Environment and Rural Affairs Monitoring & Modelling Programme

ERAMMP Year 1 Report:
'Quick Start' Modelling (Phase 1) Technical Annex

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1.1	CB	23/10/2019	Corrected 2 author names/initials
1.2	BJC	24/04/2020	1. Added figures 4.7.4 and 4.7.5 – originally left out of annex; this completes the presentation of all diffuse pollution outputs. 2. Table 2.2.1 and 3.1.1 – modified RFT/MFT names/numbers to be consistent with main report. Information content was not changed. 3. Table 4.0.1 and the tables included in figures 4.4.1 and 4.4.2 were modified to replace the sector name “Beef” with the sector name “Grazers” when discussing potential conversions to non-agricultural uses. Results were not changed. 4. Figures were reformatted where necessary to improve legibility of labels and legends, and font size of figure legends was increased and standardised. Information content was not changed. 5. Tables were reformatted where necessary for uniformity of font size, bolding and shading, and font size of table legends was standardised. Information content was not changed. 6. This version history table moved to up one page. Blank page inserted. Pages renumbered.

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Abbreviations and some of the technical terms used in this report are expanded in the project glossary: https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

1 Appendix 1 – Model descriptions

1.1 Farmscoper (ADAS)

Summary

Farmscoper is a decision support tool that can be used to assess diffuse agricultural pollutant loads on a farm and quantify the impacts of farm mitigation methods on these pollutants.

The farm systems within the tool can be customised to reflect management and environmental conditions representative of farming across England and Wales. The tool contains over 100 mitigation methods, including many of those in the latest Defra Mitigation Method User Guide.

Model rationale and description

Farmscoper (Farm Scale Optimisation of Pollutant Emission Reductions; Gooday et al., 2014) is a pollutant modelling framework that allows for the assessment of the impacts of multiple mitigation methods on multiple pollutants at both farm and catchment scale. Within this project, the following pollutants were considered: Nitrate, Phosphorus, Sediment, Ammonia, Nitrous Oxide and Methane.

For water borne pollutants, Farmscoper incorporates outputs from a suite of models including the phosphorus and sediment model PSYCHIC (Davison et al., 2008) and the nitrate model NEAPN (Lord and Anthony, 2000). Modelled pollutant loads from these source models compare favourably with available water quality datasets such as those from the Harmonised Monitoring Scheme (Defra Project WQ0223; with adjustments made to account for inputs from non-agricultural sectors such as sewage treatment works).

Both the PSYCHIC and NEAPN source models and Farmscoper have been used for policy appraisal in England and Wales, with Farmscoper recently used in the assessment of the GLASTIR scheme (Emmett et al., 2017). The database of export coefficients that drive Farmscoper was produced by applying these source models to every 1km2 in England and Wales, with the results summarised by 6 climate zones and 3 soil types. Note that Farmscoper predicts long term annual average pollutant loads based on 1971-2000 climate data.

Gaseous emissions are derived from the methodologies used in the national inventories for ammonia (NARSES; Webb and Misselbrook, 2004) and nitrous oxide and methane (IPCC; Baggott et al., 2006), except that indirect emissions of nitrous oxide are calculated from the modelled nitrate losses rather than using the inventory approach. With the exception of these indirect emissions, the gaseous emissions are not affected by the physical environment (i.e. climate and soil type).

Farmscoper was used to calculate pollutant losses occurring for a range of different farm systems, disaggregated by farm type and farm size. Farm types were based upon the Robust Farm Type classification, but with LFA Lowland Grazing farms – which are the dominant farm type in Wales – further disaggregated by Main Farm Type. Farm size was based on definitions using the Standard Labour Requirement (SLR), with Large and Very Large farms combined as one category and Medium and Small farms as separate categories. All Very Small farms, irrespective of farm type, were grouped together.

With the exception of Specialist Pig and Specialist Poultry farms, the crop areas and livestock numbers for these farm systems were derived from the 2017 June Agricultural Survey data. For the Specialist Pig and Specialist Poultry farms, the area of the farm was irrelevant to how the outputs were used (see further below), so they were simply given sufficient land area to allow the manure generated by the livestock on the farm to be applied at a realistic rate (150 kg N ha-1). Crop specific fertiliser application rates were taken from the 2017 British Survey of Fertiliser Practice, using the rates for Great Britain disaggregated by farm type group. Where possible, other farm management data were based upon Welsh information (e.g. the Second Welsh Farm Practice survey undertaken as part of the Glastir Monitoring and Evaluation Project; Emmett et al., 2017), supplemented by data available for England and Wales.

Previous and ongoing applications

FARMSCOPER was originally developed under Defra project WQ0106. It was expanded under Defra Project SCF0104 to include additional pollutants and two new workbooks – one providing greater detail on the costs of mitigation method implementation, the other allowing the tool to be applied at catchment to national scale. Under Environment Agency funding, the catchment scale data has been updated to 2015, with data now included for a range of smaller spatial scales. New documentation on applying Farmscoper at smaller spatial scales is included in the installation package.

Documents and Guidance

Farmscoper and documentation is free to download from this website: http://www.adas.uk/Service/farmscoper

1.2 CARBINE (Forest Research)

Summary

CARBINE is an analytical model developed to address questions about the carbon and GHG balances of forestry systems, and to inform the development of forest policy and practice, particularly with regard to the goal of climate change mitigation. The CARBINE model is applied to a wide range of research questions, with examples including exploring the potential impact of establishing new areas of forest on land-based carbon stocks and sequestration.

The inputs to the model include the areas of different types of forest (tree species and growth rates), tree age distribution, soil class, selected meteorological data, land use prior to tree establishment, management prescriptions for forest areas (e.g. no harvesting or harvesting on a specified rotation) and a specification for how any harvested wood is utilised.

The outputs from CARBINE include annual estimates of changes in carbon stocks (rates of carbon sequestration) in forest areas over time, levels of wood and timber production (which can be broken down into specific wood product categories if required), the development of forest age class distribution over time, and changes in the species composition of forests in response to management interventions (where relevant).

CARBINE can also produce results for GHG emissions associated with woodland creation and management and GHG emissions potentially avoided by utilising wood products in place of alternative non-wood products such as fossil fuels replaced by wood fuel and steel and concrete replaced by structural timber. These latter outputs are strictly outside the system boundary for the ERAMMP project but may be of interest in some contexts.

CARBINE has been applied extensively to support policy development on forestry ad climate change by the UK and Devolved Administrations and also by the European Union. CARBINE has been applied to National GHG Inventory calculations for the UK LULUCF sector. In 2008 to 2010, CARBINE was applied in an international context on behalf of the UK Department of Energy and Climate Change (now Business, Energy and Industrial Strategy) to provide forestry projections for many countries in support of discussions amongst parties to the UNFCCC.

The CARBINE model has also been applied as part of a European Commission project to assess the carbon impacts of consuming biomass as an energy source, in the European Union. Most recently, the UK's National Forest Accounting Plan, prepared in compliance with a new EU Regulation (Regulation (EU) 2018/841) on LULUCF, and presenting the UK's "Forest Reference Level", was developed by Forest Research based on projections produced by the CARBINE model.

Model rationale and description

The general purpose of the CARBINE model is to address questions about the carbon and GHG balances of forestry systems, and to inform the development of forest policy and practice, particularly with regard to the goal of climate change mitigation. The CARBINE model is applied to a wide range of research questions, with examples including:

- What are the carbon stocks in a defined area of forest?
- What is the impact on land-based carbon stocks and sequestration of establishing new areas of forest on a defined area of land?
- What impacts do different silvicultural systems have on the development of carbon stocks and sequestration in a defined area of forest?

- What emissions and removals of GHGs should be reported for a defined area of forest, for the purpose of reporting GHG inventories under the UNFCCC?
- What contribution could a defined area of forest make towards meeting climate change mitigation targets (e.g. UK national targets)?
- What would be the impact on carbon stocks and sequestration of introducing a programme of regular harvesting for wood production in a forest area that previously was not subject to significant human intervention?
- What would be the impact on GHG emissions of changing the uses of harvested wood, for example, diverting the use of wood from use in timber products to use for bioenergy?

The CARBINE model also has the capacity to produce estimates of other variables not directly to do with forest carbon but of great relevance to decisions about forest management, for example:

- Levels of wood and timber production (which can be broken down into specific wood product categories if required)
- The development of forest age class distribution over time
- Changes in the species composition of forests in response to management interventions (where relevant).

To address the general purpose specified, the design of the CARBINE model draws on the ideas of systems analysis and, in particular, life cycle assessment (LCA) and its precursor energy analysis (Chapman, 1975; Boustead and Hancock, 1979; Socolow et al. 1994; Bringezu et al. 1997; den Hond, 2000; Rebitzer et al. 2004; ISO 2006:14040; ISO 2006:14044). An absolutely critical step in LCA involves clearly deriving the goal, scope and system boundary for LCA calculations from a clearly and unambiguously stated research question.

The example questions addressed by the CARBINE model, listed earlier, require the adoption of different system scopes and boundaries. Hence, the scope and system boundary of CARBINE are defined relatively widely (e.g. encompassing some elements outside of actual forests). However, the specific system boundary employed when using CARBINE (for the purposes of calculations and reporting of results) is flexible and can be adjusted (widened or narrowed) to match the requirements of the specific question being addressed.

For the Quick Start element of the ERAMMP project, the CARBINE model was used to produce a “data cube” of results for different types of woodland creation activity. The output results consisted of:

- Carbon sequestration in trees, litter, soil and any wood products derived from the new woodland
- Wood production from the new woodland (where relevant for the type of management)
- GHG emissions associated with woodland creation and management

- GHG emissions potentially avoided by utilising wood products in place of alternative non-wood products such as fossil fuels replaced by wood fuel and steel and concrete replaced by structural timber.

The last two types of results are strictly outside the system boundary for the ERAMMP project but were included in case of interest.

Results for the above variables were produced for three time horizons from time of woodland creation of 5, 25 and 100 years. This was necessary because the impacts of woodland creation vary considerably over time.

The results were classified according to combinations of the following input variables:

- Climatic zones characterised for Wales (see description of ESC model)
- Previous land use (arable or grassland)
- Soil class
- Selected tree species (see description of ESC model)
- Tree growth rate (as yield class, see Matthews *et al*., 2016a)
- Selected management regime (see description of ESC model)

The resultant data cube was then processed using ESC to provide spatially explicit estimates of the potential impacts of woodland creation on land-based carbon sequestration and levels of potential wood production, depending on the selected management objectives for the new woodland (see description of ESC model).

Results for existing woodland areas were also produced for the ERAMMP project. These were based on results underlying the most recent National GHG Inventory for the LULUCF Sector in Wales, to ensure consistency with GHG Inventory reports. The ESC model was used to allocate results for different forest types (e.g. coniferous and broadleaf) to spatial data on areas of existing woodland in Wales (see description of ESC model).

The inputs to the model include the areas of different types of forest (tree species and growth rates), tree age distribution, soil class, selected meteorological data, land use prior to tree establishment, management prescriptions for forest areas (e.g. no harvesting or harvesting on a specified rotation) and a specification for how any harvested wood is utilised.

The outputs from CARBINE include annual estimates of changes in carbon stocks (rates of carbon sequestration) in forest areas over time, levels of wood and timber production (which can be broken down into specific wood product categories if required), the development of forest age class distribution over time, and changes in the species composition of forests in response to management interventions (where relevant).

CARBINE can also produce results for GHG emissions associated with woodland creation and management and GHG emissions potentially avoided by utilising wood products in place of alternative non-wood products such as fossil fuels replaced by wood fuel and steel and concrete replaced by structural timber. These latter outputs are strictly outside the system boundary for the ERAMMP project but may be of interest in some contexts.

Previous and ongoing applications

The CARBINE model was first developed by the Research Division of the Forestry Commission (now Forest Research) in 1988 (Thompson and Matthews, 1989), and has been in continuous development ever since (Matthews, 1991, 1994, 1996; Morison et al., 2012). CARBINE has common features of structure and functionality with other analytical forest sector and forest carbon accounting models, notably EFISCEN (Schelhaas et al., 2007), C-Flow (Dewar, 1990, 1991; Cannell and Dewar, 1995), CO2FIX (Mohren and Klein Goldewijk, 1990; Nabuurs, 1996; Mohren et al., 1999), CBM-CFS (Kurz et al., 2009), C-change (Beets et al., 1999) and GORCAM (Marland and Schlamadinger, 1995, 1999; Schlamadinger and Marland, 1996). Studies comparing CARBINE and C-Flow (the other main forest carbon accounting model developed in the UK) revealed many similarities and consistencies in the functioning and results produced by the two models (Robertson et al., 2003; Matthews et al., 2014).

CARBINE has ultimately developed into a national-scale scenario analysis tool and has been used to assess the impacts of current and alternative forestry practices on greenhouse gas balances in Great Britain and the United Kingdom (Matthews and Broadmeadow, 2009). CARBINE has been applied to National GHG Inventory calculations for the UK LULUCF sector, taking over from the C-Flow model in 2014 (UK Greenhouse gas Inventory, 1990-2013: Annual Report for submission under the Framework Convention on Climate Change). The application of CARBINE has permitted a more complete and refined representation of Forest Land within the UK's LULUCF GHG Inventory. In 2008 to 2010, CARBINE was applied in an international context on behalf of the UK Department of Energy and Climate Change (now Business, Energy and Industrial Strategy) to provide forestry projections for many countries in support of discussions amongst parties to the UNFCCC. The CARBINE model has also been applied as part of a European Commission project to assess the carbon impacts of consuming biomass as an energy source, in the European Union (Matthews et al., 2015). Most recently, the UK's National Forest Accounting Plan (BEIS, 2019), prepared in compliance with a new EU Regulation (Regulation (EU) 2018/841) on LULUCF, and presenting the UK's "Forest Reference Level", was developed by Forest Research based on projections produced by the CARBINE model.

Documents and Guidance

In terms of documentation, the CARBINE model has been described and discussed in a number of papers (Thompson and Matthews, 1989; Matthews, 1991, 1994, 1996; Robertson *et al.*, 2003; Matthews and Broadmeadow, 2009; Morison *et al.*, 2012). The development and improvement of the model has been a significant exercise covering many years and the publication of a complete description of CARBINE is due for completion this year (Matthews *et al.*, 2019).

Quality Assurance

Version control of the CARBINE model is handled by storing the current and previous versions in the GIT version control system.

The source code for CARBINE is controlled by logging bugs, requests for change and any consequent code changes in the Bugzilla system.

1.3 ESC (Forest Research)

Summary

Ecological Site Classification (ESC) is a knowledge-based forest classification system that has been developed as a model to assist in forest tree species selection. ESC determines species suitability and potential stand yield (m3 ha-1 yr-1) at a given site location. The model evaluates six environmental factors (four climatic variables and two soil variables, Pyatt et al., 2001), with the limiting factor determining the suitability for each species at each site. Potential stand yield is calculated as the suitability score (value between 0 and 1) multiplied by the species' potential maximum yield class in Britain. Here we assessed suitability for nine species classes across Wales at a resolution of 250 m.

For each 250 m pixel the most productive species in three different forest types in 2020 was selected for the simulation. The forest types considered were: productive conifers (Picea sitchensis, Pseudotsuga menziesii, Pinus sylvestris), native broadleaves: (quercus, fagus sylvatica, populus, betula), short rotation forestry (Picea sitchensis, Alnus rubra, populus).

In addition to the three forest types, the impact of five different management types are considered; two each for productive conifers and native broadleaves and one for Short rotation forestry: productive conifers (thinning/clearfell and continuous cover forestry), native broadleaves (amenity with no thinning or clearfell and production under continuous cover forestry) and short rotation forestry. The management type impacts the recreation and biodiversity indicators and carbon values.

The most productive species, modelled yield class, forest type and management type were used to look up values for recreation and biodiversity indicators, and, in addition to soil class and climate zone, to look up carbon values in CARBINE.

Model rationale and description

Ecological Site Classification (ESC) is a knowledge-based forest classification system that has been developed as a model to assist in forest tree species selection. ESC determines species suitability and potential stand yield (m3 ha-1 yr-1) for over 50 species at a given site location. The model uses six environmental factors (four climatic variables and two soil variables) which are provided as inputs for each site. These are: accumulated temperature (degree days above 50C), moisture deficit (mm), wind exposure (DAMS score), continentality (Conrad index), soil moisture regime (index), and soil nutrient regime (index); further information about these factors can be found in Pyatt et al., (2001). Species suitability is based on tree response curves to each of the six environmental factors, with the limiting factor determining suitability at each site. Potential stand yield class is calculated as the suitability score (0 - unsuitable to 1 - very suitable) multiplied by the species maximum potential yield class in Britain.

The environmental inputs for ESC were calculated as follows:

- The dataset of accumulated temperature (defined as degree days above 50C) was derived from the 11-member RCM A1B data from 2009 by calculating mean values over 20-year periods. A similar approach was applied to climatic moisture deficit which is the annual maximum value of the accumulated monthly excess of evaporation (Et0) minus precipitation (P) through in the growing season (April to September, inclusive). The climatic data were downscaled from Met Office gridded data and UKCP09 projections using an environmental lapse rate adjustment for AT have been generated to provide coverage of Britain with downscaling to 250 m x 250 m pixels.
- Continentality and exposure were assumed to be static in future climates so the baseline datasets from the ESC model were used. All data were interpolated to 250 m x 250 m using a 50 m resolution digital elevation model from the Ordnance Survey.
- The soil attributes of Soil Moisture Regime (SMR) and Soil Nutrient Regime (SNR) were derived from the properties of the dominant soil type as identified in the Cranfield dataset (1:250,000), and within which higher resolution Forestry Commission Soil Maps were overlaid, then sampled to create 250 m x 250 m raster datasets. Those data were assumed to be static under climate change. Using the expert opinion of FR soil surveyors, the major soil sub-groups of the National Soil Surveys of England and Wales (Cranfield) and Scotland (JHI) were converted to soil quality units of SMR (8 classes) and SNR (5 classes).

ESC suitability values were calculated for eleven species: *Alnus rubra*, *Betula pendula, Betula pubescens, Fagus sylvatica, Populus nigra, Populus tremula, Quercus robur, Quercus petraea, Picea sitchensis, Pinus sylvestris, Pseudotsuga menziesii.* When two species within the same genus (e.g. *Betula* (birch) and *Quercus* (Oak)) were present in a forest type the most suitable species was taken as indicative of site potential for the genus, on the basis that forest managers would make their silvicultural decisions according to similar principles.

For the three forest types we used the following tree species:

- Productive conifers: Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii*), Scots pine (*Pinus sylvestris*)
- Native broadleaves: oak (*Quercus*), beech (*Fagus*), aspen (*Populus*), birch (*Betula*)
- Short rotation forestry: Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), poplar (*Populus*)

For each 250 m pixel the most productive species from each forest type in 2020 was selected for the simulation for that and future time periods. In addition to the three forest types, we simulated five different management types, two each for productive conifers and native broadleaves and one for short rotation forestry:

- Productive conifers (thinning/clearfell)
- Productive conifers (continuous cover forestry/low impact silviculture system)
- Native broadleaves managed for amenity (no thinning/clearfell)
- Native broadleaves managed for production (continuous cover forestry/ low impact silviculture system)
- Short rotation forestry.

The outputs for the most productive species in 2020, yield class, forest type and management type were used to look up values for the recreation and biodiversity indicators and carbon values in CARBINE.

For the ERAMMP model pipeline, ESC provided a suitability index identifying the most productive species in each of three forest types and five management types for each 250m pixel. The tree species category (broadleaf/conifer), forest type, management type, yield class estimate, climate zone, soil class and species was were used to assign properties generated from CARBINE to index outputs over time.

Previous and ongoing applications

The ESC model was developed in the 1990s and has been widely tested by the forest sector and research community. The ESC decision support tool (ESC-DSS), now in version 4, is available for operational use to support the selection of appropriate tree species for a site and is regarded by the forest sector and research community as the leading resource when used with local expertise and accurate site information. The ESC model has been used for strategic level assessments for current and future tree species suitability and ecosystem service provision (Beauchamp et al., 2014; Ray et al., 2015, 2017).

Documents and Guidance

Guidance documents for ESC can be found in Bulletin 124 (Pyatt *et al.,* 2001), the ESC-DSS Manual and tutorial videos, which are available on the Forest Research website (www.forestresearch.gov.uk) and Forest Research's Decision Support Gateway (www.forestdss.org.uk/geoforestdss/esc4m.jsp).

Quality Assurance

The Ecological Site Classification decision support tool is version controlled and currently running version 4. Updates are documented at www.forestdss.org.uk/geoforestdss/updates.jsp.

For strategic applications ESC is implemented as an R script, following the same version control; no changes are made to the source code without documentation. For this analysis ESC version 4 was used.

1.4 ORVal (eftec)

Summary

Recreation values are based on modelling of known patterns of recreation in England and Wales, through the ORVal tool (http://www.exeter.ac.uk/leep/research/orval/). The modelling uses long-term Government survey data, and established welfare valuation approaches.

It should be noted that work in other parts of the UK suggests that cost savings to the NHS as a result of the physical activity supported through this recreation are usually at least ¼ of the magnitude of these welfare values.

Model rationale and description

The recreation resource for each test area is measured in terms of public footpaths and accessible open space. The ORVal tool uses national survey data (GOV.UK, 2014) to model households' behaviour in terms of their choices to visit there recreation areas. The visits are valued based on the value of individuals' time spent participating in the outdoor recreation. This cost of time approach is the same as that used by the Department for Transport to value time savings from transport projects (DOT, 2017) as part of assessments as to whether those projects should be supported by Government.

ORVal sums the value of all recreational visits estimated by the model to estimate the value of each footpath or accessible open space. The values of these recreational areas are summed by the tool according to administrative boundaries (e.g. Local Authorities). These values are used to estimate the baseline value in the land management scenario test areas.

The approach to estimating the public goods impacts of Brexit calculates the amount of land which would become potential recreation land with proximity (2km) to existing urban areas in each test area. Recreation value of accessible open space is mainly determined by the number of people living nearby and availability of local alternatives (or 'substitutes'). Access facilities (e.g. toilets, good paths), and other features (such as the diversity and quality of habitats) can also be important. In general, the land type (i.e. the peri-urban woodland or grassland) is a secondary factor, so it is not about it being a woodland, but its value comes from being accessible land (whatever the habitat is). The exception to this is restored peatland, as there is uncertainty as to whether this habitat can also support significant recreational use. Therefore, no recreational value has been attributed to peatland restoration areas.

Increases in recreation values from the land management scenarios modelled have been capped due to known saturation of values. The cap has been set, based on expert judgement, at 10% of the current value in the test areas if the area of recreational land within 2km of urban areas increases to by up to 100%, and at a maximum 20% if above a 100% increase.

Leisure and tourism is not included in the valuations from ORVal. Methods are available to measure tourism and leisure expenditure associated with ecosystems, and are being further refined in current work for the UK national accounts. However, estimating these impacts is highly uncertain at a Wales level. This is because any assessment of increased spend in a particular location will struggle to determine if has identified a net increase, or spending displaced from elsewhere in Wales.

Uncertainties and assumptions

- This is one of the most location dependent benefit of all benefits valued to date but is driven by the focus on peri-urban values only for now. Note values do not relate to new woodland area only. Value is derived from any land (except peatland) assumed to be made available for public access. The variation between study areas is related to the urbanisation of the case study area.
- This public good relates to new publicly accessible land (peri-urban only) taken out of agriculture within 2km of urban areas but with no current footpaths or access points (potential for recreation with investment). It assumes land no longer in agricultural use is not put to other productive use and becomes accessible for recreation (either by default or deliberate intervention).
- Its additional value will depend, inter alia, on the size of the nearby population, and the extent of existing recreational areas that population has access to, and other characteristics of the land (e.g. surrounding land, habitat type, slope, ease of access, local culture around using land for recreation). These factors can only be thoroughly investigated with more detailed modelling.
- The marginal impact of additional recreational space would be expected to have diminishing returns. This has been reflected by the use of a cap of +10-20% of current value: (a) new area 0-100% of ORVal RA, new area value = 10% ORVal RV; (b) new area > 100% ORVal RA, new value = 20% ORVal RV.
- The value of the trips is based on the cost of time for those participating in the recreation. Note: the UK Government Office of National Statistics current approach to valuing recreation for the national accounts only uses transport and entrance fee expenditures. Since most recreational activity is free, the ONS method therefore results in significantly lower values than those estimated in ORVal.
- These visitor/value figures include visits by adult local residents and non-local UK residents. It excludes visitors from overseas and children (so are an underestimate).

- Note that even though we are controlling for proximity to urban areas, the local distribution of the new resource (especially in a large area like Heads of Valley) will matter but there has been insufficient time to explore this.
- Any newly accessible land is unlikely to be evenly spatially distributed. Area which becomes accessible can be greater than land use change in the scenario since sub-field level changes are assumed to make the whole field accessible.

Previous and ongoing applications

ORVal has been subject to testing with Government and received funding from Defra to refine the modelling to create the current version. Its results have been extensively used in public policy discussions in England. ORVal featured in the Government's 25 Year Environment Plan where the government commit to: "*Continuing our ground-breaking work with Exeter University to update the world-leading Outdoor Recreation Valuation Tool (ORVal) in 2018*."

The tool has since been recommended in the Green Book (HMT, 2018) Central Government Guidance on Appraisal and Evaluation:

"*A2.13 The recreational value of the natural environment varies with the type of habitat, location, population density and the availability of substitute recreational opportunities. The University of Exeter has developed a map-based web interface which captures these complexities. The Outdoor Recreation Valuation (ORVal) Tool uses a range of spatial data layers to model the visitation rates and recreational welfare benefits that are provided by accessible green space in England and Wales. The ORVal Tool allows users to explore existing recreational values of individual or multiple sites as well as the welfare effects of creating or altering sites. It is relevant for national and local appraisals where outdoor recreational opportunities are likely to be affected*."

Documents and Guidance

Available on the ORVal website: https://www.leep.exeter.ac.uk/orval/

Quality Assurance

It's quite hard to QA specific uses, other than by expert judgement, but the model has been extensively tested.

1.5 Bird abundance and diversity model (BTO)

Summary

The BTO Bird models is based around modelled relationships between bird abundance captured with the BTO/JNCC/RSPB Breeding Bird Survey (BBS) and land use in 1km squares using a range of national sources of data. The model is a new model developed to meet the ERAMMP Quick Start requirements although similar approaches have been developed before by BTO.

Model rationale and description

The amount of different land use types within 1km squares were developed using a range of national datasets including; CEH Landcover map 2015, CEH Woody Cover Product, EA's Detailed River Network and ERAMMP Quick Start Robust Farm Types maps (RFTs).

Baseline models were fitted by BTO between bird data in BBS monitoring squares and current land use data using generalised linear models with Poisson error structures. Fixed effects included different land use and field types, total length of rivers, proportions of a range of broad habitats and farming RFTs.

Five years of data (2013-2017) was used to reduce stochasticity in counts of all species. Only species present in at least 30 1km grid squares were selected as this is a standard threshold for producing bird trends using BBS data.

Scenario runs were then run using the *Predict* function in R with changed amounts of RFT and woodland. Projections were made for BBS survey squares and all 1km squares in Wales. The latter provide less reliable results as projections may be outside the range of survey data used to build the models.

Output data was converted to total abundance values and diversity calculated using the Simpson's Diversity Index. Differences were compared using ANOVA tests and post-hoc Tukeys' test.

Results are presented for species listed as:

- Woodland (n=25)
- Farmland (n=9)
- Water and wetland (n=5)
- other (n=15)

The level of conservation concern ('amber' or 'red') is also provided.

As with all modelling approaches, there are limitations to the approach which need to be understood. These include:

- All land-use changes are likely to benefit some species and to have negative effects on others. It is simplistic to refer to such changes as being "good" or "bad" for wildlife or biodiversity in general. Moreover, there are likely to be other effects of Brexit on wildlife that are not directly linked to changes in farm types; for example, following Brexit, some environmental legislation may be lost or weakened (e.g. implementation of legislation through agreements such as RAMSAR and the Habitats Directive)(Welsh Gov., 2018). As such, results presented here only provide very crude predictions.
- Diversity indices reflect patterns of relative abundance across species and can be increased by increases or reductions in particular component species, depending upon their initial dominance within the community. In addition, a lack of change in an index can mask turnover of component species whereby the balance of numerical abundances in an area changes less than the abundances of individual species. These points need to be considered while interpreting diversity index results.
- The abundance and diversity estimates in this study are derived from raw BBS count data, which describe relative abundances within species and are not, strictly, comparable between species. This is because species vary in their detectability, both absolutely and in respect of the variation in detectability with distance from the observer. Hence, the estimates of bird population sizes provided do not represent total numbers but, rather, numbers detectable from BBS transect surveys through a 1-km square. This means that populations of more cryptic or quieter species, those with less detectable females and those found in habitats with poorer visibility and/or around transmission will have been under-estimated. However, given that most species are consistent in terms of habitat selection and the proportion of their populations that is detected can be assumed to be constant, this under-estimation will not cause bias in estimates of population change. It does, however, mean that the diversity indices that have been calculated here should only be regarded as indicative, because they depend upon estimates of absolute numbers, which are not equivalent between species (for example, a count of four mute swans is more likely to be close to the real, total number present than a count of four wrens, which is likely to reflect four singing males and an unknown number of females and birds that were more distant and not detected).

<u>Documents and Guidance</u>

ERAMMP sub-reports are available which documents the method and outputs in more detail (Kettel and Siriwardena, 2018a,b).

<u>Quality Assurance</u>

The method uses well-tested software and statistical approaches which have been reported in the peer-reviewed literature

1.6 Biodiversity Tool (CEH)

Summary

This approach uses existing spatial datasets on biodiversity to create a map of Wales with biodiversity scores which account for a wide range of taxa at both plot and landscape scales.

Model rationale and description

The approach aims to give equal weighting to a range of species and taxa, rather than focussing on species of interest to certain stakeholders or locally rare species. The importance of SSSIs and other designations has not been overlooked, these data have been extracted separately.

By ranking Wales from high to low at the resolution of a 1km grid, condition can be compared across metrics with different units, measured at different scales; in this species richness, habitat diversity and appropriate species diversity. This approach does not enable consideration of the relative importance of these different metrics, or the implications of their scaling. Further, it does not inform on whether abandonment of agricultural land would be beneficial for the existing biodiversity

This approach was previously used for the Defra SIP project as the Dynamic Typologies Tool, which combined data on over 100 environmental, social and economic indicators at 10km to assess condition and potential for sustainable intensification. https://eip.ceh.ac.uk/apps/sustainable-intensification/#

The data have been downscaled to 1km and combined and ranked in an updated tool for Wales, which has not been released. Here we have extracted only the datasets which directly relate to biodiversity.

Spatial datasets relating to biodiversity were aggregated to a 1km grid and combined and ranked from high (good biodiversity) to low (little current biodiversity) across wales, to create a rank for each 1km grid square. These data were then extracted to land which may come out of agriculture under the Brexit land use change scenarios, to assess potential benefits to biodiversity if this land was to be re-wilded.

There are no units as data are a rank from 0 (lowest) to 21822 (highest)

Where squares have the exact same value, the ranking assigns them all the same rank as the lowest, hence values do not go up to 21822 for most of the datasets

The biodiversity datasets used here were:

1. Total species richness. This was based on a wide range of taxa at national scale from multiple volunteer recording schemes at 10km: data on Bees, Birds, Plants, Bryophytes, Butterflies, Carabidae, Hoverflies, Isopoda, Ladybirds, Moths and Orthoptera were combined with equal weighting then ranked. Recorder effort is accounted for using the Frescalo method developed by Hill (2012) and the data sourced from the Biological Records Centre. Positive weighting on this dataset enables identification of areas of high biodiversity
2. Habitat diversity: An indicator of structural diversity (but in some cases may be negative indicating fragmentation). Number of unique habitats in each 1km square based on Land Cover Map 2007. Positive weighting on this dataset enables identification of areas of high biodiversity.
3. Count of CSM Positive Species indicators: This metric defines the abundance of desirable plant species in British habitats. Appropriate plant diversity is intended to cover diversity of the wider countryside, to help identify where habitats may be isolated restricting movement of fauna, or where low plant diversity may limit ecosystem resilience as well as faunal species richness. The critical issue is the constraint of ‘appropriate’ biodiversity only, since species richness can be a sign of damage in some habitats. Positive weighting on this dataset enables identification of areas of high biodiversity.

1.7 Air quality PM2.5 model (CEH)

Summary

The modelling approach is based on calculated removal rates of the pollutant PM2.5 by woodland based on outputs from a large-scale atmospheric chemistry transport model called EMEP4UK using an approach developed for the UK (Jones et al. 2017). These removal rates are then converted to total health value based on a reduction in exposure to PM2.5 concentrations involving estimates in change of Respiratory Hospital Admissions, Cardiovascular Hospital Admissions and Life Years Lost using the AlphaRiskPoll model (see also section 1.10 below).

Model rationale and description

The benefits of trees in removing air pollution have been widely discussed, and large health benefits attributed to them (Nowak et al. 2014; Rogers et al. 2015). They have also been contested as relatively small in magnitude, only achieving large economic value as a result of upscaling to a large benefitting population (Whitlow et al. 2014). Recent work in the UK, conducting a more sophisticated methodological approach using the atmospheric chemistry transport model EMEP4UK, has calculated the benefit of all vegetation in the UK being considerable, with the value of health benefits of approximately £1billion in 2015 (Jones et al. 2017). That study also showed that the average reduction in PM2.5 concentrations due to the presence of all vegetation in the UK was 10%, compared with studies in the literature which have primarily focused on urban vegetation only showing reductions in PM concentrations < 1% (Nowak et al. 2013).

Drawing on the approaches and data produced in the study by Jones et al. (2017), the same modelling approach was adapted for the three ERAMMP Quickstart test areas for land management scenarios to provide an initial rapid assessment of the potential health benefits of increased woodland planting.

Some basic assumptions and uncertainties should be noted, these include:

- Removal rates of PM2.5s vary between test study sites due to initial pollution concentrations, the spatial location of woodland in relation to pollution concentrations, as well as interactions among other pollutants and meteorology in the original model runs which were run at a 5x5 km resolution.
- It should be noted the greatest economic health value (90%) is associated with Life Years Lost.
- The test study areas do not map exactly to local authority boundaries used for calculations. These used the best fit of clusters of local authorities for each test study area.
- It is assumed that changes in pollution concentrations due to the action of vegetation within a local authority is greater than effects of vegetation outside of the local authority.
- In this quick assessment, it was assumed there is no spatial variation in pollution concentrations, woodland and benefitting population within a local authority. Methods are available to do this sub-test area analysis but insufficient time was available for this initial quick rapid assessment.

<u>Previous and ongoing applications</u>

The approach was developed for the UK and published in the peer review literature (Jones et al. 2017)

<u>Documents and Guidance</u>

An ERAMMP sub-report is available with more information (Jones et al., 2018).

<u>Quality Assurance</u>

EMEP4UK (Vieno et al. 2016) is based on the widely used EMEP model used at European domain and increasingly at a global domain for predicting pollutant transport (Simpson et al. 2012). EMEP4UK model runs are validated against measured air pollution monitoring locations within the UK.

The AlphaRiskPoll model is based on WHO and COMEAP agreed relationships between individual air pollutants and health outcomes. It uses existing mortality and morbidity data from local authorities to calculate the additional burden due to increases or decreases in air pollution concentrations.

1.8 Economic valuation of carbon (eftec)

Summary

The expected changes in carbon emissions have been valued according to latest Government Guidance, adopting the non-traded price of carbon (BEIS, 2013), which escalates from £68 in 2020 (the baseline year) to £319/tonne in 2095. Values are in 2020 prices, and present values are calculated over 75 years using HM Treasury recommended discount rates.

Model rationale and description

This is an established valuation approach across the public sector in the UK, and is widely used in policy analysis and decision-making across Government departments.

1.9 Economic valuation of water quality risks (eftec)

Summary

The modelling identifies expected increases in emissions of pollutants that create pressures on water body chemical status as defined under the Water Framework Directive. The modelling cannot predict whether these increased pressures will actually cause a deterioration in status. Therefore, the analysis identifies the risk of deterioration, defined where there is a certain % increase in a pollutant that is already known to be a pressure on the receiving water body.

Deterioration in water body chemical status is valued using the NWEBs values for water framework directive status. The values represent an estimate of the costs of potential reductions in water body status as a result of the agricultural changes modelled.

Model rationale and description

Water framework directive implementation widely adopts a risk-based approach. As the project's modelling cannot yet predict exact changes in water body status, valuing the risk of deterioration was seen as a suitable measure of policy impacts.

There are also areas where pressures on waterbodies will decrease and water framework directive status may improve. This has not been valued, partly because if factors other than chemical status (e.g. morphology) are determining status, the Directive's 'fail one fail all' criteria would mean status would not change.

Previous and ongoing applications

The NWEBs values have been extensively used in UK implementation of the water framework directive over the last decade. For example, they are used to value the impacts on water body status as part of the Environment Agency's cost benefit analysis of water company investment plans in England.

Documents and Guidance

The benefit represents the value of avoiding deterioration from a given status and is based on the National Water Environment Benefits Survey (NWEBS) values (Metcalfe, 2012).

Quality Assurance

The model providing the NWEBs values has been subject to peer review for publication and through its use in multiple Government publications.

1.10 Economic valuation of air quality (PM2.5) health effects (Alpha Risk Poll)

Summary

The AlphaRiskPoll model estimates impacts of changes in air quality, based on the damage cost per unit exposure. It calculates the economic benefit directly from mortality and morbidity data for each local authority in the UK, and the change in pollutant exposure of the receiving population, separated into two components:

- The health benefit arising from the service of air pollution removal
- The monetary account of that health benefit

Model rationale and description

The quantification of short term impacts on mortality and on hospital admissions is a straightforward multiplication of population weighted concentrations, population, rate of illness and response function. Quantification of long term impacts on mortality instead uses a life table approach (COMEAP, 2010). Life tables describe the structure of the population, accounting for inputs (births and immigration) and outputs (deaths and emigration). Changes in the risk of mortality (calculated by combining pollution data and response functions) affect the number of people moving from one age class to the next in successive years. Deaths from non-natural causes, 3.1% of all UK deaths (PHE, 2019), are excluded from the analysis. Health functions and values used are summarised in Table 1.1.1.

Table 1.1.1. Mortality and morbidity functions used in the evaluation of health benefits.

		Change in risk per 10 µg/m3	**Age group**	**Rate per person**	**Value, £ (2012)**	**Source**
PM2.5	Respiratory hospital admissions	1.09%	All age	0.01139	6,650	Atkinson et al. 2014
	Cardiovascular hospital admissions	0.91%	All age	0.01300	6,450	Atkinson et al. 2014
	Life years lost (as a result of long-term exposure)	6.00%	All [1]	1.00000	35,000	COMEAP 2010
SO2	Respiratory hospital admissions	0.50%	All age	0.01139	6,650	Defra, 2013
NO2	Respiratory hospital admissions	0.52%	All age	0.01139	6,650	Mills et al. 2016
	Cardiovascular hospital admissions	0.42%	All age	0.01300	6,450	Mills et al. 2016
	Life years lost (as a result of long-term exposure)	0.92%	All [1]	1.00000	35,000	COMEAP 2017
O3	Respiratory hospital admissions	0.75%	All age	0.01139	6,650	COMEAP 2015 ozone
	Cardiovascular hospital admissions	0.11%	All age	0.01199	6,450	COMEAP 2015 ozone
	Deaths (as a result of short term exposure)	0.34%	All age [2]	0.00915	6,000	COMEAP 2015 ozone

1 % change fed into life tables to generate adjustment factor
*2 Calculated as £18,000 per life year * 4 months/ death*

‘Life years lost’ is calculated from the life tables as the aggregate loss of life expectancy attributable to pollution exposure. Unlike QALYs (Quality Adjusted Life Years), it is not weighted for health status in any way (unlike ‘quality adjusted life years’). Valuation data are taken from Defra recommendations. Mortality and hospital admissions are valued from the perspective of willingness to pay, drawing on an earlier study by Chilton et al (2004) for Defra. For ozone, deaths are valued at £6,000 (2012 price), calculated by assuming that each ozone related death leads to the loss of (on average) 4 months of life, using a VOLY (Value Of Life Years) of £18,000 assuming that those affected are already in poor health. Life years lost associated with exposure to PM2.5 and NO2 are valued at £35,000 (2012 price), assuming those affected are in ‘normal health’.

Data on incidence and prevalence of disease

Data on mortality rates were taken from national statistics, providing data on the number of deaths for 2015 from national statistics. Data on UK incidence of hospital admissions was taken from WHO’s European Hospital Morbidity Database (WHO, 2019). Data on the variation in hospital admissions around the country, by Local Authority, were taken from work carried out by the British Lung Foundation (BLF, 2017). The BLF study focused on respiratory hospital admissions, but it was assumed here that the same pattern of disease applies also to cardiovascular admissions. Population data were obtained from official statistics for England, Wales and Scotland.

Previous and ongoing applications

The approach was developed for the UK and published in the peer review literature (Jones et al. 2017)

Documents and Guidance

An ERAMMP sub-report is available with more information (Jones et al., 2018).

Quality Assurance

The AlphaRiskPoll model is based on WHO and COMEAP agreed relationships between individual air pollutants and health outcomes. It uses existing mortality and morbidity data from local authorities to calculate the additional burden due to increases or decreases in air pollution concentrations.

2 Appendix 2 - Baseline farm-level maps

This work was carried out by CEH and ADAS.

The ERAMMP Quick Start project requires a farm-level dataset where each farm is allocated to a Robust Farm Type (RFT), and a Standard Labour Requirement (SLR)-based size class. Data was received for the 2017 June Agricultural Survey (JAS) for Wales, and the Land Parcel Identification System (LPIS) data for Wales for 2017. Two auxiliary tables allowed a linkage between LPIS polygons and the JAS to be made, in principle. The JAS is a large sample survey of around 38,000 farms. Around 25% of farms make a return annually, and the year of last return was recorded in the survey data received.

When considering the linkage between the survey records and LPIS, there were just over 20,000 records in the agricultural survey for which no match could be established with the field-level data. The majority of these are small farms of less than 5 ha, however there were 1,033 farms >100ha.

2.1 Methodology for deriving linked datasets

A final farm level dataset based on the LPIS parcels linked to the JAS dataset was developed using the following steps:

1. Parcels included in the Common Land Register were excluded from further analysis.
2. Using the Less Favoured Area (LFA) boundaries, all parcels were allocated to a single LFA status – “None”, “Disadvantaged Area” (DA), and “Severely Disadvantaged Area” (SDA).
3. Where a direct match between LPIS and the agricultural survey data existed, the data were joined.
4. Those parcels in LPIS for which no Customer Reference Number existed were allocated to the Robust Farm Type ‘Other’ with a size definition of ‘Very Small’. Since no other information existed about these parcels, it was felt they were not likely to represent larger, active agricultural holdings. Since over 14,000 of the 20,000 census records that were not matched to LPIS were records of ‘Other’ farms, and over 18,000 of the mismatched farms had a Standard Labour Requirement (SLR) of < 0.5 FTE, this was deemed appropriate.
5. The remainder of the parcels that could not be matched to the survey returns had a Customer Reference Number, and for each CRN a total land area could therefore be calculated using the IACS area of each parcel. The CRN was then linked to the most appropriate census return as follows:
    a. The unlinked LPIS CRNs, with their land area, were sorted by Small Area number and by the reverse of their land area, so that the largest farm in each Small Area was highest in the list.

   b. A script was used to go through each of these records in turn, and allocate a survey return that matched this land area most closely. The absolute difference was used to define this match, so that the allocated return could be either over- or underreporting the total land area where an exact match was not found.
   c. If the CRN had land in more than one Small Area, the survey return that matched most closely across all Small Areas the land occurred in was used.
   d. The LFA status of these CRNs was defined by the location of the majority of the land area in LPIS. CRNs with an LFA status of ‘SDA’ or ‘DA’ could not be allocated a farm type of ‘lowland beef and sheep’, and where the majority of the land was outside of the LFA the CRN could not be allocated a farm type of ‘LFA beef and sheep’.
   e. No unmatched survey return was used more than once in this process, ensuring that each CRN was allocated a unique survey return.
6. Finally, the RFT category ‘LFA beef / sheep’ was further subdivided into the main farm types ‘Specialist Beef’ (12), ‘Specialist Sheep’ (11) and ‘Mixed / Various’ (13 and 14), based on the standard output coefficients for Wales, 2010. All LFA Beef and Sheep farms that were in a Disadvantaged Area were classed as ‘Mixed / Various’. Where the original linkage with the raw census data had caused such a farm to be linked to a holding that had most of its land outside of the LFA, this was honoured and the MFT was also classed as ‘Mixed / Various’. Inside the Severely Disadvantaged Areas, a farm was classed as ‘Specialist Beef’ if over 2/3 of its livestock income was derived from beef animals, and ‘Specialist Sheep’ if over 2/3 of its livestock income was derived from sheep. Where there was no such clear dominance of one enterprise over another it was classed as ‘Mixed / Various’

There are limitations to the use of the data that has been derived using this process, and they are set out below point by point.

1. The data are more inaccurate for some farm types than for others.

   The total areas are significantly different between LPIS and agricultural survey for certain farm types. If a modelling exercise focuses on one of these farm types, this must be taken into account.

2. The data are locally inaccurate.

   While the total area held within the linked database matches that of the agricultural survey reasonably well, there is variability in how well the census matches the LPIS polygons. This is caused by a combination of areas rented in and out, inaccuracies in the linkages of census to LPIS, multiple holdings reporting to a single central holding in the survey, and out-of-date information held in the survey database.

   The consequence of this is that the data SHOULD NOT be used to make a direct linkage to the LPIS polygons and the census returns in order to map absolute areas. Rather, rates and proportions (e.g. cattle per ha, proportions of different crops) should be derived from the census records, and these should be linked to the absolute land areas held in LPIS.

3. The data are more inaccurate for older records.

   When considering smaller areas for modelling exercises, it is advisable to check the date of last return of the fields under investigation. Where a majority of records are derived from historic data this must be part of the quality consideration of the output.

2.2 Differentiating farms within the LFA

Data provided by ADAS were further processed by CEH to:

- Differentiate between farms assigned as main farm types Severely Disadvantaged Area (SDA) mixed grazing or Disadvantaged Area (DA) various grazing.
- Assign land use in areas where fields could not be assigned to a farm type based on Farm survey data, or which fell outside of the spatial extent of farm boundary dataset

The main processing steps were as follows:

1. LFA status was assigned in 3 different ways based on:
   a. most common status at field level in the ADAS dataset,
   b. maximum area at farm level of SDA, DA, not LFA “majority LFA status”
   c. maximum area at farm level of LFA, not LFA “LFA flag”
2. The values calculated in step 1 were used to generate a combination of either main farm type (where assigned) for LFA grazing, or robust farm type for the non LFA, with the most appropriate LFA flag (this was taken to be “majority LFA status” unless this is none and “LFA flag” indicated the land was mostly on LFA land, in which case LFA was assigned).
3. An ERAMMP farm type (EFT) was generated from this, with adjustments to ensure categorisation of all farms in “LFA cattle / sheep” and “Lowland cattle / sheep” (non LFA) was appropriate to the LFA status. For details and summary statistics of farms where a new type was assigned, see Table 2.2.1.
4. Unmatched data were removed (these will be mapped using broad habitat from the LCM2015 where full coverage is required). These came under 3 categories detailed in Table 2.2.2:
   a. Blank (includes pigs & poultry)
   b. Common Land
   c. No CRN - No Data

5. These data were used to overwrite the LCM2015 map using the "update" tool in ArcGIS: this creates a complete coverage for Wales, with farm outlines and associated farm type where those data are available, and a Broad Habitat classification where they are not
6. Some models will require a land use/land cover map which takes the underlying broad habitat type where farm type is LFA, lowland grazing or mixed. A further composite map was created for these models by updating the relevant farms with an intersected version of the LCM2015. To maintain underlying variance in the land cover, these cannot be aggregated to farms.

Table 2.2.1 Breakdown of re-assigned farms where RFT did not match the LFA status

June survey main farm type	LFA status	ERAMMP farm type assigned	Number of farms
13_14 LFA Mixed Grazing	No LFA	Lowland cattle/sheep	469
13_14 LFA Mixed Grazing	LFA but neither SDA nor DA dominant	DA various cattle/sheep	15
12 SDA Beef	DA	DA various cattle/sheep	2
11 SDA Sheep	DA	DA various cattle/sheep	12

Table 2.2.2 Breakdown of un-matched LPIS polygons (these were excluded before the LPIS and LCM were combined)

	Count	Minimum area (ha)	Maximum area (ha)	Average area (ha)	Sum area (ha)
Blank	8,801.0	0.0	199.1	2.2	19,250.8
Common Land	2,971.0	0.0	5,782.8	52.9	157,055.8
No CRN - No Data	50,762.0	0.0	8,034.3	1.4	71,068.6

3 Appendix 3 – Brexit land use change rules

Central to implementation of the approach was the CEH Land Use Change Toolbox.

The toolbox is a GIS-based modelling and analysis package which combined:

- anticipated changes in animal numbers in the Welsh livestock sectors in response to Brexit trade scenarios (provided by the Welsh Government Brexit Roundtable);
- field-scale national maps of current farm types in Wales (based on the Land Parcel Information System, LPIS);
- statistics describing current livestock farm characteristics and practices in Wales (from the 2017 June Agricultural Survey, JAS); and
- rule-based decision trees specifying the type, likelihood and location of livestock farm changes that potentially could occur in response to Brexit trade scenarios (based on criteria developed and agreed with Welsh Government).

The outputs of the Toolbox were spatially explicit maps (and national/regional summaries) of potential livestock and agricultural land use changes. These land use change maps could be compared to other spatially explicit datasets (e.g., socioeconomic) and were provided to a suite of environmental impact models to examine the environmental consequences of agricultural land use change.

3.1 Land use change targets and rule base

The following describes in more detail the rule base and assumptions made to convert the livestock sector responses to the Brexit scenarios provided by Welsh Government to potential areas of agricultural land use change.

1. Estimates of changes in the dairy, beef and sheep sectors were provided by WG as numbers of animals, with the following breakdown:
    - Dairy cows
    - Dairy youngstock (dairy bred females)
    - Suckler cows + bulls
    - Beef herd, sucklers + dairy calves
    - Number of breeding sheep
    - Lambs

2. These were used by CEH to calculate expected changes in Livestock Units (LU). The current breakdown of average stocking densities for RFT 6, 7(A,B,C,D) and 8 were used to generate expected area change targets for each sector in ha, accounting for increase and reduction in LU to all sectors for each sector transition.
3. A land use change spatial disaggregation tool was then applied to map these changes, using the targets and rule base indicated in Table 3.1.1.
4. The final change in LU for beef, sheep and dairy were then calculated based on average stocking density of beef, sheep and dairy animals for all transitions taking place in that scenario. For all scenarios, final LU were within 10% of the target numbers provided by WG.
5. For each scenario, data are provided as a map for farms which have changed (new farm type is in column NewRFT)
6. These were joined to the baseline data, to provide a map for all LPIS fields which were assigned RFT and/or MFT by ADAS. EFT of the original assignment is provided again as before, with a column NewRFT indicating farm type where this was changed under the scenario. The values are combined in the column EFTx, which gives EFT where unchanged, and the new farm type where changed under the scenario.

Note: although these transitions would likely take place over a period of time, the temporal aspect is not accounted for.

Table 3.1.1 Livestock change and area change targets and rule base applied in CEH Land Use Change Toolbox to map WG predicted changes in livestock numbers as change between farm types. Very Small Farms (<1FTE) were excluded from all change scenarios, based on WG expectation of no response to economic drivers.

Scenario		Target change, animals (LU)	Finalised change to/from	Target area (ha)	Criteria	Rationale
EU Deal	Dairy	+35,636	[RFT 7A,B,C,D & 8] to [RFT 5]	15,633	**Pre filter:** Small farms within 1km of existing dairy. Slope, elevation and ALC within the range of existing dairy **Ranking:** ALC best to worst	Small farms may be absorbed by nearby dairy farms looking to expand (in line with current trends). Physical constraints of topography and land quality may make land unsuitable for dairy- these can be identified by the current distribution. Better agricultural land classification (ALC) land is more suitable.

Scenario		Target change, animals (LU)	Finalised change to/from	Target area (ha)	Criteria	Rationale
	Beef	-12,374	[RFT 7A] to [RFT 7B] Increase in dairy caused sufficient reduction in beef LU that an increase in area under specialist beef was required to match expected remaining numbers.	3,600	**Pre filter:** Excluded small farms, and farms already converted to dairy. **Ranking:** ALC best to worst	WG indicated expectation that small farms not absorbed by dairy may go out of business. Sheep farms with better ALC are more likely to be suitable for beef.
	Sheep	-38,766	[RFT 7A] to [out of ag]	37,000	**Pre filter:** Excluded farms already converted to dairy or beef. **Ranking:** ALC worst to best	Farms with lower ALC may be less productive, and therefore less economically viable under reduced demand
No Deal	Dairy	+ 198,735	[RFT 7A,B,C,D & 8] to [RFT 6]	86,740	**Pre filter:** Small farms within 1km of existing dairy. Slope, elevation and ALC within the range of existing dairy **Ranking:** ALC best to worst	Small farms may be absorbed by nearby dairy farms looking to expand (in line with current trends). Physical constraints of topography and land quality may make land unsuitable for dairy- these can be identified by the current distribution. Better ALC land is more suitable.
	Beef	5,774	[RFT 7A] to [RFT 7B]	79,461	**Pre filter:** Excluded small farms, and farms already converted to dairy. **Ranking:** ALC best to worst	WG indicated expectation that small farms not absorbed by dairy may go out of business. Sheep farms with better ALC are more likely to be suitable for beef.
	Sheep	-207,399	[RFT 7A] to [out of ag]	118,013	**Pre filter:** Excluded farms already converted to dairy or beef. **Ranking:** ALC worst to best	Farms with lower ALC may be less productive, and therefore less economically viable under reduced demand

Scenario		Target change, animals (LU)	Finalised change to/from	Target area (ha)	Criteria	Rationale
MFTA (Multilateral free trade agreement)	Dairy	-11,482	[RFT 6] to [out of ag]	3,864	**Ranking:** ALC worst to best	Farms with lower ALC may be less productive, and therefore less economically viable under reduced demand
	Beef	-84,414	[RFT 7A,B,C,D & 8] to [out of ag]	85,465	**Ranking:** ALC worst to best	Farms with lower ALC may be less productive, and therefore less economically viable under reduced demand
	Sheep	-207,399	[RFT 7A] to [out of ag]	169,455	**Ranking:** ALC worst to best	Farms with lower ALC may be less productive, and therefore less economically viable under reduced demand

3.2 Agricultural Land Classifications

Agricultural Land Classification (ALC) data were from the predictive ALC map for Wales (PALC-Wales, 2018). These data replace the previous “Provisional” map withdrawn in 2017. ALC is assigned based on the principles of the Agricultural Land Classification System of England & Wales, the Revised Guidelines & Criteria for Grading the Quality of Agricultural Land (MAFF 1988). This is the freely available version of the dataset from Lle (a licensed version had not been made available at time of modelling)

The data were scaled as 1=1, 2=2, 3a=3, 3b=4, 4=5, 5=6, non-agricultural=7, urban=8. We retained urban and non-agricultural classes here to account for the proportion of farm taken up by these when selecting farms for change- it should be noted that applying a linear scaling to non-linear categories affects the influence of these areas.

3.3 Constraints on farms considered unassignable to dairy

Thresholds applied using range of all existing dairy>1FTE:

Mean ALC<=6.71

This was based on maximum individual farm mean ALC, using data scaled as per the below. Exploration of the raw data identified some SDA dairy entirely on ALC 5/worst (6 in the integer scaling described in 2.1), so ALC does not appear to be an absolute constraint. Scaling of the dataset including non-agricultural and urban pixels was therefore applied to identify farms which may not be suitable due to a combination of poor quality and non-agricultural.

Maximum elevation< 686m

This was based on maximum point elevation from the 5m Nextmap DEM (rather than farm average), to avoid skewing effects from farms with multiple holdings.

Mean slope < 14 degrees

This was based on maximum individual farm mean slope, since maximum slope at a pixel level may not be representative. Slope was calculated from the 5m Nextmap DEM.

These criteria were calculated for existing dairy at farm level: farms may be built up of several holdings under different use, hence this may not give an entirely accurate picture of the land used for dairy, but more accurate data were not available

3.4 Woodland expansion opportunities

For BREXIT scenarios we first identified farm holdings potentially changing to non-agricultural land uses. Woodland planting options were then explored, selecting only from areas identified as available (potentially changing to non-agricultural uses) under the Brexit scenarios.

1. "Unsuitable" areas to be excluded were selected in consultation with the Glastir Woodland Creation (GWC) team, using their three guideline levels: Constraints (Table 3.4.1), Sensitivities (Table 3.4.2) and Guidance (Table 3.4.3).
2. GWC data were used to create 3 masks
   I. Constraints
   II. Constraints + Sensitivities.
   III. Constraints + Sensitivities + Guidance layers
3. Three separate woodland planting opportunity layers were then created for each of the Brexit scenarios, by using the "Potential for other use" land, and masking out "unsuitable" portions
4. Carbine (carbon and yield) and ESC (biodiversity and recreation) output data were provided by FR on a 250m by 250m grid for all Wales -excluding grid squares where planting was deemed not possible by FR.
5. The FR data were extracted to suitable farm land to create a layer which also ruled out areas where planting would not be possible
6. Using these final layers of suitable land, we identified farms with more than 10ha with potential for planting (suggested by WG as a threshold for economic planting)

7. Suitable farms were then ranked according to mean ALC, and then selected in order until the target of 100,000 ha planting was achieved. (This was done by calculating cumulative area and filtering the data to cumulative area<100,000ha. Therefore the final total would be under 100,000; it is not possible to exactly match the target whilst converting at the whole farm level, unless matching the target is the optimisation criteria, which would not accurately represent real world controls on land use change)
8. For each scenario/mask combination, the FR data were used to calculate totals for carbon stocks and changes etc

NOTE: step 7 was not always necessary, i.e. total area available and suitable for woodland planting was often<100,000ha (depending on number of masks applied, and initial area made available from the Brexit scenario.

Even where more than 100,000 were available, the total woodland planting area would be slightly less than this (by an amount dependant on the size of the next most suitable farm) since the data were processed to not exceed 100,000ha. Exactly matching the target was not considered an appropriate prioritization approach.

ALC was used for consistency with other transitions, but an alternative approach could select for highest timber yields or selected public goods benefits.

Table 3.4.1 Woodland "Constraints" layers applied to potential new woodland areas.

Suitability reduced by:	Constraints layers	Applied as a combined constraints mask
NFI existing woodland (mapped as category=woodland)	GWC benefits not calculated for these locations	Y
Water bodies	GWC benefits not calculated for these locations	Y

Table 3.4.2 Woodland "Sensitivities" layers applied to potential new woodland areas.

Suitability reduced by:	Sensitivities layers	Applied as a combined constraints mask
peats	Deep peat and modified deep peat (FR Total peatland survey 2012)	GMEP updated peat map for Wales (includes modified)
areas of outstanding natural beauty	Y	Y
sites of special scientific interest	Y (plus 300m buffer)	Y (plus 300m buffer)
special protection areas	Y	Y

Suitability reduced by:	Sensitivities layers	Applied as a combined constraints mask
special areas of conservation	Y	Y
World Heritage Site	Y	Y
Historic Environment Feature, Historic Park and/or Garden	Y	Y
SAM (Scheduled Ancient Monument) with 100m buffer	Y	Y
Potential habitat for Great Crested Newts (GCN) based on 250m buffer	Y	Y
Potential habitat for fritillary butterflies	Y	Y
Potential habitat for grassland fungi	Y	Y
Potential habitat for open-ground dependent birds	Y	Y
Regionally Important Geodiversity Site (RIGS)	Y	Y
Sensitive Arable Plant Records (Post 1995)	Y	Y

Table 3.4.3 Woodland "Guidance" layers applied to potential new woodland areas.

Suitability reduced by:	Guidance layers	Applied as a combined constraints mask
red squirrel core area	Y	Y
national nature reserves		Y
national parks	Previously sensitive (except Brecon Beacons in agreement with BBNPA) with 800m buffer	Y
acid sensitive areas	Y	Y
urban areas		Y
Common land	Y	Y
Open Access	Y	Y
Water vole	Y	Y
Historic landscapes	Y (previously sensitive)	Y

3.5 Rule-based decision trees for selecting farms for potential change

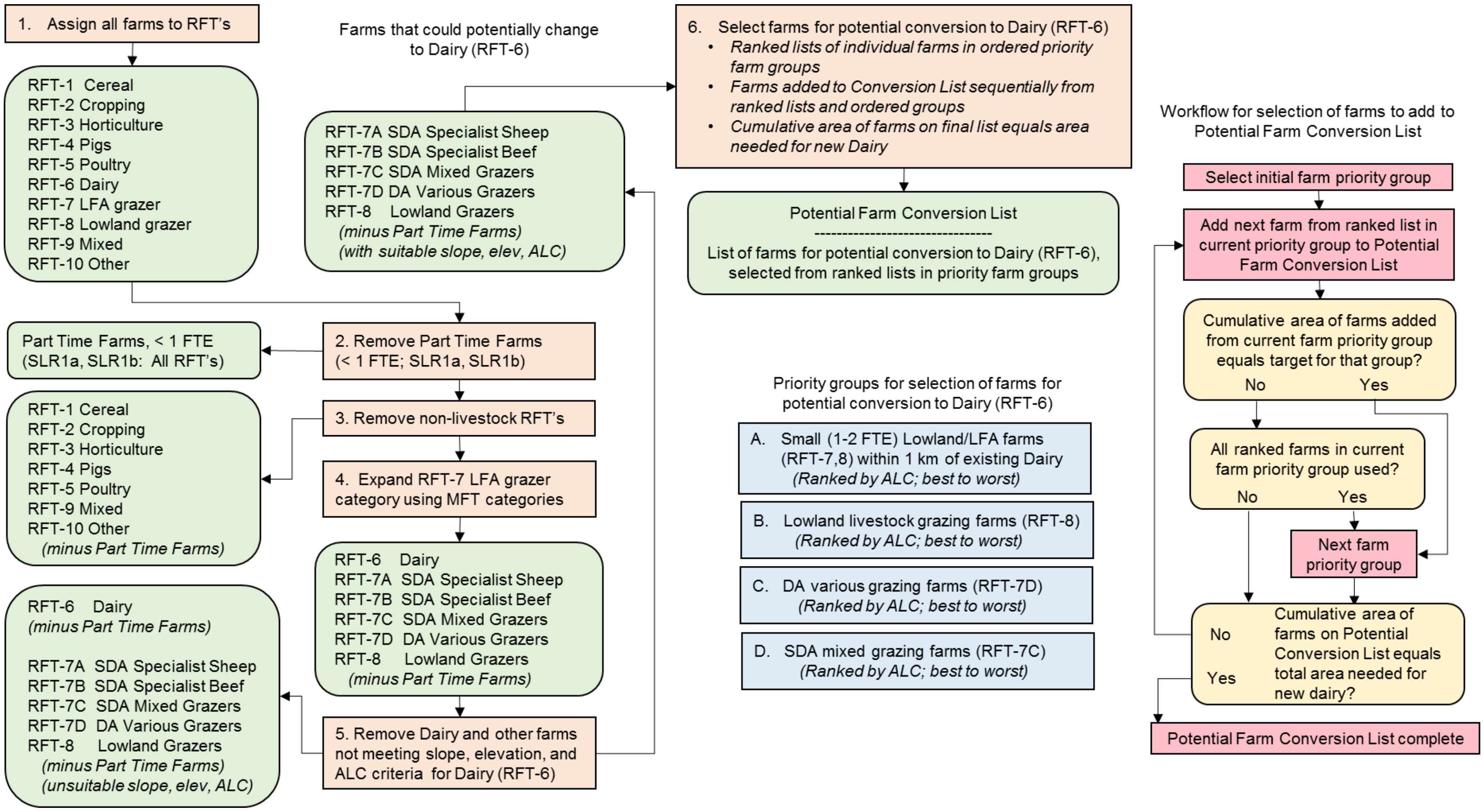


*Figure 3.5.1 Rule-based decision tree for selecting farms with potential for **DAIRY expansion**. First step removes farm types that cannot be converted to Dairy to produce a "Potential Farm Conversion List" (using rules in the orange-green decision workflow). Farms on this list are then ranked in priority order for conversion to Dairy (using rules in the blue decision workflow). Final selection of farms with potential for Dairy expansion is from the priority ordered potential list (using the rules in the red-yellow workflow).*

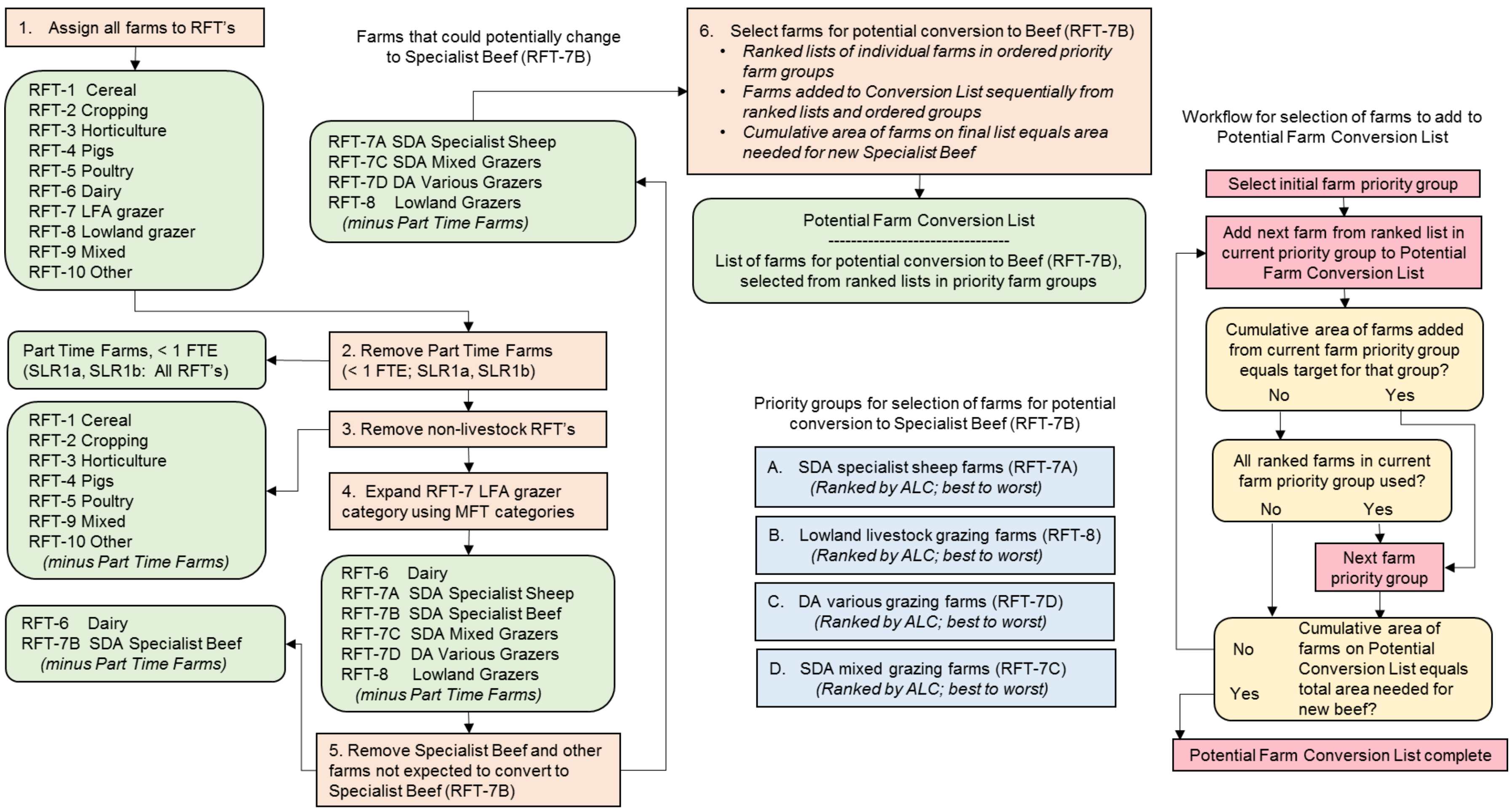


*Figure 3.5.2 Rule-based decision tree for selecting farms with potential for **BEEF expansion**. First step removes farm types that cannot be converted to Beef to produce a "Potential Farm Conversion List" (using rules in the orange-green decision workflow). Farms on this list are then ranked in priority order for conversion to Beef (using rules in the blue decision workflow). Final selection of farms with potential for Beef expansion is from the priority ordered potential list (using the rules in the red-yellow workflow).*

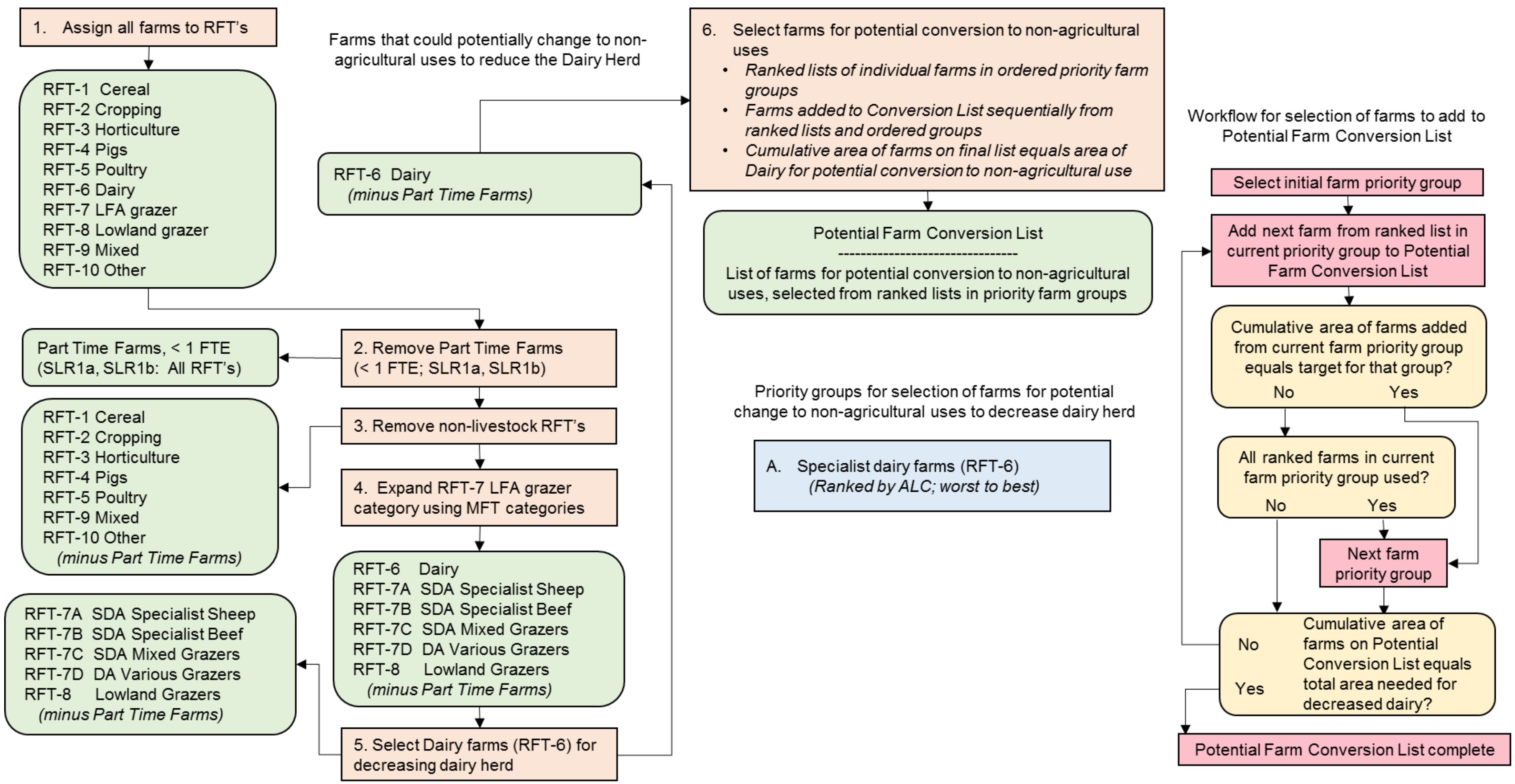


Figure 3.5.3 Rule-based decision tree for selecting farms with potential for ***DAIRY contraction****. First step removes farm types that are not related to Dairy to produce a "Potential Farm Conversion List" (using rules in the orange-green decision workflow). Farms on this list are then ranked in priority order for Dairy contraction (using rules in the blue decision workflow). Final selection of farms with potential for Dairy contraction is from the priority ordered potential list (using the rules in the red-yellow workflow).*

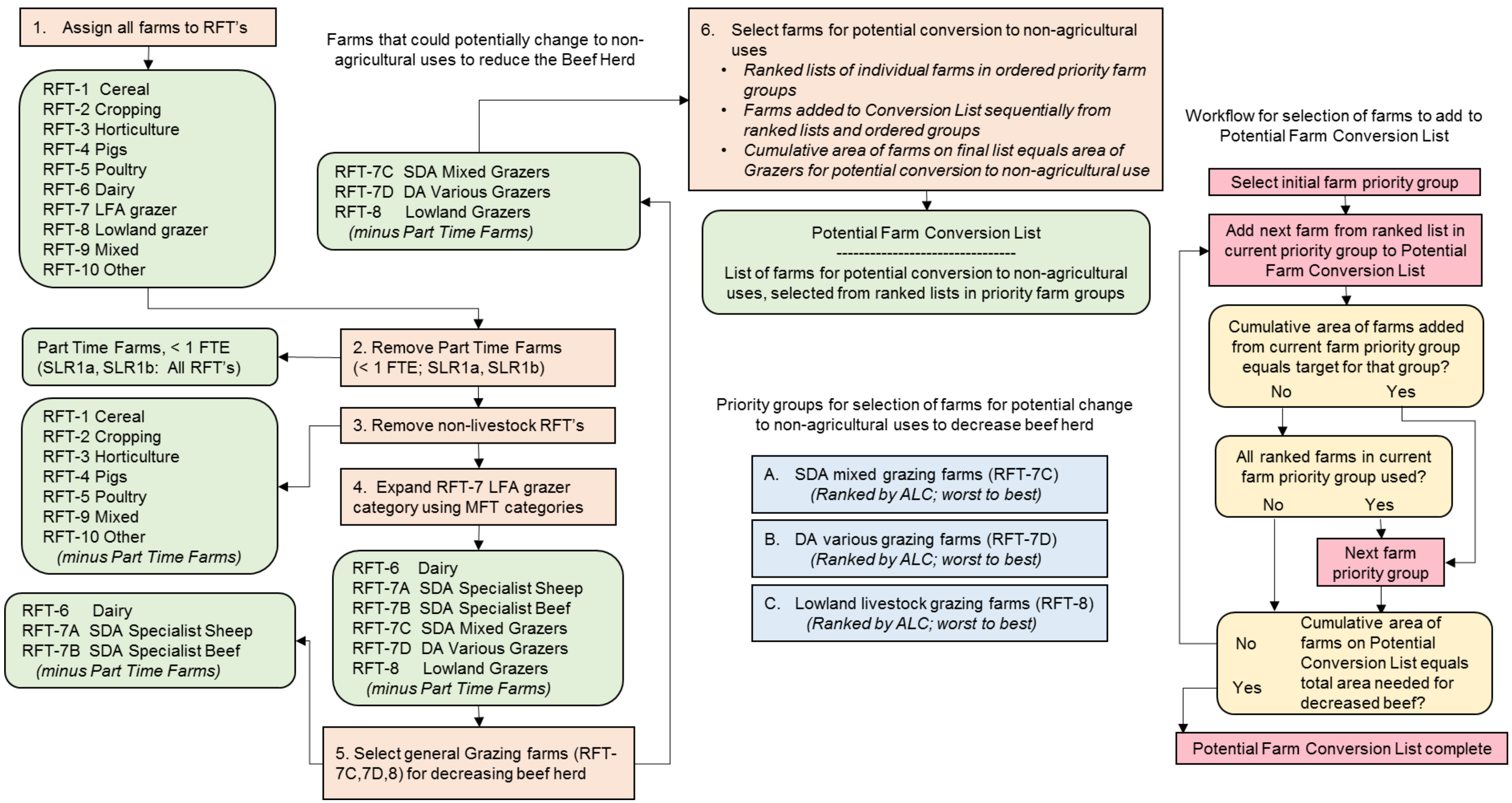


*Figure 3.5.4 Rule-based decision tree for selecting farms with potential for **BEEF contraction**. First step removes farm types that are not related to Beef to produce a "Potential Farm Conversion List" (using rules in the orange-green decision workflow). Farms on this list are then ranked in priority order for Beef contraction (using rules in the blue decision workflow). Final selection of farms with potential for Beef contraction is from the priority ordered potential list (using the rules in the red-yellow workflow).*

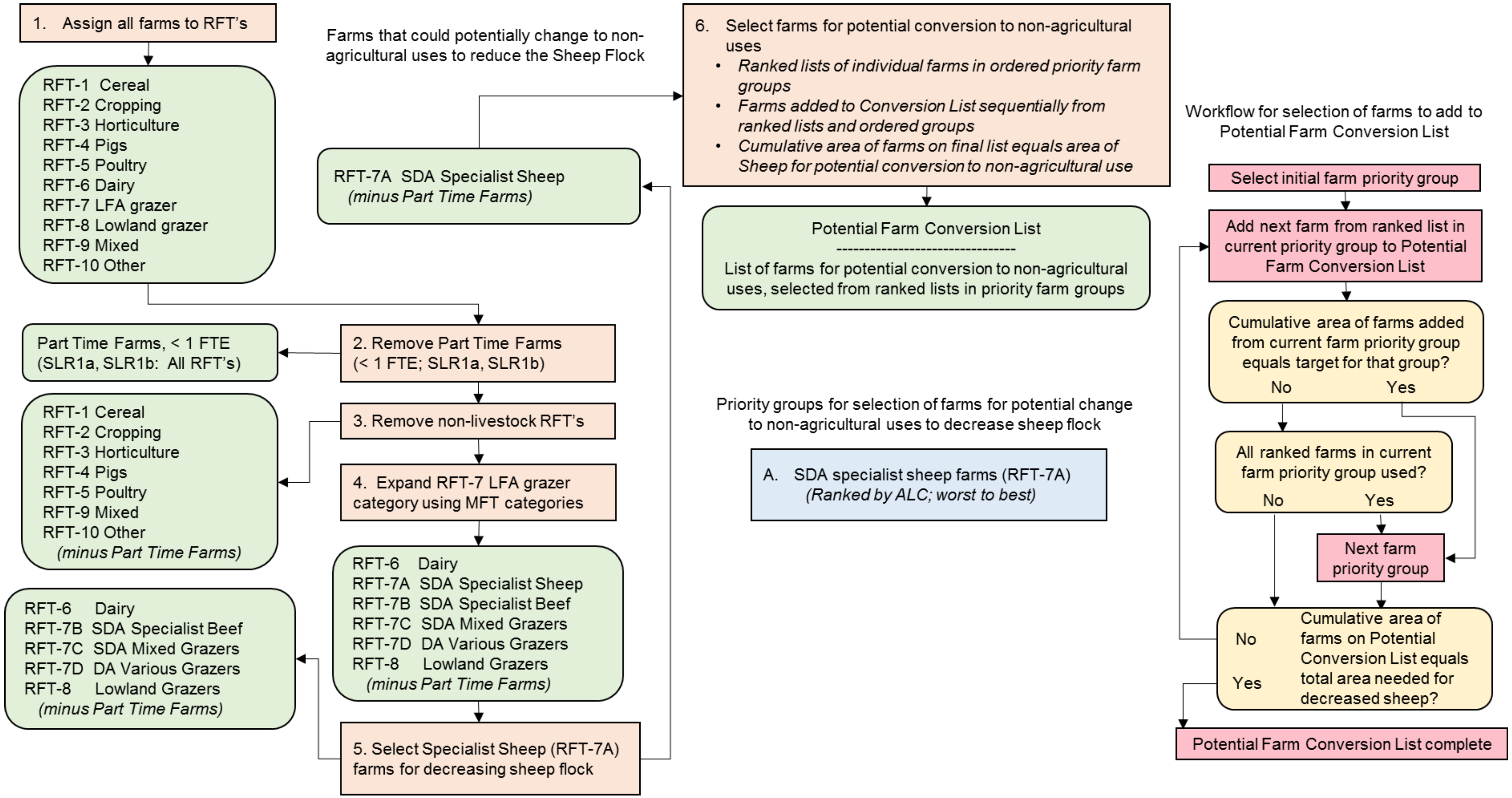


*Figure 3.5.5 Rule-based decision tree for selecting farms with potential for **SHEEP contraction**. First step removes farm types that are not related to Sheep to produce a "Potential Farm Conversion List" (using rules in the orange-green decision workflow). Farms on this list are then ranked in priority order for Sheep contraction (using rules in the blue decision workflow). Final selection of farms with potential for Sheep contraction is from the priority ordered potential list (using the rules in the red-yellow workflow).*

4 Appendix 4 - Brexit scenario results

The Brexit trade scenario work here is based on “Summary of the EU Exit Scenario Planning Workshop” published in 2018 by the Evidence and Scenarios Roundtable Sub-Working Group (https://gweddill.gov.wales/docs/drah/publications/180219-summary-of-eu-exit-scenario-planning-workshops-en.pdf). The purpose of the Sub-Working Group (SWG) report was to “draw together evidence and expert opinion around five possible scenarios for the UK leaving the EU. The report uses scenario planning as a tool to analyse the potential impacts on the agricultural, fishing, forestry and environment sectors, it explores some of the interdependencies to understand some of the complex changes that may be ahead”.

Three basic trade scenarios were identified by the SWG, with additional variables of public funding and workforce constraints (therefore five scenarios in total), to help draw out the Welsh implications of EU Exit. The work was designed to test particular trade and market vulnerabilities in key sectors including fisheries, farming and timber while drawing out interdependencies across sectors and the wider impacts on the environment and communities.

For the purpose of their report, the SWG simplified the analysis on each sector to reflect three possible trading scenarios (which were analysed in this project):

- **EU Deal:** EU-UK FTA trading environment. Trade with the EU-27, non-tariff barriers are in place increasing transaction costs. This scenario is closest to business as usual. The EU will still want to access some UK goods, services and markets.
- **No Deal:** Trade under World Trade Organisation (WTO) rules. The UK-EU trade relationship is the same as with rest of the world. This scenario would be a major change for existing business models, causing economic disruption.
- **Multilateral Free Trade Agreements (MFTA):** UK Government aspiration: FTAs with the EU-27 (and other nations also having FTAs with the EU-27), and new FTAs with countries not previously traded with. This scenario assumes a broadly similar EU trade relationship as currently in place,

Among the Key Findings of the SWG report are the following related to the livestock sectors (the focus of this Quick Start analysis)

- “The ***sheep*** sector faces severe challenges as it relies on export to balance seasonal production and to achieve carcass balance. The pressures from geographical constraints and workforce availability in abattoirs and processing mean lamb markets are likely to struggle in all scenarios.”
- “The ***dairy*** and poultry sectors are most robust because of their focus on UK internal markets and lower reliance on export.”
- “***Beef*** remains viable with a buoyant dairy industry to supply calves, with a better carcass balance and a lower dependency on export.”

To examine the potential geographic extent and pattern of sheep, dairy and beef sector responses to the Brexit scenarios, the qualitative directions of change indicated in the SWG report were converted into estimates of changes in the numbers of animals needed on Welsh farms under each Brexit scenario to meet the new market demands. Using expert judgement and cross-checking with stakeholder groups, the SWG developed projections of market demand for meat and dairy products for each Brexit scenario and extrapolated these to estimated changes in animal numbers in the Sheep, Dairy and Beef sectors in Wales (Stebbings, 2018).

Table 4.0.1 Potential agricultural land use conversions under the three Brexit trade scenarios, the total areas affected (ha), and the proportion each represents of baseline (2017) farmland of all types in Wales (1,686,733 ha).

	EU Deal (ha)	**No Deal (ha)**	**MFTA (ha)**
Potential Conversions			
Grazers to Dairy	15,489	74,373	
SDA Beef to Dairy	146	1,775	
SDA Sheep to Dairy	40	10,638	
SDA Sheep to SDA Beef	3,674	79,547	
SDA Sheep to non-agricultural uses	37,430	118,258	169,550
Dairy to non-agricultural uses			3,939
Grazers to non-agricultural uses			85,803
Area Totals			
Total Area changed to new sector (% of baseline farmland)	19,348 (1.1%)	166,334 (9.9%)	0 (0%)
Total Area changed to non-agricultural uses (% of baseline farmland)	37,430 (2.2%)	118,258 (7.0%)	259,292 (15.4%)
Total Area affected by Brexit scenario (% of baseline farmland)	56,779 (3.4%)	284,592 (16.9%)	259,292 (15.4%)

4.1 Quick Start livestock sectors.

June Agricultural Survey, Wales, 2017	Grazing Livestock			Dairy			Grazers			Specialists		Farms > 1 FTE
	RFT-6	RFT-7	RFT-8	RFT-6A	RFT-6B	RFT-6C	RFT-7C	RFT-7D	RFT-8	RFT-7A	RFT-7B	
	Dairy	LFA Grazing	Lowland Grazing	SDA Dairy	DA Dairy	Lowland Dairy	SDA Grazing	DA Grazing	Lowland Grazing	SDA Sheep	SDA Beef	QS RFT's
Farms, number	1,502	5,282	744	182	688	631	930	1,249	744	2,934	169	7,528
Standard Output, k€/farm	554	98	96	485	520	612	112	91	96	95	107	188
Gross Margin, k€/farm	224	50	50	196	209	248	58	43	50	50	50	85
Labour, FTE/farm	4.8	3.5	2.7	4.8	4.5	5.1	3.5	2.6	2.7	4.0	1.9	3.7
Land on a farm, ha	178,638	711,210	65,514	25,896	75,206	77,536	135,080	117,635	65,514	437,236	21,259	955,363
Permanent Grass, ha	116,628	435,092	47,210	18,432	52,404	45,793	90,410	82,821	47,210	246,066	15,795	598,930
New Grass, ha	34,442	51,481	7,304	3,830	13,800	16,812	11,507	12,295	7,304	25,447	2,232	93,227
Rough Grazing, ha	4,549	173,525	3,601	1,782	1,600	1,167	24,188	11,322	3,601	136,563	1,452	181,675
Stockfeed, ha	3,133	6,727	995	346	1,047	1,740	1,272	1,312	995	3,942	201	10,855
Cereals, ha	6,552	5,443	2,925	283	1,418	4,851	1,378	2,894	2,925	899	272	14,920
Other Crops, ha	7,118	1,471	1,044	203	2,076	4,839	275	736	1,044	442	19	9,633
Woods and others, ha	6,176	37,282	2,414	1,026	2,861	2,288	5,968	6,410	2,414	23,642	1,261	45,872
Dairy Cows, number	239,530	4,123	1,363	24,883	104,062	110,585	579	1,884	1,363	1,455	205	245,016
Beef Cows, number	3,415	103,109	15,795	335	1,510	1,570	34,431	26,966	15,795	32,515	9,197	122,319
Other cattle, number	261,408	240,316	62,147	26,489	109,861	125,058	72,430	86,941	62,147	58,582	22,364	563,871
Sheep, number	256,717	8,137,326	562,522	95,961	110,909	49,847	1,304,643	1,185,836	562,522	5,600,138	46,709	8,956,565

Table 4.1.1. Breakdown of economic characteristics, livestock numbers and agricultural land use patterns for each of the Quick Start RFT categories.

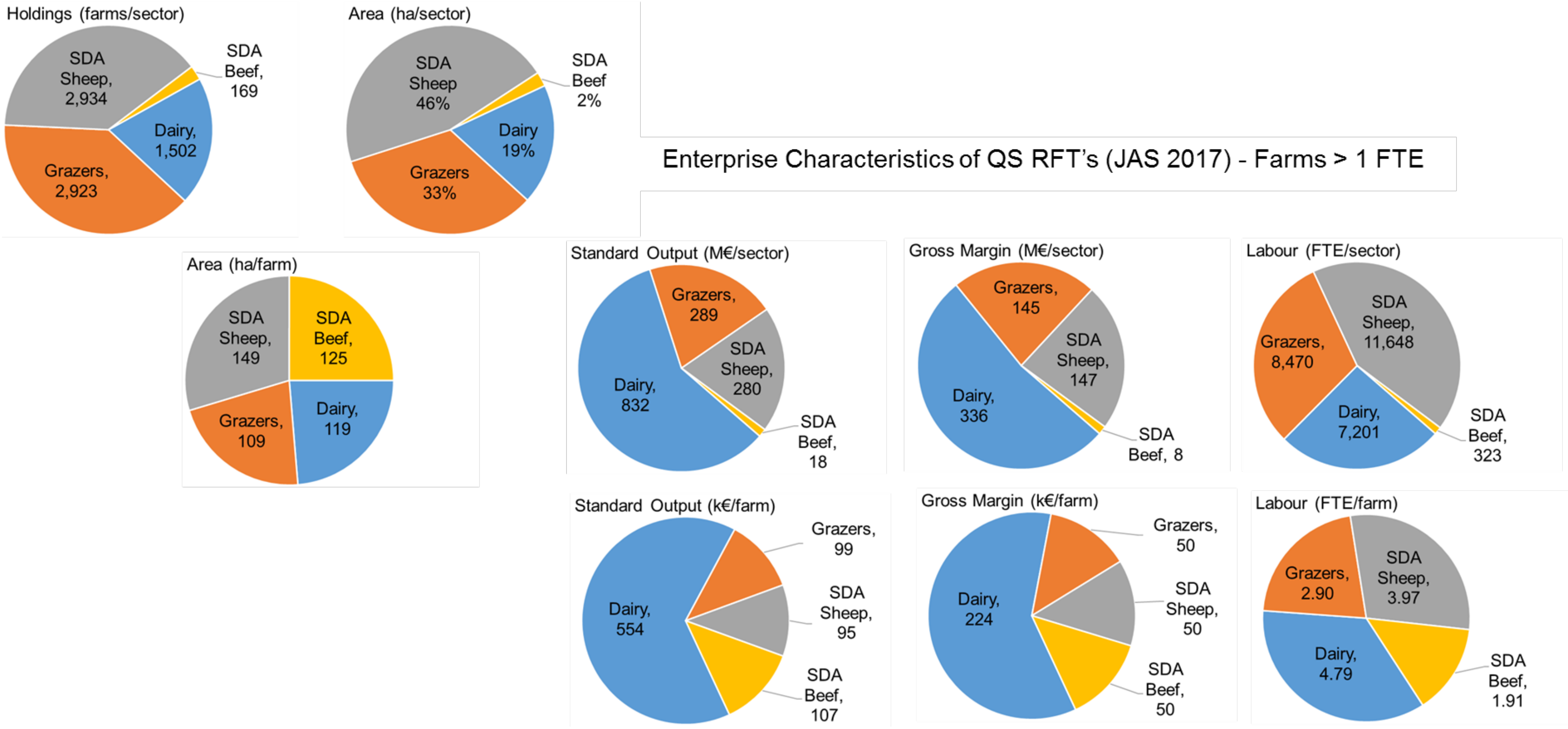


Figure 4.1.1. Enterprise characteristics of the Quick Start RFTs.

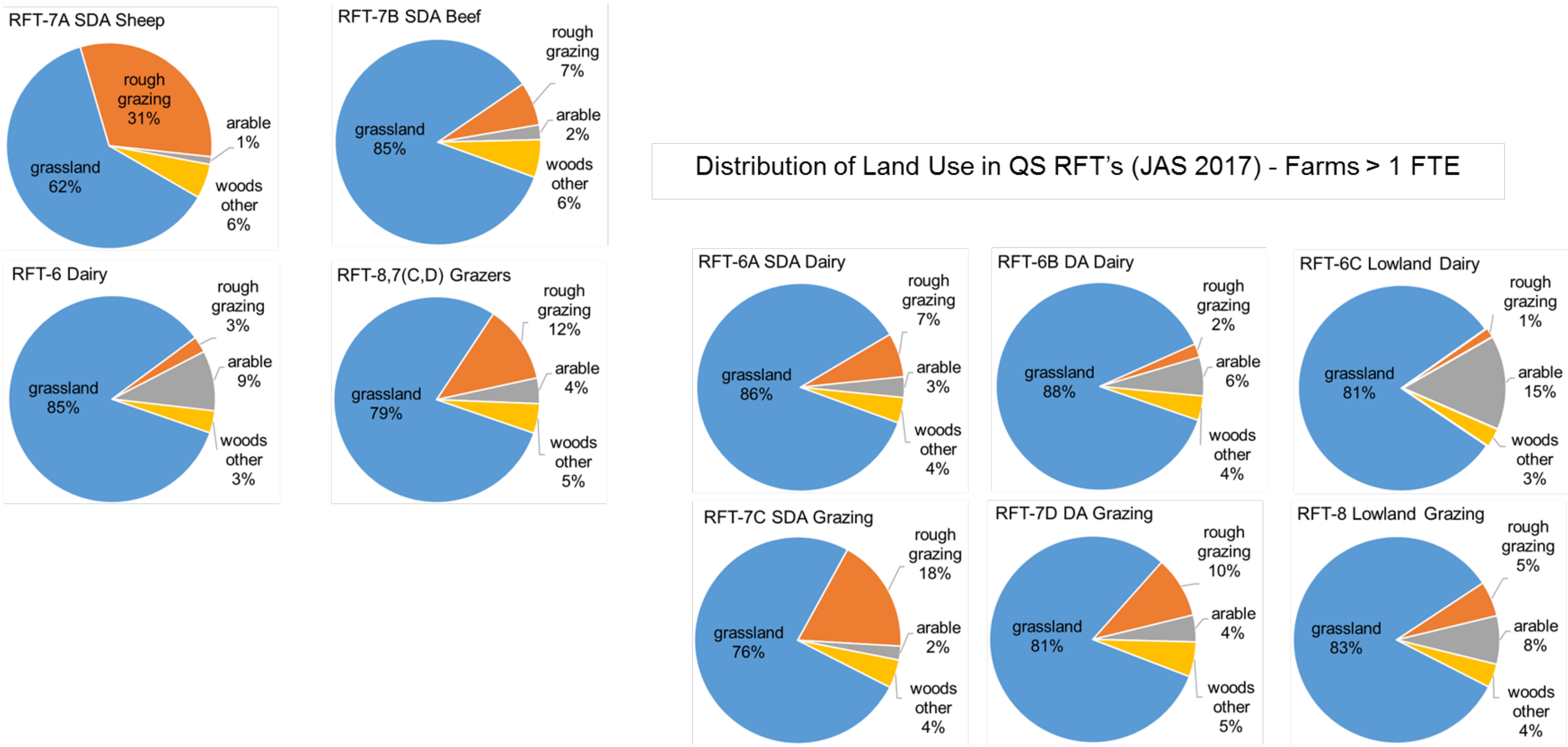


Figure 4.1.2. Proportion of land use patterns within different Quick Start RFTs.

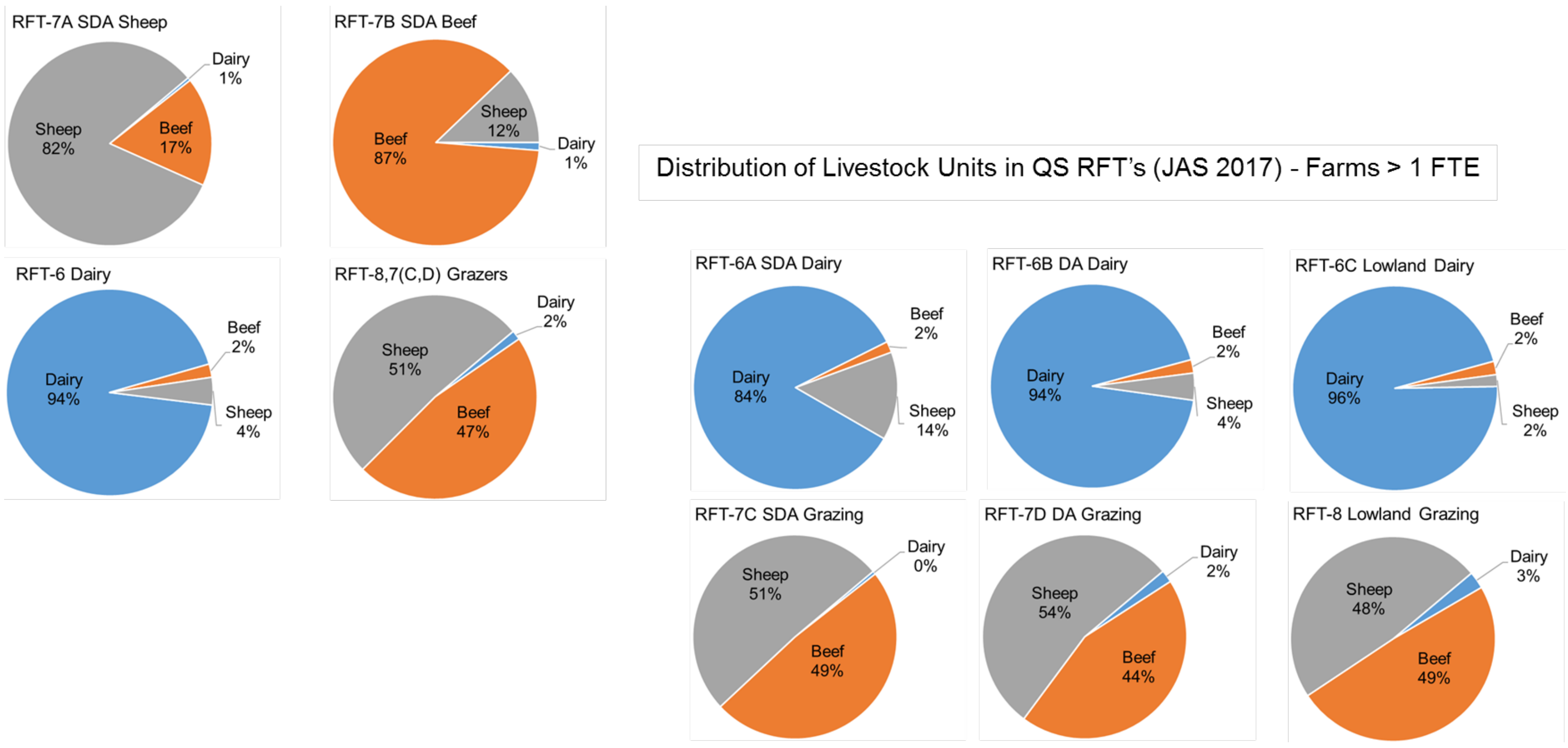
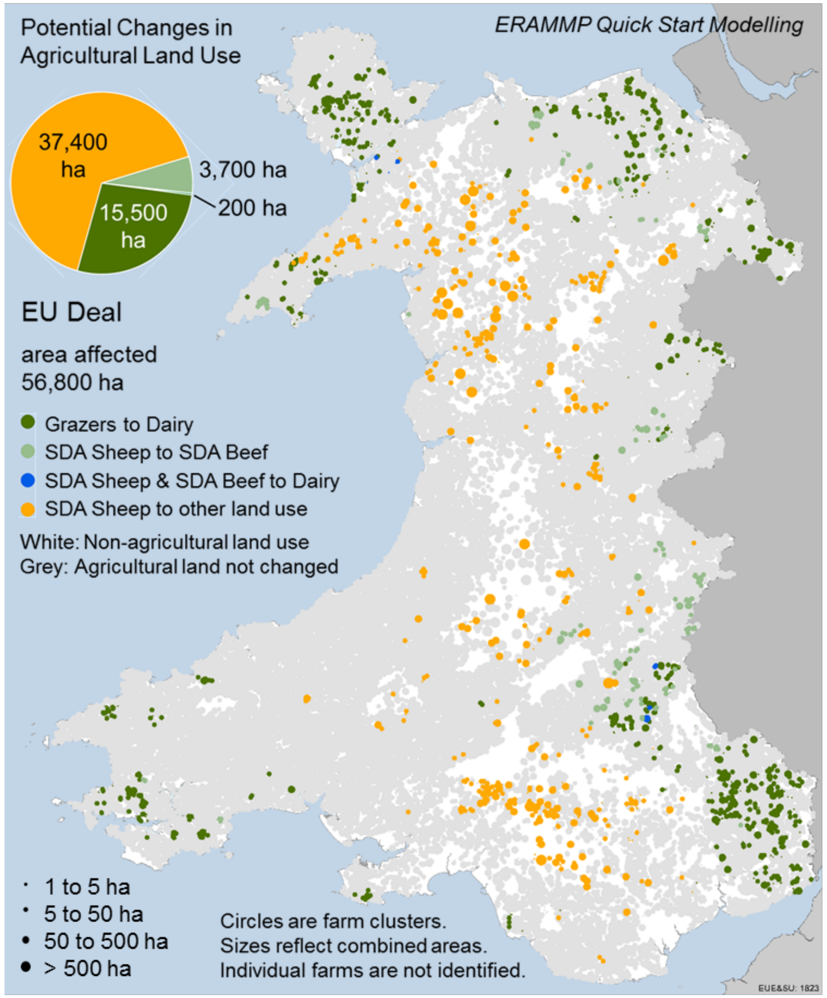
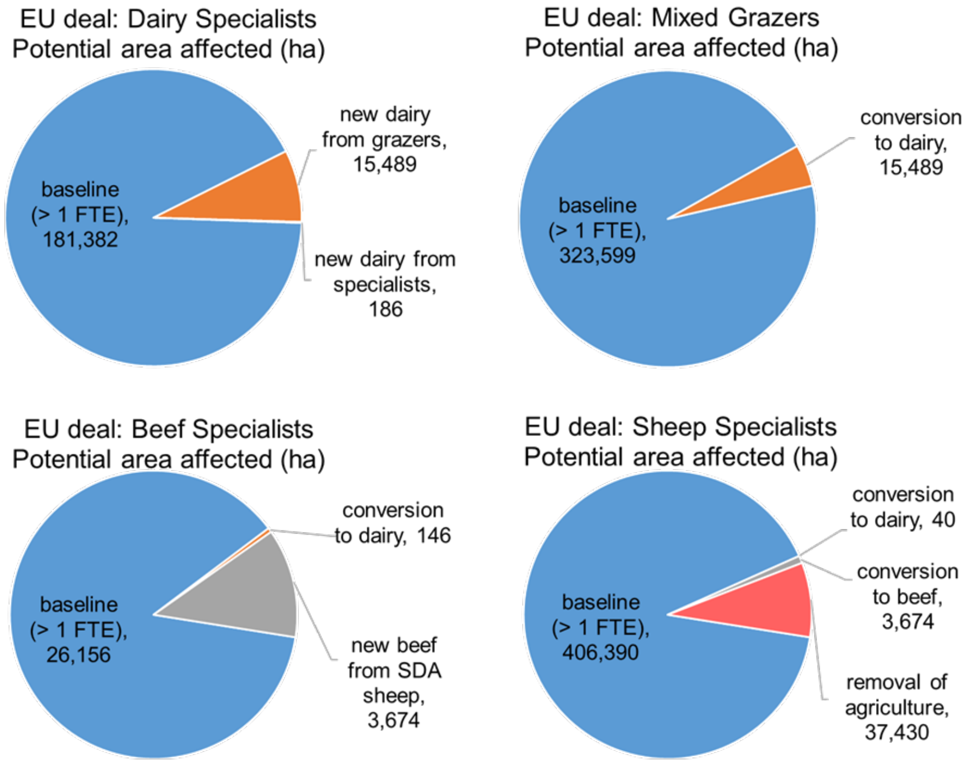


Figure 4.1.3. Proportion of livestock in different Quick Start RFTs.

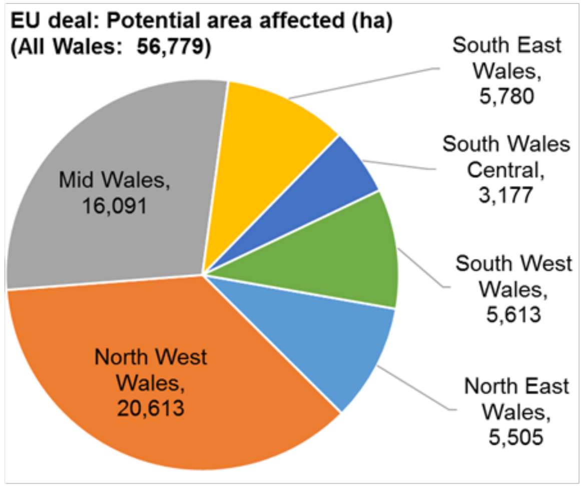
4.2 Potential Land Use Change: EU Deal

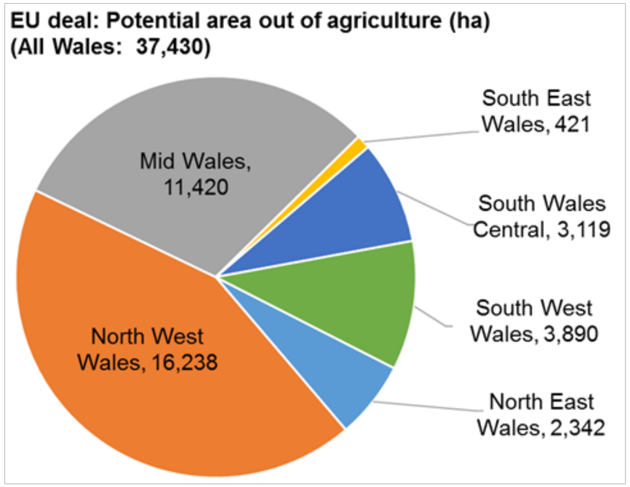


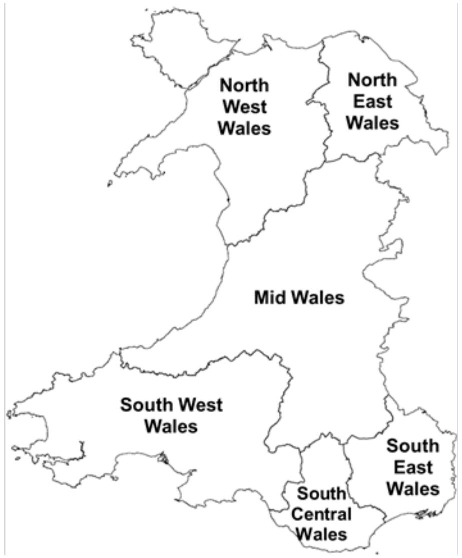


EU Deal Potential Conversion (ha)	All wales
Grazers to Dairy	15,489
SDA Beef to Dairy	146
SDA Sheep to Dairy	40
SDA Sheep to SDA Beef	3,674
SDA Sheep out of agriculture	37,430
Total Area to new RFT	19,348
Total Area out of agriculture	37,430
Total Area Affected	56,779

Figure 4.2.1. Potential land use change: All livestock sectors – EU Deal







EU Deal Potential Conversion (ha)	North East Wales	North West Wales	Mid Wales	South East Wales	South Wales Central	South West Wales	All Wales
Grazers to Dairy	2,791	3,552	2,128	5,236	58	1,723	15,489
SDA Beef to Dairy	0	58	88	0	0	0	146
SDA Sheep to Dairy	0	0	40	0	0	0	40
SDA Sheep to SDA Beef	371	766	2,415	123	0	0	3,674
SDA Sheep out of agriculture	2,342	16,238	11,420	421	3,119	3,890	37,430
Total Area to new RFT	3,162	4,376	4,670	5,359	58	1,723	19,348
Total Area out of agriculture	2,342	16,238	11,420	421	3,119	3,890	37,430
Total Area Affected	5,505	20,613	16,091	5,780	3,177	5,613	56,779

Figure 4.2.2. Potential regional changes in agricultural land use by region – EU deal

4.3 Potential Land Use Change: No Deal

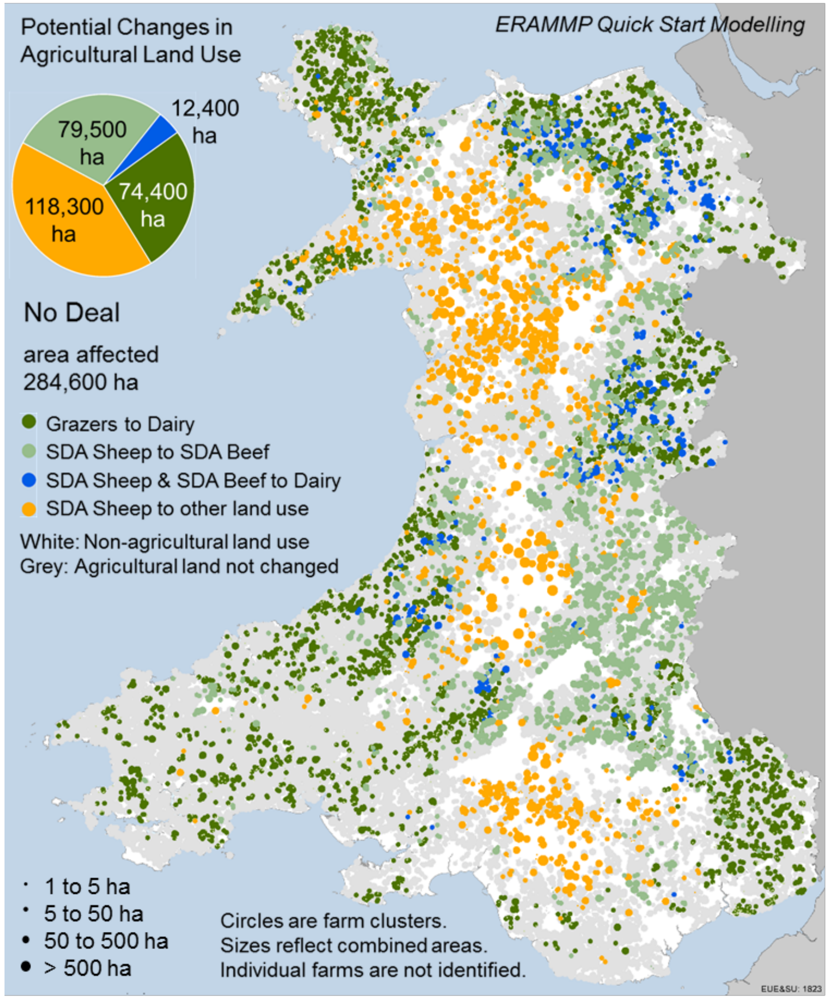
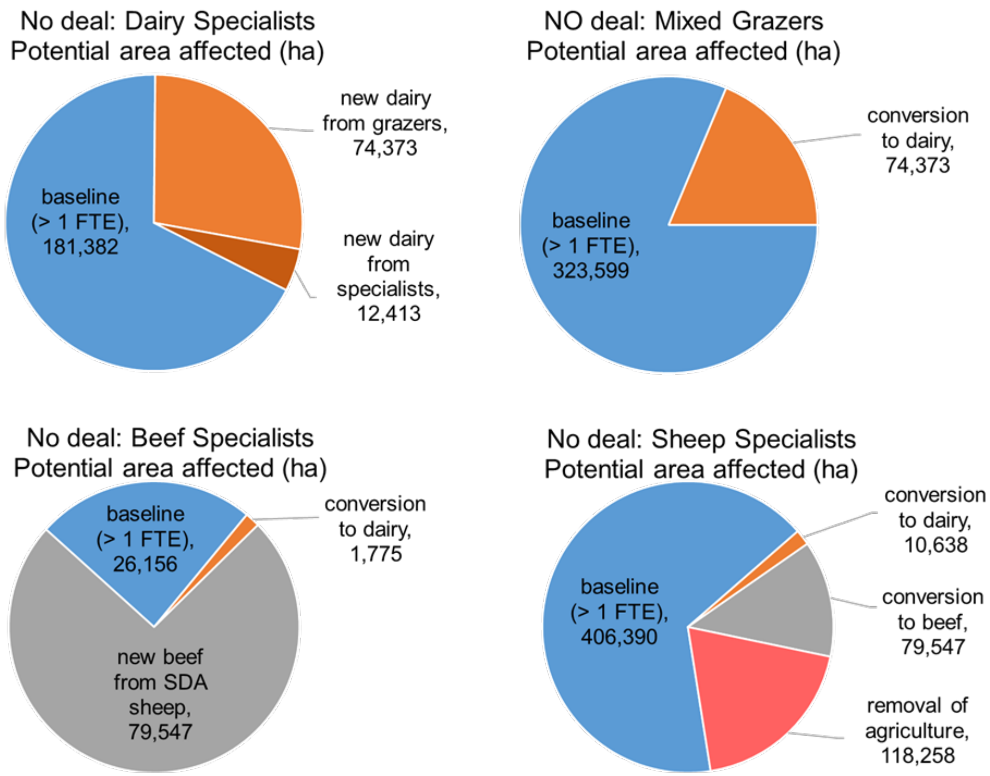
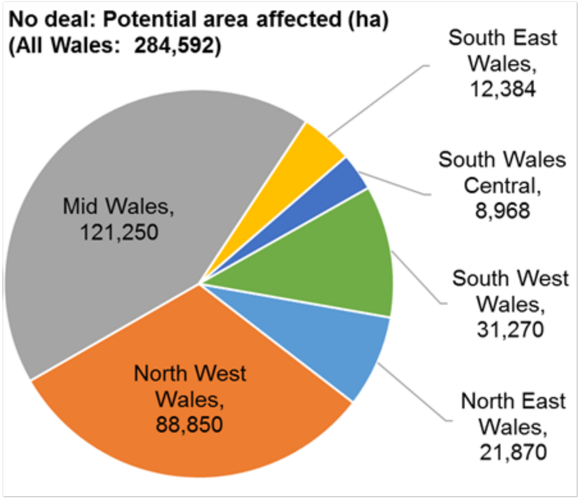
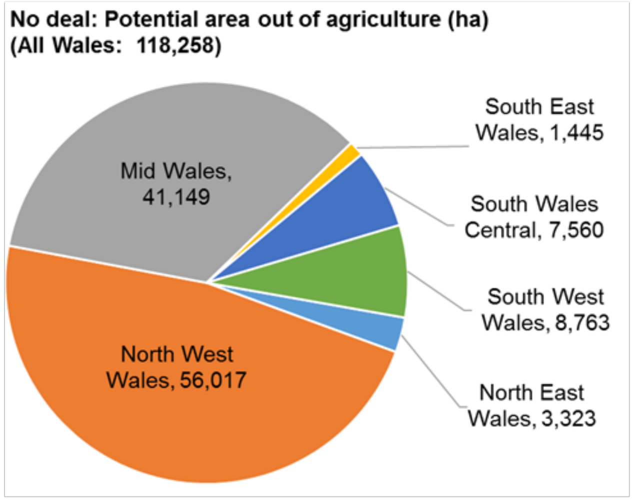


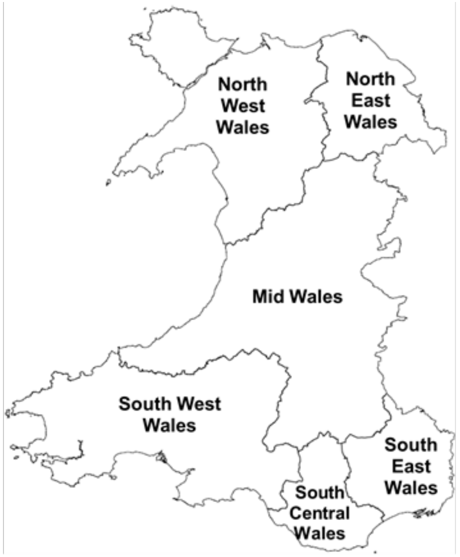
Figure 4.3.1. Potential land use change: All livestock sectors – No Deal



No Deal Potential Conversion (ha)	All wales
Grazers to Dairy	74,373
SDA Beef to Dairy	1,775
SDA Sheep to Dairy	10,638
SDA Sheep to SDA Beef	79,547
SDA Sheep out of agriculture	118,258
Total Area to new RFT	166,334
Total Area out of agriculture	118,258
Total Area Affected	284,592



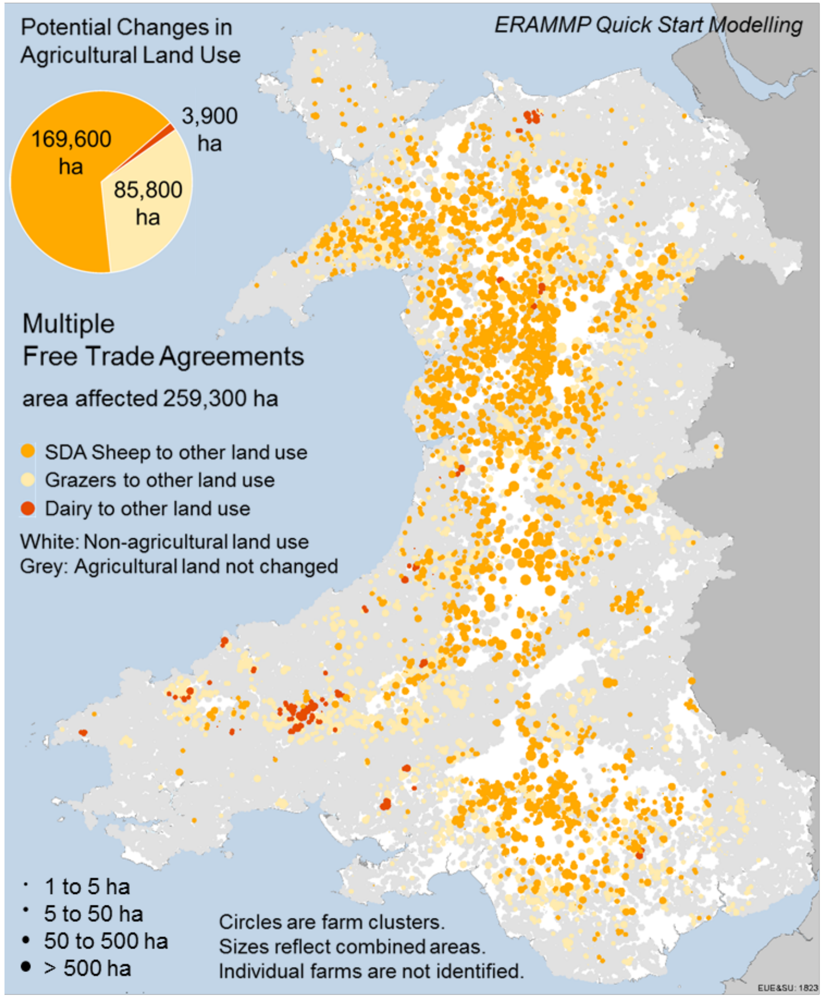


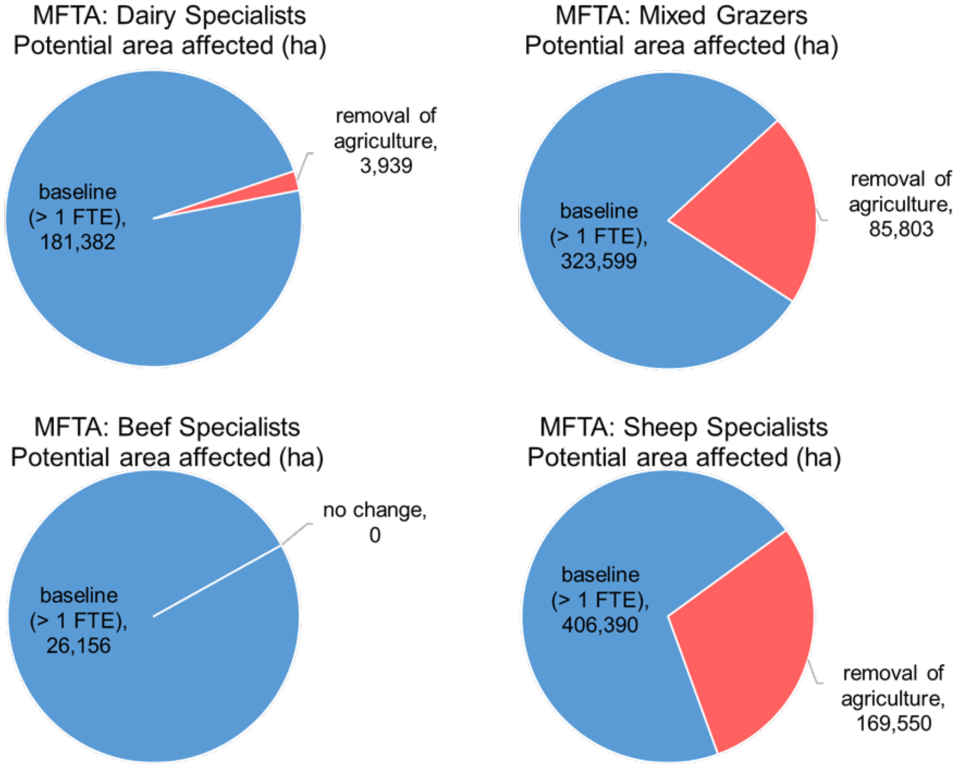


No Deal Potential Conversion (ha)	North East Wales	North West Wales	Mid Wales	South East Wales	South Wales Central	South West Wales	All Wales
Grazers to Dairy	9,329	18,856	20,022	9,664	718	15,785	74,373
SDA Beef to Dairy	740	116	792	45	0	83	1,775
SDA Sheep to Dairy	2,088	2,447	5,230	49	0	824	10,638
SDA Sheep to SDA Beef	6,390	11,413	54,057	1,181	690	5,816	79,547
SDA Sheep out of agriculture	3,323	56,017	41,149	1,445	7,560	8,763	118,258
Total Area to new RFT	18,547	32,832	80,101	10,939	1,408	22,507	166,334
Total Area out of agriculture	3,323	56,017	41,149	1,445	7,560	8,763	118,258
Total Area Affected	21,870	88,850	121,250	12,384	8,968	31,270	284,592

Figure 4.3.2. Potential regional changes in agricultural land use by region – No deal

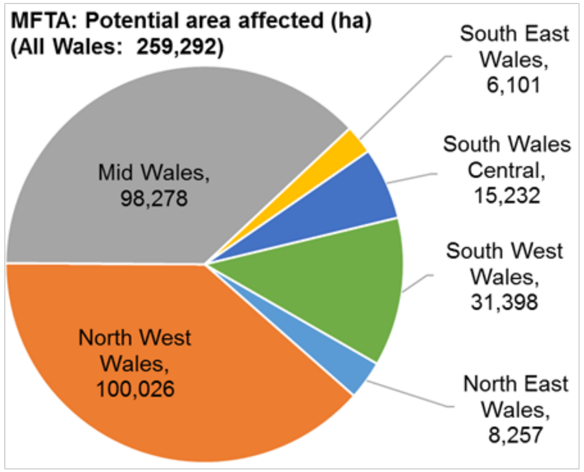
4.4 Potential Land Use Change: MFTA

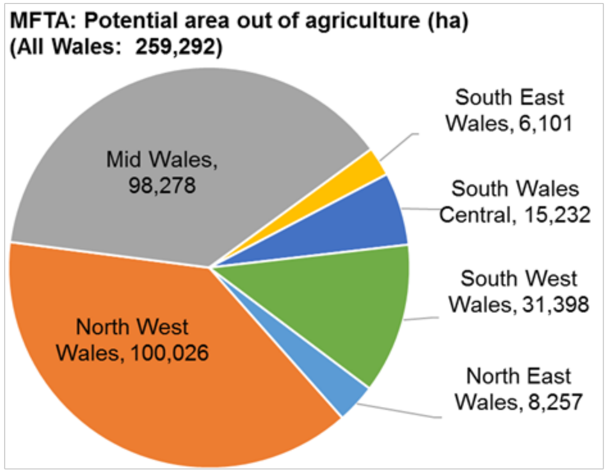


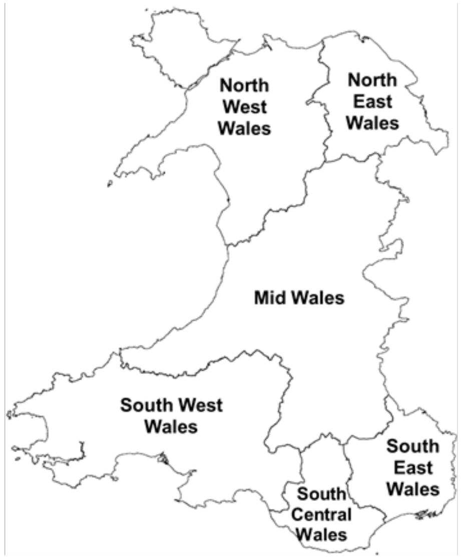


MFTA Potential Conversion (ha)	All wales
Dairy out of agriculture	3,939
Grazers out of agriculture	85,803
SDA Sheep out of agriculture	169,550
Total Area to new RFT	0
Total Area out of agriculture	259,292
Total Area Affected	259,292

Figure 4.4.1. Potential land use change: All livestock sectors – MFTA







MFTA Potential Conversion (ha)	North East Wales	North West Wales	Mid Wales	South East Wales	South Wales Central	South West Wales	All Wales
Dairy out of agriculture	0	952	306	267	0	2,414	3,939
Grazers out of agriculture	3,175	24,889	31,200	3,696	5,401	17,442	85,803
SDA Sheep out of agriculture	5,082	74,185	66,772	2,138	9,830	11,542	169,550
Total Area to new RFT	0	0	0	0	0	0	0
Total Area out of agriculture	8,257	100,026	98,278	6,101	15,232	31,398	259,292
Total Area Affected	8,257	100,026	98,278	6,101	15,232	31,398	259,292

Figure 4.4.2. Potential regional changes in agricultural land use by region – MFTA

4.5 Potential farm areas and jobs affected

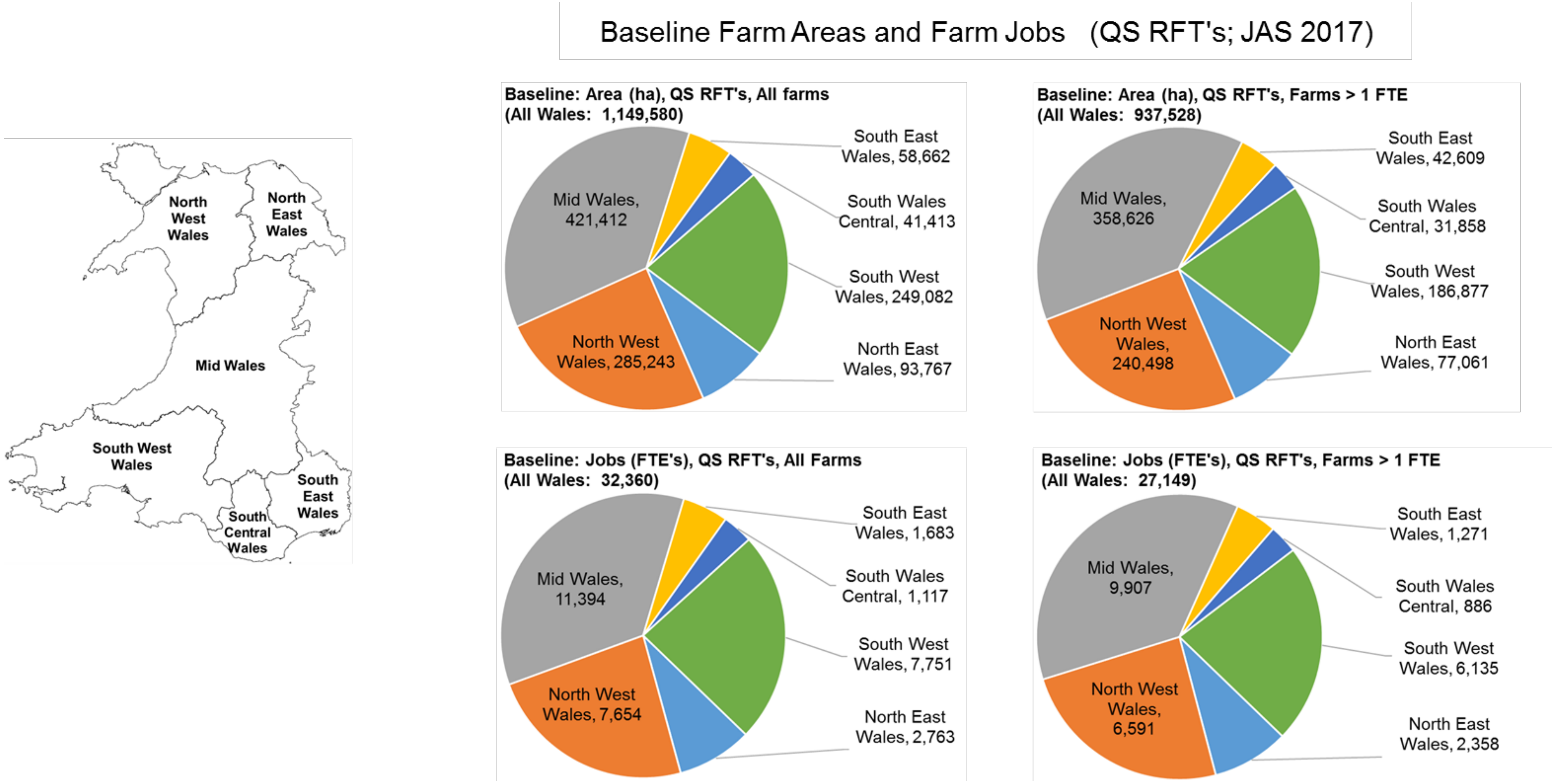


Figure 4.5.1. Baseline farm area and farm jobs by region

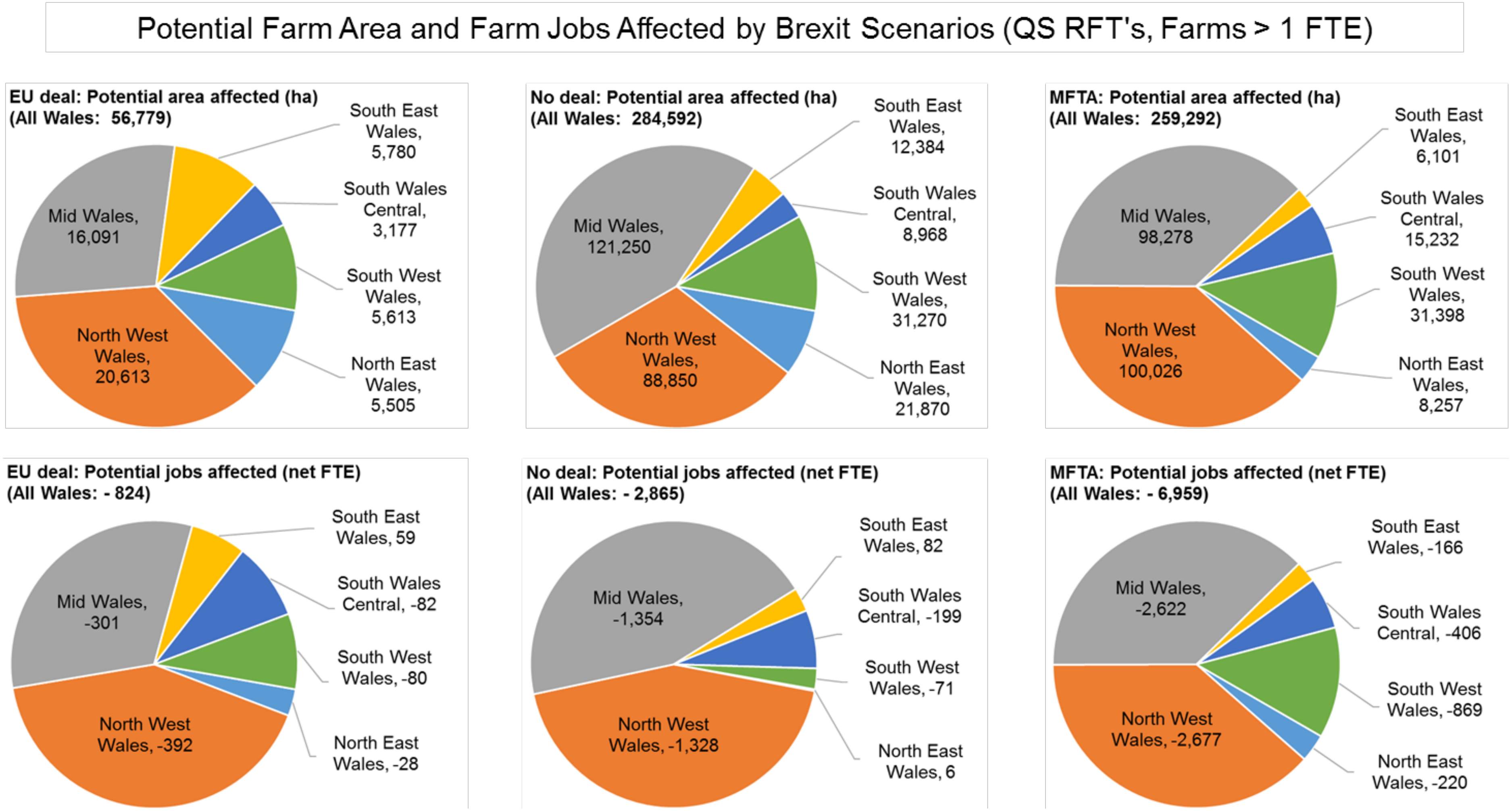


Figure 4.5.2. Potential farm area and farm jobs affected by region.

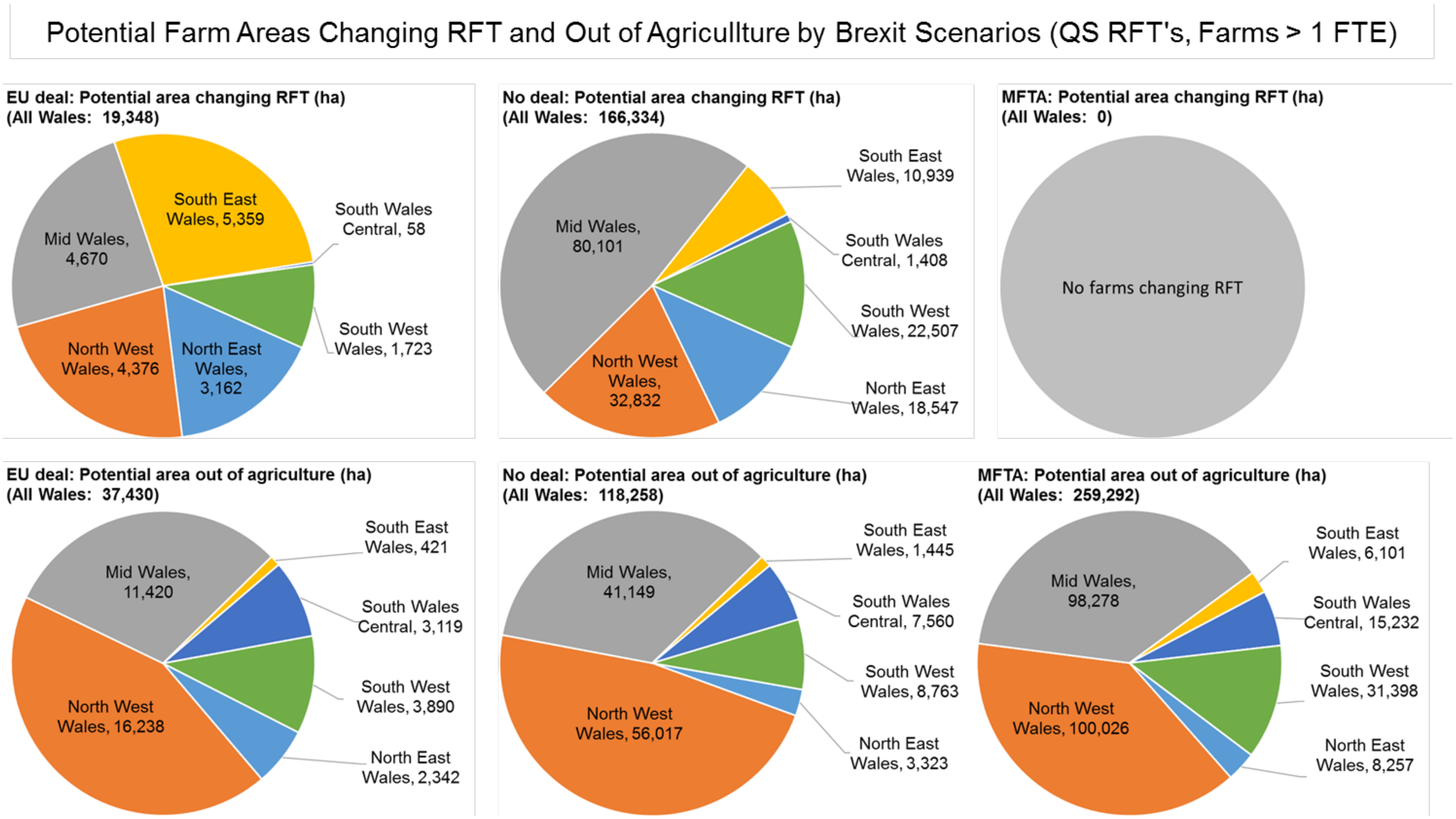
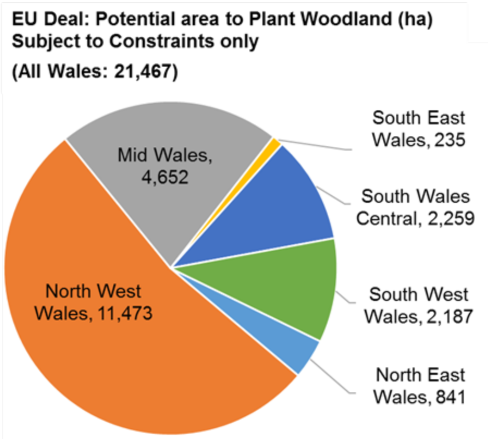
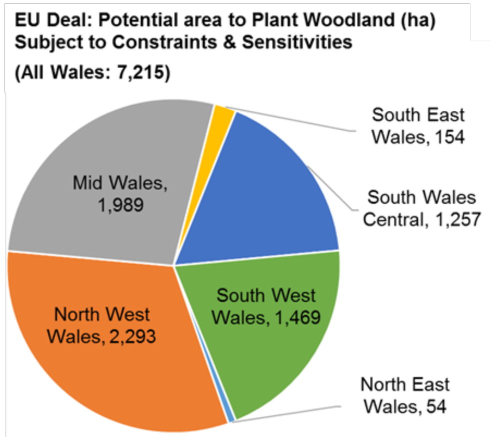


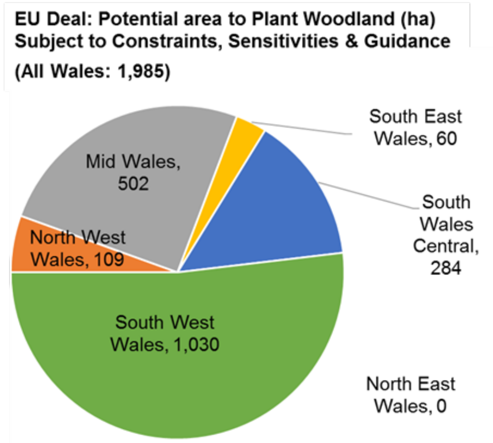
Figure 4.5.3. Potential farm area changing to new enterprise or changing out of agriculture by region.

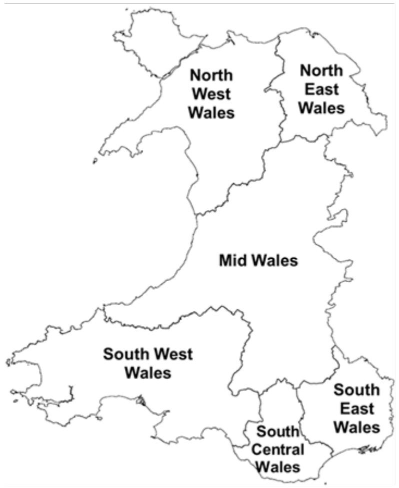
4.6 Potential for woodland creation

Potential area to plant woodland - EU Deal (QS RFT's, Farms > 1 FTE)



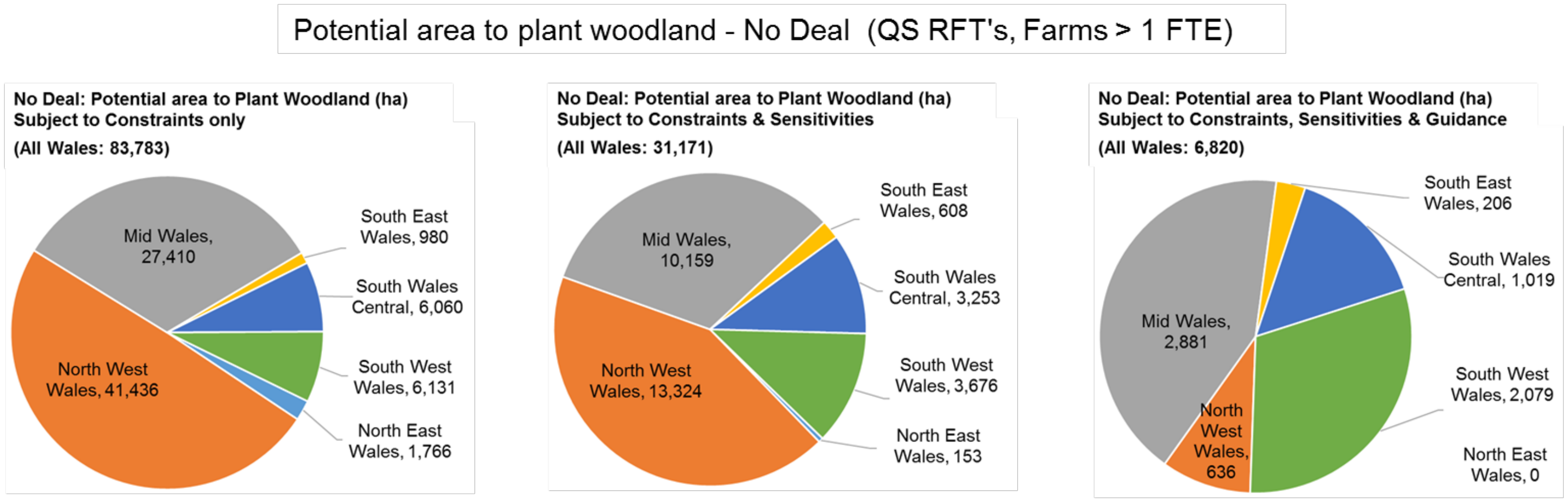


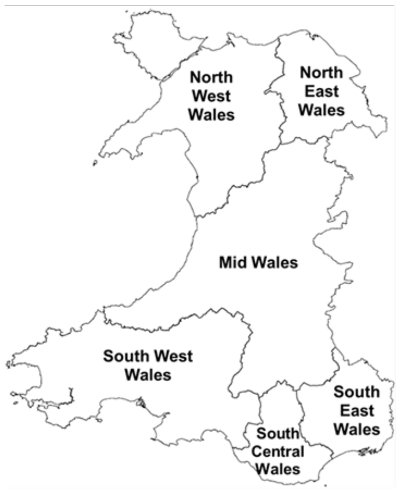




EU Deal		Potential area (ha) for planting up to 100,000 ha woodland, subject to:		
	Potential Area (ha) out of Agriculture	Constraints only	Constraints and Sensitivities	Constraints, Sensitivities and Guidance
Mid Wales	2,342	4,652	1,989	502
North East Wales	16,238	841	54	0
North West Wales	11,420	11,473	2,293	109
South East Wales	421	235	154	60
South Wales Central	3,119	2,259	1,257	284
South West Wales	3,890	2,187	1,469	1,030
All Wales	37,430	21,647	7,215	1,985

Figure 4.6.1 Variation in potential areas for new woodland planting and the impact of GWC Constraints, Sensitivities and Guidance – EU Deal

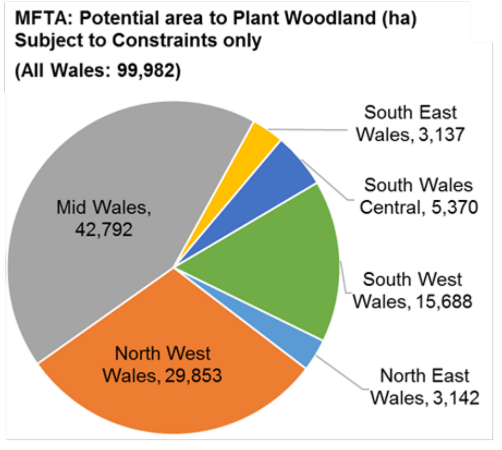


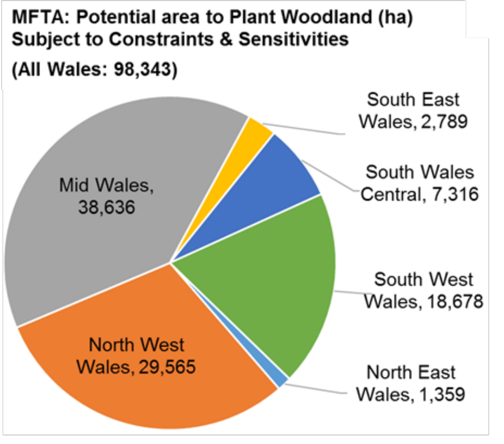


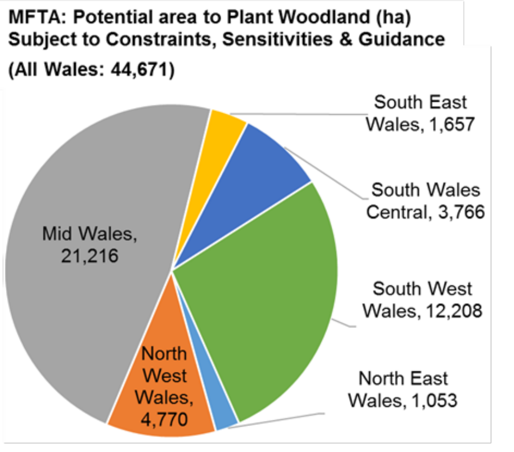
No Deal		Potential area (ha) for planting up to 100,000 ha woodland, subject to:		
	Potential Area (ha) out of Agriculture	Constraints only	Constraints and Sensitivities	Constraints, Sensitivities and Guidance
Mid Wales	3,323	27,410	10,159	2,881
North East Wales	56,017	1,766	153	0
North West Wales	41,149	41,436	13,324	636
South East Wales	1,445	980	608	206
South Wales Central	7,560	6,060	3,253	1,019
South West Wales	8,763	6,131	3,676	2,079
All Wales	118,258	83,783	31,171	6,820

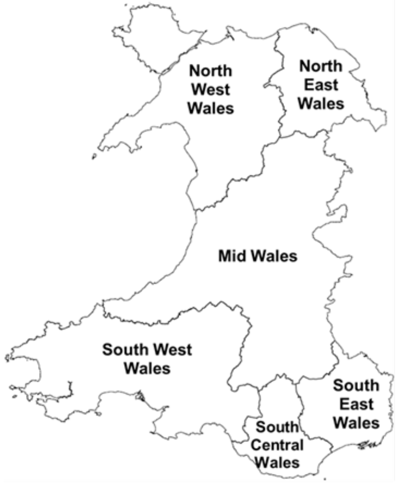
Figure 4.6.2 Variation in potential areas for new woodland planting and the impact of GWC Constraints, Sensitivities and Guidance – No Deal

Potential area to plant woodland - MFTA (QS RFT's, Farms > 1 FTE)









MFTA		Potential area (ha) for planting up to 100,000 ha woodland, subject to:		
	Potential Area (ha) out of Agriculture	Constraints only	Constraints and Sensitivities	Constraints, Sensitivities and Guidance
Mid Wales	8,257	42,792	38,636	21,216
North East Wales	100,026	3,142	1,359	1,053
North West Wales	98,278	29,853	29,565	4,770
South East Wales	6,101	3,137	2,789	1,657
South Wales Central	15,232	5,370	7,316	3,766
South West Wales	31,398	15,688	18,678	12,208
All Wales	259,292	99,982	98,343	44,671

Figure 4.6.3. Variation in potential areas for new woodland planting and the impact of GWC Constraints, Sensitivities and Guidance – MFTA

4.7 Potential changes in diffuse pollution

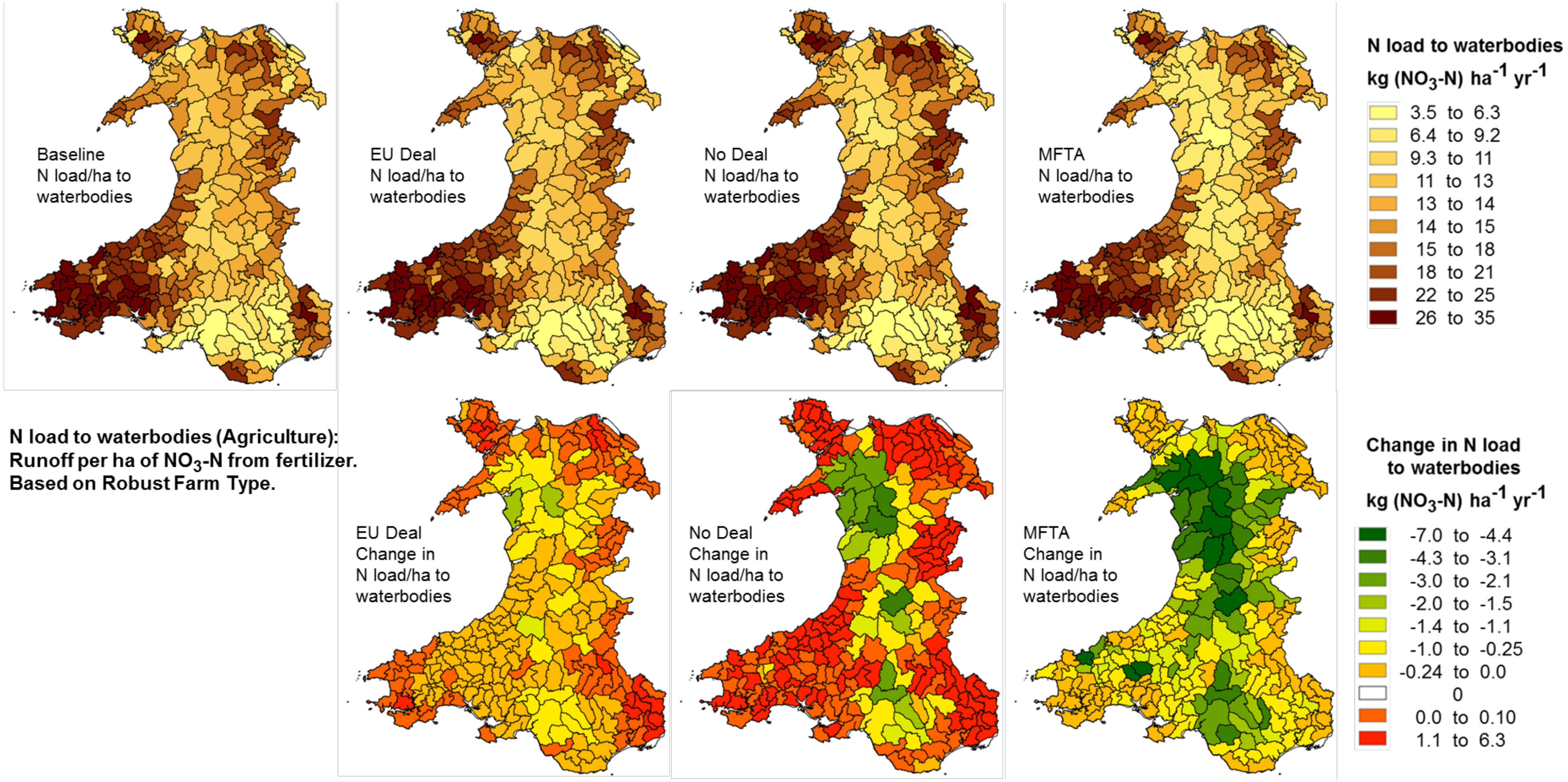


Figure 4.7.1 Spatial patterns of potential changes in agricultural Nitrogen loads to waterbodies across Wales for the Brexit trade scenarios. Changes in loads (lower plots) are relative to 2017 baseline values (upper left). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

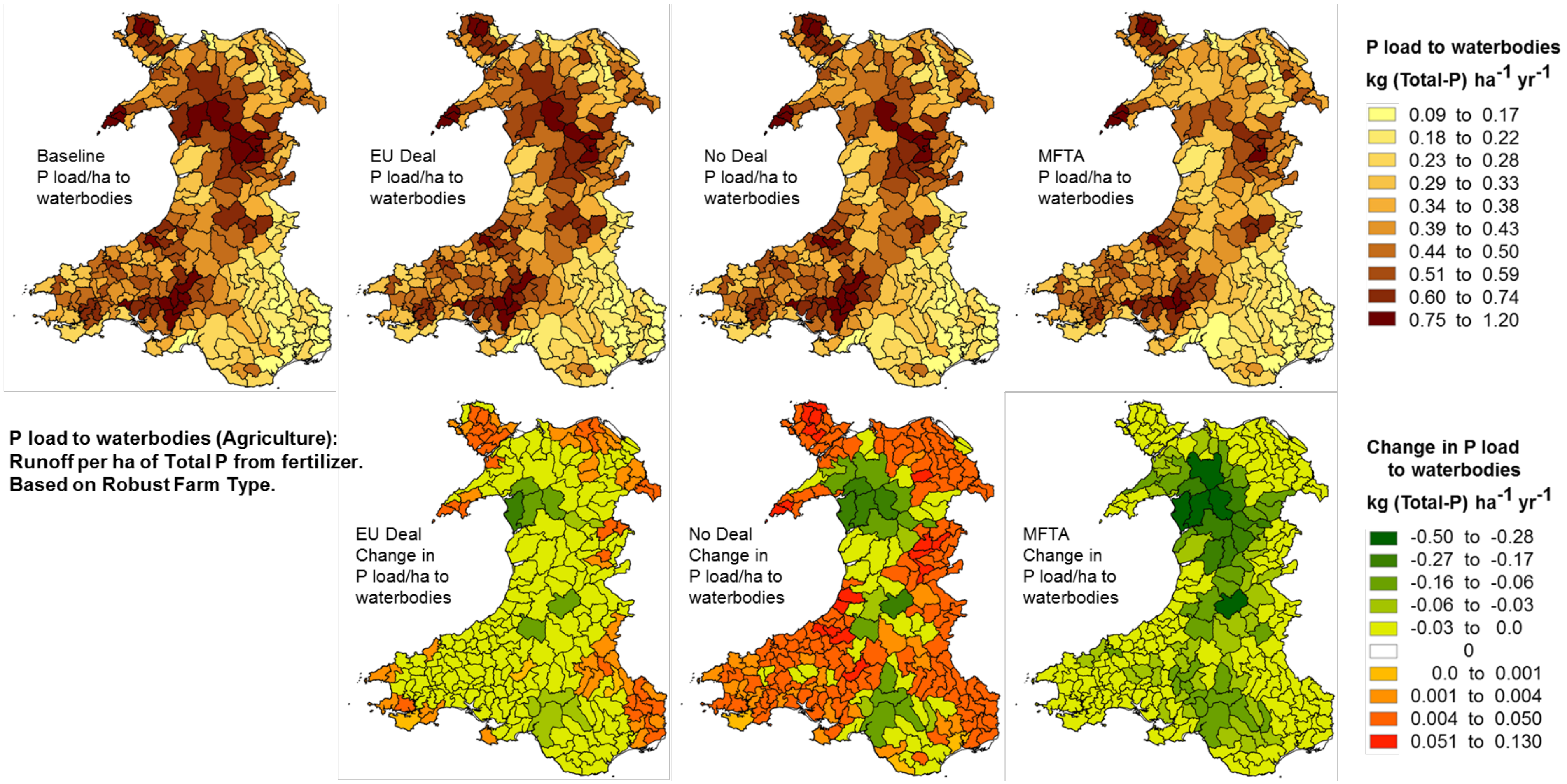


Figure 4.7.2 Spatial patterns of potential changes in agricultural Total Phosphorous loads to waterbodies across Wales for the Brexit trade scenarios. Changes in loads (lower plots) are relative to 2017 baseline values (upper left). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

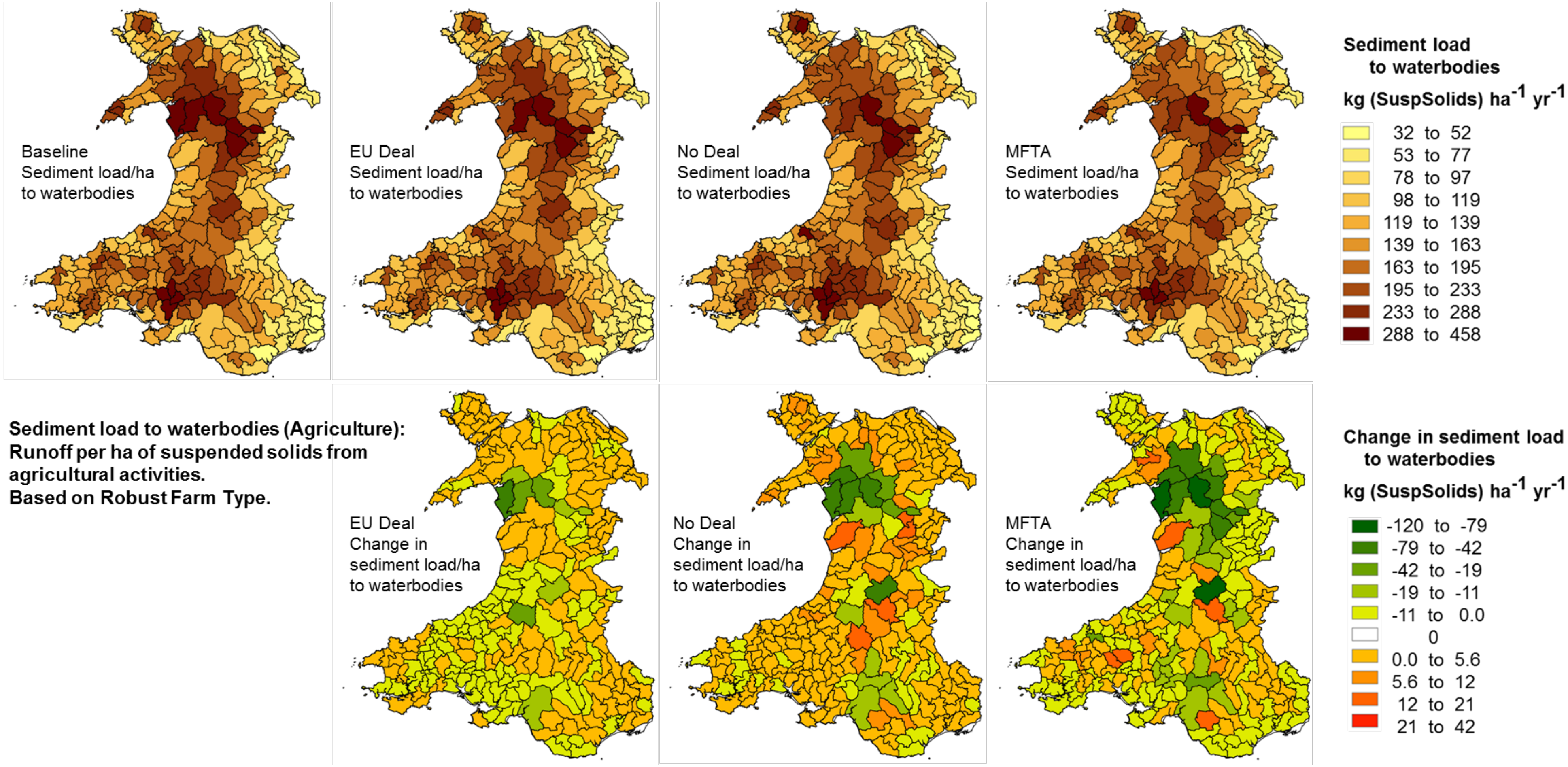


Figure 4.7.3 Spatial patterns of potential changes in agricultural Sediment loads to waterbodies across Wales for the Brexit trade scenarios. Changes in loads (lower plots) are relative to 2017 baseline values (upper left). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

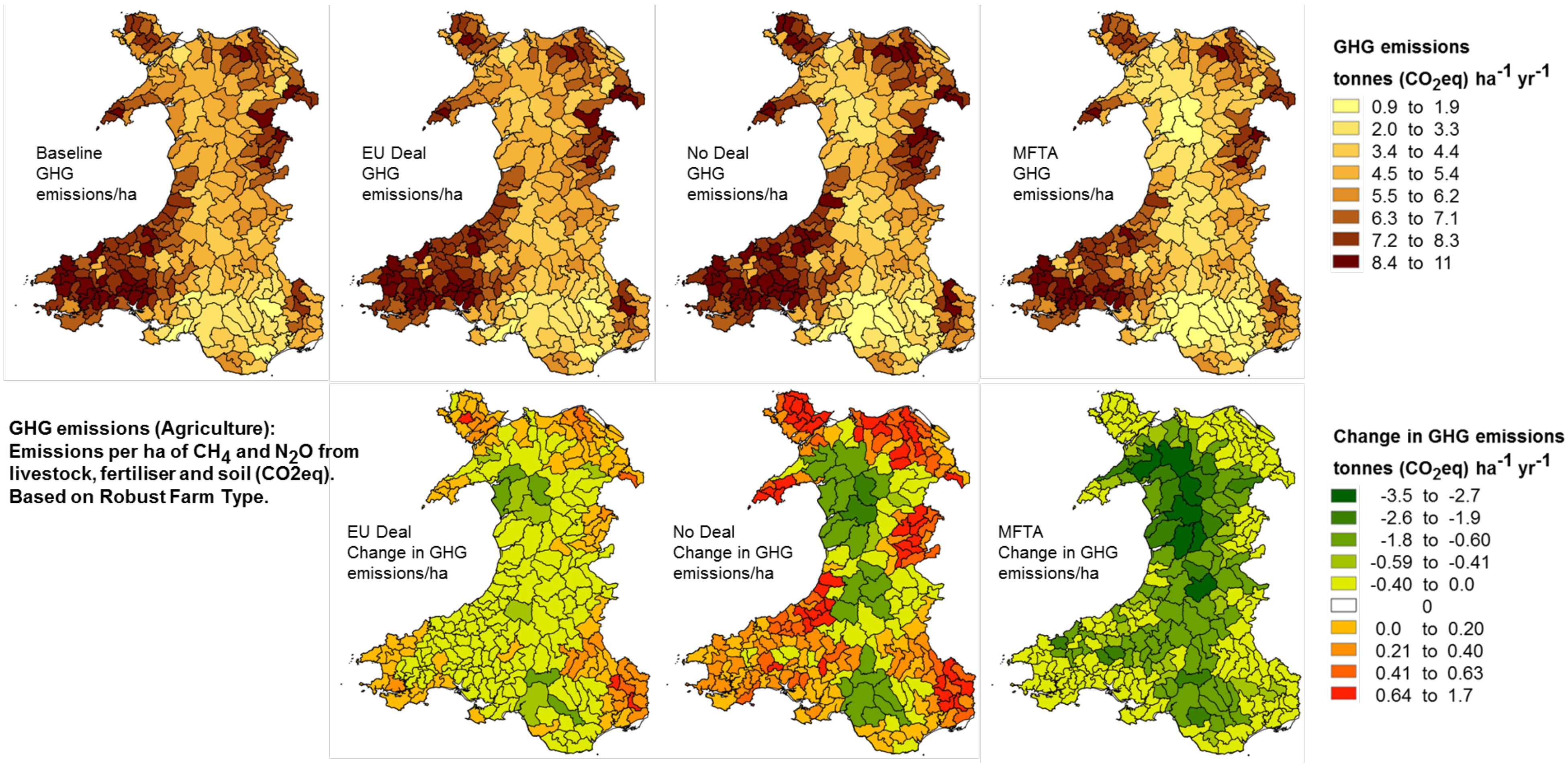


Figure 4.7.4 Spatial patterns of potential changes in agricultural GHG emissions across Wales for the Brexit trade scenarios. Changes in loads (lower plots) are relative to 2017 baseline values (upper left). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

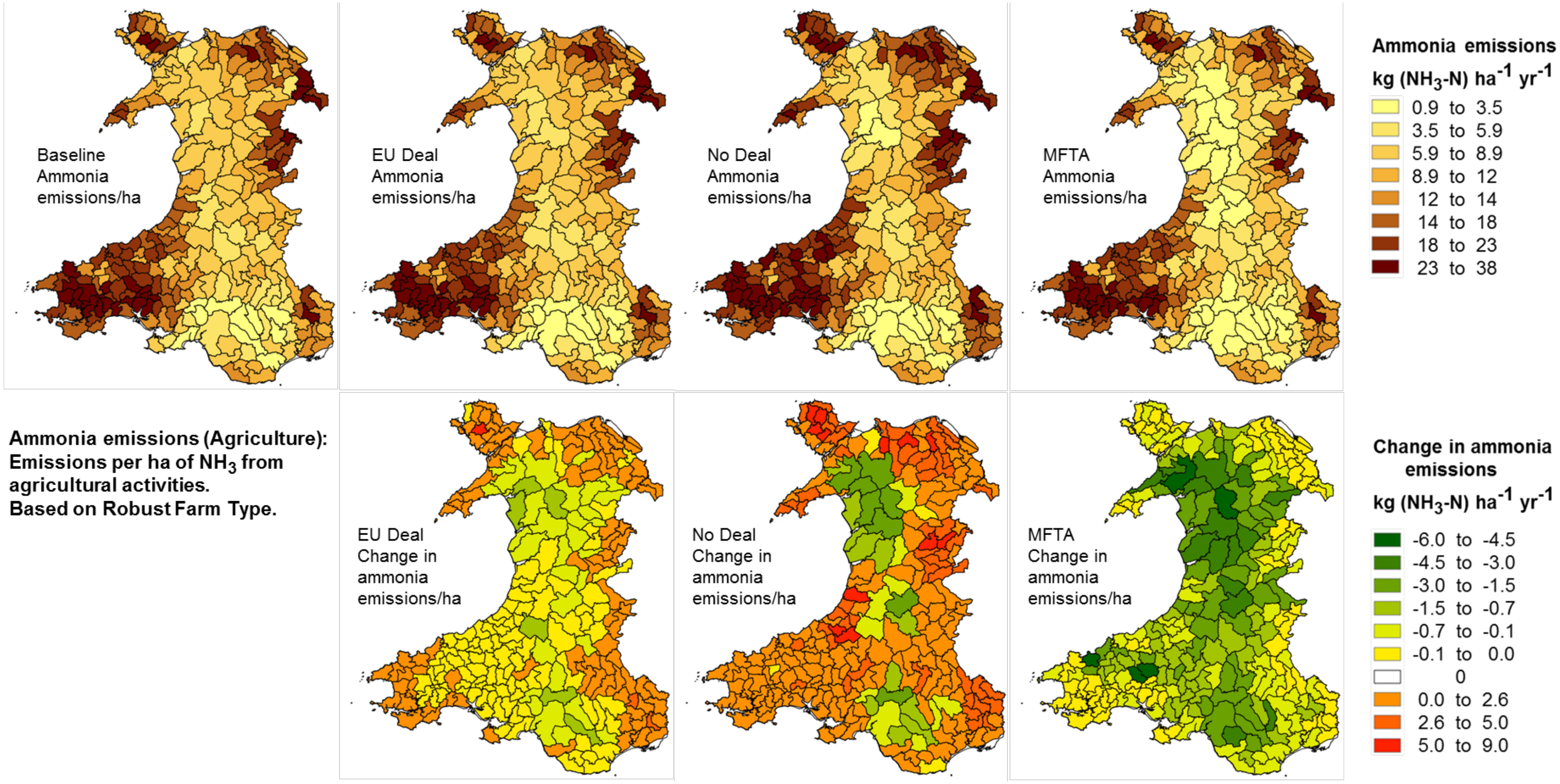


Figure 4.7.5 Spatial patterns of potential changes in agricultural ammonia emissions across Wales for the Brexit trade scenarios. Changes in loads (lower plots) are relative to 2017 baseline values (upper left). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

5 Appendix 5 - Land management scenarios

5.1 Woodland Planting

Woodland planting was considered for all farm holdings, using the following approach to avoid unsuitable locations and prioritise where to plant first:

1. New woodland with GWC: Areas subject to constraints and sensitivities as per GWC portal (substituting their peat layer for the GMEP peat layer) were ruled out. *Note* guidance layers were ignored here to maximise the potentially available area.
2. New woodland with GWC with 100,000 ha limit: Suitable farms were ranked using opportunity to increase broadleaved woodland connectivity, using the new tool developed for ERAMMP as described below. This would maximise the area of new woodland linking existing habitats even if the woodland type was conifer. Woodland planting was then assigned to farms in order, until the pro-rata'd 100,000ha target was reached. Targets for each of the test areas are indicated in Table 5.1.1.

Table 5.1.1 Land areas applied for pro-rata woodland planting

	size (ha)	**pro rata tree planting (ha)**
Conwy	58,009	2,733
Vale of Clwyd	22,405	1,056
Heads of Valley	175,565	8,272
All Wales	2,122,457	100,000

The ruling out of areas with constraints and sensitivities on planting matches the Glastir Woodland Creation Scheme opportunity mapping approach. This was applied for consistency across WG work. Although we do not know the extent to which these same conditions and restrictions would be maintained for any future WG scheme, or would be considered by and future PES, applying the GWC restrictions here enables assessment of their impacts on woodland planting opportunities.

The “pro rata” approach was applied to calculate a target area of planting for each study area which fits into the national target context based on the assumption planting would depend to some extent on PES or public support schemes which would require native species.

Opportunity to increase connectivity between existing woodland was used to rank potential new planting sites for the pro-rata scenario, in order to show the impact of using this criteria to weight the mapping. A single criteria was chosen for simplicity, but future work might consider opportunity to increase recreation for social wellbeing –once appropriate data become available.

CEH woodland connectivity tool

Opportunity to increase broadleaf woodland connectivity was mapped using the new CEH woodland connectivity tool which is based on generalisations about behaviour of broadleaf woodland focal species. This definition is too generalised for the tool to be usefully parameterised- more guidance on species of interest, and funding for parameterisation work would be required to generate a more reliable indication of opportunity to increase connectivity.

The method used here was to map connectivity opportunities for:

- Existing broadleaved woodland using areas assigned as ‘Broadleaved’ in the National Forest Inventory 2016 woodland map
- Patches/contiguous areas mapped > 500m^2.
- Applying assumption of 50% probability of travel distance of 200m for “generic woodland focal species”.

The tool identifies areas with opportunity to connect patches of existing woodland, and assigns a count of the number of woodland patches which could be connected.

5.2 Removal of agriculture from peatland

We simulated removal of agriculture from all peatland within the test areas. Livestock were removed from the whole field, rather than just the area of peat, since this is likely to be more practical. The changes in GHG emissions reported here only reflect the removal of livestock and fertilizer sources. The change in “natural” GHG emissions from the peatland itself before and after the removal of agriculture are not included. Peatlands were mapped for all areas assigned as peat in the GMEP integrated peat map (Evans et al., 2014).

5.3 Removal of agriculture from poor ALC farmland

Two scenarios were examined: removing agriculture from ALC 5 farmland, and removing agriculture from ALC 4 and 5 farmland.

Agricultural Land Classification (ALC) data were from the predictive ALC map for Wales (PALC-Wales, 2018). These data replace the previous “Provisional” map withdrawn in 2017. ALC is assigned based on the principles of the Agricultural Land Classification System of England & Wales, the Revised Guidelines & Criteria for Grading the Quality of Agricultural Land (MAFF 1988). This is the freely available version of the dataset from Lle (a licensed version had not been made available at time of modelling)

The baseline farm data was used to identify farm areas and ALC data were extracted to these. Majority ALC was used to define farms which should be abandoned. Land was taken out of agriculture based on majority ALC at farm level-i.e. including land outside of the study area boundary. Modelling of impacts only used land on fields which were at least partly inside the boundary.

The ALC data were scaled as 1=1, 2=2, 3a=3, 3b=4, 4=5, 5=6, non-agricultural=7, urban=8. We retained urban and non-agricultural classes here to account for the proportion of farm taken up by these when selecting farms for change- it should be noted that applying a linear scaling to non-linear categories affects the influence of these areas.

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