Technical Annex 4: Building ecosystem resilience. Report to Welsh Government (Contract C210/2016/2017).

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Annex 4: Building ecosystem resilience

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0.3-1.0	CK,GS,EB,SS	28/6/2019	Edit to WG comments
1.1	CK,SS,BW	8/07/2019	For publication

Contents

1 Introduction

1.1 Review brief

The brief for this section of the evidence review was described as follows:

> *"The main purpose of this task is to define those actions that a farmer can take in terms of management intervention that will cumulatively deliver broad scale improvements in the condition and diversity of biodiversity related features (i.e. not improved land) on a farm. It should cover all farmland terrestrial and wooded habitat types in Wales. In a sense, this task requires the researcher to define 'the farm' as a habitat, accepting that different kinds of farm will be different habitats (c.f. an upland sheep farm and an intensive dairy farm). The sustainable management of productive improved land will be covered by tasks 2, 3, 4, 6, 8 – although it is acknowledged that habitats and improved land exist as a mosaic across farmland, rather than as isolated features. The existence of this mosaic and the need for effective edge management should be considered as part of this task. The selection of these actions must be predicated upon the existence of a causal evidence chain confirming that the actions described will deliver the outcomes sought. It was suggested in ERAMMP workshop that the appropriate approach might be to concentrate on a few broad farm habitat types rather than specialist / rare habitat categories. This is the desired approach to deliver the outcome for this task but defining farm types in this way must be done in a defensible way. A further task will need to be developed later in the process that will address the need for specific interventions on a range of 'specialist' habitats. Resilience in this task refers to ecological resilience – defined in SoNaRR as the capacity of ecosystems to deal with disturbances, either by resisting them, recovering from them, or adapting to them, whilst retaining their ability to deliver services and benefits now and in the future. Ecological resilience is one aspect of a broader focus on supporting a change of focus to sustainable land management that will be delivered through the scheme. We assert that, broadly speaking, improvements to diversity and condition can be managed at farm scale, whereas increasing scale and connectivity needs to be planned at a landscape level. The impacts of climate change need to be factored into this task - changes to weather patterns, as well as the impacts on species altering their range and lifecycle. For the purposes of this task 'existing woodland' is taken to include broadleaf, coniferous or mixed stands of farm woodland, if feasible to include orchards, agroforestry and hedgerows. Commercial plantations are excluded."*

This brief potentially covers a very wide range of evidence on management interventions across a variety of semi-natural habitats, and considers aspects of ecosystem function, ecosystem service provision and the responses of biodiversity, via habitat condition. It also includes some notable constraints, but we understand from Welsh Government that the brief for this review as described above does not cover the full extent of issues related to biodiversity that are being considered for inclusion in the Sustainable Farming Scheme (SFS).

1.2 Interpretation of the review brief

1.2.1 Improved land

This review is concerned with evidence for interventions to improve '*the condition and diversity of biodiversity-related features (i.e. not improved land)'*. Whilst the evidence presented here does, as required by the brief, focus primarily on semi-natural habitats and features, we wish to make clear that improved land does have both existing and potential value for biodiversity conservation. There are widely recognised wildlife communities associated with farmland, including wild species that depend either wholly or partially on improved land habitats per se, such as grassland and arable flowering plants, and birds such as skylark (dependent on open-field habitats) and yellowhammer or blackbird (nesting in field boundaries and feeding in arable fields). Conservation of these communities has been recognised as a priority in Wales, the UK and across Europe for several decades, and a wide range of management interventions for conservation or habitat condition on improved land have been supported under agri-environment schemes. Interventions have included, for example, taking areas of land out of production, such as field margins or fallows in rotations, reducing management intensity (stocking rates, chemical applications, etc.) and managing non-productive features such as ponds, field corners and ditches, as well as surviving patches of recognised semi-natural habitat within improved land.

Clearly, conversion of improved or semi-improved land is critical, by definition, for any new habitat creation, which in turn is important for improving the connectivity and resilience of existing semi-natural habitats within an agricultural landscape. Similarly, new agroforestry or other in-field tree planting must be on existing improved or semi-improved land, if existing semi-natural habitats are to be conserved and improved. In reviewing evidence of landscape scale interventions we have therefore considered the scope of this review to include all farmland, from semi-natural to agriculturally improved arable or grassland.

1.2.2 Habitat condition

This review follows the brief in presenting evidence relating to habitat condition, and only considering the presence, abundance or diversity of species where these are constituents of habitat definitions or condition metrics. It is important to note that the relationship between habitat condition and species presence or abundance is largely unknown and likely to vary with habitat context, which means that one cannot simply assume that species associated with a habitat will necessarily benefit from measures targeted at improving the condition of that habitat (or vice versa). However, it has been demonstrated in a wide range of contexts, including in Wales[1] that species respond to management interventions on farmland. Habitat/species interactions are discussed further in Section 5 below and Technical Annex 10b: Considerations for the new scheme.

1.2.3 Ecological resilience

This review is specifically concerned with resilience of ecosystems. ‘Resilience’ has been used in several different ways in the ecological literature and the definition used here is taken from SoNaRR: "*the capacity of ecosystems to deal with disturbances... whilst retaining their ability to deliver services and benefits now and in the future.*" The second part of this definition potentially conflates ecosystem service provision with ecological condition, in the sense that it is possible to take a view in which habitats are valued only insofar as they provide benefits for humans. But it is equally possible to take a wider view, considering conservation as having value for its own sake. Accordingly, most research regarding interventions and their effects on biodiversity involves benefits or otherwise for plant and animal species themselves.

Deriving evidence of resilience is challenging. Simplistic relationships between species richness and resistance or recovery from shocks do not represent the complex biophysical mechanisms which may confer resilience. The more species that are present, the more ecosystem functions will be represented and the more

[1] For example, analyses conducted under GMEP: Dadam and Siriwardena (2019)

redundancy in each function will be found, but this is a statistical artefact rather than a biological mechanism.

1.2.4 Scale of management interventions

It is important to recognise that all habitat creation and restoration actually happens at the individual farm scale and the cumulative impact of this underpins the extent and connectivity of habitats which is a key contributor to ecosystem resilience. Effective improvement in habitat connectivity requires planning and targeting interventions spatially at the landscape scale, and implementing them 'in the right place' on many individual farms. This approach requires management action on both semi-natural habitats and improved land, with significant opportunities to enhance ecological resilience through habitat creation as well as through improving the condition of existing habitats.

1.2.5 Linking evidence to farm types

The brief proposes a focus on '*a few broad farm habitat types rather than specialist / rare habitat categories ... but … defining farm types in this way must be done in a defensible way*'.

Broad farm types in Wales could be characterized as lowland pasture (sheep or cattle), lowland arable/mixed, upland grazing (mostly sheep) or other (lowland, often indoor) livestock. Alternatively, the Welsh Government have used a classification of specialist pigs, specialist poultry, dairy, cattle and sheep (LFA, split into DA and SDA)[2], cattle and sheep (lowland), cereals, mixed, general cropping, horticulture and other[3]. Most of these systems are dominated by improved land, the character of which defines the farming type. Given that management of different semi-natural features will depend mostly on the characteristics of the features themselves, rather than on the broader farming system in which they are found, it is more intuitive, and fits the evidence better, to focus on types of semi-natural habitat, rather than on types of farm. We have, therefore, organised the review by habitat type rather than by farm type.

1.2.6 Uncertainty

It is important that any review of the evidence behind interventions takes proper account of uncertainty. This may be in the form of statistical uncertainty in analyses of national-scale responses, but may also be more qualitative, such as the application of spatial comparisons to infer the effects of temporal change, or the assumption that laboratory-, patch-, field- or farm-scale evidence from small-scale trials will scale up to nationally-relevant effects over the long term. For example, a test on a pair of farms with contrasting management may have used a flawless protocol, analysis and interpretation, leading to clear and precise results, but there is inherent uncertainty in assuming that such results predict national-scale responses over the period of interest. This is particularly important to recognise because it is much easier to design and to conduct experiments or controlled trials over short periods and small scales, while long-term, large-scale studies are inevitably subject to more noise and error. The former will, therefore, tend superficially to provide 'better evidence', but masking the inherent uncertainty in the wider

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[2] Less Favoured Area (LDA); Disadvantaged Area (DA); Severely Disadvantaged Area (SDA)

[3] https://statswales.gov.wales/Catalogue/Agriculture/Agricultural-Survey/Farm-Types/total-farm-land-by-year-and-farm-type

representativeness of the patterns that are revealed. Note also that uncertainty will often be particularly unclear in collated expert judgement.

All of the above means that there will be a sliding scale in the confidence that can be attached to the evidence that a given intervention will work (or not), for example in scaling up of effects from field or farm to populations/landscapes, or moving from one location to another. We therefore highlight the importance of the 'amber' category which captures interventions where the expert community agree there is an intervention logic chain which can be supported, but evidence is currently limited.

2 Outcomes

In terms of the outcomes as defined by the WG, the principal outcome of these interventions is the increased provision of functioning habitats[4] through broad-scale improvements in the habitat condition, diversity and ecological resilience of semi-natural habitats (mainly semi-natural grasslands and hay meadows, heathland and blanket bogs), farm woodlands and other trees and hedgerows within farmland. Following consideration of this review, the Welsh Government is now consulting on two outcomes, resilient ecosystems and species recovery. Functioning habitats is still a key part of the resilient ecosystems outcome.

We note that there is an issue of partially improved semi-natural grasslands in Wales, and a policy question about the ‘direction’ in which these should be managed in future to deliver this and other SFS outcomes. Put simply this is a choice between management for improved habitat condition or management for increased biomass (e.g. fodder crops or timber) production, and the most appropriate choice in each case will depend on both ecological and economic factors.

Depending on the type, scale and location within the landscape of the intervention, secondary outcomes could include:

- carbon sequestration
- flood risk mitigation
- reduction of water pollutants
- new non-agricultural income streams
- outdoor recreation

Habitats do not function in isolation from each other, and the scale, distribution and connectivity of different semi-natural features plays an important role in the functionality and resilience of habitats and species associated with farmland. In the review this aspect has been considered at a landscape scale but it also applies at farm level. For example, In Wales the livestock systems have historically been associated with the inter-dependent management of different types of semi-natural habitat both on individual farms and at a landscape scale (e.g. commons, away-wintering). Although these links have been weakened to some extent they remain very relevant to the implementation of the SFS.

We recommend for SFS funding to achieve increased provision of functioning habitats will require a combination of annual or multi-annual contracts for management action and/or outcomes (some habitat improvements will benefit from longer contracts than is current practice), plus capital support for associated actions.

[4] Defined by WG for this SFS Evidence Review as ‘*Networks of habitats will become more resilient due to improvements in quality, scale and connectivity – at farm and landscape level. Biodiversity hotspots and the wider countryside will be more joined up allowing species to move about as required for all stages of their life cycles*’

3 Policy Relevance and Policy Outcomes

These outcomes could contribute significantly to the following Natural Resources Policy priorities:

- Restoration of our uplands and managing them for biodiversity, carbon, water, flood risk and recreational benefits
- Resilient ecological networks
- Maintaining, enhancing and restoring floodplains and hydrological systems to reduce flood risk and improve water quality and supply; (including catchment management approaches, natural flood management, soil management etc.)

They also have the potential to contribute to additional priorities: This will depend on the implementation choices made on the objectives, characteristics and location of management of existing and creation of new woodland, agroforestry and other landscape features.

- Increased canopy cover and well located woodland, for example close to towns and cities where it will have the greatest recreational and ecosystem service value
- Increasing green infrastructure in and around urban areas

4 Introduction to the interventions reviewed

4.1 Intervention categories

Our starting point is the definition of four overarching intervention categories, within each of which we explore a range of more specific interventions at different levels of detail.

Management of unimproved (including semi-improved) pastures and hay-meadow habitats

This intervention category encompasses the management that is required in order to maintain, improve or create a wide range of broadly semi-natural habitats that depend to a greater or lesser extent on the pasturing of domestic livestock, or/and the harvesting of forage (generally as hay).

In terms of the UK National Ecosystem Assessment broad habitats, these semi-natural habitats are included within:

- **Mountains, moors and heaths**: including upland and lowland heathlands, moorlands, blanket bog, ffridd (or the upland fringe that encompasses land occurring between the intensively managed lowlands and the open moor), and stands of bracken in the lowlands. Only certain situations within this broad habitat are not associated with grazing, such as rock habitats.

- **Semi-natural grasslands**: including large areas of upland acid grasslands (widely associated with all of the mountain, moorland and heath habitats), purple moor grass and rush pasture, and other types of more limited extent such as calcareous grasslands and hay meadows.

Management of existing farm woodland habitats

The WG brief for this intervention category covers coniferous, broadleaved and mixed woodland on farms, whether actively managed or not, but excludes commercial plantations.

Management of other trees and shrubs in farmland (agroforestry)

This intervention category covers: hedgerows (and hedgerow trees), trees in shelterbelts, in groups and individually in fields, and other agroforestry systems.

Farmland landscapes

This category differs from the other three in its focus on the diversity, condition and functional inter-relationship (for biodiversity) of the range of habitats and features within a spatial unit at different scales – from parcel to farm to wider landscape. By definition, these landscapes include all types of farmland and woodland habitats including production habitats on improved land (which can also be managed for biodiversity).

4.2 Evidence to be explored

There are many different semi-natural habitats within the above intervention types, facing a complex set of conservation challenges (as explored below). There is a range of potential interventions for each habitat, and each potential intervention could be broken down further into a large number of variants, for example for semi-natural pastures, different stocking densities and grazing patterns, combinations of animal species, burning regimes, hay cutting dates, fertilisation, exclusion of grazing, etc. These interventions are notably more complex and quite different from those reviewed for improved grassland sward management (Technical Annex 2: Sward management).

Furthermore, interventions can and should be put together in different combinations, depending on the specific local circumstances. Given the range of different semi-natural habitat types in Wales and the list of possible management interventions in each of them, there is not sufficient time within this project to undertake a systematic review of the evidence for each potential intervention applied to each individual habitat type.

Instead the focus is more general, addressing the apparent conservation needs of the suites of semi-natural habitats described above and the evidence for broad interventions that respond to these needs. Some individual habitat types will be reviewed as examples.

Conceptually, evidence will be broadly of two types (although not presented in separate categories):

- evidence of the *need* for interventions, considered from two angles:
    - habitat extent and condition, and the condition of relevant species populations; and
    - farming trends that influence this condition;
- evidence of the *effectiveness* of specific management interventions on semi-natural habitats.

4.2.1 Availability and limitations of evidence

Evidence for the current condition of semi-natural farmland habitats comes from multiple sources, all of which have certain limitations for the purposes of this review.

'Condition' data on semi-natural habitats often refers to assessments of 'favourable'/'unfavourable' status, as used in UK-wide reporting of the conservation status of certain protected habitats and species[5]. Such data are available for designated sites, which generally represent only a limited proportion of the habitat's full extent, and these assessments often are biased towards larger habitat patches, rather than the smaller areas integrated within the wider farmed landscape, such as hedges and riparian areas.

In the wider countryside, evidence regarding habitat condition comes from metrics collated from species-level monitoring and from metrics of structure for certain key habitats, such as hedgerows. In Wales, the Glastir Monitoring and Evaluation Programme (GMEP)[6] gathered spatially explicit, fine resolution field data from a stratified sample of 1km squares between 2013 and 2016. The survey covered multiple habitat types on improved and semi-natural land (including a field and feature-level stratification of land reflecting whether under Glastir management interventions or not by habitat type). Because GMEP is based on a random spatial sample most data were collected from improved land, rather than rare habitats, but

[5] Required at seven-year intervals under EU legislation and known as Article 17 reports. The most recent report is for 2013.
[6] See https://gmep.wales/

15% of plots fell on SSSI land within the broader farmed landscape. GMEP included specific analyses of field data to inform about changes in habitat condition, as revealed by the presence of key indicator plant species in vegetation communities, hedgerow structure, and metrics describing bird and butterfly communities. GMEP also provides unique datasets on multiple taxa and habitat features, with co-located sampling, in order to allow an integrated, comprehensive assessment of ecosystem condition. To date, only limited analyses of GMEP data have been completed, mostly concerned with national trends and the effects of legacy agri-environment schemes.

Data on the distribution and extent of semi-natural habitats and the species that depend on them in Wales is drawn from a number of sources, which vary in scope, date and level of detail. These include the 2016 State of Nature in Wales Report (SoNaRR), the Countryside Survey in Wales of 2007 and aligned recent sampling from GMEP, the annual Breeding Bird Survey (for species associated with semi-natural habitats in Wales), the Welsh Government's Woodlands for Wales Indicators 2015-16 and other published sources.

4.3 Management of unimproved (including semi-improved) pastures and hay-meadow habitats

4.3.1 Mountain, moor and heath habitats - extent and condition

The 2016 SoNaRR report states that *"we only have limited information on the current distribution, extent and condition of Mountain, Moor and Heath habitats in Wales; and there are limited recent data on condition of mountains, moorlands and heaths features on SSSIs in Wales"* (Natural Resources Wales, 2016)**.**

According to the available data reported in SoNaRR, in Wales there is total of 261,824ha of mountain, moor and heath habitats, of which more than 83% (219,000ha) is in the uplands (defined as land lying above the upper limit of agricultural enclosure). In order of magnitude the most extensive elements are dry heath, bracken and blanket bog which, together with upland fen, marsh and swamp, account for 43,500ha. In the lowlands the most extensive areas of this habitat suite are dry and wet heath (8,900ha and 3,600ha, respectively) and bracken (30,100ha). Notable is the relatively smaller size of individual habitat patches in the lowlands compared to those in the uplands – these range in size from 9.9ha for lowland stands through 18.6ha for the upland fringe (including ffridd) to 25.7ha in the uplands. The report comments that *"this reflects the extent of modification and fragmentation (through habitat loss) of habitats in the lowlands."* (Natural Resources Wales, 2016).

SoNaRR reports that the condition of SSSI features for the most extensive of these semi-natural mountain, moor and heath habitats is between 63% and 73% unfavourable, but with the caveat that *"these data are based on expert judgement collated during 2003, as opposed to systematic formal condition assessment".* The main causal factors of poor condition resulting from land management identified by SoNaRR are grazing (both overgrazing and undergrazing), drainage, burning management, and invasive non-native species, including conifer seedlings. The report points out that all montane habitats are currently judged unfavourable, and at the last comprehensive review nearly three quarters of heathland features within SSSIs were judged as being in poor condition. (Natural Resources Wales, 2016).

In identifying indicators of poor condition in different habitats in this group, SoNaRR noted that for dry heath these were a closed canopy, lack of bare ground, lack of structural diversity and (especially in the lowlands) the dominance of gorse *(Ulex* *gallii);* encroachment of scrub and bracken and of invasive non-native species, particularly *Rhododendron,* were also common. In upland dry heaths indicators of overgrazing were more common, e.g. reduced heather cover and low diversity heathers and associated species, although in the lowlands localised heavy grazing can also reduce floristic and structural diversity (Natural Resources Wales, 2016). Miller et al. (2017) identified a lack of grazing and succession as pressures on lowland dry heath associated with coal spoil.

In the case of wet heath, SoNaRR again identified lack of grazing as a significant factor in the lowlands and ffridd, but found that overgrazing was more significant in the uplands. Blanket bog ecosystems in poor condition are typically dominated by grasses and heathers, with a reduced cover of *Sphagnum*, caused by past overgrazing or undergrazing, fire history and drainage. SoNaRR notes that *"Extensive areas of* Molinia *domination are a particular feature of blanket bog in central and south Wales, and the situation on the Elenydd plateaux may be unparalleled elsewhere in Britain, and certainly in Wales".* (Natural Resources Wales, 2016). Analysis of the Article 17 database for Natura 2000 habitats confirms grazing as the pre-eminent land-use activity affecting feature condition across many of the Annex I habitats included in mountain, moorland and heath.

Although in 2016, data on habitat condition (and by extension the causal factors) was reported to be largely absent for habitats outside protected sites, very recent re-analysis of GMEP data reported by CEH (Maskell et al., in press) suggests that habitat condition and plant species richness in Mountain, Moor and Heath habitats improved in the period 2013-2016 compared with the declining situation shown by Countryside Survey in Wales during the period 1990-2007. This reanalysis was based on the 'Wider Wales' survey of 150 1km squares sampled over a four year period between 2012 and 2016, and using the reporting structure for ecosystems in SoNaRR (Mountain Moor and Heath, Semi-natural grasslands, Enclosed farmland and Woodland). Although not yet officially signed off, these data add some new perspective to the 2016 SoNaRR report.

4.3.2 Semi-natural grasslands - extent and condition

Semi-natural grasslands are broadly classified as Neutral, Acid and Calcareous Grasslands in the National Vegetation Classification[7]. The 2007 Countryside Survey in Wales (Smart et al., 2009) states that Neutral Grassland covered the largest area of semi-natural grassland in 2007 at 12% of the area of Wales with 60% of this being found in the lowland zone. Acid Grassland covered 10% of the land area of Wales in 2007 and Calcareous Grassland just 0.06%.

However, most of the Neutral Grassland recorded by Countryside Survey in Wales, but perhaps also some part of Acid Grassland, are probably what is commonly called semi-improved grassland, which the Habitat Survey of Wales allocated to Improved Grassland. Therefore, very little of the Neutral Grassland described by Countryside Survey in Wales actually relates to unimproved grassland of high conservation value (a scattered, fragmented resource in both Wales and the rest of the UK). This example illustrates just how difficult it is to draw hard lines between classes of vegetation that in reality grade into one another (Smart et al., 2009).

More of the Acid Grassland recorded by Countryside Survey in Wales will correspond to grassland types that grade Dwarf Shrub Heath and Bog in the unenclosed

[7] JNCC, accessed 07/05/2019.

uplands, but very little of it is likely to grade into lowland unimproved Acid Grassland (which is of high nature conservation value but scarce and highly localised in Wales) (Smart et al., 2009).

From different sources (e.g. Blackstock et al., (2010), Natural Resources Wales (2016)) there are reports that: *"semi-natural grassland types cover around 9% of the land area (c.192,000ha), excluding upland marshy grassland but including lowland Purple Moor Grass and Rush Pasture. Just over 78,000ha of this semi-natural grassland is listed as Priority Habitats (as listed in the Environment (Wales) Act 2016, interim Section 7), more than 90% of which is in the lowlands. A total of 7,900ha (around 10% by area) of all Priority Grassland Habitat is protected on SSSIs in Wales, although the proportion is substantially higher for some types of grassland."*

The relevant Priority Habitats are Lowland Hay Meadows, Lowland Dry Acid Grassland, Lowland Calcareous Grassland, and Upland Calcareous Grassland (Smart et al., 2009).

Natural Resources Wales (2016) reports in SoNaRR that in the UK's 2013 Article 17 report to the European Commission under the requirements of the Habitat Directive, *"all eight of the Annex I grassland habitats found in Wales were considered to be in an 'unfavourable bad' conservation status. Three of these habitats declined in extent in the UK over the 2001-12 period and in Wales one showed a decrease in area of more than 1% per year".* The most frequently cited pressures and threats in the Article 17 report included long-standing issues such as agricultural improvement and grazing management. (Natural Resources Wales, 2016).

The most recent re-analysis of GMEP data reported by CEH (Maskell et al, in press) suggests that habitat condition and plant species richness in Semi-natural grassland had improved in the period 2013-2016 compared with the situation shown by Countryside Survey in Wales during the period 1990-2007.

4.3.3 Condition of species populations associated with pastoral semi-natural habitats

Semi-natural grasslands in Wales are not subject to regular, specific bird monitoring, but ongoing, annual BTO/JNCC/RSPB Breeding Bird Survey (BBS) monitoring provides data for Wales and a range of species, primarily associated with grassland that are sampled sufficiently well to support annual population indexing (Woodward et al., 2018). In addition, subject to sampling location overlap with target habitats, bird surveys from GMEP provide a standardized data source regarding the status of communities that are associated with specific habitat patches; analyses of these data have yet to be conducted. Of the relevant species that are monitored by the BBS, starling (*Sturnus vulgaris*) has shown an ongoing decline in Wales (72% since 1995), while the meadow pipit (*Anthus pratensis)* trend is strongly fluctuating but stable in the long term, and tree pipit has also fluctuated but has shown a shallow decline in the long term (net 18% since 1995). Curlew (*Numenius arquata)* has declined by 63% since 1995 and kestrel (*Falco tinnunculus)* shows a similar, smooth pattern of decline in Wales since 2005 (>80%), but based on a small sample of BBS squares. Conversely, swallow (*Hirundo rustica)* has been stable in the long term, but declining since 2006 (16%), wheatear (*Oenanthe oenanthe)* has been fluctuating but showing a net decline of 48% since 1995 and skylark (*Alauda arvensis)* fluctuating but stable in the long term. In addition, a number of relevant, rarer species are accepted as conservation priorities in Wales due to independent evidence of small population sizes and/or declines. Evidence for these patterns has been collated by Siriwardena and Dadam (2015) and Bladwell et al. (2018) from sources such as species-specific surveys, bird reports and small-sample-caveated BBS analyses. These include golden plover (*Pluvialis apricaria)* (probably declining), twite *Linaria flavirostris* (stable), chough (*Pyrrhocorax pyrrhocora*x) (increasing), yellow wagtail *(Motacilla flavia)* (declining), lapwing (*Vanellus vanellu*s) (declining) and whinchat (*Saxicola rubetra)* (declining, but more stable since 2000). Overall, these trends point to falling condition in grasslands in Wales in terms of resource provision for birds, but at the national scale: this does not preclude the existence of local-scale habitat improvements, for example due to agri-environment management.

SoNaRR (2016) reports concerns over the state of UK breeding upland birds as reflected in figures for curlew (81% decline in UK 1993-2010, with significant decline in Wales between 1995 and 2010) and golden plover (83% decline in UK 1982-2007) in Birds of Conservation Concern. Wales now has the southernmost breeding population of golden plover in Europe. Other upland fringe species such as black grouse (*Tetrao tetrix*) have increased at some sites due to intense conservation management, but their range has continued to diminish. There is a similar story for hen harriers (*Circus cyaneus*), as there has been a decline in illegal killing.

4.3.4 Evidence of farming trends & implications for habitat condition and intervention needs

Overall, it is apparent from the above evidence that livestock are a key factor in determining condition for these suites of semi-natural habitats. This is not surprising given that the existence of these habitats in their current form and distribution is largely the consequence of their management as a pasture resource for domestic animals.

Furthermore, their basic characteristics as semi-natural habitats are dependent upon an on-going regime of appropriate annual grazing (or/and mowing in the case of hay meadows) supplemented by appropriate control of shrubby vegetation by cutting or/and burning.

Under-grazing has been cited as a key factor causing poor condition of certain semi-natural habitats, and is particularly an issue for semi-natural grasslands and heaths in the lowlands. Over-grazing has also been cited in some cases in the lowlands, but more commonly in the uplands.

It is worth noting that these references (quoted above, from Natural Resources Wales, 2016) date almost entirely from the pre-2005 period before the decoupling of CAP direct payments, which until then had acted as an incentive to keep livestock (see below).

The recognised widespread problem of under-grazing, and the risk of this becoming a more widespread issue in the absence of coupled direct payments, suggests that grazing (and mowing in the case of hay meadows) of the broad suite of semi-natural habitats (including semi-improved grassland, as explored further below) is required as a general intervention.

As the basis for considering conservation needs and potential interventions in more detail and in the context of livestock farming trends, the evidence suggests the need for a practical grouping of habitats in terms of predominantly upland and lowland pasture types, and hay meadows, as follows:

- upland grasslands, heaths and blanket bogs
- lowland grasslands, heaths and saltmarsh

- hay meadows.

4.3.4.1 Uplands

In the LFA there has been a general, UK-wide reduction in grazing livestock numbers over the past 10 years or so, reinforced by the decoupling of CAP payments in 2005, and in Wales the overall grazing pressure in the LFA has reduced by 14.6%. (Silcock et al., 2012).

As a general context, overall sheep and beef cattle numbers have declined in Wales over the past 15-20 years. Sheep and lamb numbers in 2018 were down by 17% from a peak around the year 2000. Beef cattle were down by about 20% in the same period. (Statistics for Wales, accessed 30/04/19).

Silcock et al. (2012) analyse livestock trends in the LFA across the UK, including in two Welsh case-study areas, and assess the implications for habitat conservation. Alongside changes in livestock numbers, they report a number of other changes in grazing regimes in the LFA in recent years. Changes common across all four countries include: reduced cattle grazing/mixed grazing; more grazing by continental/improved breeds of cattle and sheep; on the hill, summer grazing starting later, and less out-wintering and feeding; also reductions in hefting and shepherding, grazing of commons and burning. There is more housing of cattle and an increase in indoor lambing, more intensive use of in-bye land, a shift from hay to silage, and increased finishing of stock. There are fewer farm holdings, farmers keeping stock, and active commoners, and more part-time farmers in the LFA (Silcock et al., 2012). The authors identify a range of factors driving these changes in livestock numbers and grazing regimes, including; the unprofitability of livestock farming; changing market demands and the shift to decoupled payments; the introduction and widespread uptake of agri-environment schemes; and outbreaks of livestock disease. Furthermore, an aging farmer population and the growth in off-farm income are leading to a demand for simpler systems that require less labour and management input, and fewer (or a different type of) livestock. Regional differences have probably been driven by land productivity and suitability, remoteness, options for alternative management, and the impact of government policies and support schemes. Single Farm Payments (SFP) and LFA payments are currently important in maintaining financial viability for LFA farms, but lack conditionality to reward those farms which deliver most environmental services.(Silcock et al., (2012) .

The biodiversity implications of these changes in livestock numbers and grazing regimes is polarised between semi-natural areas (where there has been reduced grazing pressure and habitat recovery that have been broadly positive for biodiversity), and improved areas (where more intensive land use and management has had a negative impact on biodiversity) (Silcock et al, 2012). The authors identify the shift from traditional breeds to continental or improved breeds of cattle and sheep as a particular cause of changes in grazing pressure within the farm, with intensification of use and management of land closest to the farm buildings (and also of some marginal land) to meet the higher nutritional requirements of these breeds. This has led to both a loss of semi-natural grassland habitats due to agricultural improvement and to under-grazing of semi-natural pastures on the hill (Silcock et al., 2012). In terms of detailed impact at habitat level they conclude that "*upland habitats such as dry heath, wet heath and blanket bog have recovered (and continue to recover) as a result of reduced grazing by sheep in particular, contributing to the improving condition of many sites. However, undergrazing and loss of vegetation structure is now occurring in some areas, with adverse impacts for some species* *such as golden plover and other waders. Less cattle and mixed grazing is contributing to the spread of ranker grasses, rush, scrub and bracken and hampering restoration efforts. A decline in hefting and shepherding is leading to overgrazing and undergrazing on different parts of the same site. Less burning is leading to older stands of heather and loss of vegetation structure*". (Silcock et al., 2012).

Moorland and Blanket bog

The consulted evidence shows that at least a minimum of livestock activity is required for the conservation of moorland and blanket bog, with the possible exception of certain locations with the most extreme environmental conditions.

Natural England reviewed a wide range of evidence on the conservation impact of moorland grazing and stocking rates in England (Martin et al., 2013), and found that: "*The evidence suggests that "moderate" and "variable" (both spatially and temporally) levels of grazing are the most appropriate for delivery of many ecosystem services (including those related to soil carbon and biodiversity), though not necessarily those related to animal production*." This review also found some evidence that the habitat condition of low productivity blanket bog and montane habitats has improved where stocking rates have been reduced to annual averages of around 0.05 LU ha^{-1} yr^{-1} or less, often with off-wintering; and that similar stocking rates have allowed some recovery of previously suppressed montane plants in some of England's rarest and most fragile upland habitats (Martin et al., 2013).

Although reducing overall stocking levels from levels perceived to be excessive can result in habitat improvement, the issue is complex. Spatial and temporal variations in grazing pressure are critical, as are the livestock species and breed.

Thus, Martin et al. (2013) found evidence that: *"A likely barrier to the achievement of ecosystem service outcomes, and possibly for biodiversity objectives in particular, is this variability in grazing pressure across a diverse grazing unit. The grazing patterns that result from sheep ranging behaviour and grazing preferences, management practices and topography are unlikely to match the conservation grazing requirements of different habitats and species. A reduction in sheep numbers, resulting either from conservation schemes or changes to farm enterprise structure, will not necessarily deliver these varying grazing requirements fully. A challenge for conservation advisers and land managers is to better match livestock grazing patterns to the requirements of different habitats. Complete removal of grazing should only be applied in a targeted way and in the short-medium term. "It is likely that prolonged grazing exclusion could be detrimental in all but the very lowest productivity or most climatically suppressed habitats, as competitive species increase and gaps for colonisation by less competitive species are lost."*

JNCC, reporting on its habitat surveillance and monitoring, has found that over-grazing of blanket bog results in loss of vegetation structure and of more palatable or vulnerable species (and their associated fauna), and the spread of rank, unpalatable plant species. In extreme cases, very heavy grazing and trampling can lead to exposure of bare peat and erosion. JNCC concludes that: *"There is, therefore, a need for grazing to be undertaken at the right time and with the right intensity. There is also a need for correct burning practices and to reinstate natural hydrology by blocking grips (lines cut through moorland for drainage purposes)"* [8].

[8] JNCC, accessed 6/5/2019

4.3.4.2 Lowlands

Semi-natural grasslands

The definition of lowland grassland includes largely enclosed grasslands (meadows and pastures) normally occurring at altitudes of 350 metres or less in the UK. This definition thus includes the enclosed hay meadows and pastures occurring in upland valleys and dales (Crofts and Jefferson, 1999). Lowland grasslands can be very important for certain species groups, in particular, bryophytes, lichens, fungi, birds and invertebrates, as well as for scarce and declining vascular plants.

Very little is known about the condition of the 90% of semi-natural grassland which lies outside statutory protected sites in Wales, although a survey in 2004 recorded significant decline in species-rich lowland grassland at 25% of non-designated sites over an average eight-year period since the previous survey (Stevens et al., 2010).

In recent decades, intensification of semi-natural grasslands by ploughing, drainage and reseeding, using more fertilisers and herbicides and shifting from hay to silage has led to a major expansion of more uniform, species-poor, agriculturally productive swards dominated by perennial rye-grass and white clover. In other cases, simply using one (or more) of these treatments and/or heavy grazing and manuring has more 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).

The abandonment or inadequate management by grazing or cutting of semi-natural grassland, as a result of their increasing irrelevance to modern intensive farming systems, is a major cause of decline (e.g. Crofts and Jefferson, 1999 and Bullock et al., 2011). As a result, in many grasslands the natural processes of plant succession begin, at first dominated by robust and vigorous grasses which suppress or reduce the smaller herbs. Then, sooner or later, species of tall shrub typically begin to invade and dense scrub growth develops, ultimately leading in most cases to woodland. (Duffey et al., 1974).

It has become less economically viable for farmers to graze or mow semi-natural grasslands of low agricultural productivity, especially in areas dominated by arable farming, due to low forage yields, higher labour costs and limitations imposed by difficult terrain or isolation. Social factors, including demographic changes, have exacerbated the trend towards abandonment. (Jefferson et al., 2014).

For lowland semi-natural grassland generally across UK SACs and A/SSSIs, under-grazing and abandonment are reported by JNCC as the main causes of unfavourable condition, commonly leading to scrub encroachment and sometimes problems with bracken and/or invasive species. JNCC reports that the causes of under-management are still thought to be "l*argely due to current agricultural economics and policies, exacerbated by, for example, BSE and Foot and Mouth disease, leading to a reluctance to keep stock (large stock in particular) on pasture perceived to have little nutritional value. Additionally, some sites are also affected by over-grazing and nutrient enrichment. Nutrient-enrichment through fertilizer application is still a concern, but is very difficult to monito*r". (JNCC[9]).

[9] http://jncc.defra.gov.uk/page-3560 accessed 06/05/2019.

Increasingly, semi-natural grasslands have become isolated and fragmented within intensively-managed farmland, surviving as isolated fields, inaccessible parts of intensively-managed fields or small groups of fields managed by elderly farmers (Blackstock et al., 1999).

In addition, local case studies in Wales and England have found that a general problem for the upkeep of semi-natural grassland is the lack of maintenance of the infrastructure associated with traditional grazing management, such as fencing, water supplies, and serviceable small-scale hay cutting equipment (Beaufoy and Jones, 2011).

Another factor considered to have caused widespread degradation of British semi-natural grasslands is atmospheric nitrogen deposition from burning fossil fuels (Bobbink et al., 1998). For certain wetter grasslands, changes in hydrology due to drainage, abstraction and flood relief are reported to be significant causes of unfavourable habitat condition and loss (Wheeler et al., 2009).

Semi-natural habitats may exist in isolation but often occur in a mosaic. For example, purple moor-grass and rush pastures may be very small sites, for example a few square metres around a discrete spring, or may form part of larger tracts of semi-natural vegetation with other habitats including dwarf-shrub heath, bogs, flushes, tall-herb fens and dry grassland.

There is also evidence of a large grey area between unimproved (semi-natural) and improved grassland. Smart et al. (2009) cautions against attempting sharp demarcations between these grassland categories, as the reality on the ground is more complex, emphasising that it can be difficult to distinguish clearly between Neutral Grassland and Improved Grassland because the varying levels of agricultural improvement have resulted in a continuum of variation in species composition. The authors note that at one end of the continuum, Neutral Grassland includes both remaining areas of less productive but species-rich pastures and traditionally managed hay meadows (grazed in spring and autumn but closed up in summer to produce a hay crop). However, these hay meadow soils are typically deeper and inherently more productive than those beneath Acid or Calcareous Grassland, and consequently many species-rich meadows were reseeded and fertilised in the latter part of the 20th century, turning them into Improved Grasslands. These authors note that in Wales it is common to find semi-improved grassland that is not completely dominated by palatable grasses such as *Lolium perenne* (perennial rye-grass), but does not have the very high density and cover of forbs typical of unimproved neutral grassland and the scarce Lowland and Upland Hay Meadows Priority Habitats. (Smart et al., 2009). Similarly, the National Vegetation Classification (NVC) includes semi-improved neutral grasslands in the broad habitat type Neutral Grasslands, stating that "*neutral grassland differs from improved grasslands by having a less lush sward, a greater range and higher cover of herbs, and usually less than 25% cover of perennial rye-grass Lolium perenne"* (JNCC, accessed 07/05/2019). Thus, MG6 is an NVC type which at one extreme borders on SSSI quality, but at the other extreme borders on MG7, a grassland type with very little botanical interest (Jefferson et al., 2014).

This large grey area of "semi-improved" land may be of significant value, especially in terms of scope for relatively simple and important conservation gains (including connectivity) by improving or restoring habitat condition through applying interventions appropriate for semi-natural land (e.g. Hayes and Lowther, 2014; Crofts and Jefferson, 1999). These areas also provide habitat for a range of widespread but declining species, such as starling, yellow wagtail and lapwing. Some local case studies in Wales and England have found that attempts to tightly target interventions at “prime grassland sites” have had the result of leaving large areas of broadly similar but unrecognised grassland to the mercy of abandonment or intensification, thus missing the opportunities to conserve larger, more interconnected areas of habitat (Beaufoy and Jones, 2011).

Hay meadows

The Elan Valley, in mid-Powys, includes some of the most important and richest examples of unimproved mesotrophic grasslands in Wales. Most of them are highly species-rich upland-fringe meadows, designated as Sites of Special Scientific Interest (SSSIs) due to their national significance. The Elan Valley Meadow Project was set up in 2004 to provide site-specific and ecologically sustainable management advice to inform the conservation of the existing species-rich grasslands and their potential expansion. Key findings of this work are summarised in Box 1.

Box 1 Management of upland species-rich hay meadows in the Elan Valley

> The NRW report on this work concluded that:
> *“Results from long-term monitoring of soils in the trial showed clear evidence of progressive soil acidification at all meadow sites studied and at a level that is unlikely to sustain the present vegetation communities, and thus highlights the need to reinstate the traditional practice of periodic liming. It is recommended that to prevent any potentially negative impacts on the present species balance that the meadows are limed with the aim of achieving a soil pH of c.5.5. This finding raises concerns that other circum-neutral species-rich sites in the locality could also be at threat from increasing soil acidification and highlights the need for wider soil testing.*
> *Light intermittent applications of farmyard manure (FYM) were also shown to be an important traditional input for maintaining appropriate levels of fertility capable of sustaining the desired plant communities together with providing a more acceptable hay crop. For some meadows the most appropriate rate of FYM inputs was shown to be c.12t/ha every two years, although a lower rate of 12t/ha every three years would be more advisable for the long-established sites that have developed particularly high levels of species diversity. Rates of FYM applied at higher rates than the above were shown to be detrimental by excessively promoting the growth of some individual meadow components and resulting in undesirable cover levels of undesirable species.*
> *Inputs of FYM and lime resulted in acceptable increases in hay yields and as such should make the meadows more agriculturally attractive, both in terms of the likelihood of successfully reinstating hay-making operations and supplying high quality winter forage for livestock*”. (Hayes and Lowther, 2014)

A further objective of the Project related to the considerable opportunities in the Elan Valley for patch expansion, restoration and linkage of species-rich grasslands by diversification of adjoining semi-improved swards. See section 4.5.15 below for details.

4.3.5 Specific types of intervention

The overarching intervention category of ‘management of unimproved (including semi-improved) pastures and hay-meadows’ can be broken down into a set of more specific interventions (though still very broad, and which would require more or less tailoring to particular habitats and circumstances on the ground):

1. **Grazing within broad annual stocking density thresholds** (lower and upper thresholds encompassing the range of situations appropriate for semi-natural habitats).

Rationale – the reviewed evidence shows that all the habitats in question require some grazing activity for their maintenance; low-intensity grazing as a broad (minimum) intervention across the suite of habitats may be a sound insurance against the apparent increasing risk of under-grazing or abandonment, while ensuring the presence of livestock and thus providing the basis for more detailed interventions involving livestock management.

2. **More detailed grazing interventions applicable to specific semi-natural habitats or mosaics of habitats,** including variations in:
    - seasonal stocking thresholds
    - temporal and spatial grazing patterns within the holding, including temporary/seasonal exclusion in particular areas
    - grazing livestock species and breeds, and combinations of species

Rationale - the evidence shows that different habitat types benefit from different grazing regimes. Adjustments are also needed depending on local conditions, management history and specific conservation objectives for the location.

3. **Management interventions generally applicable on semi-natural habitats to complement and/or facilitate appropriate grazing:**
    - temporally and spatially appropriate cutting and clearance of vegetation such as scrub, bracken, rushes, etc.
    - Improvement of fencing, gates, water points to facilitate appropriate grazing management

Rationale – Under-grazing and abandonment are the main causes of unfavourable condition for lowland semi-natural grasslands. Scrub encroachment is the common result, sometimes together with bracken and/or invasive species problems. A general problem for the upkeep of semi-natural grassland is the lack of maintenance of the infrastructure associated with traditional grazing management, such as fencing, water supply, serviceable small-scale hay cutting equipment.

4. **Management interventions specific to certain habitat types**:
    - mowing and harvesting (hay meadows)
    - fertilisation/liming (hay meadows)
    - blocking of drains and grips (blanket bog, wet grasslands)
    - burning (heather moorland)

Rationale – certain semi-natural habitats require tailored management regimes involving specific interventions, in addition to grazing, cutting and animal management.

Sections 4.3.6 to 4.3.9 below provide a summary of evidence for some of the most significant variables.

4.3.6 Stocking

4.3.6.1 Stocking rates

Appropriate stocking rates for specific semi-natural habitats depend on a range of factors and local conditions, including: type and age of vegetation; habitat productivity; soil type; the degree of grazing by other wild herbivores; site management and the conservation objective. Countryside Council for Wales undertook a review of stocking levels appropriate for use on semi-natural lowland grasslands across a wide range of geographical locations, site conditions and management objectives (Kirkham et al., 2003). Data were gathered via a questionnaire and models were developed to examine variation in stocking levels within different habitats. Guidelines based upon the data received and the models developed are presented for different grassland habitats. A very wide range of stocking densities are found to be appropriate across the habitats considered. This highlights the difficulty of proposing generic grazing regimes for maintaining or improving habitat condition.

4.3.6.2 Livestock species and grazing patterns

Mixed livestock grazing (e.g. sheep or goats and cattle or horses) generally is said to generate greater heterogeneity in vegetation structure, which can increase food resources and/or shelter for birds and other wildlife. There is a tendency for conservation attention to focus on grassland plant communities, whereas other groups of species may have different requirements. For example, small patches of bare ground created by livestock can be important as habitats for insects and reptiles, especially on dry sandy soils (Lake et al., 2001, Lake and Underhill-Day, 2004). Grazed, short grass swards can offer good foraging opportunities for birds because prey is more visible/accessible and the presence of livestock (and their dung) attracts invertebrates (Smart et al., 2006), whereas grazing by cattle tends to produce tussocky swards, which often provide suitable cover for nests. Vickery et al. (2001) warn that high grazing intensity reduces the vegetation needed by invertebrates for food and cover, so although invertebrate food resources become more accessible to birds at higher grazing intensity, the abundance of the food declines. Furthermore, the loss of tall patches of vegetation and dwarf shrubs etc. reduces cover for nesting, and high stocking densities increase the proportion of eggs and young that are lost through trampling (Vickery et al., 2001). This evidence illustrates the often complex interactions between the benefits and dis-benefits of grazing for birds.

There is a perception that grazing by sheep alone may be detrimental to conservation values in some situations. However, the evidence is not clear in the case of lowland semi-natural grasslands. Stewart and Pullin (2006) undertook a systematic literature review of studies comparing the impact of sheep grazing with that of cattle or horses on MG5 pasture in Great Britain or Ireland. They found no recent literature that provided a direct comparison of sheep and cattle-grazed MG5 pasture just one article dating from the 1920s, reporting a study of old pastures in North Wales, and a more recent study of artificially restored MG5, both of which reported that plant diversity and forb cover were lower under sheep grazing. Stewart and Pullin (2006) also report that "*analyses of raw data from Welsh MG5 grassland demonstrate that stock type and vegetation height significantly impact on plant impact on plant community composition, species richness and forb abundance. Maximising forb abundance and species richness is achieved by maintaining sward heights at 0-10 cm for cattle and horses, although maximum forb abundance is found at sward heights >10cm for sheep, perhaps suggesting that MG5 grassland cannot support sheep grazing at the same intensity as cattle and horses if forb abundance is to be maintained*" They found no empirical evidence of the impact of different breeds within a stock type and concluded that "*the available evidence suggests that conservation managers considering grazing on MG5 sites should primarily be concerned with grazing intensity. Grazing at low intensities increases sward height and forb diversity but overall plant species richness is limited as bryophyte abundance declines*." (Stewart and Pullin, 2006).

In the case of moorland, Martin et al. (2013) found evidence from heather restoration studies that interventions that cause disturbance and create bare ground, such as cattle grazing in summer, can aid the establishment of heather. They point out that "*whilst it is impractical to implement this on a large scale, there may be a role for cattle grazing on moorland in providing localised disturbance, which could aid dwarf-shrub establishment if sheep grazing pressure is low or absent. Cattle have also been shown to graze less selectively than sheep, and may graze grass species such as Nardus stricta, usually avoided by sheep. In the medium term this might increase the proportion of preferred grasses in the sward and improve the quality of semi-natural grassland for light/moderate sheep and mixed grazing. Cattle grazing on heather moorland needs careful management, however, as it can have detrimental impacts on vegetation through trampling and dunging, including damage to woody stems of heather. Evidence indicates that cattle will tend to spend most of their time on more fertile vegetation and around water supplies, and are unlikely to range evenly over a grazing unit. This may serve to reduce grazing on areas that sheep would be more likely to graze, where cattle are the sole grazers, or it may mean that target vegetation is not grazed to the degree that is required. Cattle grazing patterns can encourage sward het*erogeneity, *with potential to influence the abundance and diversity of different taxa*". (Martin et al., 2013).

4.3.7 Fertilisation

Most plant species of semi-natural grasslands have evolved in low-nutrient conditions and are out-competed by the few species that are able to take advantage of the high nutrient levels. Consequently, even low levels of fertiliser rapidly reduce the plant species diversity of semi-natural habitats (Cop et al., 2009). For example, in UK grassland high forb diversity only occurs in grasslands receiving less than 15kg/ha and only three forb species were found on livestock farms where nitrogen inputs exceeded 75kg/ha (McCracken and Tallowin, 2004).

Typical agricultural applications of fertiliser (such as liquid slurry and artificial fertilisers) lead to significantly denser and taller swards and changes in species composition, leading to grass dominance and reduced plant species diversity (Kleijn et al., 2009). The process becomes increasingly irreversible as a result of the accumulation of nutrients in the soil and gradual die-off of the former semi-natural habitat's seed bank. This is illustrated by the situation in the UK, where only three forb species were found on livestock farms where nitrogen inputs exceeded 75kg/ha (McCracken and Tallowin, 2004).

However, in research at the Elan Valley hay meadow site in mid-Powys, light intermittent applications of FYM were shown to be an important traditional input for maintaining appropriate levels of fertility capable of sustaining the desired plant communities, together with providing a more acceptable hay crop (Hayes and Lowther, 2014). For details see Box 1.

4.3.8 Site-specific cutting and clearance of scrub and other invasive vegetation

For lowland semi-natural grassland generally across UK SACs and A/SSSIs, under-grazing and abandonment are reported by JNCC as the main causes of unfavourable condition. Scrub encroachment is the common result, sometimes together with bracken and/or invasive species problems. In the case of the Elan Valley meadows reported above (Hayes and Lowther, 2014), where high quality stands of grassland were being threatened by bracken and scrub encroachment, a programme of bracken and scrub control by annual cutting (flail-mowing) and hand pulling of bracken was shown to have a significant benefit on the extent and quality of species-rich grassland at specific sites, although this management will need to be continued to achieve lasting results. There is evidence from semi-natural grassland conservation projects that annual payments for grazing management need to be complemented by capital payments for interventions such as scrub removal, fencing, walling (see for example Beaufoy and Jones, 2011).

Development of scrub is indicative of a phase of vegetation change, and although an unwelcome intruder on hay meadows and other small semi-natural grasslands, patches of scrub can make a valuable contribution to nature conservation (Mortimer et al., 2000) and to the diversity of marginal upland habitats used by widespread bird species (Woodhouse et al., 2005). As with other interventions for semi-natural habitats considered in this review, mechanical management of scrub and other vegetation should be adapted to the specific conditions and to conservation objectives of the site in question. One person's "scrub" may be another's "early successional woodland establishment" (Good et al., 1990),

There is extensive published guidance on the management of scrub, for example by FACT/English Nature (Day, Symes and Robertson, 2003), but a striking lack of research evidence about the ecology of plant species associated with "scrub" that are rapidly increasing in abundance in large areas of Wales following reduction in stocking densities, e.g. *Prunus spinosa, Crataegus monogyna, Ulex x europaeus* and *Pteridium aquilinum*.

4.3.9 Burning (moorland)

Reviews of burning practices and effects (Shaw et al., 1996, Tucker, 2003) indicate that in appropriate areas and circumstances, carefully managed burning can play an important role in the maintenance of some open semi-natural upland habitats of high conservation importance. In their review Shaw et al. (1996) note that "*fires may also help to maintain low nutrient conditions, which may be particularly important under current circumstances where eutrophication of nutrient poor habitats, such as heathlands, is occurring as a result of atmospheric pollution. Burning of small patches can also increase vegetation structural diversity and species-richness in plants, invertebrates and birds of heathland habitats. Regular burning also reduces fuel loads and thus to some extent the risks of large uncontrolled and very damaging wildfires.*" On the other hand, frequent burning and large fires, such as normally occurs for agricultural management, can result in declines in species richness and the loss of soil organic matter and increased soil erosion. The burning of vegetation on peatlands is particularly damaging.

Harper et al. (2018) point out that few studies have focused on habitat composition or biodiversity as a whole and instead monitor the impacts of burning on one species or group of species. To truly justify the use of fire for the purposes of vegetation management more studies need to be conducted directly addressing the benefits/drawbacks of burning in comparison to other techniques (e.g. cutting, layering or grazing).

In the case of bird species, the creation of fresh palatable shoots of *Calluna vulgaris* for food and taller/older sections for nesting and shelter is highly beneficial to grouse (Glaves et al., 2013). Other species of bird, e.g. whinchat (*Saxicola rubetra*) and skylarks (*Alauda arvensis*), however, do not appear to benefit from prescribed burning as they are commonly associated with different sets of vegetation characteristics, which are not promoted by burn management (Pearce-Higgins and Grant, 2006). Tucker (2003) also suggests burning is detrimental for short-eared owls (*Asio flammeus*), hen harriers and merlin if patches of older heath are not retained for nesting purposes.

It is also proposed that species diversity and richness increase in habitats with a range of vegetation at different heights created by rotational burning practices (McFerran et al., 1995). Coulson (1988) suggested that under “good practice” burning regimes, terrestrial invertebrates are effective at recolonizing areas as most are highly mobile. Relatively little is known about the impacts on whole invertebrate assemblages in upland habitats (moorland/peatland) making this a key area for future research. There is also a notable lack of studies addressing the impacts on amphibians, reptiles or mammals within UK upland areas.

4.3.10 Causality

There is a large amount of published material on the appropriate management with domestic livestock of semi-natural habitats in Britain, reflecting many years of scientific work and practical experience. Examples include Crofts and Jefferson (1999) Lowland Grassland Management Handbook, first published by English Nature, and its equivalent volumes for upland habitats and wet grasslands.

The difficulty is in converting the huge number of different variations in practice and circumstance into a small number of more general interventions for suites of semi-natural habitat at a broad scale.

4.3.11 Co-benefits and trade-offs

4.3.11.1 Soil nutrient management

There is a co-benefit in that fertiliser application rates are lower in grasslands managed for biodiversity than in improved grasslands, which may reduce the burden on fresh waters from associated nutrient surplus.

4.3.11.2 Sward management

Trade-offs: on semi-improved grassland there will often be choice between managing this marginal land to improve the habitat or converting it to more intensively management improved grassland; although the aim of sward management is to diversify the species, the agricultural species used, increased nutrient availability and management and stocking to achieve improved production could degrade the existing habitat. The alternative approach, of managing for habitat restoration simply by applying stocking, reduced fertiliser regimes and other interventions appropriate for the semi-natural grassland habitat, could be more environmentally cost-effective, especially where the net increases in livestock productivity are small because of the inherent marginal quality of the land.

4.3.11.3 Flood mitigation

There is a co-benefit for headwater drainage management from restoration of peatland habitats in upper catchments, and possibly from floodplain restoration and wetland management if this leads to improved habitat management of wet semi-natural grassland habitats

4.3.12 Magnitude

Given the extent of semi-natural pastures, hay meadows moorland, heathland and blanket bog on farmland and common land in Wales there is potential for very significant benefit.

4.3.13 Timescale

Habitat improvement should be apparent in 0-5 years, but the full effects of intervention could take much longer, and will depend on the condition of the habitat at the outset.

4.3.14 Spatial issues

The interventions discussed are generally very broad-scale in nature, being applicable (with appropriate adaptations) to broad types and mosaics of semi-natural habitat covering a large total area of farmland, fridd and commons land in Wales.

Some local case studies in Wales and England have found that attempts to tightly target interventions at “prime grassland sites” has had the result of leaving large areas of broadly similar but unrecognised grassland to the mercy of abandonment or intensification, thus missing the opportunities to conserve larger, more interconnected areas of habitat (Beaufoy and Jones, 2011).

The maintenance and enhancement of existing semi-natural grassland is clearly constrained by the locations of the existing patches; the relative connectivity or isolation of these patches is likely to influence their resilience, for example via (re)colonization of indicator species. However, increasing connectivity, including by restoration, would inevitably involve loss or conversion of improved land or other semi-natural habitat.

4.3.15 Displacement

There could possibly be limited displacement of livestock production where semi-improved grassland habitats are suitable for restoration as habitats, but this could be balanced out by agricultural improvement of other semi-improved grasslands.

There is greater risk of displacement of biodiversity functions, resulting from the constraints on converting improved agricultural land to semi-natural habitat. Management to restore an abandoned semi-natural habitat to its previous state or to convert one semi-natural habitat into another will inevitably displace some biodiversity functions. For example, scrub clearance from a former semi-natural grassland to improve the grassland habitat is a trade-off with the intrinsic ecosystem service value of the scrub.

4.3.16 Longevity

Habitats dependent on livestock grazing, restricted fertiliser use and related management interventions will be at risk of scrub invasion or conversion to improved land if appropriate management is not maintained in the long-term.

4.3.17 Climate interactions

There are benefits for C sequestration and storage of maintaining permanent grassland cover and rewetting blanket bogs.

4.3.18 Social and economic barriers

Many of these habitats are an integral part of HNV farming systems, which lack economic resilience because the biodiversity benefits and other environmental outcomes they provide are not reflected in their market returns.

4.3.19 Metrics and verification

Verification for payment under current agri-environment scheme is based on a combination of administrative checks and field inspections, to ascertain that the land manager has complied with the contractual requirements for land and livestock management. If result-based payments were to be introduced (there are none at in Wales at present) the verification for payment involves measuring indicators of the results, on the ground.

4.4 Management of existing farm woodland habitats

4.4.1 Woodland habitat - extent and condition

Wales is among the least wooded countries in Europe, 14.8% of the land area in woodland compared to an EU average of 38%, but within the UK is second only to Scotland[10]. The total area of woodland in Wales has changed little in the past 20 years, and rates of new woodland creation are low and the new woodlands of small average size and highly dependent on public funding.

There are implications for the role of the SFS in supporting woodland habitat management in the very significant differences between the Welsh Government Woodland Estate (WGWE) and the private sector in the proportions of the coniferous and broadleaved woodland they are responsible for. The private woodland sector has a very large proportion of the area of broadleaved trees (88.3%) in Wales, but little more than a third (36.4%) of the area of conifers. It is unclear what proportion of conifer woodlands are on farms, or what are the predominant species, but in Wales the most common non-native conifer species in Wales is Sitka spruce, which occupies 28.9% of woodland area[11].

Of the total of 306,000ha of woodland in Wales 94,940ha comprises ancient woodland (NRW, 2016). Estimates from the National Forest Inventory[12] suggest that around 40% of Wales' woodlands have little or no management. About a quarter of all woodland in Wales is on farms, approximately 78,000ha[13].

The overall conservation status of designated woodland habitats in Wales is regarded as unfavourable, although there is local recovery in response to targeted management. In the 17 years between the 1990 and 2007 Countryside Surveys in Wales, there was a significant reduction in species richness in the category of Broadleaved, Mixed and Yew Woodland in Wales, consistent with a general trend seen elsewhere in Britain for a reduction in abundance of species associated with

[10] Wales 14.8%, England 10.0%, Scotland 18.5%, NI 8.2%, UK average 13.1%(FC Forestry Statistics, 2018).
[11] Figure derived from FC Forestry Statistics, 2018.
[12] https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/about-the-nfi/
[13] Welsh Government (2016), based on estimates from the Welsh Agricultural Survey, June 2015.

canopy gaps, disturbance and an increase in more nutrient-demanding taller plants (Smart et al., 2009). The woodland bird index (2011 data) has improved since 1994, in contrast to the decline in farmland birds in Wales (Welsh Government, 2016).

Wales has suffered badly from the recent spread of *P. ramorum* disease which has affected around 9,000ha of larch and forced the clearance of very large areas. *Chalara* dieback of ash continues to spread and its damaging effects are likely to increase in the coming years[14]. The pressures from pests and diseases will increase in the future. There are also risks associated with water scarcity and flooding; from pests, pathogens and invasive species; and from change in frequency and/or magnitude of extreme weather and wildfire events.

The UK Biodiversity Action Plan sets targets for priority species and habitats to guide conservation action. Climate change is now recognised as a significant factor that was not taken into account when the original UK targets were set. The targets were reviewed in 2005-6 and are designed to improve the long-term viability of habitats and species populations. The following targets have been set that relate to woodland:

- maintain the extent of native woodland in the UK (no net loss of one million hectares);
- maintain the current extent and distribution of ancient semi-natural woodland, which qualifies as native woodland in the UK (no change in the existing area of 403,000ha).;
- restore 50,300ha of non-native plantations on ancient woodland sites to native woodland in the UK by 2015;
- expand the current native woodland resource in the UK by 134,500ha by 2015 through a combination of converting (restocking) existing plantations not on ancient woodland sites and creating native woodland on former agricultural land;
- expand semi-natural open-ground habitats (which will include restoration where planted with non-native conifers), e.g. lowland heathland by 7,600ha by 2015.

4.4.2 Influences on woodland condition

Estimates from NFI suggest that around 40% of Wales' woodlands have little or no management, and Natural Resources Wales (2016) identified the following pressures affecting native woodland condition in Wales:

- fragmentation, with nearly 22,000 woodlands identified as being smaller than 2ha in size;
- browsing and grazing pressures from domesticated and wild animals, especially wild deer; and
- INNS, including grey squirrel and *Rhododendron ponticum*.

Tree diseases and pests have already had a significant impact on both native woodland and plantations in Wales, including the recent spread of *Chalara* dieback of ash and *P. ramorum* disease of larch, while woodland owners are learning to cope

[14] NRW https://naturalresources.wales/guidance-and-advice/business-sectors/forestry/tree-health-and-biosecurity-1/tree-health-in-wales/?lang=en accessed 26 May 2019

with established pests such as the Great spruce bark beetle and the Green spruce aphid.

4.4.3 Evidence of benefits of intervention

An important caveat about the evidence presented here is that most of the literature refers to forest management for biodiversity, rather than specifically to farm woodland - there are obvious differences between the two, particularly in scale and purpose of management.

Furthermore much of the literature refers to forests of continental Europe, not necessarily to the UK where plantations are more prevalent and forest management systems are different.

4.4.3.1 Biodiversity management of native woodlands

The biodiversity value of forests is influenced by a combination of structural, taxonomic, and functional characteristics.

Based on a review of the literature on temperate forests with high values for biological conservation, Gotmark, et al. (2013) suggests four habitat management alternatives, which might be applicable to the remaining areas of ancient woodland in Wales:

- minimal intervention, the most common form of management, usually allows continued succession and disturbances in the forests
- traditional management, based on historical reference, is used to create other forest structures that favour biodiversity (e.g. red-listed taxa) linked to earlier cultural landscapes
- non-traditional management to produce old-growth characteristics or specific forest composition, or to favour one or a few tree species which may or may not have been abundant in the past
- species management, for threatened, indicator and other species, and rewilding.

Depending on forest size and objectives, the authors point out that combinations of these management types may be used and there is often not only one correct habitat option for conservation forests. Many more studies of the management alternatives are needed, particularly long-term experiments. In addition, management plans, decisions, and actions in practical management of conservation forests need to be studied, to clarify choices and present conditions.

Lindenmayer, et al. (2006) proposes five guiding principles for biodiversity conservation that are broadly applicable to any forested area:

- maintenance of connectivity
- maintenance of landscape heterogeneity
- maintenance of stand structural complexity
- maintenance of aquatic ecosystem integrity
- use of natural disturbance regimes to guide human disturbance regimes.

4.4.3.2 Woodland management for biodiversity and ecological resilience

In addition to the management principles outlined above, there is a strong body of scientific evidence showing the importance of **deadwood** and a range of related factors for many species. Several authors provide evidence that in most managed forests the volume and diversity of deadwood is currently too low to maintain species richness (Müller et al., 2015, Paillet et al., 2010, Cuttelod et al., 2011, Lonsdale et al., 2008). The UK has the second lowest rate of standing and lying deadwood in the EU at 3.9 m3/ha), in contrast to other Member States where the values mostly range between 5 and 15 m^3/ha, (Forest Europe, 2015). Another major issue addressed in the literature is the difference between clear cutting and more selective tree harvesting that leaves some live trees standing ("low impact silvicultural systems" or "continuous cover forestry" systems). **Clear cutting of stands of trees** has negative effects on specialist fungi, liverworts, bryophytes and invertebrates associated with live trees and woody debris (Dynesius and Hylander, 2007, Dynesius, 2015).

Seidl et al. (2011) noted that forest habitat types are well adapted to and defined by their natural disturbance regimes, which are key drivers of forest ecosystem dynamics. On the other hand, climate change is expected to increase the frequency of disturbance, and the likely impact on forest ecosystems is not clear (Kulakowski et al., 2017). A review of biodiversity indicators in plantation forests by Coote et al. (2013) confirmed that proximity to old woodland and stand age were positive indicators for vascular plants associated with forests, because nearby woodlands acted as important seed sources and colonisation increased over time. Using native tree species (rather than exotics) generally enhances biodiversity in plantations (Carnus et al., 2006, Wagner and Stephens, 2007, Brockerhoff et al., 2008).

This suggests that the interventions identified above for improving the biodiversity value of native woodland could broadly be of benefit to conifer woodland too.

4.4.3.3 Impacts of management on common woodland birds

In their review of the evidence for causes of decline of the species in the woodland birds indicator for England, Eglington and Noble (2010) identified the key drivers of decline to be maturation of woodland and cessation of active management, which had so altered woodland structure that they contributed to the decline of 13 species associated with early successional habitat, open areas within woodlands or areas with low dense vegetation (Blackbird, Bullfinch, Dunnock, Garden Warbler, Marsh Tit, Nightingale, Song Thrush, Lesser Redpoll, Tree Pipit, Spotted Flycatcher, Willow Tit, Wood Warbler and Willow Warbler). Factors contributing to the decline of other woodland birds included fragmentation and reduced connectivity of woodlands, predation, habitat changes induced by increased deer populations and continuing drying out of wet woodlands. A survey of experts in the Member States that have made significant use of the RDP afforestation measure up to 2013 reported un-quantified benefits for forest birds from the creation of new native woodlands (reported by expert members from in Ireland and the UK (Elbersen et al., 2014)).

Literature on plantation forests indicates that these have a much lower bird carrying capacity relative to native woodlands due to the lack of understorey vegetation and low structural diversity, with the majority of species present in lower densities. A small number of bird species dominate plantation forests, with coal tit (*Parus ate*r) and goldcrest (*Regulus regulus*) accounting for over 60% of total bird density (Sweeney et al., 2010). Note, however, that this result relates to coniferous plantations relative to broadleaved native woodland.

In Wales, woodland and scrub management options within Tir Gofal had only positive effects on long-term bird population growth rates, indicating strongly positive impacts at the community level (Dadam & Siriwardena, 2019).

4.4.3.4 Impacts of management on invertebrates

Empirical evidence is largely restricted to a few taxa of invertebrates, and the effects of woodland management on species associated with old-growth woodland, such as beetle species that benefit from dead wood habitats, is lacking. There is also a lack of evidence of the impact of fertilisers and pesticides on forest species (Berthinussen et al., 2013, Kreutzweiser et al., 2008). A review of biodiversity indicators in plantation forests confirmed stand age as a positive indicator for forest-associated spiders related to the development of suitable habitat as the plantation matures (Coote et al., 2013).

European woodland butterflies generally need open sunny habitats within forests and woodland, such as sparse tree cover, streams and wet areas, clearings, rides or edges (Settele et al., 2009). Where open areas are lost, as a result of lack of management woodland, this is was found to contribute to the decline of some European protected woodland butterflies (van Swaay et al., 2010, Van Swaay et al., 2006).

4.4.3.5 Impacts of management on lichens and bryophytes

Alliance Environment (2017) reviewed a number of studies of bryophytes, lichens and fungi of conservation concern in afforested plantations in the UK. While this does not provide evidence of the effect of woodland management *per se*, it does provide an indication of how changes in woodland tree species composition, rotation length, or retention of unharvested dead wood, might affect lichen and bryophyte biodiversity. They found two studies that showed, in two different regions of the UK, no significant difference in species richness of lichens and bryophytes on dead wood in non-native tree species plantations compared with native tree species stands (citing Humphrey et al., 2002; Quine and Humphrey, 2010). In Scotland, non-native Sitka spruce plantations had higher bryophyte species richness on deadwood but much lower lichen species richness than native Scots pine stands. In England, non-native Norway spruce stands had much lower lichen species richness and slightly lower bryophyte species richness than native oak (*Quercus robur*) stands (but the spruce plantations were younger than the oak stands and planted on previously forested land or close to existing woodland). Other studies have shown that mature and old non-native Sitka spruce plantations in the UK have rare fungal species presence comparable to native woodlands (Humphrey et al., 2000).

4.4.4 Causality

In the absence of a separate body of evidence specifically on farm woodlands most of the evidence presented here refers to evidence of the biodiversity impacts of woodland or forest management rather than specifically to farm woodland. Although there are obvious differences between the two, particularly in scale and purpose of management as well as in the size and landscape context of specific woodland blocks, the principles of habitat management for biodiversity are similar for both.

4.4.5 Co-benefits and trade-offs

Soil nutrient management

Possible co-benefit if improved nutrient management on adjacent improved agricultural land reduces the impact of nutrient fluxes on woodland habitats

4.4.5.1 Business resilience

Possible co-benefits in the longer term (income from timber and possible private recreation/access opportunities) if unmanaged woodland or coniferous plantations are brought into active management for biodiversity. Trade-offs between short-term management of coniferous woodland for biomass and long-term management for biodiversity.

4.4.5.2 Soil carbon management

See Technical Annex 3: Soil Carbon Management.

4.4.5.3 Air quality and well-being

See Technical Annex 8: Improving air quality and well-being

Flood mitigation

See Technical Annex 9: Flood mitigation for co-benefits of farm floodplain, riparian and catchment woodland; it is important to note that the benefits of woodland in flooding and riparian processes are highly dependent on the placement of the woodland.

4.4.6 Magnitude

In the absence of better data, simply applying the NFI's finding that 40% of woodland in Wales has little or no management to the estimated 78,000ha of farm woodland in Wales suggests that there could be more than 30,000ha of existing farm woodland where implementing the principles of biodiversity management outlined would lead to long-term improvements in habitat function and resilience to climate change and other threats.

4.4.7 Timescale

Although some biodiversity benefits would be apparent in years 0-5, for example from providing areas of open habitat within the woodland, the benefits of long-term changes the species composition, stand structure and the use of low-impact or continuous cover systems will necessarily take many years to be realised.

4.4.8 Spatial issues

There would be a need for targeting existing farm woodlands that are not managed, at farm and landscape scale, and also targeting and collaborative work required for some biodiversity objectives and taxa.

4.4.9 Displacement

No displacement because only existing woodlands are considered.

4.4.10 Longevity

Significant investment in improved woodland management lends itself to permanence, once the initial decision has been taken, but the long-term benefits depend on continuity of the habitat management system by successive land managers over many decades. Also the felling licence system precludes most farm woodland removal, although it does not prevent neglect.

4.4.11 Climate interactions

Woodland management contributes to C sequestration (in biomass, soils and harvested forest products), and to the adaptation of the woodland itself to a changing climate, and possibly also to adaptation of farmland or urban areas nearby, through micro-climate effects on surrounding land. Increased risk of pests and diseases can be expected (especially in the absence of effective quarantine control of imported infected material). Possibly also a drier climate, especially in east Wales, with associated increase in fire risk.

4.4.12 Social and economic barriers

Major barriers to implementation are farmers' lack of knowledge, technical skills and time to manage woodland, and possibly unwillingness to invest capital in non-agricultural land management. Local project officers have a very important role in supporting conservation interventions, but loss of capacity in Natural Resources Wales to provide advice to individual land owners is a concern. Coed Cymru is partly filling this gap now, but in the long-term the availability of woodland conservation expertise and experience, and the capacity to deliver it to many more landowners is likely to be a key factor in securing environmentally sustainable farm woodland in Wales.

4.4.13 Metrics and verification

As for current woodland grant programmes. Note that eight headline indices for woodland creation and management were developed and reported for the whole of Wales under GMEP. Some of these are also suitable for monitoring regional woodland areas or individual woodlands, either making use of existing data sets or via the collection of new information.

4.5 Management of other trees and shrubs within farmland (agroforestry)

The practice of agroforestry has long been well-integrated into many Welsh farming systems but the term itself is not widely used or recognised by farmers, In Wales the dominant agroforestry systems are silvopastoral systems (including shelterbelts) and boundary planting (hedgerow systems and, to a lesser extent, riparian buffer strips)

The AGFORWARD[15] project categorised European agroforestry into five 'systems': silvoarable, silvopastoral, high nature and cultural value systems, high timber value systems and a catch all of 'trees on farm' which included hedgerows (recognised as a key agroforestry component in European land use policy). (Kay, et al., 2019).

4.5.1 Extent and condition of agroforestry

Estimates of the extent of agroforestry vary considerably but a recent attempt to map agroforestry across Europe (den Herder et al., 2017) suggested there could be more than 1.5 million hectares of existing agroforestry systems in the UK, mainly wood pasture, parkland, orchards and hedgerows, but this study did not provide separate estimates for Wales. Forest Research's 2017 inventory of tree cover outside woodland in Great Britain shows Wales as having an additional 92,700ha of tree cover outside woodland - which brings the total tree cover up from 14.9% up to 19.4%. It can be assumed, once the urban component is removed, what remains would be largely agroforestry (excluding farm woodlands). There is relatively good data on the area of extent of riparian area (based on LiDAR data) but no figures are currently publicly available on the extent of shelter systems for example. Given that mapping the extent of agroforestry in Wales is challenging, it is fair to say that defining and assessing the condition of Welsh agroforestry systems is even more difficult.

4.5.2 Impact of farming practices on agroforestry

4.5.2.1 Hedgerows

[15] http://www.agforward.eu/index.php/en/ accessed 27/05/2019.

A reduction in the availability of farm labour and of contractors with the necessary skills has led to a decline in traditional management such as hedge laying, typically done on a in rotation small proportion of hedges each year to maintaining the structural integrity of the hedge and to promote new shrub and tree growth. The absence of an incentive to protect trees regenerating naturally in hedgerows means there is already an age gap in the young trees growing on to become the next generation of hedgerow trees. This has become a more immediate concern because ash trees, which are the most common hedgerow tree species in many areas, are being lost as *Chalara* ash dieback continues to spread.

4.5.2.2 Scattered trees in fields and open pastures

Over recent years the CAP rules on eligibility of farmland with trees for area-based direct payments, including the Basic Payment Scheme in Wales have been redefined in a complex way that discourages farmers from increasing the number of trees on their land. A parcel of arable or pastureland with scattered trees is completely ineligible for BPS if there are more than 100 trees/ha. Where there are fewer than 100 scattered trees/ha only the area occupied by the tree stems is ineligible (because it cannot be used for agriculture), unless some of the trees are less than 10m apart, or are in a group of more than 3 trees, in which case the total area of the tree canopy is ineligible, regardless of the agricultural benefits of the tress in providing shade, shelter, grazing or browsing for livestock[16]. These rule changes have far more to do with a drive to verify and control payments by remote sensing than with the reality of Welsh livestock farming, or the biodiversity, climate adaptation and other benefits of trees on farms. It is hardly surprising if farmers are discouraged from planting new trees in fields or allowing existing trees to develop to their full size, by possibility of reduced farm payments or even financial penalties, if they fail to adjust the area calculation as the trees grow. However, this does not explain the lack of new hedgerow trees (which, for BPS payment purposes are considered to be ‘landscape features’ to be retained, and do not affect the eligibility of the adjoining land).

The SFS offers an opportunity to design a payment system which provides farmers with an incentive to maintain and plant trees outside woodland, instead of penalising them, as the current system does.

4.5.2.3 New agroforestry systems

Although wood pastures and parkland are traditional agroforestry systems in Wales, and also, more recently, shelterbelts, these have generally been associated with livestock rearing, often on marginal land. There has been hardly any further development of these (despite the long-term field experiments at Bangor University), or of agroforestry systems within improved grassland or arable systems, as has happened elsewhere in climatic and farming contexts similar to those in Wales. For example, in England and France winter cereal production has been combined with tree or fruit crops in silvoarable ‘alley cropping’ systems. Within the AGFORWARD project, leaflets have been produced on 46 agroforestry innovations, including invisible fencing in wood pasture, multi-functional hedgerow, orchards with grazing or free-range poultry, and fodder trees for micro-nutrient supply in grass-based dairy systems (Balaguer et al., 2017). A report from the EIP-AGRI Focus group on agroforestry examines the opportunities and challenges of integrating woody vegetation into specialised farming systems (EIP-AGRI, 2017).

[16] For details, see Welsh Government (2019)

4.5.3 Evidence of biodiversity benefits of agroforestry

There is a great deal of global evidence on the benefits of agroforestry as an important intervention to address biodiversity loss, and it is mentioned in a number of high-profile documents, including the recent assessment of biodiversity and ecosystem services in Europe (IPBES 2018). At a European level there have been a number of papers looking at the broader ecosystem services benefits from agroforestry (which includes buffering of habitats, and other biodiversity benefits, but this research is still in an early phase (Fagerholm et al., 2016).

A meta-analysis of publications on European agroforestry systems found that pastoral agroforestry has a significant positive effect on biodiversity compared to specialised agricultural and forestry systems, mainly due to the effect on birds (Torralba et al., 2016). The review found no significant effects on biodiversity of arable agroforestry, although it is likely to increase landscape diversity, and thus provide a greater variety of plant micro-habitats than is the case for arable land (Palma et al., 2007).

4.5.3.1 Hedgerows

Hedgerows and field margin vegetation affect the richness and abundance of flora, invertebrates and birds (Boatman (ed) 1994, De Snoo, 1999 and Hinsley and Bellamy, 2000), and there is good evidence that the structure and form of a hedgerow and its management, in terms of differences in width, height, fenced buffer strips, frequency of cutting etc, has a big effect on biodiversity (Haddaway et al., 2018). Heterogeneity in hedgerow structural condition is important because no single set of hedgerow characteristics were found to benefit all taxa and, if uniform hedgerow management is overprescribed, some species are likely to be adversely affected by a loss of suitable habitat or resource decline (Graham et al., 2018). A report for Defra, focused on hedgerow priority species (former BAP species) and those listed as Biodiversity 2020 Farmland Indicators, presents evidence of the importance of the inter-relationship of the five structural components of hedges (trees, shrubs, hedge base, field margins and ditches). Overall, of the 107 species studied, the majority (65%) are dependent on more than one hedge component, and over a third of them (35%) are dependent on three or more components (Wolton et al., 2013).

Hedgerow management under agri-environment schemes is associated with greater use by hedgerow bird species (Davey et al., 2010, Redhead et al., 2013) but there is only limited evidence for benefits to species' population growth rates at a national scale (Baker et al., 2012) probably because this management benefits breeding productivity, but most species are limited by over-winter survival. It is inherently hard to collect empirical evidence (and thus parameterise models) of causality about use of hedgerows by species as corridors (Davies and Pullin 2007).

Hedgerow creation or restoration is a long-term process, with habitats likely to take decades to mature to provide their full biodiversity value. Hence, existing evidence on the value of hedgerows from agri-environment interventions from the 1990s onwards deals with spatial comparisons of different habitat types or management activities.

Landscape-scale studies of changes in hedgerows due to management have been difficult because of a lack of detailed, large-scale data on hedgerow locations and structure, a limitation that is now easing with the growing availability of remote-sensed data such as LiDAR.

4.5.4 Co-benefits and trade-offs

4.5.4.1 Soil nutrient management

Silvoarable systems require fewer nitrogen inputs, both because the area of crop is reduced and because the greater litter input and more extensive root systems of the trees fix nitrogen in the soil.

4.5.4.2 Soil carbon management

Some evidence of (small) hedgerow co-benefits for soil C stocks (Ford et al., 2019) and also for net GHG emissions.

4.5.4.3 Business resilience

Co-benefits of diversified income from trees, including high value tree and fruit crops in agroforestry systems.

4.5.4.4 Biosecurity

Co-benefit of (wide) hedgerows for improving biosecurity against some livestock diseases by reducing transmission between stock in adjacent fields, but wide hedgerows can also provide habitat for alleged secondary vectors (badgers).

4.5.4.5 Air quality and well-being

Co-benefits: there is evidence that hedges can be especially effective for interception of aerial pollutants, especially in urban/peri-urban environments and along roadsides (Morakinyo et al., 2016; Abhijith et al., 2017; Abhijith et al., 2019)

4.5.4.6 Flood mitigation

Co-benefits: evidence of the importance of the location/position of woody features on hillslope (and also the soil depth) for hydrological effects. Evidence of big difference between woody plant species in effect on soil hydrology, water infiltration etc., (Webb, B. et al., in prep).

4.5.5 Magnitude

Urgent action is needed to replace the farmland and hedgerow ash trees being lost from due to *Chalara* ash die-back.

Potentially significant impact if action is taken to improve biodiversity management of existing hedgerows and trees on farmland, and to create more diverse types, species and structures agroforestry systems in a way that secures long-term multiple benefits for habitat function, climate adaptation and C sequestration and storage.

4.5.6 Timescale

Biodiversity and other benefits would begin to appear in years 0-5, for example from replacing ash trees, natural regeneration of hedgerow trees and development of agroforestry systems, and continue to develop over many years as the trees mature.

4.5.7 Spatial issues

Many agroforestry systems are linear and there is potential for agroforestry systems to deliver biodiversity benefits (and other Sustainable Land Management outcomes) at scale if proper landscape design and planning occurs to maximise range of environmental benefits.

There is huge regional variation within Wales in density and form of hedgerows, presence, age and condition of infield and hedgerow trees, and of wood pasture and parkland systems.

4.5.8 Displacement

Some displacement of arable crops if large-scale agroforestry is introduced on improved land.

4.5.9 Longevity

Agroforestry interventions can be permanent, if farmers perceive the benefits of trees, hedges and shelter belts and continue to manage these features for the long-term, replacing trees lost to disease, livestock damage or harvested.

4.5.10 Climate interactions

There is emerging evidence on the potential climate mitigation and adaptation benefits of agroforestry systems. It certainly has significant role in the decarbonisation of the UK economy, with sequestration benefits dependent upon the type of system and the soil. Kay et al. (2019) show that strategic and spatially targeted establishment of agroforestry systems could provide an effective means of meeting objectives on GHG emissions whilst providing a range of other important benefits.

4.5.11 Social and economic barriers

Better management of existing systems and expansion of agroforestry in Wales could bring benefits for farm economic resilience and delivery of environmental outcomes, as noted in Section 4.5.4 above, but achieving this will depend on a significant shift in attitudes, effort and resources. Farmers are not generally aware of the positive benefits of trees on farms, and culturally there is a perception amongst some farmers that trees get in the way of farming. There are also concerns about the extent of competition with pasture/crop species. In the recent past ‘agroforestry’ was not a good term to use with farmers, although it is now becoming more commonplace. This shift in perception of farmland trees would be helped significantly by designing the SFS in a way that allows agricultural land with trees to benefit fully from area-based payments.

Farmers are often unfamiliar with tree management, and Farming Connect could play a major role in providing farmers and their advisers with the necessary skills and technical knowledge.

Agroforestry can have significant costs at establishment, particularly in pastoral systems due to the need for protective fencing. Investment and management support under the SFS could enable farmers restore existing agroforestry systems (e.g. hedgerow trees, shelter systems) and to develop new combinations of tree crops with existing arable and pasture systems, which may involve restructuring the farm business model. Targeted public support would ensure that these are designed (in terms of choice of species and systems) and located in the farmed landscape to maximise the long-term delivery of environmental outcomes and climate adaptation benefits for the sector.

4.5.12 Metrics and verification

For verification and control purposes hedgerows, trees and agroforestry systems are easily identifiable remotely, but measurement in the field is currently needed to determine different types and condition of hedgerow, including metrics relating to habitat function and connectivity. Such metrics have been developed and explored during the GMEP programme utilising the GMEP baseline field survey data that included a repeat of the earliest cohort of Countryside Survey squares in Wales.

Analyses of change that include these recent data have yet to be carried out. Results of the 2007 Countryside Survey in Wales showed a national decline in species richness in broadleaved woodlands but no change in species richness in hedgerows (Smart et al., 2009)

4.5.13 Farmland landscapes

This category differs from the others in this review in that its focus is not on specific types of habitat but on the diversity, condition and functional relationship (for biodiversity) of the range of habitats and features within a spatial unit at different scales – from parcel to farm to wider landscape.

In the current brief review we focus on issues of landscape complexity, semi-natural elements and biodiversity, extending habitat patch size, and connectivity.

4.5.14 Landscape complexity, semi-natural elements and biodiversity

Outside protected areas many landscapes still retain characteristics that make them inherently richer in opportunities for wildlife than others and, as Klein et al. (2011) have stated, "*conserving what is left is more effective than getting back what was lost*". The same authors have shown that biodiversity conservation is more likely to be effective on farmland that already is managed at low intensity and that retains a certain amount of semi-natural vegetation.

The biodiversity value of semi-natural elements combined with a diversity of land cover types is confirmed in many studies in different parts of Europe (see, for example, Billeter et al., 2008).

Tscharntke et al. (2005) refer to landscapes with less than 2% semi-natural habitats as "cleared" landscapes, where the effectiveness of conservation is limited by the basic absence of species sources. Landscapes with 2-20% semi-natural habitat in the matrix are referred to as "structurally simple" landscapes, where species sources are still present and conservation initiatives can achieve good results. In "complex" landscapes with more than 20% semi-natural habitats, the productive area is continually colonised by species from the surrounding species-rich landscape. Some ecologists regard a 20% proportion of semi-natural vegetation as a minimum threshold for maintaining biodiversity on farmland (Le Roux et al., 2008).

Landscapes characterised by complex habitat structures, high habitat diversity, woodland connectivity and hedgerows have been mapped in Wales as Type 2 High Nature Value farmland (for draft results see https://gmep.wales/biodiversity).

Future reviews aiming to increase the resilience of habitat networks in Wales should address creation or restoration of habitat on both semi-improved and improved land. Restoration and creation are essential components of landscape-scale management of semi-natural habitats.

4.5.15 Extending habitat patch size through management and restoration

The Elan Valley Meadow Project tested opportunities for patch expansion, restoration and linkage of species-rich grasslands by diversification of adjoining semi-improved swards. Hayes and Lowther (2014) report that "*a number of previously identified sites with low nutrient status and appropriate sward structure were entered into a period of restoration management and monitored to characterize the nature, rate and success* *of meadow reversion primarily by natural re-colonisation. Monitoring of the restoration sites showed highly promising indications of developing species richness purely through natural re-colonisation by indigenous meadow species. The presence of remnant populations of meadow species both within and adjacent to selected sites, together with the prevalence of highly amiable edaphic and climate condition shows that these sites are very well able to relatively rapidly respond to suitable restoration management. For example, some sites are already showing levels of species richness starting to approach that of adjacent SSSI meadows (albeit without the presence of some rarer meadow species) within just 10 years of appropriate management, a situation that would be expected to take many decades in areas with more nutrient-rich, species-impoverished conditions*".

As well as these newly restored sites acting as useful habitats in their own right, as ecological 'stepping stones' for migrating and colonising species, they can also serve a very important role as buffer-zones to help protect the existing mostly small and fragmented highly species-rich fields. Note, however, that the provision of these functions is dependent upon location with respect to existing habitat areas, so planning interventions at the landscape scale is essential.

In this context, the large grey area of "semi-improved" grassland may be of significant value (for example, as habitat for a range of widespread but declining species, such as starling, yellow wagtail and lapwing), and especially in terms of scope for relatively simple and important conservation gains (including connectivity) as a result of applying interventions appropriate for semi-natural land (e.g. Hayes and Lowther, 2014; Crofts and Jefferson, 1999), without the need for intensive habitat restoration work. Some local case studies in Wales and England have found that attempts to tightly target interventions at "prime grassland sites" have had the result of leaving large areas of broadly similar but unrecognised grassland to the mercy of abandonment or intensification, thus missing the opportunities to conserve larger, more interconnected areas of habitat (Beaufoy and Jones, 2011).

4.5.16 Connectivity

Latham et al. (2013) provide an overview of the work of the Countryside Council for Wales (CCW) on habitat network mapping and its application to understanding ecological connectivity. This report reminds us that "*many of the major issues affecting ecosystem functioning and biodiversity conservation result from the loss and fragmentation of natural habitats. Nature conservation legislation and greater public awareness have reduced the rates of decline, but losses still continue, especially the loss of smaller patches of habitat that slip below levels required for protection*." These authors emphasise that "*connectivity is a broad term, and refers to the characteristics of the landscape that affect the movement of organisms and of natural processes*". Connectivity is a term commonly used in the context of species movement, but it has much wider relevance to ecosystem functioning as a whole and ecosystem resilience. In very simple terms, connectivity can be thought of as the opposite of fragmentation, and therefore connectivity will benefit from interventions that reverse or mitigate fragmentation (Latham et al., 2013). They note the importance of good management of habitat patches as the first step, because this can increase the size and fitness of populations, making species both more able to move and more likely to do so. Latham et al. (2013) they list actions to improve connectivity, shown in Box 2 below. These have a common theme in that they require thinking beyond individual sites, and consideration of the wider landscape and how its components interact.

***Box 2** Improving landscape connectivity*

Actions to improve connectivity, listed in Latham et al. (2013:

- improving site condition through good management to improve within-patch connectivity and fitness of populations
- increasing habitat patch size
- developing buffers around patches
- expanding habitat to join patches
- developing stepping stones between patches
- developing corridors
- improving the condition of land between habitat patches to increase permeability
- improving the extent and condition of landscape features such as hedgerows, field-margins and water courses
- developing networks of habitats
- encouraging large continuous areas of habitat at a landscape-scale.

A review by Lindenmayer et al. (2008) found that most ecologists agree about the importance of connectivity, but disagree with the simplistic assumption that connectivity is achieved just by creating corridors or linear strips of a particular vegetation type to link patches of that vegetation type. These authors explain that the *"supply of corridors is just one of several approaches to providing connectivity for some species and ecological processes. The simplicity of the corridor concept and the relative ease with which corridors can be implemented in planning exercises can lead to a failure to consider the connectivity function of the surrounding areas. This emphasizes that the topic of connectivity cannot be readily divorced from others such as the amount of a particular land cover type in a landscape and the value of that cover as habitat for particular species*." (Lindenmayer et al., 2008).

For example, there is a common misconception that hedgerows are effective corridors between fragments of woodland habitat, yet there is a lack of clear evidence of the positive benefits of hedgerows in increasing landscape connectivity for woodland-dependent taxa (Davies et al., 2006, 2007) although there is good evidence of benefits of hedgerows for a different set of species (broadly described as 'edge specialists'). At the landscape scale, there is good evidence for the importance of hedgerows to vertebrates, as navigational aids and for commuting between breeding and foraging sites. There is, however, comparatively little evidence that connected hedges are important corridors for animal dispersal. This is particularly true for invertebrates, although they probably do have a facilitating role to play in this respect (Wolton et al., 2013). Direct tests of the effects of hedgerow habitat creation at a landscape scale have yet to be conducted.

Evidence from experimental and analytical studies of English farm landscapes shows that bird species vary in the spatial scale at which they show most sensitivity to landscape structure, but that many are most influenced by spatial extents that are much larger than that of most individual land-holdings (Pickett and Siriwardena 2011), and that home ranges similarly commonly extend beyond farm boundaries, even within a season (Siriwardena et al., 2006). This suggests that effective management needs to be coordinated at the landscape scale, or certainly across multiple, neighbouring farms.

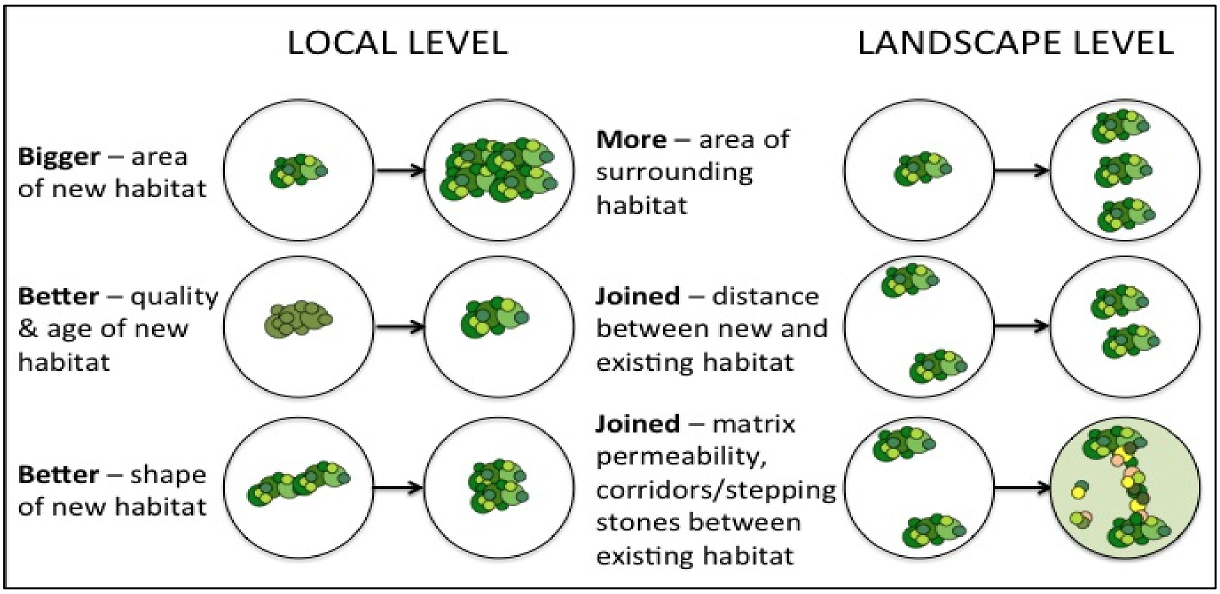

Figure 4.6.3.1 illustrates schematically the potential benefits of planning and targeting interventions at both local and landscape scales to increase landscape complexity, provide a diversity of semi-natural elements and biodiversity, and to extend habitat patch size; and increase opportunities for connectivity. The arrows depict positive changes, left to right, over time for each factor (Source: Humphrey et al. (2013) adapted from concepts set out in Lawton et al. (2010)).

5 Evidence Gaps

Notable gaps include a lack of evidence on:

1. Impact on habitats and species at a landscape scale of management for biodiversity at farm (or parcel) scale.
2. The plant species associated with “scrub” that are rapidly increasing in abundance in large areas of Wales following reduction in stocking densities.
3. Evidence of impacts on semi-natural pastoral habitats of grazing by different types and combinations of livestock at different stocking intensities.
4. Evidence of the biodiversity impacts of farm woodland management (most of the evidence is of forest management).
5. The extent, location, habitat condition and management (or lack thereof) of farm woodlands in Wales.
6. The extent, location and condition of hedgerows and hedgerow trees across the whole of Wales (regional/local data does not seem to have been collated nationally).
7. The functional interaction at farm level and the impact on ecological resilience of two broad types of biodiversity interventions – those targeted at semi-natural habitats and those targeted at species dependent on or associated with the farmed landscape (but not necessarily with one particular habitat type).
8. Relationships between the measured values of habitat condition or species richness and functional resilience.
9. Relationships between habitat condition metrics and other elements of biodiversity for all target habitats; subsequently, metrics could perhaps be enhanced by incorporating habitat extent and context, and/or vegetation structure, subject to research results.
10. It is also worth exploring the conceptual relationships between species and habitat type or habitat condition, as this may not be reflected in the habitats as precisely defined by Common Standards Monitoring categories (or other classification). More specifically, how to combine meaningful metrics of diversity, area condition and area extent into useful indicators of resilience remains an area of uncertainty and the subject of active research - a functional or trait-based approach may be worth exploring.

6 Summary

This review covers evidence for management to improve the habitat condition of semi-natural habitats within farmland and common grazings, including farm woodland and other trees and hedgerows within farmland.

The scope includes a wide range of broadly semi-natural habitats that are found on farms and common grazings, which depend to a greater or lesser extent on the land management activities of the farmer. In terms of environmental cost-effectiveness, the most appropriate habitat interventions, in order of priority, are:

i) habitat maintenance where the existing condition is good;
ii) habitat improvement and/or restoration where it is not; then
iii) habitat creation.

The review also covers evidence on another important issue, that of the combined effect of the spatial distribution of habitat types and condition at a landscape scale, not just on the resilience of the habitats themselves but also the impact of this on birds and other animals that utilise large areas.

6.1.1 Semi-natural habitats - management of unimproved (including semi-improved) pastures and hay-meadows

- The large extent and generally poor condition of semi-natural habitats justifies intervention; there is evidence of generalised under-grazing in the lowlands of Wales and of recent historical over-grazing, now shifting towards under-grazing, in the uplands.
- For specific habitats, of which large areas are found on farmland in Wales (semi-natural pastures, including semi-improved grassland, moors, heaths and blanket bogs), there is good evidence for general and more specific interventions on grazing, stocking rates, fertilisation (restrictions) and infrastructure to support habitat management. At a broad scale these would include habitat-appropriate grazing regimes, supported by tailored management of vegetation by cutting, to maintain and/or improve habitat condition. It is important to note that specific intervention requirements at site level depend on the type of habitat (often found in mosaics of different types, especially on extensive upland pastures) and the habitat condition at the time of the intervention, as well as the management history and the site-specific conservation objectives.
- In Wales these habitats include significant areas of marginal semi-natural grasslands which have been agriculturally semi-improved but retain their potential for habitat improvement. In the SFS the choice between managing this marginal land to improve the habitat or to convert it to improved grassland should take in to account both the benefits to biodiversity and ecosystem services and the risks that agricultural improvement will not be economically viable.

6.1.2 Farm woodland and agroforestry

- Farm woodlands in Wales are generally small, many of them are unmanaged other than as a source of firewood, and they are at risk of significant further decline in habitat extent and condition as a result of pests and diseases (notably *Chalara* ash dieback), invasive species and climate change.
- There is good evidence to justify interventions in farm woodlands to achieve a shift to long-term sustainable silvicultural and habitat management, with multiple benefits for habitat biodiversity, climate adaptation, soils and water. This will require a major change in farmers' approach to woodland management, supported by advice, training and investment.
- Hedgerows are important habitats, and there is evidence that more diverse management would be beneficial; an urgent need is to replace/regenerate hedgerow trees.
- There is a growing body of evidence on the ecosystem service and climate adaptation benefits of introducing trees in intensive farming systems and restoring wood-pasture systems, through agroforestry management.
- Interventions in woodland management and creation for a range of different environmental objectives have been reviewed in other ERAMMP SFS Evidence Reviews. The potential synergies and conflicts between the many possible options and objectives for government support for farm woodland management will have to resolved for the design and targeting of the SFS. From a land manager's point of view these include several different potentially conflicting priorities, for example between production objectives (grassland management and livestock shelter) and environmental objectives (woodland management and creation for habitat improvement or to reduce flood risk); between low impact silvicultural systems or agroforestry and fast-growing Sitka or Eucalyptus for the renewable energy market; and between the differing time scales and land management options for C sequestration and storage.

6.1.3 Landscape scale

- There is good evidence supporting the need to plan for improvements in habitat condition at a landscape scale, before making implementation decisions and choosing priorities to be funded at individual farm scale. This not only has benefits for targeting SFS habitat interventions most cost-effectively, but also has implications for the design of the scheme, for setting differential payment rates and other targeting strategies, and for the type and availability of advice available to individual farmers.
- Although improved land has not been covered as a habitat in itself for this evidence review, it is an important part of the matrix of different habitats and land uses that make up the rural landscapes of Wales. It is the improved and semi-improved land that provide the only opportunities for increasing the patch size, proximity and connectivity of farmland habitats at landscape scale, which evidence suggests is needed to improve the current condition and long-term resilience of existing semi-natural habitats to climate change, other environmental risks and market pressures.

Table 6.1 Semi-natural habitats, farm woodland and agroforestry

Confidence	Intervention Name	Key Outcomes	Key Benefits	Critical concerns
Semi-natural habitats - management of unimproved (including semi-improved) pastures and hay-meadows				
Blue	Prioritise improving the condition of existing semi-natural habitats, (including semi-improved grasslands)	Improved habitat condition and extent	Biodiversity	Risk of semi-improved grasslands being agriculturally improved without weighing up the relative economic and environmental benefits of the alternative of habitat restoration/improvement. Conversely, risk of abandonment on more marginal fields, with consequent loss of conservation opportunities as semi-natural grassland.
Blue	Grazing within broad annual stocking density thresholds (lower and upper thresholds encompassing the range of situations appropriate for semi-natural habitats).	Improved habitat condition	Biodiversity Reduced soil loss/damage from poaching	Difficulty of determining broad stocking densities that will be appropriate across range of situations.
Blue	More detailed grazing interventions applicable to specific semi-natural habitats or mosaics of habitats, including variations in: a. Seasonal stocking thresholds; b. Temporal and spatial grazing patterns within the holding, including temporary/seasonal exclusion in particular areas; c. Grazing livestock species and breeds, and combinations of species.	Improved habitat condition and maintenance/improvement of mosaics of habitats	Biodiversity Availability of different types of grazing during the year	Difficulty of defining detailed prescriptions that may be impractical for the land manager (results-based approach may be more efficient).
Blue	Management interventions generally applicable on semi-natural habitats to complement and/or	Improved habitat condition	Biodiversity	

Confidence	Intervention Name	Key Outcomes	Key Benefits	Critical concerns
	facilitate appropriate grazing a. Temporally and spatially appropriate cutting and clearance of vegetation such as scrub, bracken, rushes, etc.; b. Improvement of fencing, gates, water points to facilitate appropriate grazing management.	Improved habitat structure More effective management of habitat-specific grazing	Livestock management Reduced soil damage around feeding/watering points	
Blue	Management interventions specific to certain habitat types: a. Mowing and harvesting (hay meadows); b. Fertilisation/liming (hay meadows); c. Blocking of drains and grips (blanket bog, wet grasslands).	Improved habitat condition Increased diversity of characteristic hay meadow species Restoration of functioning blanket bog	Biodiversity Improved soil nutrient management C sequestration Water quality Flood risk management	Blanket prescriptions such as cutting dates may reduce diversity of management at landscape scale.
Amber	Burning where appropriate (heather moorland)	Improved structural mosaic of heather moorland (if patches burned in rotation)	Biodiversity Game management	Management by burning is not beneficial for some species
Farm woodland habitat management (including woodland habitat creation)				
Blue	Improve diversity within woodlands of: • species, by planting/natural regeneration of UK native species, including understorey spp where appropriate • genotypes of tree spp, especially for long-term resilience to climate threats	Improved habitat condition and structure Improved resilience to pests, diseases and storm damage Farm income diversification	Biodiversity Farm business resilience	Relationship with C sequestration/storage objectives needs to consider the medium to long-term conflicts/trade-offs between native spp mixed woodland and plantations of Sitka (and other fast growing spp e.g. Eucalyptus as climate becomes drier) in terms of:

Confidence	Intervention Name	Key Outcomes	Key Benefits	Critical concerns
	(pests, diseases, drought) • age structure and long-term silvicultural systems (continuous cover, LISS) • open habitats and wet habitats within the woodland Retention of deadwood	opportunities (recreation, hardwood timber in the long-term)		- adaptation risks (economic and climate change) - soil carbon (and other soil effects) - long-term C storage in construction materials using native hardwoods (e.g. Coed Cymru work on small diameter hardwood) - future government policy on using wood fuel as a renewable energy
Blue	Livestock control measures (fencing, limited grazing where appropriate)	Improved habitat condition and structure Reduced losses from grazing	Biodiversity Farm business resilience	Deer management may be required
Blue	Improve connectivity of native woodland patches by allowing natural regeneration of native species (only) or planting	Improved habitat condition and structure	Biodiversity	Ensure woodland creation, especially on marginal land, is not at the expense of other semi-natural habitats (this is a judgement call on semi-improved land, but guidelines need to be in place for scheme delivery)
Amber	Use tree species tolerant of future climate (advised from modelling) and under-represented native tree species for woodland creation and improving connectivity	Improved resilience to climate change	Climate resilience	Uncertainty about susceptibility of these species to other pressures (grazing, browsing, pests and diseases)
Amber	Control of INNS, pests and diseases (covers a huge number of detailed interventions that are positive if effective but efficacy has not always been proven)	Reduced damage and loss of woodland habitat	Biodiversity Farm business resilience	
Management of other trees and shrubs within farmland (agroforestry)				
Blue	Habitat-appropriate management of existing: • scrub habitats	Improved habitat condition, structure, extent; and resilience to	Biodiversity Farm business resilience	

Confidence	Intervention Name	Key Outcomes	Key Benefits	Critical concerns
	• parkland (including veteran trees) • hedgerows/cloddiau, • trees in hedges, field boundaries, within fields and in ffridd • old orchards	climate change and environmental threats		
Amber	Creation of new agroforestry on arable/improved grassland	Improved habitat diversity	Biodiversity Climate adaptation Farm business resilience	
Amber	Restoration of silvopastoral systems on appropriate semi-natural habitats	Improved habitat diversity	Biodiversity Climate adaptation	Change in species
Blue	Ensure eligibility of land with trees and other woody plants for SFS (compared to current CAP rules, which restrict eligibility of some farmland with trees and shrubs of biodiversity value)	Payments/ha no longer inversely proportional to the number/extent of scattered trees	More farmland trees	
ALL HABITAT INTERVENTIONS				
Blue	Skills interventions: - assessors - farmers and advisers	Appropriate application of measures to improve habitat condition and/or maintain habitats already in favourable condition	Targeting, and environmentally cost-effective delivery to supports habitat specific interventions	Assessors and advisers must have ability to communicate with farmers, ecology can be learnt. Farmer skills links to economic resilience.
Amber	Introduce pilot result-based payment schemes for key farmland habitat types	Find out if can improve cost-effectiveness of delivery of habitat improvement	Biodiversity Recognition (public and farmers') of the role of farmers in biodiversity management	New concept for farmers and delivery agencies, pilot schemes essential to test what works (and doesn't) and why, before using more widely. Not suitable for all habitats or tested for other objectives (soil, water). Usage to date has been mainly for 'higher level' habitat management.

Colour Key:

- Blue = well tested at multiple sites with outcomes consistent with accepted logic chain. No reasonable dis-benefits or practical limitations relating to successful implementation.
- Amber = agreement in the expert community there is an intervention logic chain which can be supported but either evidence is currently limited and/or there are some trade-offs or dis-benefits which WG need to consider.
- Pink = either expert judgement does not support logic chain and/or whilst logic chain would suggest it should work there is evidence of one or more of the following:
    - its practical potential is limited due to a range of issues (e.g. beyond reasonable expectation of advisory support which can be supplied and/or highly variable outcome beyond current understanding or ability to target),
    - the outcome/benefit is so small in magnitude with few co-benefits that it may not be worth the administration costs,
    - there are significant trade-offs.

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