The Second State of Natural Resources Report (SoNaRR2020)

Assessment of the achievement of sustainable management of natural resources: Enclosed Farmland

Natural Resources Wales

Final Report

Amendments:

Document version	Amendment
Version 2.0	Figure 15 replaced to include Upland Farmland bird index

About Natural Resources Wales

Natural Resources Wales's purpose is to pursue sustainable management of natural resources. This means looking after air, land, water, wildlife, plants and soil to improve Wales's well-being, and provide a better future for everyone.

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence-informed organisation. We seek to ensure that our strategy, decisions, operations, and advice to Welsh Government and others, are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

Title: **SoNaRR2020** Assessment of the achievement of Sustainable Management of Natural Resources: Enclosed Farmland

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Restrictions: None

The Second State of Natural Resources Report (SoNaRR2020) contents

This document is one of a group of products that make up the second State of Natural Resources Report (SoNaRR2020). The full suite of products are:

Executive Summary. Foreword, Introduction, Summary and Conclusions. Published as a series of webpages and a PDF document in December 2020

The Natural Resource Registers. Drivers, Pressures, Impacts and Opportunities for Action for eight Broad Ecosystems. Published as a series of PDF documents and as an interactive infographic in December 2020

Assessments against the four Aims of SMNR. Published as a series of PDF documents in December 2020:

SoNaRR2020 Aim 1. Stocks of Natural Resources are Safeguarded and Enhanced

SoNaRR2020 Aim 2. Ecosystems are Resilient to Expected and Unforeseen Change

SoNaRR2020 Aim 3. Wales has Healthy Places for People, Protected from Environmental Risks

SoNaRR2020 Aim 4. Contributing to a Regenerative Economy, Achieving Sustainable Levels of Production and Consumption

The SoNaRR2020 Assessment of Biodiversity. Published in March 2021

Assessments by Broad Ecosystem. Published as a series of PDF documents in March 2021:

Assessment of the Achievement of SMNR: Coastal Margins

Assessment of the Achievement of SMNR: Enclosed Farmland

Assessment of the Achievement of SMNR: Freshwater

Assessment of the Achievement of SMNR: Marine

Assessment of the Achievement of SMNR: Mountains, Moorlands and Heaths

Assessment of the Achievement of SMNR: Woodlands

Assessment of the Achievement of SMNR: Urban

Assessment of the Achievement of SMNR: Semi-Natural Grassland

Assessments by Cross-cutting theme. Published as a series of PDF documents in March 2021:

Assessment of the Achievement of SMNR: Air Quality

Assessment of the Achievement of SMNR: Climate Change

Assessment of the Achievement of SMNR: Energy Efficiency

Assessment of the Achievement of SMNR: Invasive Non-native Species

Assessment of the Achievement of SMNR: Land use and Soils

Assessment of the Achievement of SMNR: Waste

Assessment of the Achievement of SMNR: Water Efficiency

Updated SoNaRR evidence needs. Published as a data table on web in March 2021

Acronyms and Glossary of terms. Published as a PDF in December 2020 and updated in 2021 as a data table on the web

Recommended citation for this section of the report:

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Contents

Tables and Figures

1. Headline Messages

Issues

Sustainable food production

There is a major challenge to reduce agriculture’s negative impact on the environment while simultaneously maintaining food production for a growing population.

Climate change

Agriculture is responsible for 14% of Welsh greenhouse gas emissions; livestock and fertilisers being the major sources. Climate change is likely to have a detrimental impact on the ecosystem and its services.

Loss of farmland biodiversity

Intensive agricultural management has resulted in the loss of habitats, declines in species populations and increased habitat fragmentation. Specialist farmland species are declining the most rapidly among all the ecosystems.

Agricultural pollution

Agricultural practises involving manufactured fertilisers and animal waste cause pollution and eutrophication of both freshwater and terrestrial ecosystems.

Potential responses

Sustainable agricultural practices partnered with improved production efficiency and modified patterns of food consumption

Managing environmental sustainability on farms in some circumstances is linked to a decrease in food production. If not balanced by measures, such as improving efficiency, reducing food waste, modifying diets and technological advances, the area of land required for agricultural production may need to expand. This would risk increasing environmental pressures within Wales and abroad.

Increase the woody elements within farmland systems

Incorporating increased extent of trees and hedgerows within farming systems allows for continued food production alongside enhanced ecosystem services. By adding more woody elements into farmed landscapes, farmers can provide shade and shelter to protect livestock and crops, while sequestering carbon and supporting biodiversity and other ecosystem services.

Create resilient ecological networks

Create resilient ecological networks by expanding, enhancing and restoring existing habitats and creating new habitats. These would be multi-functional, providing nature-based solutions to issues such as carbon sequestration, flooding and pollution. Examples of measures include grassland reversion, riparian buffer strips, wetland creation and flood plain restoration.

Improved nutrient management

Provide support to enable the many actions available to increase nutrient-use efficiency; both to apply the appropriate quantity of fertilisers to land and to decrease nutrient transfer to other ecosystems.

Improved soil management

Maintain and, where necessary, improve soil condition. Improved soil structure has the potential to increase productivity and carbon storage. Provide support to enable land managers to adopt appropriate management techniques.

2. Introduction

Enclosed Farmland comprises the improved and semi-improved agricultural land in Wales that is surrounded by field boundaries. It includes arable crops, horticulture, orchards and temporary grasslands as well as agriculturally improved permanent grasslands. Enclosed Farmland, however, excludes areas of enclosed semi-natural grassland, scrub, farm woodland, and the upland fringes (ffridd).

Enclosed Farmland is an intensively managed ecosystem with small areas of high biodiversity value such as hedgerows, traditional orchards, wood pasture, parkland, and extensively managed arable land. This ecosystem covers 54% of Wales, of which the main component is agriculturally improved grassland (Figure 1).

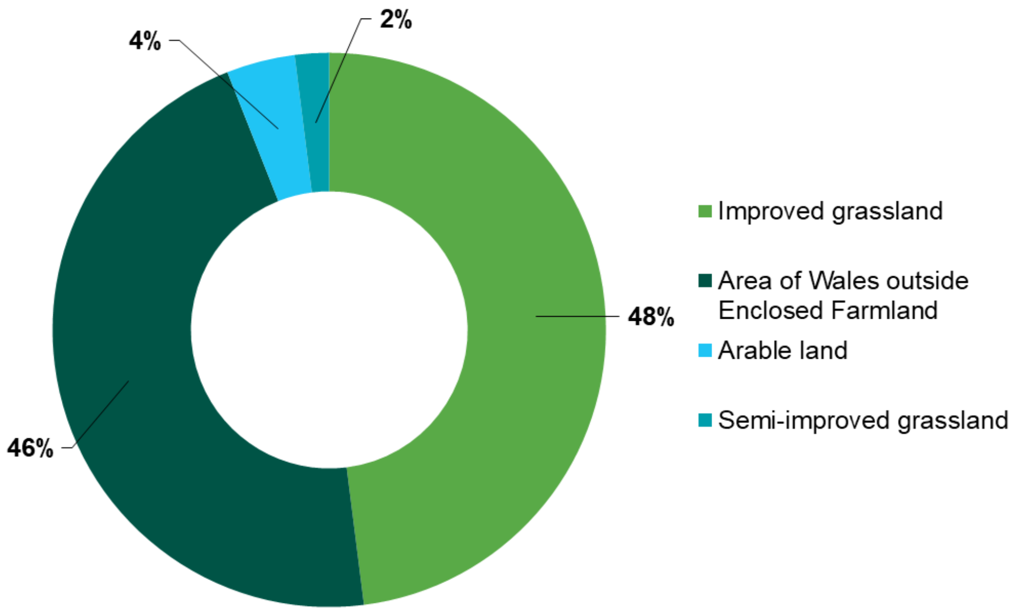


Figure 1 Proportion of the areas of Wales above mean high water that form the components of Enclosed Farmland. Figures derived from Blackstock et al., 2010 and Welsh Government, 2019a.

Since the end of the Second World War, levels of agricultural production have increased greatly, causing growth in external environmental costs and at the expense of ecosystem services besides food production. For the last two decades, agricultural productivity has remained relatively stable. Links between providing food and other ecosystem services are negative. For example, the release of nutrients from agriculture as greenhouse gases and wide-spread pollution, along with the loss of native biodiversity to replacing it with crops and species-poor grassland.

Agriculture faces a major challenge in reducing its contribution to climate change. It needs to reduce greenhouse gas emissions and has a role to play in storing carbon.

The lowland farmed landscape has been simplified over preceding decades to remove ‘weeds’, hedgerows, semi-natural grasslands, wetlands, trees and scrub. This has had a massive impact on biodiversity. The habitats of principal importance (Section 7 of the Environment Wales Act, 2016) within Enclosed Farmland are all in poor or unknown condition. Specialist farmland species such as farmland birds and wild arable plants are in serious decline. Extensively managed arable land is the only Critically Endangered habitat in the UK on the European Red List (Janssen and Rodwell, 2017).

More efficient utilisation of nutrients at field, farm and catchment scales could reduce diffuse pollution and improve soil condition without decreasing food production. However, system changes to current agricultural practices are required to fully address both the nature and climate emergencies.

This chapter will explore the current condition of productive agricultural land in Wales. It will look at what can be done to improve ecosystem resilience and services. Actions that include diversifying the land, managing soils and nutrients and using innovative, sustainable farming practices that can both improve productivity and safeguard the environment.

3. State and Trends (Aim 1)

The state and trends of Enclosed Farmland vary between the different components. This section considers the components individually. Providing a timeframe for future prospects is difficult given changes as a result of Wales leaving the European Union. This will be clearer once the Agriculture (Wales) Bill is published.

Summary Assessment of State and Trends and Future Prospects

The following tables give a brief description of the past trends and future prospects for the Enclosed Farmlands Ecosystem. These are assessed to be:

- Improving trends or developments dominate shown in green
- Trends or developments show a mixed picture shown in amber
- Deteriorating trends or developments dominate shown in red

Further information is provided to put this in context.

Table 1 Key message – past trends and future prospects for Improved Grassland

Time Period	Criteria	Indicative Assessment	Description
Past trends (1946-2019)	Extent	Mixed picture	Post Second World War there was a large increase in land being drained, limed, fertilised and converted from arable to increase productivity. More recently, conversion has continued, but at a much lower rate due to the lack of availability of suitable land and Environmental Impact Assessment (Agriculture) Regulations restricting the conversion of semi-natural land.
Past trends (1946-2019)	Condition	Mixed picture	There is a wide variation in management practice across Wales, causing differing soil conditions, sward composition, species diversity and effects on the surrounding ecosystems. Inorganic inputs have decreased across a significant area with more improved grassland being managed in a sustainable way, minimising inputs and building soil condition.

Time Period	Criteria	Indicative Assessment	Description
Past trends (1946-2019)	Biodiversity	Deteriorating	Specialist farmland species are in serious decline. This is illustrated particularly by invertebrates, plants and farmland birds.
Past trends (1946-2019)	Pressures	Mixed picture	Economic pressures for increased productivity are driving changes to management practices. A significant proportion of the built-up area in Wales occurs on high-grade agricultural land (grades 1, 2 and 3a). Due to the co-location of urban areas and high-grade soils, any urban expansion has often been at the expense of the most productive land.
Future Prospects	Extent	Mixed picture	The extent of improved grasslands will fluctuate with arable land due to economic and market pressures. The area of productive land could be reduced by the development of woodland creation and urban expansion.
Future Prospects	Condition	Mixed picture	Currently, there is a small proportion of improved land being managed for long-term sustainability. There is an increase in herb rich leys and use of legumes instead of inorganic nitrogen There is a growing appreciation of soil and its importance to production and carbon sequestration. However, how the market will affect these changes in the future is difficult to predict.

Time Period	Criteria	Indicative Assessment	Description
Future Prospects	Biodiversity	Mixed picture	This is dependent on the future direction of grassland management. A move towards more sustainable varied swards managed with less artificial inputs would be beneficial. Economic pressures leading to further intensification and more inputs to the system would be detrimental.
Future Prospects	Pressures	Mixed picture	Future prospects relating to agricultural pressures are particularly difficult to assess at this point time due to uncertainties surrounding the impacts of Brexit. There is likely to be increased pressure to convert improved grassland for woodland, biofuels and urban areas. There is an increasing risk of drought during late spring and early summer. The predominant grass species used in sown pastures is poorly adapted to drought conditions, but alternatives are under development. With the current sward compositions, drought in Wales will have large impacts on the availability of forage. There is likely to be higher rainfall during the winter leading to an increased risk of flooding. Perennial rye grass has low survival rates following flooding events leading to low forage production in the next growing season.

Robustness: There is high robustness due to multiple and reliable sources recording the increase in improved grassland since the Second World War. Contrastingly, soil data is based on analyses from a relatively small sample size collected for Glastir Monitoring and Evaluation Programme (GMEP).

Table 2 Key message – past trends and future prospects for Arable and Horticulture

Time Period	Criteria	Indicative Assessment	Description
Past trends (2000-2019)	Extent	Improving	The current area of arable crops (about 93,000 hectares (ha)) is significantly higher than it was 20 years ago (about 70,000 ha). A massive historical decline in the area of low-intensity arable land supporting arable plant communities has been observed.
Past trends (2000-2019)	Condition	Deteriorating	The condition of intensive arable land is determined primarily by its soil properties.
Past trends (2000-2019)	Biodiversity	Deteriorating	Extensively managed arable land is the only European Critically Endangered habitat in Wales. Lowland Farmland Birds and pollinators are in decline from arable land. There is lower arable bryophyte diversity in more intensively managed fields, along with the major loss in arable plants. Pesticides and herbicides have contributed to the decline in many fauna and flora species within this habitat.
Past trends (2000-2019)	Pressures	Deteriorating	Arable land is at more risk of soil erosion compared to grassland systems due to soil cover being sparse. The increase in maize is likely to have a negative impact on soil condition and soil erosion.

Time Period	Criteria	Indicative Assessment	Description
Future Prospects	Extent	Improving	The economic market, future sustainable farming schemes and climate change will all influence the future extent of arable land and horticulture. Pockets of low input arable land do still exist across Wales and could be increased with simple changes in field management.
Future Prospects	Condition	Mixed picture	Research on management techniques to improve soil condition is increasing. Mechanisms to support the adoption of techniques need to be provided.
Future Prospects	Biodiversity	Mixed picture	Prospects are very poor without financial support to maintain low input arable systems, and to provide landscape scale habitat provision for mobile species.
Future Prospects	Pressures	Deteriorating	Demand to grow more biofuel crops will place pressure on food production and, depending upon the crop, on the environment. Climate change is putting pressure on arable and horticulture from extremes of weather. There are significant financial pressures and lack of support to maintain the arable systems.

Robustness: The extent of arable and horticulture from Wales is obtained from Welsh Government Agricultural Statistics and therefore provides high robustness of data. Information on extensive arable plants is from reliable data collected by Plantlife. Soil data is based on analyses from a relatively small sample size collected for GMEP.

Table 3 Key message – past trends and future prospects for Hedgerows

Time Period	Criteria	Indicative Assessment	Description
Past trends (1946 - 2019)	Extent	Mixed picture	Since the Second World War, there has been widespread hedgerow removal to increase agricultural productivity but the extent has stabilised in recent years. Loss of hedgerow trees through lack of recruitment has been seen, but most importantly, *Chalara* will have a major negative impact.
Past trends (1946 - 2019)	Condition	Deteriorating	Woody vegetation is often over trimmed and trimmed too frequently to allow flowering and fruiting; this results in short and narrow hedges. Grazing in hedgerows can lead to gaps in the base. Gaps in the canopy effectively fragment the habitat and reduce its usefulness for navigation and movement corridors for biodiversity and for the ecosystem services delivered. A lack of long-term rejuvenation, laying and coppicing, will lead to loss of hedge structure and potentially loss of hedges. Basal vegetation has lost diversity due to fertiliser and herbicide drift.
Past trends (1946 - 2019)	Biodiversity	Deteriorating	Many farmland species that depend upon hedgerows are in decline. For example, there have been reductions in brown hairstreak butterfly and spreading bellflower *Campanula patula* populations within this habitat.
Past trends (1946 - 2019)	Pressures	Deteriorating	Poor management, particularly, over-trimming and grazing has led to poor condition. There is also observed loss from disease.

Time Period	Criteria	Indicative Assessment	Description
Future Prospects	Extent	Mixed picture	Extent is predicted to be stable or increasing **if** the importance to carbon sequestration is acted upon. Hedgerow tree loss will accelerate as a result of *Chalara*.
Future Prospects	Condition	Mixed picture	This will depend largely on support measures available and regulation in place post Brexit. Support for hedgerow management is required from future schemes.
Future Prospects	Biodiversity	Mixed picture	Moves to encourage bigger hedges and plant new hedges will be positive for biodiversity if realised on the ground.
Future Prospects	Pressures	Mixed picture	Mechanisms are required to improve current management practises. Recognition of importance for carbon sequestration, run-off interception, prevention of soil erosion, shade and shelter. More understanding of the role played in the landscape is required (National Farmers Union (NFU) and the Committee on Climate Change recommendations). Removal for development and destruction by woodland creation, if not protected, is also a pressure.

Robustness: Robustness is of medium level as data is mostly from Countryside Surveys and GMEP where sample size is relatively small.

Table 4 Key message – past trends and future prospects for Enclosed Farmland Ecosystem: Parkland, Wood Pasture, Orchards and Trees Outside Woodland

Time Period	Indicative Assessment	Description
Past trends (1958-2019)	Deteriorating	There has been a deterioration in the extent and condition of parkland and orchards over many decades. There have been large tree losses of trees outside woodlands due to Dutch Elm disease and lack of new tree recruitment. The extent and condition of wood pasture is unknown.
Future Prospects	Mixed picture	Without support, prospects will be poor. However, policy responses to climate change, should result in tree planting to increase carbon sequestration. A change in policy and support to consider trees outside woodland, in addition to woodland creation, is required.

Robustness: Robustness of data is low as there is no historical data for trees outside woodland. Recent data from the National Forest Inventory and GMEP provides some overview of the current position. The information on Orchards and Parkland extent is based on NRW registers.

Improved grassland

Extent

Mechanisms to increase food production after the Second World War led to wholescale land improvement over the following decades. Semi-natural habitats were cultivated, drained, limed and fertilised to create more productive land (Blackstock et al., 2010). Improved grassland now covers approximately half of the land surface of Wales. See SoNaRR2016 for details.

While the trend of improvement continues, the rate has become substantially slower as the availability of suitable land has decreased and Environmental Impact Assessment (EIA) (Agriculture) Regulations (2002) were introduced. Although significant, the loss of unimproved grassland is still occurring. See the semi-natural grasslands chapter for more information.

Farming systems in Wales have become more specialised over the past decades with a move from mixed farming to predominantly livestock, a 75% decline in the cultivated area between the 1930s and 1990s. This has added to the increase in the area of improved grassland as arable land was converted. Nevertheless, there has been a slight recent reverse in this trend. See Arable and Horticulture Extent below

There is 11,990 ha of improved grassland within Sites of Special Scientific Interest (SSSI). Management of this land varies according to the reason for inclusion within a SSSI. A proportion continues to be managed intensively but many areas will have reduced nutrient inputs or be in reversion to a semi-natural habitat.

There are pressures on the extent of improved grassland from other land uses, notably urban expansion, buildings for agricultural intensification and woodland creation.

Energy generation from solar farms has created a new pressure on productive land area. See the energy chapter for more information.

Lower-meat diets, an increase in bioenergy crops and the potential impact from Brexit on meat exports could all lead to the conversion of grassland to cropped land in the future.

Condition

Wide variations are found in management practices on improved grassland. Management approaches can lie anywhere between low-input systems sown with herb rich mixes, to high-input swards sown with elevated-sugar varieties of rye grass. The varying systems result in differing soil condition, sward composition and impact on the surrounding ecosystems. There is limited evidence available to quantify the areas of different management intensity, this is outlined below:

- Manufactured fertiliser inputs have decreased since the late 1980s (Figure 2) (Hayhow et al., 2019; Defra, 2019a). There is no information available on organic fertiliser inputs, but 20th century transitions towards livestock systems based on silage and slurry, combined with imported feeds for pigs and poultry, point towards increased organic nutrient levels across the majority of farmland (Aazem and Bareham, 2015). Organic manures are one of the largest contributors to ammonia emissions, with significant implications for other ecosystems (Plantlife and Plant Link UK, 2017).

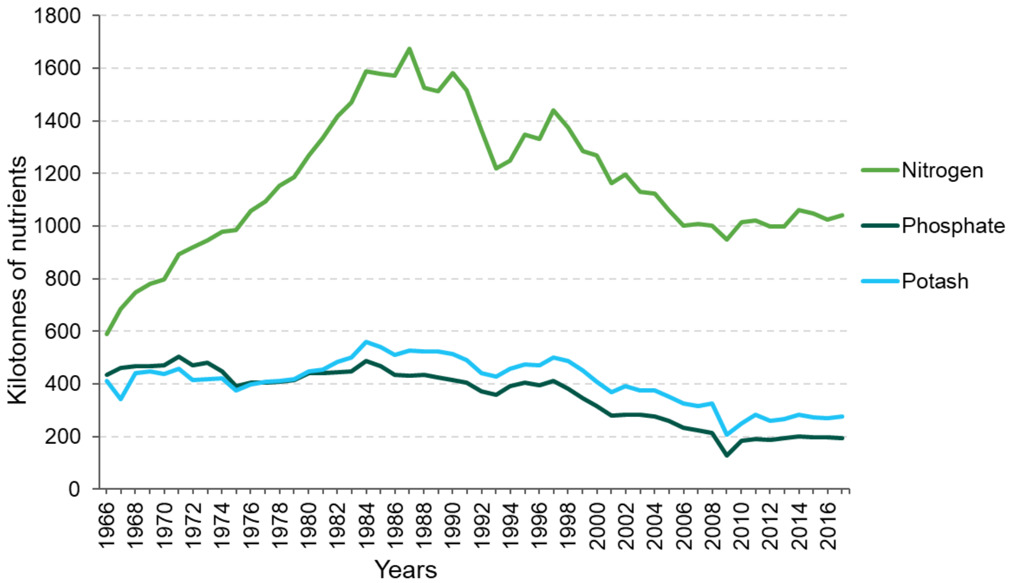


Figure 2 Total quantities of manufactured fertilisers used in the UK, 1966 to 2017 (Defra, 2019a)

- Within Glastir Advanced and Glastir Entry, 24,000 ha of grassland was entered into no fertiliser options up to 2019 (Welsh Government, 2019b).
- The weight of pesticide active ingredients applied to land has decreased over the past 25 years (Figure 3). However, this hides the true picture as the number of hectares treated with pesticides, along with the frequency of treatments, have increased, impacting soil biodiversity. In addition, there have been increases in the toxicity of pesticides and the variety of pesticides used on a single crop (Hayhow et al., 2019).

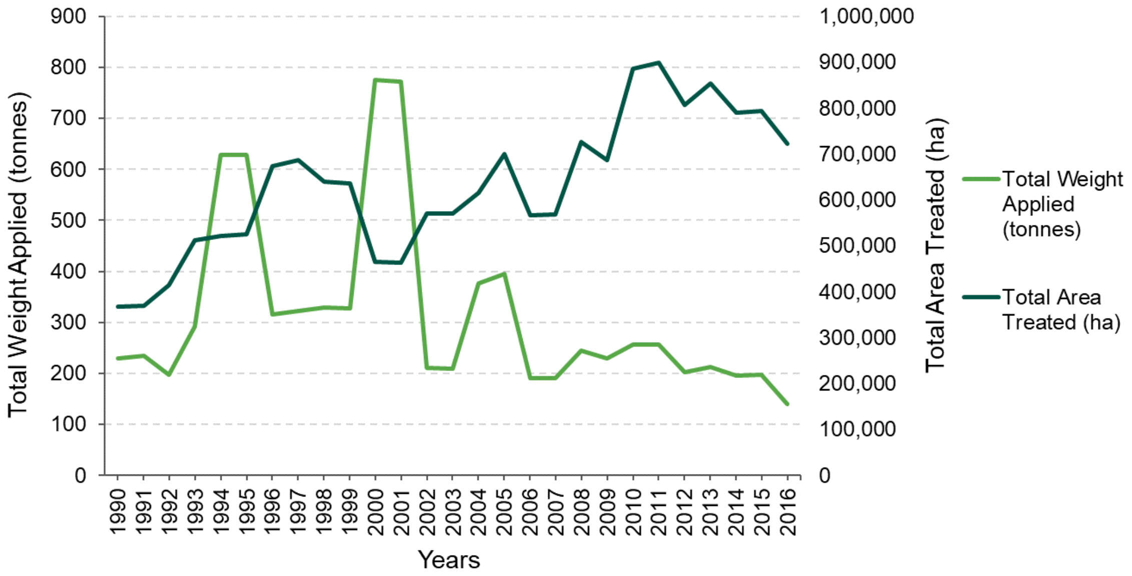


Figure 3 Trends in Pesticide use in Wales. (Fera Science, 2020)
Total Area Treated refers to the active substance treated area. This is the basic area treated by each active substance, multiplied by the number of times the area was treated.

- Legumes are of particular interest within improved grassland because of their potential to increase soil carbon (Smith et al., 2008) and provide for pollinators (Rundlöf et al., 2014) while reducing the quantity of nitrate fertiliser required for optimum productivity. They also improve livestock performance (Speijers et al., 2004) which, in turn, results in lower methane emissions from stock. Data from GMEP shows that clover is present at greater than 10% cover in 54% of improved grassland area (Alison et al., 2020).
- The majority of improved grasslands are low in species diversity, on average containing 7 species of plant that are not agricultural weeds (Alison et al., 2020).
- The use of diverse swards or herbal leys appears to be on the increase, but anecdotal evidence and total sales of seed indicate that such multi-species swards occupy a small proportion of the grassland area (Newell Price et al., 2019).

This evidence suggests that manufactured inputs have decreased across Wales, and that there is a small but growing proportion of improved land being managed in a more sustainable way that minimises inputs and builds soil condition.

Semi-improved grassland

There was 33,200 ha of partially improved grassland in Wales between 1987 and 1997 (Blackstock et al., 2010); no new data is available to report on trends in the extent of this resource. This habitat is composed of dry neutral and wet grassland that has either been fertilised or drained or both, but retains components of natural vegetation. Vegetation plots within semi-improved grassland contain an average of 13 species of plant that are not agricultural weeds (Alison et al., 2020). Semi-improved grassland provides habitat for wildlife and a range of ecosystem services but at a lower level than unimproved, semi-natural, grassland. See the semi-natural grasslands chapter for more information. By definition, the habitat is in poor condition with many components of unimproved grassland absent.

Arable and Horticulture

Extent

There has been a modest increase in the area of arable and horticulture land between 2013 and 2019, from 79,500 ha to 93,100 ha (Welsh Government, 2019a). Fluxes between improved grassland and arable land will continue to occur as market pressures change. Horticulture accounted for 1,480 ha across Wales in 2019, which includes vegetables, salads, commercial orchards and small fruits (Welsh Government, 2019a).

Condition

The condition of intensive arable land is determined primarily by its soil properties. Agricultural management that leads to a loss of soil condition, such as removal of residues, soil erosion and compaction, are a threat to the arable soils in Wales (ADAS, 2019a). See Soils section below.

Bare fallow land increased from 609 ha in 2012 to 2,210 ha in 2019 (Welsh Government, 2019a), potentially related to increased maize growing. See the Regenerative economy (Aim 4).

There has been a massive historical decline in the area of low-intensity arable land with arable plant communities. Prior to the widespread use of herbicides, arable land supported rich plant communities (Wilson and King, 2003). There continues to be a downward trend in the remaining area; only 1,600 ha of arable land supporting some remnants of species-rich arable plant communities were identified by survey between 2014 and 2017 (Walker et al., 2017). Arable land managed by low-intensity agricultural methods is the only European Critically Endangered habitat in Wales (Janssen and Rodwell, 2017). Just one 20 ha site of species-rich arable land is protected as a SSSI.

Uptake of the arable option, fallow margins, within Glastir has been poor for optimum management for arable plants; these covered just 16 ha of land in 2019 (Welsh Government, 2019b). Feedback from farmers on low uptake points towards low payment rates and lack of knowledgeable support from contract managers.

Hedgerows

Extent

Measures to increase productivity following the Second World War resulted in widespread hedgerow removal. Rates of destruction were extremely high, 25% loss in Wales between 1984 and 1990 (Barr et al., 1991), until the introduction of the Hedgerow Regulations in 1997 followed by cross-compliance protection in 2004. Hedgerow extent stabilised in the 1990s, then increased in the period to 2007 (Smart et al., 2009). Between 2007 and 2015, hedgerow length has remained relatively constant (Alison et al., 2020).

Between 1951 and 2007, the number of hedgerow trees fell dramatically across Britain from over 56 million to less than 2 million (Carey et al., 2008); around half of these were elm trees killed by Dutch Elm Disease (Firbank et al., 2011). Trees within hedgerows are continuing to decline in number (Alison et al., 2020). More recent tree losses have been caused by felling for road safety considerations, agricultural reasons and wood fuel. Loss of traditional management and ubiquitous use of flails have also severely reduced the recruitment of young trees within hedgerows. Hedgerow tree losses are almost certainly on the cusp of accelerating due to Ash Dieback (*Chalara*). Over the next 5 to 10 years, losses caused by *Chalara* are likely to dwarf losses for other reasons. (The Tree Council, 2015, also see the Woodlands chapter).

Condition

The overall condition of hedgerows in Wales is poor, with only 17% of hedgerows fulfilling all the criteria for good condition, 2% on arable land. However, the structural condition appears to have improved since 2007, with 61% of hedgerows now fulfilling the criteria for good structural condition (Figure 4).

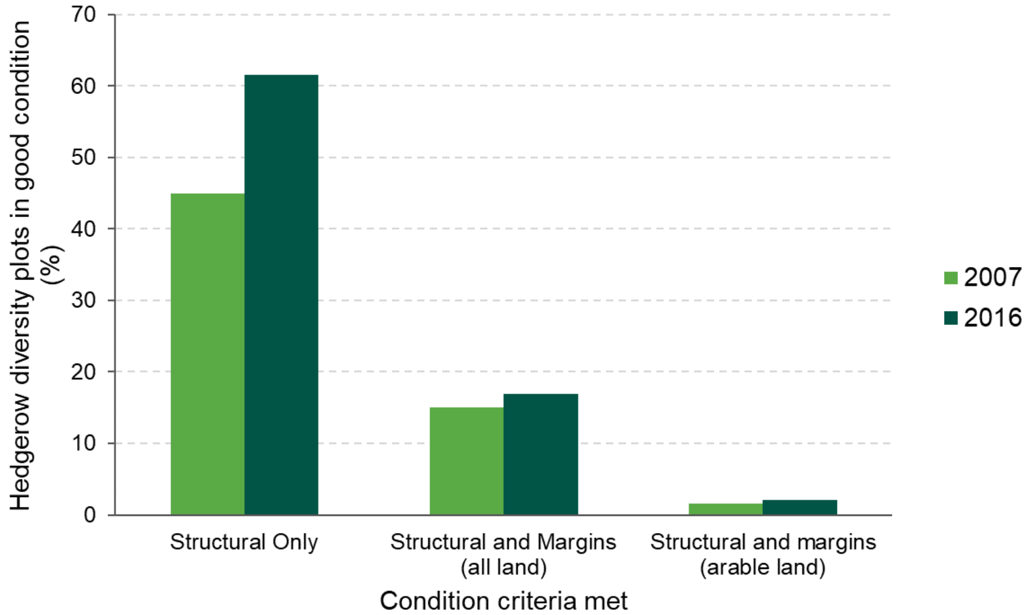


Figure 4 The percentage of 30m long Hedge Diversity Plots in managed hedges in Wales that met condition criteria in 2007 (n=406) and 2016 (n=521) (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0)

A high proportion of hedgerows are either over-managed or neglected. Current management practice is often to flail the hedge once a year (Korn et al., 2020), preventing shrubs from flowering and fruiting, and removing valuable food supply from the landscape (Figure 5). Good management practice is not well understood, with Korn et al., 2020, showing that 68% of farmers had never used any hedgerow management advice.

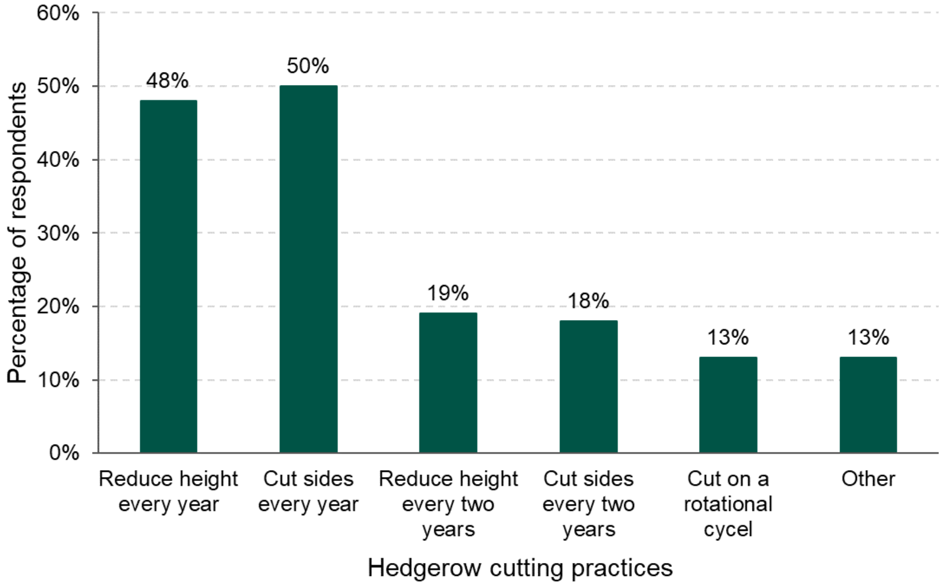


Figure 5 Current hedgerow cutting practices in Wales (Korn et al., 2020)

Hedges require long-term rejuvenation, laying or coppicing, before they become lines of trees, to ensure their continued survival and maintain key wildlife habitats into the future (Staley et al., 2015). Insufficient management of this type is occurring, and will lead to degradation of the hedge structure and loss of hedges in the long-term (Figure 6).

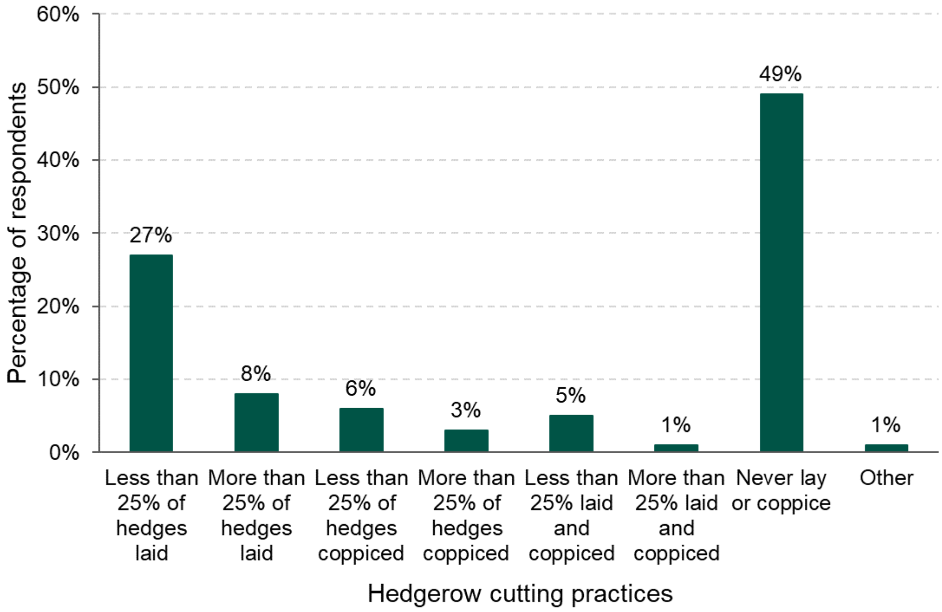


Figure 6 Hedgerow management practices as reported in a survey of Welsh land managers. (Korn et al, 2020)

Chalara represents a major threat to hedgerows, with ash trees a frequent component of the shrub level and the most common hedgerow tree species (Maskell et al., 2013). See the woodland chapter for more information. Loss of the shrub layer will create gaps and loss of connectivity. Furthermore, loss of ash standards will have a major visual impact on the landscape as well as on biodiversity (Mitchell et al., 2014) and carbon storage.

The ground flora of hedgerows often consists of residual fragments of semi-natural habitats and can be an important refuge for woodland and grassland plants and associated fauna. There is evidence that eutrophication is resulting in less diverse plant communities (Peterken and Wood, 2020). Hedgerow ground flora plots recorded in GMEP show that species that thrive in high nutrient conditions such as nettle and cleavers are becoming more frequent; 16% of plots had greater than 20% eutrophic vegetation in 2007 increasing to 42% in 2016 (Alison et al., 2020).

The future prospects for hedgerows will depend largely on the support measures available and regulation in place post-Brexit. Currently, hedgerows benefit from both agri-environment support and protection within the cross-compliance regulations.

Recent reports from the UK Committee on Climate Change and the National Farmers Union have recognised the potential for hedgerows to sequester carbon. This should lead to positive measures to increase the volume of existing hedgerows and to new hedgerows.

Parkland, Wood pasture, Orchards and Trees outside woodland

Extent

There has been no new data collected on the extent of parkland, traditional orchards or wood pasture since SoNaRR2016.

Around 200 ha of existing traditional orchards and 70 ha of newly created, traditionally managed orchards are now included within Glastir. In 2019, the extent of commercial orchards across Wales was 336 ha with a further 474 ha that includes other orchards and small fruits (Welsh Government, 2019a). It is unclear if these figures include traditional orchards, and it is undetermined how much of this is overlap.

Trees outside woodlands (TOWs) are trees that do not fall within the definition of woodland and, therefore, are not included in the National Forest Inventory. These consist of patches of trees less than 0.5 ha, strips narrower than 20 m, and lone trees (Rouquette and Holt, 2017). The total distribution of tree cover outside woodland has been estimated as 59,900 ha within the rural land category in Wales. Many lone trees are associated with boundary features, such as hedges or fences, but these have been identified separately and the figure above only includes lone trees in open land (Forest Research, 2017).

The map of tree cover in Wales indicates that TOWs can account for as much as a third of all tree canopy in some areas (Forest Research, 2017). The physical extent and connectivity of this tree canopy cover are much more significant than the figure for the tree area. They are a vital habitat for wildlife, providing ecological connectivity between patches of other semi-natural habitats through a landscape that has generally become more hostile to wildlife over recent centuries (Feber, 2017).

Analysis of GMEP data found that although trees are often present in boundaries, trees were absent from 74 to 90% of improved and semi-improved fields (Figure 7) that were surveyed across Wales (Alison et al., 2020).

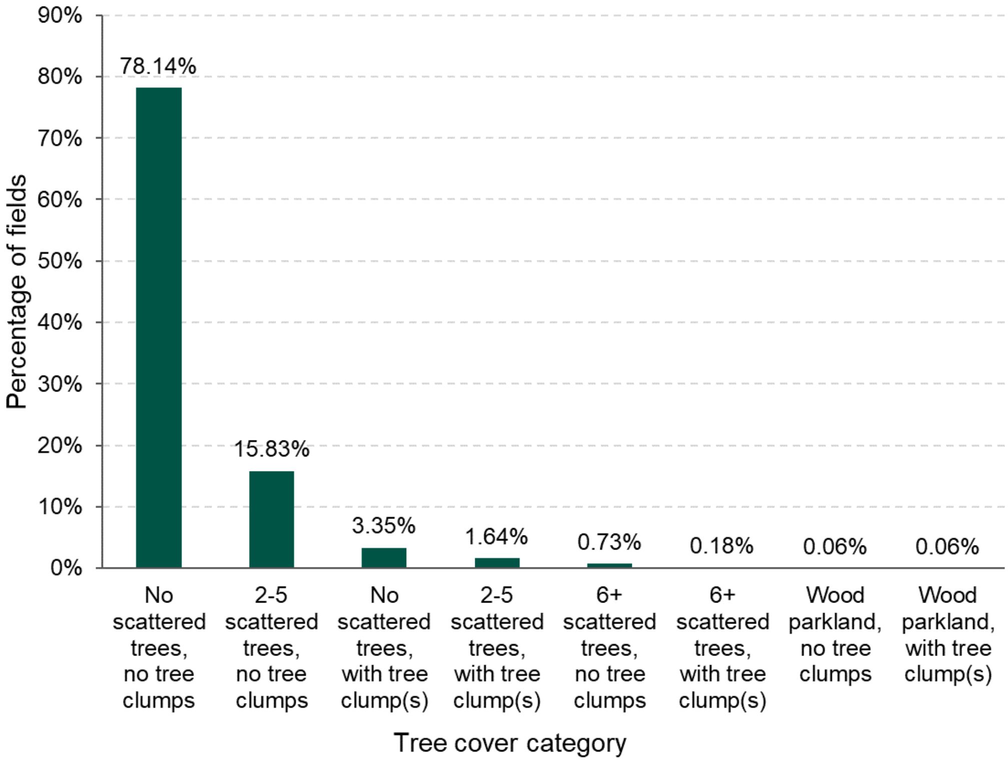
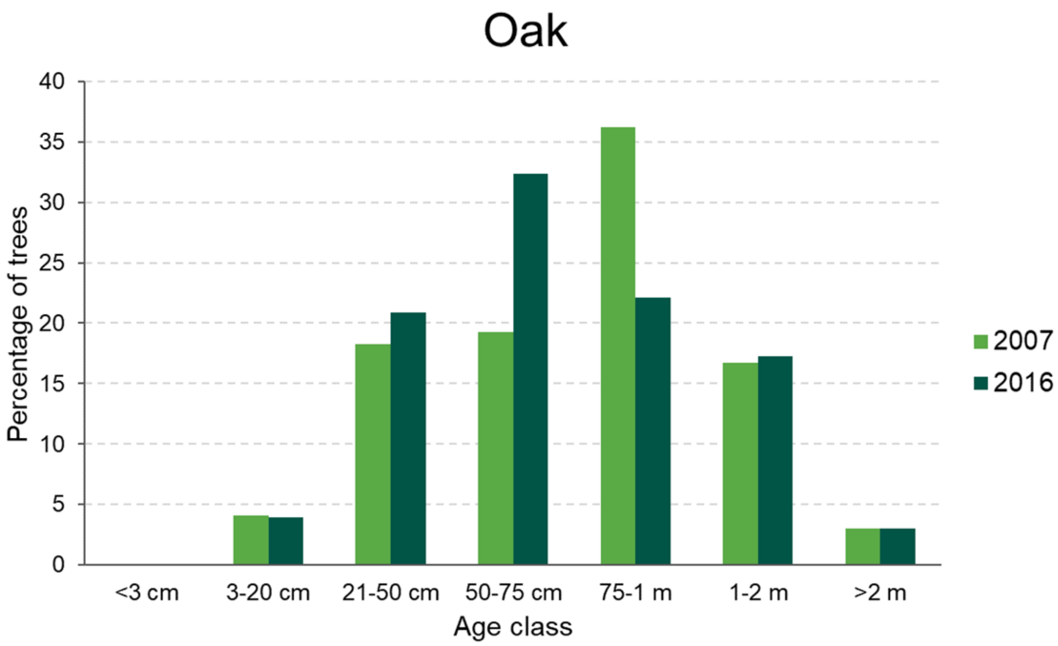


Figure 7 Percentage of large (more than 1 ha) improved grassland fields in different categories based on the presence and frequency of trees in 2016 (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0)

Ancient and veteran trees have significant intrinsic value and, as a habitat, support a great number of other species. Wales and the rest of the UK have particularly high populations of ancient trees compared with many parts of mainland Europe, making them a feature of global significance. There is no comprehensive data on the number of ancient or veteran trees in Wales. Analysis of the age distribution of trees outside woodland from GMEP shows that trees of significant age,diameter greater than 2 m, are rare in Wales (Figure 8).



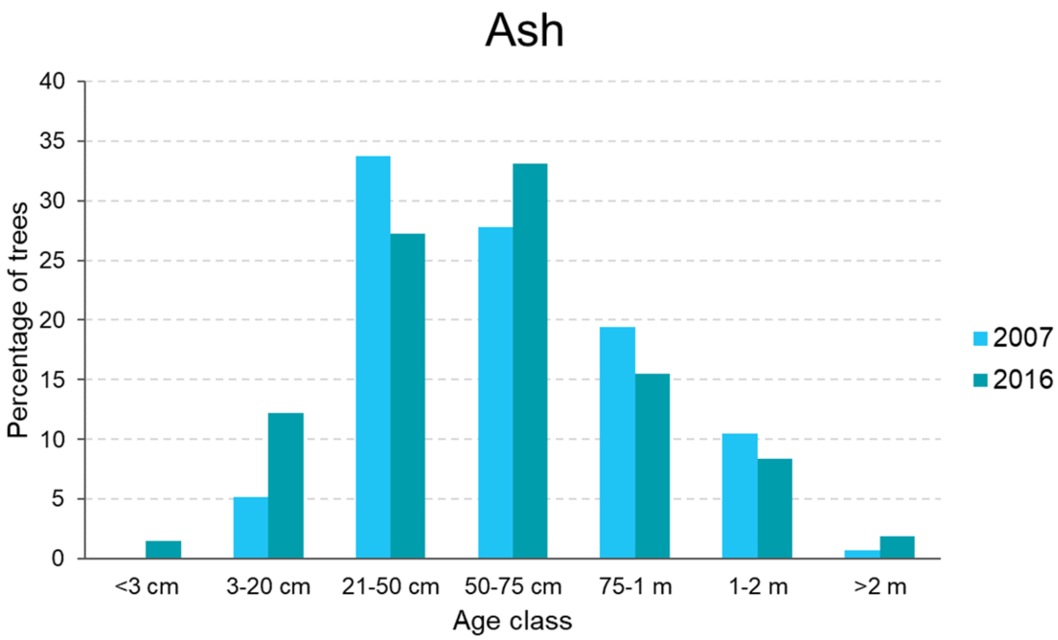


Figure 8 The distribution of trees in age classes in 2007 and 2016 for Oak and Ash (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0)

Condition

Features on veteran trees, such as wounds or decay, provide habitats for many species such as lichens, fungi and wood-boring insects. GMEP analysis of veteran tree condition found that the majority of trees surveyed had positive features such as dead wood and epiphytes. A very small proportion, less than 3%, however, had buffers around their bases to protect them from damage during farming operations (Alison et al., 2020).

The species-rich lichen communities found on veteran trees are declining in Welsh farmland. Nitrogen deposition, in particular, is having a negative impact.

Studies at Dinefwr Park SSSI and Gregynog SSSI show that diverse lichen communities are lost from tree trunks exposed to nitrogen enrichment (Bosanquet, 2019). The lichen *Anaptychia ciliaris* is identified through the Environment (Wales) Act 2016 section 7 list as a species of key significance to sustain and improve biodiversity in relation to Wales. It illustrates the decline in specialist veteran tree lichens.This lichen has been lost from 5 of its 11 known Welsh sites due to tree felling or nitrogen pollution and is being smothered by nitrogen-loving algae at a sixth site. Of the remaining locations, the lichen is found on ash trees that are vulnerable to *Chalara* (Bosanquet, 2019).

There is inadequate young tree recruitment to replace existing stock; this is often caused by grazing pressure but also by lack of replacement planting in parkland and orchards. Uptake of agroforestry options to create new wood pasture within Glastir have been very low with less than 10 ha funded between 2015 and 2018 (Welsh Government, 2019b).

Ash is one of the commonest species of tree outside woodlands. Although at risk of *Chalara* there are signs of resistance within the population as nowhere across Europe has yet reached 100% mortality. Natural woodlands are showing lower levels of mortality than plantations and natural regeneration has low mortality rates in some regions (Coker et al., 2019).

A significant number of traditional orchards and parklands (Oram et al., 2014) are being abandoned; the resulting lack of management is detrimental to their condition and long-term existence.

There is a risk of intensification to the ground flora of parkland, wood pasture and orchards; cultivation, fertiliser and pesticide application all reduce the diversity of plant species.

Soils

Extent

Modelling of the loss of high-quality agricultural land using the Agricultural Land Classification (ALC) system was undertaken by ADAS in 2019. It estimated that in 2011 Best and Most Versatile (BMV) agricultural land, grades 1, 2 and 3a, covered 18% of the land in Wales (Lewis-Reddy and Behrendt, 2020). This does not take account of areas at risk of flooding and frost that will downgrade land further as many BMV soils are alluvial in valley bottoms. The actual figures may be closer to

10-15% (J Cooke, 10 August 2020, personal communication). Due to the co-location of urban areas and high-grade soils, urban expansion has often been at the expense of the most productive land. The total loss of BMV land over the period 1939 to 2011, was 21,300 ha, 6.7% of the resource. The predicted annual loss of BMV land to urbanisation over the next five decades is expected to be minimal when compared to historical losses: an estimated 125 ha, on average, of BMV land will be lost to urbanisation per annum over the period 2018 to 2065 (Lewis-Reddy and Behrendt, 2020).

Condition

There is a growing appreciation of soil condition and the impact it has on food production and carbon sequestration, although there are currently no agreed indicators for measuring and reporting on soil condition. Data from GMEP provides metrics for trends in a set of soil properties as set out in Figure 9 (Alison et al., 2020).

Nitrogen and phosphorous concentrations show a downward trend in arable and improved grasslands, the decrease is significant for phosphorous and nitrogen in improved grassland after 1998, mirroring the trend in manufactured fertiliser use.

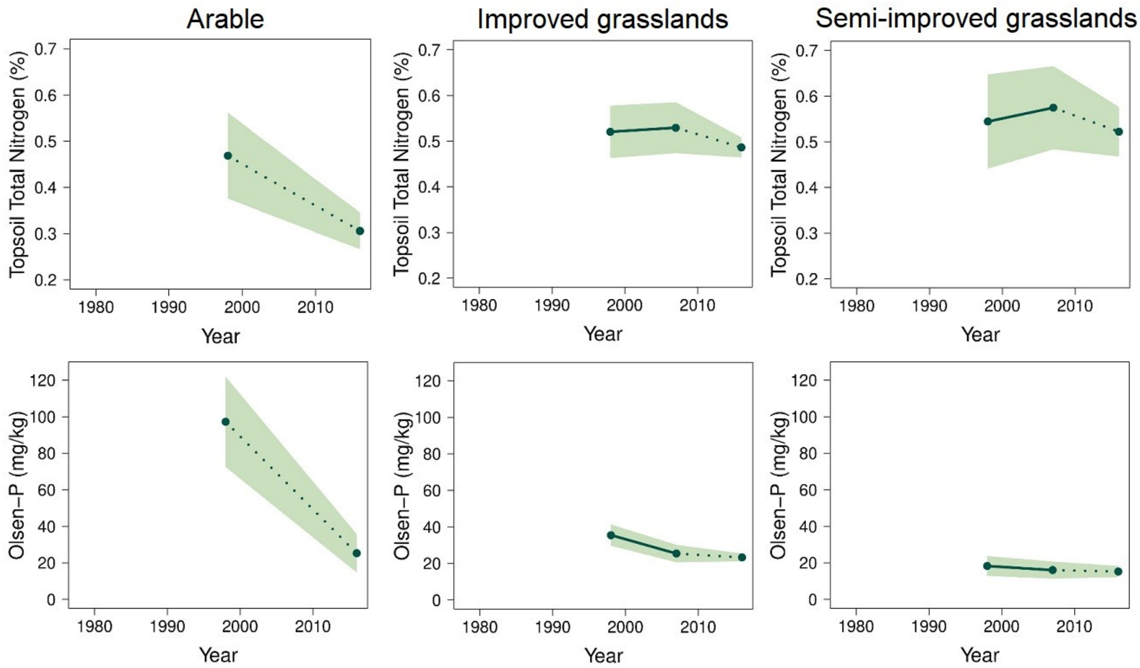


Figure 9 Trends in soil nitrogen and phosphorous concentrations across arable, improved and semi-improved grassland. Green dots and lines represent estimates, light green areas represent 95% confidence intervals (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0).

There has been a decrease in soil pH since 2007 on improved grassland, due to current low levels of lime usage, and an increase on semi-improved grassland since 1978 (Figure 10). On average, soil pH remains below recommended levels for sustained production in improved land (Alison et al., 2020).

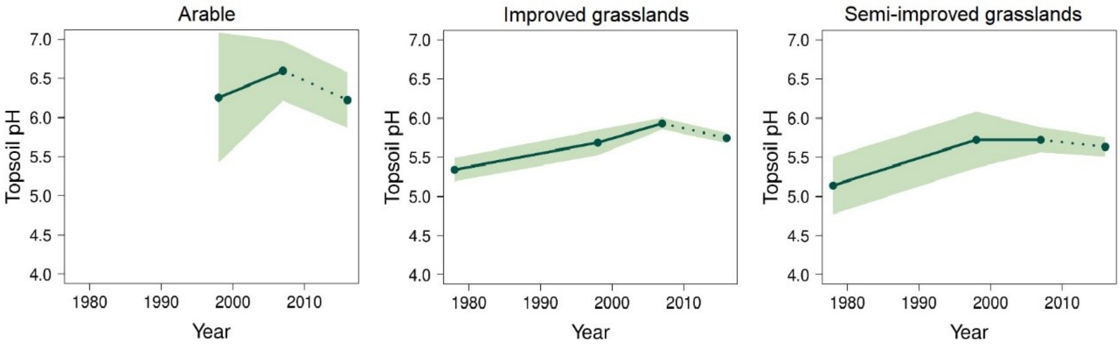


Figure 10 Trends in soil pH across arable, improved and semi-improved grassland. Green dots and lines represent estimates, light green areas represent 95% confidence intervals (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0) .

Soil carbon concentrations in topsoil appear to be stable with no significant changes (Figure 11; Alison et al., 2020). Arable land has the lowest carbon concentrations; this is unsurprising as loss of soil carbon is triggered by removal of organic matter and soil disturbance. Absolute total organic matter content of soils is unknown as most studies have only focused on the top 15 cm of soil.

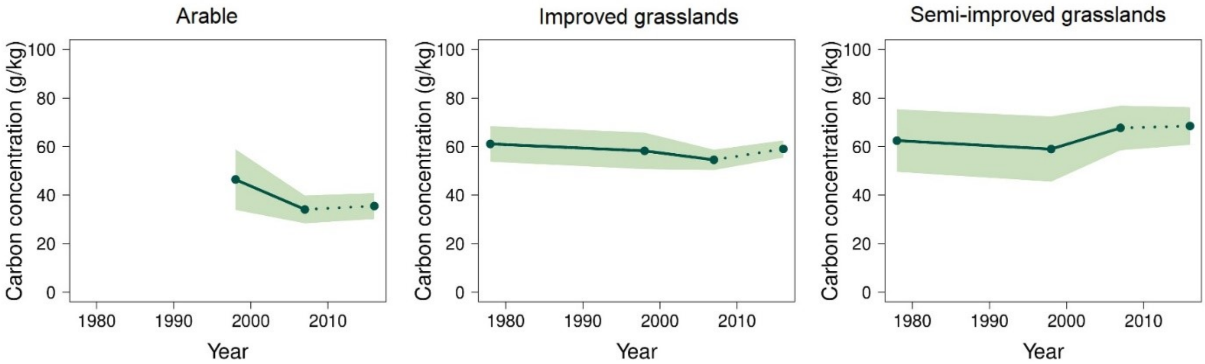


Figure 11. Trends in soil carbon concentrations across arable, improved and semi-improved grassland. Green dots and lines represent estimates, light green areas represent 95% confidence intervals (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0).

Analysis of bulk density, a measure of soil compaction, within GMEP (Alison et al, 2020) showed the highest values in improved grassland but with a significant decrease since 2007 (Figure 12). See the Land use and soils chapter for more information. This may indicate reduced compaction of improved soils in Wales. However, these results are contradicted by other studies on compaction in grassland soils reported for England and Wales that show 10-15 % of sites were in poor condition and 50-60% in moderate structural condition (Cranfield Soil and Agrifood Institute, 2016). Anecdotal reports suggest that there could be issues around increased reliance on contractors, preventing operations being timed for optimal weather conditions.

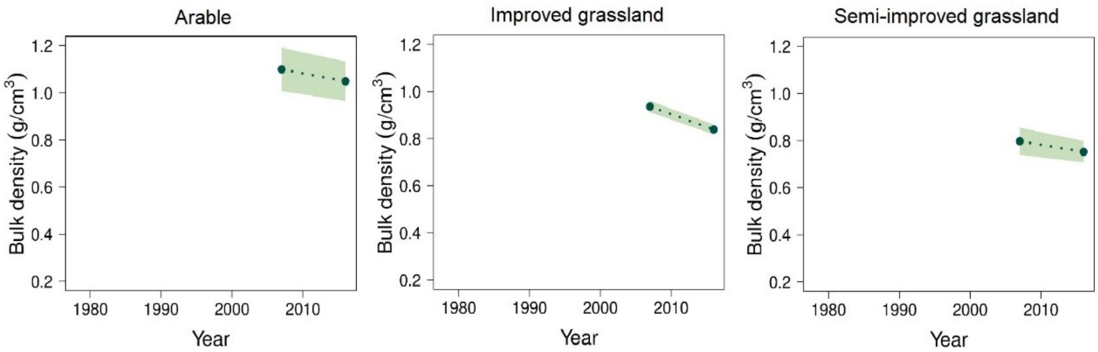


Figure 12 Trends in soil bulk density across arable, improved and semi-improved grassland. Green dots and lines represent estimates, light green areas represent 95% confidence intervals (Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0).

There is no direct evidence of erosion rates or frequency in Wales. Soil is most vulnerable to erosion when soil cover is sparse, especially when intensive rainfall is more common. High stock density, outdoor wintering of livestock and associated impacts can cause compaction and poaching, which may also promote soil run-off and erosion (ADAS, 2019a).

Participation in Glastir has increased management to prevent soil erosion and run-off, specifically leaving stubble in fields over winter, 59% within scheme vs 44% outside, and the establishment of buffer strips on arable land, 42% within scheme vs 16% outside. Glastir has also raised the uptake of soil nutrient testing, 61% vs 51%, and the likelihood of calibrating fertiliser spreaders, 72% vs 62% (Anthony et al., 2017) See the Land use and soils chapter for more information.

Soil Biodiversity

Intensive land management has a large impact on the organisms that live in the soil. A genetic metabarcoding analysis across different Welsh ecosystems shows that below-ground animal and microbial richness have divergent responses to soil properties and land use intensification. High microbial richness is found in arable and intensive grasslands, is suggested to be influenced by soil nitrogen levels and regular disturbance. However, soil animal richness was lowest in the most intensively managed crop sites in comparison to infertile grasslands which have the greatest diversity (George et al, 2019). See the Land use and soils chapter for figures and semi-natural grasslands chapter for more information.

Biodiversity

Agricultural intensification and specialisation have simplified the farmed environment and created a domain for few species where once there was abundant diversity. Of the 1,467 flowering plants in the Welsh flora, 38 are extinct and 302, 20.6%, are considered to be threatened or nearly so in Wales since 1800, 95% of which grow on productive farmland (Plantlife, 2014). A typical improved field will be home to only around seven different species of wild plants, and an intensive arable field home to around six (Figure 13). By contrast, an established well-managed meadow could contain 160 species; a diversity that sustains a wealth of pollinators and other wildlife.

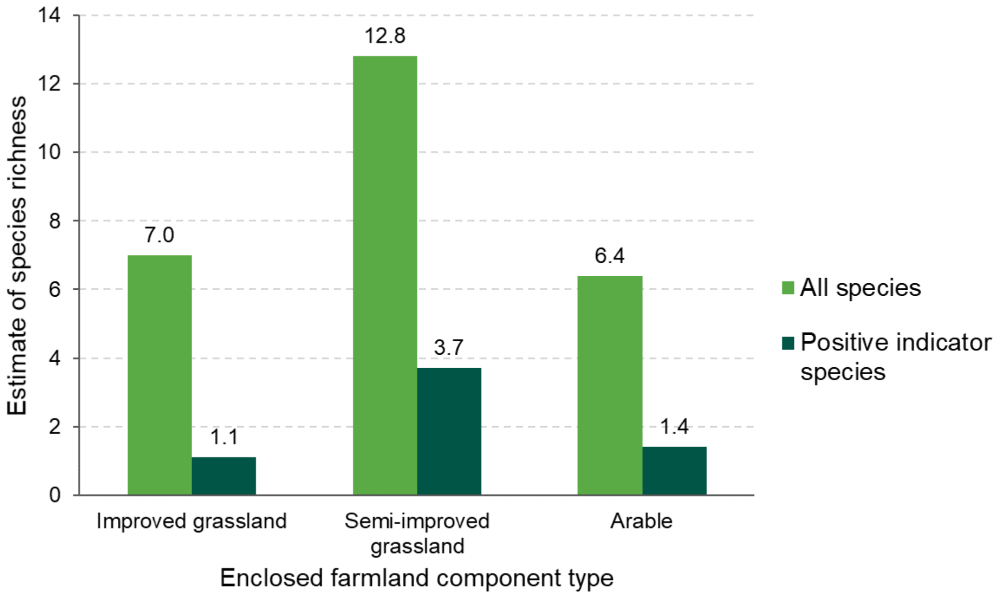


Figure 13 Estimates of species richness in vegetation plots from GMEP 2016, excluding non-native species. Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0.

Arable flora

Once so abundant they were a significant burden to farmers, several wild arable flowers, such as the shepherd's-needle, are now practically extinct (Plantlife, 2012). Over 120 plant species make up the flora of arable land in Wales but, despite their role in sustaining farmland wildlife, wild arable plants are the fastest declining group of plants (Plantlife, 2012). Changes in farming practices since the Second World War, including the increased use of herbicides and inorganic fertilisers, efficient seed cleaning, more competitive crop varieties and changes from spring-sown to autumn-sown cropping, have taken their toll (Wilson and King, 2003). The conversion of arable land to permanent pasture is a particular problem. As a result, arable flowers such as corn buttercup, red hemp-nettle and small-flowered catchfly are now highly endangered (Walker et al., 2017).

Wales also has a diverse arable bryophyte, mosses and liverworts; a GB-wide survey found the most diverse site to be located in south-east Wales (Preston et al., 2010). However, there have been long-term national declines in bryophytes of arable land such as *Anthoceros agrestis* (Callaghan and Hodgetts, in press). The long-term shift from spring to autumn cultivation has had a detrimental impact on the survival of many arable bryophytes that produce spores in late winter.

Plants are the basis of ecosystems, and extensive loss of flowering plants from the enclosed farmland landscape has far-reaching implications for other groups such as insects, birds and mammals. There is global concern that invertebrate populations are declining rapidly, particularly in agricultural habitats. See the biodiversity chapter for more information. Declines have been attributed to the intensification of farming systems, with many studies focussing on a lack of semi-natural habitat in the landscape and the use of insecticides. However, within-field arable weeds are also an important driver of invertebrate abundance and the ecosystem services to which they contribute (Smith et al., 2020a).

Pollinators

Many species of wild pollinator, including bumblebees, solitary bees and hoverflies, are under threat (Goulson et al., 2008; Powney et al., 2019). Biesmeijer et al. (2006) found significant UK landscape-scale declines in native bee species richness. Both hoverfly and bee communities have gradually become dominated by a few common species, with 29% fewer bee and hoverfly species occurring in Britain since 1980. Other studies have shown similar trends, for example, Powney et al. (2019) estimate a net loss of over 2.7 million occupied 1 km^2 grid cells in Great Britain across all wild bee and hoverfly species between 1980 and 2013. Reliance on a small group of pollinators for plant pollination is not advisable as the community may not be resilient to future variations in climate, resource provision and disease outbreaks.

There are a number of pressures on pollinator populations, including the loss of basic habitat requirements in landscapes such as breeding sites, floral resources, the promotion of monocultural crops, larger fields and less traditional boundary features, and the intensive use of agro-chemicals.

Brown hairstreak butterfly

The brown hairstreak butterfly has undergone a 43% contraction of its range since the 1970s and monitored populations in Wales are showing large recent declines (Figure 14) (Butterfly Conservation, 2020). The butterfly’s main habitat requirements are for young blackthorn shoots. Mechanical flailing of hedges or scrub during the September to February period has been shown to remove 80-90% of eggs. If hedges are mechanically flailed year on year, the remaining population vanishes within a couple of years.

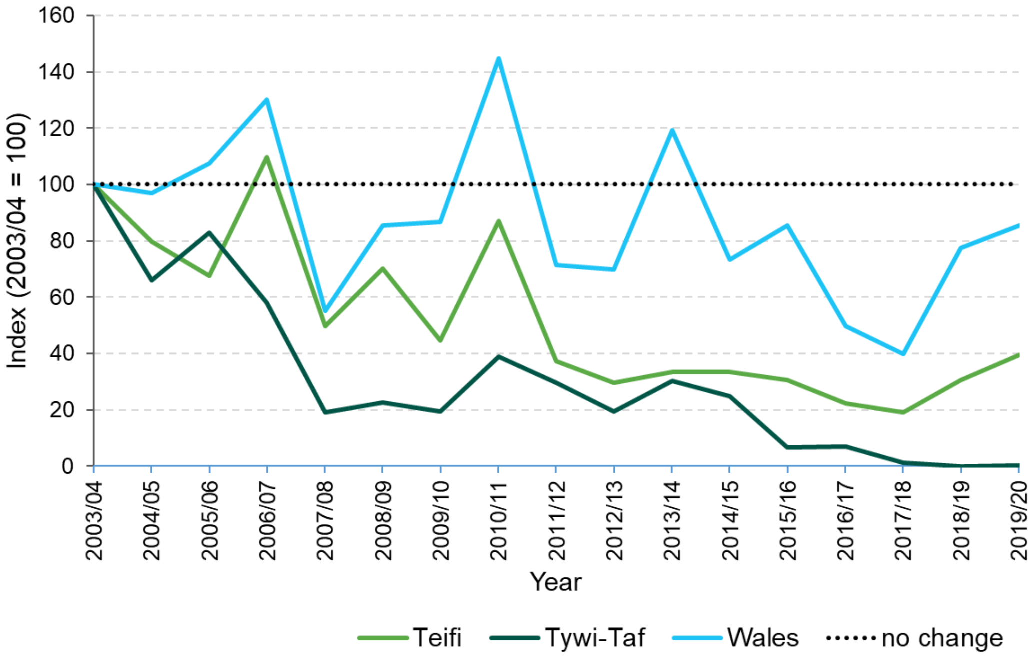


Figure 14 Brown hairstreak butterfly populations around the Teifi and Tywi-Taf monitored between 2003 and 2018 (Butterfly Conservation, 2020).

Lowland Farmland Birds

The lowland farmland bird indicator for Wales, 1994-2016, highlights the accelerating declines in birds of farmed habitats. The lowland farmland indicator has fallen by nearly 30% since 1994 (Figure 15). For example, between 1995-2016 starlings have declined by 72%, curlew by 63%, yellowhammers by 58% and both turtle dove and corn bunting are virtually extinct as breeding birds in Wales (Bladwell et al., 2018).

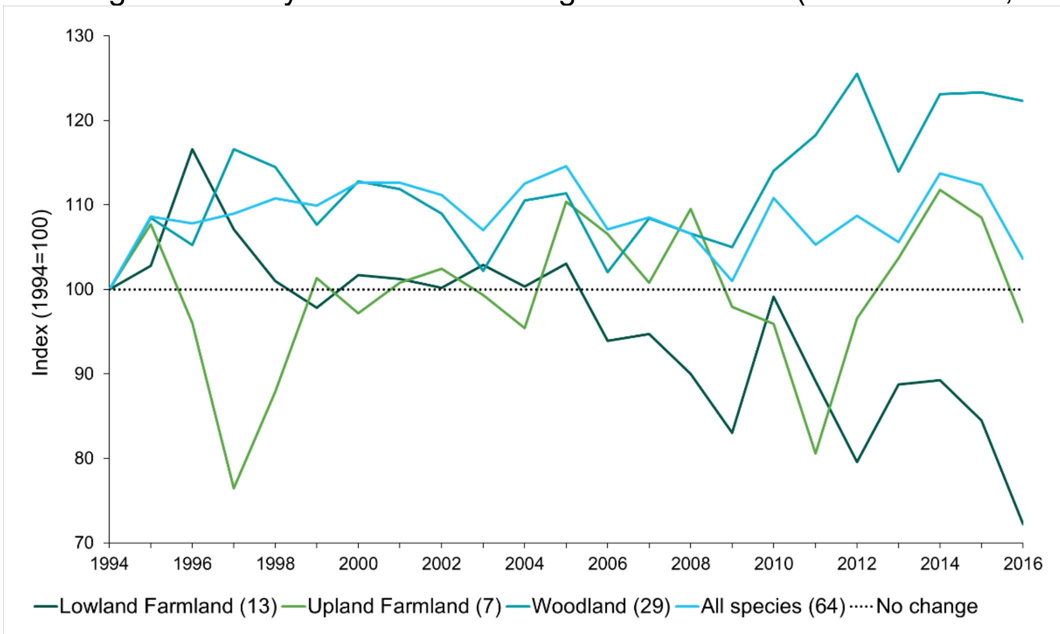


Figure 15. Bird population indices for Wales (Bladwell et al., 2018)

Of the eight ecosystems, lowland farmland bird species on the Section 7 list show the worst long-term trends in range (Figure 16), with six declining in range by more than 25% over the longer-term period, 1970–2010, and four, grey partridge, yellow wagtail, turtle dove and tree sparrow, by more than 50% (Bladwell et al., 2018).

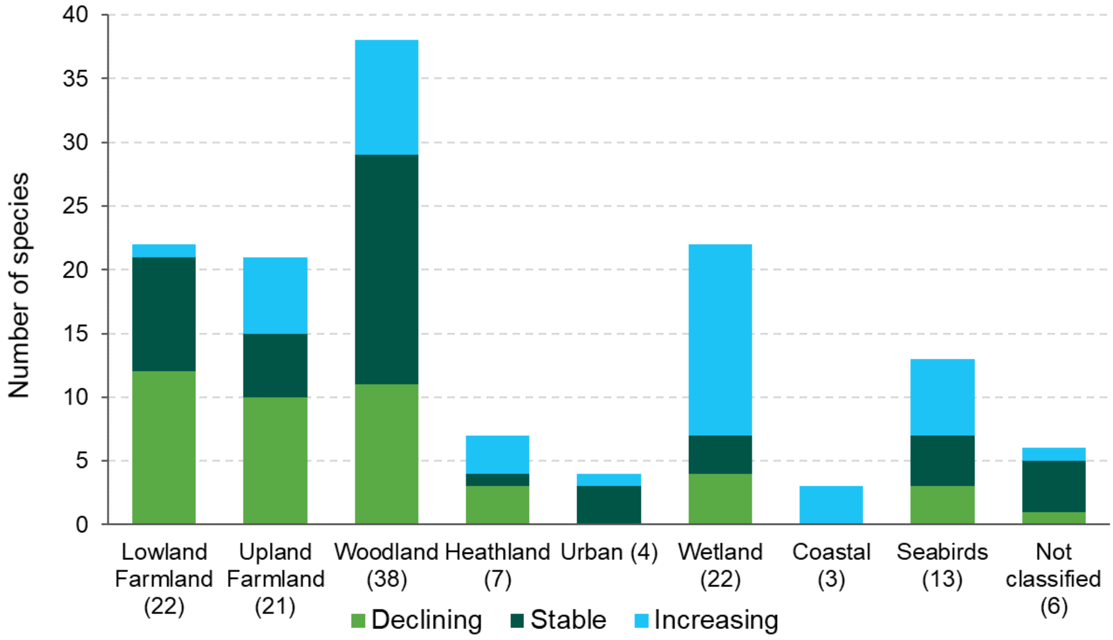


Figure 16. Wales Long-term Bird Indicator, based on changes in range in all breeding bird species between the 1968-71 and the 2007-11 Bird Atlases. (Bladwell et al., 2018)

Agricultural management during the period of the index has had the greatest impact on farmland birds through the loss of seed and invertebrate dietary resources.

Greater Horseshoe bats

Studies have shown that the diet of the greater horseshoe bat is dominated by cockchafer beetles, dung beetles and moths. The use of antiparasitic drugs, such as avermectins, negatively affects dung beetle populations and can therefore impact juvenile and adult survival. By managing the usage of avermectins in the cattle which graze areas close to greater horseshoe roosts, and ensuring cattle are moved at appropriate times of the year closer to summer roosts and winter hibernation sites, positive trends in survival and population growth (Figure 17) have been recorded (Ransome, 1996; Ransome, 1997).

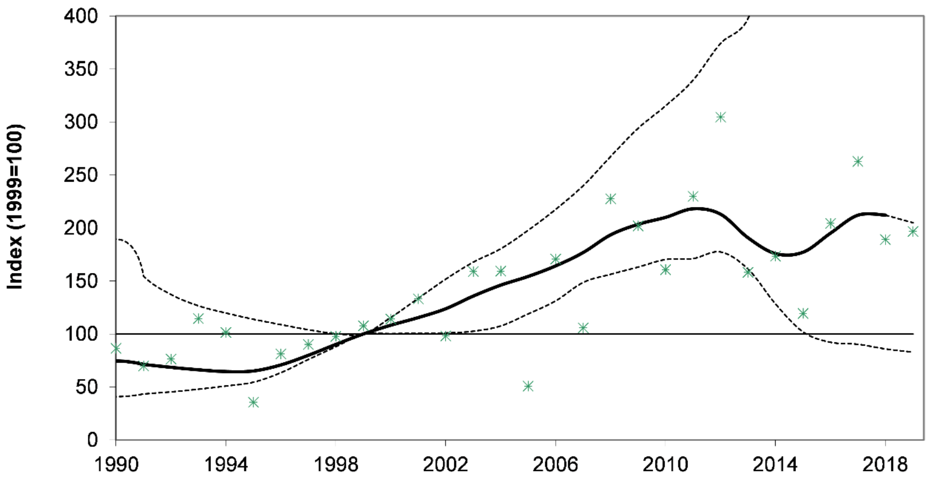


Figure 17 Wales's index of greater horseshoe bat population from Hibernation Surveys showing the unsmoothed index value for each year (green crosses), the smoothed trend (solid line) and 95% confidence intervals (dotted lines). The smoothed trend for 2018 is shown as a dashed line to indicate that it is provisional (Bat Conservation Trust, 2019).

In agricultural landscapes, biodiversity is greatest where there are heterogeneous habitats over multiple scales of space and time (Benton et al., 2003). Biodiversity that is dependent on farmland requires a landscape with greater structural diversity, more flowering plants, and more invertebrates both above and below ground. The small shifts towards more sustainable, varied swards, managed with less artificial inputs, are beneficial. Any driver that leads to further loss of diversity and more inputs to the system would be detrimental.

Drivers of change

The negative trends in biodiversity and ecosystem functions are projected to continue or worsen in response to indirect drivers such as rapid human population growth, and unsustainable production and consumption (IPBES, 2019).

Although the Welsh population is forecast to remain relatively stable, population growth across the UK is projected to be 9% over the 25 years between 2018 and 2043 (Office for National Statistics, 2019). This will drive an increased demand for food production whether this is from within the UK or overseas.

Intensification and unsustainable agricultural practices to fulfil this need would exacerbate the current issues that affect many ecosystems and natural resources (Table 5)

Table 5 Ecosystems impacted by activities within Enclosed Farmland.

Impact	Where felt
Direct nutrient enrichment	Enclosed Farmland
Nutrient run-off	Freshwater, wetlands. See freshwater and mountains, moorlands and heaths chapters.
Pesticide run-off	Freshwater. See freshwater chapter.
Sediment run-off	Freshwater, wetlands, coastal and marine See freshwater, marine and mountains, moorlands and heaths chapters.
Biodiversity loss	Habitat and species loss from all terrestrial and freshwater ecosystems. See biodiversity chapter.
Greenhouse gas emissions	Climate change impact on all ecosystems. See climate change chapter.
Ammonia and NOx emissions	Nitrogen deposition impact on all ecosystems. See air quality chapter.

Changes to production systems over the last decades have mostly been driven by economic pressures and policy change. Future prospects relating to agricultural pressures are particularly difficult to assess currently due to uncertainties surrounding the impacts of Brexit. Management and land use changes are highly likely as a result of changing economic markets and subsidies. See Land use and soils chapter for more information.

Altered water availability due to climate change, see climate change chapter, is forecast to increase the risk of more frequent prolonged periods of dry weather during late spring and summer and higher rainfall during the winter months. Intense rainfall can lead to an increased risk of soil saturation, standing water and flooding.

These changes are likely to have an impact on all vegetation, but productive grassland is particularly vulnerable because of its low diversity. Perennial rye grass, *Lolium perenne*, is poorly adapted to drought conditions (Cyriac et al., 2018) and has low survival rates following flooding events (McFarlane et al., 2003). Given that perennial rye grass is the predominant species in productive grasslands, sometimes to the exclusion of all other species, drought and flooding are likely to have a large impact on the availability of forage. Although new longer-rooted hybrids of *Lolium* and *Festuca* grasses, *Festulolium*, are being developed that are better able to cope with drought conditions and also increase rainfall infiltration rates (Macleod et al., 2013).

Prolonged periods of dry weather and higher rainfall in winter and spring are also likely to drastically alter the ability of the land to grow crops (Figure 18) (Bell et al., 2020).

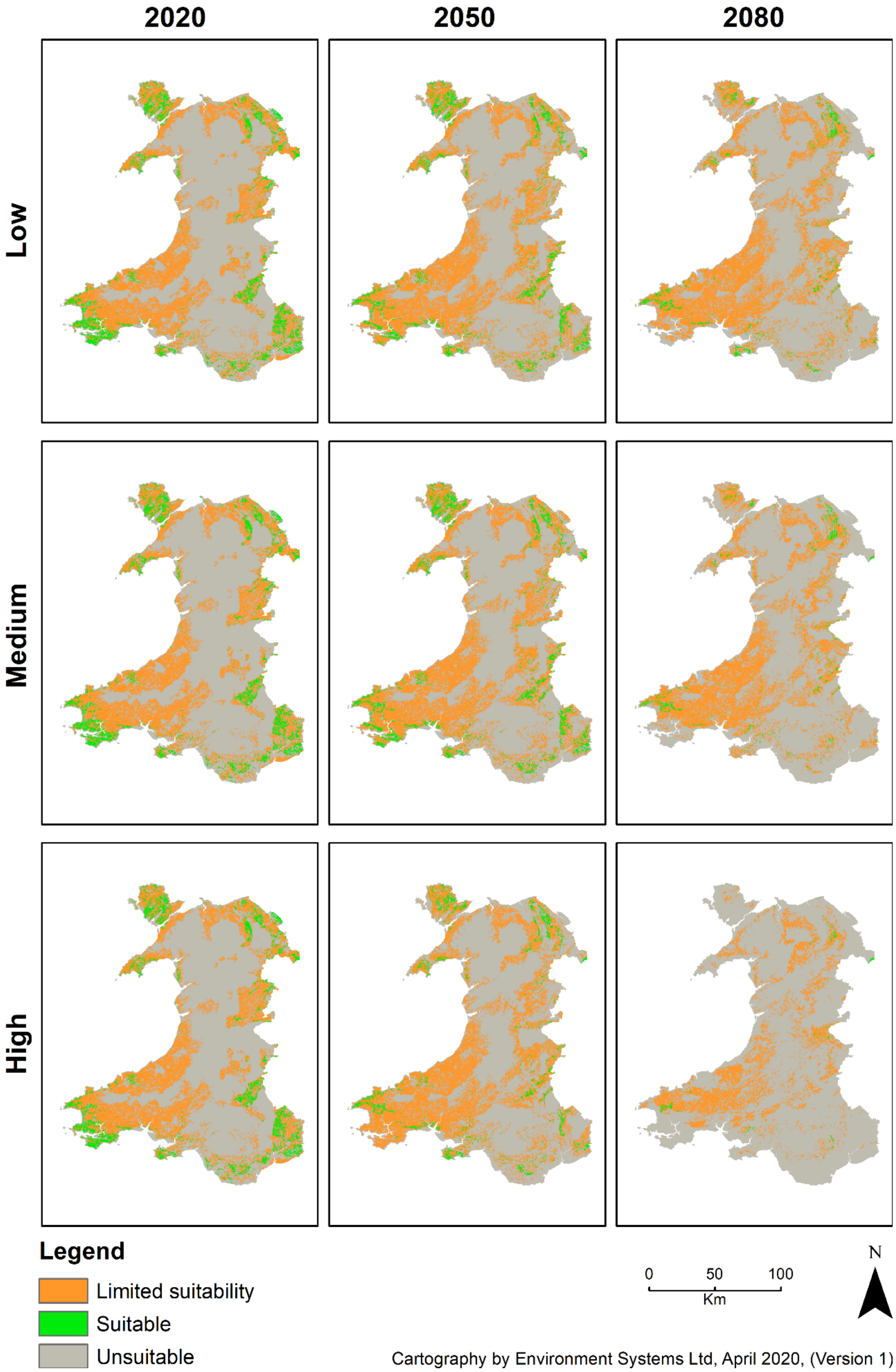


Figure 18 Overall suitability for potato growing on a commercial basis modelled for three climate change scenarios for 30 and 60 year projections. Bell et al, 2020.

4. Assessment of Resilience (Aim 2)

Resilience in the enclosed farmland landscape varies between the different components and attributes.

Improved grassland, as the predominant land cover, has the largest impact. Although covering a large area and forming connected blocks, resilience is low due to the reliance of an extremely low number of species within the grassland and high external inputs. Management techniques that reduce inputs, improve soil condition and reduce impacts on surrounding ecosystems, such as the use of legumes instead of inorganic nitrogen, precise nutrient application and introducing deep-rooted plants into sward mixes, help to improve the condition and resilience of the ecosystem.

Biodiversity in intensive arable systems is very low; cropping relies on monocultures with extremely limited native plant cover. Alternative systems with higher crop diversity such as intercropping are rare. Current arable systems rely on high external inputs. Traditional arable land has a high diversity of wild plants but covers an extremely small area in Wales and is highly fragmented.

Hedgerow diversity, both species composition and structural, is variable but can be extremely high. The condition of hedgerows is generally poor which, particularly when gaps in the length occur, can have a negative impact on connectivity. Hedgerow connectivity is naturally high; the majority of hedgerows connect together and often have associated features such as ditches, verges and banks. However, *Chalara* has the potential to create more gaps in hedgerows and kill hedgerow trees, thereby reducing resilience.

Other woody habitats within enclosed farmland, wood pasture, parkland, orchards and individual trees, can also be highly diverse in terms of structure, species mix and supported biodiversity. Condition is low due to several pressures. Connectivity is more variable; wood pasture, often found in ffridd landscapes, can be well connected but traditional orchards and parklands are highly fragmented. For species dependent upon veteran trees, connectivity over time is a serious concern as veteran trees lost without replacements nearby can lead to local extinctions.

Looking at the enclosed farmland as a whole, creates a picture of a landscape simplified by farming-system specialisation and production intensification. Fragments of semi-natural habitat persist in a matrix of highly modified landcover. Low diversity of land cover and structure leads to low resilience. Semi-natural grassland, trees, hedgerows and other habitats all add species and structural diversity to the landscape, therefore increasing ecosystem services, reducing the impact of food production on surrounding ecosystems and ultimately increasing resilience. See more about ecosystem services in Healthy places for people (Aim 3) and Regenerative economy (Aim 4).

Many farmland species depend upon different components in the landscape to provide the requirements for their whole lifecycle. The reduction of this diversity is contributing to significant declines in farmland species. See Lowland Farmland Birds

Table 6 SoNaRR2020 Ecosystem Resilience Assessment: Attributes of resilience of each enclosed farmland habitat unit

Practical habitat unit	Diversity	Extent	Condition	Connectivity
Improved land	**Low** Often very low – these are heavily modified habitats with dominance of a few species.	**High** Very high – half of Wales's land surface.	**Low** Generally low – high input/output systems dominate.	**High** Although superficially high, the low condition and diversity mean that suitable habitat is fragmented for many species. Acts as a barrier to dispersal for many species.
Arable land	**Low** Generally low in intensively managed systems. High biodiversity in traditional systems has largely been lost and remnants are very vulnerable.	**Medium** Large historical loss, but small increases recently. High-diversity areas are rare and under threat from intensification.	**Low** Generally low – high input/output systems dominate.	**Low** Poor. Spatial and temporal connectivity has been largely lost.
Hedgerows	**High** Variable – high in ancient hedgerows, medium in Enclosure hedgerows. Variable in ground flora.	**Medium** Historical loss, more recently stabilised.	**Low** Generally poor. Issues with management, high inputs and tree diseases. Eutrophication of ground flora.	**High** Naturally very high, although often affected by gaps in length.

Practical habitat unit	Diversity	Extent	Condition	Connectivity
Parkland, Wood Pasture and Individual Trees	**High** Structurally diverse. Species diversity is high.	**Low** Parkland – low Wood pasture – unknown Loss of individual trees.	**Low** Unknown/low Issues with air pollution, inputs and tree recruitment.	**Medium** Parkland – highly fragmented. Wood pasture – connectivity in the ffridd is often good. Individual trees are often isolated.
Traditional Orchards	**High** High in traditional systems, but diversity poorly maintained.	**Low** Substantial loss historically, with newly created orchards of less biodiversity value than traditional sites.	**Low** Limited management of traditional sites.	**Low** Traditional sites very small, although often occurring in concentrations.

5. Healthy places for people (Aim 3)

The Regulating and Cultural ecosystem services for well-being provided by enclosed farmlands ecosystems are outlined in Table 7 and Table 8 below. They are developed from the set of services and definitions of the UK NEA Conceptual Framework (Mace et al., 2011). The Wales assessment is our current interpretation based on expert opinion.

Table 7 Regulating ecosystem services provided by Enclosed Farmland Ecosystem in Wales.

Regulating Services	Level of importance	Description
Climate	High	Strong negative score: emissions of greenhouse gases.
Water quantity	High	Important for catching water for ground and surface waters, though flood risk, mitigation potential often compromised by management.
Disease and Pests	High	Positive for biological pest control. Negative as crop and stock densities increase disease transmission.
Pollination	Medium	Strong negative score: rapidly declining invertebrate populations.
Water Quality	High	Negative impacts on water quality as a result of diffuse pollution and sediment run-off.
Air Quality	Medium - High	Strong negative impact from ammonia emissions.

This table is adapted from that in UKNEA synthesis (UK National Ecosystem Assessment, 2011).

Table 8 Cultural ecosystem services provided by Enclosed Farmland Ecosystem in Wales.

Cultural services	Level of importance	Description
Employment	Medium - High	Farming and associated industries are important to economics of rural communities.
Sense of place and aesthetics	Medium - High	Farming management is largely responsible for the landscapes that many people cherish.
Leisure	Medium	Farmland is widely used for walking, running and horse riding.

This table is adapted from that in UKNEA synthesis (UK National Ecosystem Assessment, 2011).

Regulating services

The large area of Enclosed Farmland gives it a potential key role in regulating services. However, current agricultural management often generates emissions of greenhouse gases and releases nutrients to air and water, resulting in Enclosed Farmland causing net disbenefits to many services.

Climate regulation

Soils within Enclosed Farmland store a large quantity of carbon. See the Land use and soils chapter for more information. These soils can be stable, actively sequestrating carbon or releasing carbon to the atmosphere (ADAS, 2019b). Current evidence from GMEP suggests that carbon stores on productive land are stable (State and Trends (Aim 1)). The direction of carbon flow can be influenced to a certain degree by management. Although large increases in soil carbon are unlikely, management can maintain soil carbon or uplift equilibrium levels.

Hedges and trees can store and accumulate significant amounts of carbon both in biomass and soil carbon. Hedges left uncut may accumulate up to 7 tonnes Carbon per hectare per year (Axe et al., 2017). Extending tree cover and allowing hedges to increase in volume has the potential to contribute significantly towards targets for carbon sequestration and storage (Walter et al., 2003). Alternatively, hedges can be cost-effectively cropped for wood fuel, substituting for fossil fuel use (Westaway et al., 2013).

In 2018, agriculture is estimated to have contributed around 14% of total Welsh greenhouse gas (GHG) emissions. These are dominated by methane, at 62%, and nitrous oxide, at 28%, with only 10% of sector emissions as carbon dioxide (Welsh Government, 2019c; NAEI, 2020a). The majority of methane emissions are associated with livestock and nitrous oxide associated with fertiliser use in the agriculture sector. Emissions from soils are also an important source, caused by the application of manure, digestates from anaerobic digestion, and manufactured fertiliser, especially urea-based fertilisers (Richmond et al., 2020).

The aim for a Low Carbon Wales is for the agriculture sector emissions to reduce by 28% from baseline 1990 levels to the year 2030 through improved efficiency of livestock production; improved crop and nutrient management; and improved on-farm fuel and energy efficiency (Welsh Government, 2019c). The National Farmers Union has also set a goal of reaching net zero GHG emissions across the whole of agriculture in England and Wales by 2040 (NFU Cymru, 2020).

Water resources

Due to its large expanse, Enclosed Farmland contributes significantly to water collection and storage, although storage capacity may be greatly reduced by intensive management (see Flood alleviation below).

Flood alleviation

Enclosed Farmland has a potentially large role to play in flood alleviation. Farmland flood plains store water and slow the flow downstream. Within Wales, 1229 km^2 of productive land is on a flood plain, with 4-9% being arable land and 50-51% improved grassland (Rothero et al., 2018). However, rivers in Wales are generally poorly connected to their flood plains and many rivers running through farmland have been significantly straightened in the past. See the Freshwater chapter for more information.

Land management has a large impact on the speed at which water reaches rivers and streams. Plant cover, root architecture, drainage, field boundaries and soil condition all contribute to speeding up or slowing the movement of water across farmland. Much agricultural land is drained; this can increase the flood risk downstream. Other issues such as soil compaction, due to high levels of stock grazing or machinery use, and sediment deposition can also increase the speed of water run-off.

Areas of less intensively managed land within enclosed farmland can have a positive impact. For example, hedgerows can reduce the volume and rate of water moving downslope by acting as physical barriers and increasing water penetration into the ground (Wolton et al., 2014). Evidence shows that hedge networks can reduce peak flows of nearby watercourses following heavy rainfall by up to 50% (Benhamou et al., 2013; Marshall et al., 2014; Marshall et al., 2009; Merot, 1999). Targeted tree planting can significantly increase soil infiltration rates and help reduce peak flood flows (Woodland Trust, 2012).

Water quality

Also see the Freshwater chapter.

Agriculture accounts for approximately 60% of nitrates in rivers (Hunt et al., 2004) and, consequently, influences coastal water quality and fisheries (EEA, 2001). The agricultural sector is also a major source of phosphorus, the primary nutrient responsible for eutrophication in freshwater (Jarvie et al., 2010). This negatively affects the ecological balance of the aquatic environment and leads to changes in animal community structure (Maier et al., 2008; Jarvie et al., 2010).

Phosphate loads are generally higher under arable than grassland systems (Watson and Foy, 2001), although pathways are highly site-specific and grassland loads can be high where grazing pressure is intense, and where there are high levels of slurry spreading or poor slurry storage.

There is a negative impact on water quality from sediment from soil erosion and livestock poaching entering watercourses. See the Freshwater chapter for more information.

There are human health risks arise from parasites found in livestock faeces, such as *Escherichia coli* and *Cryptosporidium* (Medema et al., 2006) within run-off into watercourses.

Air quality

The major impacts of the management of Enclosed Farmland on air quality are the emissions of methane, see Climate change above, and ammonia, see the Air Quality chapter.

Ammonia can be dispersed through the air and in rainfall, to be deposited on soils and vegetation, acidifying and adding nitrogen to systems, causing an odour nuisance, and negatively impacting biodiversity in both terrestrial and aquatic environments. Ammonia can also contribute to particulate pollution in urban areas, leading to increased cardiovascular and respiratory disease.

Agricultural sources are responsible for 92% of ammonia emissions, with cattle manure management alone accounting for at least 36% of emissions (Figure 19 and Figure 20). The trend in ammonia emissions had been largely driven by declining animal numbers and manufactured fertiliser use, which had decreased emissions until 2008. However, increased emission from manure management practices, particularly for dairy cattle, and from the application of ammonium nitrate and digestate fertilisers to soils, have seen emissions increase since their minimum in 2008 (NAEI, 2020b).

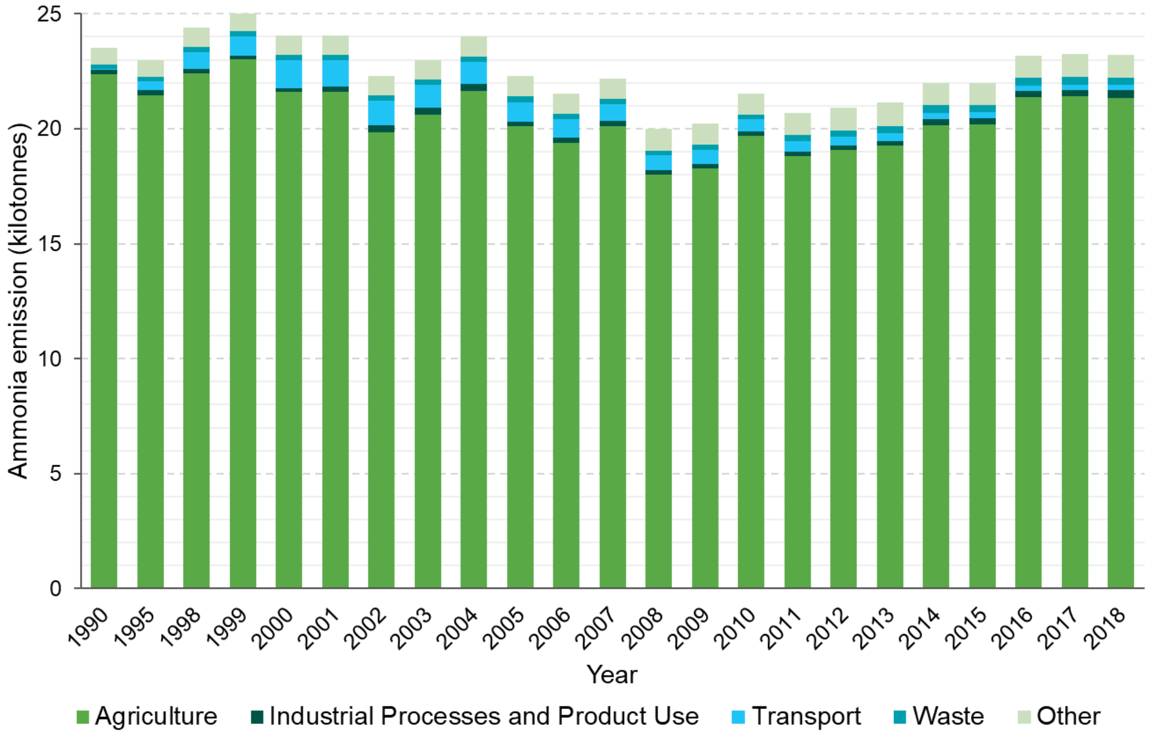


Figure 19 Ammonia emissions in Wales from 1990 to 2018 (NAEI, 2020b)

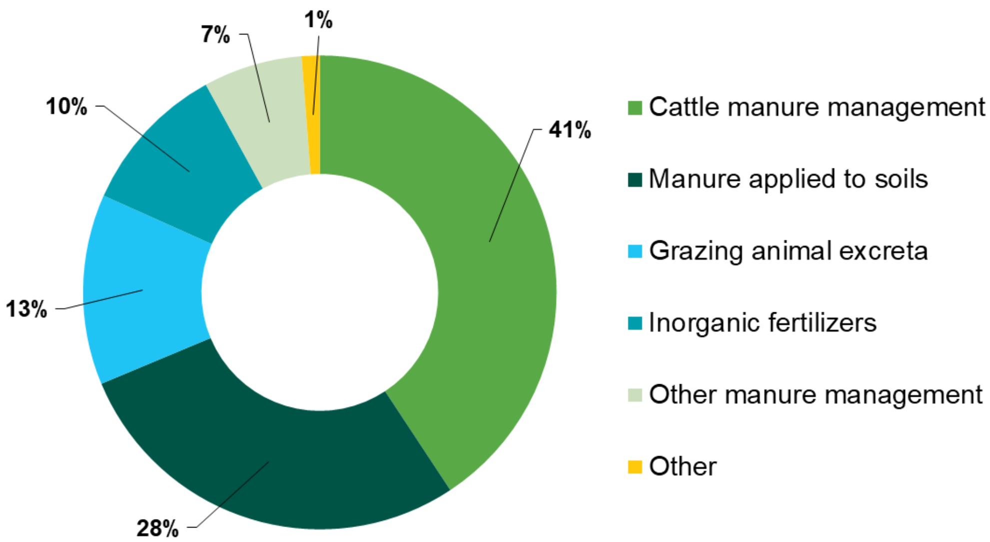


Figure 20 Disaggregation of ammonia emissions from the agriculture sector, 2018 (NAEI, 2020b)

Waste breakdown

Enclosed Farmland can provide waste breakdown services for waste biological material for anaerobic digestion or composting.

Anaerobic digestion uptake is increasing in Wales. See the energy chapter. Agricultural manures, domestic organic waste materials and crops such as maize are digested to produce methane for use as an energy source; digestates are then returned to the land to enhance soil organic matter and carbon (Banks et al., 2018). Maize production in Wales has increased which is likely to be partly in response to increased demand for digesters. See Regenerative economy (Aim 4)

In 2018 the total treated sewage sludge produced and applied to agricultural land in Wales was 43,194 tonnes of dry solids spread over an area of 7,844 ha (NRW, 2020). Sewage sludge containing persistent organic pollutants such as dioxins and polycyclic aromatic hydrocarbons can contaminate soils and have an adverse impact on human health. See the Waste chapter for more information.

Shelter provision

Hedges and trees managed as shelterbelts and arable agroforestry systems can improve crop yields due to reduced wind erosion, improved microclimate, increased soil moisture, and reduced crop damage (Kort, 1988; Donnison, 2012). Likewise, there is plentiful evidence to show that livestock benefit from the protection from wind, driving rain, snow and heat stress which can be provided by hedges and trees (Bird, 1998). Windbreaks can reduce livestock mortality, particularly of young animals, and increase growth rates, milk yield, disease resistance and fertility (Van Laer et al., 2014).

Pollination

Insect pollinators contribute directly to the quality and quantity of a large number of crops including vegetables, fruits, nuts and oils. One potential consequence of declining populations of pollinators, see Pollinators, is a decline in the rate of pollination (Gallai et al., 2009). This may lead to a decrease in the reproduction of a large number of flowering plants, including rare species and a number of crops, with knock-on effects to the animals that rely on these plants.

While humans are unlikely to starve due to lack of pollinators because a number of staple crops such as grains are self-fertilising or wind-pollinated, the balanced diets that are currently enjoyed and which are important for healthy nutrition could be threatened (Ollerton et al., 2011).

By providing breeding sites, floral resources, shelter, protection and flight lines, well-managed hedges and trees within farmland can enhance population size and diversity of pollinators and export them into surrounding areas (Hannon and Sisk, 2009; Pywell et al., 2005).

Disease and Pest Control

Natural biological pest control is often provided by predator or parasite species present in the local environment. Analysis of GMEP data showed that across broad habitats, arable land contained the highest density of predator hoverflies (Figure 21) (Alison et al., 2020). Many insects that play a role in pest suppression are carnivorous during their larval stage, but require nectar, and sometimes pollen, during their adult life stage. The scarcity of flowering plants in modern arable fields can therefore constrain the effective performance of these beneficial species (Van Rijn and Wäckers, 2015). Both hedgerows and trees can have a beneficial effect on predator species populations (Miñarro and Prida, 2013; Haenke et al., 2014).

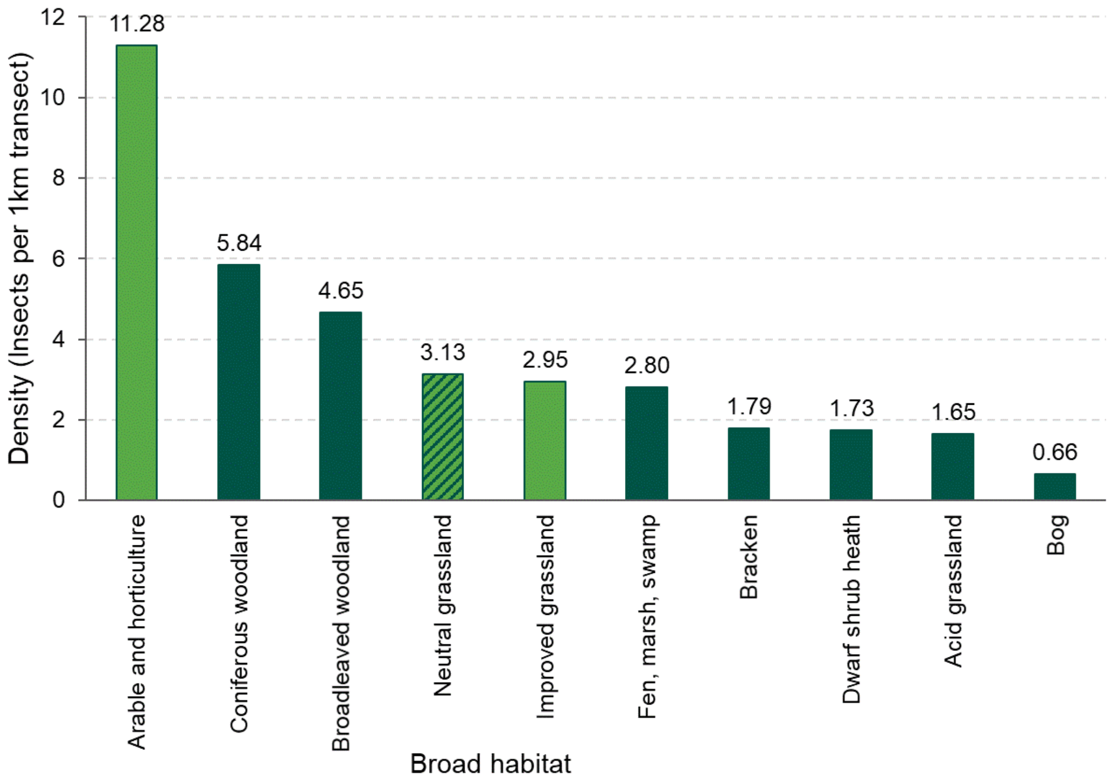


Figure 21. Estimates of density of aphid eating hoverflies within ten broad habitat categories. Enclosed Farmland is shown in lighter green; although neutral grassland includes enclosed farmland and semi-natural grassland Contains data from the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), reproduced from Alison et al. 2020, under the Open Government License 3.0).

Research shows that the risk of bovine tuberculosis in cattle is reduced on farms that have a higher density of hedgerows. Hedgerow characteristics, such as abundance and the number of gaps, were found to be strong predictors of breakdown incidence (Mathews et al., 2006).

Cultural services

Enclosed Farmland is a working landscape and an important source of employment, with 52,860 workers employed in 2019 (Welsh Government, 2019a). Many rural areas are dependent upon farming and associated businesses to sustain local communities.

Farmland is important in providing opportunities for leisure and exercise, in particular walking and running.

A significant area of land is used for keeping horses, calculated at 60,000 ha, based on an estimated Welsh horse population of 130,000 from the 2019 National Equestrian Survey, many of which will be kept on Enclosed Farmland.

Enclosed farmland is an important part of Welsh landscape character and is a strong feature of every Designated Landscape. Just under half the landscapes, 933,100 ha, that are associated with scattered rural and farm settlements are valued as high or outstanding (Cottrell and Medcalf, 2019). These tranquil, pastoral landscapes have a sense of place, time-depth and cultural identity, contributing to the mental and physical well-being for those that live and work there, and delivering similar benefits to those who visit for recreation and tourism.

Field boundaries are a complex reflection of cultural, economic, topographical and climatic influences, and a local response to the availability of natural resources and countryside skills. An example of this is the slate pillar fencing of Snowdonia and South West Anglesey associated with slate quarrying, or the cloddiau of Pembrokeshire, Llyn and Anglesey. Culturally, boundary patterns give the landscape form, pattern, and historical continuity. They can be important habitats and plant diversity within areas of farmland, and important relics of the prehistoric landscape, medieval and post medieval periods, for example, the medieval strip fields of Gower or the irregular Neolithic field patterns in Ardudwy, Snowdonia.

Farmland is important for the wider historic environment with 13,894 earthwork sites and 5,264 buried archaeological sites recorded on agricultural land (Historic Environment Group, 2020)

6. Regenerative economy (Aim 4)

The Provisioning ecosystem services for well-being provided by enclosed farmlands ecosystems are outlined in Table 9 below. They are developed from the set of services and definitions of the UK NEA Conceptual Framework (Mace et al., 2011). The Wales assessment is our current interpretation based on expert opinion.

Table 9 Provisioning ecosystem services provided by Enclosed Farmland Ecosystem in Wales.

Provisioning Services	Level of importance	Description
Food and fibre from arable and horticulture crops	Medium	Strong positive score: areas of land managed specifically for crop production.
Food and fibre from livestock	High	Strong positive score: farmland primarily managed for livestock production.
Trees and standing vegetation	Low - Medium	Positive score: timber, wood fuel for domestic use and biomass crops.
Wild Species Diversity	High	Strong negative score: high potential but large negative impact of current agricultural practices on biodiversity.

This table is adapted from that in UKNEA synthesis (UK National Ecosystem Assessment, 2011).

Food production is the foremost ecosystem service provided by Enclosed Farmland; it underpins the Welsh agri-food sector. Increases in agricultural production seen over the last few decades have often been at the expense of external environmental costs and of other ecosystem services. See the Land use and soils chapter for more information.

Food production includes livestock, arable crops, horticulture and wild food. Livestock are covered in the Land Use and Soils chapter as they occur across the uplands and lowlands.

Arable production changes annually but in over 20 years, there has been a shift to producing more wheat, stockfeed and maize in Wales as shown in Figure 22. Less spring barley was grown in 2019 than 1999; this has implications for farmland species that depend upon spring-sown crops for habitat. Stockfeed production has increased from 7% to 19% which has the potential to decrease the environmental costs of transportation.

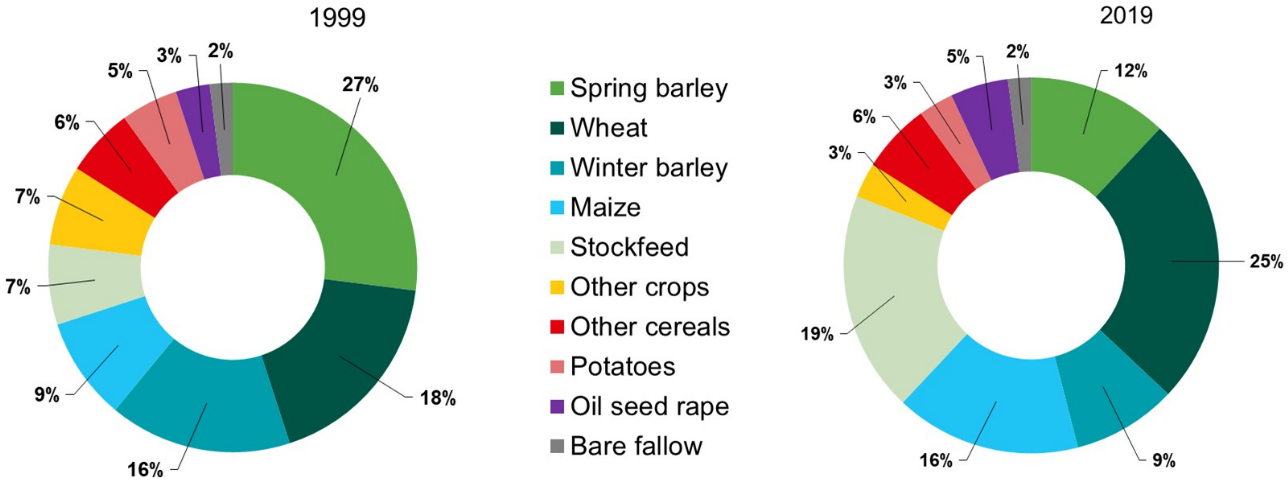


Figure 22 Figures on the area of land under different crops in 1999 compared to 2019. (Welsh Government, 2019a)

In 2019, the area of maize produced was estimated at 14,500 ha in Wales compared to 6,100 ha in 1999. Maize is mainly grown for livestock feed but is increasingly grown as a feedstock for anaerobic digestion production, although there are currently no figures separating the two uses. Maize growing generally has a negative impact on soil condition and soil erosion (ADAS and Ricardo Energy & Environment, 2016).

Research suggests that bioenergy cropping for anaerobic digestion could increase in England and Wales. Official statistics on the amount and type of crops grown used for anaerobic digestion are currently limited to maize (Defra, 2019b).

Welsh Government carried out a detailed analysis in 2009 to identify how much farmland in Wales is agronomically capable and environmentally suitable for growing energy crops. The study identified approximately 600,000 ha that could grow these crops. However, competing demands for livestock and other crops mean that only a small proportion of this total is ever likely to be used for energy crops (Welsh Government, 2009).

Miscanthus has been identified as an important crop for bioenergy (Radley, 2019). The Institute of Biological, Environmental and Rural Sciences (IBERS), Aberystwyth have developed a *Miscanthus* breeding programme to deliver both UK and international efforts to provide sustainable renewable bioenergy through the production of varieties with high net energy yields per hectare that are economic to establish, harvest and process (IBERS, 2020).

Horticulture in total has decreased in Wales since 2017, apart from non-commercial orchards and small fruit (Welsh Government, 2019a). However, the total area of soft fruit crops grown in Wales is low compared to the rest of the UK at only 1%, (Fera Science, 2020). Commercial horticulture activities occupy only 1.9% of the land used for crop production in Wales in 2018 but contributed 51% of the £108m productivity of cultivated land (Barrow, 2020).

Table 10. Areas of Horticulture crops grown in Wales between 2017 and 2019 (Welsh Government, 2019a).

Type of Horticulture	**2017**	**2018**	**2019**
Vegetables and salad grown in the open	464 ha	499 ha	325 ha
Commercial orchards	373 ha	357 ha	336 ha
Other orchards and small fruit	428 ha	433 ha	474 ha
Total hardy nursery stock	410 ha	366 ha	319 ha
Glasshouse	27 ha	23 ha	26 ha
Total	**1,702 ha**	**1,678 ha**	**1,480 ha**

There is a small sector growing other plant-derived products such as ornamental plants and cut flowers.

Fibre products in the form of fleece, leather and straw are also important.

There is very limited information available on how much of the food production in Wales is sustainable. Practices such as intercropping, complex multi-year crop rotations, cover crops, reduced tillage and integrated pest management are relevant to improving the sustainability of arable land. For livestock rearing, improving soil condition, sustainable forage management and livestock health are considered important elements of sustainability.

Organic agriculture is one form of sustainable agriculture with standards that prohibit the use of synthetic fertilisers and pesticides. The focus on utilising lower off-farm inputs with biological and mechanical pest management has multiple benefits for the environment. Organic agriculture tends to support higher levels of biodiversity, soil carbon stores and has fewer negative impacts on water quality and air quality than conventional agriculture (Seufert and Ramankutty, 2017). The nutritional value of food can also potentially be higher (Średnicka-Tober et al., 2016).

Organic farming has a modest uptake in Wales with 84,400 ha of land managed organically in 2019 (Figure 23). The organically managed area is decreasing with a 12% reduction in the area between 2014 and 2019 (National Statistics, 2019 and 2020).

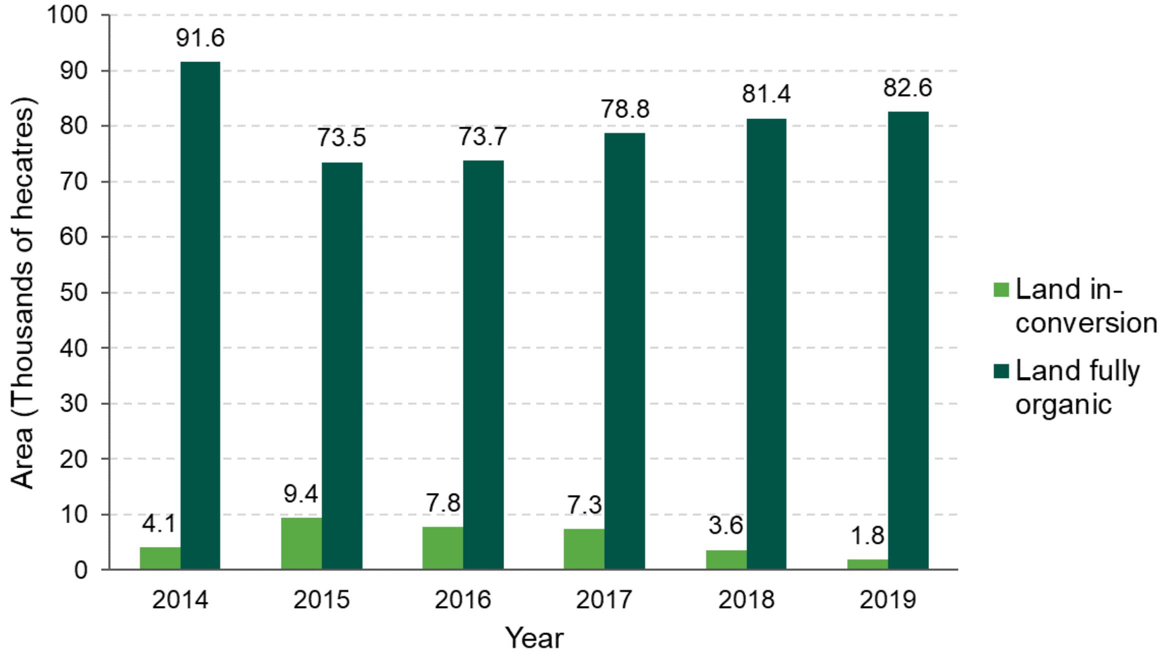


Figure 23. Organic and in conversion land in Wales 2014-2019 in thousands of hectares (National Statistics, 2019 and 2020).

7. Synergies and Trade-offs

Enclosed Farmland faces a difficult balancing act. To meet different human needs, it must simultaneously produce more food for a rising population; provide economic opportunities for rural communities; and reduce environmental impacts, including ecosystem degradation and high greenhouse gas emissions.

54% of Wales is currently intensively managed for agriculture. The International Panel on Biodiversity and Ecosystem Services (IPBES 2019) and the UK Committee on Climate Change (UKCCC, 2020a) both recommend the transformation of agricultural systems to reverse biodiversity decline and prevent further climate change.

Crop and Pasture Yield Challenge

In 2019, the UK produced 55% of the population’s food requirements (Defra, 2020), showing that that just under half the UK’s food is imported. To continue to supply the same proportion of food and meet increasing population requirements, see Drivers of change, without expanding the annual area managed intensively, crop and livestock yields will need to increase by more than 9 percent by 2050, based on current diets and consumption rates. See Drivers of change. In intensive systems, there is usually a trade-off between food production and other ecosystem services. Increasing food production by using more external inputs, will have negative consequences for greenhouse gas emissions, biodiversity and ecosystem services.

By modifying current practices much can be done to improve the productivity of many agricultural systems, while limiting the expansion of agricultural land as well as safeguarding and enhancing the environment. Efficiency in productivity has, in the past, been mostly expressed in terms of yield (kg per hectare of production) but future productivity increase should consider more dimensions. Water and energy-smart production systems will become increasingly important as water scarcity increases and as agriculture seeks ways to reduce the emission of greenhouse gas. (FAO, 2020).

Ecosystem challenge

Over the last half century, intensive agriculture has been the largest driver of biodiversity decline across the UK (Burns et al., 2016). The loss of semi-natural habitats and fragmentation of those remaining has caused massive declines in farmland species. Meanwhile, agriculture depends strongly on healthy ecosystems for a diversity of supporting ecosystem processes, including nutrient remineralisation, soil health, insect pollination, and biological pest control. Farming systems need to change to reflect dependence on ecosystems and the services they provide (Kok et al., 2017). The IPBES recommends the following actions on farmland (IPBES, 2019):

Promote sustainable agricultural and agroecological practices. Practices that work with nature to reduce artificial inputs. The volume of production may be reduced but profitability for landowners is often improved (van der Ploeg et al., 2019).

Increase biodiversity-friendly management practices. A wide range of practices can be used, for example, introducing flowering legumes to grasslands, leaving fallow crop margins and planting hedgerows; most will have benefits for ecosystem services, many will benefit the carbon balance. Productivity may be positively or negatively affected depending on the practice.

Retain and increase areas of semi-natural habitat within and around production systems. While benefiting biodiversity, other ecosystem services will also be improved. Productivity may fall or be balanced by benefits from improved ecosystem services such as drought tolerance or disease control.

Promote sustainable and healthy diets. Decrease the land area demand for food production by reducing food waste and changing diets to foods that can be produced more efficiently and sustainably.

Climate Change Challenge

Changes to farming systems are urgently required to reduce greenhouse gas emissions and to sequester carbon. The UK Committee on Climate Change recommends the following actions on farmland (UKCCC, 2020a):

Create more woodland. The Welsh commitment to tree planting will take land out of agricultural production. Depending on species and location choice, new woodlands can sequester carbon and deliver improved ecosystem services, but in the wrong place, they can have a negative impact on both. See the woodlands chapter.

Agroforestry and hedgerow expansion. Increased numbers of trees and hedges in farmland will sequester carbon and increase ecosystem services while maintaining the primary purpose of food production.

Grow more bioenergy crops. This would take land out of food production. Without careful management, bioenergy crops could have negative impacts on biodiversity, soil health and water quality (Wu et al., 2018).

Reduce consumption of carbon-intensive foods. While reducing meat and dairy consumption would have a positive impact on carbon balance, it would also require increased arable production that could have negative impacts on biodiversity, soil health and water quality. As part of the global food system, increased plant production could drive a release of land to support more tree planting or bioenergy crops. These measures imply a shift towards meeting healthy eating guidelines that would have a positive impact on human health (UKCCC, 2020b).

Increase low-carbon management practices. Using measures such as: improving livestock health, precision farming of crops, preventing soil compaction, applying biochar, anaerobic digestion, controlled release fertilisers, as well as livestock and manure management. These farming practices can have multiple other benefits, including improved productivity, improved air, water and soil quality, reduced pests and diseases, and improved soil structure.

Combined Challenges

The interactions between options for competing pressures should not be overlooked (Table 11). For example, growing bioenergy crops may deliver well for climate change but is likely to have negative impacts on all other ecosystem services.

Table 11 The impact of suggested interventions on ecosystem services

Suggested intervention	Food Production	Biodiversity	Climate Change	Other Ecosystem Services
Increase yields by increasing inputs	Positive	Strong negative	Strong negative	Strong negative
Sustainable farming practises	Either positive or negative or both	Positive	Positive	Strong positive
Biodiversity-friendly management	Either positive or negative or both	Strong positive	Positive	Positive
Semi-natural habitat expansion	Negative	Strong positive	Positive	Strong positive
Dietary changes	Positive	Either positive or negative or both	Positive	Either positive or negative or both
Increase semi-natural woodland	Strong negative	Strong positive	Strong positive	Strong positive
Increase non-native woodland	Strong negative	Either positive or negative or both	Strong positive	Positive
Agroforestry and woody habitat expansion	Either positive or negative or both	Strong positive	Strong positive	Strong positive
Bioenergy crops	Strong negative	Strong negative	Strong positive	Strong negative

Of the interventions suggested within the IPBES and UKCCC reports and the mainstream food production systems, there are no options that solve all problems. However, there are synergistic options for some challenges and combinations of options that together could provide benefits across the board.

Increases in food production alongside other ecosystem services are the most difficult to achieve. It is important that this area is addressed so that environmental degradation associated with intensive food production is not just exported to other parts of the world.

Changing diets, reductions in food waste, and increased efficiency to enable increased or sustained levels of food production from a smaller area of land looks to be a key option to enable changing practises to benefit climate change mitigation and biodiversity.

Integrated options that allow for continued food production, alongside environmental benefits, will also decrease the pressure on food production. Of these, sustainable farming practices and expanding the woody components within farmland provide multiple benefits across ecosystem services.

8. Opportunities for Action

Ecosystem resilience is the cornerstone of productive farming. Food and fibre production rely on air, soil, water and biodiversity. The provisioning and regulating services derived from these natural resources are impacted by agricultural systems and yet are essential to maintain productive capacity.

Sustainable farming methods offer huge potential and opportunities for farmers and could provide the basis for the transformation of agricultural policy. Sustainable methods not only provide healthier food but also considerably improve farmers' incomes. Studies show that throughout Europe, systems employing a range of more sustainable practices delivered between 10 and 110% increase in farm income (van der Ploeg et al., 2019).

Knowledge transfer to land managers is essential to promote these changes. To this end, the Sustainable Farming Scheme is a key opportunity to provide both knowledge transfer and financial support to enable these changes to be realised.

Diversifying the landscape

Diversifying at all scales, from field to landscape, will increase ecosystem resilience and ecosystem services. Managing whole systems and landscapes to treat less-intensive areas as integral to the farm and valued for their role in providing ecosystem services such as reducing nutrient run-off, sequestering carbon and supporting biodiversity. Options include:

- Create resilient ecological networks by enhancing and restoring existing habitats and creating new habitats through, for example, restoring grasslands, wetlands and coastal habitats. Improving ecosystem resilience will require linking and enlarging existing small and fragmented habitat areas to allow species to move between them and to provide for all stages of their life cycles.
- Create or restore semi-natural vegetation on flood plains and improve riparian habitats throughout water catchments to reduce the risk of flooding to downstream communities and to improve water quality.
- Incorporate more trees and woody habitats within farming systems to enhance ecosystem services alongside continued food production. By mixing trees or shrubs into operations, farmers can provide shade and shelter to protect livestock and crops, while sequestering carbon and enhancing other ecosystem services. This can be achieved by:
    - increasing the volume of existing hedgerows and planting new hedgerows. Increasing the volume of existing hedgerows alone could sequester an additional 3.0 Mt CO_2e (Axe, 2020).
    - replacing the 54 million hedgerow trees lost since the 1950s
    - maintaining and expanding wood pastures and orchards
    - planting or enabling natural regeneration to create shelter belts and flood plain woodland
    - adopting in-field agroforestry practices
- Increase mixed farming that integrates livestock and crops. Industrial agriculture tends to keep plant and animal production separate, with animals living far from the areas where their feed is produced, and crops growing far away from abundant manure fertilisers. Smart integration of crop production and animal farming can be more efficient and profitable (ADAS, 2019b).
- Increase grassland diversity either by sowing a mixture of productive species or reverting to a semi-natural sward. Diverse swards can include deeper rooting and nitrogen-fixing species, which can potentially reduce the amount of manufactured nitrate fertiliser applied to the land and store higher levels of carbon (Garnett et al., 2017; Smith, 2014; Ricardo, 2020). See the Semi-natural grassland chapter for more information.
- Incentivise extensive arable management particularly in areas of known arable species interest. Pockets of low input arable land do still exist across Wales and, crucially, many species remain viable in the soil seed bank for years and may be brought 'back to life' through simple changes in field management. Even in an intensively grown cereal, arable weeds at 10% cover can play an important role in maintaining and restoring invertebrate populations (Smith et al., 2020a).
- Promote nature-friendly management with horse owners. Approximately 6% of Enclosed Farmland is managed for equines. See Cultural services. Currently, this land is not considered in land use policy and is often poorly managed. There are significant opportunities to promote land management practices that could

potentially benefit both biodiversity and equine health, but further research is required to characterise the equine health benefit and trial appropriate management approaches (Vialls, 2019).

Soil management

Soil is the foundation of productivity on farmland. Building soil condition has the potential to increase productivity and to maintain or enhance soil carbon stores. There are many approaches for both grassland and arable land:

- Soil conservation through actions such as cover crops, intercropping and strip cropping, longer grass ley rotations and buffer strips alongside water bodies.
- Protecting soil structure from damage, by actions such as preventing poaching, using minimum till cultivation (Bhogal et al., 2008), careful timing of farming operations, reducing stocking densities, keeping tractor axel weights down and protecting soil macro-fauna, as animals such as earthworms and dung beetles play an important role in soil structure formation. Higher sward diversity could potentially improve soil structure, provide greater resistance to soil compaction and increase water infiltration rates (Newell Price et al., 2019).
- There is potential to increase grassland carbon stocks in Wales through effective soil management, although research is required to determine how significant this could be. Organic carbon content can be increased by many of the above measures plus additional actions that specifically address soil carbon include sowing deep-rooted species and legumes (Garnett, et al., 2017; Smith, 2014; Ricardo, 2020), using biochar as a soil additive (Downie et al., 2009) and adding nutrients from organic fertilisers rather than manufactured fertilisers.

Nutrient management

Improved nutrient efficiency can increase farm profitability and reduce the agricultural impact on the environment.

Actions to decrease nutrient inputs include precision fertiliser application, soil sampling to ensure correct application rates, good legume cover in the sward and maintaining optimum soil pH.

Actions to decrease nutrient transfer to other ecosystems, in addition to those above, include riparian corridors, new wetlands created to intercept run-off, drainage into semi-natural wetlands prevented, unfertilised buffers around semi-natural habitats, clean and dirty water separation on yards, use of constructed wetlands, slurry separation, and adequate slurry storage.

Interventions to prevent ammonia release to the air include covering slurry stores, restricting urea-based fertilisers and injecting slurry.

Water resource management

Improving water use efficiency can reduce water demand during periods of dry weather and increase business profitability. Possible actions include: recycling rainwater, undertaking a water audit to understand and reduce unnecessary use, and creating water storage ponds that collect winter rainfall for spring/summer use.

Food use

Reducing food waste can decrease the pressure for high productivity both in Wales and abroad. As could encouraging the consumption of sustainably produced food and food with a low carbon footprint.

Innovation

Innovations in practises and technology are essential to increase food production efficiency and farm business profitability while preserving and enhancing ecosystem resilience and services.

There is often slow take-up for innovative practises in farming; to promote adoption, a range of social, economic and behavioural interventions should be implemented.

9. Evidence needs

The evidence requirements for Enclosed Farmland are broad due to the far reaching questions around sustainable food production and the diverse components of this ecosystem.

There are some fundamental gaps in our evidence required to ensure high levels of confidence in the assessment of SMNR within Enclosed Farmland. Basic extent, condition, connectivity and biodiversity data is out of date and incomplete in some areas, providing difficulties with evaluating stocks of natural resources or detecting trends. Fit for purpose evidence relating to stocks of natural resources is essential as it informs many other elements of the SMNR assessment, enables prioritisation and informs focus areas for other evidence needs. To enable us to better tackle key issues, further understanding of where pressures are leading to impacts is required and what the drivers behind these pressures are.

More complex is the need to predict future trends to enable us to prepare and respond to these pressures, for example the impacts of climate change. These are areas where there would be a need for strategic research and targeted long-term monitoring. Identification of opportunities for restoration of habitats and nature-based solutions are also key evidence needs to respond to the climate and nature emergencies.

While there is a growing body of research on a wide range of sustainable farming practises, there is little information on their take up in Wales nor on the impact these are having at a landscape scale. Research to better understand the range, extent, spatial distribution and impact of the many different sustainable practises and their trade-offs would enable informed policy decisions to be taken to support farmers move towards sustainable practises.

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