Nature Net Zero

Part 4: Land use synergies & trade-offs when expanding habitats for carbon

August 2025

Natural England Commissioned Report NECR569

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Catalogue code: NECR569

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Keywords

Trade-offs, synergies, ecosystem services, land use, land use framework, net zero, nature net zero, nature recovery, nature restoration, functional ecosystems.

Acknowledgements

We would like to thank members of Natural England's Climate Change Team for answering technical queries, clarifying best approach to issues and wider discussions on report outputs. Particularly on the carbon side Jessica Elias, Jodie Harthill and Mike Morecroft. On the climate risks Dean Mason, Sarah Taylor and Simon Duffield. For proof reading, sense checking and support across the whole project Rebecca Nash.

Citation

A. Evans, F. Hesketh, C. Wardale, E. Tugwell and I.E. Crosher (2025) Nature Net Zero. Natural England Commissioned Report NECR569. Natural England.

Part 4 Executive summary

Natural England's Nature Net Zero (NNZ) research aims to assess the potential for England's ecosystems to deliver the greatest increase in biodiversity in ways that preserve carbon storage, increase carbon sequestration rates and reduce greenhouse gas emissions. The research seeks to identify the habitats and geographical locations that would make the best return on investment to deliver biodiversity targets and achieve long term functional recovery of "carbon in nature".

Natural England commissioned TEP to carry research and spatial analysis. Part 4 of the research provides an overview of the trade-offs and synergies that would result from land use changes to meet both biodiversity expansion targets and climate targets that seek to reduce emissions from peatlands and sequester carbon in new woody habitats.

Trade-offs and synergies are summarised for five habitat creation and restoration scenarios which would expand coverage of 'high-carbon, high-nature' habitats;

- peat-based priority habitats
- deciduous woodland
- coastal habitats
- grasslands and heathlands
- wetlands

The scenarios are quantified in the Part 3 report of this Nature Net Zero research. They illustrate different pathways for achieving the nature recovery targets, whilst also increasing carbon stored in, and sequestered by, the new priority habitats.

The Climate Change Committee has estimated that approximately 21% of agricultural land in the UK will need to change function – to forestry, agroforestry, peatland, or energy crops in order to meet our net zero commitments (Climate Change Committee, 2020).

To achieve the Environment Improvement Plan (EIP 2023) targets along with the linked Convention on Biological Diversity (CBD) commitments by 2030, ecosystems and the services they deliver need to be in good health (functioning ecosystems). As a result, when land-use changes, a "trade-off" will occur and the type, magnitude and mix of services delivered by an ecosystem will change.

Done well through spatial awareness and good ecological underpinning, land use change will result in better 'multi-functional' places that deliver greater public benefits at larger scales.

Synergies and/or trade-offs were identified between the five habitat scenarios considered, with additional subdivision into upland and lowland scenarios where feasible. Positive or negative relationships were assigned, and where uncertainty on the relationship exists, a question mark (?) was used. Where there is no relationship between the existing land-use and the habitat scenario the term 'n/a' was used. Table 8 in the main body of the Part 4 report displays all the synergies and trade-offs considered.

Peat based habitats

Up to 349,000 hectares of peat-based priority habitats could be restored from their current, non-priority, status. This includes about 280,000 hectares of upland peat-based habitats, such as blanket bog, and 69,000 hectares of lowland habitats, principally lowland fen. These areas are within England's Habitat Network, principally around existing priority habitats.

Restoration of these areas could protect over 113 million tonnes of carbon storage, deliver significant abatement of ongoing greenhouse gas emissions. Furthermore, 150,000 hectares of deep and shallow peatlands, presently in agricultural land use could also be restored, with about 39% of deep fen peats currently under cultivation (Natural England, 2010). This would bring the total peat-based opportunity to approximately 500,000 hectares.

Trade-offs with food production are assessed using the Agricultural Land Classification (ALC), with Grades 1 and 2 accounting for 23% (~115,000 ha) of the peat-based opportunity. In the less productive areas, ALC Grades 4 & 5 make up 59% (298,000 Ha) of peat-based habitat expansion opportunities.

Restoration of peat-based habitat in upland areas has more potential to deliver synergy with ecosystem services such as water supply, climate impact reduction and recreation.

Woodland habitats

Up to 254,000 hectares of priority deciduous woodland could be created in the Habitat Network, in ancient woodland and wood pasture and parkland enhancement and action zones. This scenario excludes planting on peaty soils. This would deliver 26 million tonnes of stored carbon and additional sequestration of 891,000 t CO_2e y-1.

These priority woodland restoration potential areas have only 12 % overlying Grades 1 and 2 ALC land. The majority (57%) overlies Grade 3 ALC land. 19% of the woodland potential overlies Grades 4 and 5 ALC land, where much less wood pasture and parkland and ancient woodland survives.

Even on higher-grade farmland, there is still opportunity for priority woodland creation without significant trade-offs to food production especially if targeted to least productive areas of the farm such as field corners, stream sides and steeper sloping land. Alternatively, integration of food and tree systems together through an agro-forestry approach offers real potential to deliver wider ecosystem services such as soil and water quality protection.

Establishing new deciduous woodland on grasslands of low biodiversity and limited existing carbon stocks requires fewer trade-offs. Beyond our estimate of priority woodland creation in the Habitat Network, the Forestry Commission has identified 3 million hectares as having no obvious environmental or societal protections that would be adversely affected by woodland creation (Forestry Commission, 2024).

Coastal habitats

Up to 119,000 hectares of coastal habitat could be restored in the Habitat Network. This includes salt marsh, sand dune, vegetated shingle and maritime cliff and slope that could be created or restored giving benefits for biodiversity, carbon sequestration and burial of carbon in saltmarsh sediment. This would deliver 29 million tonnes of carbon storage and additional sequestration of 395,000 t CO_2e y-1.

Much of these low-lying coastal areas once had extensive areas of saltmarsh and coastal wetlands that have been drained to allow agriculture to be the major land use. In situations where settlements are at risk from coastal or tidal flooding, creating coastal habitats adjacent to these areas can provide a natural form of protection from sea-level rise and buffer the effect of storms.

About 13 % of the new coastal habitat opportunities overlie Grades 1 and 2 ALC land, 37% overlie Grade 3 ALC land, and 12% overlie Grades 4 and 5. Other coastal opportunity lies on land not subject to ALC grading. Trade-offs and synergies will be habitat specific with maritime cliff and slope being much harder to farm than low-lying lost coastal wetland areas under agriculture that are currently protected from the sea's inundation by flood walls.

Grassland & Heathland Habitats

The future grassland and heathland creation and restoration potential is large at 890,000 hectares, in part as the remaining remnants of habitats are small and fragmented and thus have a large 'edge effect' which increases the extent of Habitat Network capable of being enhanced and de-fragmented to be joined to form bigger blocks. 75% of the opportunity is in lowland areas. This extent of new or restored priority grassland and heathland would deliver 69 million tonnes of stored carbon. It would also 'abate' current emissions of greenhouse gases where the existing habitat is currently a high emitter.

With only 6% on grade 1& 2 ALC land, the food impact of habitat restoration in these areas would be relatively small.

The majority of these habitat opportunities are on grade 3 (41%) & 4 (29%) land offering more opportunity to reduce food trade-offs and greater synergies. Targeting of habitat work would be adjacent to and complementing landscape features such as floodplains, scarps and steeper valley sides, delivering pollinator and soil stabilisation benefits.

Lowland Wetlands & Floodplains

The future lowland wetland habitat network 156,000 hectares of priority wetland habitats (lowland fens and reedbeds) can be created or restored. This opportunity could deliver a carbon store of 26 million tonnes over time. These habitats would remain as net emitters of greenhouse gases, but, depending on the original habitat type and condition, abatement of current emissions may occur.

Additionally, there is major potential around the Coastal floodplain grazing marsh habitat – the extent of this potential may be assessed in future when the priority habitat inventory is updated to classify this as floodplain wetland mosaic habitat.

Only 13% of best and most versatile land (ALC 1,2 & 3) is located in the floodplain. With the majority of the potential wetland restoration areas sitting in grade 3 (40%) & 4 (24%) ALC land the focus could be on these locations leaving more of the grade 1 (4%) & 2 (9%) to stay in agricultural land use.

It is clear that these functioning floodplain areas are highly important and deliver much greater public benefits increasing resilience to floods and drought, and potential water quality improvements. Floodplains occupy only 5% of land area in the UK, yet targeted investment here would yield significant savings and gains for society as a whole (Lawson et. al., 2018).

Multifunctional Land Use Discussion

There is a finite amount of land in England, and the United Kingdom, and multiple benefits need to be derived from it. The Nature Net Zero project has shown that it is possible to deliver the Government's nature targets by creation and restoration of 'high-carbon' habitats.

The creation and restoration of these habitats would increase natural carbon storage and sequestration, and would also be likely to increase the supplies of other ecosystem services such as flood mitigation, climate regulation, water quality and pollination. These synergies provide positive public benefits to society and to land managers.

Increasing the area and/or quality of high-carbon habitats brings the potential for trade-offs against food production. There are likely to be more trade-offs in terms of volume and value of food production (intensive meat and dairy and cultivated crops) in the lowlands as a result of habitat creation and restoration.

This is explored by using the Agricultural Land Classification (ALC) for the different scenarios (see table below). That said, in certain of parts of the country such as the Fens, prevailing agricultural practices and best and most versatile land classes may not be sustainable in their current form, due to fast diminishing soil resources, increasing costs of artificial drainage and climate change impacts.

Habitat opportunity areas and relationship with Agricultural Land Classification grades (1 is best)

Habitat Opportunity scenario	Grade 1 (ha) %	Grade 2 (ha) %	Grade 3 (ha) %	Grade 4 (ha) %	Grade 5 (ha) %	Non agric./urban/ no ALC (ha) %
Peat based habitat	57,875 ha 11.55%	57,358 ha 11.45%	47,329 ha 9%	71,459 ha 14%	227, 306 ha 45%	36,715 ha 7%
Woodland	2,089 ha 1%	27,346 ha 11%	146,068 ha 57%	44,328 ha 17%	5,470 ha 2%	3,340 ha 11%
Coastal Habitats	5,972 ha 5%	10,038 ha 8%	43,947 ha 37%	12,452 ha 10%	1,958 ha 2%	44,798 ha 38%
Grassland & Heathland	4,918 ha 1%	47,584 ha 5%	366,885 ha 41%	257,616 ha 29%	141,871 ha 16%	71,465 ha 8%
Lowland wetlands	6,204 ha 4%	13,420 ha 9%	62,940 ha 40%	37,663 ha 24%	6,016 ha 4%	29,555 ha 19%

Food production trade-offs in the uplands are also likely. Whilst perhaps lesser in terms of absolute volume and value, the effects on farm business margins and operational sustainability also need to be recognised.

The issue of food supply is further complicated by the extent of the UK's reliance on food imports.

The following useful principles have been identified in this study to maximise synergies and minimise trade-offs:

- Plan habitat creation at a landscape scale
- Explore and celebrate multi-functionality
- Adopt the 'Place, People and Public value' approach when introducing change
- Balance the use of Best and Most Versatile Land for food production with other ecosystem services it can deliver
- Develop a pathway for agricultural transition on deep lowland peats
- Avoid displacement of carbon
- Factor in climate changes over time
- Recognise that changes in land use are inevitable to meet net zero targets
- Recognise energy as part of the mix of rural land uses
- Recognise geographical variations in the impacts of climate change
- Embrace multifunctionality at farm and/or landscape scale

The concept of farming at ‘Maximum Sustainable Output’ (MSO), or perhaps more colloquially, the ‘sweet spot’ where outcomes for food and nature are optimised, is emerging. For example, Clark and others (2019) showed that on upland and marginal livestock farms, reducing output and stock numbers to a level where stock are grazed only on the farm’s naturally available grass (i.e. without artificial fertilisers), increases profit through significant savings on variable and often volatile costs. These farming practices increase nature and on carbon-rich soils, will also reduce greenhouse gas emissions from soils and enable restoration of priority habitats.

Contents

1. Introduction

The Environment Partnership (TEP) was commissioned by Natural England in November 2023 to assess the potential for England's ecosystems to deliver biodiversity targets in ways that also prioritise reducing greenhouse gas emissions and increasing carbon sequestration rates; in short a rapid review of the contribution that semi-natural habitats can make to the Net Zero mission. The project seeks to identify those habitats and geographical locations that would make the best return on investment to achieve long term functional recovery of carbon in ecosystems. The project has four strands:

Part 1: A national assessment of the range of carbon storage and sequestration values in existing priority habitats, generating a short-list of high carbon habitats.

Part 2: An assessment of the impacts of climate change on high carbon habitats to determine the risks to their mitigation value and potential adaptation measures to reduce vulnerability at 1.5, 2 & 4 degrees of heating.

Part 3: An evaluation of the potential of new habitats & ecosystems restoration to deliver the greatest increase in biodiversity while retaining carbon storage and increasing sequestration rates. Based on the above evidence, analysis of what types of landscapes are needed to achieve the functional restoration of these ecosystems and be most effective in delivering carbon & biodiversity outcomes in the long term. Part 3 also includes Nature Net Zero 'pathways'; in other words various scenarios which deliver carbon benefit and nature recovery.

Part 4: An outline of the trade-offs and synergies between different land uses and where good integrated delivery can achieve better outcomes.

This report assesses the trade-offs and synergies between creating and restoring habitats for biodiversity, carbon storage, sequestration in terms of impacts on land use in England. It identifies principles for where good integrated delivery can achieve better outcomes.

It considers the five habitat creation and restoration scenarios constructed and analysed for Part 3 of the research – Habitat Expansion for Carbon.

- Scenario 1: Focused on maximising restoration of peat-based habitats
- Scenario 2: Focused on maximising tree and woodland planting opportunities
- Scenario 3: Focused on maximising new coastal habitats
- Scenario 4: Focused on maximising new grassland & heathland habitats
- Scenario 5: Focused on maximising new wetlands

2. Background

The government set out several targets to restore nature and protect the environment in the Environment Improvement Plan (DEFRA, 2023a). These are directly linked to the Convention on Biological Diversity (CBD) commitments the UK is signed up to deliver by 2030. In England, these targets are to:

- Restore or create more than 500,000 hectares of wildlife-rich habitat by 2042, alongside an international commitment to protect 30% of our land and ocean by 2030 (CBD, 2022), with an interim target to restore or create 140,000 hectares of wildlife-rich habitats outside protected sites by 2028, compared to 2022 levels.
- Increase tree canopy and woodland cover from 14.5% to 16.5% of total land area in England by 2050, with a new interim target to increase this by 0.26% (equivalent to 34,000 hectares) by 31 January 2028.
- Restore approximately 280,000 hectares of peatland in England by 2050, with an interim aim to fund the restoration of over 35,000 hectares of peatlands by 2025 through the Nature for Climate Peatland Grant Scheme

The England Peat Action Plan (UK Govt., 2021) set out the government's long-term vision for the management, protection and restoration of all our peatlands, which total some 1.4 million hectares.

The Climate Change Committee has estimated that approximately 21% of agricultural land in the UK will need to change function – to forestry, energy crops, peatland or agroforestry – in order to meet our net zero commitments (Climate Change Committee, 2020).

To achieve such targets will require a change in some land uses, most of which will be in the rural environment. Land use in England is dominated by agriculture which occupies 63.1% of the land with 20.1% occupied by forestry, open land and water (DLUHC, 2022).

Most ecosystems are capable of delivering more than one ecosystem service and can be regarded as 'multi-functional'. While management interventions can enhance the output of some services, it is apparent that in some situations not all services can be delivered simultaneously (Medcalf and others, 2014). As a result, when land-use changes, a "trade-off" will occur and the type, magnitude and mix of services delivered by an ecosystem will change.

The land management actions required to deliver habitat creation and restoration alongside actions to mitigate and adapt to climate change have significant potential co-benefits or synergies, such as improved air and water quality, enhanced biodiversity and improved recreational opportunities. However the creation or restoration of 'high-nature, high-carbon' habitats can also reduce other ecosystems services currently provided. For example the creation of new deciduous woodland on arable farmland would reduce the production of food and lead to a loss of farmland bird communities it supports.

This project has identified five habitat creation and restoration scenarios which would achieve a synergy between enhancement of biodiversity and the climate regulation ecosystem service provided by priority habitats that store and sequester carbon. These scenarios would also deliver the England-wide targets for protection and restoration of nature cited in the Environment Improvement Plan.

These five scenarios are focussed on;

- peat-based priority habitats,
- deciduous woodland,
- coastal habitats,
- grasslands and heathlands
- wetlands.

The scenarios are quantified in the Part 3 report of this Nature Net Zero project. They illustrate different pathways for achieving the nature recovery targets, whilst also estimating the increase in carbon stored in, and sequestered by, the new priority habitats.

Part 3 also demonstrates that there are options about how the nature recovery targets are delivered, and some choices could have little impact in terms of increasing habitat carbon because of:

- The relatively small areas of land involved
- The lack of clear spatial information on the opportunities that creation of high-carbon wildlife-rich habitats could deliver.
- The need for much more front-loaded delivery of high-carbon habitats that take several decades to achieve their ultimate carbon store, such as peatlands and deciduous woodland; on the basis that early investment will bring early benefit in terms of abatement of current emissions, improved resilience to future unavoidable climate change and slowing current habitat degradation and loss of peaty soil resources.

Each of the five 'higher carbon' scenarios would involve local and landscape-scale changes in land use and hence trade-offs with current land-uses and the ecosystem services they provide would be inevitable. There are a range of definitions for trade-offs including 'the balance achieved between two desirable but incompatible states or situations' (Haase and others, 2012) or "management choices that intentionally or otherwise change the type, magnitude, and relative mix of services provided by ecosystems" (Millennium Ecosystem Assessment, 2005). For this study, trade-offs are described as the increase of the provisioning of one ecosystem service and the simultaneous decline of another service.

The local and landscape-scale changes in land use may also however also provide synergies by the enhancement of multiple ecosystem services. This is where increasing the supply of one service contributes to the enhancement of others i.e. a 'win-win' situation (Haase and others (2012), Metcalf and others (2014)).

This paper outlines the range of trade-offs and synergies that could come into play as the result of the five habitat and carbon scenarios; and the associated changes to land use.

3. Methodology

Trade-offs and synergies are identified and analysed using an 'ecosystem services framework', based on the services identified within the UK National Ecosystem Assessment (UKNEA, 2011). The following ecosystem services were assessed as they are considered the most appropriate for the predominantly rural situations where the habitat creation or restoration scenarios would be implemented:

- Carbon storage
- Biodiversity
- Timber, hay and other materials
- Plant-based energy
- Cultivated crops
- Intensive meat and dairy
- Extensive meat and dairy
- Water supply
- Water quality
- Flood protection
- Pollination
- Climate regulation

For the purposes of this assessment these ecosystem services are defined as the components of nature that are directly enjoyed, consumed, or used in order to maintain or enhance human well-being (Lusardi and others, 2018).

Synergies or trade-offs were identified between the five habitat scenarios considered in Part 3 and ecosystem services currently provided by existing land uses.

Positive or negative relationships were assigned based on professional judgement and literature review. Where uncertainty on the relationship exists, a question mark (?) was used. Where there is no relationship between the existing land-use and the habitat scenario the term 'n/a' was used.

The five habitat scenarios were also subdivided into upland and lowland scenarios, where feasible, to provide additional focus. The narrative for each scenario considers where land use trade-offs and synergies can provide positive public benefits, such as flood mitigation, climate regulation, water quality and pollination.

The narrative also considers, at a high level of analysis, the extent to which food production may be impacted, by reference to Provisional Agricultural Land Classes (ALC) and the definition of best and most versatile land. Where food production might be significantly affected, the narrative considers whether the works need to implement habitat restoration could also mitigate the effects of climatic heating on food production; for example measures to re-wet upland bogs could benefit farming enterprises by improving livestock's resilience to future summer droughts.

Data sources

Table 1. GIS data sources and dataset currency

Dataset	Download Data	Dataset Currency
Habitat Networks (Individual Habitats) (England)	22-01-2024	06-06-2023
Peaty Soils Location (England)	04-12-2023	25-04-2022
Priority Habitats Inventory (England)	21-11-2023	28-07-2023
Provisional Agricultural Land Classification (ALC) (England)	30-04-2024	01-04-2019

Limitations

This is a rapid review of trade-offs and synergies intended to assist with consideration of how the five habitat scenarios might be implemented. The over-arching aim of the Nature Net Zero project is to identify landscape-scale interventions that achieve landscape and nature recovery whilst also building carbon in nature. Engagement with stakeholders such as landowners, community, visitors, businesses would be needed to refine the process of identifying trade-offs in a particular location.

The subdivision between lowland and upland habitat scenarios is a simplification of the complexity and variety of farming and rural enterprise.

The Provisional Agricultural Land Classification (ALC) data is a national dataset digitised from the published 1:250,000 maps which was in turn compiled from the 1 inch to the mile maps published in the period 1967 to 1974. The dataset has not been updated to reflect subsequent development on agricultural land. The dataset shows only five grades: its preparation preceded the subdivision of Grade 3 (into 3a and 3b), with 'Best and Most Versatile' agricultural land subsequently graded 1 to 3a . Despite these limitations it provides a useful indicative reference to assess trade-offs and synergies against.

Some ecosystem services and land uses are not included in the analysis. For example production of fish and sporting use of land such as for game shooting are not included. While trade-offs and synergies will occur for these services, these are not universal issues and trade-offs will need to be identified at a local scale.

Cultural ecosystem services are not included in this analysis of trade-offs and synergies. These are very important and will need to be considered when decisions on land use are made for particular areas and stakeholder views are sought, but given the study budget and timeframe, these were excluded from consideration for this England wide analysis.

As a general principle, however, cultural services such as sense of place and spiritual connections to nature are likely to be positively affected by creation and restoration of priority habitats; and are unlikely to decline as a result of habitat creation and restoration.

4. Results and Discussion

The assessment of the individual scenarios is set out below and summarised in Table 8.

Peat based habitats

The present extents of peat-based priority habitats are:

- 230,000 ha of blanket bog
- 13,000 ha of lowland raised bog
- 7,300 ha of lowland fen on peat,
- 9,500 ha of upland flushes, fens and swamps on peat
- 183,000 ha of upland heathland on peat
- 41,000 ha of coastal floodplain and grazing marsh on peat.

From an analysis in Part 3 we have identified that up to 349,000 hectares of peat-based habitats (currently not identified as priority habitat) could be restored for nature and carbon in the Habitat Network. This falls in the following categories:

Uplands

- Blanket bog: 182,000 hectares
- Upland flushes, fens and swamps: 50,000 hectares
- Upland heathland: 48,000 hectares

Lowlands

- Lowland fen: 66,000 hectares
- Lowland raised bog: 3,000 hectares

In addition, about 150,000 hectares of deep and shallow peat outside habitat enhancement and fragmentation action zones could be restored; typically underlying agricultural land such as the Fens.

Full details of the opportunity for restoration of 349,000 hectares of peat-based priority habitat, together with the estimated future carbon storage and sequestration is given in the Part 3 report, and summarised in Table 2 below.

Table 2. Peat based habitat opportunities within Network Enhancement Zone 1 (NEZ1) and Fragmentation Action Zone (FAZ). Total carbon storage based on typical values with a consideration for peat. Total carbon sequestration based on typical rates.

Habitat Network	Restoration Opportunity Area hectares	Future Carbon Storage if Ecosystem restoration delivered t C	Future Total Carbon Sequestration $t\ CO_{2}e\ y^{-1}$
Blanket bog	181,789	37,423,695	621,718
Lowland fen	66,021	54,099,501	218,529
Lowland raised bog	2,948	4,745,570	10,081
Upland flushes, fens and swamps	50,102	10,829,799	171,350
Upland heathland	48,103	6,113,342	2,598
Total	**348,962**	**113,211,907**	**1,024,275**

Restoring peat based habitats, particularly those on degraded deep peat can provide significant carbon storage benefits. Although net sequestration may not occur in the short and medium term, nevertheless restoration of priority peatland habitats would result in rapid abatement of current emissions and slowing down of the loss of peaty soils.

Restoring blanket bogs, raised bogs and fen peats will provide significant biodiversity benefits. In doing so the management action of raising of water levels to restore the peat provides multiple other benefits and synergies including improved water quality in catchments and enhanced water storage to reduce the risk of flooding downstream and aquifer recharge that offsets summer drought.

However in some landscapes there would be a negative trade-off from restoring peatlands such as a reduction in the area of cultivated crops in the lowlands, where agricultural land is switched to alternative land uses such as nature conservation or paludiculture.

When the 349,000 hectares of restoration of peat-based priority habitats in the Habitat Network is combined with the restoration of 150,000 hectares of land overlying deep and shallow peats outside the Habitat Network, a total of around 500,000 hectares of peat-based habitat could be restored; accepting that the 150,000 hectares may not be full restoration to priority habitat status.

Table 3 shows the relationship between peat based habitat opportunities and ALC grades. Approximately 23% of the peat based habitat opportunities overlie Grades 1 and 2 ALC land, which are located in the lowlands, and 59% in Grades 4 and 5 predominantly in the uplands.

Table 3. Areas of peat based habitat opportunities and relationship with ALC grades

Grade 1 (ha) %	Grade 2 (ha) %	Grade 3 (ha) %	Grade 4 (ha) %	Grade 5 (ha) %	Non agric./urban/ no ALC (ha) %
57,875 ha 11.55%	57,358 ha 11.45%	47,329 ha 9%	71,459 ha 14%	227, 306 ha 45%	36,715 ha 7%

In the lowlands the majority of peatland has been converted to agricultural use. As drainage lowers the peat water table, air penetrates deeper into the peat which enables the previously stored carbon to be decomposed into CO_2. About 39% of deep fen peats are currently under cultivation (Natural England, 2010). Much of this is classified as the best and most versatile land i.e. Grades 1, 2 and 3a under the Agricultural Land Classification (ALC), with Grades 1 and 2 accounting for 21%, and SubGrade 3a for 21% of the agricultural land in England (Natural England, 2012). As an example the extent of peat and comparative ALC grades (Provisional) for an area of the Fens (Landscape Description Unit 22334 LWW) are illustrated in Figure 1 and 2.

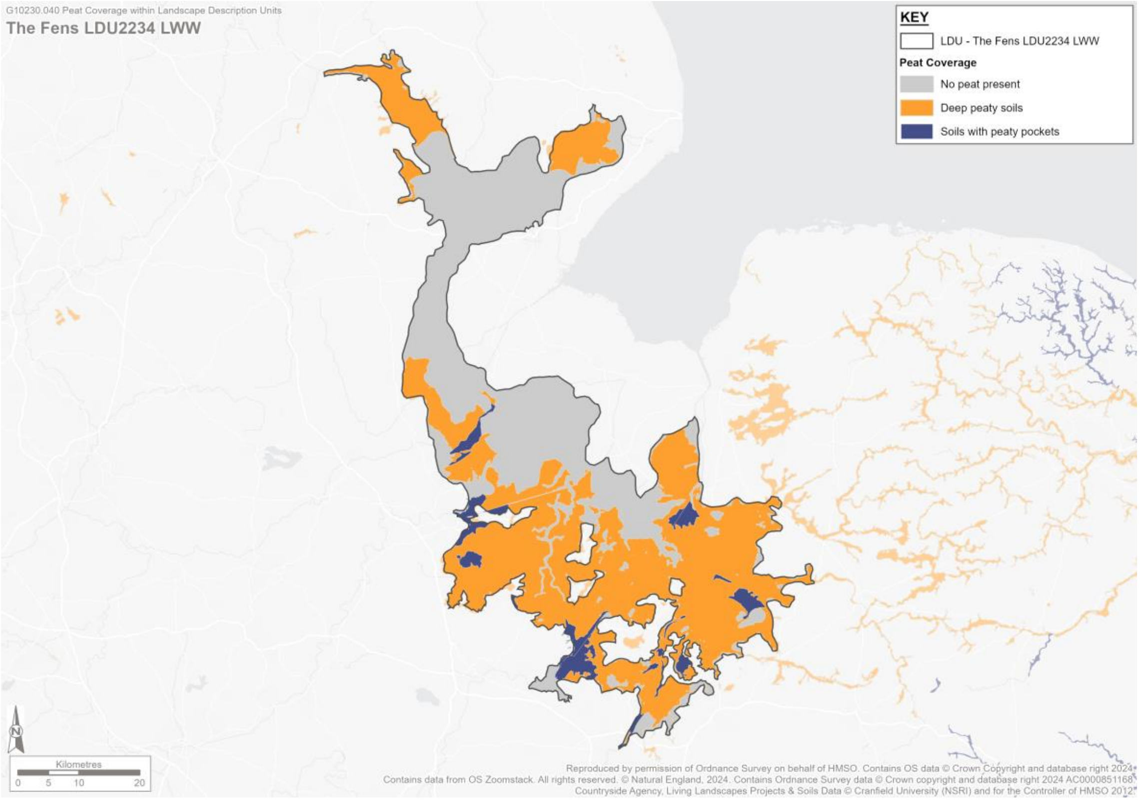

Figure 1. Extent of peat in the Fens (LDU 2234 LWW).

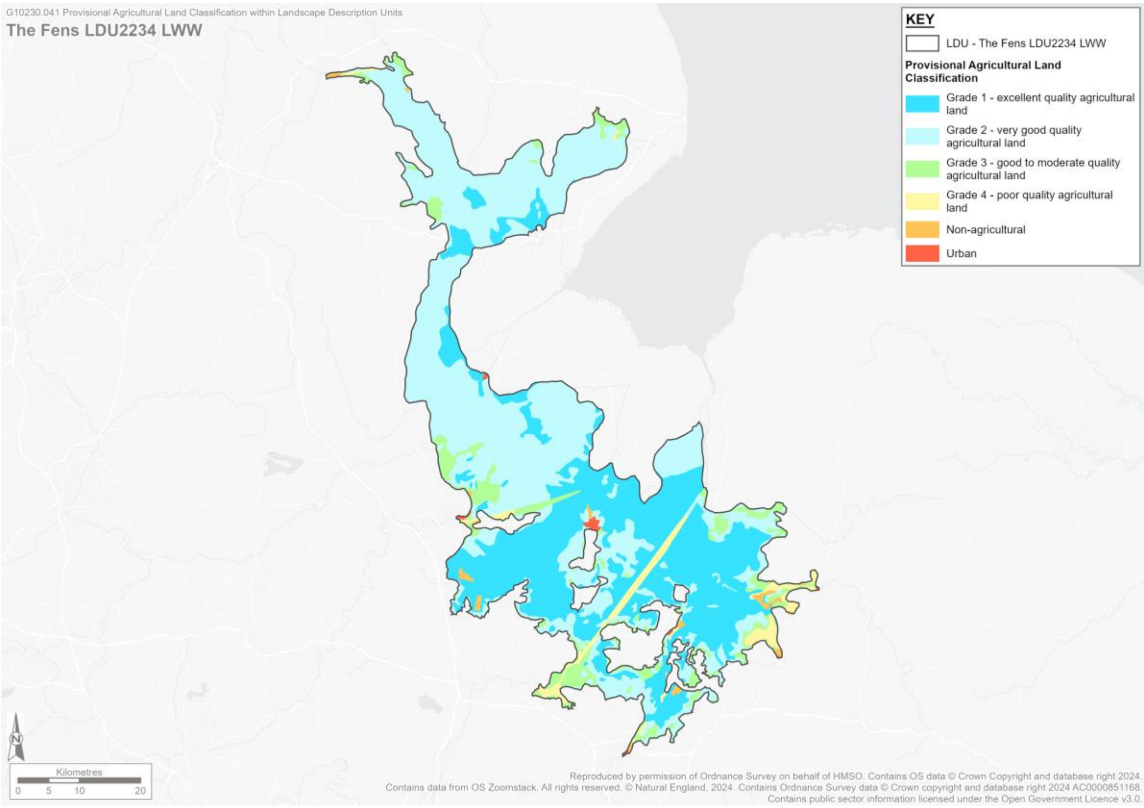

Figure 2. Agricultural Land Classification Grades (Provisional) in the Fens (LDU 2234 LWW).

Much of this land can be highly profitable to farm. For example the Fens of East Anglia cover less than 4% of England's farmed area, but contribute to more than 7% of England's total agricultural production which is worth £1.23 billion to the UK economy (National Farmers Union, 2019).

Wasted peat, peat that has been substantially degraded following years of drainage and cultivation so that the peat is now more dominated by underlying mineral material, has a lower agricultural value than deep fen peat, but the cost of artificially maintaining water levels through controlled drainage to enable intensive agriculture in these areas is likely to rise. The unabated use of our remaining deep fen peats for agriculture is therefore unlikely to be viable (Natural England, 2010).

Restoration of peatlands in the lowlands would result in changes in land use but would not necessarily result in a total cessation of agriculture. The land still could be used for low intensity farming possibly through wet agriculture, or paludiculture, defined as farming and agroforestry systems designed to generate a commercial crop from wetland conditions using species that are typical of (or tolerant of) wetland habitats (Mulholland et al. 2020).

Government funding has already been provided through the Paludiculture Exploration Fund (PEF) to unlock barriers to making commercial paludiculture viable on lowland peat soils in England (Natural England, 2022). In some situations paludiculture can appear to be a return to management akin to historical land use practices such as the growing and harvesting of reedbeds or the low-intensity, seasonal grazing of livestock on semi natural fen (International Union for the Conservation of Nature (IUCN) UK Peatland Programme, 2023).

Similarly restoration of peatland habitats in the uplands, notably on degraded blanket bog, is likely to require minor trade-offs such as a reduction in livestock grazing, predominantly sheep, and a decrease in the provision of livestock products.

The extent of the grasslands in the uplands classified as grass moorland (non priority habitat) with potential to restore peat-based habitat is notable. There is 141,857ha of grass moorland, of which 70% (99,007 hectares) overlies deep and shallow peat and therefore through restoration back to peat-based habitats can store a significant amount more carbon, reversing the present carbon emissions. Grass moor is often a result of overgrazing of previous high quality habitats, through CAP upland headage payments which caused consequential damage and degradation of these habitats present prior to its introduction.

Our research showed that grass moorland stores 12,341,602 t C (refer to Part 1 report - Appendix 2 table 14). The grasslands in the uplands are also generally less productive than grasslands in the lowlands so more extensive management is less likely to impact food production, but significantly increase other public benefits.

Although such land is not the most productive, predominantly Grades 4 and 5, agriculture plays an important economic and social role in the rural uplands of England. There are examples of upland farmers taking a soil-led approach to husbandry of peaty soils, for example by amending grazing periods to reduce pressure on wet ground, fencing out watercourses, and using natural flood management techniques.

This approach, reported by Clark and others (2019) has shown that on the upland and marginal livestock farms examined, reducing output (and hence stock numbers) to a level where stock are grazed only on the farm's naturally available grass (i.e. without artificial fertilisers), increases profit (or reduces losses), through significant savings of variable costs. This is termed 'Maximum Sustainable Output' (MSO), or more colloquially, farming at the 'sweet spot' to deliver food and nature.

Similar research to that undertaken by Clark and others and the Nature Friendly Farming Network and The Wildlife Trusts (2023) on farm profitability in the uplands is needed, alongside practical support, into how to deliver these changes long-term and across ownership boundaries so they are effective at landscape and catchment scales. This would include case studies of good practice where upland farm profitability can be increased by reducing inputs of materials such as fertiliser and pesticide, management time; whilst also accepting a reduction in livestock impacts on peat-based habitats.

Trees and woodlands

We identified in Part 3 that at least 254,000 hectares of priority deciduous woodland expansion can be achieved in network enhancement and fragmentation action zones around existing ancient woodland and wood pasture and parkland. This expansion would not require any planting on peaty soils. This compares to the existing area of deciduous priority woodland of 759,522 hectares.

Much greater areas of priority woodland expansion, up to 543,000 hectares, can also be achieved around traditional orchards, but as the Part 3 report indicates, this would not deliver as many concentrated habitat connectivity benefits as the expansion of deciduous woodland in ancient woodland and wood pasture and parkland networks.

Deciduous woodland creation is an important tool to achieve Net Zero and deliver biodiversity targets in England. Woodland can also provide multiple benefits to society including increasing timber supply, reducing flood risk and providing shade and cooling, particularly along watercourses.

However woodland creation is about 'planting the right tree in the right place' to maximise the benefits and minimise any impacts. Afforesting high quality farmland (Grades 1,2,3a) should generally be avoided, other than in pockets of land that are unproductive, prone to flooding or difficult to farm, as it is likely to reduce the UK's capacity to grow food and place an even greater reliance on food imports. There is a trade-off, as high-grade land (1,2,3) will grow better and bigger trees that delivers greater carbon benefits on less land. Similarly afforestation of peatland and carbon-rich soils needs to be avoided to prevent disturbance of long held stores of carbon. Funding for woodland creation through existing Forestry Commission grant schemes already excludes land which contains peat of more than 30cm depth (Defra, 2023b).

Establishing new deciduous woodland on grasslands of low biodiversity and limited existing carbon stocks requires fewer trade-offs. The Forestry Commission have identified 3 million hectares as having no obvious environmental or societal protections that would be adversely affected by woodland creation (Forestry Commission, 2024).

Table 4 shows the relationship between woodland based habitat opportunities and ALC grades. Only 12 % of the woodland habitat opportunities overlie Grades 1 and 2 ALC land, and 19% in Grades 4 and 5. The majority 57% overlie Grade 3 land, though as previously described the data is not split into Grades 3a and 3b. It should be remembered that this measure of woodland opportunity only includes the habitat network for ancient woodland and wood pasture and parkland, because a habitat network for deciduous woodland has not been defined.

Table 4. Area of woodland habitat opportunities and relationship with ALC grades

Grade 1 (ha) %	Grade 2 (ha) %	Grade 3 (ha) %	Grade 4 (ha) %	Grade 5 (ha) %	Non agric./urban/ no ALC (ha) %
2,089 ha 1%	27,346 ha 11%	146,068 ha 57%	44,328 ha 17%	5,470 ha 2%	3,340 ha 11%

Food and timber production could be combined through agroforestry to provide synergies, either through integrating trees and woodlands into arable (silvoarable) systems or livestock (silvopastoral) systems). Although currently not widely practiced in the UK agroforestry could provide climate mitigation benefits through the presence of trees, better soil conservation and increased soil carbon (Stafford et al. 2021). It could also assist with climate adaptation through reducing flood risk, providing microclimate benefits and preventing soil erosion.

More extensive on-farm woodland reduces yield but may provide alternative market products such as timber and wood fuel to diverse farm income streams as well as public goods such as habitats for wildlife and improved amenity value (The Royal Society, 2023) especially if targeted to least productive areas of the farm such as field corners, stream side and steeper sloping land. Other less extensive habitats such as orchards, hedgerows and scrub can also provide similar synergies.

Coastal habitats

Part 3 of the report identifies that up to 119,000 hectares of coastal habitat (salt marsh, sand dune, vegetated shingle and maritime cliff and slope) could be created or restored in network enhancement and fragmentation action zones.

An increase in the area of coastal habitats, particularly the creation of new areas of salt marsh would have benefits for biodiversity, carbon sequestration and burial of carbon in saltmarsh sediment. Much of these low lying coastal areas once had extensive areas of saltmarsh and coastal wetlands that have been drained to allow agriculture to be the major land use.

In situations where settlement is at risk from coastal or tidal flooding, creating coastal habitats adjacent to these areas can provide a natural form of protection from sea-level rise and buffer the effect of storms. Shoreline Management Plans provide a framework for assessing the feasibility and benefits of coastal habitat creation and restoration for the purpose of adapting to sea level rise and protecting settlements. Further information is provide at www.gov.uk/guidance/shoreline-management-plans

The creation of saltmarsh would require a change in land use and trade-off in areas of low lying arable and grassland used for intensive food production, which are often protected by hard defences; a process sometimes termed 'managed realignment'.

Table 5 shows the relationship between coastal habitat opportunities and ALC grades. About 13 % of the new coastal habitat opportunities overlie Grades 1 and 2 ALC land, and 12% in Grades 4 and 5. 37% overlies Grade 3 land, though as previously described the data is not split into Grades 3a and 3b.

Table 5. Area of coastal habitat based opportunity and relationship with ALC grades

Grade 1 (ha) %	Grade 2 (ha) %	Grade 3 (ha) %	Grade 4 (ha) %	Grade 5 (ha) %	Non agric./urban/ no ALC (ha) %
5,972 ha 5%	10,038 ha 8%	43,947 ha 37%	12,452 ha 10%	1,958 ha 2%	44,798 ha 38%

Existing saltmarshes already provide important grazing grounds for extensive agricultural systems, such as markets for saltmarsh-grazed meat, so there are opportunities for managing the trade-off by switching to different forms of food production.

Saltmarshes can also provide a role in regulating water quality by reducing high nutrient levels as the ecosystem takes up inorganic nutrients such as phosphates and nitrates (Hudson and others, 2021).

Grasslands and heathland

The Part 3 report identifies that up to 890,000 hectares of priority grassland and heathland habitats has the potential to be created or restored in network enhancement and fragmentation action zones. This breaks down into:

- 665,000 hectares in the lowlands (calcareous, acid, neutral meadows and lowland heathland)

- 225,000 hectares in upland and transitional landscapes (purple moor grass and rush pastures, upland calcareous grassland, hay meadows and heathlands).

It is noted that these are significant extents and far exceed the amount of existing priority grassland and heathland habitats, and may not be feasible to deliver at pace. For example the current extent of priority lowland calcareous grassland is 65,662 ha, whereas the habitat network opportunity for this priority habitat is 215,268 ha.

Creation and restoration of these habitats in the lowlands would generally occur on existing intensive grasslands and some cultivated croplands. The process would involve conversion to permanent extensive grasslands, through a reduction of fertiliser and pesticide inputs, changes to water level management or changes to hay cropping and livestock management; whatever is appropriate to increase floristic diversity in the specific situation. Greater benefits will be obtained on steeper sites, next to water courses, adjacent to existing habitat patches and where access is more complex. As shown in Table 6, 45% of the grassland and heathland habitat opportunities overlie poorer grades (Grades 4 and 5) land.

Table 6. Areas of grassland and heathland habitat opportunity and relationship with ALC grades

Grade 1 (ha) %	Grade 2 (ha) %	Grade 3 (ha) %	Grade 4 (ha) %	Grade 5 (ha) %	Non agric./urban/ no ALC (ha) %
4,918 ha 1%	47,584 ha 5%	366,885 ha 41%	257,616 ha 29%	141,871 ha 16%	71,465 ha 8%

As the extent of opportunity is so large, there is a significant longer-term benefit in terms of increasing carbon stored in soils, including vegetation litter layers. The increase in national annual sequestration is limited, because the change from one form of grassland to another has relatively little impact on carbon fluxes.

The increase of extensive management of grasslands for carbon storage and biodiversity benefits has less of a trade-off with existing agricultural activity, when compared to some of the other scenarios notably woodland creation as it can still be utilised for food production. Grassland soils can also absorb and filter water, cycle nutrients and store carbon and can increase water filtration rates and reduce flood risk (Ellis, undated).

As noted in the peat scenario, there are large areas of 'grass moorland' (a non-priority habitat) in the uplands. There is 141,857ha of grass moorland, of which 70% (99,007 hectares) overlies deep and shallow peat and therefore through restoration back to peat-based habitats can store a significant amount more carbon, reversing the present carbon emissions. Grass moor is often a result of overgrazing of previous habitats through CAP upland headage payments which caused consequential damage to habitats present prior to its introduction.

The grasslands in the uplands are also generally less productive than grasslands in the lowlands so more extensive management is less likely to impact food production, but significantly increase other public benefits. As noted for blanket bog, there are case studies of upland farmers taking a soil-led approach to livestock husbandry and farm management, and finding ways of maintaining profitability even when livestock numbers and/or freedom of grazing is reduced.

More extensive management of grasslands in the lowlands is likely to have more of an impact on food production as there would be a reduction in intensive production of meat and milk. Where Table 8 shows a positive synergy between grassland expansion and extensive meat and dairy operations, this usually reflects an earlier prior negative trade-off with cultivated crops or intensive meat and dairy operations.

The creation and restoration of heathlands on former agricultural land requires bespoke techniques targeted at particular soil types. It can bolster heathland networks and increase habitat connectivity. Creating heathland from ex-arable land in the lowlands will result in increased carbon sequestration in soils and vegetation. Restoring degraded heathland (e.g. overgrazed and transformed into grassland), will also result in increased carbon sequestration in soils and vegetation (Stafford et al. 2021).

Heathlands are typically low output systems and support much lower stock levels than grassland habitats, but extensive grazing still allows some food production. In the uplands the creation or restoration of heathlands would also provide benefits of water storage and flood prevention. In the lowlands, particularly in southern England, there are also potential benefits of water purification, recreational opportunities and possibly water supply.

Lowland wetlands

The Part 3 report identified that up to 156,000 hectares of priority wetland habitats (lowland fens and reedbeds) can be created or restored in habitat network enhancement and fragmentation action zones, much of which is in floodplain.

There is also a considerable opportunity for creation of coastal and floodplain grazing marsh, but this cannot be mapped or quantified at present.

This opportunity would be realised primarily on existing grasslands and some cultivated croplands. Some of this overlaps with the peat-based habitat scenario described earlier.

When functioning naturally, freshwater habitats and floodplains mostly function as carbon sinks, so re-naturalisation of watercourses and wetland restoration can provide natural flood management in catchments by a shift of land use from intensive agricultural production to semi-natural habitats that can help to slow, store and filter water.

However restoring areas of wetland habitats could result in trade-offs notably from predominantly arable and intensive livestock agriculture. Table 7 shows that much (40%) of the wetland habitat opportunity overlies Grade 3 agricultural land (though with no subdivision between Grades 3a and 3b) and 28% in Grades 4 and 5.

Table 7. Areas of wetland habitat opportunity and relationship with ALC grades

Grade 1 (ha) %	Grade 2 (ha) %	Grade 3 (ha) %	Grade 4 (ha) %	Grade 5 (ha) %	Non agric./urban/ no ALC (ha) %
6,204 ha 4%	13,420 ha 9%	62,940 ha 40%	37,663 ha 24%	6,016 ha 4%	29,555 ha 19%

Conflicts with food production could be reduced by minimising the conversion of high-grade agricultural land. Only 13% of England's best and most versatile land (ALC Grades 1, 2 and 3) is located in the floodplain, though this does include more than half (58%) of the total resource of Grade 1 agricultural land (Defra, 2011). Creation of new priority wetlands in the Habitat Network would involve only 6,204 hectares of loss of Grade 1 land, so at a national scale, this loss is relatively insignificant.

Where Table 8 shows a positive synergy between wetland expansion and extensive meat and dairy operations, this is more likely to occur on newly-created coastal and floodplain grazing marsh and usually reflects an earlier prior negative trade-off with cultivated crops or intensive meat and dairy operations that would have to be sacrificed to enable wetland restoration.

A literature review (Lawson et. al., 2018) demonstrated that semi-natural floodplain habitats are a vitally important component of the UK's natural capital and can provide a wider range of goods and services than intensive arable/ horticultural crops, so society would benefit from this trade-off.

Summary

Table 8 summarises the trade-offs and synergies associated with a change of land use to deliver 'high-carbon, high-nature' habitats by restoration of peatlands and creation of new priority woodlands, coastal habitats, grasslands and wetlands.

Table 8. Land use trade-offs and synergies

Ecosystem services / habitat scenario	Carbon Storage	Climate Regulation	Biodiversity	Timber, hay and other materials	Plant-based energy	Cultivated crops	Water supply	Intensive meat & dairy	Extensive meat & dairy	Water quality	Flood protection	Pollination
Max. peat - lowlands	++	++	+	?	n/a	-	+	-	-	+	+	+
Max. peat - uplands	++	++	+	?	n/a	n/a	++	-	-	++	++	+
Max. trees - lowlands	++	++	+	+	++	-	+	-	-	+	+	+
Max. trees - uplands	+	+	+	+	+	n/a	++	-	-	++	++	+
Max. coastal habitats	+	+	+	n/a	n/a	-	+	-	+	+	+	+
Max. grassland - lowlands	+	+	+	+	n/a	-	+	-	+	+	+	++
Max. grassland – uplands	+	+	+	+	n/a	n/a	+	-	+	+	+	+
Max. heathland - lowlands	+	+	+	+	n/a	-	?	-	+	+	+	++
Max. heathland – uplands	+	+	+	+	n/a	n/a	+	n/a	+	+	+	+
Max. lowland wetlands	+	+	+	+	+	-	+	-	+	++	+	+

Key: + positive impact on ecosystems goods and services; - negative impact on ecosystems goods and services; ? uncertain impacts; n/a not applicable

Principles for Integrated Delivery

The Government consulted on a draft Land Use Framework in spring 2025. Its aim is to provide a set of principles for decision-making to ensure English land performs a range of functions over the long term. An example of how the draft LUF recognises the multiple functions of land in the face of climate change is the following statement: "A thriving natural environment and stable climate are the foundations of our economy and are essential to food security and profitable farm businesses. Changes in English land use are required to reverse the decline of our natural environment, help absorb greenhouse gases, adapt to the impacts of climate change, and increase the resilience of our food systems, infrastructure, homes and communities"

The Nature Net Zero project has shown that it is possible to deliver the Government's nature targets by creation and restoration of 'high-carbon' habitats, thus contributing to net zero targets and the ecosystem service of 'climate regulation'.

In itself this is an example of integrated delivery, but to further maximise synergies and minimise the trade-offs shown at Table 8, some useful principles are available from literature review.

Plan at a landscape scale to accommodate all land use needs within the context of a finite amount of land.

Explore and celebrate multi-functionality. There are opportunities where land can deliver multiple benefits such as carbon storage, food production and nature recovery through the concept of multifunctional land use which is increasingly being recognised as a way to deliver multiple benefits from land (House of Lords, 2022), (The Royal Society, 2023). Some locations have much greater opportunity to deliver this spatially than others.

Adopt the 'Place, People and Public value' approach when introducing change. The Food, Farming and Countryside Commission (2023) proposed a multifunctional land use framework around the headings of Place, People and Public Value:

- Place - Land use decisions should be land-led to ensure that land is used for what it is best suited – ensuring that the best agricultural land is used to produce food and not afforested, for example – and that land is managed to be adaptive and resilient to future climate impacts.
- People - A Land Use Framework must be locally responsive, ensuring that local stakeholders and citizens can be genuinely included in decision-making, and those land use decisions strongly relate to their connections with other places and future generations.
- Public Value - Land must be used to encourage multifunctionality in order to meet the challenges of the country, and contribute prosperity to local communities.

Balance the use of Best and Most Versatile Land for food production with other ecosystem services it can deliver. This study has shown, acknowledging the ALC data limitations, that with the exception of peat based habitat opportunities the identified habitat creation and restoration opportunities do not have an major overlap with high quality agricultural land available for food production. With approximately 25% of the peat based habitat opportunities overlying Grades 1 and 2 ALC land, which are located in the lowlands of England, a balance will need be struck between the retention of the Best and Most Versatile land for food production and the other ecosystem services, notably carbon storage and sequestration, the land can provide.

Nevertheless, loss of BMV will sometimes be unavoidable due to climate change e.g. where it is in floodplains or areas vulnerable to coastal squeeze – in these circumstances a transition to priority habitats will usually bring a wide range of public benefits including more carbon sequestration, improved flood resilience and improved water quality.

Develop a pathway for agricultural transition on deep lowland peats. As noted earlier, food production on the drained lowland deep peat soils particularly of the East Anglian Fens makes a very significant contribution to the national economy, both in terms of GDP and food security. However, this results in losses of stored carbon in the deep peats. This may be considered as an inevitable negative consequence of the economic need for food production. Yet continued intensive use is ultimately unsustainable as a result of its major greenhouse gas emissions, ongoing loss of soils to erosion and oxidation, along with the increasing need for irrigation and pumped water storage to maintain productivity in the face of increasingly hotter and drier summers.

Avoid displacement of carbon. The creation and restoration of semi-natural habitats and securing their carbon storage and sequestration benefits at one location needs to avoid an intensification of production or an adverse change of land use on carbon-rich habitats in the UK or overseas; therefore resulting in no net carbon benefit.

Factor in climate changes over time. Food production itself will also be impacted by climate change. General climate change trends projected over UK land for the 21st century in UKCP18 are broadly consistent with earlier projections (UKCP09) showing an increased chance of warmer, wetter winters and hotter, drier summers along with an increase in the frequency and intensity of extremes (Met Office, 2022).

In the short- and medium-term, there may be positive impacts on UK food production from climate change, with warmer and drier conditions increasing the variety of food products that can be grown in the UK, benefiting crop yields, extending the growing season, allowing new areas now suitable for different crops and reducing costs of housing livestock during warmer winters (UK Health Security Agency, 2023). However, without the introduction of sufficient adaptation measures to climate change, increasing temperatures are expected to reduce net crop yields in the longer term.

Recognise uncertainty. Specific impacts on food production arising from changes in land use are difficult to predict with any certainty. The total food supply in the UK, measured in terms of the quantity of food produced domestically and the origin and quantity of food produced elsewhere, varies greatly by type of food and season. Commonly cited statistics state that around 46% of the UK's food is obtained from overseas (DEFRA, 2021).

Therefore changes to alternative land uses from current agricultural use may not necessarily impact food security due to the well-established arrangements for food imports as well as opportunities to improve efficiency in agriculture.

Recognise that changes in land use are inevitable to meet net zero targets. The independent review of the food system, the National Food Strategy (2021), estimated that between 5% and 8% of farmland would need to be freed from production almost entirely, largely to plant broadleaf woodland and restore peat bogs to meet government climate change targets. Integrated delivery might maintain more land in active farming, and help rural businesses to transition, but change is unavoidable.

Recognise energy as part of the mix of rural land uses. The UK Climate Change Commission has advised that 260,000 hectares of domestic agricultural land needs to be shifted to bioenergy production by 2035 in order to meet net zero (Climate Change Committee, 2020).

Careful consideration needs to be given to how this change occurs, to avoid damaging wildlife habitats, impacting hydrology or shifting associated emissions onto other countries to meet the demands of the UK food market. The benefits of energy crops also be compared with other potential uses that could give greater carbon benefits, such as native-tree planting, as well as the impact on availability of high-value land for food production. Building understanding on how bioenergy crops could be delivered in an integrated way through the addition of more temporary wildlife enhancements offers in agri-environment schemes.

The carbon embodied in bioenergy crops is fixed from the atmosphere but as an energy source it is not without emissions. The land on which bioenergy crops is grown is then not available for other forms of carbon sequestration and storage, or for food production – the emissions associated with displaced food production might outweigh any benefits of producing bioenergy grassland to plant crops can leave soil exposed and vulnerable to erosion, leading to water pollution and flood risk. However, growing perennial biomass on poor agricultural land with depleted soils may improve soil quality and sequester carbon.

Land is also seen for potential delivery of renewable energy including solar farms, on shore wind and bioenergy. Solar and onshore wind farms have lesser impacts on land use compared to bioenergy. Different types of bioenergy crops compete directly with other land functions: biofuel crops and maize for anaerobic digestion compete most directly with arable food production, while biomass crops which can be grown on land less suitable for agriculture compete with forestry or land managed for nature.

Recognise geographical variations in the impacts of climate change. This research has shown that for some climatic parameters such as summer rainfall and temperatures the climatic changes and resulting impacts on key habitats such as blanket bog will be markedly more pronounced in the south west of England compared to the north. There is also uncertainty of whether habitats will store or sequester the same amount of carbon if the species composition of habitats changes in response to climatic pressures. Those which are more hydrologically dependent may be at greater risk.

Embrace multifunctionality at farm and/or landscape scale. There is growing evidence that within agricultural landscapes the recovery of many species can be achieved without undermining our ability to produce food through a three-pronged approach (Brotherton, 2021; Finch and others, 2019).

This approach consists of 'sparing' some land for nature (i.e. converting it to wildlife habitat and restored ecosystems); 'sharing' some land through high nature value farming which both produces food and benefits some species; and having some land under high yield agriculture.

This approach could be similarly adopted for carbon storage and sequestration e.g. the land 'spared' for nature is used for high-carbon habitats, while the land 'shared' with nature is subject to agricultural practices which build carbon-rich soils.

The optimum balance in this three-pronged approach will vary between different types of enterprise and across different types of landscape. Agri-environment support schemes in particular areas can be influenced by the national targets for nature recovery with guidance on whether the targeted habitat can be achieved best by 'sparing' or 'sharing' approaches at farm scale.

5. Recommendations and Conclusions

The assessment demonstrates there are trade-offs and synergies in increasing carbon storage and sequestration through habitat creation and restoration, as a result of the associated land use change.

There are likely to be more trade-offs in terms of food production (provision of intensive meat and dairy and cultivated crops) in the lowlands as a result of habitat creation and restoration, though in certain parts of the country such as the Fens current agricultural practices are not sustainable in the their current form, as a result of diminishing soil resources, major carbon emissions, increasing costs of artificial drainage and increasingly hotter and drier summers as the climate changes. The issue of food supply is further complicated by the UK's reliance on food imports.

Food production trade-offs in the uplands are also likely. Whilst perhaps lesser in terms of absolute volume and value, the effects on farm business margins and operational sustainability also need to be recognised. Given the value of upland farms to rural society and stewardship of the environment, case studies of good business practice and enterprise support may be beneficial to back up agri-environmental incentives that promote 'high-carbon, high-nature' outcomes in the uplands.

The creation and restoration of habitats in addition to increasing carbon storage and sequestration also have the potential to increase the supplies of other ecosystem services such as flood mitigation, climate regulation, water quality and pollination. These synergies provide positive public benefits to society.

There is a finite amount of land in England, and the United Kingdom, and multiple benefits need to be derived from it. The Nature Net Zero project has shown that it is possible to deliver the Government's nature targets by creation and restoration of 'high-carbon' habitats, thus contributing to net zero targets and the ecosystem service of 'climate regulation'.

The Government has committed to the publication of a Land Use Framework to manage the multiple objectives of food production, carbon sequestration, restoring nature, and growing energy crops and, following a consultation, is due to be published in 2025.

The following useful principles have been identified in this study to maximise synergies and minimise the trade-offs:

- Plan at a landscape scale
- Explore and celebrate multi-functionality
- Adopt the Place, People and Public value approach when introducing change
- Balance the use of Best and Most Versatile Land for food production with other ecosystem services
- Develop a pathway for agricultural transition on deep lowland peats
- Avoid displacement of carbon
- Factor in climate changes over time
- Recognise that changes in land use are inevitable to meet net zero targets
- Recognise energy as part of the mix of rural land uses
- Recognise geographical variations in the impacts of climate change
- Embrace multifunctionality at farm and/or landscape scale

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Glossary

Term	Definition
Ecosystem service	A function of the natural environment that directly or indirectly provides benefits for people (e.g. improving air quality or stormwater retention).
Synergy	Enhancement of multiple ecosystem services. Increasing the supply of one service contributes to the enhancement of others
Trade-off	The increase of the provisioning of one ecosystem service and the simultaneous decline of another service

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