowing cultivations in autumn (Smith 1994) may be avoided by early sowing of winter crops.		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	• New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	

N.B. Anything highlighted in red in the 'Specific response variable' column is thought to contradict the highlighted evidence obtained from the literature.

Small-flowered Catchfly

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Agricultural Crops *Silene gallica* is an annual species growing predominantly in arable fields, but is also occasionally found at disturbed anthropogenic sites (wasteground etc.) and on sandy seashores (Preston et al. 2002). Some occurrences are due to its seeds being a contaminant of imported clover seed (Smith 1994). The majority of populations are found on nutrient-poor sands and sandy loams (Wilson & King 2003). Seed germination takes place predominantly in the autumn (Smith 1994), but some germination can also occur in spring (Wilson & King 2003). Nonetheless, in arable situations, *S. gallica* is mainly found in spring-sown crops, perhaps through its inability to compete with the dense crop canopy in some autumn-sown crops (Wilson 2008); in autumn-sown crops it can only persist if crop cover is sufficiently sparse (Wilson 2008). Some of the best populations of *S. gallica* are found in fields where root crops are a major component of rotations (Wilson 2008). Flowering time according to Fitter & Peat (1994) is from June to October). Populations can be successfully boosted by management of field margins within agri-environment schemes (Wilson 2008). *S. gallica* is a poor competitor and as such has suffered particularly strongly from N fertilization and improved crop varieties. While there is no information available on its susceptibility to herbicides, it appears likely that	27. Fallow margins 28. Retain winter stubbles	• New fallow crop margin on improved land • Situated next to cereals, OSR, linseed, maize or root crops • Fallow margin width of 2m to 8m • Cultivated annually in spring (before 15 May for cereals; before 31 May for maize; before 1 July for root crops) • Not cut before 1 August or until 14 weeks after sowing (whichever is later) • No fertiliser applied • Area must not be used as a track, but acceptable to allow machine access for hedgerow trimming • May be rotated • New winter stubble on improved land following a cereal crop • Straw removed within two weeks of harvest • Any grazing not to exceed 0.4 LU × ha^{-1} at any one time • No maize and no undersowing of the stubble • Any cut no earlier than 15 February	Habitat mapping, A & M plots Habitat mapping & X plots

it is affected by the majority of broad-band herbicides (Wilson 2008). *S. gallica* has short-term seed bank persistence (Thompson et al. 1997), and should thus be able to tolerate crop rotations including crops that are unfavourable as long as every few years crops are planted that are compatible with its life cycle. These would be crops that are ideally cultivated in mid-autumn or in early spring. Due to low competitiveness, in competitive situations, it may be necessary to take measures to reduce the impact of competitive weeds (Wilson 2008).		• Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • Before 1 March, herbicides only applied to control notifiable weeds and invasive alien species • No manure stored on the area • No supplementary feed on the area • May be rotated •	
	30. Unsprayed spring sown cereals or pulses	• On improved land not certified organic • Non-maize cereal or pulse crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No undersowing • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated •	Habitat mapping & X plots
	31. Unsprayed spring sown cereals retaining winter stubbles	New unsprayed spring sown non-maize cereals retaining winter	Habitat mapping & X plots

		stubbles on improved land that has been cultivated previously and has not been certified organic • Crop established by cultivation in spring before 15 May • Crop not cut before 1 August or until 14 weeks after sowing (whichever is later) • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • Straw removed within two weeks of harvest • Grazing only from January onwards and not to exceed 0.4 LU × ha^{-1} at any one time • No undersowing • Any cut no earlier than 15 February • Ploughing, cultivating, and drilling only from 1 March onwards • No slurry application between harvest and 1 March • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated	
	34B. Unfertilised and unsprayed cereal headland	• New unfertilised and unsprayed cereal headland on improved land • Width of 3m to 6m	Habitat mapping, A & M plots

		• Cultivated annually in spring (before 15 May) • Crop not harvested or grazed before 1 August or until 14 weeks after sowing (whichever is later) • No fertilisers, manures, lime or slag applied • Other than the use of glyphosate to spray off vegetation prior to sowing, herbicides only used to control notifiable weeds and invasive alien species • No insecticide • No fungicides unless applied to the seed pre-sowing • No molluscicides unless drilled with the seed • May be rotated • <u>Stubble left after crop harvest</u> (to allow completion of life cycle)	

Three-lobed crowfoot

Indicators Obtained from Evidence	Target Species and Glastir Measures	Specific Response Variables	GMEP Survey Data That Captures Measure or Target
Heathland *Ranunculus tripartitus* is a winter annual species found in shallow seasonal bodies of water drying out in summer, such as ditches, ponds, and trackways. It is usually found over moderately base- and nutrient-rich clays and sands (Preston et al. 2002), e.g. within wet heathland and related communities (Byfield 1994). In Wales it tends to occur in areas dominated by M16 (Erica tetralix – Sphagnum compactum wet heath) and/or M25 (Molinia caerulea - Potentilla erecta mire) NVC communities. Also, it often occurs specifically in transition zones between improved or semi-improved pasture and M23 (Juncus effusus/acutiflorus - Galium palustre rush-pasture) (Lansdown & Evans 2000). *R. tripartitus* is sensitive to competition, and this is reflected in its low Ellenberg N value of 3 and its high Ellenberg L value of 9 (Hill et al. 2004). It requires open habitat that is maintained by disturbance, e.g. due to water level fluctuation, grazing and poaching by livestock (Byfield 1994). Large populations are usually found in situations where there is localised, heavy poaching of seasonally inundated areas (Lansdown & Evans 2000). *R. tripartitus* typically flowers between March and May (Fitter & Peat 1994), and completes its lifecycle before its habitat dries out in the summer. Main threats include the destruction of heathland, the cessation of disturbance activities such as grazing, and habitat modification, e.g. through drainage or infilling (Byfield 1994). While there is no data available on seed longevity, it is generally assumed that buried seeds can survive for at least several years, which would help populations to persist at degraded sites, allowing re-emergence once favourable conditions have been restored (Byfield 1994), e.g. through reinstatement of grazing or dredging of ponds to their original profile.	119 Lowland heath habitat expansion - establishment on grassland 140 Lowland bog and other acid mires with more than 50% purple moor-grass	• Adhere to permitted range of seasonal grazing levels: Option 119: 1 April – 30 June: 0.00-0.10 LU/ha 1 July – 30 Sept.: 0.00-0.05 LU/ha 1 Oct. – 31 Mar.: 0.00*-0.01 LU/ha Option 140: 1 April – 30 Sept.: 0.20-0.30 LU/ha 1 Oct. – 31 Mar.: 0.00-0.10 LU/ha	Habitat mapping (specifics of grazing won't be captured)

REFERENCES FOR SECTION 42 PLANTS

Scleranthus annuus (Annual knawel)

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Muller, F.M. (1978) Seedlings of the North-Western European Lowland. A Flora of Seedlings. Dr W. Junk B.V. Publishers, The Hague, Netherlands.

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Salisbury, E. (1961) Weeds & Aliens. Collins, London, UK.

Thompson, K., Bakker, J.P. & Bekker, R.M. (1997) The Soil Seed Banks of North West Europe: Methodology, Density and Longevity. Cambridge University Press, Cambridge, UK.

Valerianella rimosa (Broad-fruited cornsalad)

Fitter, A .H. & Peat , H.J. (1994) The Ecological Flora Database. *Journal of Ecology* **82**: 415-425.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Wilson, P.J (2008) Valerianella rimosa (Bastard). Unpublished report. http://www.plantlife.org.uk/uploads/documents/Valerianella_rimosa_dossier.pdf (accessed on 26/11/2014)

Wilson, P. & King, M. 2003. Arable Plants - a field guide. English Nature and WildGuides, Old Basing, UK.

Chamaemelum nobile (Chamomile)

Winship, H. & Chatters, C. (1994) *Chamaemelum nobile* (L.) All. – Chamomile. p. 110 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Fitter, A .H. & Peat , H.J. (1994) The Ecological Flora Database. *Journal of Ecology* **82**: 415-425.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Kay, Q.O.N. & John (1994) Population genetics and demographic ecology of some scarce and declining vascular plants of Welsh lowland grassland and related habitats. Countryside Council for Wales Science Report No. 93. Countryside Council for Wales, Bangor, UK.

Plantlife (2013) Species fact sheet: Chamomile – *Chamaemelum nobile*. http://www.plantlife.org.uk/uploads/documents/Chamomile.pdf (accessed on 12/12/2014)

Winship, H.R. (1994) Chamomile – the herb of humility in demise. *British Wildlife* **5**: 163-165.

Ranunculus arvensis (Corn Buttercup)

Kutschera, L. (1960) Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen. DLG-Verlags-Gesellschaft, Frankfurt am Main, Germany.

Potts, G.R. & Vickerman, G.P. (1974) Studies on the Cereal Ecosystem. Advances in Ecological Research Vol. 8: 107-197

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Salisbury, E. (1961) Weeds & Aliens. Collins, London, UK.

Schneider, C., Sukopp, U. & Sukopp, H. (1994) Biologisch-ökologische Grundlagen des Schutzes gefährdeter Segetalpflanzen. Schriftenreihe für Vegetationskunde 26. Bundesamt für Naturschutz, Bonn, Germany.

Smith, A. (1994) Ranunculus arvensis L. – Corn buttercup. p. 350-351 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Thompson, K., Bakker, J.P. & Bekker, R.M. (1997) The Soil Seed Banks of North West Europe: Methodology, Density and Longevity. Cambridge University Press, Cambridge, UK.

Wilson, P.J (1990) The ecology and conservation of rare arable weed species and communities. PhD thesis, Southampton University of Southhamton, Southhampton, UK.

<u>Centaurea cyanus (Cornflower)</u>

Barralis G., Chardoeuf R. & Lonchamp J.P. (1988) Longevité des semences de mauvaises herbes annuelles dans un sol cultivé. Weed Research 28: 407–418.

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Schneider, C., Sukopp, U. & Sukopp, H. (1994) Biologisch-ökologische Grundlagen des Schutzes gefährdeter Segetalpflanzen. Schriftenreihe für Vegetationskunde 26. Bundesamt für Naturschutz, Bonn, Germany.

Smith, A. (1994) Centaurea cyanus L. – Cornflower. p. 100-101 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Svensson, R. & Wigren, M. (1982) Nagra ograsarters tillbakagang belyst genom konkurrens-, godslings- och herbicidforsok (Competition, nutrient and herbicide experiments illustrating the decline of some weeds.) Svensk Botanisk Tidskrift 76: 241-258.

Svensson, R., Wigren, M. (1985) Blaklintens historia och biologi i Sverige. (History and biology of Centaurea cyanus in Sweden.) Svensk Botanisk Tidskrift 79: 273-297.

Wilson, P.J (2007) The status of Centaurea cyanus in Britain. Unpublished report. http://www.plantlife.org.uk/uploads/documents/WilsonP(2007)The-Status-of-Centaurea-cyanus-in-Britain.pdf (accessed on 26/11/2014)

Wilson, P. & King, M. 2003. Arable Plants - a field guide. English Nature and WildGuides, Old Basing, UK.

<u>Galeopsis speciosa (Large-flowered hemp-nettle)</u>

Fitter, A .H. & Peat , H.J. (1994) The Ecological Flora Database. *Journal of Ecology* **82**: 415-425.

Håkansson, S. (2003) Weeds and weed management on arable land: an ecological approach. CABI Publishing, Wallingford, UK.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Karlsson, L.M., Ericsson, J.A.L. & Milberg, P. (2006) Seed dormancy and germination in the summer annual *Galeopsis speciosa*. *Weed Research* **46**: 353-361.

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Salisbury, E. (1961) Weeds & Aliens. Collins, London, UK.

Solokova, T.D. (2009) *Galeopsis speciosa* Mill. - Bee-nettle. In Afonin, A.N., Greene, S.L., Dzyubenko, N.I. & Frolov, A.N. (eds.) Interactive agricultural ecological atlas of Russia and neighboring countries. Economic plants and their diseases, pests and weeds. http://www.agroatlas.ru/en/content/weeds/Galeopsis_speciosa/ (accessed on 20/11/2014)

Thompson, K., Bakker, J.P. & Bekker, R.M. (1997) The Soil Seed Banks of North West Europe: Methodology, Density and Longevity. Cambridge University Press, Cambridge, UK.

Lycopodiella inundata (Marsh Clubmoss)

Byfield, A. & Stewart, N. (2007) *Lycopodiella inundata* (L.) Holub. Unpublished report. http://www.plantlife.org.uk/uploads/documents/Lycopodiella_inundata_dossier.pdf (accessed on 15/12/2014)

Dorland, E.; Hart, M.A.C., Vermeer, M.L. & Bobbink, R. (2005) Assessing the success of wet heath restoration by combined sod cutting and liming. *Applied Vegetation Science* **8**: 209-218.

Headley, A.D. (1994) Lycopodiella inundata (L.) Holub – Marsh clubmoss. p. 250-251 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Øllgaard, B. (1985) Observations on the ecology of hybridisation in the clubmosses (Lycopodiaceae). *Proceedings of the Royal Society of Edinburgh B* **86**: 245-251.

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Rasmussen, K.K. & Lawesson, J.E. (2002) *Lycopodiella inundata* in British plant communities and reasons for its decline. *Watsonia* **24**: 45-55.

Pilularia globulifera (Pillwort)

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Jermy, A.C. (1994) Pilularia globulifera (L.) – Pillwort. p. 311-312 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Plantlife (2010) Species fact sheet: Pillwort – *Pilularia globulifera*. http://www.plantlife.org.uk/uploads/documents/Brief%20sheet%20-%20Pillwort%20Pilularia_briefing_sheet.pdf (accessed on 17/12/2014)

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Scott, M., Scott, S. & Sydes, C. (1999) A Scottish perspective on the conservation of Pillwort. *British Wildlife* **10**: 297-302.

Slater, F.M., Hemsley, A. & Wilkinson, D.M. (1991) A new sub-association of the Pilularietum globuliferae Tuxen 1955 in upland pools in the mid-Wye catchment of central Wales. *Vegetatio* **96**: 127-136.

Szczęśniak, E. & Szlachetka, A. (2008) Pillwort *Pilularia globulifera* L. in Lower Silesia – biology and ecology. p. 161-171 in Szczęśniak, E. & Gola, E. (eds.) Club mosses, horsetails and ferns in Poland – resources and protection. Institute of Plant Biology, University of Wrocław, Wrocław, Poland.

Wilkinson, D.M. (1998) relationship between species richness and rarity in Welsh aquatic floras. *Watsonia* **22**: 29-32.

Fumaria purpurea (Purple-ramping fumitory)

Fitter, A .H. & Peat , H.J. (1994) The Ecological Flora Database. *Journal of Ecology* **82**: 415-425.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Lockton, A.J (2003) Fumaria purpurea in the British Isles. Whild Associates, Shrewsbury, UK. http://www.bsbi.org.uk/Fumaria_purpurea_2003.pdf (accessed on 21/11/2014)

Pearman, D.A. & Preston, C.D. (1994) Fumaria purpurea Pugsley – Purple ramping fumitory. p. 181 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Roberts, H.A. & Feast, P.M. (1973) Emergence and longevity of seeds of annual weeds in cultivated and undisturbed soil. *Journal of Applied Ecology* **10**: 133-143.

Thompson, K., Bakker, J.P. & Bekker, R.M. (1997) The Soil Seed Banks of North West Europe: Methodology, Density and Longevity. Cambridge University Press, Cambridge, UK.

Galeopsis angustifolia (Red hemp-nettle)

Smith, A. & Wilson, P.J. (1994) Galeopsis angustifolia Ehrh. Ex Hoffm. – red hemp-nettle. p. 184-185 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Sotherton, N.W. (1990) The environmental benefits of conservation headlands in cereal fields. Pesticide Outlook 1: 14-18.

Wilson, P. & King, M. 2003. Arable Plants - a field guide. English Nature and WildGuides, Old Basing, UK.

Scandix pecten-veneris (Shepherd's-needle)

Brenchley, W.E. (1920) Weeds of Farmland. Longmans, Green & Co., London, UK.

Brenchley, W.E. & Warington, K. (1936) The weed seed population of arable soil. III. The re-establishment of weed species after reduction by fallowing. Journal of Ecology 24: 479-501.

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Smith, A. (1994) Scandix pecten-veneris L. – Shepherd's-needle. p. 372-373 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Sotherton, N.W. (1990) The environmental benefits of conservation headlands in cereal fields. Pesticide Outlook 1: 14-18.

Wilson, P.J (1990) The ecology and conservation of rare arable weed species and communities. PhD thesis, Southampton University of Southhamton, Southhampton, UK.

Wilson, P.J. (1999) The effect of nitrogen on populations of rare arable plants in Britain. p. 93-100 in Boatman, N.D. (ed.) Field margins and buffer zones: ecology, management and policy. Aspects of Applied Biology 54. Association of Applied Biologists, Wellesbourne, UK.

Wilson, P.J (2006) Scandix pecten-veneris Dandy. Unpublished report. http://www.plantlife.org.uk/uploads/documents/Scandix_pecten-veneris_dossier.pdf (accessed on 27/11/2014)

Wilson, P. & King, M. 2003. Arable Plants - a field guide. English Nature and WildGuides, Old Basing, UK.

Silene gallica (Small-flowered catchfly)

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Smith, A. (1994) *Silene gallica* L. – Small-flowered catchfly. p. 383-384 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Thompson, K., Bakker, J.P. & Bekker, R.M. (1997) The Soil Seed Banks of North West Europe: Methodology, Density and Longevity. Cambridge University Press, Cambridge, UK.

Wilson, P.J (2008) Silene gallica (L.). Unpublished report. http://www.plantlife.org.uk/uploads/documents/Silene_gallica__dossier.pdf (accessed on 27/11/2014)

Wilson, P. & King, M. 2003. Arable Plants - a field guide. English Nature and WildGuides, Old Basing, UK.

Ranunculus tripartitus (Three-lobed crowfoot)

Byfield, A.J. (1994) *Ranunculus tripartitus* DC. – Three-lobed crowfoot. p. 354-355 in Stewart, A., Pearman, D.A. & Preston, C.D. (eds.) Scarce plants in Britain. Joint Nature Conservation Committee, Peterborough, UK.

Fitter, A .H. & Peat , H.J. (1994) The Ecological Flora Database. *Journal of Ecology* **82**: 415-425.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT - Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats. Centre for Ecology and Hydrology, Huntingdon, UK.

Lansdown, R.V. & Evans, S.B. (2000) Three-lobed crowfoot *Ranunculus tripartitus* DC. in Wales. *BSBI Welsh Bulletin* **68**: 21-22.

Preston, C.D., Pearman,D. A. & Dines, T.D. (2002) New atlas of the British and Irish flora. Oxford University Press, Oxford, UK.

Appendix 6.1

Modelling the impacts of Glastir options using the Bangor Carbon Footprinting tool

1. Model description

The Bangor CF takes real farm data on all inputs, land management practices (and history for Land Use Change) and monthly stock diary data to generate annual C footprints that are PAS 2050 compliant (unless soil and biomass C sequestration effects are included). It adopts Tier 1 emission factors for most N_2O and CH_4 emissions (enteric fermentation based on animal category numbers x average EFs; soil emission factors; manure storage by type *etc*…). But it includes a simplified Tier 2 estimate of soil C accumulation under grassland, and accounts for on-going C sequestration in tree biomass. A monthly stocking diary enables more accurate estimation of annual enteric fermentation (x animal numbers) and manure management (N excretion and CH_4 EFs). It uses a Life Cycle Analysis approach, and boundaries can include embedded GHG emissions associated with feed and fertiliser production and transportation to the farm.

1.1 Model outputs

The Bangor CF Tool outputs include: gases - enteric methane, manure methane, direct excreta, soil and manure heap N_2O; N_2O associated with nitrate leaching and N deposition (indirect N_2O); CO_2 from energy use; embedded greenhouse gas emissions associated with inputs (feed, fertiliser, agrochemicals, pharmaceuticals, significant consumables); and agricultural productivity. Above and below ground carbon annual increments in soils and biomass are modelled and reported separately from the system GHG emissions framework.

1.2 Recent applications of the model

The Bangor CF Tool was initially developed to assess the policy-relevant GHG emissions and carbon-sequestration impacts of a sustainable farming initiative in mid-Wales (Taylor et al. 2010); and for research into GHG emissions from mixed farming systems (Wyn Jones et al. 2011, Taylor et al. 2014). Further development took place under a previous Welsh Government funded project to assess the contribution of previous Welsh agri-environment schemes to the maintenance and improvement of soil and water quality, and to the mitigation of climate change (Taylor et al., 2012; chapter in Anthony et al 2012). It is currently being used in a number of projects to assess GHG impacts at the farm scale, including the annual variability in farm GHG emissions and the development of novel forage proteins for livestock production.

1.3 Emission Factors

The Bangor CF Tool generally uses IPCC Guidelines (2006) emission factors for calculating CH_4 and N_2O emissions from agriculture, maintaining compliance with PAS2050 where specific emissions factors are required for farm practices. Default emission factors are used with farm-specific management and productivity data (e.g. fertiliser use and dairy cattle milk yield) and livestock numbers and age classes are recalculated iteratively for each month of the farming year. Adherence to IPCC Guidelines means that model is consistent with UK Inventory methodology. Any additional emission factors are selected from review of the published literature on UK based field studies, in order to reflect as closely as possible the Welsh climate and natural soil attributes for N_2O - e.g. including the effects of temperature, atmospheric CO_2, pH, organic matter content, saturation and aeration.

1.4 N budget and N_2O emissions modelling

The Bangor CF Tool calculates the farm year organic N budget from livestock diaries using breed- and farm-specific animal growth rates; and mineral N from fertiliser formulation-use data. Stored manure (including incorporated bedding materials) and direct-deposition organic N (excreta and daily-spread manure) are modelled separately based on farm practice data.

Nitrate leaching, direct N and indirect N_2O emissions are calculated as emissions and losses from stored manures using IPCC standard Tier 1 methodology, with reference to farm storage practices (aerobic/anaerobic, lagoons etc.) specific to each animal type. Soil N_2O emissions are calculated from applied organic N (stored manure corrected for storage losses specific to store method), excreta organic N and applied mineral N (using a single EF for the N content of all fertiliser formulations applied, although formulation-specific EF's can be applied) per IPCC guidelines. Additional N_2O emissions are calculated per unit area of peat soils reported by the landowner and under management which includes N deposition (fertiliser, manure, grazing); corresponding to "managed peat soils" per IPCC recommendation. In the modelling of emissions from managed peat soils, where the IPCC standard temperate zone emission factor is 8 kg N_2O-N ha^{-1} (range 2-24 kg N_2O-N ha^{-1}) the Bangor model uses a much lower value from ECOSSE studies of North Wales peat soils (Smith et al 2010c), at 0.25 kg N_2O-N ha^{-1} (range -0.99-3.7 kg N_2O-N ha^{-1}).

1.5 Methane emissions modelling

The Bangor CF Tool calculates manure and excreta CH_4 emissions from the detailed livestock diaries using breed- and farm-specific animal growth rates. Monthly livestock numbers per animal type and age class are used with IPCC Tier 1 methodology and published relevant emissions rates for the relevant UK production systems. In order to avoid double-accounting, emissions from animals on the farm that remain the property of another holding are calculated separately: their direct emissions remain within the system boundary of their home farm, whilst soils and excreta emissions (N_2O and CH_4) are incorporated into the farm on which they are grazing. A common example of this is 'tack' sheep – livestock belonging to another farm, grazing in return for payment (usually £x per animal per week or month) and offering rotational grazing benefits to the destination farm.

1.6 Farm inputs

The Bangor CF Tool calculates embodied GHG emissions and transport emissions from point-of-sale to the farm gate for all farm inputs that can be identified and quantified. Farm inputs are identified during discussions with farmers, and details of their provenance, purchased amounts, transport method etc. collected in all available detail. PAS2050 allows the exclusion of inputs whose GHG impact totals less than 5% of the total emissions footprint, as long as the total GHG value of all excluded inputs remains below this 5% threshold. For each input, the embodied GHG emissions may be (in order of preference) a) extracted from relevant published PAS2050-compliant studies including IPCC databases; b) estimated using published or collected formulations or production data (relevant to fertilisers and animal feeds); c) estimated using data for farm exports calculated using the Bangor Tool during previous studies (relevant to bought-in livestock) or d) estimated using nearest-equivalent generic values from GHG emissions databases.

For inputs with annually-varying embodied GHG values, the published emissions value for the year in which the inputs were purchased is used (relevant to electricity and fuels). For complex inputs such as animal feeds, GHG emissions are calculated using feed formulation and individual ingredient provenance and published footprint data sourced in the same way as for other farm inputs.

1.7 Uncertainty

Citing a single precise figure as the output of a carbon footprinting exercise may be misleading as GHG calculations have to deal with issues of variability, uncertainty and subjectivity, each of which can reduce the accuracy and precision of the final result. For example, within the agricultural context, there is tremendous biophysical variability between farms producing the same products, and this can generate large differences in the calculated GHG emissions of the farm business. Welsh Lamb may be produced on an upland farm where there are very few inputs, but there is also low productivity per hectare; or on fertile lowland farms with higher unit productivity but more fertiliser input. Management also varies between farmers; and even neighbouring farms of the same type, e.g. dairy producers, can have different yields and GHG footprints which are partly a function of the personality and skills of the farmer. The weather can also have a large impact on the way a farm is managed. As a result the exact footprint of a farm may vary over time due to interactions between the climatic environment and the associated management decisions of the farmer. Finally, carbon footprints vary with the underlying soil type. As a result the underlying soil type of a farm can have a large impact on the final footprint for that farm. This sort of variation has not typically been reported in carbon footprints to date, but in the Welsh context Edwards-Jones et al. (2009b) suggest that the footprint from farms on organic (peat-derived) soils can be substantially greater than those on mineral soils.

In addition to genuine biophysical variation between farms and years there is also considerable uncertainty inherent in GHG emission factors. This uncertainty is related to the limitations of our understanding of ecosystem-level processes. Emission factors reported in standard databases are derived from studies using a range of system boundaries, data collection techniques, data definition and processing methodologies etc. The choice of emission factor database is a subjective process, while the variation between emission factors for the same process can introduce variability into the process of carbon footprinting. The scientific literature presents a range of emission factors for most processes. However, scientific understanding of these complex processes is limited, partly because their measurement is time-consuming and spatially and temporally variable. The IPCC approach to this problem has been to produce standard emission factors through meta-analysis of all the available experimental data. These may be applied worldwide or be relevant to large geographical regions, but can have limited relevance to local conditions.

In addition to variability and uncertainty, carbon footprints also include an element of subjectivity: the analyst is required to represent a real farm in a simplified form, which requires a series of simplifying assumptions to be made. It is important that analysts recognise the subjective nature of their activities. To date, few studies have tried to report this uncertainty and variability (exceptions include Lloyd & Ries 2008; Edwards-Jones et al. 2009). Similarly, many of the studies reported in the literature have used modelling approaches, rather than using real farm data: which does not allow for an assessment of differences between individual farms (e.g. Williams et al. 2006; Weiske et al. 2006; Hirschfeld et al. 2008).

The Bangor CF Tool retains uncertainty throughout the calculation process by presenting three sets of calculation results. The commonly cited value is calculated using the mid-values for all emissions factors, the value considered by the authors of source studies to be the most likely representation of an accurate value. In addition, a result is calculated using the maximum range values for all emissions factors (worst-case scenario) and a third result using the minimum range values (best-case scenario). These extreme values are likely to represent the absolute maximum range of possible GHG emissions produced by the farm system under analysis.

1.8 Arable crops and Land-use Change

Nitrous oxide emissions from arable land are calculated per IPCC guidelines for soil area, crop type and yield data collected from the farmer. Crop residues are modelled as removed (grazed, harvested) or incorporated (e.g. stubble ploughed-in) depending on stated management practices.

For land areas under management that has changed in the last 20 years, default land-use change values from Jones and Emmett (2009) and other relevant published literature are applied on an area basis. Relevant changes include C loss consonant with ploughing permanent grassland (to re-sow grassland or add to arable rotations); or C gains associated with woodland and hedgerow planting. C impacts of land-use change occur over a period of time (e.g. ploughing impacts occur in the first year, tillage changes over 10 years, etc) and the C impacts are modelled for one year's net impact after the stated number of elapsed years. In order to avoid double-accounting, these soil GHG impacts of land-use change are included in the PAS2050-compliant emissions calculations, but soil areas subject to such changes are excluded from the C sequestration (soils) calculations.

1.9 Modelling carbon sequestration in soils and biomass

Carbon sequestration in soils and biomass is modelled independently of the PAS2050-compliant GHG emissions components of the Bangor CF Tool but uses the same Tier 1 approach and retains the same flexibility for scenario modelling. Calculations fall into the following categories:

a) ≥75% closed-canopy trees (woodland and forestry) over 20yo – modelled as woodland by area using site-specific Forestry Commission tree growth models (soil, aspect, altitude, rainfall, species or species mix) assuming stable soil carbon content. Timber extraction modelled as carbon losses sensitive to brash handling (burning, composting) and including litter decomposition.
b) ≥75% closed-canopy trees (woodland and forestry) under 20yo – modelled as woodland by area using site-specific Forestry Commission tree growth models (soil, aspect, altitude, rainfall, species or species mix) assuming increasing soil carbon content.
c) Dispersed or isolated trees including emergent from hedgerows – counted by landowner – are modelled as free-grown standards using site-specific Forestry Commission tree growth models (soil, aspect, altitude, rainfall, species mix).
d) Hedgerows are measured from aerial photographs in consultation with landowner. Hedges flailed in the sample year are assumed to maintain biomass equilibrium. Hedges not flailed in the sample year are modelled using growth increments for the equivalent area (length x width) of established alley-cropped short-rotation coppice. Boundary hedges (with

neighbouring farms) are assumed to be shared-ownership and 50% of their area excluded to avoid double-accounting un up-scaling results to national estimates.

e) Soil C sequestration is considered to be in equilibrium under arable and rotational (improved) grassland. For permanent grassland on mineral soils, a low-average default net ecosystem change value for UK grasslands of 0.24 t $ha^{-1}y^{-1}$ (range 0.04 – 0.44 t $ha^{-1}y^{-1}$, Janssens et al. (2005)) is used, pending further review of studies relevant to Welsh agricultural land. Buckingham et al. (2013) acknowledge the scarcity of relevant data for Welsh grassland but cites a similar rate of increase in SOC of 1 to 4 t ha^{-1} over 10 years as a consequence of manure application. For permanent grassland on organic soils default C sequestration rates for unmanaged peatlands are taken from Watson et al. (2000) (IPCC special report).

2. The Virtual Farm – scenario modelling using a completed farm model

2.1 GHG Mitigation modelling

A completed Bangor CF Tool is, in effect, a virtual model of an individual farm in a specified business year. The model is made very detailed to reflect that farm system and the management practices developed by the individual farmer, but it retains as calculation options all the alternative management practices specified by IPCC and encountered during previous Bangor farm modelling work. In consequence, it is possible to alter any component of the virtual farm and look for impacts of such changes. Potential mitigation methods affecting N_2O and CH_4 emissions would include manure storage (aerobic/anaerobic methods, digesters), fertiliser application rates, livestock types and stocking rates. Other possible mitigation options including dietary changes can be modelled by applying appropriate Tier 1 emissions factors from published literature or other model outputs (as % modifiers to soil emission rates, for example).

A range of other potential options for reducing GHG emissions can be applied to the virtual farm. These include modifying inputs such as energy use (including investment in self-generation and renewables) or livestock feeds. Feedstuff modification can be a simple reduction in feed purchase, or a change to feed formulation (e.g. reduced protein content, change of protein type) or feed provenance (switch from South American to EU-grown soya).

2.2 Productivity

The Bangor CF Tool also incorporates details of production (sales and exports by weight) for all farm produce in the sample year. These data are used to allocate GHG emissions to products for the purposes of product and supply-chain GHG footprinting beyond the farm gate. Allocation to products is compliant with PAS2050 and separates farm enterprises (direct and indirect emissions from cattle enterprise allocated to cattle products) as completely as possible. Notable exceptions include agrochemicals applied to pastures grazed by livestock from different enterprises (sheep and cattle), and energy inputs (electricity and diesel) which are allocated economically by enterprise sales revenues. 75-90% of total emissions can generally be allocated directly to the correct enterprises. A collateral benefit of these data is to investigate the potential impacts of mitigation or agri-environment scheme practices on production, with obvious benefits for predicting impacts of such schemes on national food security.

The Bangor Carbon Footprinting Tool outputs include: soil direct N_2O, indirect N_2O associated with nitrate leaching and N deposition, enteric CH_4, manure CH_4, CO_2 associated with electricity and energy use, embedded greenhouse gas emissions associated with feed and fertiliser production, agricultural productivity.

3. Applying Glastir options as modelled scenarios in complete farm models

To explore baseline greenhouse gas emissions from Welsh farms, we selected a subset of farms from a database of completed Welsh farm models produced in previous carbon footprinting studies at Bangor University. Farms were selected to represent a number of farming typologies representative of those found in Wales (in terms of size, altitude, stocking rates *etc*). Some of these farms had been in previous Welsh agri-environment schemes. Appendix 5.1 summarises the characteristics of these farms.

3.1 Glastir measures and assumptions

The Glastir measures which were assessed were the same as those used agreed by the steering group to be used in the ADAS modelling, *i.e.* Retain winter stubbles (AWE Option No. 28), Woodland margin extension (AWE Option No. 24), Grazing Management of Open Country (AWE Option No. 41A), Grazed Permanent Pasture – No Inputs (AWE Option No. 15), Create New Streamside Corridor – Both Sides / Tree Planting (AWE Option 9B). The assumptions used in developing the model runs were the same as those adopted for the ADAS model runs (see Year 1 Report - section 2.2). Change in soil and vegetation carbon stocks were not implemented in this application. A brief description of each measure is summarised below:

3.1.1 Grazed Permanent Pasture – No Inputs ("Zero Inputs") requires that no manufactured or organic fertiliser nitrogen is applied to permanent grazed grassland. Grassland is maintained using grazing stock to remove the entire year's grass growth (with no supplementary feeding of livestock). This requires a reduction in nitrogen fertiliser application to permanent grass, and a reduction in cattle and sheep stocking rate in proportion to reduction in effective forage production. Thus, CH_4 and N_2O emissions would be expected to be reduced accordingly.

The modelling assumed a reduction of N inputs to zero for selected areas (marginal land parcels) adding up to 1/3 of grassland or 18ha of improved /semi-improved grassland, according to Welsh Government farm entry statistics. N inputs were adjusted relative to the proportion of the farm impacted, and stock numbers (% across all year) reduced relative to the proportion of farm impacted. The assumption that fertiliser reductions occurred on only one-third of the permanent grass area is different to that used by the ADAS model, and is a little closer to reality. These stock changes were based on previous data on farms with/without fertiliser use, e.g. for beef this modification would be from a stocking rate of 1.4 LU on fertilised grass to 1.1 LU on non-fertilised grass. This impacts on direct, indirect and manure emissions. Feed, feed delivery, bedding, bedding delivery, pharmaceuticals, plastics *etc.* were also adjusted according to reductions in stock numbers.

3.1.2 Grazing Management of Open Country ("Open Country") aims at reducing stock numbers on farms stocked to their forage carrying capacity (based on forage production) to levels conducive with maintenance and restoration of habitat quality, and would reduce livestock numbers (and hence reduce CH_4 emissions from ruminant and manure sources, as well as N_2O associated with N in excreta and less fertiliser N production and use).

Specific modelling reduced stock levels to 'sustainable' levels defined by Welsh Government. This meant reducing N use of zero for improved grassland and adjusting stocking rates accordingly (using approach outlined above). This effects direct, indirect and manure emissions – with reduced requirements for feed, bedding, pharmaceuticals, plastics *etc*.

3.1.3 Woodland extension ("Woodland Margin") is aimed at existing grassland and arable land, with often the existing fence between agricultural land and woodland being replaced 6m into the field. This results in reduced nutrient (N and P) input to the field (and should result in reduced soil N_2O emissions, and greenhouse gas emissions associated with feed and fertiliser manufacturing), and an assumed proportional reduction in the number of stock that can be carried (reduced enteric and manure CH_4 emissions). In terms of sources of greenhouse gas emissions, less fertiliser nitrogen would be required and fewer stock carried.

This measure requires farms with woodland bordering grassland or arable land. This was not the case for many of the farms selected for this modelling assessment. For those that did, affected areas were calculated, and reductions in stock numbers and associated fertiliser, feed, bedding, pharmaceuticals, plastics applied.

3.1.4 Create New Streamside Corridor ("Riparian Margin") requires the fencing of an average area of 7 square metres per 1 metre length of watercourse (shared between both sides of the water course, hence an average buffer strip width of 3.5 m). The area must be fenced and native trees planted. The primary aim of this measure is to intercept particulates and enhance infiltration of pollutants in surface runoff. But the reduction in the agricultural land area will results in reduced cattle and sheep stocking rates (in proportion to reduction in effective forage production), and a reduction in the quantity of manufactured fertiliser nitrogen applied. Hence CH_4 and N_2O emissions would be expected to be reduced accordingly. There would also be prevention of direct excretion by animals using the watercourse for drinking water or cooling, and a reduction in bank-side erosion. This measure requires farms with streams bordering grassland or arable land. This was not the case for many of the farms selected for this modelling assessment. For those that did, affected areas were calculated, and reductions in stock numbers and associated fertiliser, feed, bedding, pharmaceuticals, plastics *etc.* calculated.

3.1.5 Retention of winter stubbles is primarily aimed at reducing the mobilisation of particulate pollutants due to protection of soil from raindrop impact, and some reduction in nitrate leaching associated with reduced mineralisation from later soil disturbance (ploughing) and uptake of N by weed species/volunteer grasses. However, after consideration of the modification in land, livestock and input management changes involved with this measure, it was clear that there was insufficient management change which the Bangor Carbon Footprinting Tool could model.

3.2 Baseline characteristics of the selected farm models

Baseline greenhouse gas emissions and carbon sequestration estimates for the example farms are summarised in Appendix 5.2. The warming potential of the different gases involved are standardised against the warming potential of carbon dioxide over 100 years in the atmosphere; they are expressed in kg CO_2 equivalents or CO_2e.

In the common pattern of ruminant livestock enterprises the main source of emissions is methane, which is 40 to 51% of emissions and primarily from enteric fermentation. The dairy and mixed farms (with dairy cattle) are at the higher end of the range, reflecting the high ruminant emissions associated with dairy production (**Table 5.2.1**).

Standardising emissions by land area (**Table 5.2.2**) allows a more direct comparison between farm types. Beef and sheep farms tend to be extensive rather than intensive and this is reflected in proportionally lower 13-18% embodied GHG emissions from inputs (feed, fertiliser, bedding etc); the dairy and mixed farms use more land treatments and imported feeds and their embodied inputs are higher at 24-30% of GHG emissions. Most farms buy-in small numbers of replacement animals per year; the high emissions in the beef group are due to Farm 5 which is a *beef finisher*, without adult cattle and buying-in all livestock rather than breeding and rearing young-stock.

Nitrous oxide emissions are modelled from stored manure, emissions from excreta and emissions from soil in response to N applications (fertiliser, manure and excreta). For most farms N_2O emissions represent about 20% of total GHG emissions.

Carbon sequestration estimates were made for woodland and scattered trees, hedgerows and soils; on some farms there is an additional component for land under changed management (land-use change) where this change affects net C storage, such as conversion of grassland to woodland or establishing permanent grassland on arable land (**Table 5.2.3**). The most important component of C-sequestration is the soil under permanent grassland: although sequestration rates per ha are low (the values used in this model are conservative) they are by far the largest sequestration resource on the farm because livestock farms have a very high proportion of their land under permanent pasture. The impact of arable management on soil C-sequestration can be seen on the dairy and mixed farms - where more arable is grown (cut forages) and short-term leys are used, and regular tillage negates soil C sequestration. On dairy farms, soil under grassland still represents the majority of C storage but is only 62% of the total (**Table 5.2.4**).

Total GHG equivalent sequestered on the more intensive dairy and mixed farms represents about 10% of emissions: on the beef farms it is higher at 18% largely because these farms have more scattered trees. Sheep producers are the most extensive (low emissions per ha) and maintain hedgerows on all field boundaries, and their C sequestration averages 98%. This average is strongly leveraged by farm 1, where sequestration represents 2 ½ times GHG emissions; the average for the other sheep producers is just under 50% of emissions.

3.3 Results of modelling Glastir measures with the Bangor Carbon Footprinting Tool

3.3.1 Grazed Permanent Pasture – No Inputs

Reducing nitrogen inputs to grazed permanent grassland reduces the carrying capacity of the grassland, and therefore animal numbers carried by the farm. This option could be applied to 15 of the 16 farms; sheep farm 4 used no inputs to permanent grassland and livestock was already at or below the prescribed carrying capacity so no stock reductions could be applied. Beef farm 2 was registered Organic and had no N inputs to reduce; but stock numbers were reduced to bring them down to prescribed carrying capacity for the land areas affected.

Table 3.3.1. *Changes in N use and livestock numbers* – On most of the farms N use was reduced by 8-10%; the overall average was 12%. Sheep numbers reduced by 5% and cattle by 10%. Reducing livestock numbers has a consequential effect on modelled productivity, with lamb sales down by 5%, beef by 8% and milk by 10%.

Table 3.3.1 and 3.3.2. *Changes in GHG emissions* – Modelling links changes in animal numbers to farm inputs such as feed purchases as well as 'downstream' emissions from soils and the livestock itself. Overall, GHG emissions for the 16 farms reduced by an average of 7%, or 107 metric tonnes of CO_2 equivalent per annum. The changes were distributed across farm inputs such as feed and fertiliser purchases (-1%), embodied GHG in imported livestock (-7%), N_2O emissions from manure, excreta and soils (-1% and -2%), methane emissions (-3%) and CO_2 from lime application (-8%). It is noteworthy that reducing inputs and bought-in stock will impact on the markets and producers of youngstock, extending the influence of the scheme option beyond the boundaries of the participating farm.

Table 3.3.3 and 3.3.4. *Changes in C sequestration* – this scheme option affected land use primarily through the effects of land-use change, which in this case increases soil C sequestration under grassland by removing and reducing nitrogen inputs. Applied inorganic nitrogen stimulates carbon loss to atmosphere by increasing soil bacterial activity and reducing plant diversity. Nitrogen in manure and excreta has a similar effect but its impact is reduced compared with synthetic N because manures also contain organic carbon sources. Land-use change C sequestration on the farms was very small in the baseline assessments, and increased by between 16 and 31 tonnes CO_2e per year. The net impact on carbon sequestration was an increase of 6% overall; with the largest impacts on the more extensive beef and sheep farms (4.5% and 17% respectively) and a much smaller impact on the dairy and mixed farms (1.4% and 2.5%) because of their lower proportion of permanent grassland.

Table 3.3.5. *Net impacts on farm GHG balance* – this scheme option has a slightly greater impact on GHG emissions than on C-sequestration. Overall farm C-sequestration increased from 35% of farm emissions to 43% of farm emissions (21% to 25% without the leveraging effect of sheep farm 1).

3.3.2 Grazing Management of Open Country

The Open Country management option could be applied to 10 of the 15 farms (beef farms 1,3,4 and 5; dairy farms 1 and 3; mixed farm 3 and sheep farms 2,3 and 4). Applying the option reduced sheep stocking rates but not cattle stocking rates, as the land entering this option is generally grazed by sheep rather than cattle (and certainly not dairy cattle).

Table 5.4.1. *Changes in livestock numbers* – Sheep numbers reduced by 13% overall; with smaller reductions where sheep were the secondary enterprise (beef farms 7%, dairy farms 14%). The impact of the option was greatest on sheep-only farms where stock reductions averaged 23%. Reducing livestock numbers has a consequential effect on modelled productivity, with lamb sales down by an average of 5% (22% on dairy farms – only one of which produces lamb – and 19% on sheep farms).

Table 5.4.1 and 5.4.2. *Changes in GHG emissions* – the modelling links changes in animal numbers to farm inputs such as feed purchases as well as 'downstream' emissions from soils and the livestock itself. Overall, GHG emissions for the 10 farms on which this option was applied reduced by an average of 5%, or 24 metric tonnes of CO_2 equivalent per annum. The changes were distributed across farm inputs such as feed and fertiliser purchases (-1%), embodied GHG in imported livestock (-7%), N_2O emissions from manure, excreta and soils (-2%) and methane emissions (-3%). Similarly to the Zero N option, these reductions to inputs and bought-in stock will impact on the markets and producers of youngstock, extending the influence of the scheme option beyond the boundaries of the participating farm.

Changes in C sequestration – this scheme option result in no modellable effect on C sequestration, since no land management change was applied. No studies could be found to support any assumptions about changes in sequestration rates in upland soils caused by small changes in stock densities.

Table 5.4.3. *Net impacts on farm GHG balance* – overall, this option reduced GHG emissions but had no modellable effect on C sequestration. On the farms where this option applied, net impact was an increase in farm C-sequestration from 26% to 28% of farm emissions. On the sheep farms where this option had the most effect, C-sequestration increased from 48% to 55% of farm GHG emissions.

3.3.3 Woodland margin extension

Extending the woodland margin increases woodland area at the expense of grassland – which constitutes a land-use change as well as reducing farmed land area and therefore stock carrying capacity and inputs associated with livestock and land management. This option could be applied to only four of the 15 farms (beef farms 1 and 2, dairy farm 3 and sheep farm 4).

Table 5.5.1. *Changes in N use and livestock numbers* – The land area converted from grassland to woodland was very small. Modelled nitrogen reductions averaged 1.5% and livestock were reduced by only about 1%. Reducing livestock numbers has a consequential effect on modelled productivity, with meat sales down by 0.5% and milk by 3.8%.

Table 5.5.1. *Changes in GHG emissions* – the modelling links changes in animal numbers to farm inputs such as feed purchases as well as 'downstream' emissions from soils and the livestock itself. Overall, GHG emissions for the five farms reduced by an average of 1.5%, or 23 metric tonnes of CO_2 equivalent per annum. The changes were distributed across farm inputs such as feed and fertiliser purchases (-0.02%), N_2O emissions from manure, excreta and soils (-0.1%), methane emissions (-0.3%) and CO_2 from lime application (-1.6%).

Table 5.5.2. *Changes in C sequestration* – this scheme option affected C sequestration through the effects of land-use change, increased woodland area and decreased soil area under grassland. Land-

use change C sequestration on the farms was very small in the baseline assessments, and increased by 0.06%. The net impact on carbon sequestration was an increase of 0.03% overall; with the largest impacts on farms with the most woodland margin (beef farm 2 sequestration increased by 0.08%). The decrease in sequestration under grassland (-0.07%) was more than offset by the increase in woodland sequestration (+3%). The modelled conversion of grassland to woodland has a net positive impact on C storage although the farm impacts are small because woodland boundary length (ie applicable land area for this option) on most farms is small.

Table 5.5.3. *Net impacts on farm GHG balance* – this scheme option has a slightly greater impact on GHG emissions than on C-sequestration. Overall farm C-sequestration across the participating farms increased from 26% to 27% of farm emissions.

3.3.4 Create New Streamside Corridor – Both Sides / Tree Planting

Planting woodland on the riparian margin (Streamside Corridor) increases woodland area at the expense of grassland – which constitutes a land-use change as well as reducing farmed land area and therefore stock carrying capacity and inputs associated with livestock and land management. This option could be applied to only five of the 15 farms (beef farm 2, dairy farm 3, mixed farms 2 and 3 and sheep farm 2).

Table 5.6.1. *Changes in N use and livestock numbers* – The land area converted from grassland to woodland was very small. Nitrogen reductions modelled were less than 0.5% and livestock were reduced by only 0.02%. Reducing livestock numbers has a consequential effect on modelled productivity, with meat sales down by 0.02% and milk by 0.05%.

Table 5.6.2. *Changes in GHG emissions* – the modelling links changes in animal numbers to farm inputs such as feed purchases as well as 'downstream' emissions from soils and the livestock itself. Overall, GHG emissions for the five farms reduced by an average of 0.11%, or 1.4 metric tonnes of CO_2 equivalent per annum. The changes were distributed across farm inputs such as feed and fertiliser purchases (-0.03%), N_2O emissions from manure, excreta and soils (-0.03%), methane emissions (-0.04%) and CO_2 from lime application (-0.4%).

Table 5.6.3 and 5.6.4. *Changes in C sequestration* – this scheme option affected C sequestration through the effects of land-use change, increased woodland area and decreased soil area under grassland. Land-use change C sequestration on the farms was very small in the baseline assessments, and increased by 6% or 3 tonnes CO_2e per year. The net impact on carbon sequestration was an increase of 0.5% overall; with the largest impacts on farms with the most river margin (sheep farm 2 sequestration increased by 1.6%). The decrease in sequestration under grassland (-0.5%) was more than offset by the increase in woodland sequestration (+2.3%). The modelled conversion of grassland to woodland has a net positive impact on C storage although the farm impacts are small because riparian boundary length (ie applicable land area for this option) on most farms is small.

Table 5.6.5. *Net impacts on farm GHG balance* – this scheme option has a slightly greater impact on C-sequestration than on GHG emissions. Overall farm C-sequestration increased from 22% to 23% of farm emissions.

3.4 Discussion

On this set of virtual farms, the Glastir measures applied had the intended effect of reducing modelled GHG emissions and (in most cases) increasing modelled C-sequestration in biomass and soils. The net impact of these changes was generally relatively small, either because the land areas on which options were applied represented a small proportion of farm area, or the management changes applied were subtle. The most effective option was “no inputs to grazed permanent pasture”, where farm GHG emissions reduced by an average of 7% and C sequestration increased by 6%. Over time, the annual impact of this C sequestration increase will fall, as the soil and grassland vegetation adjust to the changed N regime. IPCC guidelines and Jones and Emmett (2009) recommend that land-use change is modelled as an annually declining impact over a period of several years.

The effectiveness of the different options in reducing GHG and increasing C sequestration varied between farm types. This is partly a function of farm types being associated with different bio-geographical environments – sheep tend to be produced on farms at higher altitude with greater access to open country upland grazing; dairy farms are generally in lowland areas with a very high proportion of flatter land under intensive improved grassland or arable / cut forage management. This effect was most obvious in the “Grazing management of Open Country” option, where farms of all four broad types could take advantage of the option but its impacts varied widely. The overall average of 5% GHG reduction was not representative of impacts on different farm types – with a 14% reduction on sheep farms, 2% reduction on dairy farms (where sheep are primarily used as a tool for grazing quality management) and 1% reduction on farms where the main enterprise is beef cattle.

GHG reductions were mediated primarily through reductions in livestock, with small additional reductions associated with lower requirements for farm inputs associated with stock management. These reductions to inputs extend the impact of the scheme option beyond the boundaries of the participating farm, and into the upstream agricultural supply chain. Impacts on the wider supply chain might be positive or negative, and are difficult to predict with confidence. In the context of the Welsh national GHG budget and national food security, such changes are likely to decrease imports of fertilisers and protein feeds (primarily soya), and reduce demand of replacement livestock (extending the option impact to non-participating livestock producers). However, reduced supply of livestock products may be compensated by increasing food imports if national demand remains constant. A further complication is farmer behaviour: informal observations suggest that under previous agri-environment schemes apparent grazing-pressure livestock reductions have been produced by increasing stock movements (e.g. tack grazing outside the farm boundary, region or even English farms).

Reductions in livestock numbers may or may not lead to reductions in farm productivity and hence the economic and supply performance of the farm. The precise impacts of livestock reductions are difficult to predict, since reducing grazing pressure may induce a range of changes from vegetation change (‘scrubbing up’ requiring mechanical management and hence increasing fuel use etc.) to increased forage availability and therefore improved livestock quality, fertility and output per head (more finished lambs per ewe).

The conversion of grassland to woodland results in a net increase in carbon sequestration but the effectiveness of the “woodland margin extension” and “streamside corridor” options is limited by the small number of farms with applicable land. Although an effort was made to ensure that some of the farms selected would be able to apply this option, few farms have woodland or river margins within the farm boundary. If this option were also applied to farms with adjacent rivers or woodland (even if held by a different landowner) its applicability and impact might be greatly increased.

3.5 Conclusions

- On this set of virtual farms, the Glastir measures modelled had the intended effect of reducing GHG emissions and (in most cases) increasing C-sequestration in biomass and soils.
- The effectiveness of the different options in reducing GHG and increasing C sequestration varied between farm types
- GHG reductions were mediated primarily through reductions in livestock, with small additional reductions associated with lower requirements for farm inputs associated with stock management. These reductions to inputs extend the impact of the scheme option beyond the boundaries of the participating farm, and into the upstream agricultural supply chain.
- Reductions in livestock numbers may or may not lead to reductions in farm productivity and hence the economic and supply performance of the farm, although this is difficult to predict with confidence.
- The conversion of grassland to woodland results in a net increase in carbon sequestration but the effectiveness of the “woodland margin extension” and “streamside corridor” options is limited by the small number of farms with applicable land.

3.6 Reference list

Buckingham, S., Cloy, J., Topp, K. Rees, R. and Webb, J. 2013. Capturing cropland and grassland management impacts on soil carbon in the UK Land Use, Land Use Change and Forestry (LULUCF) inventory Literature review for DEFRA Project SP1113 14 October 2013.

Edwards, P.N and Christie, J.M. 1981. Yield models for forest management. Forestry Commission Booklet. no 48. (1981).

Edwards-Jones, G., Plassmann, K., Harris, I M. 2009. Carbon footprinting of lamb and beef production systems: insights from an empirical analysis of farms in Wales. UK. J. Agric. Sci. 147, 1-13.

Hirschfeld, J., Weiß, J., Preidl, M., Korbun, T. 2008. Klimawirkungen der Landwirtschaft in Deutschland. Schriftenreihe des Instituts für ökologische Wirtschaftsforschung (IÖW), Berlin.

IPCC 2002 Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use. Eggleston, S et al (ed) (2006)

IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman, J et al (ed) (2003)

Janssens, et al. 2005. The carbon budget of terrestrial ecosystems at a country scale - a European case study. Biogeosci 2:15-29

Janssens, et al. 2005. The carbon budget of terrestrial ecosystems at a country scale - a European case study. Biogeosci 2:15-29

Jones, D.L. and Emmett, B.A. 2009. Potential of soils and land use change to reduce greenhouse gas emissions from agriculture in Wales, draft report.

Lloyd, S.M. and Ries, R. 2008. Characterising, propagating and analysing uncertainty in Life Cycle Assessment: A survey of quantitative approaches. J. Industrial Ecol. 11, 161-179.

Smith, J., Gottschalk, P., Bellarby, J., Richards, M., Nayak, D., Coleman, K., Hillier, J.Wattenbach, M., Aitkenhead, M., Yeluripurti, J., Farmer, J. and Smith, P. 2010c. Model to estimate carbon in organic soils-sequestration and emissions (ECOSSE) user-manual. University of Aberdeen, UK, pp 1-76, 2010.

Taylor, R.C., Jones, A. and Edwards-Jones, G. 2010. Measuring holistic carbon footprints for lamb and beef farms in the Cambrian Mountains Initiative. CCW Policy Research Report No. 10/8 © CCGC/CCW 8.

Taylor, R.C., Omed, H. and Edwards-Jones, G. 2014. The greenhouse emissions footprint of free-range eggs. Poultry Science 93, 231-237.

Taylor, R.C., Skinner, C., Jones, A., and Edwards-Jones, G. 2012. Chapter in Anthony et al. 2012. Assessment of the Contribution of the Wales Agri-Environment Schemes to the Improvement of Water Quality and the Mitigation of Climate Change (Welsh Government report).

Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo D.J. and Dokken D.J. (Eds.) (2000). SpecialReport of the IPCC on Land Use, Land-Use Change, and Forestry. Cambridge University Press, UK. pp375

Weiske, A., Vabitsch, A., Olesen, J.E., Schelde, K., Michel, J., Friedrich, R., Kaltschmitt, M. 2006. Mitigation of greenhouse gas emissions in European conventional and organic dairy farming. Agric. Ecosyst. Environ. 112, 221-232.

Williams, A.G., Audsley, E., Sandars, D.L. 2006. DEFRA Research Project IS0205. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Bedford: Cranfield University and DEFRA.

Wyn Jones, R.G., Taylor, R.C., Omed, H.M., Edwards-Jones, G. 2011. Climatic mitigation, adaptation and dryland food production. Proceedings of the International Dryland Development Commission (IDDC) Tenth International Conference on Dry Land Development.

Table 3.2.1. Baseline **farm year total GHG** emissions data for the 15 test farms. Bold, italic numbers represent group average contribution to the overall GHG emissions total.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Total annual GHG emissions kg CO_2e	GHG annual emissions breakdown (kg CO_2e per farm year): Embodied GHG in farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from all sources	Methane from all sources	CO_2 from lime application	NET GHG from land use change
BEEF	1	460	168	350	**2,737,627**	218,127	1,132,134	444,889	716,393	91,675	114,848
	2	96	10	290	**418,983**	40,364	0	83,610	290,227	3,667	-36
	3	279	64	240	**2,361,458**	600,892	5,489	554,248	1,097,108	96,259	0
	4	140	0	220	**992,016**	165,915	19,999	288,703	512,329	5,066	0
	5	90	0	70	**1,964,612**	158,339	1,453,612	128,977	175,932	45,838	1,915
						13.6%	***23.5%***	***19.1%***	***40.5%***	***2.2%***	***0.9%***
DAIRY	1	70	42	266	**843,609**	272,511	0	177,247	385,392	3,575	0
	2	188	0	125	**2,188,313**	430,259	0	442,629	1,303,962	11,459	0
	3	182	1	100	**2,503,118**	947,137	52,069	515,905	962,866	25,000	0
	4	340	0	50	**2,564,250**	827,274	21,028	504,272	1,163,444	48,221	0
						30.5%	***0.7%***	***20.4%***	***47.3%***	***1.0%***	***0.0%***
MIXED	1	158	0	215	**1,272,893**	362,056	14,294	248,198	620,843	27,503	0
	2	214	0	175	**2,261,067**	562,089	0	454,500	1,198,640	45,838	-302
	3	108	0	60	**689,560**	126,096	34,259	174,951	353,505	742	-72
						23.9%	***2.0%***	***21.7%***	***51.0%***	***1.4%***	***0.0%***
SHEEP	1	117	40	310	**66,049**	15,272	0	23,098	22,973	0	0
	2	39	10	300	**72,486**	16,444	553	15,912	38,472	0	0
	3	143	68	100	**355,790**	52,818	11,664	114,377	169,082	0	0
	4	69	0	60	**130,080**	13,728	0	51,885	64,467	0	-108
						17.8%	***1.0%***	***32.2%***	***46.2%***	***0.0%***	***0.0%***

Table 3.2.2. Baseline GHG emissions **per-ha** for the 15 test farms. Bold, italic numbers represent group average contribution to the overall GHG emissions total.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	**Total annual GHG emissions kg CO_2e per ha**	**GHG annual emissions breakdown (kg CO_2e per farm year)** Embodied GHG in farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from all sources	Methane from all sources	CO_2 from lime application	NET GHG from land use change
BEEF	1	460	168	350	**5,951**	474	2,461	967	1,557	199	250
	2	96	10	290	**4,368**	421	-	872	3,026	38	- 0
	3	279	64	240	**8,464**	2,154	20	1,987	3,932	345	-
	4	140	0	220	**7,072**	1,183	143	2,058	3,652	36	-
	5	90	0	70	**21,829**	1,759	16,151	1,433	1,955	509	21
						13.6%	***23.5%***	***19.1%***	***40.5%***	***2.2%***	***0.9%***
DAIRY	1	70	42	266	**12,052**	3,893	-	2,532	5,506	51	-
	2	188	0	125	**11,635**	2,288	-	2,353	6,933	61	-
	3	182	1	100	**13,726**	5,194	286	2,829	5,280	137	-
	4	340	0	50	**7,534**	2,431	62	1,482	3,418	142	-
						30.5%	***0.7%***	***20.4%***	***47.3%***	***1.0%***	***0.0%***
MIXED	1	158	0	215	**8,076**	2,297	91	1,575	3,939	174	-
	2	214	0	175	**10,542**	2,621	-	2,119	5,588	214	- 1
	3	108	0	60	**6,385**	1,168	317	1,620	3,273	7	- 1
						23.9%	***2.0%***	***21.7%***	***51.0%***	***1.4%***	***0.0%***
SHEEP	1	117	40	310	**563**	130	-	197	196	-	-
	2	39	10	300	**1,859**	422	14	408	986	-	-
	3	143	68	100	**2,488**	369	82	800	1,182	-	-
	4	69	0	60	**1,885**	199	-	752	934	-	- 2
						17.8%	***1.0%***	***32.2%***	***46.2%***	***0.0%***	***0.0%***

Table 3.2.3. Baseline **farm-year total** carbon sequestration data for the 15 test farms. Bold, italic numbers represent group average contribution to the overall carbon sequestration total.

					GHG (carbon) sequestration breakdown (kg CO_2e per farm year)							
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	**Total annual GHG emissions**	NET GHG from land use change	**Total annual C sequestration**	Woodland	Other trees	Hedgerows	Soils under grassland	Soils under wetlands
BEEF	1	460	168	350	**2,737,627**	114848	**434,125**	7165	32352	25220	365615	513
	2	96	10	290	**418,983**	-36	**80,589**	7840	207	3767	66438	2337
	3	279	64	240	**2,361,458**	0	**204,105**	0	0	0	204105	0
	4	140	0	220	**992,016**	0	**412,123**	32312	224244	51464	100663	0
	5	90	0	70	**1,964,612**	1915	**122,491**	45457	41	9075	67866	52
						0.9%	***18.3%***	***11.3%***	***12.4%***	***6.1%***	***69.3%***	***0.6%***
DAIRY	1	70	42	266	**843,609**	0	**124,846**	2925	62	0	61764	0
	2	188	0	125	**2,188,313**	0	**192,830**	22634	135	17675	152179	208
	3	182	1	100	**2,503,118**	0	**399,434**	123827	25337	70777	139743	779
	4	340	0	50	**2,564,250**	0	**206,221**	17310	550	10263	177892	207
						0.0%	***11.9%***	***13.4%***	***1.7%***	***8.0%***	***62.4%***	***0.1%***
MIXED	1	158	0	215	**1,272,893**	0	**152,699**	12198	930	15043	123901	0
	2	214	0	175	**2,261,067**	-302	**136,381**	11515	70	6408	118241	0
	3	108	0	60	**689,560**	-72	**98,330**	21125	0	0	77205	0
						0.0%	***10.8%***	***12.6%***	***0.2%***	***4.8%***	***82.1%***	***0.0%***
SHEEP	1	117	40	310	**66,049**	0	**165,042**	10034	2198	54776	96783	935
	2	39	10	300	**72,486**	0	**40,834**	3082	873	0	34070	26
	3	143	68	100	**355,790**	0	**117,161**	5811	10992	0	96702	2809
	4	69	0	60	**130,080**	-108	**69,500**	7458	0	1682	60344	0
						0.0%	***98.1%***	***7.3%***	***3.2%***	***8.9%***	***77.9%***	***0.8%***

Table 3.2.4. Baseline carbon sequestration **per ha** data for the 15 test farms. Bold, italic numbers represent group average contribution to the overall carbon sequestration total.

						GHG (carbon) sequestration breakdown (kg CO_2e per ha)						
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	**Total annual GHG emissions per ha**	NET GHG from land use change	**Total annual C sequestration**	Woodland	Other trees	Hedgerows	Soils under grassland	Soils under wetlands
BEEF	1	460	168	350	**5,951**	250	**944**	16	70	55	795	1
	2	96	10	290	**4,368**	- 0	**840**	82	2	39	693	24
	3	279	64	240	**8,464**	-	**732**	-	-	-	732	-
	4	140	0	220	**7,072**	-	**2,902**	230	1,599	367	718	-
	5	90	0	70	**21,829**	21	**1,361**	505	0	101	754	1
						0.9%	***18.2%***	***11.3%***	***12.6%***	***6.1%***	***69.4%***	***0.6%***
DAIRY	1	70	42	266	**12,052**	-	**1,784**	42	1	-	882	-
	2	188	0	125	**11,635**	-	**1,025**	120	1	94	809	1
	3	182	1	100	**13,726**	-	**2,190**	679	139	388	766	4
	4	340	0	50	**7,534**	-	**606**	51	2	30	523	1
						0.0%	***11.9%***	***13.4%***	***1.7%***	***8.0%***	***62.4%***	***0.1%***
MIXED	1	158	0	215	**8,076**	-	**969**	77	6	95	786	-
	2	214	0	175	**10,542**	- 1	**636**	54	0	30	551	-
	3	108	0	60	**6,385**	- 1	**910**	196	-	-	715	-
						0.0%	***10.8%***	***12.6%***	***0.2%***	***4.8%***	***82.1%***	***0.0%***
SHEEP	1	117	40	310	**563**	-	**1,406**	86	19	467	825	8
	2	39	10	300	**1,859**	-	**1,047**	79	22	-	874	1
	3	143	68	100	**2,488**	-	**819**	41	77	-	676	20
	4	69	0	60	**1,885**	- 2	**1,007**	108	-	24	875	-
						0.0%	***98.1%***	***7.3%***	***3.2%***	***8.9%***	***77.9%***	***0.8%***

Table 3.3.1. Changes in N input, livestock, production and farm-year total GHG emissions data for all farms with "No Inputs" option modelling applied. Bold, italic numbers represent group average contributions to the overall GHG emissions total. All GHG emissions values in kg CO_2e.

						Livestock change		Production change				GHG emissions change by farm source (kg CO_2e per farm year)					
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Change in N use (kg)	Sheep (head)	Cattle (head)	Lamb kg	Beef kg	Milk litre	**Change in total annual GHG emissions (kg CO_2e)**	Embodied GHG in farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from manure and excreta	N_2O from all sources	Methane from all sources	CO_2 from lime application
BEEF	1	460	168	350	-3,866	-189	-14	-4,332	-11,016	0	**-277,841**	-57,515	-90,571	-15,735	-46,995	-52,141	-30,619
	2	96	10	290	0		-14	0	0	0	**-34,863**	-1,166	0	-4,394	-7,324	-26,080	-293
	3	279	64	240	-2,491	-57	-42	0	-11,232	0	**-188,612**	-43,239	-439	-17,331	-42,943	-94,290	-7,701
	4	140	0	220	-855	-37	-22	-1,060	-1,615	0	**0**	0	0	0	0	0	0
	5	90	0	70	-480	-21	-6	-1,260	-8,494	0	**-154,321**	-9,981	-116,289	-5,092	-9,873	-14,511	-3,667
												-22,380	***-41,460***	***-8,510***	***-21,427***	***-37,404***	
DAIRY	1	70	42	266	-408	-32	-12	-630	0	-67,313	**-68,704**	-17,878	0	-7,808	-15,039	-35,500	-286
	2	188	0	125	-1,064		-56	0	-1,242	-190,000	**-196,840**	-24,652	0	-24,387	-41,887	-129,384	-917
	3	182	1	100	-2,987		-39	0	0	-168,356	**-170,696**	-21,480	-4,165	-19,527	-46,764	-96,287	-2,000
	4	340	0	50	-3,671		-49	0	0	-144,461	**-237,023**	-66,751	-2,103	-14,964	-47,002	-116,344	-4,822
												-32,690	***-1,567***	***-16,671***	***-37,673***	***-94,379***	
MIXED	1	158	0	215	0	-43	-20	-1,714	0	-74,000	**-104,241**	-23,796	-1,144	-12,281	-20,263	-56,838	-2,200
	2	214	0	175	-1,480		-26	0	-5,733	-115,475	**-191,675**	-31,722	0	-22,954	-41,835	-114,451	-3,667
	3	108	0	60	-748	-20	-6	-866	-1,386	-37,450	**-55,292**	-6,830	-2,741	-6,709	-13,474	-32,188	-59
												-20,783	***-1,295***	***-13,981***	***-25,190***	***-67,826***	
SHEEP	1	117	40	310	-167	-11	0	-193	0	0	**-5,006**	-1,461	0	-653	-2,167	-1,378	0
	2	39	10	300	0	-9	0	-173	0	0	**-3,039**	-834	-33	-558	-796	-1,376	0
	3	143	68	100	-176	-70	0	-903	0	0	**-19,816**	-2,479	-700	-3,732	-6,823	-9,814	0
	4	69	0	60	0	0	0	0	0	0	**0**	0	0	0	0	0	0
												-1,194	***-183***	***-1,236***	***-2,446***	***-3,142***	***0***

Table 3.3.2. Percentage changes in N input, livestock, production and GHG emissions data for all farms with "No Inputs" option modelling applied. Bold, italic numbers represent group average contributions to the overall GHG emissions. All GHG emissions values presented as % change from baseline.

						Livestock % change		Production % change				% GHG emissions change by farm source					
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	N use	Sheep	Cattle	Lamb	Beef	Milk	**Change in total annual GHG emissions**	Embodied GHG in farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from manure and excreta	N_2O from all sources	Methane from all sources	CO_2 from lime application
BEEF	1	460	68	100	-33	-6	-9	-6	-9		**-10**	-2%	-8	-1%	-2%	-2%	-33
	2	96	0	60			-9		0		**-8**	0%		-1%	-2%	-6%	-8
	3	279	0	0	-8	-6	-9	0	-9		**-8**	-2%	-8	-1%	-2%	-4%	-8
	4	140	168	350	-8	-6	-9	-6	-9		**0**	0%	0	0%	0%	0%	0
	5	90	10	290	-8	-6	-9	-6	-9		**-8**	-1%	-8	0%	-1%	-1%	-8
											-6%	***-1%***	***-6***	***-1%***	***-1%***	***-3%***	***-11***
DAIRY	1	70	64	240	-8	-6	-10	-6		-10	**-8**	-2%		-1%	-2%	-4%	-8
	2	188	0	220	-8		-10		-9	-10	**-9**	-1%		-1%	-2%	-6%	-8
	3	182	0	70	-8		-10			-10	**-7**	-1%	-8	-1%	-2%	-4%	-8
	4	340	42	266	-10		-10			-10	**-9**	-3%	-10	-1%	-2%	-5%	-10
											-8%	***-2%***	***-9***	***-1%***	***-2%***	***-5%***	***-9***
MIXED	1	158	0	125		-6	-10	-6		-10	**-8**	-2%	-8	-1%	-2%	-4%	-8
	2	214	1	100	-8		-10		-9	-10	**-8**	-1%		-1%	-2%	-5%	-8
	3	108	0	50	-8	-6	-10	-6	-9	-10	**-8**	-1%	-8	-1%	-2%	-5%	-8
											-8%	***-1%***	***-8***	***-1%***	***-2%***	***-5%***	***-8***
SHEEP	1	117	0	215	-33	-6		-6			**-8**	-2%		-1%	-3%	-2%	
	2	39	0	175		-5		-5			**-4**	-1%	-6	-1%	-1%	-2%	
	3	143	0	60	-6	-6		-6			**-6**	-1%	-6	-1%	-2%	-3%	
	4	69	40	310		0		0			**0**	0%		0%	0%	0%	
											-4%	***-1%***	***-6***	***-1%***	***-2%***	***-2%***	

Table 3.3.3. Changes in farm-year total carbon sequestration data for all farms with "No Inputs" option modelling applied. Bold, italic numbers represent group average contributions to the overall sequestration total. All carbon sequestration values in kg CO_2e.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Total annual GHG emissions kg CO_2e	Total annual GHG emissions per ha	Change in annual C sequestration (kgCO_2e) Total annual C sequestration	Total annual C sequestration kgCO_2e per ha	CO_2 in LAND-USE CHANGE
BEEF	1	460	168	350	**-277,841**	-604	60,667	132	60,667
	2	96	10	290	**-34,863**	-363	21,718	226	21,718
	3	279	64	240	**-188,612**	-676	53,667	192	53,667
	4	140	0	220	**0**	0	-	-	0
	5	90	0	70	**-154,321**	-1,715	18,289	203	18,289
							30,868	***151***	***30,868***
DAIRY	1	70	42	266	**-68,704**	-981	16,240	232	16,240
	2	188	0	125	**-196,840**	-1,047	29,178	155	29,178
	3	182	1	100	**-170,696**	-936	37,609	206	37,609
	4	340	0	50	**-237,023**	-696	18,885	55	18,885
							25,478	***162***	***25,478***
MIXED	1	158	0	215	**-104,241**	-661	32,667	207	32,667
	2	214	0	175	**-191,675**	-894	31,090	145	31,090
	3	108	0	60	**-55,292**	-512	20,300	188	20,300
							28,019	***180***	***28,019***
SHEEP	1	117	40	310	**-5,006**	-43	24,551	209	24,551
	2	39	10	300	**-3,039**	-78	12,600	323	12,600
	3	143	68	100	**-19,816**	-139	29,367	205	29,367
	4	69	0	60	**0**	0	-	-	0
							16,630	***184***	***16,630***

Table 3.3.4. Changes in carbon sequestration data for all farms with "No Inputs" option modelling applied. Bold, italic numbers represent group average contributions to the overall sequestration total. All carbon sequestration values presented as % change from baseline.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Total annual GHG emissions kg CO_2e	% Change in annual C sequestration: Total annual C sequestration	Total annual C sequestration $kgCO_2e$ per ha	CO_2 in LAND-USE CHANGE
BEEF	1	460	68	100	**-10**	14%	14%	1,861
	2	96	0	60	**-8**	5%	5%	
	3	279	0	0	**-8**	2%	2%	
	4	140	168	350	**0**	0%	0%	0
	5	90	10	290	**-8**	1%	1%	
					-6.9%	***4.5%***	***4.5%***	***930%***
DAIRY	1	70	64	240	**-8**	4%		27
	2	188	0	220	**-9**	0%		
	3	182	0	70	**-7**	1%	1%	97
	4	340	42	266	**-9**	1%	1%	
					-8.3%	***1.4%***	***0.9%***	***62%***
MIXED	1	158	0	125	**-8**	3%	3%	5,210
	2	214	1	100	**-8**	1%	1%	21,164
	3	108	0	50	**-8**	4%	0	
					-8.2%	***2.5%***	***1.9%***	***13187%***
SHEEP	1	117	0	215	**-8**	0%		7,808
	2	39	0	175	**-4**	45%	45%	453
	3	143	0	60	**-6**	9%	9%	3,468
	4	69	40	310	**0**	16%	16%	0
					-4.3%	***17%***	***23%***	***2,932***

Table 3.3.5. Overall changes to GHG emissions, C sequestration and farm offset (kg CO_2e and % offset) for all farms where "No inputs" option modelling was applied. Bold, italic numbers represent group averages.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Baseline Total annual GHG emissions kg CO_2e	Baseline Total annual C sequestration	Baseline Farm balance GHG emission		Zero N total annual GHG emissions kg CO_2e	Zero N total annual C sequestration	Zero N farm balance GHG emission	
BEEF	1	460	168	350	2,737,627	434,125	2,303,501	16%	2459786	494792	1,964,994	20%
	2	96	10	290	418,983	80,589	338,394	19%	384120	102307	281,813	27%
	3	279	64	240	2,361,458	204,105	2,157,353	9%	2172846	257772	1,915,074	12%
	4	140	0	220	992,016	412,123	579,893	42%	992016	412123	579,893	42%
	5	90	0	70	1,964,612	122,491	1,842,120	6%	1810291	140780	1,669,511	8%
								18%				***22%***
DAIRY	1	70	42	266	843,609	124,846	718,763	15%	774905	141086	633,819	18%
	2	188	0	125	2,188,313	192,830	1,995,483	9%	1991473	222008	1,769,465	11%
	3	182	1	100	2,503,118	399,434	2,103,684	16%	2332422	437043	1,895,379	19%
	4	340	0	50	2,564,250	206,221	2,358,030	8%	2327227	225106	2,102,121	10%
								12%				***14%***
MIXED	1	158	0	215	1,272,893	152,699	1,120,193	12%	1168652	185366	983,286	16%
	2	214	0	175	2,261,067	136,381	2,124,685	6%	2069392	167471	1,901,920	8%
	3	108	0	60	689,560	98,330	591,230	14%	634268	118630	515,637	19%
								11%				***14%***
SHEEP	1	117	40	310	66,049	165,042	**-98,993**	**250%**	61043	189593	**-128,550**	**311%**
	2	39	10	300	72,486	40,834	31,652	56%	69446	53434	16,012	77%
	3	143	68	100	355,790	117,161	238,629	33%	335975	146528	189,447	44%
	4	69	0	60	130,080	69,500	60,580	53%	130080	69500	60,580	53%
								98%				***121%***

Table 3.4.1. Changes in N input, livestock, production and farm-year total GHG emissions data for all farms with Open Country option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions total. All GHG emissions change values in kg CO_2e.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Livestock change: Sheep (head)	Livestock change: Cattle (head)	Production change: Lamb kg	Production change: Beef kg	Production change: Milk litre	Change in total annual GHG emissions (kg CO_2e)	Change in GHG by farm source: CO_2e in agrochemicals	CO_2e in feeds	CO_2e in bedding	Embodied GHG in all farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from all sources	Methane from all sources
BEEF	1*	460	168	350	-366	0	-6822	0	0	**-78,635**	-7	0	0	-7	0	-30,832	-47,796
	2	96	10	290													
	3*	279	64	240	-53	0	0	0	0	**-15,527**	-1	-106	-38	-146	-231	-6,972	-8,179
	4*	140	0	220	-73	0	-1793	0	0	**0**	0	0	0	0	0	0	0
	5*	90	0	70	-3	0	-186	0	0	**-1,595**	-1	0	0	-1	-825	-365	-404
											-2	***-27***	***-10***	***-38***	***-264***	***-9,542***	***-14,095***
DAIRY	1*	70	42	266	-149	0	-2293	0	0	**-38,131**	-9	-3,726	-10	-3,745	0	-13,317	-21,069
	2	188	0	125													
	3*	182	1	100	0	0	0	0	0	**0**	0	0	0	0	0	0	0
	4	340	0	50													
											-4	***-1,863***	***-5***	***-1,872***	***0***	***-6,659***	***-10,534***
MIXED	1	158	0	215													
	2	214	0	175													
	3*	108	0	60	0	0	0	0	0	**0**	0	0	0	0	0	0	0
											0	***0***	***0***	***0***	***0***	***0***	***0***
SHEEP	1	117	40	310													
	2*	39	10	300	-61	0	985	0	0	**-10,942**	0	3,963	0	3,963	158	-5,518	-9,546
	3*	143	68	100	-358	0	-3733	0	0	**-87,024**	-1	-4,389	-124	-4,632	-2,893	-29,535	-49,963
	4*	69	0	60	-17	0	-193	0	0	-4579	0	-228	-49	-278	0	-1,851	-2,450
											0	***-218***	***-58***	***-316***	***-912***	***-12,301***	***-20,653***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with upland or upland margin grazing land including rough grassland and unenclosed grassland.

Table 3.4.2. Changes in N input, livestock, production and GHG emissions data for all farms with Open Country option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions. All GHG emissions values in presented as % change from baseline.

					Livestock % change	Production % change		Change in GHG by farm source						
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Sheep	Lamb kg	**Total annual GHG emissions**	CO_2e in agrochemicals	CO_2e in feeds	CO_2e in bedding	Embodied GHG in all farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from all sources	Methane from all sources
BEEF	1*	460	68	100	-12	-9	**-3**	-0.3	0.0		0.0%	0.0%	-1.1%	-1.7%
	2	96	0	60										
	3*	279	0	0	-6	0	**-1**	0.0	-0.1	-0.7	0.0%	-4.2%	-0.3%	-0.3%
	4*	140	168	350	-12	-10	**0**	0.0	0.0	0.0	0.0%	0.0%	0.0%	0.0%
	5*	90	10	290	-1	-1	**0**	-0.9	0.0	0.0	0.0%	-0.1%	0.0%	0.0%
					-7	***-5***	***-0.9%***	***0%***	***0%***	***0%***	***0.0%***	***-1.1%***	***-0.4%***	***-0.5%***
DAIRY	1*	70	64	240	-28	-22	**-5**	-4.1	-2.0	-1.1	-0.4%		-1.6%	-1.3%
	2	188	0	220										
	3*	182	0	70	0		**0**	0.0	0.0	0.0	0.0%	0.0%	0.0%	-0.8%
	4	340	42	266										
					-14	***-22***	***-2.3%***	***-2%***	***-1%***	***-1%***	***-0.2%***	***0.0%***	***-0.8%***	***-1.1%***
MIXED	1	158	0	125										
	2	214	1	100										
	3*	108	0	50	0	0	**0**	0.0	0.0	0.0	0.0%	0.0%	0.0%	0.0%
					0	***0***	***0%***	***0.0***	***0.0***	***0.0***	***0.0%***	***0.0%***	***0.0%***	***0.0%***
SHEEP	1	117	0	215										
	2*	39	0	175	-35	-29	**-15**	-28.5	-28.5		-5.5%	-28.5%	-7.6%	-13.2%
	3*	143	0	60	-31	-25	**-24**	-0.5	-24.8	-24.8	-1.3%	-24.8%	-8.3%	-14.0%
	4*	69	40	310	-4	-4	**-4**	-3.6	-3.6	-3.6	-0.2%		-1.4%	-1.9%
					-23	***-19***	***-14.4%***	***-11%***	***-19%***	***-14%***	***-2.3%***	***-26.7%***	***-5.8%***	***-9.7%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with upland or upland margin grazing land including rough grassland and unenclosed grassland.

Table 3.4.3. Overall changes to GHG emissions, C sequestration and farm offset (kg CO_2e and % offset) for all farms where Open Country option modelling was applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group averages.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Baseline Total annual GHG emissions kg CO_2e	Baseline Total annual C sequestration	Baseline Farm balance GHG emission		Open Country total annual GHG emissions kg CO_2e	Open Country total annual C sequestration	Open Country farm balance GHG emission	
BEEF	1*	460	168	350	2,737,627	434,125	2,303,501	16%	2,658,992	434,125	2,224,866	16%
	2	96	10	290								
	3*	279	64	240	2,361,458	204,105	2,157,353	9%	2,345,931	204,105	2,141,826	9%
	4*	140	0	220	992,016	412,123	579,893	42%	992,016	412,123	579,893	42%
	5*	90	0	70	1,964,612	122,491	1,842,120	6%	1,963,017	122,491	1,840,526	6%
								18%				***18%***
DAIRY	1*	70	42	266	843,609	124,846	718,763	15%	805,478	124,846	680,632	15%
	2	188	0	125								
	3*	182	1	100	2,503,118	399,434	2,103,684	16%	2,503,118	399,434	2,103,684	16%
	4	340	0	50								
								15%				***16%***
MIXED	1	158	0	215								
	2	214	0	175								
	3*	108	0	60	689,560	98,330	591,230	14%	689,560	98,330	591,230	14%
								14%				***14%***
SHEEP	1	117	40	310								
	2*	39	10	300	72,486	40,834	31,652	56%	61,543	40,834	20,709	66%
	3*	143	68	100	355,790	117,161	238,629	33%	268,767	117,161	151,606	44%
	4*	69	0	60	130,080	69,500	60,580	53%	125,501	69,500	56,001	55%
								48%				***55%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with upland or upland margin grazing land including rough grassland and unenclosed grassland.

Table 3.5.1. Changes in N input, livestock, production and farm-year total GHG emissions data for all farms with Woodland Margin option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions total. All GHG emissions change values in kg CO_2e.

						Livestock change		Production change				Change in GHG by farm source (kg CO_2e)				
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	N use	Sheep (head)	Cattle (head)	Lamb kg	Beef kg	Milk litre	**Change in total annual GHG emissions (kg CO_2e)**	Embodied GHG in farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from all sources	Methane from all sources	CO_2 from lime application
BEEF	1*	460	168	350	-74	-15	-1	-348	-918	0	**-15,689**	-1,112	-7,280	-2435	-4273	-590
	2*	96	10	290	0	0	-3	0	0	0	**-7,280**	-273	0	-1521	-5418	-69
	3	279	64	240												
	4	140	0	220												
	5	90	0	70												
												-692	***-3,640***	***-1,978***	***-4,845***	***-329***
DAIRY	1	70	42	266												
	2	188	0	125												
	3*	182	1	100	-1419	0	-15	0	0	-63969	**-89,537**	-30,611	-1,978	-19412	-36585	-950
	4	340	0	50												
												-30,611	***-1,978***	***-19,412***	***-36,585***	***-950***
MIXED	1	158	0	215												
	2	214	0	175												
	3	108	0	60												
												0	***0***	***0***	***0***	***0***
SHEEP	1	117	40	310												
	2	39	10	300												
	3	143	68	100												
	4*	69	0	60	0	-8	0	-97	0	0	-2192	-140	0	-883	-1168	0
												-140	***0***	***-883***	***-1,168***	***0***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with areas of owned woodland adjacent to pasture.

Table 3.5.2. Changes in C sequestration data for all farms with Woodland Margin option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions. All GHG emissions values presented as % change from baseline.

					% Change in GHG (carbon) sequestration breakdown				
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	**% Change in total annual C sequestration**	**% Change in annual C sequestration per ha**	Woodland	Land-use change	Soils under grassland
BEEF	1*	460	68	100	0.05%	0.05%	0.08%	0.19%	-0.03%
	2*	96	0	60	0.08%	0.43%	0.56%	0.00%	-0.14%
	3	279	0	0					
	4	140	168	350					
	5	90	10	290					
					0.07%	***0.24%***	***0.32%***	***0.09%***	***-0.08%***
DAIRY	1	70	64	240					
	2	188	0	220					
	3*	182	0	70	0.00%	0.48%	0.56%	0.05%	0.00%
	4	340	42	266					
					0.0%	***0.5%***	***0.6%***	***0.0%***	***0.0%***
MIXED	1	158	0	125					
	2	214	1	100					
	3	108	0	50					
					0%	***0%***	***0%***	***0%***	***0%***
SHEEP	1	117	0	215					
	2	39	0	175					
	3	143	0	60					
	4*	69	40	310	0.00%	1.00%	10.49%	0.01%	-0.13%
					0.00%	***1.00%***	***10.49%***	***0.01%***	***-0.13%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with areas of owned woodland adjacent to pasture.

Table 3.5.3. Overall changes to GHG emissions, C sequestration and farm offset (kg CO_2e and % offset) for all farms where Woodland Margin option modelling was applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group averages.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Baseline Total annual GHG emissions kg CO_2e	Baseline Total annual C sequestration	Baseline Farm balance GHG emission		Open Country total annual GHG emissions kg CO_2e	Open Country total annual C sequestration	Open Country farm balance GHG emission	
BEEF	1*	460	168	350	2,737,627	434,125	2,303,501	16%	2,658,992	434,125	2,224,866	16%
	2*	96	10	290	418,983	80,589	338,394	19%	418,983	80,589	338,394	19%
	3	279	64	240								
	4	140	0	220								
	5	90	0	70								
								18%				***18%***
DAIRY	1	70	42	266								
	2	188	0	125								
	3*	182	1	100	2,503,118	399,434	2,103,684	16%	2,503,118	399,434	2,103,684	16%
	4	340	0	50								
								16%				***16%***
MIXED	1	158	0	215								
	2	214	0	175								
	3	108	0	60								
SHEEP	1	117	40	310								
	2	39	10	300								
	3	143	68	100								
	4*	69	0	60	130,080	69,500	60,580	53%	125,501	69,500	56,001	55%
								53%				***55%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with areas of owned woodland adjacent to pasture.

Table 3.6.1. Changes in N input, livestock, production and farm-year total GHG emissions data for all farms with Riparian Margin option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions total. All GHG emissions change values in kg CO_2e.

					fertilisers change (kg)			Livestock change		Production change				Change in GHG by farm source (kg CO_2e)				
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	N use	P use	K use	Sheep (head)	Cattle (head)	Beef kg	Milk litre	**Change in total annual GHG emissions (kg CO_2e)**	**Change in total annual GHG emissions (kg CO_2e) per ha**	Embodied GHG in farm inputs (excluding livestock purchases)	Embodied GHG in livestock purchases	N_2O from all sources	Methane from all sources	CO2 from lime application
BEEF	1	460	168	350														
	2*	96	10	290	0	0	0	0.0	0	0	0	**-801**	**-8**	-84	0	-147	-523	-47
	3	279	64	240														
	4	140	0	220														
	5	90	0	70														
														-84	***0***	***-147***	***-523***	***-47***
DAIRY	1	70	42	266														
	2	188	0	125														
	3*	182	1	100	-232	0	-22	0.0	0	0	-1567	**-4,850**	**-27**	-2,134	-48	-1616	-896	-155
	4	340	0	50														
														-2,134	***-48***	***-1,616***	***-896***	***-155***
MIXED	1	158	0	215														
	2*	214	0	175	-29	-2	-22	0.0	0	-14	-273	**-945**	**-4**	-350	0	-248	-275	-72
	3*	108	0	60	-23	-7	-8	-0.1	0	-5	-136	**-465**	**-4**	-170	-11	-164	-118	-2
														-260	***-6***	***-206***	***-196***	***-37***
SHEEP	1	117	40	310														
	2*	39	10	300	0	0	0	-0.1	0	0	0	**-30**	**-1**	-7	0	-8	-14	0
	3	143	68	100														
	4	69	0	60														
														-7	***0***	***-8***	***-14***	***0***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with river margins within the farm boundary and bordering pasture.

Table 3.6.2. Changes in N input, livestock, production and GHG emissions data for all farms with Riparian Margin option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions total. All GHG emissions in % change from baseline.

					% change in fertiliser use			% Livestock change		% production change			**% change in GHG emissons**			
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	N use	P use	K use	Sheep	Cattle	Beef	Milk	**% Change in total annual GHG emissions**	Embodied GHG in farm inputs (excluding livestock purchases)	N_2O from all sources	Methane from all sources	CO_2 from lime application
BEEF	1	460	68	100												
	2*	96	0	60				0.0%	-0.2%	0.0%		**-0.19%**	-0.02%	-0.04%	-0.1%	-1.3%
	3	279	0	0												
	4	140	168	350												
	5	90	10	290												
													-0.02%	***-0.04%***	***-0.12%***	***-1.29%***
DAIRY	1	70	64	240												
	2	188	0	220												
	3*	182	0	70	-0.62		-0.62	0.00	-0.09		-0.09	**-0.19%**	-0.1%	-0.1%	0.0%	-0.6%
	4	340	42	266												
													-0.09%	***-0.06%***	***-0.04%***	***-0.62%***
MIXED	1	158	0	125												
	2*	214	1	100	-0.16	-0.16	-0.16	0.00	-0.02	-0.02	-0.02	**-0.04%**	-0.02%	-0.01%	-0.01%	-0.16%
	3*	108	0	50	-0.24	-0.24	-0.24	0.00	-0.04	-0.03	-0.04	**-0.07%**	-0.02%	-0.02%	-0.02%	-0.24%
													-0.02%	***-0.02%***	***-0.01%***	***-0.20%***
SHEEP	1	117	0	215												
	2*	39	0	175				-0.05	0.00			**-0.04%**	-0.01%	-0.01%	-0.02%	0.00%
	3	143	0	60												
	4	69	40	310												
													-0.01%	***-0.01%***	***-0.02%***	***0.00%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with river margins within the farm boundary and bordering pasture.

Table 3.6.3. Changes in N use, livestock, production and C sequestration data for all farms with Riparian Margin option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions. All GHG emissions values presented in kg CO_2e per farm year.

					Change in fertiliser (kg)			Livestock change		Production change				Change in GHG (carbon) sequestration breakdown (kg CO_2e)		
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	N use	P use	K use	Sheep (head)	Cattle (head)	Beef kg	Milk litre	**Change in total annual C sequestration (kg CO_2e)**	**Change in annual C sequestration per ha (kg CO_2e)**	Woodland	Land-use change	Soils under grassland
BEEF	1	460	168	350												
	2*	96	10	290	0	0	0	0.0	0	0	0	**2,023**	**21**	3035	53	-1065
	3	279	64	240												
	4	140	0	220												
	5	90	0	70												
												2,023	***21***	***3,035***	***53***	***-1,065***
DAIRY	1	70	42	266												
	2	188	0	125												
	3*	182	1	100	-232	0	-22	0.0	0	0	-1567	**6,161**	**34**	7004	44	-887
	4	340	0	50												
												6,161	***34***	***7,004***	***44***	***-887***
MIXED	1	158	0	215												
	2*	214	0	175	-29	-2	-22	0.0	0	-14	-273	**1,416**	**7**	1593	9	-186
	3*	108	0	60	-23	-7	-8	-0.1	0	-5	-136	**1,498**	**14**	1675	9	-186
												1,457	***10***	***1,634***	***9***	***-186***
SHEEP	1	117	40	310												
	2*	39	10	300	0	0	0	-0.1	0	0	0	**1,136**	**29**	1328	10	-202
	3	143	68	100												
	4	69	0	60												
												1,136	***29***	***1,328***	***10***	***-202***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with river margins within the farm boundary and bordering pasture.

Table 3.6.4. Changes in C sequestration data for all farms with Riparian Margin option modelling applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group average contributions to the overall GHG emissions. All GHG emissions values presented as % change from baseline.

					Fertiliser % change			Livestock % change				% Change in GHG (carbon) sequestration breakdown		
Primary producer type		area (ha)	peat (ha)	Altitude (masl)	N use	P use	K use	Sheep	Cattle	**Change in total annual C sequestration (%)**	**Change in annual C sequestration per ha (%)**	Woodland	Land-use change	Soils under grassland
BEEF	1	460	68	100										
	2*	96	0	60				0.0	-0.2	0.5%	0%	4%		-1%
	3	279	0	0										
	4	140	168	350										
	5	90	10	290										
										0.5%	***0.5%***	***3.8%***	***0.0%***	***-1.3%***
DAIRY	1	70	64	240										
	2	188	0	220										
	3*	182	0	70	-0.6		-0.6	0.0	-0.1	0.2%	0.2%	1.8%	11.3%	-0.2%
	4	340	42	266										
										0.2%	***0.2%***	***1.8%***	***11.3%***	***-0.2%***
MIXED	1	158	0	125										
	2*	214	1	100	-0.2	-0.2	-0.2	0.0	0.0	0.1%	0.1%	1.2%	6.3%	-0.1%
	3*	108	0	50	-0.2	-0.2	-0.2	0.0	0.0	0.2%	0.2%	1.7%		-0.2%
										0.1%	***0.1%***	***1.4%***	***0.1%***	***-0.2%***
SHEEP	1	117	0	215										
	2*	39	0	175				-0.1	0.0	1.6%	1.6%	3.3%	0.4%	-0.5%
	3	143	0	60										
	4	69	40	310										
										1.6%	***1.6%***	***3.3%***	***0.4%***	***-0.5%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with river margins within the farm boundary and bordering pasture.

Table 3.6.5. Overall changes to GHG emissions, C sequestration and farm offset (kg CO_2e and % offset) for all farms where Riparian Margin option modelling was applied. Farm numbers with asterisks represent farms where the option was applicable. Bold, italic numbers represent group averages.

Primary producer type		area (ha)	peat (ha)	Altitude (masl)	Baseline Total annual GHG emissions kg CO_2e	Baseline Total annual C sequestration	Baseline Farm balance GHG emission		Riparian Margin total annual GHG emissions kg CO_2e	Riparian Margin total annual C sequestration	Riparian Margin farm balance GHG emission	
BEEF	1	460	168	350								
	2*	96	10	290	418,983	80,589	338,394	19%	418,182	82,612	335,570	20%
	3	279	64	240								
	4	140	0	220								
	5	90	0	70								
								19%				***20%***
DAIRY	1	70	42	266								
	2	188	0	125								
	3*	182	1	100	2,503,118	399,434	2,103,684	16%	2,498,269	405,594	2,092,674	16%
	4	340	0	50								
								16%				***16%***
MIXED	1	158	0	215								
	2*	214	0	175	2,261,067	136,381	2,124,685	6%	2,260,122	137,798	2,122,324	6%
	3*	108	0	60	689,560	98,330	591,230	14%	689,094	99,828	589,266	14%
								10%				***10%***
SHEEP	1	117	40	310								
	2*	39	10	300	72,486	40,834	31,652	56%	72,455	41,970	30,485	58%
	3	143	68	100								
	4	69	0	60								
								56%				***58%***

*Modelling was applied to farms where the Glastir option was applicable – in this case, farms with river margins within the farm boundary and bordering pasture.

Appendix 6.2

Application of the ECOSSE- model to estimate greenhouse gas and soil organic carbon fluxes and assessing the impacts of climate change on the gas fluxes from Wales

WP9

Final Report

Mohamed Abdalla, Mark Richards, Mark Pogson and Pete Smith

University of Aberdeen

Institute of Biological & Environmental Sciences, 23 St Machar Drive, AB24 3UU, Aberdeen, UK

CONTENTS **Page**

Summary

The Welsh government is committed to reduce greenhouse gas (GHG) and soil organic carbon (SOC) fluxes from agricultural systems and combat the effects of future climate change. In this study, the ECOSSE model was spatially applied to estimate GHG and SOC fluxes for Wales using Welsh soil data 2005 (NSRI, 2005) and UKCP09 climate data as inputs to the model. A land cover map (LCM2007) was applied and four major ecosystems (arable, grass, forest and natural) were investigated. The aims of the simulations were: 1) to estimate the annual net GHG fluxes from Wales; 2) to investigate the efficiency of the Glastir measure of reducing N fertilizer, on the net GHG fluxes, and 3) to investigate the effects of future climate change on the net GHG fluxes and net primary productivity (NPP). Nitrogen fertilizer was applied in the form of inorganic fertilizer (ammonium nitrate) and at a rate equal to the annual crop N demand. To investigate the effectiveness of the Glastir measure of reducing N fertilizer, fluxes of GHG and SOC at two reduced fertilizer application rates (80 and 60% of crop N demand) were compared to baseline (100% crop N demand). Three climate scenarios: baseline (1961-1990) and two future climate scenarios (2015-2050) low and high were studied. Results reveal that ECOSSE can credibly simulate GHG and SOC fluxes for Wales. However, the model underestimated CH_4 fluxes from saturated areas due to lack of observed spatial data on water table depth. The predicted annual net GHG flux for Wales at baseline (1961-1990) is 0.20 t CO_2e /ha/y which is equivalent to an annual C flux from the whole country of 0.37 Mt CO_2e /y. Reducing N fertilizer by 20% and 40% is efficient, and could reduce the overall average annual N_2O fluxes by 13 and 22%, respectively, and thereby reduce the net GHG fluxes. If the current N fertilizer application rate continues, future climate change by the year 2050 would not significantly affect the net GHG fluxes or NPP from Welsh soils. The difference between the two climate scenarios is, however, small (±2%). Our results demonstrate a robust basis to allow a much wider range of Glastir measures to be explored using the ECOSSE model (e.g. create 2- 3 meter wildlife corridor to include tree and shrub planting; establish a wildlife cover crop on improved land, and conversion from arable to grassland) though the model may need some modifications to do this.

1. Introduction

The Welsh Government is committed to reduce greenhouse gas (GHG) and soil organic carbon (SOC) fluxes from agriculture, protect the environment and combat the effects of future climate change. To achieve these objectives, the Glastir programme, in which farmers are adopting a range of on-farm measures to protect soil C, reduce GHG emissions, improve water quality and enhance biodiversity, is applied. This report gives a summary of ECOSSE-model simulation work to examine baseline emissions, quantify the impact of the Glastir measure of reducing N on GHG fluxes, shows the input data used to run the simulations and the spatial application of the model for Wales. The main aims of this work were: 1) to estimate the national annual average of GHG (CH_4 and N_2O) and SOC fluxes; 2) to investigate the effects of the low N Glastir measure on GHG and SOC fluxes; and 3) to investigate the effects of climate change on GHG and SOC fluxes. The ECOSSE spatial simulation covered four main ecosystems across Wales: (1) arable land (2) grassland (3) forestry and (4) natural land (i.e. dry heaths, abandoned grass, peat bogs and all semi-natural areas that are not designated as grass).

2. Methodologies

2.1 ECOSSE model

In this study, we applied the latest version of the ECOSSE (Estimation of Carbon in Organic Soils-Sequestration and Emissions; v. 5.0.1) model to estimate GHG and soil SOC fluxes across Wales. The ECOSSE model uses a pool type approach, and all of the major processes of C and N turnover in the soil are included and described using well-established equations driven by readily available input variables (Smith et al., 2010). ECOSSE can be used to carry out site-specific simulations with detailed input data, or spatial simulations using the limited data typically available at larger scales. Data describing SOC, soil water, plant inputs, nutrient applications and timing of management operations are used to run the model.

The water module in ECOSSE is based on SUNDIAL (Bradbury et al., 1993, Smith et al., 1996), where water streams through the soil pores as ‘piston flow’. The soils profile is divided into 5cm layers. Precipitation fills the uppermost soil layer with water until it reaches field capacity. Any remaining precipitation then fills the next layer to field capacity. This process is repeated until no precipitation remains or the bottom of the profile is reached. Water remaining after filling all layers to field capacity is partitioned between drainage (water leaving the soil profile), and excess, which fills layers to saturation from the bottom of the profile upwards. The ECOSSE model uses the observed depth of the water table, the available water at saturation and weather data to calculate the restriction to drainage (i.e. the fraction of the remaining water that becomes excess), that is required to achieve the observed water table depth. Addition or loss of C and N from different vegetation types are estimated using the C and N fractions in different parts of the plant, and harvest index for crops.

Potential evapotranspiration is calculated using the Thornthwaite equation (Thornthwaite, 1948). Total SOC and inert organic C amounts are added as inputs. The ECOSSE model then estimates the amount of organic matter (OM) input from plant material if information on plant yield is not provided. This is carried out using the amount of SOC as an input. The total SOC estimated by a steady-state (10,000 year) run using default plant inputs is compared to the total measured SOC, and a revised estimate is made of the OM inputs so that simulated steady state SOC matches the measured values. Plant material is divided into resistant and decomposable material, based on a decomposable plant material (DPM): resistant plant material (RPM) ratio of 1.44 (as used in the RothC model (Coleman and Jenkinson, 1996)).

The ECOSSE model simulates the soil profile up to 3 metres deep where the soil is divided into 5cm layers to facilitate the accurate simulation of processes to depth. During the decomposition process, material is exchanged between the soil organic matter (SOM) pools according to first-order rate equations, characterised by a specific rate constant for each pool. The rate constant of each pool is modified dependent on the temperature, water content, plant cover and pH of the soil (with additional modifiers dependent upon soil bulk density and inorganic N concentration in the case of anaerobic decomposition). The decomposition process results in gaseous losses of CO_2 and CH_4, with CO_2 losses dominating under aerobic conditions and CH_4 losses under anaerobic conditions. ECOSSE also simulates the oxidation of atmospheric CH_4, which, under aerobic conditions, can lead to the soil being a net consumer of CH_4.

The nitrogen (N) content of the soil follows the decomposition of the SOM, with a stable C: N ratio defined for each SOM pool at a given pH, and N being either mineralised or immobilised to maintain that ratio. Nitrogen is released from decomposing SOM as ammonium (NH_4^+) or nitrified to nitrate (NO_3^-). C and N may be lost from the soil by the processes of leaching (NO_3^-), dissolved organic C, and dissolved organic N, denitrification to nitric oxide (NO) and nitrous oxide (N_2O), volatilisation or crop off-take. C and N may be returned to the soil by plant inputs, inorganic fertilisers, atmospheric deposition or organic amendments (e.g. manure, crop residues). More details about the ECOSSE approach is found in Smith et al. (2010).

2.2 Spatial simulations

Application of the ECOSSE model to spatially simulate GHG and SOC fluxes was carried out for the whole Wales on a 1 km^2 soil grid basis. Grid simulations represent the 5 dominant soil types in each grid cell to capture soil heterogeneity at the sub-grid cell level. Each grid cell value in the model output represents the area-weighted mean of the simulations carried out for each soil type in the grid cell. The Land Cover Map (LCM2007; Morton et al., 2011) was applied, and four main ecosystems were simulated (arable, grassland, forest and natural). Rotational grassland is included in “arable land” in ECOSSE, as the grass ley phase forms part of a crop rotation.

ECOSSE is initialised before running each simulation, based on the assumption that the SOC in the soil column is at stable equilibrium under the initial land use at the start of the simulation. The model simulates physical fragmentation of soil organic matter resulting from cultivation by moving a proportion of the C and N in the humus pool, (which has a slow decomposition rate), to the decomposable and resistant plant material pools (which have faster decomposition rates). Redistribution of SOM during cultivation is simulated by homogenising the vertical distribution of the SOM pools down to the cultivation depth. For all ecosystems, the changes in GHG and SOC fluxes are calculated for the top metre of the soil profile. Only the top metre is considered because this is the depth to which soil parameters are provided by the soil database.

Results of N_2O, CH_4, SOC and net GHG balance were all reported in terms of CO_2-equivalent values (CO_2e) using the IPCC 100-year global warming potentials (GWPs) (IPCC, 2001). Net GHG flux is therefore referred to as net GHG balance throughout this report. Recent IPCC report (2013) has provided updated GWPs from those given in the IPCC 2001 report. However, for consistency and ease of comparisons with national GHG inventory, we have used the IPCC 2001 GWP values, where N_2O has a GWP of 296 and CH_4 has a GWP of 23 greater than CO_2 over an 100 year period (as these are used in all National GHG Inventories). Net GHG balance represents the combined impact of changes in N_2O, CH_4 and CO_2 from SOC change (expressed as CO_2e) and calculated as the sum of N_2O and CH_4 fluxes, minus the change in SOC (as CO_2). A positive net GHG balance is harmful and a negative net GHG balance is beneficial, discounting all other factors.

2.2.1 Soil data

Welsh soil data (NSRI, 2005) were used to provide initial soil conditions in the model. The data set provides soil data to a depth of 1 metre at a resolution of 1 km for the dominant soil types in each grid cell. The soil properties used from this database to drive the ECOSSE model were: organic C content, bulk density, pH, and sand, silt and clay faction. However, the Welsh data do not include information on the water-holding capacities of soils, so these were estimated using British Soil Survey pedotransfer functions (Hutson and Cass, 1987), which performed well in evaluations (Donatelli et al, 1996; Givi et al, 2004). The soil data also provide the percentage of each grid cell area covered by each soil type. The percentage cover is applied to the ECOSSE results for each dominant soil type in each grid cell to produce area-weighted grid cell mean responses.

2.3.2 Climate data

As input data, the ECOSSE model requires precipitation and air temperature to drive the soil water model and to determine temperature-based rate modifiers of various soil processes. The meteorological data were taken from the Spatially Coherent Projections (Murphy et al, 2009). UKCP09 provides, for high and low emissions scenarios, average monthly temperature and precipitation for Wales on a 25 km UKCP09rotated pole grid for overlapping 30-year periods centred upon decades ranging from the 2020s to the 2080s; the data were reprojected to the British National Grid for compatibility with other data in ECOSSE.

To investigate the effects of climate change on GHG and SOC fluxes, two climate scenarios (high and low emission scenarios) for a 35-year period running from 2015 to 2050 were applied and compared to the baseline climate scenario (1961-1990). The UKCP09 low and high emission climate scenarios correspond to the B1 and A1F1 emission scenarios of the IPCC (2007). See Appendix 1.

2.3.3 Yield data

In order to estimate the monthly plant inputs to the soil, the ECOSSE model requires yield data for each land use type. Yield data for the different arable crops have been obtained from EUROSTAT, whilst biomass data for other ecosystems were estimated using the Miami model (Lieth, 1975). Miami is an empirical net primary production (NPP) model that estimates annual net primary production from mean annual temperature and precipitation. The Miami estimate of net primary production was calculated for each decade in each grid cell using the same UKCP09 meteorological data and Welsh soil data, and was used to modify the equilibrium soil carbon inputs via changes in NPP over time.

2.3.4 Fertilizer application

Nitrogen fertilizer was applied in the form of inorganic fertilizer (ammonium nitrate) and at a rate equal to the annual crop N demand. Ammonium nitrate is assumed for N fertilizer because it is the most widely used form of fertilizer in the UK. Across all crops and grass in Great Britain in 2012 ammonium nitrate represented 39.6% of total fertilizer product used, whereas urea was represented only 7.3% (see the link: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/192605/fertiliseruse-report2012-25apr13.pdf). Crop N demand is a function of plant yield and the C: N ratio of the plant. Full fertilisation level (100%) meets 100% of the annual crop N demand whilst, 80% and 60% fertilisation levels meet only 80% and 60% of the annual crop N demand, without affecting yield in the model. It is assumed that crop yield would not be affected and that N fertilizer reductions could be achieved through efficiency improvements (better application rate, timing and placement). If crop yields were affected, N reduction would not be a viable option. The arable and grass lands are assumed to be fertilised whilst the forest and natural lands are assumed to remain unfertilised. The annual full N fertilizer application rate (for the grass and arable lands) estimated by ECOSSE was later back-calculated using the N_2O flux values and an emission factor of 1% (IPCC, 2006).

3. Results

3.1 Estimated present GHG and SOC fluxes in Wales

Figures 1 and 2 show the predicted mean annual GHG and SOC fluxes under baseline climate (1961-1990) for Wales. Fluxes of GHG and SOC were variable, depending on the ecosystem investigated. These variations in GHG and SOC fluxes resulted in variations in the amount of net GHG balance (+ve net GHG balance is detrimental and -ve net GHG balance is beneficial) between the different ecosystems as shown in Table 1. For all ecosystems, N_2O fluxes were the highest and major contributor to the net GHG balance especially for the grass and arable ecosystems, where N fertilizer was applied. However, fluxes of N_2O from the forest and natural ecosystems were low and contributed less to net GHG balance compared with that from the grass and arable ecosystems (Table 1 and Appendix 2). The overall annual average of N_2O fluxes from Wales is 0.2 t CO_2e /ha/y. For all ecosystems, fluxes of CH_4 were very low and represent a small sink for atmospheric C. The overall annual average uptake of CH_4 is 0.014 t CO_2e /ha/y (Table 1 and Appendix 3) though this value was probably underestimated by the ECOSSE model due to the absence of measured water table input data. Likewise, the fluxes of SOC were a minor sink with an overall average C uptake of 0.013 t CO_2e /ha/y. The overall average net GHG balance combining all gas fluxes is 0.198 t CO_2e /ha/y. This is equivalent to an annual C loss to the atmosphere of 54 kg C /ha/y. The highest emitting ecosystems are grass and arable, with net GHG balance of 0.449 and 0.205 t CO_2e/ha/y, respectively. The net fluxes from the forest (0.053 t CO_2e /ha/y) and natural (0.086 t CO_2e /ha/y) ecosystems are relatively small compared with that from the grass and arable ecosystems. Considering the net GHG balance of 0.199 t CO_2e /ha/y and the Welsh land use area of 1857690 ha (NS, 2004) the calculated annual fluxes for the whole of Wales at baseline climate (1961-1990) is 0.37 Mt CO_2e /y. As mentioned earlier, ECOSSE estimated N fertilizer depending on the crop N demand. However, back calculating the annual amount of this ECOSSE estimated N fertilizer using our N_2O flux values resulted in an equivalent value of 137 kg N /ha/y for the grass and arable lands.

Table 1: ECOSSE estimated mean annual GHG (N_2O and CH_4), SOC fluxes and net GHG balance (t CO_2e /ha/y*) at baseline climate 1961-1990, for Wales.

Ecosystem	N_2O	CH_4	SOC	Net GHG balance
Grassland	0.441	-0.014	-0.022	0.449
Arable land	0.200	-0.002	-0.007	0.205
Forest	0.050	-0.007	-0.010	0.053
Natural	0.108	-0.035	-0.013	0.086
Average	0.200	-0.014	-0.013	0.199

***** Where GWP for N_2O is 296 and for CH_4 is 23 times greater than CO_2 over a 100 year period.

3.2 Effects of the Glastir measure of reducing nitrogen on GHG and SOC fluxes in Wales

Figures 3 and 4 show the predicted annual N_2O and GHG fluxes from the grass and arable ecosystems at baseline (100% crop N demand) compared to two reduced fertilizer application rate scenarios (80% and 60% crop N demand) for Wales. Application of N fertilizer at 100% crop N demand resulted in higher N_2O fluxes and thereby, higher net GHG fluxes from soils (Table 2). However, application of reduced fertilization rates resulted in low N_2O fluxes and consequently low net GHG fluxes as shown in Figures 3 and 4. Reducing applied N fertilizer by 20% reduced annual N_2O fluxes from 0.44 to 0.37 t CO_2e /ha/y (-16%) and from 0.20 to 0.16 t CO_2e /ha/y (-20%) for the grass and arable lands, respectively. However, reducing applied N fertilizer by 40% resulted in reduced annual N_2O fluxes from 0.44 to 0.32 t CO_2e /ha/y (-27%) for the grassland and from 0.20 to 0.14 t CO_2e /ha/y (-30%) for arable land (Table 2). The overall annual N_2O fluxes, from all ecosystems, reduced from 0.20 to 0.18 (-13%) and 0.16 (-22%) t CO_2e /ha/y for 20% and 40% N fertilizer reductions, respectively. Consequently, the annual net GHG balance reduced from 0.20 to 0.17 (for 20% reduction) and 0.15 (for 40% N reduction) t CO_2e /ha/y (Table 2). This is equivalent to annual reductions in C loss of 7 and 12 kg C /ha/y for the 20% and 40% N fertilizer reductions, respectively, compared to the baseline (application of 100% crop N demand). The CH_4 production and SOC fluxes were not affected by reducing N fertilizer application rate.

Nevertheless, the amounts of net CH_4 and SOC fluxes, at all fertilisation scenarios, represented small sinks of 0.014 and 0.013 t CO_2e /ha/y, respectively, (Table 2 and Appendices 4 and 5).

Table 2: ECOSSE estimated changes in annual GHG (N_2O and CH_4), SOC fluxes and net GHG balance (t CO_2e/ ha/y*) due to reduced N fertilization rate in Wales.

Scenario	N_2O	CH_4	SOC	Net GHG balance
Baseline	0.200	-0.014	-0.013	0.199
20% fertilizer N reduction	0.175	-0.014	-0.013	0.173
40% fertilizer N reduction	0.156	-0.014	-0.013	0.154

***** Where GWP for N_2O is 296 and for CH_4 is 23 times greater than CO_2 over a 100 year period.

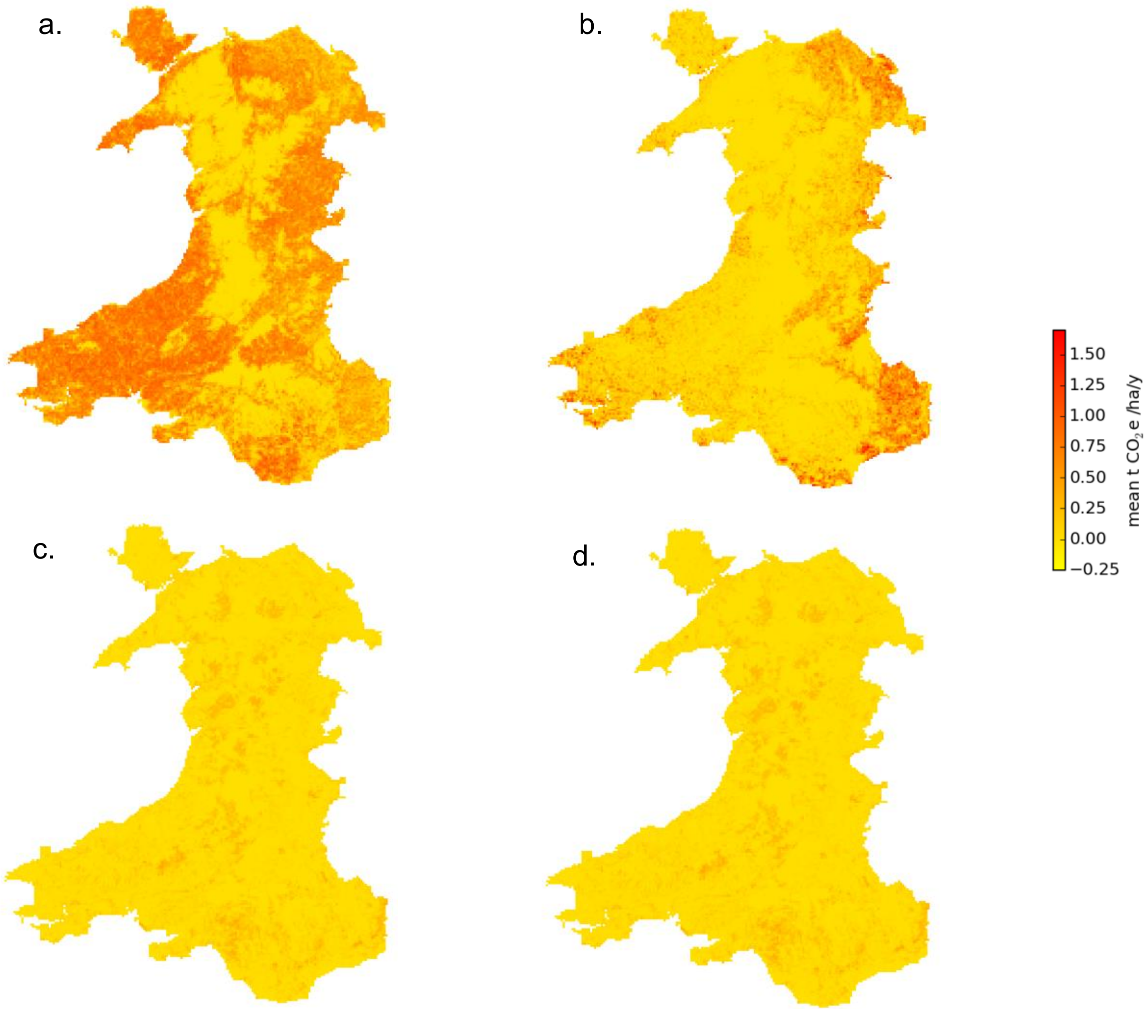


Figure 1: ECOSSE estimated mean annual net GHG fluxes (t CO_2e /ha/y) from the Welsh grassland (a), arable land (b), forest (c) and natural ecosystem (d), at baseline climate (1961-1990).

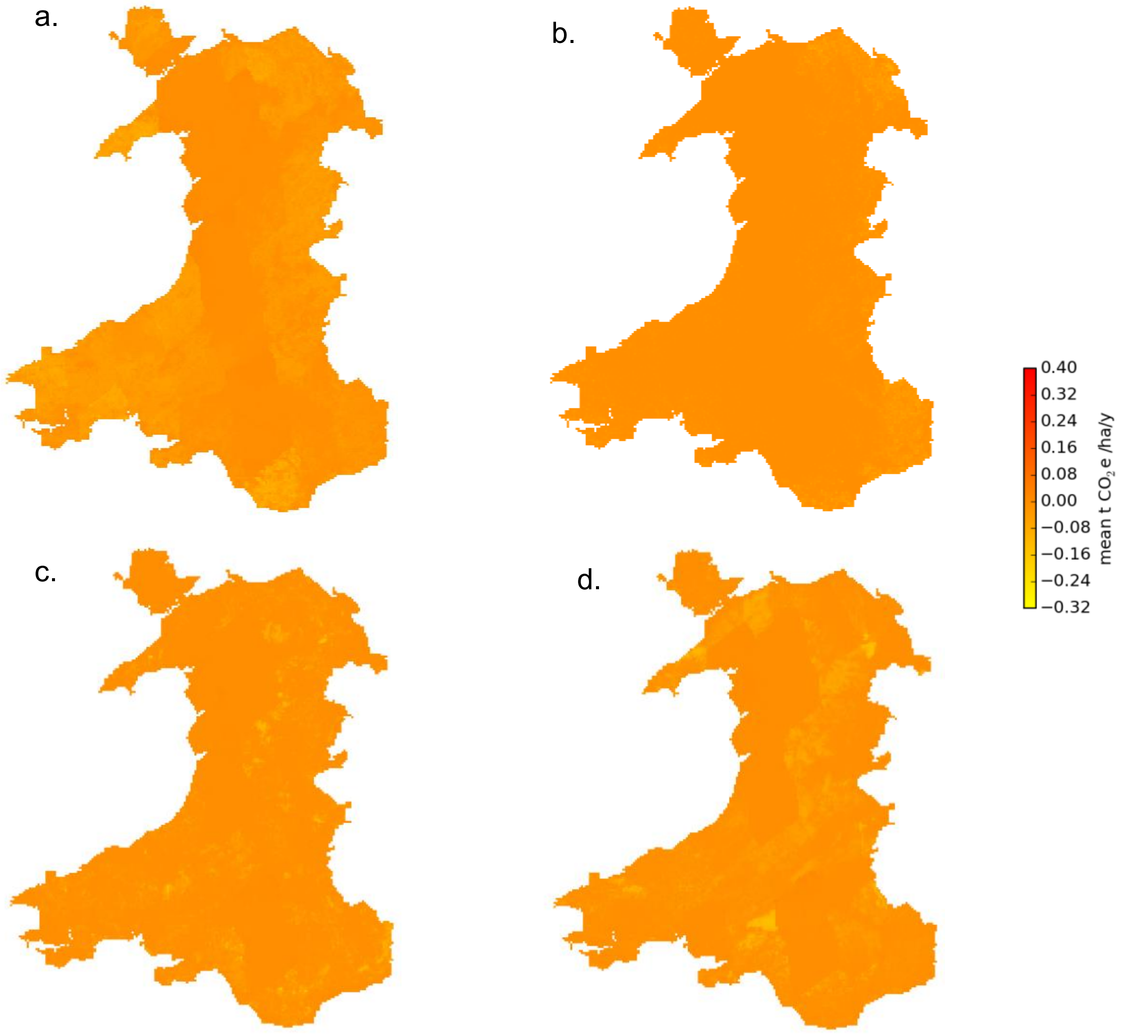


Figure 2: ECOSSE estimated mean annual SOC fluxes (t CO_2e /ha/y) from the Welsh grassland (a), arable land (b), forestry (c) and natural ecosystems (d), at baseline climate 1961-1990. (-ve sign means C sequestration in soils).

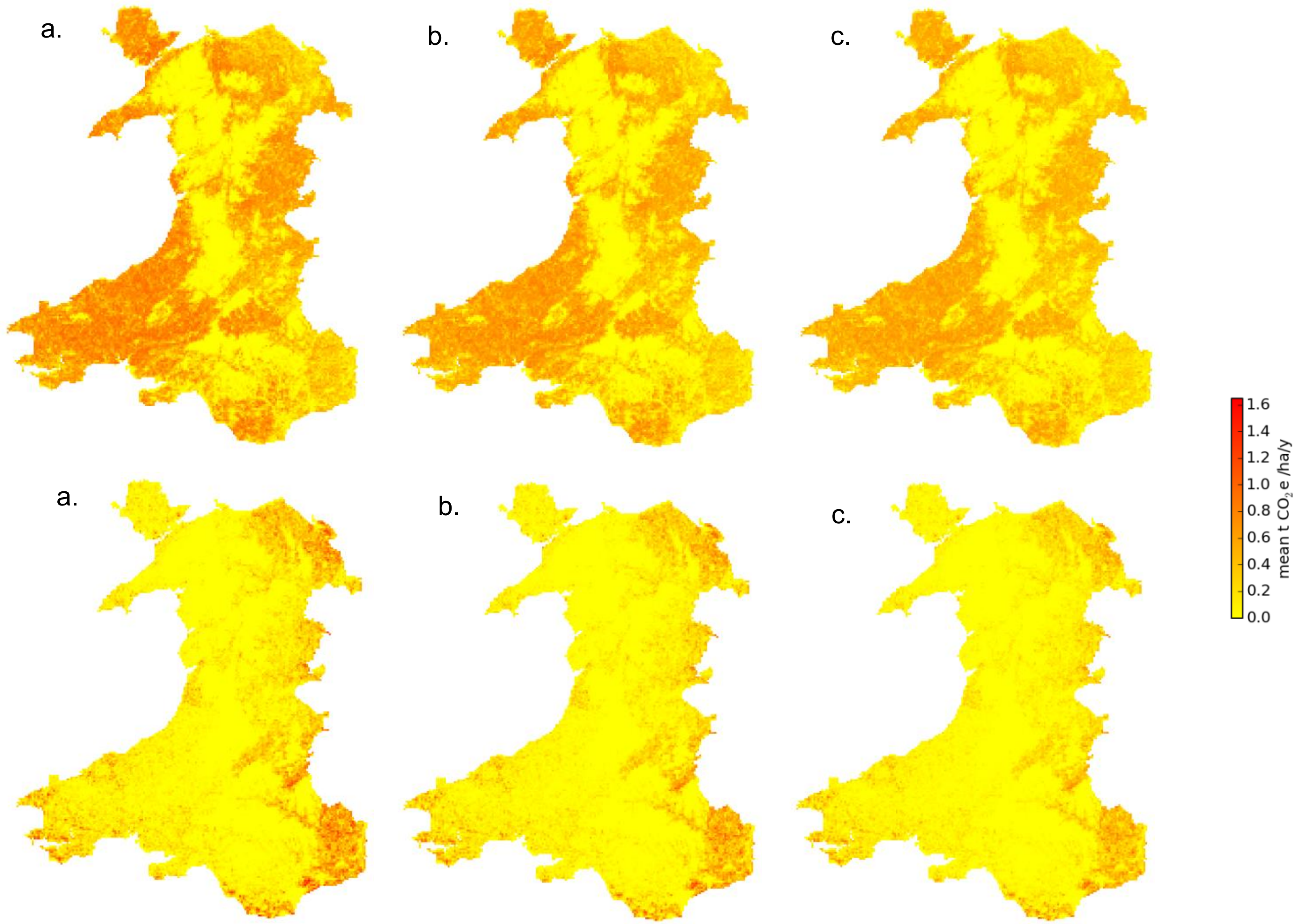


Figure 3: ECOSSE simulated N_2O fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable lands (below) at baseline (a) and 20% (b) and 40% (c) reduced N fertilizer application rates.

Figure 4: ECOSSE simulated annual GHG fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable (below) lands at baseline (a) and 20% (b) and 40% (c) reduced N fertilizer application rates.

3.3 Effects of climate change on GHG and SOC fluxes for Wales

The ECOSSE model was applied to assess the effects of climate change on GHG and SOC fluxes and NPP for Wales. Two future climate scenarios (low and high; 2015-2050) were compared with the baseline climate (1961-1990) as described in Section 2.3.2. Figures 5 and 6 show the ECOSSE predicted annual net GHG and SOC fluxes, from the different ecosystems, at baseline climate compared to the low and high climate scenarios. Under climate change, the net GHG fluxes, for all ecosystems and both climate scenarios, were slightly decreased compared to the baseline climate (Figures 5 and 6). The NPP under the low and high warming climate is 8% and 10% higher compared with that at baseline, respectively. Future N_2O flux values would slightly increase compared to those under the baseline climate scenarios (Table 3; Appendices 6 and 7). The N_2O flux difference between the low and high climate scenarios was very small (Table 3). However, all ecosystems remain a small sink for CH_4 (Appendices 8 and 9). For all ecosystems, SOC fluxes were increased by climate change as shown in Table 3 and Appendices 10 and 11. Under climate change, all ecosystems become small sources for SOC in place of a sink under the baseline climate scenario. Generally, under climate change Welsh soils will continue to have a positive net GWP. The overall annual net GHG balances were slightly lower (C uptake of 0.181 and 0.195 t CO_2e /ha/y) for the low and high climate scenario, respectively, compared to the baseline climate (0.200 t CO_2e /ha/y) (Table 3). The difference between the two climate scenarios is, however, small (about ±2%).

Table 3: ECOSSE simulated mean annual GHG, SOC fluxes and net GHG balance (t CO_2e / ha/y*) at baseline climate and the low and high climate scenarios to 2050, for Wales.

Gas flux	Baseline	Low climate scenario	High climate scenario
N_2O	0.200	0.208	0.212
CH_4	-0.014	-0.004	-0.005
SOC	-0.013	0.023	0.013
Net GHG balance	0.199	0.181	0.195

***** Where GWP for N_2O is 296 and for CH_4 is 23 times greater than CO_2 over a 100 year period.

Figure 5: ECOSSE simulated GHG fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable (below) lands at baseline (a), low (b) and high (c) climate scenarios.

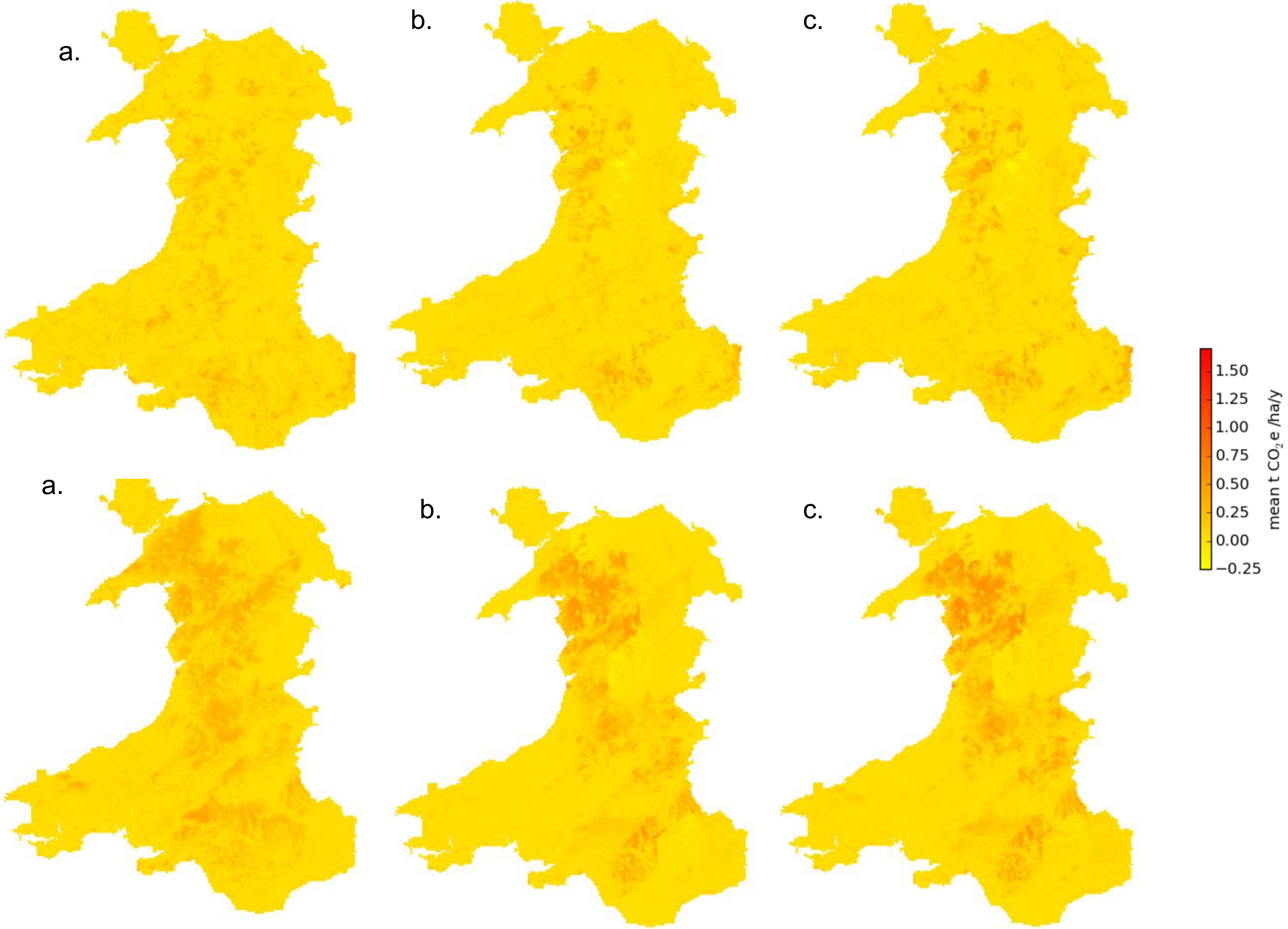


Figure 6: ECOSSE simulated GHG fluxes (t CO_2e /ha/y) from the Welsh forest (above) and natural (below) ecosystems at baseline (a), low (b) and high (c) climate scenarios.

4. Discussion

4.1 Evaluation of the ECOSSE model and GHG and SOC fluxes at baseline

In this study, the ECOSSE model was used to predict GHG and SOC fluxes for Wales. The overall annual net GHG balance of 0.199 t CO_2e /ha/y predicted by ECOSSE for the baseline (1961-1990), shows that Wales has a positive net GWP equivalent to a net annual loss of 54 kg C /ha/y. The calculated total net annual fluxes from the whole of Wales are estimated at 0.37 Mt CO_2e /y, driven primarily by N_2O fluxes. The model responded appropriately to changes in air temperature, timing of precipitation events, land use and system management, which have strong impacts on GHG and SOC fluxes. ECOSSE estimated credible N_2O fluxes and showed sensitivity to N fertilizer application rate. The N fertilizer application rate estimated by ECOSSE, calculated from the crop N demand, is equivalent to 137 kg N /ha/y. Compared with the measured average field N fertilizer application rate, for Wales in the period 1974-2012, of 121 kg N /ha/y (BSFP, 2012), the ECOSSE estimation is a little higher, but reasonable. This is especially promising considering that the field N fertilizer application rate in Wales has fallen in recent years, hence the average for the modelled period is likely to be higher than the quoted value (BSFP, 2013).

ECOSSE was previously tested and showed good agreement between measured and modelled N_2O results (Bell et al., 2012; Khalil et al., 2013). Higher N_2O fluxes were observed from the grass and arable ecosystems compared to the forest and natural ecosystems due to the addition of N fertilizer. The fluxes were also higher in coastal areas (Appendix 1) where rainfall was higher and, consequently, soil moisture was high. Both soil moisture and soil N availability are co-required for high N_2O fluxes. Similar results at field level studies have been demonstrated in maize (McSwiney and Robertson, 2005) and in forest and grassland systems (Maljanen et al., 2002; Abdalla et al., 2009a). Soil moisture stimulates denitrification by temporarily lowering oxygen diffusion into the soil (Dobbie and Smith, 2001) as well as by increasing the solubility of organic carbon and nitrate (Bowden and Bormann, 1986). The strong relationship between N_2O fluxes, and the interaction between soil moisture and soil nitrate, suggest that a high rainfall in winter and early spring, together with soil properties such as drainage characteristics, are important in the regulation of N_2O flux. Fluxes of N_2O were also increased with increasing air temperature (Appendix 1). Most soil processes e.g. like decomposition, N mineralisation; nitrification and nutrients uptake are dependent on temperature (Stark and Firestone, 1996; BassiriRad, 2000; Shaver et al., 2000; Shaw and Harte, 2001), and consequently GHG emissions (Raich and Schlesinger, 1992; Abdalla et al., 2009b).

ECOSSE predicted very low soil CH_4 fluxes across Wales. However, although fluxes under mineral soils are generally low (Abdalla et al., 2014a), fluxes from areas with organic soils, which are typically poorly-drained in their natural state (Levy et al., 2012), are underestimated by the model. Khalil et al. (2013) also reported that ECOSSE predicted CH_4 fluxes from Irish croplands less accurately. The model uses water table depth to simulate CH_4 production from soils (Bradbury et al., 1993, Smith et al., 1996). However, due to unavailability of observed spatial water table input data for the model, all soils in the simulations were assumed to be freely drained, with no specific water table depth. This assumption resulted in some uncertainty in the simulated CH_4 fluxes in areas of saturated soils (Worrall et al., 2011). Additionally, the model simulates the oxidation of atmospheric CH_4, which, under aerobic conditions, can lead to the soil being a net consumer of CH_4. For all investigated ecosystems, SOC fluxes at baseline were negative representing small sink of atmospheric C. This is because, prior to each simulation, the model was initialised based on the assumption that the SOC in the soil column is at stable equilibrium under the initial land use at the start of the simulation.

The effect of soil types on GHG and SOC fluxes in this spatial study is complicated but can be understood by looking to the key soil properties used by ECOSSE to modulate gas fluxes from soil. Soil clay content has large effect on soil organic matter decomposition. As clay content increases, a smaller proportion of decomposed C would be lost as CO_2 (i.e. the efficiency of decomposition increases), and a greater proportion is retained in the biomass and humus soil organic matter pools. Clay forms aggregates that physically protect SOC from microbial decomposition (Rice, 2002). Thus the relative SOC losses would be small for areas in which soil has high clay content. Soil pH also has a significant effect on the rate of soil organic matter decomposition (Andersson and Nilsson, 2001; Abdalla et al., 2014b). In ECOSSE, the pH rate modifier for aerobic decomposition decreases linearly as pH drops below 4.5. Ye et al. (2012) reported that low pH limited microbial metabolism. Bulk density affects the rate of CH_4 oxidation (i.e. consumption of CH_4). Some empirical evidence showed that soils with a low bulk density have higher rates of methane oxidation (Borken and Brumme, 1997). Here soils are more permeable which allow atmospheric methane and oxygen to diffuse freely into the soil (Dörr et al., 1993). However, because in this study ECOSSE simulated CH_4 production rates were generally very low, bulk density has no significant effect on the net GHG balance. Emission factor was not calculated as the model was not run to simulate crops without application of N fertiliser.

4.2 Effects of the Glastir measure of reducing nitrogen on GHG and SOC fluxes for Wales

In this simulation, ECOSSE was applied to assess the efficiency of the Glastir measure of reducing N fertilizer application rate to reduce GHG and SOC fluxes. Fertilizer was applied in the form of inorganic N fertilizer at a rate equal to the annual crop N demands as mentioned earlier (Section 2.4.4). There are no databases that define application of N fertilizer spatially. ECOSSE therefore estimates the N fertilizer application rate depending on the crop N demand. This is the only way to apply N fertilizer in ECOSSE without having spatially disaggregated application rates. The model is not sensitive to grazing or addition of animal manure. However, back-calculating the N amount applied at baseline using our N_2O figures and comparing to the average N fertilizer application rate for Wales (1974-2012) gave a reasonable value of 137 kg N /ha/y. Heavy utilization of synthetic N fertilizers in the grass/ arable lands typically results in high N_2O fluxes from soils. However, reducing N fertilizer application rate by 20 and 40% from the baseline resulted in 12% and 22% less N_2O fluxes and thereby, lower net GHG emissions. Nitrous oxide production has a non-linear response to mineral N content of the soils, with the curve flattening off at high mineral N (McSwiney and Robertson, 2005) as at lower levels, the N is taken up by the crop, as only surplus N is available for denitrification to N_2O.. Nitrous oxide has a high GWP, thus reducing its emissions would result in beneficial change to net GHG balance (IPCC, 2007). Availability of mineral N has a direct influence on N_2O production by provision of N for both nitrification and denitrification (Baggs and Blum, 2004; Abdalla et al., 2010). Reduced N fertiliser inputs lead to slow denitrification rate and a lower proportion of denitrified N emitted as N_2O. Nitrous oxide fluxes from soils occur in short-lived bursts following the application of N fertilizers (Leahy et al., 2004). The spatial variability in N_2O fluxes is high (Van den Heuvel et al., 2008) and controlled by interacting abiotic and biotic factors, such as plants, micro-organisms, precipitation and nutrients. These factors may vary on an annual basis with a significant effect on the magnitude of the N_2O flux. The flux is also expected to vary on a temporal basis depending on the dominant controlling factor (Mummey et al., 1997). However, less reduction in N_2O fluxes was observed in coastal areas where precipitation is high, whilst higher reduction was observed in drier areas of the country. Higher soil water content leads to a higher denitrification rate. However, although the proportion of denitrified N emitted as N_2O decreases, the net result is an increase in N_2O emissions as soil water content increases. This ECOSSE response reflects the empirical evidence for N_2O emissions increasing as soil water content increases (e.g. Schindlbacher et al., 2004; Luo et al., 2013). Abdalla et al (2010) reported that reducing fertilizer application rate by 50% for low input agriculture in Ireland is an acceptable strategy in that there was no significant effect on grain yield or quality in terms of required protein content, but it significantly reduced seasonal fluxes of N_2O.

ECOSSE does simulate the effects of N availability on C cycling. It works as follows: The N:C ratio of the biomass (BIO) and humus (Hum) pools have fixed N:C ratio that must be maintained. As C and N flow into these pools following decomposition of the decomposable plant material (DPM) and resistant plant material (PRM) any extra N required to maintain the BIO and HUM N:C is taken from the mineral N pools (NH_4 and NO_3). If insufficient N is available in these pools to meet the demand then the N:C of the organic matter entering the BIO and HUM is increased by decreasing the efficiency of decomposition (i.e. more CO_2 is given off, and less C is retained in the organic matter) . More explanation is given in the ECOSSE manual (Smith et al., 2010).

4.3 Effects of climate change on GHG and SOC fluxes for Wales

The effects of climate change on GHG and SOC fluxes for Wales until 2050 were investigated using two climate scenarios, low and high. Although temperature under climate change scenarios was higher than under the baseline climate scenario, fluxes of N_2O were not increased due to climate change. Under climate change, soil nitrogen increases due to increasing mineralization with changing temperature and precipitation (Wennman and Katterer, 2006; Abdalla et al., 2009a). Soil mineral nitrogen and N mineralization are the main sources of N_2O production (Bouwman, 1990; Abdalla et al., 2010). Soil characteristics and environmental conditions affect this mineralization (Schoenau and Campbell, 1996). Changes in precipitation (Izaurralde et al., 2003; Mearns, 2003), temperature (Fiscus et al., 1997) and atmospheric carbon dioxide concentrations could also have positive effects on the productivity of plants (Anwar et al., 2007). Many factors are responsible for CO_2 effects (i) high CO_2 directly affects C availability by stimulating photosynthesis and reducing photorespiration (Akita and Moss, 1973) (ii) high CO_2 concentrations reduce stomatal conductance (Morison and Gifford, 1984) which decreases the transpiration rate per unit leaf area. Low transpiration rates increase the leaf temperature and thereby further increase photosynthesis (Acock, 1990). An increase in photosynthesis combined with a decrease in transpiration result in an increase in the water use efficiency (iii) increases in CO_2 decrease the crop N concentration (Hocking and Meyer, 1991). In this study, the NPP under climate change was estimated to be 8-10% higher compared to baseline. An increase in grass dry matter production in Ireland due to climate change for the period 2061-2090 was also predicted by Fitzgerald et al (2009) and Abdalla et al. (2010). The fluxes of N_2O have a threshold response to N, and the amount of N lost to the atmosphere depends on the amount of N taken by plants (McSwiney and Robertson, 2005; Abdalla et al., 2010). The SOC fluxes were increased under both future climate scenarios compared to the baseline climate with a small difference between the two scenarios. Future high CO_2 concentration can increase plant photosynthesis, growth, belowground C input and substrate leading to greater root and microbial activities and respiration (Edwards and Norby, 1999; Zak et al., 2000; Anderson et al., 2001). Previous studies indicate that prediction of soil C fluxes in response to climate change should consider changes in biotic factors i.e. plant growth and substrate supply and abiotic factors i.e. temperature and moisture (Wang et al., 2007; Xia et al., 2009). Temperature is one of the main driving factors affecting C flux from soils (Tang et al., 2006; Jabro et al., 2008). The increase in plant growth and aboveground biomass produces more litter-fall and contributing to higher C loss through soil respiration (Zak et al., 2000; Deng et al., 2010). Both soil organic matter decomposition and microbial response to other perturbations, such as fertilisation, temperature and rainfall, can increase (Wennman and Katterer, 2006). However, contradicting findings about the effects of rainfall and soil moisture are reported in the literature with increased (Jabro et al., 2008) or unaffected (Ding et al., 2007) C fluxes.

In this study, CH_4 fluxes were low and not affected by climate change. Future overall net GHG balance from Welsh soil is slightly decreased compared to the baseline climate but remain a C equivalent source. However, the magnitude of the source could be underestimated due to ECOSSE potentially underestimating CH_4 fluxes. Both changes in SOC fluxes and plant C inputs (i.e. plant growth) are due to changes in climate, mainly arising through temperature and soil moisture (Smith et al., 2007). This suggests that if the current N fertilizer application rate continues, climate change up to the year 2050 would not significantly affect net GHG balance or NPP from Welsh soils.

5. Conclusions

1. ECOSSE provides broadly reliable predictions of GHG and SOC fluxes for Wales.
2. ECOSSE estimated mean annual net GHG balance at baseline climate of 0.2 t CO_2e /ha/y, which is equivalent to a net C loss of 54 kg C /ha/y.
3. The Glastir measure of reducing N fertilizer to reduce GHG and SOC fluxes is efficient and could reduce the annual net GHG balance from 0.20 to 0.17 (for 20% N reduction) and 0.15 (for 40% N reduction) t CO_2e /ha/y, respectively.

4. Climate change will not significantly affect net GHG fluxes or NPP from Welsh soils. The difference between the two climate scenarios is, however, small (about ±2%).

References

Abdalla, M., Hastings, A., Helmy, M., Prescher, A., Osbourne, B., Lanigan, G., Forristal, D., Killi, D., Maratha, P., Williams, M., Rueangritsarakul, K., Smith, P., Nolan, P. & Jones, MB. (2014a). Assessing the combined use of reduced tillage and cover crops for mitigating greenhouse gas emissions from arable ecosystem. *Geoderma* 223, 9-20.

Abdalla, M., Hastings, A., Bell, M.J., Smith, J.U., Richards, M. Nilsson, M.B., Peichl, M., Löfvenius, M.O., Lund, M., Helfter, C., Nemitz, E., Sutton, M.A., Aurela, M., Lohila, A., Laurila, T., Dolman, A.J., Belelli-Marchesini, L., Pogson, M., Jones, E., Drewer, J., Drosler M. & Smith, P., 2014b. Simulation of CO_2 and attribution analysis at six European peatland sites using the ECOSSE model. *Water Air and Soil pollution* 225, 2182. DOI 10.1007/s11270-014-2182-8

Abdalla, M., Jones, M., Yeluripati, J., Smith, P., Burke, J &Williams, M., 2010. Testing DayCent and DNDC model simulations of N_2O fluxes and assessing the impacts of climate change on the gas flux and biomass production from a humid pasture., *Atmospheric Environment*, 44, 2961-2970.

Abdalla, M., Jones, M., Ambus, P. & Williams, M., 2010. Emissions of nitrous oxide from Irish arable soils: effects of tillage and reduced N input. *Nutrient Cycling in Agroecosystems* 86, 53-65.

Abdalla, M., Jones & Williams, M., 2009a. Simulation of nitrous oxide emissions from Irish arable soils: effects of climate change and management. *Biology and Fertility of Soils* 6, 247-260.

Abdalla, M., Wattenbach, M., Smith, P., Ambus, P., Jones, M. & Williams, M., 2009b. Application of the DNDC model to predict emissions of N2O from Irish agriculture. *Geoderma* 151, 327-337.

Acock, B., 1990. Effects of carbon dioxide on photosynthesis, plant growth, and other processes. In: Impact of Carbon Dioxide, Trace Gases, and Climate Change on Global Agriculture. American Society of Agronomy, Madison WI ASA especial pub. No. 53.

Akita, S. & Moss, D.N., 1973. Photosynthetic responses to CO_2 and light by maize and wheat leaves adjusted for constant stomatal apertures. *Crop Science* 13, 234-237.

Anderson, L.J., Maherali, H., Johnson, H.B., Wayne, H. & Jackson, R.B., 2001. Gas exchange and photosynthetic acclimation over subambient to elevated CO_2 in a C3-C4 grassland. *Global Change Biology* 7, 693-707.

Andersson, S. & Nilsson, S.I., 2001. Influence of pH and temperature on microbial activity, substrate availability of soil-solution bacteria and leaching of dissolved organic carbon in a mor humus. *Soil Biology and Biochemistry* 33, 1181-1191.

Anwar, M.R., O'Leary, G., McNeil, D., Hossain, H. & Nelson, R., 2007. Climate change impact on rain fed wheat in south-eastern Australia. *Field Crops Research* 104, 139-147.

Baggs, E.M. & Blum, H., 2004. CH_4 oxidation and emissions of CH_4 and N_2O from *Lolium perenne* swards under elevated atmospheric CO_2. *Soil Biology and Biochemistry* 36, 713-723.

BassiriRad, H., 2000. Kinetics of nutrient uptake by roots: responses to global change. *New Phytologist* 147, 155-169.

Bell, M. J., Jones, E, Smith, J., Smith, P., Yeluripati, J., Augustin, J., Juszczak, R., Olejnik, J. & Sommer, M., 2012. Simulation of soil nitrogen, nitrous oxide emissions and mitigation scenarios at 3 European cropland sites using the ECOSSE model. *Nutrient Cycling in Agroecosystems* 92, 161-181.

Borken, W. & Brumme, R., 1997. Liming practice in temperate forest ecosystems and the effects on CO_2, N_2O and CH_4 fluxes. *Soil Use and Management* 13, 251-257.

Bouwman, A.F., 1990. Exchange of greenhouse gas between terrestrial ecosystems and atmosphere. In: Bouwman, A.F. (Ed.), Soil and the Greenhouse Effects. Wiley, Chichester, UK, pp. 61-127.

Bowden,W.B. & Bormann, F.H., 1986. Transport and loss of nitrous oxide in soil water after forest clear cutting. *Science* 233, 867-869.

Bradbury, N.,J., Whitmore, A.P., Hart, P.B.S. & Jenkinson. D.S., 1993. Modelling the fate of nitrogen in crop and soil in the years following the application of 15N-labelled fertilizer to winter wheat. *Journal of Agricultural Sciences* 121, 363-379.

BSFP, 2013. The British Survey of Fertilizer Practices. Fertilizer use on farm crops for crop year 2012.

Coleman, K. & Jenkinson, D.S., 1996. ROTHC-26.3-A model for the turnover of carbon in soil. In: Evaluation of Soil Organic Matter Models Using Existing Long-Term Datasets, NATO ASI Series I, Vol. 38, Springer-Verlag, Heidelberg, pp. 237-246.

Deng, Q., Zhou, G., Liu, J., Liu, S., Duan, H. & Zhang, D., 2010. Responses of soil respiration to elevated carbon dioxide and nitrogen addition in young subtropical forest ecosystems in China. *Biogeosciences* 7, 315-328.

Ding, W., Cai, Y., Cai, Z., Yagi, K. & Zheng, X., 2007. Soil respiration under maize crops: effects of water, temperature, and nitrogen fertilization. *Soil Science Society of America Journal* 71, 944-951.

Dobbie, K.E. & Smith, K.A., 2001. The effects of temperature, water filled pore space and land use on N_2O emissions from imperfectly drained gleysol. *European Journal of Soil Science* 52, 667-673.

Donatelli, M., Acutis, M. & Laruccia, N., 1996. Pedotransfer functions: evaluation of methods to estimate soil water content at field capacity and wilting point. www.isci.it/mdon/research/bottom_modeling_cs.htm pp. 6–11.

Dörr, H., Katruff, L. & Levin, I., 1993. Soil texture parameterization of the methane uptake in aerated soils. *Chemosphere* 26, 697-713.

Edwards, N.T. & Norby, R.J., 1999. Below-ground respiratory responses of sugar maple and red maple saplings to atmospheric CO_2 enrichment and elevated air temperature. Plant Soil 206, 85-97.

Fiscus, E.L., Reid, C.D., Miller, J.E. & Heagle, A.S., 1997. Elevated CO_2 reduces O_3 flux and O_3-induced yield losses in soybeans: possible implications for elevated CO_2 studies. *Journal of Experimental Botany* 48, 307-313.

Fitzgerald, J.B., Brereton, A.J. & Holden, N.M., 2009. Assessment of the adaptation potential of grass-based diary systems to climate change in Ireland - the maximized production scenario. *Agricultural and Forest Meteorology* 149, 244-255.

Givi, J., Prasher, S.O. & Patel, R.M., 2004. Evaluation of pedotransfer functions in predicting the soil water contents at field capacity and wilting point. *Agricultural Water Management* 70, 83-96.

Hocking, P.J. & Meyer, C.P., 1991. Carbon dioxide enrichment decreases critical nitrate and nitrogen concentrations in wheat. Journal of Plant Nutrition 14, 571-584.

Hutson, J.L. & Cass, A., 1987. A retentivity function for use in soil water simulation models. *Journal of Soil Science* 38, 105-113.

IPCC, 2013. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker TF, D. Qin, G.-K. Plattner, M.

Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2007. Changes in Atmospheric Constituents and in Radiative Forcing. Cambridge University Press, UK and New York USA.

IPCC, 2001. Climate Change 2001. Third assessment Report of the IPCC, Cambridge University Press UK.

Izaurralde, R.C.C., Rosenberg, N.J., Brown Jr., R.A. & Thomson, A.M., 2003. Integrated Assessment of Hadley Centre (HadCM2) climate-change impacts on agricultural productivity and irrigation water supply in the conterminous United States. Part II. Regional agricultural production in 2030 and 2095. *Agricultural and Forest Meteorology* 117, 97-122.

Jabro, J.D., Sainju, U., Stevens, W.B. & Evans, R.G., 2008. Carbon dioxide flux as affected by tillage and irrigation in soil converted from perennial forages to annual crops. *Journal of Environmental Management* 88, 1478-1484.

Khalil, M.I., Richards, M., Osborne, B., Williams, M. & Müller, C., 2013. Simulation and validation of greenhouse gas emissions and SOC stock changes in arable land using the ECOSSE model. *Atmospheric Environment* 81, 616-624

Leahy, P., Kiely, G. & Scanlon, T.M. 2004. Managed grasslands: a greenhouse gas sink or source? *Geophysical Research Letters* 31, L20507.

Levy, P.E., Burden, A., Cooper, M.D.A., Dinsmore, K.J., Drewer, J., Evans, C., Fowler, D., Gaiawyn, J., Gray, A., Jones, S.K., Jones, T., McNamara, N.P., Mills, R., Ostle, N., Sheppard, L.J., Skiba, U., Sowerby, A., Ward, S.E., Zielińksi, P., 2012. Methane emissions from soils: synthesis and analysis of a large UK data set. *Global Change Biology* 18, 1657-1669, doi:10.1111/j.1365-2486.2011.02616.x.

Lieth, H., 1975. Modeling the primary productivity of the world. In: Primary productivity of the biosphere (pp. 237-263). Springer Berlin Heidelberg.

Luo, G.J., Kiese, R., Wolf, B., Butterbach-Bahl, K., 2013. Effects of soil temperature and moisture on methane uptake and nitrous oxide emissions across three different ecosystem types. *Biogeosciences* 10, 3205-3219.

Maljanen, M., Martikainen, P.J. & Aaltonen, H., 2002. Short term variation in fluxes of carbon dioxide, nitrous oxide and methane in cultivated and forested organic boreal soils. *Soil Biology and Biochemistry* 34, 577-584.

McSwiney, C.P. & Robertson, G.P., 2005. Non-linear response of N_2O flux to incremental fertilizer addition in a continuous maize (Zea mays L.) cropping system. *Global Change Biology* 11, 1712-1719.

Mearns, L.O., 2003. Issues in the impacts of climate variability and change on agriculture. *Climatic Change* 60, 1-6.

Morison, J.I.L. & Gifford, R.M., 1984. Plant growth and water use with limited water supply in high CO_2 concentrations. 1. Leaf area, water use and transpiration. Australian. *Journal of Plant Physiology* 11, 361-374.

Morton, D., Rowland, C., Wood, C., Meek, L., Marston, C., Smith, G., Wadsworth, R. & Simpson I.C., 2011. Final Report for LCM2007 - the new UK Land Cover Map. Countryside Survey Technical Report No. 11/07 NERC/Centre for Ecology & Hydrology (CEH Project Number: C03259)

Mummey, D.L., Smith, J.L. & Bolton, H. Jr 1997. Small-scale spatial and temporal variability of nitrous oxide flux from a shrub-steppe ecosystem. *Soil Biology and Biochemistry* 29, 1699-1706.

Murphy, J.M., Sexton, D.M.H., Jenkins, G.J., Booth, B., Brown, C.C., Clark, R.T., Collins, M., Harris, G.R., Kendon, E.J., Betts, R.A., Brown, S.J., Humphrey, K.A., McCarthy, M.P., McDonald, R.E., Stephens, A., Wallace, C., Warren, R., Wilby, R. & Wood, R.A., 2009. UK Climate projections science report: climate change projections. Met Office Hadley Centre, Exeter.

National Soil Resources Institute, 2005, HORIZON_FUNDAMENTALS: LandIS, Cranfield University, Cranfield, UK.

National Statistics (2004). UK 2005. The Official Yearbook of the United Kingdom of Great Britain and Northern Ireland. London: The Stationery Office. p. 279. ISBN 0-11-621738-3.

Raich, J.W. & Schlesinger,W.H., 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. *Tellus* 44B, 81-99.

Rice, C.W., 2002. Organic matter and nutrient dynamics. In: *Encyclopedia of soil science*, Marcel Dekker Inc., New York, pp. 925-928.

Schindlbacher, A., Zechmesiter-Boltenstern, S. & Butterbach-Bahl, K., 2004. Effects of soil moisture and temperature on NO, NO_2 and N_2O emissions from European forest soils. *Journal of Geophysical Research* 109, 1-12.

Schoenau, J.J. & Campbell, C.A., 1996. Impact of crop residues on nutrient availability in conservation tillage systems. *Canadian Journal of Plant Science* 76, 621-626.

Shaver, G.R., Canadell, J., Chapin III, F.S., Gurevitch, J., Harte, J., Henry, G., Ineson, P., Jonasson, S., Melillo, J., Pitelka, L. & Rustad, L., 2000. Global warming and terrestrial ecosystems: a conceptual framework for analysis. *Bioscience* 50, 871-882.

Shaw, M.R. & Harte, J., 2001. Control of litter decomposition in a subalpine meadow-sagebrush teppe ecotone under climate change. *Ecological Applications* 11, 1206-1223.

Smith, J., Gottschalk, P., Bellarby, J., Richards, M., Nayak, D., Coleman, K., Hillier, J., Wattenbach, M., Aitkenhead, M., Yeluripurti, J., Farmer, J., & Smith, P., 2010. Model to estimate carbon in organic soils-sequestration and emissions (ECOSSE) user-manual (pp. 1-76). UK: University of Aberdeen.

Smith, J.U. & Glendining, M.J., 1996 A decision support system for optimising the use of nitrogen in crop rotations. Rotations and cropping systems. *Aspects of Applied Biology* 47, 103-110.

Smith, P., Chapman, S.J., Scott, W.A., Black, H.I.J., Wattenbach, M., Milne, R., Campbell, C.D., Lilly, A., Ostle, N., Levy, P., Lumsdon, D.G., Millard, P., Towers, W., Zaehle, S., Smith, J.U., 2007. Climate change cannot be entirely responsible for soil carbon loss observed in England and Wales, 1978-2003. *Global Change Biology* 13, 2605-2609.

Stark, J.M. & Firestone, M.K., 1996. Kinetic characteristics of ammonium-oxidizer communities in a California oak woodland-annual grassland. *Soil Biology and Biochemistry* 28, 1307-1317.

Tang, X.L., Zhou, G.Y., Liu, S.G., Zhang, D.Q., Liu, S.Z., Li, J. & Zhou, C.Y., 2006. Dependence of soil respiration on soil temperature and soil moisture in successional forest in southern China. *Journal of Integrative Plant Biology* 48, 654-663.

Thornthwaite, C.W., 1948. An approach toward a rational classification of climate. *The Geographical Revew* 38, 55-94.

Van den Heuvel, R.N., Hefting, M.M., Tan, N.C.G., Jetten, M.S.M. & Verhoeven, J.T.A. 2008. Nitrous oxide hotspots at different spatial scales and governing factors for small scale hotspots. *Science of the Total Environment* 407, 2325-2332.

Wang, W., Guo, J. & Oikawa, A.T., 2007. Contribution of root to soil respiration and carbon balance in disturbed and undisturbed grassland communities, northeast China. *Journal of Biosciences* 32, 375-384.

Wennman, P. & Katterer, T., 2006. Effects of moisture and temperature on carbon and nitrogen mineralisation in mine tailing mixed with sewage sludge. *Journal of Environmental Quality* 5, 1135-1141.

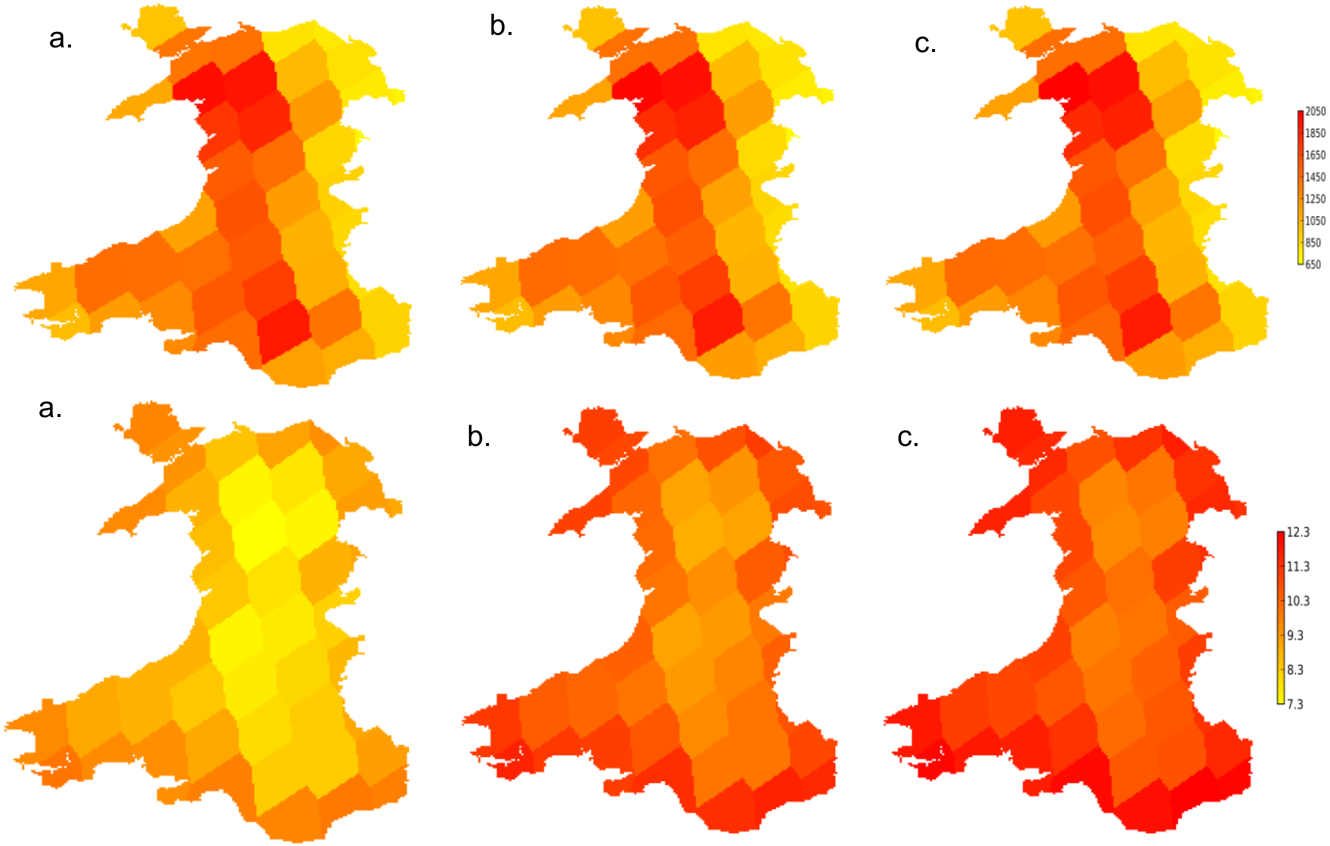
Worrall, F., Chapman, P., Holden, J., Evans, C., Artz, R., Smith, P. & Grayson, R., 2011. A review of current evidence on carbon fluxes and greenhouse gas emissions from UK peatlands. Report to JNCC.

Xia, J., Han, Y., Zhang, Z. & Wan, S., 2009. Non-additive effect of day and night warming on soil respiration in a temperate steppe. *Biogeosciences Discussion* 6, 4385-4411.

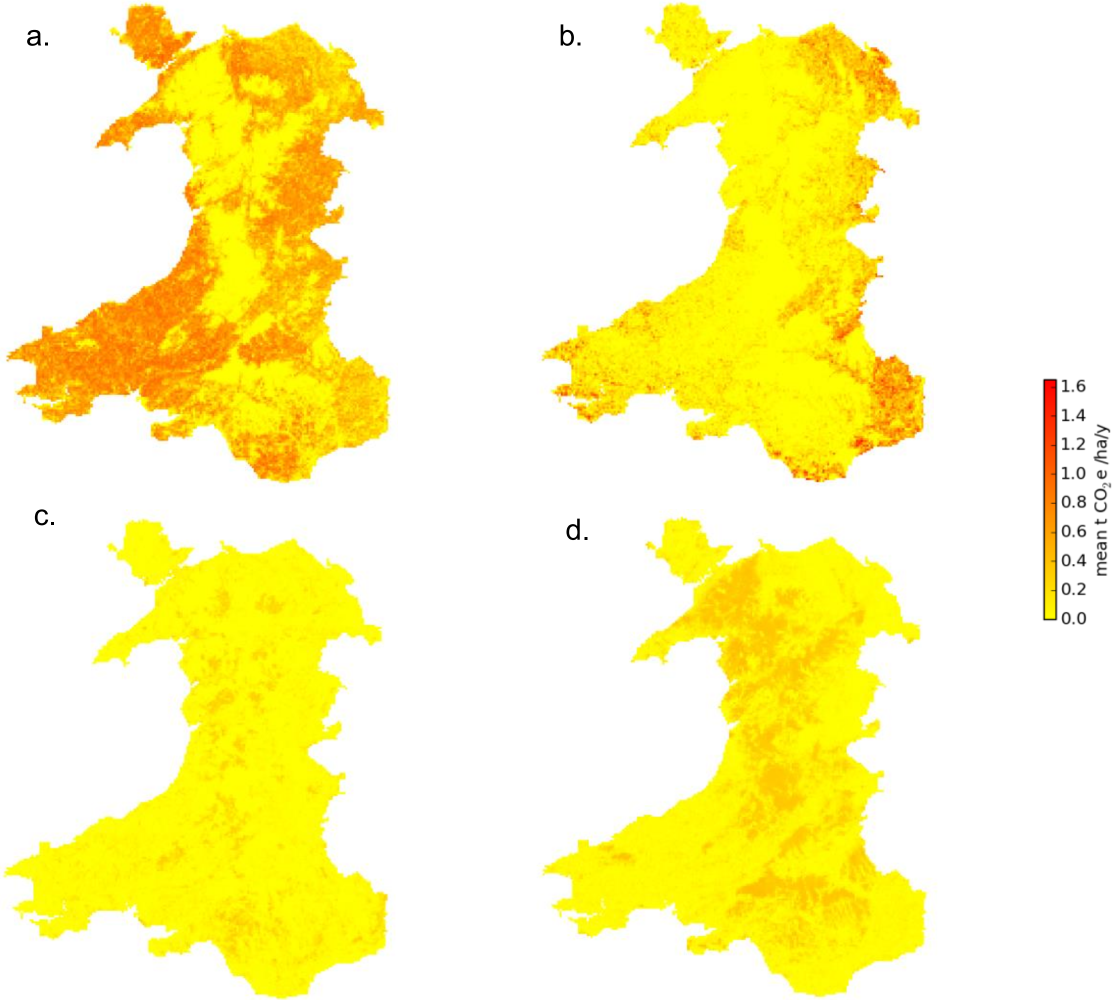
Ye, R., Jin, Q., Bohannan, B., Keller, J.K., Mc Allister, S.A. & Bridgham, S.D., 2012. pH controls over anaerobic carbon mineralization, the efficiency of methane production, and methanogenic pathways in peatlands across an ombrotrophic- minerotrophic gradient. *Soil Biology and Biochemistry* 54, 36-47.

Zak, D.R., Pregitzer, K.S., King, J.S. & Holmes, W.E., 2000. Elevated atmospheric CO_2, fine roots and the response of soil microorganisms: a review and hypothesis. *New Phytologist*147, 201-222.

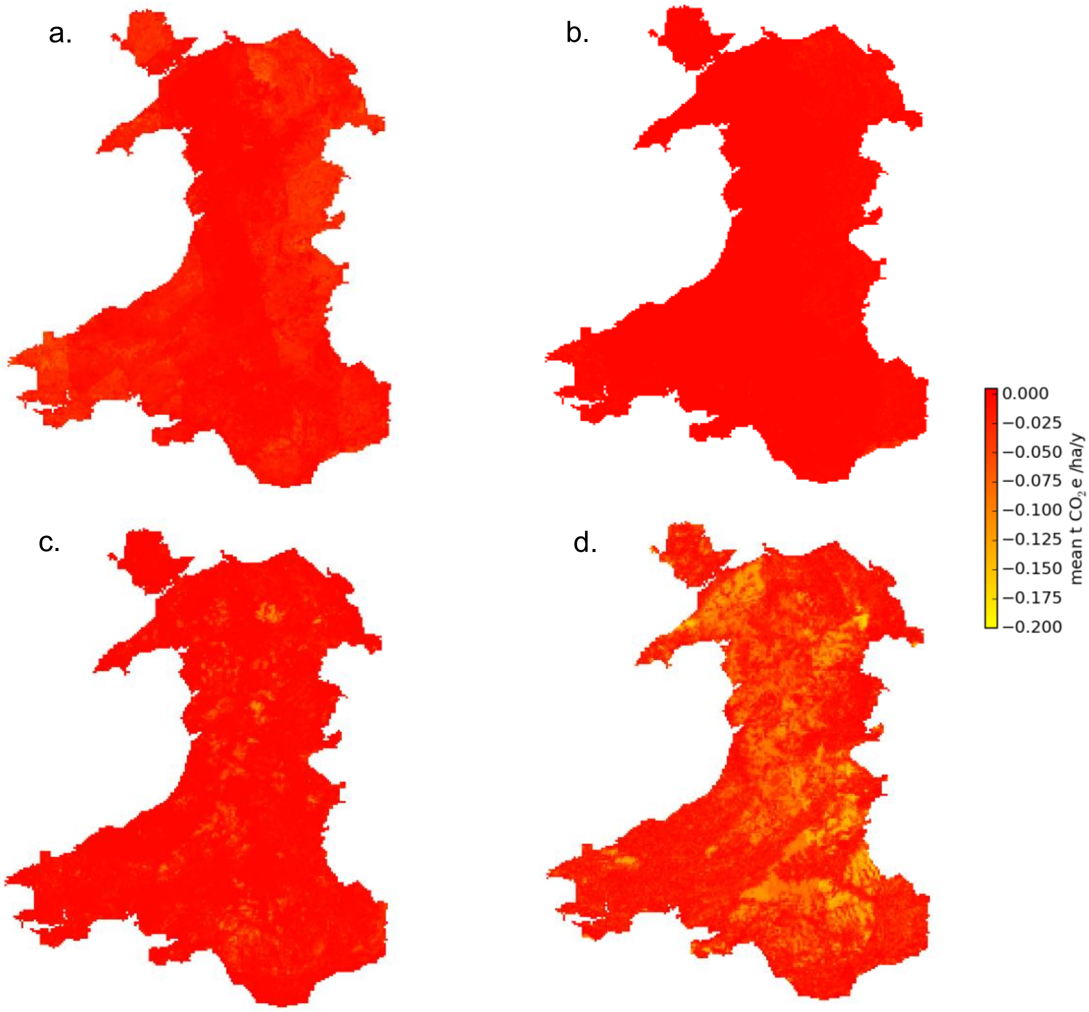
Appendices



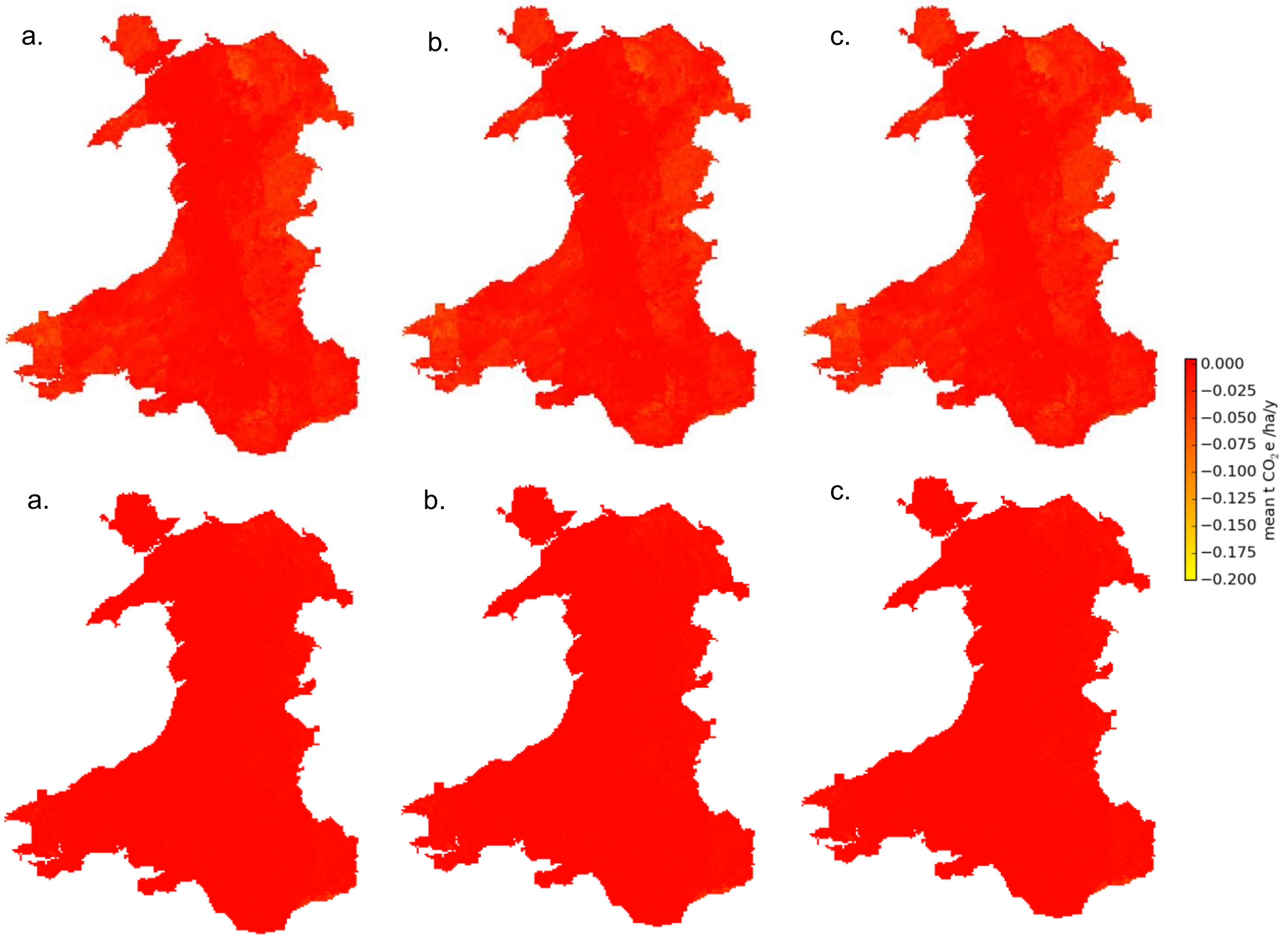
Appendix 1: Mean precipitation (above; mm) and air temperature (below; ^{o}C) at baseline (a), low (b) and high (c) climate scenarios.



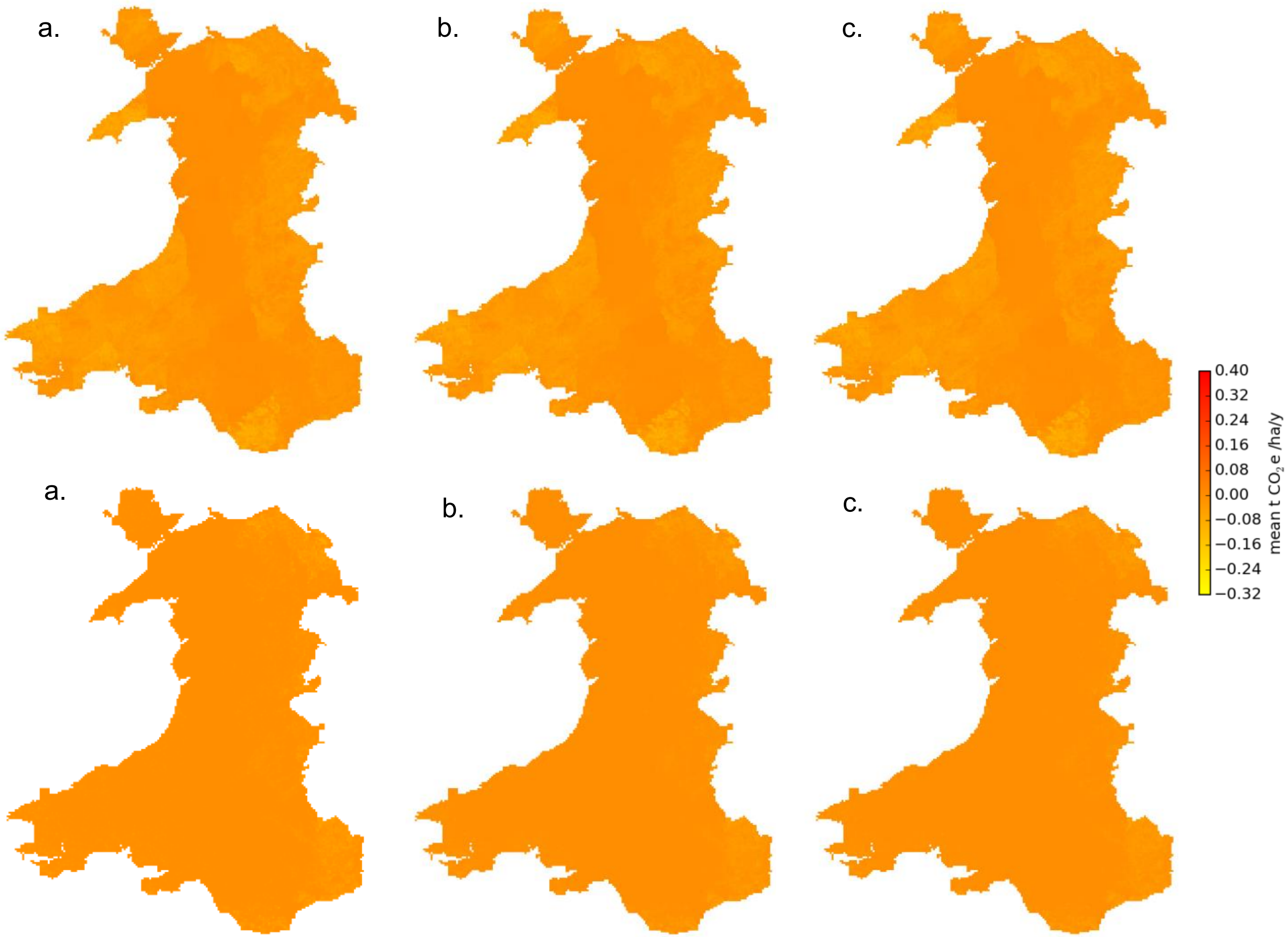
Appendix 2: ECOSSE estimated mean annual N_2O fluxes (t CO_2e /ha/y) from the Welsh grassland (a), arable land (b), forest (c) and natural ecosystem (d), at baseline climate (1961-1990).



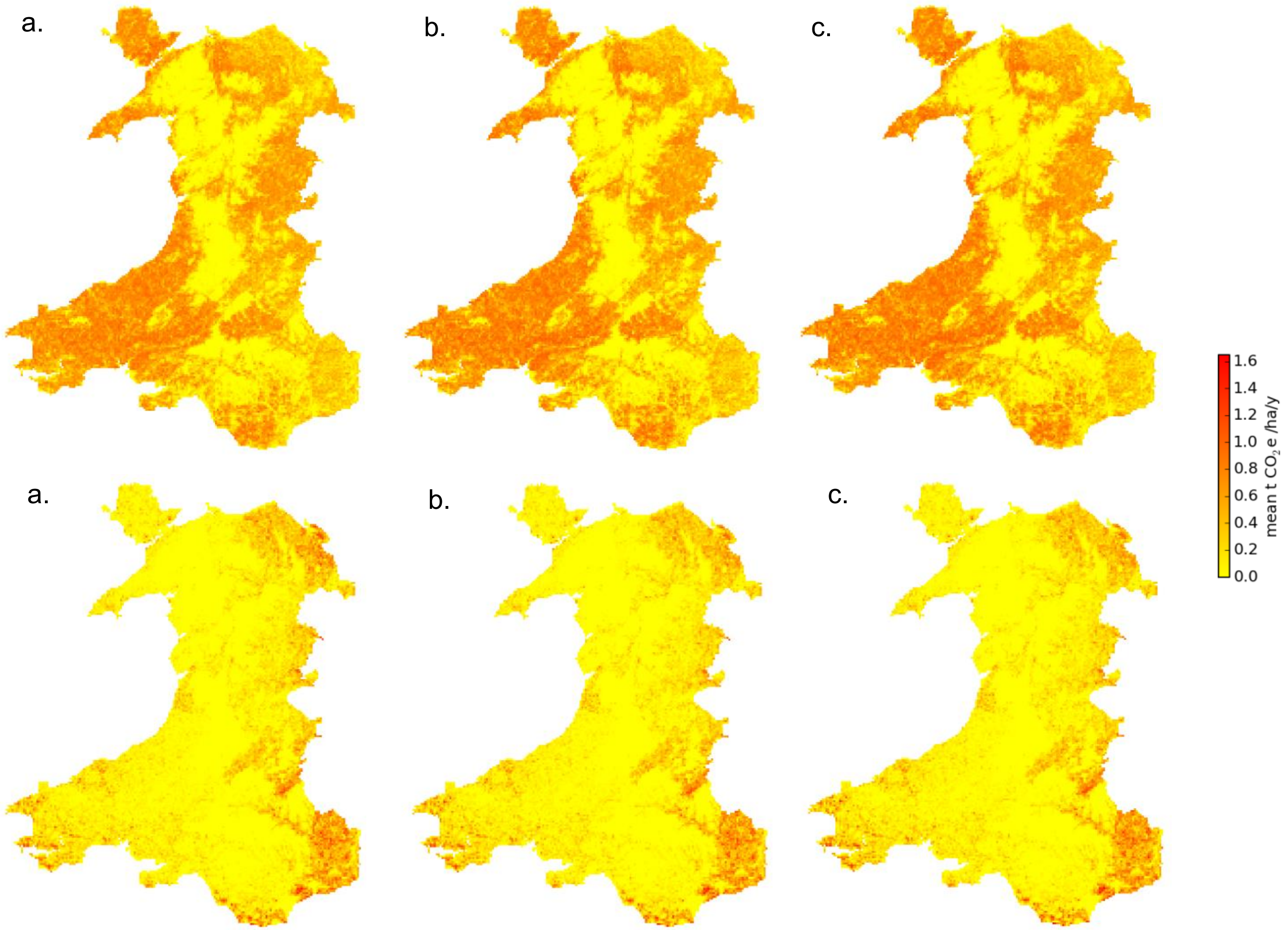
Appendix 3: ECOSSE estimated mean annual CH_4 fluxes (t CO_2e /ha/y) from the Welsh grassland (a), arable land (b), forest (c) and natural ecosystem (d), at baseline climate (1961-1990).



Appendix 4: ECOSSE simulated CH_4 fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable lands (below) at baseline (a) and 20% (b) and 40% (c) reduced N fertilizer application rates.

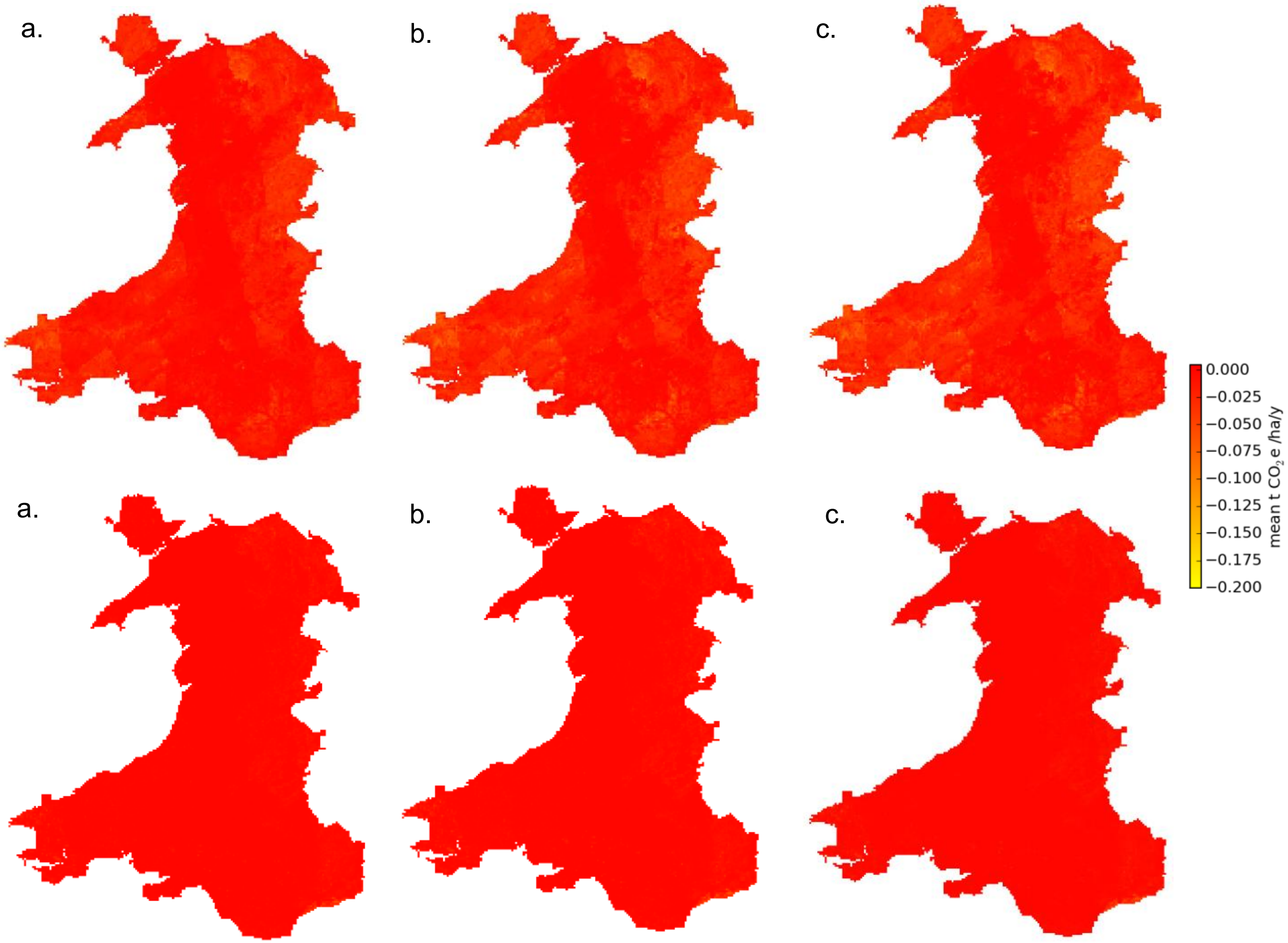


Appendix 5: ECOSSE simulated SOC fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable lands (below) at baseline (a) and 20% (b) and 40% (c) reduced N fertilizer application rates.

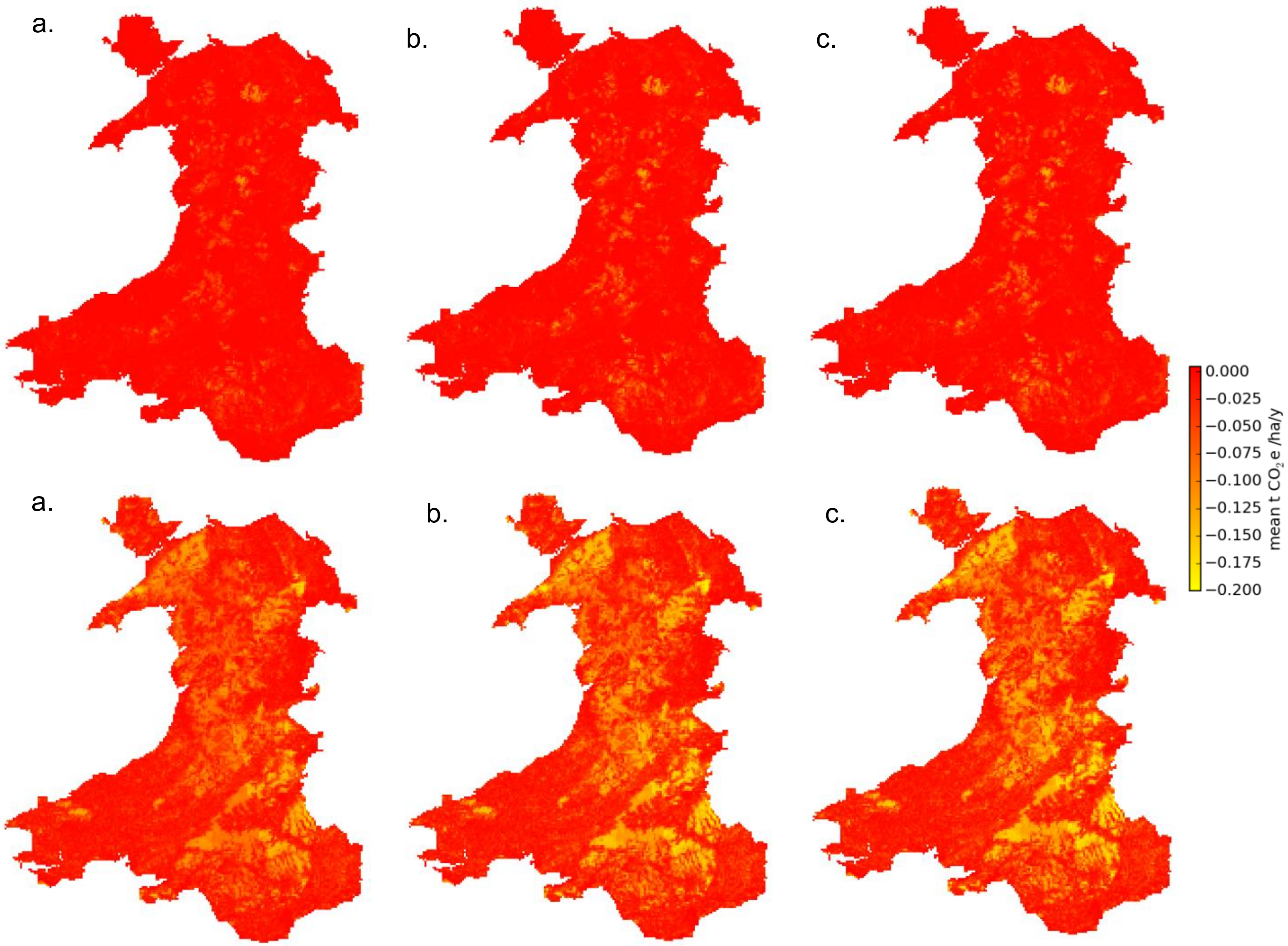


Appendix 6: ECOSSE simulated N_2O fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable (below) lands at baseline (a), low (b) and high (c) climate scenarios.

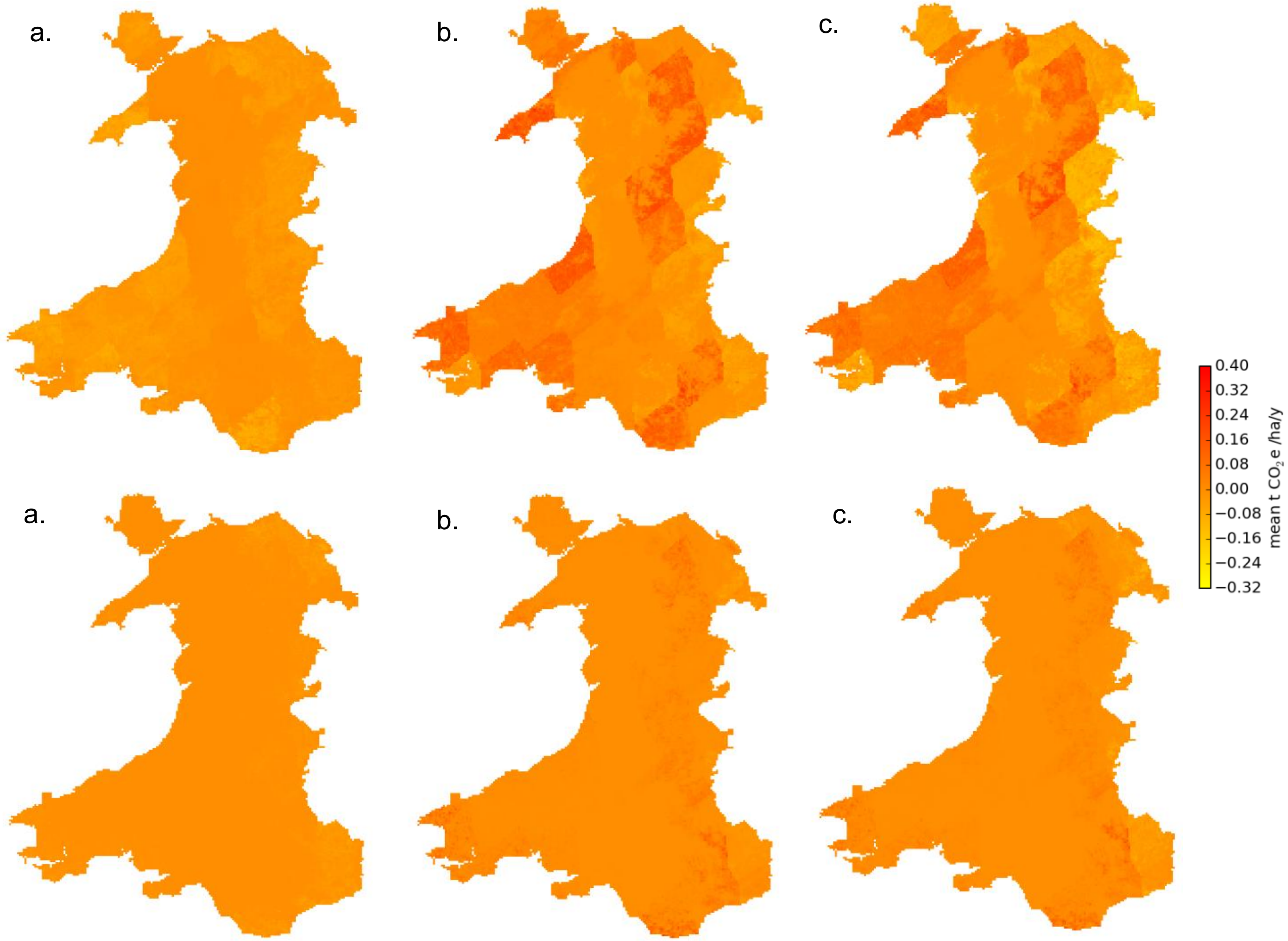
Appendix 7: ECOSSE simulated N_2O fluxes (t CO_2e /ha/y) from the Welsh forest (above) and natural (below) ecosystems at baseline (a), low (b) and high (c) climate scenarios.



Appendix 8: ECOSSE simulated CH_4 fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable (below) lands at baseline (a), low (b) and high (c) climate scenarios.



Appendix 9: ECOSSE simulated CH_4 fluxes (t CO_2e /ha/y) from the Welsh forest (above) and natural (below) ecosystems at baseline (a), low (b) and high (c) climate scenarios.



Appendix 10: ECOSSE simulated SOC fluxes (t CO_2e /ha/y) from the Welsh grass (above) and arable (below) lands at baseline (a), low (b) and high (c) climate scenarios.

Appendix 11: ECOSSE simulated SOC fluxes (t CO_2e /ha/y) from the Wlsh forest (above) and natural (below) ecosystems at baseline (a), low (b) and high (c) climate scenarios.ppendix 11: Mean precipitation (above; mm) and air temperature (below; °C) at baseline (a), low (b) and high (c) climate scenarios.

Appendix 6.3

WP9. Climate Change Mitigation and Diffuse Water Pollution Mitigation

A Review of Model Assumptions

Dave Chadwick, Steve Anthony, Rachel Taylor, Janet Moxley, Mohamed Abdalla and Pete Smith

Introduction

Welsh Government has developed a targeted approach to the delivery of improved environmental goods from farmland via the new Glastir Programme. Farmers accrue points for adopting a range of on-farm measures aimed at protecting soil C, reducing greenhouse gas (GHG) emissions, improving water quality and enhancing biodiversity.

The Glastir Monitoring and Evaluation Programme (funded by WG and led by CEH) aims to assess the success of the Glastir Programme in delivering it's goals. As such, WP9 will quantify the potential of Glastir measures to increase carbon storage (above and below ground) and reduce emissions of nitrous oxide (N_2O) and methane (CH_4). This will be achieved by taking an ensemble modelling approach, since no one model is able to account for all the sources of GHG emissions and carbon stores.

The four models used in this study are: i) the ADAS modelling framework (Anthony et al., 2012), ii) the Landuse, Landuse Change and Forestry (LULUCF) emissions reporting system (IPCC, 2003; IPCC, 2006), iii) the Bangor Carbon Footprinting model (Taylor et al., 2010), and iv) the mechanistic model ECOSSE (Smith et al., 2007; Smith et al. 2010a, b). Table 1 summarises the sources of N_2O and CH_4 emissions and C stores each model can account for.

IPCC Approach	Methane	Nitrous oxide	Carbon Dioxide	Carbon stocks	Diffuse water pollutants
Tier 1 (some Tier 2)	**Bangor Carbon Footprinting Tool**				
	Ruminant and manure	Direct and indirect + embedded losses	CO_2 energy, incl. embedded losses	Soil and vegetation	
Tier 1 (some Tier 2)	**ADAS Tool**				
	Ruminant and manure	Direct and indirect	CO_2 energy		NO_3,NH_4, P,sediment
Tier 1	**LULUCF**				
	Soil Fires (wildfires and forest clearance)	Direct from soil disturbance and fires	Soil respiration (Rh)	Soil and vegetation	
Tier2/Tier 3	**ECOSSE**				
	Soil	Direct and indirect	Soil respiration	Soil and vegetation	

Table 1. Sources of GHG emissions and soil Carbon stocks predicted by the different modelling tools.

All of the models incorporate specific assumptions and use values of emission factors or rates of carbon accumulation based on basic principles, empirically derived data, and expert judgement representing the best knowledge at the time of construction. They have been updated and revised as new and better knowledge has become available. This review summarises key assumptions and values used for emission factors and rates of carbon accumulation for each of the four models, comparing these assumptions and values with recent literature (grey and published), which could be used to update the models where appropriate. This information may help to explain any differences in model outputs for a given change in farming practices.

ADAS Modelling Framework (Steve Anthony)

Model description
In the ADAS model, mitigation impact is quantified using the Wales Diffuse Pollutant Emissions Modelling Framework developed under the previous project, 'Eco Systems Lot 3' (Anthony et al., 2012). In this framework present-day pollutant emissions are first calculated by application of a range of empirical and process based models including PSYCHIC (Davison et al., 2008) for phosphorus and sediment, and N-CYCLE, NITCAT and MANNER (Scholefield et al., 1991; Lord, 1992; Chambers et al., 1999) for nitrate, and IPCC tier one and two for N_2O and methane (Baggott et al., 2006). Each model is modified to provide an explicit source apportionment of emissions by source, area and pathway for representative farm system types across Wales. The impact of a mitigation method is then calculated as a percentage reduction against emissions from targeted coordinates. The reductions may be trivially calculated if the mitigation option maps directly to a modelled pollutant source (e.g. a reduction in fertiliser nitrogen), or are based on a synthesis of experimental literature and further computer modelling for representative scenarios. The impact of a mitigation method depends on the relative contribution of the targeted coordinates to total pollutant emissions, and the extent to which a mitigation method is already widely practiced.

Model outputs
ADAS Model outputs include: gases - enteric methane, manure methane, direct soil N_2O, N_2O associated with nitrate leaching (indirect N_2O), CO_2 from energy use; diffuse water pollution – nitrogen, phosphorus, sediment

Recent applications of the model
The ADAS Modelling framework was used in a previous Welsh Government funded project to assess the contribution of previous Welsh agri-environment schemes to the maintenance and improvement of soil and water quality, and to the mitigation of climate change (Anthony et al., 2012).

Emission Factors
The ADAS modelling system generally uses IPCC Guideline (1996/2000) emission factors for calculating CH_4 and N_2O emissions from agriculture, with the exception of FracLeach which is calculated from the ADAS MANNER, NITCAT and NEAP-N nitrate leaching models. Default emission factors are used with country specific management and productivity data (e.g. fertiliser use and dairy cattle milk yield) and Adherence to IPCC Guidelines means that model is consistent with UK Inventory methodology. Emission factors do not necessarily reflect the Welsh climate and soil attributes for N_2O, e.g. effect of pH, organic matter content and aeration.

However, the UK GHG Inventory is to move to the IPCC 2006 Guidelines, which will change the following key emission factors:

- Methane conversion factor for cattle from 6.5 to 6%
- Methane conversion factor for slurry storage from 39 to 10%
- Methane conversion factor for FYM storage from 1 to 2%
- Nitrous oxide emission factor for slurry storage from 0.1 to 0%
- Nitrous oxide emission factor for FYM storage from 2 to 0.5%
- Nitrous oxide emission factor for poultry manure storage from 2 to 0.1%
- Nitrous oxide emission factor for direct emissions from N to soil from 1.25 to 1%
- Nitrous oxide emission factor for indirect emissions from leached N from 2.5 to 0.75%
- Nitrous oxide emission factor for sheep excreta N at grazing from 2 to 1%

(*We could do a simple sensitivity analysis for the impact of these changes. However, it is not worth committing to any revisions until the Defra GHG Platform has reported on UK evidence for emission factors*).

Environmental Condition
ADAS modelling system uses MANNER, NEAP-N and NITCAT models to calculate nitrate leaching and indirect N_2O emissions. As a result, emissions will vary spatially in response to rainfall and soil texture.

ADAS modelling system modifies the emission factor for N_2O from N applied to soil to represent impact of soil compaction and poaching. We assume that all managed grass fields have a small permanent visibly poached area around tracks and feeders that covers 2% of the field area. We also assume that all fields that have reported evidence of poaching damage had an additional seasonal visibly poached area (3%) on and around gates and camping areas, and a more widely spread permanent area (20%) of less visible compaction and sparse vegetation cover. Oenema *et al.* (1997) in a review of N_2O emissions from grassland cite a 2 to 3.6 fold increase of emissions due to compacted grassland soil. Bhandral *et al.* (2007) measured N_2O emissions from compacted grassland soils that were 3.6 to 6.7 times greater than from non-compacted soils receiving urine, ammonium and urea; and up to 18 times greater for soils receiving nitrate. van Groenigen *et al.* (2005) reported that N_2O emissions of urine applied to a sandy soil increased 5 fold when the soil was compacted under moist conditions, which was comparable to a factor of 3.5 reported by Yamulki and Jarvis (2002). Matthews *et al.* (2010) reported N_2O emissions from gateways and poached land around water trough that were 10 times greater than from neighbouring managed pasture. Finally, Smith and Smith (2004) used a constant multiplier of 2 for fields grazed by cattle; and 1.3 for fields grazed by sheep for an improved calculation of N_2O emissions for Scotland. This was a landscape scale multiplier against emissions from mineral fertiliser that is assumed to represent the net effect of poached and non-poached fields.

Based on this evidence, we used a N_2O emission multiplier of 10 for the visibly poached areas of a field (2 to 5%) and a multiplier of 5 for the wider damaged soil area (20%). The net impact of this was that N_2O emissions were increased by a factor of 2.25 on poached fields, and by 1.18 on all non-poached fields. At landscape scale, and assuming that 50% of fields were poached, the net N_2O emission would be increased by a factor of 1.7 in the absence of mitigation. We believe that this multiplier is both representative of the empirical literature and comparable to the landscape scale treading coefficient used by Smith and Smith (2004). The exception here is that we apply the factor to losses from nitrogen in all of fertiliser, manure and excreta rather than just mineral fertiliser as in Smith and Smith (2004). For this work we did not make a distinction between grazing by sheep and cattle as this was implicitly represented by the survey evidence on the increased incidence of poaching on the dairy farm type.

Farm Practice
The ADAS modelling system calculates emissions from managed manures using animal / farm type specific and Welsh survey data on the proportion of manures managed as FYM and slurry. As the emission factors for FYM and slurry are very different this may result in different emission totals compared to calculations using the UK Inventory default values for management practices that are UK averages.

Mitigation
The ADAS modelling system represents the effect of a small number of mitigation methods affecting N_2O and CH_4 emissions. Most of these are indirect, i.e. reductions in nitrogen inputs or methods to reduce nitrate leaching. Methods are represented as a percentage modifier to the default emission factors, also modified by estimates of uptake of the method.

For N_2O, there are additional direct impacts of: minimal cultivation; avoiding application of manure or fertiliser at high risk times; rough ploughing and other soil management techniques (to remove soil compaction effects);

For CH_4, there are additional direct impacts of: covering FYM heaps; and reduced concentrate use on organic farms.

LULUCF emissions reporting system (Janet Moxley and Heath Malcolm)
The LULUCF reporting quantifies emissions and removals associated with changes in land use and some land management practices for inclusion in the UK Greenhouse Gas emissions inventory. Direct emissions of soil- CO_2, CH_4 and N_2O from this sector are included, but it does not include emissions allocated to the Agriculture sector, such as N_2O emissions from fertiliser application. It includes emissions due to changes in above- and below-ground biomass, soil and dead organic matter, and emissions of CO_2, CH_4 and N_2O from wildfires and biomass burning during deforestation. Emissions of methane and nitrous oxide from agricultural activity are captured in the Agricultural sector of the greenhouse gas inventory.

The IPCC LULUCF reporting system uses activity data from surveys such as the Countryside Survey, Agricultural Censuses and the National Inventory of Woodland and Trees to assess areas subject to different land uses, and to some extent is able to incorporate information on areas subject to different land managements. Because the finest scale for many of these data is the individual administration level, it is not sensitive to the local causes of variation such as climate, or soil. A “vector” approach to land use change is being developed for implementation in the 1990 – 2014 inventory. This will use the IACS Land Parcel Identification System data supplemented with remotely sensed data from the CORINE dataset to make the model spatially explicit and allow better integration with other datasets.

LULUCF reporting can use three Tiers of reporting of varying complexity to assess emission from the Land Use, Land Use Change and Forestry sector. Tier 1 is the simplest level of reporting, and Tier 3 the most complex. Tier 1 and 2 reporting are used for most activities. Tier 1 reporting uses national (UK) level activity data from censuses and surveys and default emission factors given in the IPCC Guidance. Tier 2 reporting uses higher resolution activity data (devolved administration or regional level) and UK-specific emissions factors where available. Tier 3 reporting uses modelling to assess emissions and is only currently used for the emissions from LULUCF activity related to Forestry (including deforestation to other land uses). Forest Research’s CARBINE model (Forest Research) was used for the first time in the 2012 Inventory replacing the simpler CEH C-Flow model.

While LULUCF reporting captures land use change and has the potential to capture emissions from land management activity, the UK has currently only elected to report on a limited number of land management interventions on agricultural land, namely liming of grassland and cropland, emissions from wildfires, emissions from drainage of peatland for use as Cropland, removals due to changes in the biomass of agricultural crops due to improved agronomy, and emissions from peat extraction. A Defra funded project, SP1113, has developed a methodology for capturing emissions from changes in soil carbon stocks due to land management activities on Cropland, which will be implemented in the 1990 – 2012 inventory. The project attempted to model emission factors for a range of Cropland management practices, but scarcity of long term UK-relevant field data to calibrate and validate the model meant that confidence in the output was very low. Because of this Tier 1 emission factors will be used for most activities except for tillage reduction where both the literature review and the modelling work suggested no effect under UK conditions when the full soil depth was considered and bulk density effects were accounted for. , and Lack of data on the effect of Grassland management, particularly the effect of management of grassland on upland soils meant that it was not possible to set up a reporting framework for this at present. DECC funded work will look at the effect of land management on emissions and removals due to changes in biomass carbon stocks on Grassland and perennial Cropland is in progress.

Model outputs
LULUCF outputs include:

- CO_2 emissions and removals from change in soil carbon stocks associated with land use change.
- CO_2 emissions and removals from change in biomass carbon stocks associated with land use change.
- Emissions of N_2O from soils as a result of disturbance during land use change.

- Emissions of CO_2, CH_4, and N_2O from biomass burning during deforestation to other land uses and wildfires on all land use types.
- Emissions of CO_2 from carbonate used in liming Cropland and Grassland.
- Emissions from drainage of peat (histosols) for use as Cropland.
- Emissions from peat extraction and use.
- Emissions and removals from change in residue and manure inputs to Cropland.
- Emissions and removals from change between annual and perennial crops.

Recent applications of the model

The LULUCF reporting system is used for annual reporting of emissions and removals by the LULUCF sector in the UK as required to meet international reporting requirements under the UN Framework Convention on Climate Change, the Kyoto Protocol and the EU Monitoring Mechanism. As part of these reporting processes it produces reports for each UK administrations and maps emissions to local authority areas.

Emission Factors

The IPCC Guidance on LULUCF reporting gives default emission factors which can be used where no more specific national or regional factors can be identified. However, UK or regional emission factors are available for some activities (Table 2).

Emission Source	EF Tier	Comments
Change in biomass carbon stocks in biomass, soils and dead organic matter (DOM) Forests and deforested land	3	Carbon stocks in Forest biomass, soils and DOM are obtained from the Forest Research CARBINE model (Forest Research), which includes yield data for all tree species in the UK (Edwards and Christie, 1981) and includes information on the distribution of tree types within the UK. This feeds into assessment of removals by the forestry sector as well as emissions from deforestation to other land uses. When land is deforested, it is assumed that 60% of living biomass is removed for timber, and the remaining biomass and dead organic matter (DOM) is burnt.
Emissions from Forest burnt in controlled burns during deforestation and in wildfires	3	Stocks of living biomass and DOM are obtained from CARBINE. Other emissions factors are default IPCC Tier 1 factors
Soil carbon stocks for non-Forest land	2	Obtained from a database of soil carbon density (Bradley et al, 2005).
Biomass carbon stocks for non-Forest land uses	2	Derived from Milne and Brown (1997),
Emissions from carbonate used in liming	1	IPCC default values based on chemical stoichiometry
Emissions from peatland drainage for cropland	3	Has been modelled using Century (Burton 1995; Bradley 1997). However the work used as this basis for this modelling does not account for bulk density changes, so it is proposed to revert to IPCC default factors from the 2006 Guidelines, pending development of Tier 3 emission factors in the process of work to implement the Wetlands Supplement.
Removals due to crop yield improvements	2	Change in plant biomass predicted to follow trend 1980 – 2000 (Sylvester-Bradley et al, 2002)

N_2O from soil disturbance during conversion to Cropland	1	IPCC default emission factors
Onsite emissions from peat extraction	1	IPCC default emission factors
Emissions from horticultural peat	2	Carbon content taken from Thomson et al (2011).
Effect of cropland management on soil carbon stocks	1	IPCC default stock change factors

Table 2. Sources of emission factors for LULUCF emission sources.

Environmental Condition

The LULUCF reporting system uses a broad brush approach which is not spatially explicit and so is generally not sensitive to environmental condition. The exception is data on Forest carbon stocks generated by the CARBINE model which takes account of variation in climate and soil.

It is planned to implement a spatially explicit approach using land use vectors from the 1990 – 2014 inventory which will allow better consideration of environmental conditions such as soil type, climate or slope.

Farm Practice

The effects of land use change between Cropland and Grassland are captured. The SP1113 project has started to develop a vector approach to mapping land use change between Cropland and Grassland based on IACS data. It is intended to fully implement this in the 1990 – 2014 inventory this will improve estimation of rotational practices. The effects of key Cropland management practices affecting CO2 emissions will be included in the 1990 – 2013 inventory. (Agricultural emissions of non-CO2 greenhouse greens are captured in the Agricultural inventory. Creation of farm woodland and tree planting is only partially captured in the LULUCF inventory, as the definition of woodland is taken from the National Forest Inventory and does not include wooded areas of less than 1 ha or areas with a potential canopy cover of less than 20%. This means that small farm woodlands, shelter belts and hedges may not be included.

Similarly changes of use from Cropland to Grassland which only cover small areas such as riparian buffer strips and uncultivated field margins may not be captured in the Countryside Survey data, which is currently the main source of data used to generate the land use change matrices used in LULUCF reporting although data on afforestation and deforestation is obtained from Forest Statistics and felling licence data which are updated annually. The use of Countryside Survey data to assess land use change also limits the sensitivity of LULUCF reporting to land use change in the short term as Countryside Surveys are only carried out approximately decadally. From the 1990-2014 inventory onwards IACS data will be used as the main source of data on land use in agricultural areas, however it is not clear whether or not this will be better at capturing practices which affect small areas of land on farms.

The LULUCF reporting system only captures a limited number of farm practices at present, namely direct emissions from liming and changes in biomass of agricultural crops due to improved agronomy. From the 1990 – 2013 inventory onwards it will include the effects of change in soil carbon stocks resulting from manure and residue inputs to Cropland and will distinguish between annual and perennial crops. It has not been possible to develop a framework for assessing the effects of Grassland management on soil carbon stocks because of lack of information, particularly with regard to upland grassland. The DECC project is currently assessing the feasibility of incorporating the effect of Cropland management on stocks of living biomass.

Mitigation

LULUCF reporting captures the effect of a limited number of mitigation options. It does capture the effect of land use change e.g. change from Cropland to Grassland or Grassland to Forest. However as discussed above there are some limitations to the sensitivity of this reporting in terms of the minimum change of area included, definitions of Forest and the timescale for detecting change which for change between Cropland and Grassland depends on Countryside Surveys.

LULUCF should capture reductions in emissions due to reduced liming, but this is assessed using disaggregated GB data, so may not be sensitive to initiatives taken specifically in Wales unless these are replicated by other GB administrations.

From the 1990 – 2013 inventory the effect of Cropland manure and crop residue inputs on soil carbon stocks will be included and a distinction made between annual and perennial crops. Tillage reduction was not found to have any effect on soil carbon stocks under UK conditions when the whole soil depth was considered and bulk density effects taken into account. Reporting on the effect of land management on Grassland has proved more problematic because of the difficulty in assessing the effect of intensification on different Grassland types. Work is currently underway to assess the effect of Cropland management on biomass stocks. Only perennial crops act as permanent store of biomass. While only small areas are likely to be involved, policies to increase production of biomass fuels could be reflected in LULUCF reporting if suitable activity and stock change factor data is available.

The Bangor Carbon Footprinting Model (Rachel Taylor)

Model description

The Bangor CF takes real farm data on all inputs, land management practices (and history for Land Use Change) and monthly stock diary data to generate annual C footprints that are PAS 2050 compliant (unless soil and biomass C sequestration effects are included). It adopts Tier 1 emission factors for most N_2O and CH_4 emissions (enteric fermentation based on animal category numbers and bodyweights x average EFs; soil emission factors; manure storage by type *etc*…). But it includes a simplified Tier 2 estimate of soil C accumulation under grassland, and accounts for on-going C sequestration in tree biomass. A monthly stocking diary enables more accurate estimation of annual enteric fermentation (x animal numbers) and manure management (N excretion and CH_4 EFs). It takes a Life Cycle Analysis approach, and boundaries include embedded GHG emissions associated with feed and fertiliser production and transportation to the farm.

Model outputs

The Bangor CF Tool outputs include: gases - enteric methane, manure methane, direct excreta, soil and manure heap N_2O; N_2O associated with nitrate leaching and N deposition (indirect N_2O); CO_2 from energy use; embedded greenhouse gas emissions associated with inputs (feed, fertiliser, agrochemicals, pharmaceuticals, significant consumables); and agricultural productivity. Above and below ground carbon annual increments in soils and biomass are modelled and reported separately from the system GHG emissions framework.

Recent applications of the model

The Bangor CF Tool was initially developed to assess the policy-relevant GHG emissions and carbon-sequestration impacts of a sustainable farming initiative in mid-Wales (Taylor et al. 2010); and for research into GHG emissions from mixed farming systems (Wyn Jones et al. 2011, Taylor et al. 2014). Further development took place under a previous Welsh Government funded project to assess the contribution of previous Welsh agri-environment schemes to the maintenance and improvement of soil and water quality, and to the mitigation of climate change (Taylor et al., 2012; chapter in Anthony et al 2012). It is currently being used in a number of projects to assess GHG impacts at the farm scale, including the annual variability in farm GHG emissions and the development of novel forage proteins for livestock production.

Emission Factors

The Bangor CF Tool generally uses IPCC Guidelines (2006) emission factors for calculating CH_4 and N_2O emissions from agriculture, maintaining compliance with PAS2050 where specific emissions factors are required for farm practices. Default emission factors are used with farm-specific management and productivity data (e.g. fertiliser use and dairy cattle milk yield) and livestock numbers and age classes are recalculated iteratively for each month of the farming year. Adherence to IPCC Guidelines means that model is consistent with UK Inventory methodology. Any additional emission factors are selected from a review of the published literature on UK based field studies, in order to reflect as closely as possible the Welsh climate and natural soil attributes for N_2O - e.g. including the effects of temperature, atmospheric CO_2, pH, organic matter content, saturation and aeration. For example, the IPCC standard EF used for N_2O emissions from managed peat soils is 8 kg (range 2 – 24) N_2O-N ha^{-1}, but we currently apply the ECOSSE model value of 0.25kg (range -0.99 – 3.7) N_2O-N ha^{-1}, calculated for a North Wales study site (ECOSSE 2007).

N budget and N_2O emissions modelling

The Bangor CF Tool calculates the farm year organic N budget from livestock diaries using breed- and farm-specific animal growth rates; and mineral N from fertiliser formulation-use data. Stored manure (including incorporated bedding materials) and direct-deposition organic N (excreta and daily-spread manure) are modelled separately based on farm practice data.

Nitrate leaching, direct N and indirect N_2O emissions are calculated as emissions and losses from stored manures using IPCC standard Tier 1 methodology, with reference to farm storage practices (aerobic/anaerobic, lagoons etc.) specific to each animal type. Soil N_2O emissions are calculated from applied organic N (stored manure corrected for storage losses specific to store method), excreta organic N and applied mineral N (IPCC (2006) EF of 0.01 (0.00 – 0.03) kg N_2O-N kg^{-1} N applied to total N content of all fertiliser formulations applied) per IPCC guidelines. Additional N_2O emissions are calculated per unit area of peat soils reported by the landowner and under management which includes N deposition (fertiliser, manure, grazing); corresponding to "managed peat soils" per IPCC recommendation and using a Wales-specific emission factor (ECOSSE).

Methane emissions modelling

The Bangor CF Tool calculates manure and excreta CH_4 emissions from the detailed livestock diaries using breed- and farm-specific animal growth rates. Monthly livestock numbers per animal type and age class are used with IPCC Tier 1 methodology and published relevant emissions rates for the relevant UK production systems. In order to avoid double-accounting, emissions from animals on the farm that remain the property of another holding (eg. 'tack' sheep) are calculated separately: their direct emissions remain within the system boundary of their home farm, whilst soils and excreta emissions (N_2O and CH_4) are incorporated into the farm on which they are grazing.

Farm inputs

The Bangor CF Tool calculates embodied GHG emissions and transport emissions from point-of-sale to the farm gate for all farm inputs that can be identified and quantified. Farm inputs are identified during discussions with farmers, and details of their provenance, purchased amounts, transport method etc. collected in all available detail. PAS2050 allows the exclusion of inputs only where their GHG impact represents less than 5% of the total emissions footprint, as long as the total GHG value of all excluded inputs also remains below this 5% threshold. For each input, the embodied GHG emissions may be (in order of preference) a) extracted from relevant published PAS2050-compliant studies including IPCC databases; b) estimated using published or collected formulations or production data (relevant to fertilisers and animal feeds); c) estimated using data for farm exports calculated using the Bangor Tool during previous studies (relevant to bought-in livestock) or d) estimated using nearest-equivalent generic values from GHG emissions databases.

For inputs with annually-varying embodied GHG values, the published emissions value for the year in which the inputs were purchased is used (relevant to electricity and fuels). For complex inputs such as animal feeds, GHG emissions are calculated using feed formulation and individual ingredient provenance and published footprint data sourced in the same way as for other farm inputs.

Uncertainty

Citing a single precise figure as the output of a carbon footprinting exercise may be misleading as GHG calculations have to deal with issues of variability, uncertainty and subjectivity, each of which can reduce the accuracy and precision of the final result. For example, within the agricultural context, there is tremendous biophysical variability between farms producing the same products, and this can generate large differences in the calculated GHG emissions of the farm business. Welsh Lamb may be produced on an upland farm where there are very few inputs, but there is also low productivity per hectare; or on fertile lowland farms with higher unit productivity but more fertiliser input. Management also varies between farmers; and even neighbouring farms of the same type, e.g. dairy producers, can have different yields and GHG footprints which are partly a function of the personality and skills of the farmer. The weather can also have a large impact on the way a farm is managed. As a result the exact footprint of a farm may vary over time due to interactions between the climatic environment and the associated management decisions of the farmer. Finally, carbon footprints vary with the underlying soil type. As a result the underlying soil type of a farm can have a large impact on the final footprint for that farm. This sort of variation has not typically been reported in carbon footprints to date, but in the Welsh context Edwards-Jones et al. (2009b) suggest that the footprint from farms on organic (peat-derived) soils can be substantially greater than those on mineral soils.

In addition to genuine biophysical variation between farms and years there is also considerable uncertainty inherent in GHG emission factors. This uncertainty is related to the limitations of our understanding of ecosystem-level processes. Emission factors reported in standard databases are derived from studies using a range of system boundaries, data collection techniques, data definition and processing methodologies etc. The choice of emission factor database is a subjective process, while the variation between emission factors for the same process can introduce variability into the process of carbon footprinting. The scientific literature presents a range of emission factors for most processes. However, scientific understanding of these complex processes is limited, partly because their measurement is time-consuming and spatially and temporally variable. The IPCC approach to this problem has been to produce standard emission factors through meta-analysis of all the available experimental data. These may be applied worldwide or be relevant to large geographical regions, but can have limited relevance to local conditions.

In addition to variability and uncertainty, carbon footprints also include an element of subjectivity: the analyst is required to represent a real farm in a simplified form, which requires a series of simplifying assumptions to be made. It is important that analysts recognise the subjective nature of their activities. To date, few studies have tried to report this uncertainty and variability (exceptions include Edwards-Jones et al. 2009, Lloyd & Ries 2008). Similarly, many of the studies reported in the literature have used modelling approaches, rather than using real farm data: which does not allow for an assessment of differences between individual farms (e.g. Williams et al. 2006; Weiske et al. 2006; Hirschfeld et al. 2008).

The Bangor CF Tool retains uncertainty throughout the calculation process by presenting three sets of calculation results. The commonly cited value is calculated using the mid-values for all emissions factors, the value considered by the authors of source studies to be the most likely representation of an accurate value. In addition, a result is calculated using the maximum range values for all emissions factors (worst-case scenario) and a third result using the minimum range values (best-case scenario). These extreme values are likely to represent the absolute maximum range of possible GHG emissions produced by the farm system under analysis.

Mitigation

A completed Bangor CF Tool is, in effect, a virtual model of an individual farm in a specified business year. The model is made very detailed to reflect that farm system and the management practices developed by the individual farmer, but it retains as calculation options all the alternative management practices specified by IPCC and encountered during previous Bangor farm modelling work. In consequence, it is possible to alter any component of the virtual farm and look for GHG impacts of such changes. Potential mitigation methods affecting N_2O and CH_4 emissions would include manure storage (aerobic/anaerobic methods, digesters), fertiliser application rates, livestock types and stocking rates. Other possible mitigation options including dietary changes can be modelled by applying appropriate Tier 1 emissions factors from published literature or other model outputs (as % modifiers to soil emission rates, for example).

A range of other potential options for reducing GHG emissions can be applied to the virtual farm. These include modifying inputs such as energy use (including investment in self-generation and renewables) or livestock feeds. Feedstuff modification can be a simple reduction in feed purchase, or a change to feed formulation (e.g. reduced protein content, change of protein type) or feed provenance (switch from South American to EU-grown soya).

Arable crops and Land-use Change data

Nitrous oxide emissions from arable land are calculated per IPCC guidelines for soil area, crop type and yield data collected from the farmer. Crop residues are modelled as removed (grazed, harvested) or incorporated (e.g. stubble ploughed-in) depending on stated management practices, and N_2O emissions associated with the N content of incorporated residues are calculated in accordance with IPCC guidelines.

For land areas under management that has changed in the last 20 years, default land-use change values from Jones and Emmett (2009) and other relevant published literature are applied on an area basis. Relevant changes include C loss consonant with ploughing permanent grassland (to re-sow grassland or add to arable rotations); or C gains associated with woodland and hedgerow planting. C impacts of land-use change occur over a period of time (e.g. ploughing impacts occur in the first year, tillage changes over 10 years, etc) and the C impacts are modelled for one year's net impact after the stated number of elapsed years. These soil GHG impacts of land-use change are included in the PAS2050-compliant emissions calculations, and soil areas subject to such changes are excluded from the C sequestration (soils) calculations.

Few data are available on the C implications of land-use change (DEFRA REVIEW SP1113). The values applied in the Bangor CF Tool are those associated with significant management changes, taken from Jones and Emmett (2009). On cropland the most commonly applied changes are conversion to grassland (+3.2t CO_2e ha^{-1}, 100% in year 1) and hedgerow planting (+0.05t CO_2e ha^{-1}, 100% in year 10). Improved grassland changes commonly include conversion to permanent grassland (+1.01t CO_2e ha^{-1}, 100% in year 1), hedgerow planting (as for cropland) or woodland planting (+0.88t CO_2e ha^{-1}, 100% in year 30 to 50); for reduced grazing impacts on semi-natural grasslands the GHG impact applied is (+2.84t CO_2e ha^{-1}, 100% in year 1). For some of these changes a range of values are presented in (DEFRA REVIEW SP1113); for example the conversion of cropland to grassland GHG impact is +0.87t C $ha^{-1}yr^{-1}$ (Germany) and +0.5t C ha^{-1} yr^{-1} (Sweden) which represent +3.19 and +1.84 t CO_2e ha^{-1} yr^{-1} , both considerably higher than the UK values.

Land-use change GHG calculations are applied for changes in soil C (as CO_2e). Where a land-use change includes significant biomass change (woodland conversion including hedgerow planting), biomass values are calculated independently using forest growth models (see section on C sequestration). A cautious approach is taken over land-use change from detailed management (e.g. changes in fertiliser type or crop type) as these changes are often difficult to clarify with farmers or represent gradual alterations in practices rather than the activity of a particular year. The subset of land-use changes most commonly applied are summarised in Table 3 and represent midpoint emissions values taken from Jones and Emmett (2009).

Land use type	**Land use change** (cf. Jones and Emmett 2009)	**Greenhouse gas emissions (EF)** (t CO_2 eq/ha/y^{-1})		**Mitigation potential after elapsed time** (% of maximal annual emission rate)			
		midpoint	range	1 year	10 years	30 years	50 years
Croplands	Enhanced fertiliser management (N/lime)	0.72	0.02-1.42	100	30	5	0
	Set aside and field margins	3.21	0.00-6.41	100	95	10	0
	Conversion to grassland	3.2	0.00-6.40	100	95	10	0
	Agroforestry / hedgerow	0.05	0 - 0.1	10	100	10	0
	Conversion to forestry (managed)	0.85	0.3-1.4	10	50	100	10
	Conversion to forestry (unmanaged)	0.85	0.3-1.4	5	15	50	100
Improved Grasslands	Stop re-seeding (i.e. reduced tillage)	1.01	0.73-1.28	100	90	15	5
	Agroforestry / hedgerow	0.05	0.00-0.10	10	100	10	0
	Conversion to forest (managed)	0.88	0.37-1.38	10	50	100	10
	Conversion to forest (unmanaged)	0.88	0.37-1.38	5	15	50	100
Semi-natural Grasslands	Agroforestry / hedgerow	0.05	0.00-0.10	10	100	10	0
	Conversion to forest (managed)	0.88	0.37-1.38	10	50	100	10
	Conversion to forest (unmanaged)	0.88	0.37-1.38	5	15	50	100

Table 3. Effects of land use change on soil C stocks, expressed as CO_2 eq ha^{-1} y^{-1}.

A comprehensive review of soil C under land-use change (Poeplau et al. 2011) compiled data from 95 studies covering 322 temperate zone studies in order to model soil C change in topsoil (30cm depth). Values from this study converted to annual C change are represented in $CO_2e\ ha^{-1}$ and compared with the model values from Jones and Emmett (2009) (Table 4).

The values used in the Bangor model for cropland converted to grassland, and grassland converted to forest are very similar to those in the meta-review. This review calculated higher emissions values for croplands converted to forest, although the range of values included in the review encompasses the value from Jones and Emmett (2009). The authors noted that C accumulation in forest soil was a linear relationship (IPCC assumes that soil under woodland reaches C equilibrium after 60 years) and was strongly influenced by mean annual temperature; this may be the reason for the more conservative values Jones and Emmett applied to Welsh soils.

Land-use type	**Land-use change**	**GHG emissions (t CO_2 eq/ha/y^{-1})**				Equilibrium (years)	**Mitigation potential development after conversion**							
							% maximum GHG emissions or *% of initial C stock							
		over 20y		over 100y			1 year	10 years	20 years		30 years	50 years	100 years	
Croplands	Cropland to grassland	3.37	±6.19	2.18	±3.7	>120			*39.8	± 11			*128.4	± 23.2
	Jones& Emmett 2009	***3.20***	***± 0.70***			***30***	***100***	***95***			***10***	***0***		
	Cropland to forest (only mineral soil)	1.63	±3.81	1.70	±3.96	>120			*16	± 7.4			*83.4	± 38.8
	Jones& Emmett 2009	***0.85***	***± 0.55***			***30-50***	***5-10***	***15-50***			***~100***	***~100***		
Forest	Forest to cropland	-8.46	±-3.99	-1.74	±-0.88	23			*-31.4	± 20.4			*-32.2	± 19.9
	Jones& Emmett 2009	***-0.85***	***± 0.55***			***10***	***5-10***	***15-50***			***~100***	***~100***		
Grasslands	Grassland to cropland	-7.61	±-10.45	-1.52	±-2.09	17			*-36.1	± 4.6			*-36.1	± 4.6
	Jones& Emmett 2009	***-3.20***	***± 0.70***			***30***	***100***	***95***			***10***	***0***		
	Grassland to forest (only mineral soil)	-0.61	±-0.11	-0.18	±0.69	>150			*-4.3	± 3.7			*-6.5	± 22.6
	Jones& Emmett 2009	***-0.88***	***± 0.50***			***30-50***	***5-10***	***15-50***			***~100***	***~100***		

Table 4. Effects of land use change on soil carbon, expressed as CO_2 eq ha^{-1} y^{-1}: a comparison of studies.

The greatest disagreement in values is in the conversion of forest to cropland, although the value from Jones and Emmett (2009) is within the range of values for annual change over 100 years from Poeplau et al. (2011). This value represents only 15 studies, and the authors note the impact of limited data (high scatter and therefore high uncertainty in model fit); of soil type (higher soil C loss from clay soils) and mean annual temperature (higher C loss in warmer climates). Clay soil is relatively uncommon on Welsh farms and the climate is cool, supporting the decision to use values at the low end of the reviewed range.

Modelling carbon sequestration in soils and biomass

Carbon sequestration in soils and biomass is modelled independently of the PAS2050-compliant GHG emissions components of the Bangor CF Tool, and of the land-use change calculations but uses the same Tier 1 approach and retains the same flexibility for scenario modelling. Calculations fall into the following categories:

a) ≥75% closed-canopy trees (woodland and forestry) over 20yo – modelled as woodland by area using site-specific Forestry Commission tree growth models (soil, aspect, altitude, rainfall, species or species mix) assuming stable soil carbon content. Timber extraction modelled as carbon losses sensitive to brash handling (burning, composting) and including litter decomposition.
b) ≥75% closed-canopy trees (woodland and forestry) under 20yo – modelled as woodland by area using site-specific Forestry Commission tree growth models (soil, aspect, altitude, rainfall, species or species mix) assuming increasing soil carbon content.
c) Dispersed or isolated trees including emergent from hedgerows – counted by landowner – are modelled as free-grown standards using site-specific Forestry Commission tree growth models (soil, aspect, altitude, rainfall, species mix).
d) Hedgerows are measured from aerial photographs in consultation with landowner. Hedges flailed in the sample year are assumed to maintain biomass equilibrium. Hedges not flailed in the sample year are modelled using growth increments for the equivalent area (length x width) of established alley-cropped short-rotation coppice. Boundary hedges (with neighbouring farms) are assumed to be shared-ownership and 50% of their area excluded to avoid double-accounting un up-scaling results to national estimates.
e) Soil C sequestration is considered to be in equilibrium under arable and rotational (improved) grassland. For permanent grassland on mineral soils, a low-average default net ecosystem change value for UK grasslands of 0.24 t $ha^{-1}y^{-1}$ (range 0.04 – 0.44 t $ha^{-1}y^{-1}$, Janssens et al. (2005)) is used, pending further review of studies relevant to Welsh agricultural land. Buckingham et al. (2013) acknowledge the scarcity of relevant data for Welsh grassland but cites a similar rate of increase in SOC of 1 to 4 t ha^{-1} over 10 years as a consequence of manure application. For permanent grassland on organic soils default C sequestration rates for unmanaged peatlands are taken from Watson et al. (2000) (IPCC special report).

Productivity

The Bangor CF Tool also incorporates details of production (sales and exports by weight) for all farm produce in the sample year. These data are used to allocate GHG emissions to products for the purposes of product and supply-chain GHG footprinting beyond the farm gate. Allocation to products is compliant with PAS2050 and separates farm enterprises (direct and indirect emissions from cattle enterprise allocated to cattle products) as completely as possible. Notable exceptions include agrochemicals applied to pastures grazed by livestock from different enterprises (sheep and cattle), and energy inputs (electricity and diesel) which are allocated economically by enterprise sales revenues. 75-90% of total emissions can generally be allocated directly to the correct enterprises. A collateral benefit of these data is to investigate the potential impacts of mitigation or agri-environment scheme practices on production, with obvious benefits for predicting impacts of such schemes on national food security.

ECOSSE (Mohamed Abdalla and Pete Smith)

Model Description

The ECOSSE (Estimating Carbon in Organic Soils - Sequestration and Emissions) model was developed to simulate soil organic carbon (SOC) in highly organic soils from concepts originally derived for mineral soils in the RothC and SUNDIAL models. ECOSSE contains additional descriptions of a number of biogeochemical processes in mineral soils, including simulation of anaerobic processes in organic soils (Smith *et al*. 2007, 2010c). It uses a pool type approach, and all of the major processes of C and N turnover in the soil are included and described using simple equations driven by readily available input variables. It can be used to carry out site-specific simulations with detailed input data, or national-scale simulations using the limited data typically available at larger scales. Data describing SOC, soil water, plant inputs, nutrient applications and timing of management operations are used to run the model. In the case of missing information, it can still provide accurate simulations of GHGs (N_2O associated with nitrification and denitrification, CO_2 corresponds to heterotrophic respiration and CH_4 through a balance between methanogenesis and methanotrophy) and changes in SOC stock. It can be used for both organic and mineral soils, providing accurate values of net change to soil C and N in response to changes in land use and climate. This model calculates outputs for each soil layer for each time step. Thus, it may be used to inform GHG inventories at the field and national scale, assess mitigation options and provide information for policy decisions.

Model outputs

ECOSSE model outputs include: soil methane, soil CO_2 (heterotrophic respiration), soil N_2O (direct), soil carbon stocks and above ground carbon stocks.

Model applications

The ECOSSE model has been applied at both national and European levels. It was used to simulate soil nitrogen, nitrous oxide emissions and mitigation in European croplands (Bell *et al*., 2012). The model was also applied to simulate Rh and attribution to variability in natural and anthropogenic drivers in European peatland ecosystems (Abdalla *et al*., 2014) and soil carbon under short rotation forestry energy crops in Britain (Dondini et al., 2014).

Emission Factors

ECOSSE model can be used to calculate emission factor for N_2O by, for example, subtracting simulated cumulative (seasonal/annual) flux data for unfertilized fields from that of the fertilized fields, and dividing by the amount of N fertilizer applied. EFs can be further evaluated by integrating the predicted daily fluxes (seasonal/annual), and the corresponding measured values. Khalil et al. (2013) successfully predicted measured EF, using ECOSSE, for an 8-years N_2O study on Irish croplands. Emission factors on national and regional levels can also be calculated by using the limited version of the model.

Farm Practice

ECOSSE can be used to investigate how farm management could affect GHG emissions and soil C. Thus, management that increase anthropogenic GHG emissions could be avoided or reduced e.g. drainage could significantly increase CO_2 emissions from European peatlands (Abdalla et al., 2014) and therefore, alternative strategies at a regional level are required. The model can also be used to assess the impacts of potential future land management interventions, and help guide best practice land-management decisions.

Mitigation

The correct estimation for the effects of future climate change and land-use on GHG emissions and C sequestration are essential for advising land use policy on mitigation options. The ECOSSE model can be used to predict these future changes in soil C and N for both mineral and organic soils by comparing GHG emissions and soil C under baseline and future climate and land-use scenarios. The model can provide accurate values of net change to soil C and N in response to changes in land use and climate and can be used to determine uncertainty in national simulations and advise reporting to UKGHG inventories (Smith et al., 2007). ECOSSE is one of the few models suitable for examining the impacts of land-use and climate change on organic soils. Anaerobic decomposition process which result in emissions of CH_4 is included in ECOSSE. In wetlands, methane is produced by methanogenic bacteria in soil when decomposition occurs under anaerobic conditions and is significantly contribute to global warming. The rate of methane emissions are increase with increasing temperature therefore, could have positive feedback due to climate change. ECOSSE estimate CH_4 emissions using a simple but process-based approach. Methane emissions are calculated as the difference between CH_4 production and oxidation, the oxidation process adding to emissions of CO_2. Thus, ECOSSE can help in understanding the processes that control CH_4 emissions, how they react to both environmental and land use changes and predict mitigation options.

REFERENCES

Abdalla, M., Hastings, A., Bell, M.A., Smith, J.U., Richards, M., Nilsson, M.B., Peichl, M., Löfvenius, M.O., Lund, M., Helfter, C., Nemitz, E., Sutton, M.A., Aurela, M., Lohila, A., Laurila, T., Dolman, A.J., Belelli-Marchesini, L., Pogson, M., Jones, E., Drewer, J., Drosler, M. and Smith, P. 2014. Simulation of $CO_2$and attribution analysis at six European peatland sites using the ECOSSE model. Biogeosciences. Under review.

Anthony, S., Jones, I., Naden, P., Newell-Price, P, Jones, D., Taylor, R., Gooday, R., Hughes, G., Zhang, Y., Fawcett, L., Simpson, D., Turner, A., Fawcett, C., Turner, D., Murphy, J., Arnold, A., Blackburn, J., Duerdoth, C., Hawczak, A., Pretty, J., Scarlett, P., Laize, C., Douthwright, T., Lathwood, T., Jones, M., Peers, D., Kingston, H., Chauhan, M., Williams, D., Rollett, A., Roberts, J., Old, G., Roberts, C., Newman, J., Ingram, W., Harman, M., Wetherall, J. and Edwards-Jones, G. (2012) Contribution of the Welsh agri-environment schemes to the maintenance and improvement of soil and water quality, and to the mitigation of climate change. Welsh Government, Agri-Environment Monitoring and Technical Services Contract Lot 3: Soil, Water and Climate Change (Ecosystems), No. 183/2007/08, Final Report, 477 pp + Appendices.

Baggott, S., Brown, L., Cardenas, L., Downes, M., Garnett, E., Hobson, M., Jackson, J., Milne, R., Mobbs, D., Passant, N., Thistlethwaite, G., Thomson, A. and Watterson, J. (2006) United Kingdom greenhouse gas inventory, 1990 to 2004. AEA Technology Ltd, 468 pp.

Bhandral, R., Saggar, S., Bolan, N. and Hedley, M. (2007) Transformation of nitrogen and nitrous oxide emission from grassland soils as affected by compaction. Soil and Tillage Research, 94, 482-492.

Bell, M.J., Jones, E., Smith, J., Smith, P., Yeluripati, J., Augustin, J., Juszczak, R., Olejnik, J. & Sommer, M. 2012. Simulation of soil nitrogen, nitrous oxide emissions and mitigation scenarios at 3 European cropland sites using the ECOSSE model. Nutrient Cycling in AgroEcosystems 92, 161-181.

Bradley, R.I Carbon loss from drained lowland fens in : « Carbon Sequestration in Vegetation and Soils » Cannell M.G.R. London. Department of Environment, (1997)

Bradley, R.I ; Milne, R ; Bell, H ; Lilly, A ; Jordan, C and Higgins, A. A soil carbon and land use database for the United Kingdom. Soil Use and Management 21 363-369.

Buckingham, S., Cloy, J., Topp, K. Rees, R. and Webb, J. 2013. Capturing cropland and grassland management impacts on soil carbon in the UK Land Use, Land Use Change and Forestry (LULUCF) inventory Literature review for DEFRA Project SP1113 14 October 2013.

Burton, R. Evaluating organic matter dynamics in cultivated organic topsoils – use of historical analytical data. MAFF contract to SSLRC no. LE0203-81/3830

Chambers, B., Lord, E., Nicholson, F. and Smith, K. (1999) Predicting nitrogen availability and loses following applications of manures to arable land: MANNER. Soil Use and Management, 15, 137-143.

Davison, P., Withers, P., Lord, E., Betson, M. and Stromqvist, J. (2008) PSYCHIC – A process based model of phosphorus and sediment mobilisation and delivery within agricultural catchments. Part 1 – Model description and parameterisation. Journal of Hydrology, 350, 290-302.Baggott et al. (2006)

Dondini et al., 2014. Evaluation of the ECOSSE model for simulating soil carbon under short rotation forestry energy crops in Britain. GCB Bioenergy (2014), doi: 10.1111/gcbb.12154

Edwards, P.N and Christie, J.M. 1981. Yield models for forest management. Forestry Commission Booklet. no 48. (1981).

Edwards-Jones, G., Plassmann, K., Harris, I M. 2009. Carbon footprinting of lamb and beef production systems: insights from an empirical analysis of farms in Wales. UK. J. Agric. Sci. 147, 1-13.

Forest Research http://www.forestry.gov.uk/website/forestresearch.nsf/ByUnique/INFD-633DXB

Hirschfeld, J., Weiß, J., Preidl, M., Korbun, T. 2008. Klimawirkungen der Landwirtschaft in Deutschland. Schriftenreihe des Instituts für ökologische Wirtschaftsforschung (IÖW), Berlin.

IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman, J et al (ed) (2003)

IPCC 2002 Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use. Eggleston, S et al (ed) (2006)

Janssens, et al. 2005. The carbon budget of terrestrial ecosystems at a country scale - a European case study. Biogeosci 2:15-29

Jones, D.L. and Emmett, B.A. 2009. Potential of soils and land use change to reduce greenhouse gas emissions from agriculture in Wales, draft report.
Lord (1992)

Khalil, M.I., Richards, M., Osborne, B., Williams, M. and Müller, C. 2013. Simulation and validation of greenhouse gas emissions and SOC stock changes in arable land using the ECOSSE model. Atmospheric Environment 81 (2013) 616-624

Lloyd, S.M. and Ries, R. 2008. Characterising, propagating and analysing uncertainty in Life Cycle Assessment: A survey of quantitative approaches. J. Industrial Ecol. 11, 161-179.

Lord, E. and Anthony, S. (2000) MAGPIE: A modelling framework for evaluating nitrate losses at national and catchment scales. Soil Use and Management, 16, pp. 167-174.

Lord, E. I. (1992) Modelling of nitrate leaching: Nitrate Sensitive Areas. Aspects of Applied Biology, 30 ,19-28.

Matthews, R., Chadwick, D., Retter, A., Blackwell, M. and Yamulki, S. (2010) Nitrous oxide emissions from small scale farmland features of United Kingdom livestock farming systems. Agriculture, Ecosystems and Environment, 136, 192-198.

Milne, R and Brown, T.A. Year. Carbon in the vegetation and soils of Great Britain. Journal of Environmental Management 49: 413 – 433.

Oenema, O., Velthof, G., Yamulki, S. and Jarvis, S. (1997) Nitrous oxide emissions from grazed grassland. Soil Use and Management, 13, S4, 288-295.

Poeplau C., Don A., Vesterdal L., Leifeld J., Van Wesemael, B., Schumacher J. and Gensior A. Temporal dynamics of soil organic carbon after land-use change in the temperate zone – carbon response functions as a model approach. Global Change Biology (2011) 17, 2415–2427.

Scholefield, D., Lockyer, D., Whitehead, D. and Tyson, K. (1991) A model to predict transformations and losses of nitrogen in UK pastures grazed by beef cattle. Plant and Soil, 132, 165-177.

Smith, P. and Smith, J. (2004) Review of the contributions to climate change (though greenhouse gas emissions) of fertiliser use on different soil types and through different application methods. Scottish Executive project ABRG: UEH/007/03, Final Report, 99 pp.

Smith, J.U., Gottschalk, P., Bellarby, J., Chapman, S., Lilly, A., Towers, W., Bell, J., Coleman, K., Nayak, D.R., Richards, M.I., Hillier, J., Flynn, H.C., Wattenbach, M., Aitkenhead, M., Yeluripurti, J.B., Farmer, J., Milne, R., Thomson, A., Evans, C., Whitmore, A.P., Falloon, P., Smith, P. 2010a. Estimating changes in national soil carbon stocks using ECOSSE-a new model that includes upland organic soils. Part I. Model description and uncertainty in national scale simulations of Scotland. Climate Research 45, 179–192.

Smith, J.U., Gottschalk, P., Bellarby, J., Chapman, S., Lilly, A., Towers, W., Bell, J., Coleman, K., Nayak, D.R., Richards, M.I., Hillier, J., Flynn, H.C., Wattenbach, M., Aitkenhead, M., Yeluripurti, J.B., Farmer, J., Milne, R., Thomson, A., Evans, C., Whitmore, A.P., Falloon, P., Smith, P. 2010b. Estimating changes in national soil carbon stocks using ECOSSE-a new model that includes upland organic soils. Part II. Application in Scotland. Climate Research 45, 193–205.

Smith, J., Gottschalk, P., Bellarby, J., Richards, M., Nayak, D., Coleman, K., Hillier, J.Wattenbach, M., Aitkenhead, M., Yeluripurti, J., Farmer, J. and Smith, P. 2010c. Model to estimate carbon in organic soils-sequestration and emissions (ECOSSE) user-manual. University of Aberdeen, UK, pp 1-76, 2010.

Sylvester-Bradley, R., Lunn, G., Foulkes, J., Shearman, V., Spink, J. and Ingram, J. 2002. Management strategies for high yields of cereals and oilseed rape. HGCA R&D Conference - Agronomic Intelligence: The basis for profitable production, Home-Grown Cereals Authority (2002).

Taylor, R.C., Jones, A. and Edwards-Jones, G. 2010. Measuring holistic carbon footprints for lamb and beef farms in the Cambrian Mountains Initiative. CCW Policy Research Report No. 10/8 © CCGC/CCW 8.

Taylor, R.C., Omed, H. and Edwards-Jones, G. 2014. The greenhouse emissions footprint of free-range eggs. Poultry Science 93, 231-237.

Taylor, R.C., Skinner, C., Jones, A., and Edwards-Jones, G. 2012. Chapter in Anthony et al. 2012. Assessment of the Contribution of the Wales Agri-Environment Schemes to the Improvement of Water Quality and the Mitigation of Climate Change (Welsh Government report).

Thomson, A., Fitton, N., Dinsmore, K., Billett, M., Smith, J., Smith, P. and Misselbrook, T. 2012. Scoping study to determine feasibility of populating the land use component of the LULUCF inventory. Final Report of Defra project SP1105 (2012).

van Groenigen, J., Kuikman, P., de Groot, W., abd Velthof, G. (2005) Nitrous oxide emission from urine treated soil as influence by urine composition and physical conditions. Soil Biology and Biochemistry, 37, 463-473.

Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo D.J. and Dokken D.J. (Eds.) (2000). SpecialReport of the IPCC on Land Use, Land-Use Change, and Forestry. Cambridge University Press, UK. pp375

Weiske, A., Vabitsch, A., Olesen, J.E., Schelde, K., Michel, J., Friedrich, R., Kaltschmitt, M. 2006. Mitigation of greenhouse gas emissions in European conventional and organic dairy farming. Agric. Ecosyst. Environ. 112, 221-232.

Williams, A.G., Audsley, E., Sandars, D.L. 2006. DEFRA Research Project IS0205. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Bedford: Cranfield University and DEFRA.

Wyn Jones, R.G., Taylor, R.C., Omed, H.M., Edwards-Jones, G. 2011. Climatic mitigation, adaptation and dryland food production. Proceedings of the International Dryland Development Commission (IDDC) Tenth International Conference on Dry Land Development.

Yamulki, S., and Jarvis, S. (2002) Short term effects of tillage and compaction on nitrous oxide, nitric oxide, nitrogen dioxide, methane and carbon dioxide fluxes from grassland. Biology and Fertility of Soils, 36, 224-231.