Qualitative Impact Assessment of Land Management Interventions on Ecosystem Services ("QEIA")

Report-3 Theme-5B: Biodiversity - Grassland

30-June-2023

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Citation

How to cite

Keenleyside, C.B. & Costa Domingo, G. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-5B: Biodiversity - Grassland. (Defra ECM_62324/UKCEH 08044)

This report is one of a set of reviews by theme:

Braban, C.F., Nemitz, E., Drewer, J. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA").* Report-3 Theme-1: Air Quality (Defra ECM_62324/UKCEH 08044)

Birnie, J., Magowan, E., Law, R., Lucas, O.T., Hassin, A.E.J. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA").* Report-3 Theme-2: Greenhouse Gases (GHG) (Defra ECM_62324/UKCEH 08044)

Newell Price, J.P., Williams, A.P., Bentley L. & Williams, J.R. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-3: Soils (Defra ECM_62324/UKCEH 08044)

Williams, J.R., Newell Price, J.P., Williams, A.P., Bowes, M.J., Hutchins, M.G. & Qu, Y. et al. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3, Theme-4: Water (Defra ECM_62324/UKCEH 08044)

Staley, J.T., Botham, M.S., Broughton, R.K., Carvell, C., Pywell, R.F., Wagner, M. & Woodcock, B.A. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-5A: Biodiversity - Cropland (Defra ECM_62324/UKCEH 08044)

Keenleyside, C.B. & Costa Domingo, G. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-5B: Biodiversity - Grassland (Defra ECM_62324/UKCEH 08044)

Maskell, L. & Norton, L. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-5C: Biodiversity - Semi-Natural Habitats (Defra ECM_62324/UKCEH 08044)

Siriwardena, G.M. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-5D: Biodiversity - Integrated System-Based Actions (Defra ECM_62324/UKCEH 08044)

Bentley, L., Feeney, C., Matthews, R., Evans, C.D., Garbutt, R.A., Thomson, A. & Emmett, B.A. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3 Theme-6: Carbon Sequestration (Defra ECM_62324/UKCEH 08044)

Short, C., Dwyer, J., Fletcher, D., Gaskell P., Goodenough, A., Urquhart, J., McGowan, A.J., Jones, L. & Emmett, B.A. (2023). *Qualitative impact assessment of land management interventions on Ecosystem Services ("QEIA")*. Report-3.7: Cultural Services (Defra ECM_62324/UKCEH 08044)

A list of all references used in the reports is also available as a separate database.

Foreword

The focus of this project was to provide a rapid qualitative assessment of land management interventions on Ecosystem Services (ES) proposed for inclusion in Environmental Land Management (ELM) schemes. This involved a review of the current evidence base by ten expert teams drawn from the independent research community in a consistent series of ten Evidence Reviews. These reviews were undertaken rapidly at Defra's request and together captured more than 2000 individual sources of evidence. These reviews were then used to inform an Integrated Assessment (IA) to provide a more accessible summary of these evidence reviews with a focus on capturing the actions with the greatest potential magnitude of change for the intended ES and their potential co-benefits and trade-offs across the Ecosystem Services and Ecosystem Services Indicators.

The final IA table captured scores for 741 actions across 8 Themes, 33 ES and 53 ES-indicators. This produced a total possible matrix of 39,273 scores. It should be noted that this piece of work is just one element of the wider underpinning work Defra has commissioned to support the development of the ELM schemes. The project was carried out in two phases with the environmental and provisioning services commissioned in Phase 1 and cultural and regulatory services in a follow-on Phase 2.

Due to the urgency of the need for these evidence reviews, there was insufficient time for systematic reviews and therefore the reviews relied on the knowledge of the team of the peer reviewed and grey literature with some rapid additional checking of recent reports and papers. This limitation of the review process was clearly explained and understood by Defra. The review presented here is one of the ten evidence reviews which informed the IA.

Acknowledgments

This project work and the resultant reports and databases were made possible by funding from the Department of Environment, Food and Rural Affairs, under contract ECM_62324. UKCEH and all the project participants are very grateful for the support we have received from DEFRA colleagues. In particular we would like to thank Tracie Evans, Hayden Martin, Daryl Hughes, Chris Beedie and Catherine Klein for their support and constructive inputs to the exercise. We would also like to thank our numerous external contributors and reviewers, some of whom have chosen to remain behind the scenes, and we are very grateful for the expansive and meticulous body of peer-reviewed evidence our authors have been able to refer to and make use of.

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INDEX OF ACTION CODES IN THIS REPORT

1 Introduction

The scope of this review covers agricultural grasslands both improved and semi-improved, including hay meadows. Other semi-natural pastoral habitats are covered by QEIA review Report-3-5C *Biodiversity: Semi-natural habitats*.

2 Outcomes

Primary outcomes the theme will achieve (related to Ecosystem Services).

Service	Indicator for Services Flow
Biodiversity	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
	Atmospheric deposition of N and exceedance of critical loads
	Connectivity of small 'feature' habitats
	Enhance condition of agricultural land by enhancing abundance and species richness of wider farmland biodiversity
	Enhance condition of semi-natural habitat
	Favourable condition of SSSIs
	Maintain good condition of agricultural land by maintaining abundance and species richness of wider farmland biodiversity
	Maintain good condition of semi-natural habitat
	Presence of rare (red list) species Presence of priority species
INNS	National species occurrence
Pest and disease control	Evidence of outbreaks of pests and disease
Pollination and seed dispersal	Increased abundance, distribution & species richness of pollinators & seed dispersers

3 Management Bundles

The actions fully assessed in this report for their influence on biodiversity associated with grassland are presented grouped in the following management bundles and sub-bundles:

1. Habitat creation/Grassland

EBHE-214C	Create locally distinctive flower rich/hay meadows using traditional techniques
ECPW-022C	Create species-rich grassland habitats
ECPW-237EMx	Create wildflower/legume rich swards
ECPW-237Cx	Create in-field vegetation including grass, scrub, trees
EHAZ-010X	Create permanent grasslands

2. Specific wildlife targeted actions

EHAZ-010Z	Enhance/ manage grasslands to benefit invertebrates
ETPW-103	Leave uncut margins in meadows to provide refugia for invertebrates and birds, to be aftermath grazed or cut late
ETPW-245	Set ryegrass seed as winter food for birds

3. Restoration, management and enhancement/Grassland

EBHE-214EM	enhance and manage locally distinctive flower rich/hay meadows using traditional techniques

EBHE-214-X	Manage locally distinctive flower rich/hay meadows using traditional techniques
ECCM-014	Use low-intensity grazing systems using biodiverse sward mixtures
ECCM-028	Manage temporary grassland reseeding frequency
ECPW-022EM	Enhance or manage species-rich grassland habitats
ECPW-237Cy	Enhance/ manage in-field vegetation including grass, scrub, trees
ECPW-237EMy	Enhance/ manage wildflower/legume rich swards
EHAZ-010Y	Enhance or manage permanent grasslands
ETPW-101	On meadows, make field- dried hay and minimise haylage and silage
ETPW-104	Reduce stocking rate (grazing) to restore structure and flowering, maintain ground cover, and reduce poaching
ETPW-105	Use low intensity mixed livestock grazing
ETPW-106	Manage timing of grazing and select livestock type to allow flowering and seed return, and control competitive and invasive species.
ETPW-110	When fields are cut for hay or haylage, aftermath graze with cattle
ETPW-111	Harvest seeds / take green hay to restore other grassland sites, following best practice
ETPW-115	Control cutting of grasslands to promote flowering and structure for target species, where appropriate
ETPW-150	Manage localised grazing pressure
ETPW-156	Replace grazing of sheep with cattle grazing, particularly on limestone habitats
ETPW-157	Create and use a grazing plan including stocking rates; monitor and adjust in line with grass productivity (especially where there are multiple graziers)
ETPW-216	Leave areas of grassland uncut
Grassland_02	Mob grazing
Grassland_01	Adapt mowing or first grazing dates on improved or semi-improved grassland; use mowing techniques to reduce mortality

4. Restoration, management and enhancement/ Coastal

ETPW-091	Restore/ enhance/ manage permanent grassland in coastal areas

5. Actions for habitats with specific hydrological characteristics/Peatlands and wetlands

ECCM-038	Raise water levels in areas of farmed peatland and adapt farming systems accordingly

6. Soil management and protection/Cover cropping

ECPW-295	Maintain soil cover (e.g. grass, crop or geotextile), to reduce soil erosion and loss around livestock shelters/feeders/troughs; e.g. for outdoor pigs.
ETPW-270	Re-seed grassland by slot-seeding or over-seeding

7. Fertiliser, nutrient, manure and mulch management

ECAR-015	Replace nitrogen fertiliser application by using clover in pasture or arable cropping systems
ECCM-059	Incorporate clovers and other legumes in grazed pastures
ECPW-265	Use crops / varieties with differing root structures to improve soil structure and nutrient uptake

8. Climate measures/Climate change and adaptation

ECCM-012	Integrate high-sugar grass varieties

The scope of each bundle and main expected outcome are outlined briefly, followed by the list of actions reviewed, each with its assessment scores against the 12 ecosystem service (ES) indicators defined for this study (if an action is assessed as not contributing to one or more of the ES indicators these are omitted).

3.1 Bundle: Habitat Creation/Grassland

This bundle involves actions to create new habitats on existing improved and semi-improved grasslands or on cropland. Actions which increase the species richness of improved and semi-improved grassland but do not change their habitat type are considered enhancement rather than creation and are assessed in section 3.3 (Grassland habitat restoration, management, and enhancement).

The expected outcomes are an increase in the extent and diversity of grassland habitat types and the species they support, appropriate for the pedo-climatic conditions. Newly created habitats will require specific management until they are established – in the early years this may differ from the 'maintenance' management of existing habitats of a similar type.

3.1.1 Actions Considered

EBHE-214C	Create locally distinctive flower rich/hay meadows using traditional techniques
ECPW-022C	Create species-rich grassland habitats
ECPW-237	Create/ enhance/ manage in-field vegetation including grass, scrub, trees and wildflower/legume rich swards
ECPW-237Cx	Create wildflower/legume rich swards
ECPW-237Cy	Create in-field vegetation including grass, scrub, trees
EHAZ-010	Create, enhance or manage permanent grasslands
EHAZ-010C	Create permanent grasslands

3.1.1.1 Causality

EBHE-214C	Create locally distinctive flower rich/hay meadows using traditional techniques
AMBER LT**	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER LT**	Connectivity of small 'feature' habitats
GREEN LT**	Enhance condition of agricultural land
GREEN LT**	Maintain good condition of agricultural land
GREEN **	Increased abundance, distribution & species richness of pollinators & seed dispersers

It is assumed that this refers to the creation of flower rich and hay meadow from cropland or species poor improved/semi-improved grassland. Traditional techniques can be used to create locally distinctive flower rich and hay meadows including changes in grazing and cutting management and methods to introduce wildflowers such as green hay, slot seeding and using plug plants. The specific methods chosen will depend on site-specific characteristics and the tools available to individual farmers.

There is good evidence that creating additional flower rich/hay meadows and in field vegetation increases the diversity of vegetation types on grassland which is likely to be beneficial to biodiversity across different types of grassland and at multiple spatial scales (Woodhouse, 2005). Flower rich meadows can enhance the condition of agricultural land and create vital feeding and breeding habitats for native insect, bird and mammal species. Wildflower meadows can be important for priority species and other threatened species such as the Barn Owl (*Tyto alba*), Greater Horsehoe Bat (*Rhinolophus ferrumequinum*), Adonis Blue butterfly (*Polyommatus bellargus*), and Shorthaired Bumblebee (*Bombus subterraneus*) (Jarvis, 2014).

The success of different traditional techniques to create locally distinctive flower rich/ hay meadows will depend on site preparation, restoration practices, post restoration management and site-specific variables including local ecology and climate, site conditions prior to restoration, current and previous management, and availability of donor sites. When there is a high availability of propagules, spontaneous succession can be a good option for the creation of grassland (Torok, 2011). However, the unassisted recreation of flower rich/ hay meadows from spontaneous colonisation of sites is limited. This is due to limitations in the dispersal of target species' seeds, and to microsite limitations in site-specific conditions which affect the establishment of target species' seeds. Several techniques are applied to overcome these constraints (Wagner, 2020). Two key methods are typically used to overcome seed limitations and facilitate the introduction of target species - actively introducing seeds and using seed mixes and the transfer of green hay from species-rich donor sites. There is evidence that both these recreation methods can benefit grassland biodiversity, particularly by increasing plant diversity. Sowing species-rich commercial seed mixes designed for grassland re-creation can create locally distinctive wildflower/ hay meadows on arable land or improved grassland. It is important that these mixes use local genotypes to preserve the locally distinctive genetic integrity of the population (Kiehl, 2010).

Green hay is composed of harvested wildflowers and grasses which are shedding seeds which can then establish in nearby recipient sites such as ex-arable land or intensively used improved grassland (Save our magnificent meadows, unknown). The success of the establishment of target species from green hay depends on site preparation, good practice in the preparation and transfer of the green hay, and site conditions and target species. Species that are less abundant at the donor site or that have specific growth requirements which hamper immediate establishment typically have lower establishment success (Wagner, 2020). A review of grassland restoration and recreation measures in Central and Northwestern Europe showed that near-natural techniques can lead to high establishment rates of local target plant species, leading to the development of target communities (Kiehl, 2010). Other studies in the Czechia also found grassland recreation methods on arable land established species richness and functional groups similar to that of donor sites (Albert, 2019) (Prach, 2013). In Hungary, the sowing of low diversity seed mixtures on arable soils led to the establishment of grassland vegetation, but was detrimental to some specialist species (Torok, 2010). These new flower rich/hay communities can increase sward structure complexity creating new habitats and increasing the availability of new niches which can be occupied by a variety of grassland species. A study in Norway found that sowing a local seed mix from a species-rich hay meadow in a ploughed experimental field led to an increased occurrence of endangered species (Losvik, 2002). Only one out of 25 endangered species found in donor meadows were found in the recipient site before sowing a local seed mixture. After sowing, 16 additional endangered species were recorded in the recipient meadow. Additional measures such as biodiversity-friendly cutting and grazing increased the abundance of these species. A review of different grassland restoration treatments on arable land in the UK found that sowing species-rich seed mixtures of locally adapted species was the most effective method (Pywell, 2002).

Flower species selection and spatial management need careful consideration and planning to ensure a year-long supply of flowering resources. Species that flower during different periods of the year need different mowing regimes and can therefore not be grown in the same area (Jarvis, 2014).

EHAZ-010X	Create permanent grasslands
AMBER LT*	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T**	Enhance condition of agricultural land
AMBER T**	Maintain good condition of agricultural land
AMBER T**	Presence of rare (red list) species Presence of priority species
AMBER LT**	Evidence of outbreaks of pests and disease
AMBER T**	Increased abundance, distribution & species richness of pollinators & seed dispersers

The creation of improved and semi-improved grasslands on arable land can enhance the condition of agricultural land by increasing vegetation diversity and creating additional habitat for grassland species, including pollinating species. However, in the case of creating improved agricultural grassland, that will be used for grazing or silage, evidence does not show clear biodiversity benefits from the conversion from arable land. A study in the South Downs in Sussex, UK found that brown hares (*Lepus europaeus*), avoided improved grassland (Wakeham-Dawson, 1995). Another study, also in Sussex, found that Grey Partridge (*Perdix perdix*) numbers declined when arable fields were converted into improved grassland (Aebischer, 1998). A study in southern England found that Eurasian Skylarks (Alauda arvensis), Corn Buntings (*Miliaria calandra*) and Meadow Pipits (*Anthis pratensis*) showed no increase in richness when arable land was converted to improved grassland (Wakeham-Dawson, 1998). The lack of clear biodiversity benefits is also seen for vegetation, with a study in Czechia finding that arable fields reverted to grassland showed to increase in plant species richness (Houlbec, 2009).

ECPW-237EMx Create wildflower/legume rich swards

GREEN*** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER L* Connectivity of small 'feature' habitats
GREEN *** Enhance condition of agricultural land
GREEN *** Maintain good condition of agricultural land
GREEN *** Increased abundance, distribution & species richness of pollinators & seed dispersers

ECPW-237EMy Enhance/ manage wildflower/legume rich swards

AMBER *** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN *** Enhance condition of agricultural land
GREEN *** Maintain good condition of agricultural land

ECPW-022C Create species-rich grassland habitats

AMBER ** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN *** Connectivity of small 'feature' habitats
GREEN *** Enhance condition of agricultural land
GREEN *** Enhance condition of semi-natural habitat
AMBER T* Presence of rare (red list) species Presence of priority species
AMBER T* National species occurrence
GREEN *** Increased abundance, distribution & species richness of pollinators & seed dispersers

Wildflower/ legume and herb rich swards can be sown along with grasses in temporary short-term leys for grazing, can benefit a range of species, including pollinators. Legumes can provide food for long-tongued bee species while other wildflower and herb species can provide feeding resources for other insects. Seed mixes to establish grasses, legumes and non-leguminous forbs into grassland were shown to increase pollinator species richness and abundance through increasing the availability of flower resources. In turn, this increased pollination benefits which contributed to the long-term establishment of the forbs (Woodcock, 2014). A study in the UK found that bumblebee abundance, species richness and diversity increased after the introduction of sown components (including legumes) in the sward. Even small increases in conventional grassland species richness have been linked to enhanced pollination (Orford, 2016). Alison et al. (2017) demonstrated that created grasslands with a higher diversity of chalk grassland wildflowers, including key legumes such as *Lotus corniculatus*, supported a higher abundance of chalk grassland moths However, the ability of pollinator species to colonise recreated flower rich/ hay meadows will depend on their traits. A study in Sweden found that solitary bees present in the landscape were less likely to recolonise recreated habitats than were bumblebees and hoverflies. In addition, both mobility and resource use affected the ability of bumblebee, solitary bee and hoverfly species to recolonise (Ockinger, 2017). In addition, these benefits to arthropods can ripple through grassland food webs, because insects provide food for other taxa such as birds and bats. A study looking at the impacts of England's Countryside Stewardship schemes aiming to provide more diverse swards by introducing grasses, legumes and herbs found that these options provided additional food resources to pollinating insects and granivorous birds during summer and ither seed eating species in autumn (Jones et al 2018). In addition, as discussed under section 3.5.2 below, the incorporation of legumes can achieve biodiversity benefits through their nitrogen cycling ecosystem services which can in turn reduce the need of artificial nitrogen fertiliser inputs. Moreover, by introducing species with different rooting depths, such as the deep-rooting chicory, soil structure and water infiltration can be enhanced.

The introduction of botanically rich swards, alongside biodiversity-friendly grassland management, in improved grasslands can also contribute to pest control by creating habitat for natural pest enemies. However, pest enemies, particularly ground dwelling species, typically have low dispersal abilities. As a result, biocontrol services from in-field vegetation might only be delivered if the improved grassland is near natural sources of pest enemy populations, such as semi-natural grasslands (Holland, 2016).

ECPW-237Cx Create in-field vegetation including grass, scrub, trees
GREEN ** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN ** Connectivity of small 'feature' habitats
GREEN ** Enhance condition of agricultural land
AMBER DT Enhance condition of semi-natural habitat
GREEN ** Maintain good condition of agricultural land
AMBER DT Maintain good condition of semi-natural habitat
AMBER Increased abundance, distribution & species richness of pollinators & seed dispersers

ECPW-237Cy Enhance/ manage in-field vegetation including grass, scrub, trees
AMBER L** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER L* Connectivity of small 'feature' habitats
GREEN ** Enhance condition of agricultural land
GREEN *** Maintain good condition of agricultural land
AMBER * Increased abundance, distribution & species richness of pollinators & seed dispersers

There is good evidence for the biodiversity benefits of the creating in-field vegetation as it increases ecosystem complexity and resilience leading to enhanced condition of agricultural land, creates additional habitat for species and enhances ecosystem service delivery. Woody vegetation can increase ecosystem heterogeneity in grasslands as it alters floristic composition, diversity and mean pasture height (Lopez-Pintor, 2006).

A study in North-western Spain found that, under appropriate management, woody vegetation can increase taxonomic and functional diversity by creating new niches and promoting trait divergence. However, biodiversity benefits are impacted by a range of site-specific factors and by the surrounding landscape (Rolo, 2016). The introduction of woody vegetation such as hedges provides food and habitat for a range of species including for mammals (Pereira and Rodríguez, 2010), birds (Siriwardena, Cooke and Sutherland, 2012), butterflies (Smart et al, 2000), bees and hoverflies (pollinators) (Garibaldi et al, 2014). For example, the presence of woody linear features such as hedgerows in Scotland's agricultural landscape was found to increase the diversity of ground beetle communities (Petit, 1998). In Switzerland, woody features such as hedges were associated with increased moth abundance and richness (Kuhne, 2015). For birds, a study in England found that some granivorous species with preferences for woodland habitat showed positive associations with hedgerows (e.g. Willow Warbler (*Phylloscopus trochilus*), Marsh Tit (*Poecile palustris*) and Eurasian nutchatch (*Sitta europaea*)), however other species showed negative associations (e.g. Common Whitethroat (*Curruca communis*), and Great Tit (*Parus major*) (Broughton, 2021).

The negative associations were likely due to limited seed resources over winter for these species. Ground feeding insectivores also showed some negative associations, despite the fact that they may have been expected to have higher earthworm and beetle larvae availability. In general, two studies found that woody-features were more beneficial to populations on arable farmland than on grassland, in particular for taller hedgerows and tree lines (Broughton, 2021), (Sullivan, 2017). This was possibly due to fewer or less accessible seed and invertebrate food resources in grassland. This suggests that diversifying grassland habitats in the landscape context might be important for bird species abundance in grassland alongside introducing woody features.

A study examining the effect of broad-leaved trees on biodiversity in improved grassland within silvopastoral systems found that maturing trees increased floral diversity and structural heterogeneity leading to enhanced habitat condition (Whiteside, 2002). In addition, the introduction of trees increased the diversity of spiders and ground beetles by providing new habitat through increased sward structure complexity and prey populations. This increased invertebrate diversity also increased bird species diversity. The species benefitting from habitat creation by the introduction of trees gradually changed as trees matured and the canopy closed. In addition, the study proposed that the root systems of the infield trees improved soil physical characteristics leading to improvements in earthworm abundance and soil fertility which in turn can improve broader habitat condition.

The creation of scrub habitat in improved grassland can increase bird species abundance and diversity by creating habitat for scrub and woodland species. For example, the House Martin (*Delichon urbica*) and Swallow (*Hirundo rustica*) have been significantly associated with improved grassland with scrub or bracken in Wales and Sweden (Woodhouse, 2005). Other vegetation is associated with habitat creation in improved grassland, such as Gorse (*Ulex spp*.) which provides habitat to Yellowhammers (*Emberiza citrinella*) by creating song posts in the breeding season and to Linnets (*Linaria cannabin*) by creating foraging and nest sites (Woodhouse, 2005).

The creation of additional grassland habitat can also increase habitat connectivity and landscape permeability by creating habitat patches and corridors through which species can move and disperse. As such, the creation of additional agriculturally semi-improved distinctive flower rich/ hay meadows and the creation of additional infield vegetation within semi improved and improved grassland, can benefit the biodiversity of nearby semi-natural grasslands and contribute to the survival of key species that depend on these habitats.

3.1.1.2 Co-Benefits and Trade-offs

[TOCB Report-3-5D Systems **EHAZ-010X**] Arable reversion to grassland might be expected to deliver increases in soil carbon, but performance in carbon sequestration may actually be poor, due to reduced available soil nitrogen (Gosling et al. 2017).

3.1.1.3 Magnitude

No studies were found quantitatively measuring the impact of habitat creation on biodiversity indicators. Moreover, the magnitude of impacts will likely vary considerably across different sites as it will depend on a variety of other factors such as previous management and site ecological, soil and climate characteristics.

3.1.1.4 Timescale

(0-5 years, 5-10 years) Grassland habitats take time to mature after creation. The creation of distinctive flower rich/ hay meadows might take some years. For example, perennial flower species take at least a year after sowing to flower (Jarvis, 2014). Some studies show that the establishment of target plant communities on arable sites can happen as quickly as within two years.

However, grassland priority creation actions typically take closer to 10 years, and the creation of species composition which is closer to semi-natural habitats can happen over much longer timeframes of up to 100 years (Warwickshire County Council, 2018).

3.1.1.5 Spatial issues

Targeting is critical for creation of hay meadows and species-rich grassland. The ability of species to colonise additional re-created grassland habitat will depend on species-specific traits such as dispersal ability and resource use, as well as on the connectivity and permeability of the surrounding landscape. The spatial configuration of the surrounding landscape will therefore impact the biodiversity outcomes of grassland habitat creation measures (Rotches-Ribalta, 2018).

3.1.1.6 Displacement

If new, permanent grassland habitats replace intensively managed ryegrass swards or arable cropping the reduction in biomass production or arable cropping may be displaced, within the farm or elsewhere, possibly leading to intensification of other semi-improved grasslands or their conversion to arable.

3.1.1.7 Maintenance and longevity

Careful ongoing management and annual maintenance is needed for the maintenance of flower rich hay meadows (Jarvis, 2014) (Save our magnificent meadows, unknown). This is usually achieved through carefully planned cutting and grazing or combinations of both which considers the flowering times and specific needs of target species. Most grassland wildflowers are perennial, but weeds and fast-growing grasses must be controlled to allow the native meadow flowers to establish.

The full delivery of the potential biodiversity benefits of creating in-field vegetation depend on careful planning and appropriate maintenance. For legume or herb rich swards, plants must be given time to fully flower before cutting in order to provide nectar and pollen resources for pollinators. Therefore, careful biodiversity-friendly mowing and cutting management is needed (see also sections 3.3 and 3.6). In addition, many of the species in legume rich swards do not persist in the sward for many years[1] and ongoing management is therefore needed. Furthermore, the outcomes and species persistence from the introduction of grass, wildflower and legume rich swards depend on the species mixes selected and on site condition including pH and organic carbon[2].

3.1.1.8 Climate adaptation or mitigation

No assessment.

3.1.1.9 Climate Factors / Constraints

Increased habitat availability and connectivity can increase the resilience of agricultural grassland habitats and species to climate change by creating some redundancy which can compensate for some of the inevitable habitat loss which will happen due to climate change, by increasing genetic resilience and facilitating the movement of species to adapt to climate-driven habitat shifts.
The introduction of in-field vegetation can contribute to climate change mitigation and adaptation through introducing additional vegetation and deeper-rooting vegetation which can store additional carbon in biomass and soil stocks.

3.1.1.10 Benefits and Trade-offs to Farmer/Land-manager

Plant diversity is often associated with low biomass yield and forage quality, and vice versa. A one-year assessment of plant diversity effects on biomass yield, forage quality, quality-adjusted yield and revenues across different management intensities on subplots of the Jena experiment in Germany found that plant diversity substantially increased quality-adjusted yield and revenues. These findings hold for a wide range of management intensities in semi-natural grasslands. Plant diversity was an important production factor independent of management intensity, as it enhanced quality-adjusted yield and revenues similarly to increasing fertilisation and cutting frequency. The authors conclude that maintaining and re-establishing plant diversity could be a way to sustainably manage temperate grasslands. (Schaub et al., 2020)

3.1.1.11 Uptake

No information.

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[1] https://farmwildlife.info/how-to-do-it/flower-rich-habitats/rotational-legume-and-herb-rich-swards/
[2] https://enrd.ec.europa.eu/sites/default/files/evaluation_publications/14467_ek21finalreport-2019.pdf

3.1.1.12 Other notes

None

3.2 BUNDLE: SPECIFIC WILDLIFE TARGETED ACTIONS

This bundle is expected to deliver a range of biodiversity benefits, particularly by supporting populations of invertebrates and birds which depend on grasslands for feeding, shelter or breeding.

3.2.1.1 Causality

EHAZ-010Z Enhance/ manage grasslands to benefit invertebrates

AMBER ***	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN ***	Connectivity of small 'feature' habitats
GREEN ***	Enhance condition of agricultural land
GREEN ***	Enhance condition of semi-natural habitat
AMBER T**	Favourable condition of SSSIs
AMBER **	Maintain good condition of agricultural land
GREEN **	Maintain good condition of semi-natural habitat
AMBER TL*	Presence of rare (red list) species Presence of priority species
GREEN ***	Increased abundance, distribution & species richness of pollinators & seed dispersers

ETPW-103 Leave uncut margins in meadows to provide refugia for invertebrates and birds, to be aftermath grazed or cut late

AMBER **	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T**	Connectivity of small 'feature' habitats
AMBER T*	Enhance condition of agricultural land
AMBER T**	Maintain good condition of agricultural land

The management of grasslands for invertebrates includes a range of measures reviewed under different bundles, such as reducing management intensity, controlled grazing and mowing, and creation of locally distinctive flower rich meadows. Carefully managed grasslands to create well-connected micro-habitats can increase invertebrate abundance and diversity. This can be achieved by actions to increase sward structural diversity such as heterogeneous grazing management which promotes tussock grasses that benefit many invertebrates, and temporal variation in grass cutting. (Littlewood, 2011). Measures to introduce target plant species can also benefit invertebrate species, which are typically associated with specific plants. Well-selected plant species can enhance the diversity of invertebrates supported by plant assemblages (Littlewood, 2011). Enhancing grassland management to benefit invertebrates can in turn lead to positive outcomes for broader habitat condition, for example by improving soil condition, and species abundance in other taxa (e.g. by increasing prey availability for insect feeding birds such as yellowhammers and song thrushes). Increasing insect diversity can also promote plant diversity, as they influence competitive interactions between plants (Rand, 2003). In addition, the delivery of some ecosystem services can be enhanced such as pollination, biocontrol and nutrient cycling (Woodcock, 2009).

However, some management measures which benefit other taxa can sometimes have a negative impact on invertebrate species. For example, an experimental study in the Netherlands found that grasslands managed for meadow birds have lower pollinator abundance and diversity, and support less unique pollinator assemblages. This is due to reduced flower abundance and diversity as well as less favourable mowing practices which limit suitable habitat and food for bees, hoverflies and butterflies (Tanis, 2020). Conflicts can also arise with measures to enhance plant diversity as invertebrates often prefer taller grasslands and measures to increase the topographic heterogeneity of grasslands and create patches of bare ground to benefit insects can be incompatible with the requirements of some key plant species like orchids (Littlewood, 2011).

ETPW-245 Set ryegrass seed as winter food for birds

AMBER T* Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN ** Enhance condition of agricultural land
AMBER ** Maintain good condition of agricultural land
GREEN ** Presence of rare (red list) species Presence of priority species

The intensification of grassland management in the UK has led to the loss of seed-rich wintering habitat for granivorous birds. The decline of winter food availability is a key factor driving declines in granivorous farmland birds, particularly on agricultural grassland which are poor winter foraging habitats (Siriwardena, 2007). The production of ryegrass over winter can address this by providing food and habitat for granivorous birds in grasslands isolated from seed-rich arable crops. Ryegrass seeds are abundant and easily gleaned by birds and remain on the plant into early spring providing winter over the winter months (Keenleyside, 2020). This is a critical period as farmland birds typically face seed shortages in late winter and other interventions such as sown seed mixtures are often depleted of seed in late winter (Johnstone, 2019). Setting ryegrass seed as winter food for birds is therefore a potentially valuable conservation measure for priority bird species (Buckingham, 2011). This can be achieved by leaving strips or whole fields of ryegrass to set seed by stopping mowing and cutting on ryegrass dominated grassland in summer and leaving the vegetation undisturbed until early spring.

The management of silage fields to produce ryegrass over winter can successfully establish seed-rich habitat for wintering birds in grassland. A study in England found that buntings (a priority species), selected seeded ryegrass plots on agriculturally improved grassland habitat to feed, and that these ryegrass plots provided enough nutrition to maintain healthy body weights similar to those on arable land with high-quality wintering habitat (Buckingham, 2011). Another experimental study in the UK assessed the effectiveness of unharvested cereal crops and seeded ryegrass for providing overwinter food for birds in grassland dominated agricultural land (Johnstone, 2019). The study found that both provided winter food but while cereal crop seeds were depleted in January, ryegrass plots provided seed until late winter. When comparing ryegrass species, Italian Ryegrass *(Lolium. multiforum* had a higher seed yield than Perennial Ryegrass (*L. perenne)*. The experimental plots provided 60% and 90% of all winter foraging observations for yellowhammer, a red listed priority species, and reed bunting. Despite this, the intervention had no significant effect on local yellowhammer and bunting population size. A review of four field studies on the impacts of agri-environmental measures in the UK found that leaving ryegrass uncut delivered benefits for granivorous birds including yellowhammers and reed buntings, but not finches (Buckingham and Peel, 2010).

Another study on 12 farms in the UK found that granivorous birds (yellowhammer and reed bunting), preferred to feed on ryegrass fields that were only cut once and not grazed while birds feeding on both seeds and insects, meadow pipits, and only insects, winter wrens, showed no preference (Williams, 2020). A replicated controlled study on dairy farms in England found that the ryegrass patches left to seed attracted higher numbers of yellowhammers and reed buntings. Both species preferred foraging in ungrazed plots (Buckingham and Peach, 2006). One controlled seed choice experiment study found that tree sparrows avoided rye grass seeds. However, these seeds were provided through feeders and not through silage swards left to seed, which may be more attractive to birds as they can remove large seed strips at once; it is possible that differences in bill morphology and adaptation to seeds could results in contrasting benefits of setting ryegrass to seed between bird species (Perkins, 2007). In addition, the landscape surrounding ryegrass crop areas that are allowed to set seed will affect the resulting biodiversity benefits. For example, near hedges species such as tree sparrow and yellowhammer will likely be favoured, while in the open field species such as skylarks, corn buntings and grey partridge will be favoured.
Leaving areas of uncut ryegrass in grasslands can also potentially provide overwinter food resources for small mammals, as well as additional habitat and shelter from harvesting machinery. However, no studies were found evaluating the impacts of setting ryegrass seed on other species.

3.2.1.2 Co-Benefits and Trade-offs

No assessment.

3.2.1.3 Magnitude

Despite strong evidence of the usage of ryegrass seeded plots by granivorous birds, studies so far have not detected significant impacts on the bird population, perhaps indicating that winter food availability is not the largest limiting factor to population size (Johnstone, 2019)

3.2.1.4 Timescale

(0-5 years) The benefits from leaving ryegrass to seed can be seen within the first year, as soon as ryegrass has produced adequate seed over winter from being uncut and ungrazed in summer. One experiment found that birds were attracted to ryegrass plots left to seed over two winters (Buckingham, 2010).

3.2.1.5 Spatial issues

The wider landscape surrounding the grassland sites where this intervention is applied will impact the benefits it delivers. Setting ryegrass seed will be most beneficial and potentially broadscale in areas dominated by grassland and intensive livestock production, where birds will not have access to seed from other land uses such as arable land or semi-natural land. In addition, multiple plots of set aside ryegrass are typically needed in the same area to avoid increased predation risk and consequent avoidance of the plots by birds (Johnstone, 2019).

3.2.1.6 Displacement

Likely to be some displacement of grassland biomass production, as the result of leaving the ryegrass to set seed, rather than grazing or mowing it for silage.

3.2.1.7 Maintenance and longevity

The choice and management of ryegrass seed has to be carefully considered to ensure a continuous supply of seeds to birds, particularly during the late winter ‘hungry gap’ (Buckingham, 2011). In order to ensure sufficient seed resources are produced, maintenance is needed such as the protection from further defoliation in the two weeks following closure date and, in spring, the removal most of the dead vegetation from plots (Johnstone, 2019).

3.2.1.8 Climate adaptation or mitigation

Climate change will impact farmland bird populations including by affecting their habitats, food availability.

3.2.1.9 Climate Factors / Constraints

As climatic conditions impact seed fall geographical location and timing as well as the availability of other resources for more generalist species, such as insects, ensuring that seed resources are available throughout the winter on grassland might become increasingly important.

3.2.1.10 Benefits and Trade-offs to Farmer/Land manager

Limited trade-off in reduced biomass production.

3.2.1.11 Uptake

Johnstone (2019), in reviewing Countryside Stewardship uptake, notes that “Productive farmland suitable for growing cereals or improved grassland (Lolium) has a restricted availability in this region and is highly valued by farmers who are concerned about producing sufficient supplies of forage to sustain their livestock through the winter should weather extremes occur. Consequently, most landowners were only willing to devote small areas of the available productive land to our interventions."

3.2.1.12 Other notes

None

3.3 BUNDLE: RESTORATION, MANAGEMENT AND ENHANCEMENT

3.3.1 Restoration, management and enhancement/Grassland

This bundle of actions concerns the restoration, ongoing management and enhancement of existing and newly created semi natural grassland habitats, (e.g. hay meadows), plus the management and enhancement of more intensively managed grassland, In some cases for the purpose of improving productivity and/or biodiversity value. The bundle has been subdivided into three groups, **grazing actions**, **mowing and meadows**, and **other grassland management**.

This bundle is expected to deliver a range of biodiversity benefits including maintaining and improving the condition of a range of grassland habitats, and thereby protecting and increasing the abundance, richness and occurrence of characteristic species associated with those habitats, including priority and rare species and also pollinator species, which may lead to an increase in pollination.

Grazing Actions

Grazing is a key management measure on improved, semi-improved and semi-natural grasslands needed to maintain habitat structure and condition. However, inadequate or inappropriate grazing management can result in the degradation of grassland habitats through both over grazing and under grazing. This group of biodiversity-friendly grazing management measures including actions for the management of grazing intensity, the timing and seasonality of grazing, and the livestock types used.

3.3.2 Groups of Actions

ECCM-014 Use low intensity, grazing systems using biodiverse sward mixtures

GREEN T** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T** Connectivity of small 'feature' habitats
GREEN T** Enhance condition of agricultural land
GREEN T** Enhance condition of semi-natural habitat
AMBER T* Favourable condition of SSSIs
GREEN T** Maintain good condition of agricultural land
GREEN T** Maintain good condition of semi-natural habitat
AMBER L** Increased abundance, distribution & species richness of pollinators & seed dispersers

ETPW-104 Reduce stocking rate (grazing) to restore structure and flowering, maintain ground cover, and reduce poaching

GREEN T** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN T** Enhance condition of agricultural land
GREEN ** Enhance condition of semi-natural habitat
GREEN T** Maintain good condition of agricultural land
GREEN ** Maintain good condition of semi-natural habitat
AMBER LT* Increased abundance, distribution & species richness of pollinators & seed dispersers

ETPW-105 Use low intensity mixed livestock grazing

GREEN T** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN T** Enhance condition of agricultural land
GREEN ** Enhance condition of semi-natural habitat

GREEN T**	Maintain good condition of agricultural land
GREEN **	Maintain good condition of semi-natural habitat
ETPW-106	Manage timing of grazing and select livestock type to allow flowering and seed return, and control competitive and invasive species
GREEN T**	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN T**	Enhance condition of agricultural land
GREEN T**	Maintain good condition of agricultural land
GREEN **	National species occurrence
AMBER *LT	Increased abundance, distribution & species richness of pollinators & seed dispersers
ETPW-110	When fields are cut for hay or haylage, aftermath graze with cattle
AMBER L*	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER L*	Enhance condition of agricultural land
AMBER L*	Enhance condition of semi-natural habitat
AMBER L*	Maintain good condition of agricultural land
ETPW-156	Replace grazing of sheep with cattle grazing, particularly on limestone habitats
AMBER L*	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN ***	Enhance condition of semi-natural habitat
GREEN ***	Favourable condition of SSSIs
GREEN ***	Maintain good condition of semi-natural habitat
GREEN ***	Presence of rare (red list) species Presence of priority species
GREEN ***	Increased abundance, distribution & species richness of pollinators & seed dispersers
ETPW-157	Create and use a grazing plan including stocking rates; monitor and adjust in line with grass productivity (especially where there are multiple graziers)
GREEN T	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN T	Enhance condition of agricultural land
GREEN T	Maintain good condition of agricultural land
Grassland_02	Mob grazing
AMBER L*	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER L*	Enhance condition of agricultural land
AMBER L*	Enhance condition of semi-natural habitat
AMBER L*	Maintain good condition of agricultural land
AMBER L*	Maintain good condition of semi-natural habitat
AMBER L*	Increased abundance, distribution & species richness of pollinators & seed dispersers
ETPW-150	Manage localised grazing pressure
GREEN T**	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN T**	Enhance condition of agricultural land
GREEN **	Enhance condition of semi-natural habitat
GREEN T**	Maintain good condition of agricultural land
GREEN **	Maintain good condition of semi-natural habitat

3.3.2.1 Causality

Grazing management is vital to maintain the open landscape of improved and semi-improved grassland. However, intensive grazing can lead to negative biodiversity outcomes through trampling, changes in species diversity and composition, reduced soil fertility, and over-fertilisation from manure. There is strong evidence for the benefits of low intensity grazing systems to biodiversity. Extensive grazing can improve grassland habitat heterogeneity and condition leading to the protection of plant and animal species and including some rare species which depend on grassland habitats (Metera et al, 2010). A systematic review of studies across north-western Europe found that reduced grazing intensity on permanent grassland generally delivered benefits for the richness of birds, plants, and invertebrates including grasshoppers, butterflies, bees, and wasps (Dicks et al, 2013) (Wallis De Vries, Van Swaay and Plate, 2012). A study in northern Germany found that extensive grazing increased species richness for a range of insect taxa. However, the same study did not find evidence for increased plant species diversity, vegetation height and vegetation heterogeneity (Tscharntke et al, 2002). In some cases, low intensity grazing can even lead to negative biodiversity outcomes. For example, in the UK, low intensity grazing led to an increase in competitive grasses leading to decreased plant species diversity.

Trampling by livestock can increase bird chick mortality and destroy the nests of ground-nesting grassland birds, reducing their breeding success and abundance. Studies support positive impacts on ground-nesting bird survival with decreased grazing duration and intensity (Pinches et al, 2013) (Ramos, 2021). Lapwing nesting disturbance has been correlated to increased grazing intensity in English grasslands for both sheep and cattle grazing (Pinches et al, 2013). However, grazing intensities preferred by meadow birds vary across species with some species such as lapwing preferring a moderate level of grazing which results in a shorter sward, while other species such as the skylark, curlew and snipe prefer low intensity grazing which creates more heterogenous vegetation (Pinches, 2013). These species-specific responses mean that grazing regimes can be designed to create particular sward structures that provide habitat for targeted species (Breitsameter et al, 2017) (Perrin et al, 2020). No studies specify the exact stocking rate at which breeding birds are protected. However, some studies give quantitative estimates for the reductions of nesting success due to livestock trampling with over 50% of nest losses in redshank and 23% for lapwing. A study suggested grazing in spring to an average sward height of 5-6cm and grazing cessation before the 15th of May benefits flowering plant diversity (Pinches, 2013). In addition, although grazing is potentially dangerous for birds, grazing can also benefit some bird species through the creation of vegetation structure and potentially reducing predation by deterring small nest predators.

Low intensity grazing can also deliver benefits to mammals although studies show some conflicting results. In the Mediterranean, brown hares preferred moderately grazed pastures rather than lightly grazed pastures as it might be easier to detect predators in uniformly low vegetation (Karmiris and Nastis, 2007), in the UK hares preferred pastures with heterogeneous structures (Smith et al, 2004), while in Switzerland they referred extensively managed grassland (Zellweger-Fischer, Kéry and Pasinelli, 2011). Species poor grassland, formerly intensified, may have the potential to restore a degree of sward diversity and support reasonable performance of grazing animals if managed to increase biodiversity by grazing at a low stocking rate (Isselstein et al., n.d.)

Stocking rates are considered optimal for biodiversity when they promote and maintain heterogenous vegetation mosaics which promote survival of a wider variety of species. This is often only achieved at low stocking rates which are lower than the theoretical carrying capacity of the sward. However, in practice, it is difficult to calculate this theoretical optimal stocking rate (Olmeda et al, 2019). In Hungary, a comparison of semi-natural pastures stocked at >1cow/ha with those stocked at 0.5 cow/ha found no effect on the number of species, abundance or cover of bees and insect-pollinated plants, but under the more extensive regime plants which flower in June had higher species richness, and those with short flowering periods had higher cover (Batáry et al 2010). A different study in Hungary found that decreasing grazing intensity by reducing cattle stocking rates did not measurably impact the diversity or abundance of plants, birds and arthropods, but did result in differences in insect-pollinated plant composition (Báldi, Batáry and Erdos, 2005). Decreasing stocking rates can deliver benefits for grassland bird populations. A study in the UK found that decreasing the number of sheep in upland grassland increased the breeding success of hen harriers (Amar et al, 2011). However, the evidence for the impacts of reduced sheep grazing on plant species is mixed (Albon et al, 2007) (DeGabriel et al, 2011).

Reducing grazing intensity and stocking rates can increase vegetation and soil cover which can protect soil against erosion from trampling and poaching and benefit soil biodiversity (Metera et al, 2010) (Mayel, Jarrah and Kuka, 2021). However, impacts on soil erosion depend on the type of soil and livestock used, so these should be carefully considered before implementing grazing management to maintain ground cover and reduce poaching (Metera et al, 2010).

Livestock types and breeds differ in their impacts on grassland species diversity and composition and may, in some cases, differ in grazing intensity due to differences in feeding preferences and behaviour (Soher, 2013) (Schmitz and Isselstein, 2020). Grazing by a mix of livestock species therefore generally results in a greater heterogeneity of vegetation structure. This can be beneficial for a range of grassland species which rely on vegetation structure for food and shelter including birds, invertebrates such as pollinating insects, spiders and beetles, and small mammals (Metera et al, 2010). Co-grazing by sheep and goats has also been highlighted as beneficial to increasing vegetation diversity (Metera et al, 2010). Generally, although decreased nesting success is associated with increased grazing density, for all livestock types, the impacts are less pronounce for sheep than cattle (Pinches, 2013) (Metera et al, 2010). Mixed cattle and sheep low-intensity grazing has been shown to increase the breeding abundance of birds such as the meadow pipit in the UK by improving prey availability through increased landscape heterogeneity (Evans et al, 2006). Continental or improved breeds have been linked to intensification of grazing in some studies (Traill et al, 2010). Finally, local or indigenous breeds are also emphasised as being valuable, because they are adapted to local conditions (Metera et al, 2010) (Kovacsne, 2019). However, studies on the biodiversity impact of using mixed livestock grazing on grasslands are not always consistent highlighting that scale and site-specific conditions should be carefully considered when implementing grazing plans (Metera et al, 2010).

Grazing plans are used by farmers to match livestock requirements to available grassland resources, but it is important that they should also take into account the relationship with and impact on biodiversity, in terms of habitat quality and needs of specific taxa and species characteristic of that habitat. Managing localised grazing pressures to avoid under or overgrazing, may require moving stock by shepherding, especially on open semi-natural grasslands.

Aftermath grazing can help maintain maximum diversity of MG3 grassland and related grassland types (Pinches et al, 2013) and can increase habitat suitability for breeding waders.

Adapting first grazing dates on improved or semi-improved grassland can impact biodiversity in a similar way to adapting mowing dates (see action **Grassland_01** in mowing section below). Spring-time grazing directly impacts the growth and flowering of grassland plant species, as this is when most growth takes place. In upland hay meadows delaying the 'shut-up' date at which sheep are removed in spring delays maturation of the sward, since grazing constantly promotes new leaf growth rather than development of flowers and seeds (Pinches et al, 2013). Adapting the timing of mowing can also increase pollination services as pausing grazing in summer can lead to enhanced benefits of sowing grass and legumes to pollinators (Woodcock et al, 2014). Lenient early season grazing and early stopping of grazing is likely to change vegetation structure in grassland. This can deliver benefits for grassland species which rely on vegetation structure and can increase food provision for invertebrate and bird species. A study in England found lenient early season grazing increased invertebrate abundance and early stopping increased grass cover. The consequences of these changes for insectivorous birds is therefore unclear as although food availability may increase, access to food resources may be restricted (Eschen, 2012). For winter seed-feeding birds, summer suspension of grazing or avoiding late season sward cuts can help ensure food resources (Pywell et al, 2010).

Mob grazing is a type of rotational grazing management involving shorter more intensive grazing periods with longer rest periods. Although total grazing pressure might be reduced from the longer rest periods, short-term peaks might be more intense than under traditional grazing. This technique can take many forms depending on the management approaches adopted by individual farmers, but in general they aim to maximise grassland productivity and ecological benefits. Often farmers will implement mob grazing alongside other management actions such as sowing species-rich swards, making it hard to determine the isolated impact of mob grazing. Therefore, impacts on biodiversity might be mixed with some positive impacts from longer swards and increased flowering of legume and herb species if higher more diverse swards are achieved, and some negative impacts from increased trampling and high density of dung and urea inputs (Keenleyside, 2020). To date, there are no studies on the effects of mob grazing on biodiversity in Europe specifically. In the USA, a study found mob grazing significantly enhanced plant species composition creating additional habitat for grassland species (Russell et al, 2013). However, short periods of intense grazing may be detrimental for some invertebrate species which need a continuity of grassland structure throughout their life cycle (Omeda, 2019). A global meta-analysis of the impacts of similar grazing regimes, rest grazing, found that ground cover was higher under strategic-rest grazing than continuous grazing. However, no impact was found for biomass, plant richness and diversity. On the other hand, increasing the relative rest time increased both biomass and ground cover (MacDonald et al, 2019).

3.3.2.2 Co-Benefits and Trade-offs

Where stocking rates and intensity are reduced as a result of matching grazing to the requirements of the habitat there may be a reduced burden on fresh waters from nutrient run-off. Decreased grazing by livestock can sometimes lead to increased grazing by wild animals such as deer that can lead to unexpected biodiversity outcomes at the landscape level (DeGabriel et al, 2011). Increased soil erosion by grazing can lead to off-site impacts on fresh-water habitats by increased surface run-off risk.
There may also be trade-offs between different biodiversity objectives for the grassland e.g. between floristic diversity and habitats for breeding waders.

[TOCB Report-3-2 GHG **ETPW-156**] The main impact of the replacement of sheep with cattle is the increased biodiversity of plant species resulting in higher numbers of invertebrates, reptiles and bird species. There are also some very strong trade-offs. The replacement of sheep with cattle means that a much lower level of livestock production can take place on a given area of land, negatively impacting farm economic output. In addition, cattle require a much higher level of management than sheep do, raising farm management costs. Cattle also require heavier, more expensive equipment in addition to housing requirements during winter. The cattle will also result in increased GHG emissions than if the land was stocked with sheep. The specific impact of soil type on GHG emissions from cattle or sheep is not well documented, and again using the information cited above, there is almost certainly a system/soil type/stock type/management approach interaction which heavily impacts emissions.

[TOCB Report-3-2 GHG **ECCM-014**] There are a number of co-benefits associated with multi-species grass including air quality benefits, soil compositional benefits (over an extended period of time), water quality benefits (mainly through reduced run-off and leeching) and reduced chemical fertiliser use. Multi-species are also likely to enable additional sequestering of Carbon.

[TOCB Report-3-3 Soils **ECCM-014** and others]: Grazing at lower stocking rates and increasing the plant species diversity of grass swards could potentially have limited positive benefits for soil erosion and soil structure, although the evidence for this is limited. The timing and location of grazing can often be more important for poaching risk than the stocking rate (Newell Price et al., 2013).

[TOCB Report-3-6 Carbon **Grassland_02**] The impacts of mob grazing on grassland carbon stocks are still relatively unknown (Alison et al., 2019). A recent review by Prosser et al. (in prep) found that evidence for mob grazing's effect on soil carbon stocks was small and contradictory across studies.

Food and fibre production	Area under production or yield and outside of ELM	**N**
Global, regional & local climate regulation	Above ground carbon sequestration	**N**
	Below ground carbon sequestration	**LD***

*Duplicate evidence base: **EHAZ-010Y** Enhance or manage permanent grasslands*

[TOCB Report-3-6 *Carbon* **ETPW-157**] Grassland soil carbon stocks are sensitive to management and grazing intensity, with evidence that no grazing (on nutrient poor soils) and high intensity grazing can be detrimental to soil carbon stocks, but responses are highly site specific (see QEIA Report 3-6 Carbon, section 3.19.1). Using expert opinion, it is reasonable to assume that monitoring grassland productivity to prevent over grazing would help prevent losses due to grassland degradation and soil erosion (Alison et al., 2019; Gregg et al., 2021).

Food and fibre production	Area under production or yield and outside of ELM	**N**
Global, regional & local climate regulation	Above ground carbon sequestration	**T**
	Below ground carbon sequestration	**T**

*Duplicate evidence: **EHAZ-010Y** Enhance or manage permanent grasslands*

3.3.2.3 Magnitude

Providing quantitative estimates of the magnitude of the biodiversity impacts of grazing management is difficult as biodiversity metrics used differ between studies, and impacts are highly context dependent.

3.3.2.4 Timescale

(0-5 years) Studies assessing the impacts of grazing intensity, timing, and livestock types typically recorded measurable impacts in the first 1-2 years after implementing the measures.

3.3.2.5 Spatial issues

Grazing management for biodiversity requires site-specific targeting, taking into account the grassland type and context, biodiversity objectives, and effects on different habitats, taxa and species.

3.3.2.6 Displacement

No assessment.

3.3.2.7 Maintenance and longevity

Biodiversity friendly grazing management is a management practice that has to be implemented consistently and maintained in the long-term in order to secure its biodiversity benefits.

3.3.2.8 Climate adaptation or mitigation

Climate change is expected to have profound impacts on grassland ecology, distribution, and its optimal management. Generally, grassland productivity and annual grazing capacity is projected to increase. This will affect the optimal grazing intensity and stocking rate for different grasslands. In addition, phenological shifts are predicted which will result in an earlier start to grazing across European grasslands (Chang et al, 2017). Climate change will change grassland plant growth and their response to management measures. Spring temperature and precipitation impact the early growth of grassland plants and influence the impact of the timing of grazing cessation on biodiversity. In warm, wetter springs, grazing cessation is expected to have a larger impact than in colder springs (PINCHES et al, 2013).

3.3.2.9 Climate Factors / Constraints

Grazing regimes which promote grassland structure, heterogeneity and species diversity can increase the ecological resilience of grassland ecosystems by increasing functional redundancy and therefore increase their resistance to the environmental disturbances expected under climate change.

3.3.2.10 Benefits and Trade-offs to Farmer/Land-manager

No assessment.

3.3.2.11 Uptake

No information.

3.3.2.12 Other notes

None

3.3.3 MOWING AND MEADOW ACTIONS

This bundle involves biodiversity-friendly mowing and cutting methods which typically include delayed mowing or a mid-June to July first mowing/ grazing date; leaving uncut areas and margins; mosaic management where different parts of a grassland are mown at different points in time; and the implementation of mowing techniques to reduce species mortality. One action under this bundle targets specific wildlife by adapting mowing to control cutting so that flowering and structures for target species are promoted.
Mowing can increase mortality and reduce breeding success of grassland species. Adapting mowing is therefore expected to contribute to a range of biodiversity outcomes for species by decreasing their mortality and increasing their breeding success thereby increasing their abundance, distribution, and richness. Controlled cutting can also promote flowering thereby benefitting species, including pollinators, which rely on flowering resources. More broadly, adapted mowing can also lead to improved condition of grassland by improving structure which can also benefit species populations occurring in those habitats.

3.3.3.1 Causality

ETPW-216	Leave areas of grassland uncut
AMBER **	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T**	Connectivity of small 'feature' habitats
AMBER T*	Enhance condition of agricultural land
GREEN *	Maintain good condition of agricultural land

There is evidence that leaving uncut margins in intensively managed grassland can deliver biodiversity benefits, including enhancing agricultural habitat condition and increasing species abundance and diversity. Leaving uncut margins creates increase habitat complexity by increasing the heterogeneity of vegetation structure which provides habitat for a more diverse range of species, and creates additional, extensively managed habitat within improved and semi-improved grassland (Woodcock, 2007). The impacts of grass margin cutting regimes vary from species to species, depending on their habitat requirements and life history In Scotland, uncut margins significantly improved carabid beetle diversity after three years by increasing the area of habitats between crops (Haysom, 2004). This also increased habitat connectivity by creating ecological corridors, refuges and over wintering sites. The increased beetle assemblage complexity achieved by uncut areas decreased with distance from the grassland field edge suggesting that this technique is of greatest biodiversity benefit when applied to field margins. Extensive management of field margins (including less frequent cutting) also had positive impacts on seed/flower feeding beetle species diversity and abundance in a 2005 study in the UK. Extensive management changed the succession trajectory of beetle assemblages when compared to intensively managed grassland. This can improve structural complexity of semi-improved and improved grassland fields promoting a diversification of beetle, and likely other taxa, species composition while retaining productivity (Woodcock, 2007).

Small mammals such as voles, mice and shrews were more abundant in grassland margins cut only every 2-3 years, but there is little evidence for any effect of mowing extensification on the abundance and status of other mammals such as hares (Keenleyside et al, 2020). Evidence for bats seems to be mixed with one study finding grey long-eared bats benefit from grassland management while no impacts were recorded for common pipistrelle bats (Keenleyside et al, 2020). Limited and circumstantial evidence suggests that grass field margin buffer strips are beneficial for common toad, grass snake and common lizard, providing habitat and/or improving connectivity, for example between farmland ponds. (Keenleyside et al, 2020.)

Grassland_01 Adapt mowing or first grazing dates on improved or semi-improved grassland; use mowing techniques to reduce mortality

GREEN **	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN *	Enhance condition of agricultural land
GREEN *	Enhance condition of semi-natural habitat
GREEN *	Maintain good condition of agricultural land
GREEN T*	Maintain good condition of semi-natural habitat

There is good evidence for the delivery of positive biodiversity outcomes for wild plants and invertebrates, including pollinators, from adapting mowing or first grazing dates on improved or semi-improved grassland (Keenleyside et al, 2020). Although annual mowing has generally positive effects on vegetation, mowing early in the summer can have negative impacts on flowering plant species diversity as it interferes with their reproductive cycle. As a result, delaying mowing is linked to positive impacts on vascular plant biodiversity (Humbert et al, 2012). Adapting mowing or first grazing dates and controlling cutting to promote flowering and structure can contribute to improved grassland habitat condition and structure (Keenleyside et al, 2020). Although mowing can be harmful to invertebrates in the short term, a range of studies find that adapted mowing can benefit a range of species including butterflies, spiders, grasshoppers, and ground beetles which rely on vegetation structures promoted by delayed mowing. A meta-analysis of studies looking at the impacts of delaying the first mowing date in European meadows on plant species richness and invertebrate species richness and abundance found that, generally, delayed mowing leads to either positive or neutral biodiversity outcomes (Humbert et al, 2012). Delaying mowing from spring to summer increased plant species richness, while delaying from spring to autumn, or from early summer to autumn led to reduced species richness. Insect species richness also increased with delayed mowing as this led to improved sward structure. However, insect species abundance showed a weaker impact with only some studies finding increases after delayed mowing. In fact, despite an overall support for positive outcomes, there were important differences between studies suggesting that some factors such as differences between taxa and grassland types might be influencing biodiversity impacts (Humbert et al, 2012). Delaying mowing and leaving uncut refuges can be particularly beneficial to lepidoptera, sawflies, moths, wasps, wild bees, hoverflies, ground beetles and rove bees whose larvae and grassland vegetation dwelling (van Klink et al, 2019). An earlier UK study reviewing field studies found that delaying mowing until mid-July led to the best outcomes for species richness of upland hay meadows (Jefferson, 2005). Field studies in England have shown that pausing mowing and grazing of grasslands during the summer enhances the benefits of sowing grass-legume mixes for pollinator species. However, this was not the case when sowing grass mixes or grass-legume-forb mixes (Keenleyside et al, 2020).

Other studies show evidence for stronger biodiversity benefits for mowing techniques other than delayed mowing such as decreasing frequency of mowing to cut only every 2-3 years (Valkó et al, 2012). Despite this, a review found similar effects on flora and fauna from mowing once a year, mowing several times a year, and mowing every fifth, second or third year (Balazs, 2018). However, these effects vary across habitats and sites. The impacts of adapting mowing on bird species are less clear. A study on the impacts of grassland management activities, including mowing management, on farmland birds in England found no significant effect on national population growth rates across bird species (Keenleyside et al, 2020). Despite this, there is a strong evidence base for the benefits of adapting mowing for certain European grassland bird populations (Keenleyside et al, 2020). Adapted mowing regimes can reduce nest destruction and chick mortality of ground-nesting bird, such as corncrake (*Crex crex)* and whinchat (*Saxicola rubetra)*, thereby increasing their breeding success (Keenleyside et al, 2020). Another study in the Netherlands found breeding productivity for the black-tailed godwit was higher on grassland with delayed mowing or mosaic management (Schekkerman, Teunissen and Oosterveld, 2008), and a study in the UK found increased fecundity of skylarks from delayed mowing (Buckingham, Giovannini and Peach, 2015). However, adapting mowing on its own does not always lead to positive outcomes for bird populations. For example, a study in the Netherlands concluded that in order to increase the breeding success of waders, additional management was needed to restore their habitat to an open vegetation structure such as raising water levels and reducing fertiliser use (Keenleyside et al, 2020).

There is strong evidence that sparing grassland zones from mowing can reduce direct mortality of mowing by creating refuges for vulnerable wildlife. Seven studies (including four replicated trials of which one randomised, and one controlled and three reviews) from Germany, Ireland, Switzerland and the UK found that using specific mowing techniques can reduce mortality or injury in birds, mammals, amphibians or invertebrates (Dicks et al 2020). A variety of mowing techniques can be implemented that reduce bird chick and insect mortality associated with mowing (Valkó et al, 2012). These include manipulating silage mowing height, leaving unmown strips or corridors to create refuges, mosaic management, mowing from the inside of the filed outwards, or using machinery which needs fewer passes. It is widely accepted that ground-nesting bird breeding success is threatened by insufficient time between silage cuts, as birds do not have enough time to establish nests or for chicks to fledge. Techniques such as raising the cutting height on some parts of grassland fields could theoretically reduce these impacts yet studies evaluating these techniques for skylarks have failed to demonstrate positive impacts on nesting success (Keenleyside et al, 2020).

A review found the UK corncrake population increased around the same period that Corncrake Friendly Mowing schemes were introduced, and a replicated trial found that changing the mowing pattern reduced the number of corncrake chicks killed. Sixty-eight percent of chicks escaped mowing when fields were mown from the centre outwards, compared to 45% during conventional mowing from the field edge inwards (Dicks et al 2020). Two studies (one review, one randomised, replicated trial) found bar mowers and one report found double chop mowers caused less damage or lower mortality among amphibians and/or invertebrates than other types of mowing machinery. A review found evidence that twice as many small mammals were killed by rotary disc mowers with conditioners compared to double blade mowers. Two studies found that using a mechanical processor or conditioner killed or injured more invertebrates than without a conditioner, however one replicated controlled study found mower-conditioners resulted in higher Eurasian skylark nest survival than using a tedder. A study in Switzerland found that although delaying mowing led to positive impacts on wild bee abundance and richness, leaving 10-12% of extensive meadow area uncut was even more beneficial as it led to a cumulative positive impact on abundance over the years which will likely lead to an increase in pollination services (Buri, Humbert and Arlettaz, 2014). Summer cutting in early June applied to half of the site has also been linked to better pollination benefits from nectar flower mixes as it extends flowering season and reduces butterfly habitat damage (Pywell et al, 2011). In Czechia, mosaic mowing increased butterfly, ground beetle, orthopteran and spider diversity (Cizek et al, 2012). These alternative mowing regimes aimed at supporting invertebrate biodiversity have been shown to have no detrimental effects on vascular plants and mosses (van Klink et al, 2017). However, the quantity, configuration and quality of refuge zones in grasslands have to be carefully considered to ensure they truly deliver benefits to local populations (Lebeau, Wesselingh and Van Dyck, 2015).

Finally, the choice of mowing machinery can also lead to positive biodiversity outcomes. Using wider machinery and reducing the number of machinery passes has been linked to increased chick survival for Skylark (Buckingham et al, 2010). Rotary mowers and conditioners were also found to be particularly harmful to larger invertebrates (Humbert et al, 2010). However, mowing machinery will ultimately always lead to some species mortality, supporting the use of uncut areas to protect grassland populations. Mowing techniques may also impact soil biodiversity, including microbial diversity, and these impacts may sometimes differ to those on above ground biodiversity (Józefowska et al, 2018)

ETPW-115 Control cutting of grasslands to promote flowering and structure for target species, where appropriate

AMBER T** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN T** Enhance condition of agricultural land
GREEN T** Maintain good condition of agricultural land
AMBER T** Increased abundance, distribution & species richness of pollinators & seed dispersers

Cutting of grasslands can be managed to suppress dominant grasses and enhance plant species diversity (Mládková et al, 2015). For example, Immediate effects from both adapting mowing/cutting and delaying mowing and grazing have been reported for butterflies, orthopterans, spiders and wild bees (Buri, Humbert and Arlettaz, 2014). This study of the outcomes for pollinators of different mowing regimes on lowland hay meadows in Switzerland found that, in the second year, leaving 10-12% of the meadow uncut leads to wild bee abundance that is 2.4 times higher than that of control meadows, and twice as high as that of meadows where mowing was delayed by a month. Species richness of wild bees was around 1.75 times higher in meadows with 10-12% uncut than in those with delayed mowing, and 1.4 higher than in control meadows. In the first year, delayed cutting led to more immediate positive effects for both wild bees and honeybees. (Buri, Humbert and Arlettaz, 2014),

3.3.3.2 Co-Benefits and Trade-offs

[TOCB Report-3-6 Carbon **ETPW-216**] The effects of cutting grass on net carbon sequestration and storage are relatively unknown for the UK, particularly compared to the impacts of grazing. A review of carbon sequestration and storage in UK habitats by (Gregg et al., 2021) found no data for the effects of grass cutting in the UK, but that mowing was associated with 20% higher soil respiration rates, and 17% greater above ground biomass than grazing under a permanent semi-arid pasture, under traditional extensive management in the Kiskunság National Park, Hungary (Koncz et al., 2015). Expert opinion suggests that leaving areas of grassland uncut would increase carbon stocks due to greater above ground biomass, and reduce sequestration rates. However, effects on below ground soil carbon stocks are uncertain due to potentially complex relationships between cutting and litter or plant residue production, below ground growth rates and soil disturbance. The net effect on carbon sequestration will also be dependent on the typical processing of cut grass after its removal and whether any of that carbon could be sequestered through other means.
*Duplicate evidence: **EHAZ-010Y** Enhance or manage permanent grasslands*

Food and fibre production	Area under production or yield and outside of ELM	**N**
Global, regional & local climate regulation	Above ground carbon sequestration	**L***
	Below ground carbon sequestration	**LTD***

3.3.3.3 Magnitude

Quantitatively measuring biodiversity impacts is challenging due to the multifaceted nature of the biodiversity concept, and the site-specificity of impacts on biodiversity measures. In addition, even where similar metrics are used, it is often difficult to compare the quantitative impacts of mowing techniques across studies due to differences in experimental set up. Few studies have quantitatively measured the effects of uncut strips on species (Lebeau, Wesselingh and Van Dyck, 2015).

3.3.3.4 Timescale

(0-5 years) Delayed mowing can lead to immediate positive effects on biodiversity, including pollinator diversity. The positive impacts from leaving uncut strips to create refuges lead to measurable positive outcomes for wild bees in as little as a year, and benefits increase year on year (Buri, Humbert and Arlettaz, 2014).

3.3.3.5 Spatial issues

The wider surrounding context can determine biodiversity outcomes of mowing and cutting regimes for some species, particularly for mobile species (Keenleyside et al, 2020). Targeting of actions for particular species will improve outcomes, e.g. for pollinators on hay meadows.

3.3.3.6 Displacement

Some displacement of biomass production from leaving areas of silage fields uncut.

3.3.3.7 Maintenance and longevity

Mowing and cutting are management practices which must be continuously supported in order to safeguard the biodiversity outcomes they deliver.

3.3.3.8 Climate adaptation or mitigation

Climate change is expected to impact improved grasslands and their management in a variety of complex ways which vary across sites and grassland types. For example, less frequent mowing might become more suitable in xeric grassland under increased droughts, while regular mowing might still be suitable for mesic grassland under climate change (Maalouf et al, 2012). In addition, climate change will likely result in a shift of the grassland growing season. Some studies suggest that phenological shifts expected under current climate change scenarios will result in grass growth earlier in spring across most European grasslands (Chang et al, 2017). This might enable earlier mowing and grazing, and influence the suitability of delayed mowing.

3.3.3.9 Climate Factors / Constraints

In some cases, adapting mowing might also contribute to climate adaptation. The improved structure and diversity of grasslands promoted by biodiversity-friendly mowing practices may improve the resilience of grassland ecosystems making them more resistant to the disturbances expected under climate change.

3.3.3.10 Benefits and Trade-offs to Farmer/Land-manager

Reduced biomass production, for example from delayed mowing and leaving areas uncut, especially on ryegrass swards used for silage.
Improved pollinator services if hay meadow mowing regimes target these species.

3.3.3.11 Uptake

No information, but economic effects of leaving substantial areas of grassland uncut (for silage) on dairy farms, and the need to fence off uncut field margins.

3.3.3.12 Other notes

None

3.3.4 OTHER GRASSLAND MANAGEMENT

A variety of management interventions can enhance permanent improved and semi-improved grasslands. This bundle overlaps with the other grassland bundles which include actions that can lead to an improved condition of grassland habitats through grazing and mowing, the introduction of leguminous species, and the creation of additional habitat. Particularly, the grassland habitat creation bundle (3.1.1) has very strong links to grassland habitat restoration as many of the measures needed to create grassland habitat on arable land can be used to enhance and restore agriculturally improved grasslands, for example through the use of green hay and harvested seeds. Furthermore, this bundle includes actions to enhance the habitat condition and species richness in improved and semi-improved grasslands while remaining in their habitat category.

Some specific actions to enhance grassland which have not been previously touched on include the re-seeding of grasslands by slot and over-seeding. Under appropriate management, common wildflower species can be established on improved grassland by oversowing (Hofmann, 2005). In addition, some management interventions can target specific actions such as the enhancement of grassland to benefit invertebrates or the enhancement of in-field vegetation.

3.3.4.1 Causality

EBHE-214EM Enhance and manage locally distinctive flower rich/hay meadows using traditional techniques

GREEN ** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER *** Connectivity of small 'feature' habitats
GREEN ** Enhance condition of agricultural land
GREEN ** Enhance condition of semi-natural habitat
AMBER T* Favourable condition of SSSIs
AMBER ** Maintain good condition of agricultural land
GREEN ** Maintain good condition of semi-natural habitat
AMBER T* Presence of rare (red list) species Presence of priority species
GREEN ** Increased abundance, distribution & species richness of pollinators & seed dispersers

ETPW-111 Harvest seeds / take green hay to restore other grassland sites, following best practice

AMBER T** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN ** Enhance condition of agricultural land
AMBER * Enhance condition of semi-natural habitat
GREEN ** Maintain good condition of agricultural land
AMBER L* Increased abundance, distribution & species richness of pollinators & seed dispersers

ECPW-022EM Enhance or manage species-rich grassland habitats

AMBER *** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN *** Connectivity of small 'feature' habitats
GREEN *** Enhance condition of agricultural land
GREEN *** Enhance condition of semi-natural habitat
AMBER T** Favourable condition of SSSIs
AMBER ** Maintain good condition of agricultural land
GREEN ** Maintain good condition of semi-natural habitat
AMBER TL* Presence of rare (red list) species Presence of priority species
GREEN *** Increased abundance, distribution & species richness of pollinators & seed dispersers

As with grassland habitat creation, the restoration of grassland habitats often relies on the active introduction of target species through seed mixes and the transfer of green hay from species-rich donor sites. For example, a project in Cumbria which restored 35 grassland sites, used for grazing and winter fodder, by sowing wildflower seed mixes collected using brush harvesting[3] found an increase in plants species richness, and signs that species assemblages were shifting towards that of traditional upland hay meadows (Cornish, 2012). A study in the Pennines shows that green hay transfer is an important first step in meadow restoration, by examining the restoration of 18 upland hay meadows using green hay transfer from 11 donor meadows in two study areas (the Forest of Bowland and the Yorkshire Dales) over an 11-year chronosequence[4]. Results showed that although time affected the community composition of the restoration meadows, the similarity between restoration sites and donor sites did not increase with time. Some target species were easily transferred whilst others were not found in the restoration meadows, or were found at low levels of cover. Isolation was not significant. The authors conclude that further restoration activity, such as seed addition, is likely to be required if restoration sites are to resemble closely the reference donor sites. (Sullivan et al., 2020)

EHAZ-010Y Enhance or manage permanent grasslands

[3] A method of collecting seeds, which leaves the majority of the hay crop behind to be taken by the farmer at a later date.
[4] A set of ecological sites that share similar attributes but represent different ages.

AMBER LT* Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN ** Enhance condition of agricultural land
GREEN ** Maintain good condition of agricultural land
GREEN ** Presence of rare (red list) species Presence of priority species
AMBER LT** Evidence of outbreaks of pests and disease
GREEN ** Increased abundance, distribution & species richness of pollinators & seed dispersers

In low-quality agriculturally improved grassland, diversification of the sward can be challenging, as closed sward structures can limit the ability of species to establish. In these cases, more modest enhancement management can be beneficial to biodiversity, with the aim of increasing the biodiversity associated with the current landscape rather than recreating the community structure of non-improved grassland (Littlewood, 2011). Under appropriate management, common wildflower species can be established on improved grassland by oversowing (Hofmann, 2005).

There is very strong evidence that management extensification in agriculturally improved grassland can benefit invertebrates across trophic levels and feeding guilds. Sward architecture is one of the key factors influencing species diversity across both herbivorous and predatory invertebrate groups (Woodcock, 2009). This is because higher sward heterogeneity leads to a higher niche availability which can be occupied by a higher diversity of species and which facilitates species co-existence. Improving sward diversity in agriculturally improved and semi-improved grassland increases food availability for pollinators and granivorous birds (Jones, 2018). Forb and grass species richness has also been associated with increased invertebrate species richness. However, this relationship is not always observed in all cases, with some studies focusing on restricted taxonomic groups finding the opposite pattern particularly where a variety of insect species feed on a few host plants which are not always present in species rich swards (Woodcock, 2009). Despite this, generally, management to increase sward diversity benefits invertebrate species abundance. Similarly, as previously outlined, decreasing the cutting frequency of grassland field margins can improve agricultural habitat condition and the abundance of nationally and ecologically important species. Other more extensive practices such as reduced fertiliser use can also contribute to improved agricultural habitat condition [Woodcock, 2007).

ETPW-101 On meadows, make field-dried hay and minimise haylage and silage
GREEN *** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
GREEN *** Enhance condition of agricultural land
GREEN *** Maintain good condition of agricultural land
GREEN *** Increased abundance, distribution & species richness of pollinators & seed dispersers

There is very strong evidence for this action, especially on existing and former hay meadows. Grass for silage is usually grown on highly fertilised, reseeded swards which are mown every few weeks from spring until autumn. Hay is cut later, in mid to late summer, allowing many plant species to set seed which may be released during hay-making, or deposited back onto the grassland in dung from hay-fed stock (Boatman et al., 2007). Hay meadows are typically grazed early in the spring and in late summer (aftermath grazing). Silage making largely prevents grasses and forbs from flowering and seeding, thus reduces food for birds and other animals, and silage cutting machinery also poses a risk to young hares using the grassland for feeding or cover (Boatman et al., 2007). Three studies found that earlier cutting dates of hay meadows, especially where there was a switch to silage, as one of the main reasons for the long-term decline in yellow wagtail populations in the Yorkshire Dales (Pinches et al 2013). A review of research on upland hay meadows in England concluded that the evidence evaluated supports traditional hay meadow management regime, but this should be accompanied by less uniformity of hay cutting dates at the landscape scale, to mimic the longer hay cutting window in the past when botanical diversity was higher (Pinches et al 2013). The same review also recommends more flexibility to respond to spring weather conditions in any one year, for example by taking stock off the meadows earlier in warm springs (Pinches et al 2013). This is supported by a more recent 5-year study of *Anthoxanthum odoratum–Geranium sylvaticum* upland hay meadows in Northern England, which concludes that recent reductions in the nature value of these grasslands might be a consequence of high stocking densities persisting until later in the spring, carried out during a 1-year period with warmer temperatures (Smith et al, 2017).

ETPW-270 Re-seed grassland by slot-seeding or over-seeding
AMBER L* Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER L* Enhance condition of agricultural land
AMBER L* Maintain good condition of agricultural land
AMBER L* Increased abundance, distribution & species richness of pollinators & seed dispersers

Re-seeding improved grassland by slot-seeing or over-seeding, instead of ploughing or rotavating to establish a seedbed, can benefit grassland biodiversity. Slot seeding and/or broadcasting of hay seed to establish parasitic species, like Yellow Rattle (*Rhinanthus minor*), on improved grassland can reduce grass vigour leading to decreased competition from dominant sward species which allows other wildflower species to establish and thereby increases in floral diversity (Decleer, 2013).

ECCM-028 Manage temporary grassland reseeding frequency
AMBER T* Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T* Enhance condition of agricultural land
AMBER T* Maintain good condition of agricultural land

The objective of reseeding is to improve pasture productivity, and is normally achieved by ploughing or rotavating before reseeding, followed by fertiliser application (and lime in the uplands). In recent decades, intensification of semi-natural grasslands by a range of agricultural improvement techniques, including reseeding and fertilisation has gradually converted semi-natural grasslands into semi-improved grassland dominated by a small range of grass species and few remaining forbs (Jefferson et al., 2014). Reviewing data from the Farm Practices Surveys of England (2015-2018) Newell Price et al (2019) found that a high proportion of farms with temporary grassland are reseeding at a frequency of every two to ten years, but the most common frequency for reseeding with clover was every three to five years; of livestock holdings with temporary grassland around 30% had sown all their temporary grassland with a clover mix, and 70% had sown a proportion of it. Anecdotal evidence and total sales of seed indicate that the use of diverse swards or herbal leys are increasing, but such multi-species swards occupy a small proportion of the grassland area (Newell Price et al (2019).
There is limited evidence of the impact of conventional methods of reseeding grassland on biodiversity, and the sward disturbance involved is unlikely to benefit species which depend on a stable sward. However, a study in Scotland found that reseeding to improve productivity of upland pastures can temporarily benefit arable weeds that survive for long periods in the seedbank, providing short-term nectar and pollen resources for bumblebees, hoverflies and soldier flies (Grassland Biodiversity (2016)).

Potential future biodiversity benefits are likely to be linked to changes in seed mixes to include legumes and herbs, and use of alternative reseeding techniques such as slot-seeding which reduce soil disturbance.

3.3.4.2 Co-Benefits and Trade-offs

A field trial on a representative upland farm between 2017 and 2019 showed that reseeding unimproved land as method of improving productivity produced more N_2O emissions per unit of grass yield, than simply applying lime and fertiliser. (Williams et al., 2021).

[TOCB Report-3-6 *Carbon* **ECCM-028**] There is evidence that sward diversification has a positive effect of soil carbon content (see carbon sequestration review, Report-3-6). However, maintaining species richness can require re-seeding, which can involve substantial disturbance of soil carbon, particularly if soils are ploughed prior to re-seeding. The negative impacts of disturbance during reseeding can potentially be offset overtime by elevated productivity from a more diverse sward (Kayser et al., 2018). However, regular reseeding of a non-degraded, diverse sward is likely detrimental. (Kayser et al., 2018) found that reseeding caused below ground carbon stocks to decrease by 21 and 14 tC ha^{-1} compared to an intact (non-degraded) grassland when sward renovation (including ploughing) was conducted every 5 to 10 years.

They also found that losses were greater when reseeding in spring, as opposed to later in the year. More generally, the evidence base to assess this action is lacking.

Food and fibre production	Area under production or yield and outside of ELM	**N**
Global, regional & local climate regulation	Above ground carbon sequestration	**N**
	Below ground carbon sequestration	**L***

3.3.4.3 Magnitude

The positive impact of extensive management practices on invertebrates varies in magnitude with the largest effects associated with management practices that increase sward complexity, followed by diversity, and smaller impacts from grazing and cutting actions (Woodcock, 2009).

3.3.4.4 Timescale

(0-5 years, 5-10 years) Using evidence from the Conservation Evidence website, studies assessing grassland restoration in Europe vary in the timescale needed to restore grassland communities, with six studies seeing positive results in less than five years, 11 within 10 years and two over 10 years (Warwickshire County Council, 2018).

Management practices to benefit invertebrates can lead to significant impacts on invertebrate diversity as soon as two years after their implementation (Woodcock, 2009). However, the complete re-establishment of invertebrate assemblies can be a long process as invertebrates are typically more limited by dispersal (Warwickshire County Council, 2018).

3.3.4.5 Spatial issues

Reseeding is a widespread practice on livestock farms.
None (the objective is to improve productivity.
Maintenance and longevity.
Varies, but in the range 3-10 years.

3.3.4.6 Displacement

None.

3.3.4.7 Maintenance & Longevity

Not assessed

3.3.4.8 Climate adaptation or mitigation

Effect of drought or flooding may require increased frequency of reseeding.

3.3.4.9 Climate Factors / Constraints

The management of grasslands to benefit invertebrates can increase the resilience of grassland ecosystems to environmental change through increasing functional redundancy and adaptability of ecosystems (Thebault, 2005).

3.3.4.10 Benefits and Trade-offs to Farmer/Land-manager

Higher cost of biodiversity friendly seed mixes (but also potential for improved livestock performance and reduced need for N fertiliser).

3.3.4.11 Uptake

When farmers with agreements under the Countryside Stewardship option of reseeding temporary grassland with a mixed sward of grasses, legumes and herbs/wildflowers were asked 'would you use this option again?', 84% (n=52) said they would, six were undecided and only two would definitely not use the option in future. However, evidence from the field survey indicated that, although agreement holders were positive about the option, sward composition requirements were often not met. Those that were intending to continue with the option felt it was a good mix for livestock, getting good results, profitable and easy to do. Several were enjoying the wildlife and environmental benefits and the benefits to the soil. Twenty said they would use the option again because it fits well into the management and/or rotation. (Jones et al, 2018).

3.3.4.12 Other notes

None

3.3.5 ETPW-091 Restore/ enhance/ manage permanent grassland in coastal areas (salt marsh regarded as semi natural grassland)

This action is too broad in scope to review as a single action, because coastal grasslands vary so much in soil/habitat type and current management from intensively managed grasslands that are regularly reseeded, to semi-intensive pastures and semi-natural habitats that may have no active management and are scrubbing up.

Specific actions for permanent grassland reviewed above are relevant to some coastal grasslands, and other coastal actions are reviewed in QEIA Report-3-5C *Biodiversity: Semi-natural*, including: **EHAZ-067** Control grazing on permanent coastal grassland; **ECPW-083** Control grazing on sand dunes; **ETPW-081EM** Enhance/ manage coastal habitats; and **ETPW-081EMY** Enhance/ manage coastal scrub.

3.3.5.1 Co-Benefits and Trade-offs

[TOCB Report-3-6 *Carbon* **ETPW-091**] No evidence could be found for the carbon content or sequestration potential of coastal grasslands specifically, also known as coastal grazing marsh (JNCC, 2008a). The carbon stocks of grasslands more generally are sensitive to overgrazing, compaction, and species composition (see QEIA Report-3-6 *Carbon*, section 3.19). Drainage of coastal grasslands could significantly influence greenhouse gas exchange, particularly where sediments have significant organic matter content, where drainage is associated with greater rates of oxidisation (C. D. Evans et al., 2021).

Food and fibre production	Area under production or yield and outside of ELM	**N**
Global, regional & local climate regulation	Above ground carbon sequestration	**LT***
	Below ground carbon sequestration	**LT***

Duplicated evidence: ***EHAZ-067*** *Control grazing on permanent coastal grassland &* ***ECCM-046*** *Use controlled grazing on intertidal, saline, salt marsh and coastal grassland*

3.4 Bundle: Actions for habitats with specific hydrological characteristics

3.4.1 Actions for habitats with specific hydrological characteristics/Peatlands and wetlands

Peatlands cover around 3.0 million hectares, > 12% of the total UK land area (Evans et al, 2017) and can be classified into three broad types: blanket bogs, raised bog and fen. Peatlands in near-natural condition are nationally and internationally recognised for their biodiversity value, but only around 22% of UK peatlands are estimated to be in this state. Large-scale drainage and conversion of lowland peatlands created highly productive farmland for arable, horticultural and livestock in the East Anglian Fens and Somerset Levels). In the uplands, blanket bogs were cut for fuel and burned to improve grazing quality for centuries, and in the post-war period much of the open moorland was drained ('gripped') (Evans et al, 2017). Drained peatlands lose their key ecological functions including the ability to accumulate peat, leading to their degradation and associated loss of their biodiversity and ecosystem services. In terms of agricultural use:

- upland peatlands are mainly used for extensive livestock grazing and forestry
- around 8% of the UK's total peatland area is managed as grassland (both extensive and intensive) with around 141,000 ha of lowland peatland under intensive grassland and 35,000 ha on 'wasted peat', defined as retaining a peat layer < 40cm deep (Evans et al 2017).
- arable cropland occupies just 7% of the UK's peat area, but has the highest GHG emissions per unit area of any land-use, as a result of drainage and fertilisation (Evans et al 2017).

ECCM-038 Raise water levels in areas of farmed peatland and adapt farming systems accordingly

AMBER T**	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T**	Enhance condition of agricultural land
AMBER T*	Favourable condition of SSSIs
AMBER T**	Maintain good condition of agricultural land
AMBER T*	Presence of rare (red list) species Presence of priority species

EBHE-164C	Create wetland habitats
EBHE-164EM	enhance/ manage wetland habitats
EBHE-212C	Create raised water level areas by appropriate installation and operation of water level controls
EBHE-212EM	Maintain raised water level areas by appropriate installation and operation of water level controls
EBHE-216	Rewet moorland (including common land), eg through appropriate traditional grazing techniques - make it 'Enhance or manage moorland ...'?
ECAR-041	Reduce managed burning on non SAC/SPA designated sites and on shallow peat
ECCA-007C	Create wetland habitat mosaics, including creating the appropriate hydrological conditions
ECCA-007EM	Enhance/ manage wetland habitat mosaics, including creating the appropriate hydrological conditions
ECCA-013C	Create artificial wetlands
ECCA-013EM	enhance/ maintain artificial wetlands
ECCM-030	Restore/ manage upland and lowland peatlands including blanket bog and raised bog
ECCM-031	Use controlled grazing (bogs and peatlands)
ECCM-032	Manage hydrology in wetland habitats to restore functional processes,
ECCM-033	Restore peatland vegetation
ECCM-034	Remove non-peat habitat vegetation

ECCM-035	Use no-till cultivation on agricultural lowland peatland
ECCM-037	Restrict root crops in agricultural peatlands
ECCM-038	Raise water levels in areas of farmed peatland and adapt farming systems accordingly
ECCM-039	Restore areas of farmed peatland to wetland
EHAZ-063	Block drains, ditches and grips
EHAZ-129C	Create fen
EHAZ-129EM	enhance or manage fen
EHAZ-134	Restrict deep ploughing on agricultural lowland peatland
EHAZ-137	Use paludiculture
ETPW-153	Stabilise eroding peat through targeted restoration work
ETPW-155	Remove grazing from recovering peatland, susceptible habitats and sensitive vegetation
ETPW-158	Manage the dominance of graminoid or ericaceous species on bog by hydrological restoration, light summer grazing and cutting

3.4.1.1 Causality

On peatland, habitat restoration and enhancement depend primarily on raising water levels (i.e. rewetting) to re-establish near-natural peatland hydrology. This can be achieved through blocking or filling in drainage ditches or gripes, usually with dams or peat plugs. Additional measures, such as peat reprofiling, scrub and tree removal, using straw mulch to increase water storage capacity, removing the top layer of dried-out peat, and vegetation re-introduction may be needed on certain sites. The restoration potential of drained peatland depends on a variety of factors, such as its level of degradation before restoration (including extent of hydrological modification and water table level) and site-specific characteristics including peatland type, climatic condition, and past and current management.

There is good evidence for the biodiversity benefits of raising water level in areas of farmed peatland and adapting farming systems accordingly (Renou-Wilson, 2019). However, simply raising the water table might not be sufficient to restore all peatland ecological processes and additional measures might be needed to achieve the full potential biodiversity benefits of rewetting. Rewetting grassland can improve habitat condition by re-establishing ecological conditions and vegetation needed to restore peatland ecosystem functions and services. A review of 36 studies evaluating the effects of rewetting on peatland vegetation, excluding planting measures, found rewetting can benefit vegetation community structure, composition, and species richness (Taylor, 2020). Changes in vegetation community composition from drier grassland community to communities more typical of peatland ecosystems were found in seven studies in Finland, Hungary, Sweden, Poland, and Germany (Taylor, 2020). In addition, five studies, including one in the UK, found that rewetting increased the abundance of peatland characteristic plants. However, these communities can differ from those of intact natural peatlands, with three site comparison studies finding different plant community composition in rewetted peatlands. In addition, three studies in Germany and the UK found that rewetting had no effects on plant community composition, and six studies found no effect on characteristic plant abundance, or a negative effect. For example, study in Hungarian sites found that rewetting re-established plant community structure and composition which was closer to that of natural wetlands (Timmermann, 2006).

The successful re-introduction of peatland vegetation was dependant on the water level post restoration, with the establishment of potentially peat forming vegetation being mostly confined to long-term shallow inundated sites (where the water level in winter was 0-30cm above surface). A replicated study of grassland on fen peat also found changes in plant community structure and composition seven to 10 years after rewetting (the water table was raised to 20-50cm above the peat surface), with characteristic peatland species such as cattail (*Typha latifolia*), sedges (*Carex* spp), and common reed (*Phragmites australis*); the authors suggest that a future management option would be to annually harvest aquatic and wetland plants to reduce nutrient levels in restored mire ecosystems (Zerbe et al, 2013). A number of studies also found increases in total plant richness and diversity, moss cover and abundance, herb cover (including cotton grass, sedge, and reed/rush). For example, a study in seven degraded peatlands in England found that plant species richness increased after rewetting, but that plant community type was unchanged (Taylor, 2020). However, five studies found to effect on overall plant richness in bogs in Czechia and Latvia and fens in Sweden and Germany and a study in the Netherlands found impacts were scale-dependent. Another review on the biodiversity benefits of peatland restoration (not only focusing on rewetting), identified a range of studies assessing vegetation responses, but fewer finding evidence for benefits to invertebrates and microbes, and a very limited number looking at birds, amphibians, reptiles and mammals (Douglas, 2019).

Healthy peatlands provide habitat and food for unique species which depend on wetland habitats for their survival. Several wetland bird species of conservation concern, particularly warblers, nest in wet grassland. Restoring wet grassland conditions can deliver benefits for breeding waders. Wader chicks need wet foraging habitats with healthy invertebrate populations to provide prey throughout the pre-fledgling period. The introduction of shallow wet features, also known as foot drains, connected to ditches can raise water levels on grazing marshes creating nesting habitat and feeding areas for waders. A study on grazing marshes in eastern England found that wet features increased invertebrate populations with a doubling in the biomass of surface-active invertebrates and an increase in the abundance of aerial invertebrates (Eglinton, 2010). This was associated with an increase in northern lapwing (*Vanellus vanellus*) chick foraging rate, particularly late in the season. Waders benefit the most when a heterogeneous sward structure is maintained creating a mosaic of shorter and longer swards which can meet the ecological requirements of a greater number of species.

A study in Sweden found restored wet grassland areas increased local bird species richness, included red listed species, with a correlation between degree of water level increase and richness (Żmihorskim 2016). Beta diversity[5] was highest in grazed and flooded sites, which was attributed to heterogeneous vegetation structure which can provide nesting and foraging habitats for a wider variety of wet grassland bird species. Some evidence also exists for the positive impact of peatland restoration on invertebrate populations. For example, craneflies were found to benefit from increased water levels within 1-4 years (Carroll, 2011), (Noreika, 2015). Fourteen studies assessing the impact of peatland restoration on microbe populations, generally find a positive impact on microbe composition and function in just a few years (Douglas, 2019). For example, a study in England found that rewetting increased microbial biomass and community resilience on grassland (Cole, 2019).

After re-wetting, land can be taken out of management to create semi-natural habitats (covered in more depth under the semi-natural habitats review 5C), or sustainable alternative land uses can be established. such as extensive grazing or paludiculture (covered in more depth under the systems review 5D). The most appropriate farming system after restoration will depend on the specific social and ecological context of the site, including the height of the water table established. For example, extensive grazing with adapted livestock such as water buffalo can be established on shallowly drained peatland (Buschmann, 2020). An experimental study in Germany and review of biodiversity management by water buffalo found that moderate grazing can deliver benefits for a range of species including birds, amphibians, vegetation and insects (Gerhard, 2010). For example, existing pools on re-wetted pasture and buffalo wallows can create habitat for amphibians. Paludiculture (reviewed separately in the systems review 5D) covers the cultivation of commercial crops on rewetted peatland by growing species which are adapted to wetland conditions, established after rewetting.

[5] In its simplest form, beta diversity is defined as the ratio between gamma (regional) and alpha (local) diversities.

Crops which can be used for bioenergy, fodder, or building material are suitable for paludiculture including Common Reed (*Phragmites australis*), Reed Canary Grass (*Phalaris arundinacea*), *Spahgnum* bog moss and Sweet Grass (*Glyceria fluitans*) (for more see the 'UK Paludiculture Live list'). The establishment of these species for commercial use can create suitable conditions for other characteristic peatland vegetation including rushes, sedges and wetland grasses such as the Soft Rush (Juncus effusus), the moss (*Polytrichum commune*) and Common Cotton Grass (*Eriophorum angustifolium*). However, some of these are problematic for paludiculture as they are considered weeds (Gaudig, 2017) (McBride, 2011). A study on fen peatlands in Germany found that paludicultural restoration, including the establishment of moist grassland cut for hay, of areas previously under intensive agricultural management increased bird species richness, including species of high conservation value, and alpha diversity by a factor of 3-6 (over 19 years) (Gorn, 2015).

3.4.1.2 Co-Benefits and Trade-offs

Avoidance of GHG emissions from drained peatland. Water quality. Flood risk management.

[TOCB Report-3-5A Croplands **ECCM-038** and others] Fenland peatland was found to have reduced soil carbon loss when managed under conservation grassland or with raised water levels, compared to intensive arable production (Graves and Morris, 2013).

3.4.1.3 Magnitude

Potentially significant biodiversity benefits on the area rewetted.

3.4.1.4 Timescale

(5-10 years, >10 years) Some peatland habitats can only be restored over long timescales of up to a century (e.g. peat bogs). The re-establishment of peatland vegetation in species poor fen grassland typically happens over shorter time periods and may begin as early as 2-7 years and 4-6 years after rewetting (Taylor, 2020) (Timmermann, 2006). However, even under the right conditions, restoration in species poor grasslands can take decades after rewetting or may even fail due to competition from other species (Timmermann, 2006).

3.4.1.5 Spatial Issues

The successful restoration of peatland habitat will depend on the site location as surrounding habitat, size and access of a site will impact the colonisation success of wetland species and topography, water flows, and soil types impact the success of rewetting. In some cases, peatland degradation can be worsened by off-site pressures which impact peatland hydrology. Integrated catchment management may therefore sometimes be needed.

Rewetting agriculturally productive lowland peat in intensive arable or grassland use carries a very high opportunity cost to the land manager.

3.4.1.6 Displacement

Significant, particularly of arable and horticultural crops and dairy production on lowland peat. Less significant per unit area in the uplands, but the total area could be much greater on which stocking rates are significantly reduced or grazing is removed altogether after rewetting.

3.4.1.7 Maintenance and Longevity

Rewetting peatland is a long-term land use change, requiring high water levels to be maintained in perpetuity to achieve the full potential of both biodiversity and GHG benefits.

3.4.1.8 Climate Adaptation or Mitigation

Raising water tables in farmed peatland may become increasingly important with climate change. Species which depend on wet features, such as wading birds, will be heavily impacted by changes in seasonality of precipitation in Europe and appropriately managed wet features on grassland can provide some buffer against periods of low rainfall. However, the potential benefits of wet features to wader chicks are also impacted by changes in seasonality and intensity of rainfall meaning that future management of wet grasslands for these species will need to account for climate change (Eglington, 2010).

3.4.1.9 Climate Factors / Constraints

Paludiculture could play a key role in climate mitigation through avoided carbon emissions from drained peatland and can contribute to climate adaptation by increasing food security through increasing the long-term viability of peatland agriculture.

3.4.1.10 Benefits and Trade-offs to Farmer/Land-manager

Very significant economic trade-offs, especially on sites not suitable for paludiculture.

3.4.1.11 Uptake

Although paludiculture is not currently an economically viable solution that can be implemented at scale in the UK, it can play a key role in creating more sustainable peatland farming systems in the future and should therefore be supported (for an in-depth review of the potential of paludiculture in England and Wales see (Mulholland et al, 2020).

There are likely be significant socio-economic and cultural barriers to uptake, especially among lowland farmers. A study of the socioeconomic and ecological business environment for developing low emission alternatives on farmed peatland found that under current conditions farmers would only be likely to consider land use alternatives if water level changes are moderate, management practices can be maintained to a large extent and financial losses are compensated for (Buschmann et al., 2020).

3.4.1.12 Other Notes

The development of the UK Peatland Code[6] and emerging carbon markets in the UK may in future provide farmers with an additional incentive for peatland rewetting.

[6] https://www.iucn-uk-peatlandprogramme.org/peatland-code/introduction-peatland-code

3.5 BUNDLE: SOIL MANAGEMENT AND PROTECTION

3.5.1 ECPW-295 Maintain soil cover (e.g. grass, crop or geotextile), to reduce soil erosion and loss around livestock shelters/feeders/troughs; e.g. for outdoor pigs.

GREEN **	Enhance condition of agricultural land
GREEN **	Maintain good condition of agricultural land
AMBER D	Maintain good condition of semi-natural habitat

3.5.1.1 Causality

Measures that prevent soil structural degradation caused by compaction or erosion will also benefit soil biodiversity. Some remediation measures may be expensive so where possible it will be more cost effective to mitigate rather than remediate (Welsh Government, 2019). Maintaining soil cover can play an important role in reducing soil degradation by providing physical protection against water and wind erosion and can enhance soil health by increasing soil organic carbon inputs (Posthumus and Morris, 2010). The introduction of deep-rooted cover crops (e.g. tillage radish and mustard), can help alleviate soil compaction through bio-drilling (Piccoli et al, 2022). However, cover crops do not always lead to reduced compaction, and it is important to optimise the selection and management of crop species for different pedo-climatic conditions. There is good evidence to show that soil compaction decreases soil biodiversity by decreasing microbial biomass, enzymatic activity, soil fauna, and ground flora (Nawaz et al., 2013, Tibbett et al., 2020). Through its impacts on soil biodiversity, soil compaction will also affect grassland birds which feed on soil invertebrates as their prey availability and accessibility is reduced. These impacts will be highest for bird species which are most dependent on the invertebrate species which are impacted by compaction including the song thrush, starling, lapwing, redshank and snipe (Defra, 2007). In addition, there is good evidence for the positive biodiversity impacts of cover crops through the creation of additional shelter and food resources for indicator species including birds, spiders, carabid beetles, butterflies, wild bees, and grasshoppers (see the cropland evidence review) (Prechsl et al, 2017). Similarly, soil erosion and biodiversity are closely connected. However, their relationship is complex due to the large species and functional diversity of soil organisms. There is currently little direct evidence for the ecological impact of erosion on soil biological communities and their associated aboveground biodiversity (Orgiazzi and Panagos, 2018). Despite this lack of evidence, there is strong evidence for the importance of reducing soil erosion and loss for soil health, and for the strong relationship between soil health and wider ecosystem condition. Reduced soil erosion increases nutrient retention, soil organic carbon accumulation, and water retention, all of which can potentially have positive impacts on soil-dwelling species, plant species and the animal species which depend on these groups for their survival (Kuhlman, Reinhard and Gaaff, 2010).

There is some evidence for a unimodal direct relationship between bare ground and species diversity following the intermediate disturbance hypothesis. A study on 86 agricultural grasslands in Germany found that bryophyte abundance was highest at around 12% of bare ground cover (Müller et al, 2014). Levels of bare ground exceeding that had negative impacts on bryophyte diversity, likely due to mechanical destruction. However, it is important to note the small effect size of this relationship suggesting that other factors are also at play when explaining bryophyte diversity patterns. For example, the availability of propagules is often a more important limiting factor in increasing vegetation diversity rather than the availability of adequate germinating sites provided by intermediate levels of soil disturbance. In contrast, annual vascular plants showed a positive correlation to bare ground while perennial plant species richness showed no significant relationship to bare ground cover. The lack of a relationship for perennial plants may be explained by the fact that local extinctions due to disturbance could be compensated by colonisation from adjacent patches, seed banks or dispersal from surrounding sites. Moreover, other studies found a decrease in perennial plant diversity where bare ground exceeded the levels included in the German study, which would apply to the levels of bare ground around uncovered feeders, shelters and troughs. Therefore, there is some evidence showing that high levels of bare ground cover in grasslands lead to reduced vascular plant and bryophyte diversity through mechanical disturbance (e.g., trampling and grubbing from livestock), particularly if there is a low availability of propagules to naturally recolonise disturbed patches (Müller et al, 2014). However, experimental studies on soil disturbances are scarce and no studies were found specifically looking at the impacts of bare ground around livestock feeders, shelters, and troughs on the broader biodiversity of surrounding grasslands.

3.5.1.2 Co-Benefits and Trade-offs

Reduced sediment loss in surface water.

[TOCB Report-3-4 Water **ECPW-295** and others] Reducing sediment and nutrient inputs in rivers is likely to enhance freshwater biodiversity as well as riverbank and riverside habitats. A proportion of the nitrogen accumulated in the cover crop will become available for crop uptake by the following cash crop reducing the need for manufactured fertiliser applications to meet optimal crop demand. The cover crop residues will also provide a source of organic matter which will help maintain and improve soil function especially in soils with sub-optimal soil organic matter content.

3.5.1.3 Magnitude

Unknown.

3.5.1.4 Timescale

0-5years.

3.5.1.5 Spatial Issues

Small scale.

3.5.1.6 Displacement

None.

3.5.1.7 Maintenance and Longevity

May need to move livestock shelters/feeders/troughs regularly to maintain the benefits.

3.5.1.8 Climate Adaptation or Mitigation

May become more challenging to implement in areas where high-rainfall events become more common

3.5.1.9 Climate Factors / Constraints

Not assessed

3.5.1.10 Benefits and Trade-offs to Farmer/Land-manager

Improved animal welfare and soil functionality.

3.5.1.11 Uptake

n/a

3.5.1.12 Other Notes

None

3.5.2 Fertiliser, nutrient, manure and mulch management

This bundle includes actions aiming to incorporate legume species, such as clovers, into grazed pastures, and also other 'herbal' species such as chicory, yarrow, ribwort, plantain, forage burnet, black knapweed, common sorrel. Although the impact of these mixtures on biodiversity has attracted less attention, grass-legume mixtures can also lead to positive outcomes for grassland biodiversity.

The main outcomes expected from the inclusion of legumes, such as clovers, in grazed pasture include the enhancement of the condition of agricultural land through higher species diversity in swards, and the reduction of risk of loss of nitrogen into the environment. This can contribute to maintaining favourable condition of improved grassland habitats and supporting populations of key species, namely pollinators and other invertebrates.

3.5.2.1 Causality

ECAR-015 Replace nitrogen fertiliser application by using clover in pasture (or arable cropping systems)

AMBER * Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T* Connectivity of small 'feature' habitats
AMBER * Enhance condition of agricultural land
AMBER * Maintain good condition of agricultural land

ECCM-059 Incorporate clovers and other legumes in grazed pastures

AMBER * Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER T* Connectivity of small 'feature' habitats
AMBER * Enhance condition of agricultural land
AMBER * Maintain good condition of agricultural land

Pastures consisting of mixtures of grasses and nitrogen-fixing legume species, such as clovers and alfalfa, are increasingly recognised as sustainable and competitive grazing systems by reducing the need for inorganic nitrogen inputs and improving forage quality and yield (Jaramillo et al, 2021). Incorporating forage legumes into grazing systems can lead to biodiversity benefits through increased plant species diversity. Species diversity, particularly plant species diversity, can enhance the coexistence of different species such as niche differentiation, positive interspecific interactions, and control of competitive species. In addition, grass-legume mixtures can increase nutritive value and can even increase the accumulation of herbaceous species (Jaramillo et al, 2021).

Incorporating legumes into pastures may also deliver benefits to biodiversity through increasing the delivery of ecosystem services such as soil fertility. In addition to improving soil fertility through nitrogen fixation, there is some evidence for enhanced soil organic carbon (SOC) accumulation when legumes are incorporated into pastures, possibly as the nitrogen fixed by legumes is a substrate for SOC formation (Jaramillo et al, 2021). Another possible pathway for increased SOC is the higher rooting density of grass-legume mixes when compared to monocultures which is expected to improve soil structure and enhance SOC build-up (Haas et al, 2019). SOC can benefit both above-ground and below-ground biodiversity as it is a key component of many of the biochemical processes needed to support life. Furthermore, grass-clover mixtures have been linked to positive impacts on soil biodiversity, such as higher earthworm abundance and soil biota activity, due to a higher quality of food resources and better soil structure (Haas et al, 2019).

Clover and grass-clover mixtures may also deliver positive outcomes for aboveground biodiversity such as farmland birds. Grass-clover mixtures may improve foraging and chick survival for meadow bird species, such as the northern lapwing and common starling, which benefit from the typically shorter swards of legume species (Haas et al, 2019). Moreover, there is some evidence for grass-red clover mixtures being suitable breeding sites of some farmland birds such as skylarks (Haas et al, 2019).

More evidence exists for positive impacts of incorporating legumes on insect pollinator species, including red list bee species, and their associated pollination ecosystem services (Narjes Sanchez, Cardoso Arango and Burkart, 2021) (Haas et al, 2019). Improved grasslands have been highlighted as important habitats to increase resource provision for pollinators in the UK due to their large area (Harris and Ratnieks, 2021). Most legume species are insect-pollinated, and their pollen is particularly protein-rich, meaning they can potentially support wild pollinator populations by providing valuable nutrients (Harris and Ratnieks, 2021) (Cole et al, 2022). However, the potential of grass-legume mixes to deliver benefits for pollinators largely depends on their implementation and management. Intensively managed forage legumes are sometimes grazed or cut to minimise flowering plants, and, if they are part of grain monocultures, their flowering periods are short meaning they do not provide pollen and nectar resources to pollinators year-round (Cole et al, 2022). In addition, the choice of legume species will determine the quantity and quality of pollen and nectar provided, timing of flowering, and the pollinator taxa that can access the resources, as some legumes have complex flower structures which can only be reached by specific pollinator functional groups (Cole et al, 2022). White clovers and red clovers likely support honey bee populations and legumes such as *Fabacea* are critical food sources for bumblebees in the late summer, which is often a gap in flowering food resources in monocultures (Harris and Ratnieks, 2021). However, clovers and *Fabacea*e are likely less beneficial to other pollinating insects such as hoverflies, as their long flower structure makes them inaccessible. Similarly, species such as *Apiceae* and *Asteraceae* are probably more beneficial to solitary wild bees than *Fabacea* (Haas et al, 2019). Therefore, grass and legume mixes will deliver pollination services only if they are planned to ensure a diversity of functional traits and phenology which can provide resources to a wide range of wild pollinators throughout the growing season. For instance, legume species such as *Trifolium incarnatum* could be integrated alongside more economically viable species such as *Vivia faba* to provide pollinator resources for longer periods of time (Cole et al, 2022). Finally, diverse grass-legume mixes alone cannot deliver all of the resources required by pollinators so should be complemented with other measures which fill some of these gaps (e.g. early-season forage and nesting habitats).

Grass-clover mixtures can also contribute to weed-suppression ecosystem services. Clover and grass have different functional characteristics, such as temporal development, supporting a higher maintained resistance to week invasion when compared to grass monocultures (Finn et al, 2013). Although some studies show high weed suppression in grass monocultures when compared to clover monocultures, mixtures show weed suppression benefits that are at least as high as those of grass monocultures (Haas et al, 2019).

Replacing nitrogen fertilisation by using clover in pastures can lead to positive impacts on the condition of agricultural land and on species occurrence as lower nutrient levels can favour species found in natural and semi-natural habitats. Natural and semi-natural habitats are typically lower in nutrients and species which have evolved in these ecosystems are often outcompeted when nutrient inputs increase. Therefore, reduced nitrogen fertilisation can support higher species diversity and changes in composition (Cop, Vidrih and Hacin, 2009). There is good evidence that increased nitrogen inputs from nitrogen fertilisers have contributed to a decrease in plant species richness in European semi-natural grasslands (Helsen et al, 2014). In turn, this can have negative impacts on animal populations that depend on this vegetation for habitat such as invertebrates and grassland-nesting birds (Oeckinger, 2006) (Wilson, Evans and Grice, 2009). However, the impacts of changes in sward composition will vary across taxa. For example, a study in the UK found that the impacts of intensive grassland management on bird population varied depending on their feeding habits, with insectivorous birds being negatively impacted by intensive management while soil invertebrate feeding birds preferred intensive management during winter (Atkinson, 2005).

However, incorporating clovers into grassland can sometimes lead to trade-offs with biodiversity outcomes. As clovers typically require higher levels of phosphorus than grass species, pastures with clovers might be at higher risk of phosphorus loss into the environment where additional phosphorus fertiliser is used (Ledgard et al, 2009). Excess phosphorus has persistent negative effects on biodiversity and can therefore outweigh the positive effects from reduced nitrogen fertilisation (Ceulemans et al 2014).

ECPW-265 Use crops / varieties with differing root structures to improve soil structure and nutrient uptake

AMBER L** Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate
AMBER L** Enhance condition of agricultural land
AMBER L** Maintain good condition of agricultural land

Loss of plant diversity has important effects on soil, but understanding of how plant diversity impacts the soil physical environment remains limited. Muhandiram et al. (2020) found that the grass root structures of *Festuloliums* can assist soil water infiltration in non-compacted soils in spring, and that *Festuloliums* have total dry matter yield equivalent to that of ryegrass. A glasshouse and long-term grassland field study in the UK and Germany (respectively) shows that high plant diversity in grassland systems increases soil aggregate stability, and that root traits play a major role in determining diversity effects (Gould et al., 2016). A diverse sward structure benefits invertebrates and the inclusion of herbs benefits pollinators and granivorous birds where seed is allowed to set. Chicory and red clover can potentially improve soil structure, through long tap roots (Jones et al 2018).
Defra project BD5001 found that the introduction of deep-rooting herbs and legumes had no effect on earthworm biomass, earthworm numbers (Lees et al., 2016) or the foraging success/behaviour of starlings (Newell Price et al, 2019).

3.5.2.2 Co-Benefits and Trade-offs

Through decreasing the need for exogenous nitrogen inputs, incorporating legumes into grazed pastures can reduce the risk of nitrogen leaching into water leading to biodiversity benefits downstream (Harris and Ratnieks, 2021).

[TOCB Report-3-2 GHG **ECAR-015**] Benefits of reducing fertiliser use include the reduction of loss of N_2O into the atmosphere and reduced run-off, improving water quality. Trade-offs centre around the cost of establishing and maintaining clover / legumes in swards.

[TOCB Report-3-6 Carbon **ECAR-015**] Bai et al. (2019) found that SOC sequestration was greater under leguminous crops (including clover) than non-leguminous crops.

3.5.2.3 Magnitude

Quantifying the biodiversity impacts of grass-clover mixes is challenging due to the multifaceted nature of biodiversity and the site-specificity of biodiversity impacts. Some studies provide specific measures for specific biodiversity impacts. For example, foraging bumblebee queen abundance was found to be 71% higher in landscapes with red clover monocultures in Sweden (Haas et al, 2019). However, it is difficult to extrapolate these context dependent results.

3.5.2.4 Timescale

(0-5 years) Biodiversity benefits from the incorporation of legumes into grass pastures have been measured as early as 1 year after the establishment of a grass-clover ley (Haas et al, 2019).
Spatial issues
Highly competitive legumes, such as *Vicia faba* and *Vicia sativa*, can also lead to the competitive exclusion of other species leading to decreased biodiversity. To mitigate this, highly competitive species can be planted in discrete patches (Cole et al, 2022). Other spatial issues might occur for pollinator insect benefits as it has been suggested that the abundance of honeybees and bumblebees in adjacent habitats might decrease with mass-flowering from clover species as they are attracted to the abundant nectar and pollen resources in the clover-rich pasture. However, this might lead to positive landscape level impacts as it could decrease competition for other flowering resources which can then be accessed by other insect groups (Haas et al, 2019). Similarly, benefits to pollinators are dependent on the surrounding landscape (Haas et al, 2019).

Actions to incorporate legumes into grazed pastures should therefore carefully consider the wider landscape context in order to maximise biodiversity outcomes.

3.5.2.5 Spatial Issues

Not assessed

3.5.2.6 Displacement

None likely.

3.5.2.7 Maintenance and longevity

Some grass-legume mixes can result in poor establishment and persistence due to competition between species (Jaramillo et al, 2021). Therefore, mixtures should be carefully assessed to ensure competitive species do not prevent other less competitive legumes from establishing and flowering longer term (Cole et al, 2022). The delivery of some important biodiversity benefits, such as pollination, also relies on maintenance such as biodiversity-friendly grazing and mowing regimes. For example, alternative grazing regimes like tall grass grazing can increase the value of legumes for pollinators by facilitating flowering (Cole et al, 2022).

3.5.2.8 Climate adaptation or mitigation

Legume forage quality and yield is expected to be impacted by climate change through abiotic stresses such as increased temperatures, increased carbon dioxide levels, increased ozone concentrations, reduced water availability and changes to rainfall patterns, increased weather extremes and drought frequency and intensity (Kulkarni et al, 2018). Adaptation of crop selection and management and advances in assisted breeding techniques offer some possibilities to enhance the adaptation of the species incorporated in these actions to climate change (Kulkarni et al, 2018)..

3.5.2.9 Climate Factors / Constraints

Some studies suggest grass-clover mixtures might contribute to climate adaptation as their increased functional trait distribution increases their resilience to environmental change. In fact, some grass-clover mixtures achieve better resource use by plants under drought conditions than do grass monocultures (Haas et al, 2019). Deeper rooting herbs are more likely to be able to access water during dry periods.

3.5.2.10 Benefits and Trade-offs to Farmer/Land-manager

Overall, there were no detrimental effects of including chicory in swards grazed by beef cattle on their performance, carcass characteristics or helminth parasitism, when compared with steers grazing ryegrass (Marley et al., 2014)). There is potential for the genetic improvement of specific root traits within the forage species that are currently being used in UK grassland agriculture. (Marshall et al., 2016)

3.5.2.11 Uptake

Potentially widespread on all farms with grazing livestock. Newell Price et al (2019) found that of livestock holdings with temporary grassland in England in 2015-2018 around 30% had sown all their temporary grassland with a clover mix, and 70% had sown a proportion of it. Anecdotal evidence and total sales of seed indicate that the use of diverse swards or herbal leys is increasing, but such multi-species swards occupy a small proportion of the grassland area (Newell Price et al (2019).

3.5.2.12 Other notes

None

4 KEY ACTION AND EVIDENCE GAPS

4.1 BUNDLE: CLIMATE MEASURES

4.1.1 Climate change and adaptation: ECCM-012 Integrate high-sugar grass varieties

High-sugar grasses (HSG) have higher concentrations of water-soluble carbohydrates, which help ruminant livestock to utilise N from forage. When fed to dairy cows and other livestock HSG varieties have potential to reduce N leaching. Newell Price et al (2019) found that in the 2015-18 period high sugar grasses were sown on around 60% of livestock holdings with temporary grassland.

4.1.1.1 Causality

No evidence was found on the biodiversity impact of HSG but a UK study using life cycle analysis to model the environmental footprint of HSG dairy systems, suggests that re-seeding conventional ryegrass pastures with HSG ryegrass varieties both improves productivity and, especially if combined with improved manure management, could lead to reductions in the environmental footprint of milk production. However, the study suggests that the high costs of improved manure management could make HSG a more attractive short-term measure for farmers (Soteriades et al., 2018).

4.2 Bundle: Maintenance and restoration of cultural heritage sites [Trade-off/Co-Benefits only] EBHE-290: Establish/ maintain a continuous grass sward/vegetation cover over Scheduled Monuments/ heritage assets on the SHINE database that are not Listed Buildings or Scheduled Monuments with no ground disturbance, bare patches or erosion with no ground disturbance, bare patches or erosion.

4.2.1.1 Co-Benefits and Trade-offs

Biodiversity benefits, particularly if semi-natural grassland or other vegetative cover is established and managed without fertilisers and maintained by light grazing or mowing (not PPP).

[TOCB Report-3-6 *Carbon* **EBHE-290**] Introducing vegetation cover to bare ground will provide a small increase in carbon sequestration rates above and below ground. If vegetation cover is supplied by grassland as opposed to woody vegetation then sequestration rates and changes to above ground carbon stocks are likely to be relatively small. See the carbon sequestration review for the sequestration potential associated with different habitat types and grassland managements. Maintaining vegetation cover can also reduce rates of erosion, potentially restore soil compaction (Maskell et al., 2019). Where the sward has high diversity or nitrogen fixing species are introduced, the productivity of the system may be further enhanced (Fornara & Tilman, 2008). However, this action is unlikely to contribute significantly to national carbon storage

Food and fibre production	Area under production or yield and outside of ELM	N
Global, regional & local climate regulation	Above ground carbon sequestration	*
	Below ground carbon sequestration	*

4.2.2 EBHE-293: **Manage a permanent grassland for Scheduled Monuments/ heritage assets on the SHINE database that are not Listed Buildings or Scheduled Monuments refer to grassland**

4.2.2.1 Co-Benefits and Trade-offs

Biodiversity benefits, if semi-natural grassland or other vegetative cover is established and managed without fertilisers and maintained by light grazing or mowing (not PPP).

[TOCB Report-3-6 *Carbon* **EBHE-293**] Impacts for carbon are highly dependent on management, with the potential for small benefits or dis-benefits depending on the course of action. For more information on the impact of grassland managements on carbon sequestration see section 3.19 in the carbon sequestration review.

Food and fibre production	Area under production or yield and outside of ELM	N
Global, regional & local climate regulation	Above ground carbon sequestration	LTD*
	Below ground carbon sequestration	LTD*

4.2.3 EBHE-289: **Maintain Scheduled Monuments/ heritage assets on the SHINE database that are not Listed Buildings or Scheduled Monuments under grass cover within woodlands.**

4.2.3.1 Co-Benefits and Trade-offs

Biodiversity benefits for a range of woodland species (plants, invertebrates) open areas of semi-natural grassland managed without fertilisers and maintained by grazing or mowing (not PPP).

4.2.4 EBHE-088 **Maintain the visibility of upstanding Scheduled Monuments/ heritage assets that are on the SHINE database that are not Listed Buildings or Scheduled Monuments**

4.2.4.1 Co-Benefits and Trade-offs

Biodiversity impacts will depend on the existing land cover and management, and on what replaces it. A change from intensively managed forestry or agriculture to extensively semi-natural grassland would be beneficial. However, removal of existing semi-natural vegetation will generally be detrimental to biodiversity.

4.3 Trade-off and co-benefits for other actions

4.3.1 EBHE-297 **Re-site vehicle and stock access routes, supplementary feed areas, water troughs etc for Scheduled Monuments/ heritage assets on the SHINE database that are not Listed Buildings or Scheduled Monuments**

4.3.1.1 Co-Benefits and Trade-offs

Re-siting choices should take into account the potential impact on biodiversity in the new locations. Risk of damaging semi-natural habitats and species.

4.3.2 ECCA-014 **Create/ enhance/ maintain swales**

4.3.2.1 Co-Benefits and Trade-offs

Beneficial for amphibians such as toads and newts, and some invertebrates.

4.3.3 ECCA-017EM **Manage trees to slow water, particularly cross-slope planting**

4.3.3.1 Co-Benefits and Trade-offs

On agriculturally improved grassland or arable, benefits for a wide range of biodiversity taxa if understorey is protected from spray drift and heavy grazing and managed without fertilisers and PPP.

4.3.4 ECPW-168 **Create/ maintain leaky woody structures and woody debris in small water courses and their flood plains**

4.3.4.1 Co-Benefits and Trade-offs

Positive benefits for biodiversity of wetland habitats and the species that are associated with them.

4.3.5 ECPW-205 **Produce a water supply resilience plan**

4.3.5.1 Co-Benefits and Trade-offs

Assuming the plan is implemented, potential benefits for biodiversity from creating and enhancing natural water storage systems – but also risks to existing wetland and freshwater habitats if abstraction from them increases.

4.3.6 ECPW-213 **Reduce routes of entry to water from pesticide use**

4.3.6.1 Co-Benefits and Trade-offs

Biodiversity benefits for aquatic habitats and species.

4.3.7 ECPW-236 **Test fertilisers (inorganic and organic) as well as composts, soil improvers and anaerobic digestate for potential contaminants (heavy metals)**

4.3.7.1 Co-Benefits and Trade-offs

Assuming this leads to setting and observing baseline levels of contaminants, positive benefits for biodiversity.

4.3.8 ECPW-245 **Graze and cut grass later when fibre content higher (to slow digestion in ruminants)**

4.3.8.1 Co-Benefits and Trade-offs

Positive benefits for grassland biodiversity, especially where this is late enough to allow forbs to flower, but Johansen et al (2019) notes that for pollinator conservation, heterogeneous mowing times within a landscape need to be encouraged when possible, and that strict focus on late mowing may lead to shortage of flower resources late in the summer.

Other exceptions would be semi-natural grasslands managed for species which require low-level grazing throughout the year.

4.3.9 EHAZ-031 Use controlled traffic farming (CTF)

4.3.9.1 Co-Benefits and Trade-offs

Benefits for soil biodiversity from reduced risk of compaction and reduced cultivation depth.

4.3.10 EHAZ-051 Remove constraints to river movement (e.g. remove bank protection and embankments to enable channel migration within the floodplain)

4.3.10.1 Co-Benefits and Trade-offs

This process promotes distinctive floodplain biodiversity (vegetation, but presumably associated fauna as well) and landscape heterogeneity (Jakubínský et al. 2021)

4.3.11 ETPW-123 Restock trees for resilience

4.3.11.1 Co-Benefits and Trade-offs

Positive biodiversity benefit, especially if increases species diversity and age structure of the woodland

4.3.12 ETPW-151 Limit supplementary feeding to severe weather conditions

4.3.12.1 Co-Benefits and Trade-offs

Biodiversity benefits on semi-natural habitats by reducing stocking rates in winter to levels that the habitat can support; and avoiding soil nutrient load and compaction around feeding sites

4.3.13 ETPW-221 Add organic matter (e.g. paper pulp or sawdust waste) to soil

4.3.13.1 Co-Benefits and Trade-offs

Limited evidence for biodiversity effects. A replicated study in Switzerland found that sawdust from local beech trees had no effect on plant diversity and species richness of mountain grassland but reduced grass cover slightly (Spiegelberger et al 2009).

4.3.14 ETPW-249 Test soils regularly for heavy metals or potentially toxic elements (PTEs) and avoid over-application of inputs with high levels of heavy metals e.g. sewage sludge and certain waste products

4.3.14.1 Co-Benefits and Trade-offs

Assuming that the results of the tests do lead in practice to reductions in such inputs there is potential for biodiversity co-benefits, but any actual benefits will depend on the type, level of toxicity and persistence in the soil of any remaining (or additionally applied) heavy metals and PTEs.

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