Nature Net Zero

Part 3: Habitat expansion for carbon

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Part 3 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 out research and spatial analysis. Part 3 of the research evaluates the potential of habitat creation and ecosystem restoration to deliver the greatest increase in biodiversity while protecting stored carbon and increasing sequestration rates.

Government Targets for Nature Recovery

The government's targets to restore nature and protect the environment are set out in the Environment Improvement Plan (DEFRA, 2023) and enshrined in The Environmental Targets (Biodiversity) (England) Regulations 2023.

The habitat restoration and creation targets are area-based and include peatland, deciduous woodland and other 'wildlife-rich' habitats, a term defined by section 10 of the Regulations, which includes S41 priority habitats and other habitats listed at Schedule 1 of the Regulations (S1 habitats).

Natural England has published Environment Act Habitat Target – Definitions and Descriptions which sets out how the habitat targets will be defined and measured. It includes definitions for restoration and creation, the list of wildlife-rich habitats, and the actions that will count toward the target.

Some targets overlap. The headline target to 'restore or create more than 500,000 hectares of wildlife-rich habitat outside protected sites by 2042' includes an estimate of 100,000 hectares of biodiverse woodland and can include peatland restoration works. The targets are tabulated below, with notes on where delivery is possible.

Targets can be delivered in different areas:

1. Within existing habitat areas recognised in the priority habitat inventory (PHI); for example, restoration of degraded peatland habitats such as blanket bog.
2. Within habitat expansion zones in the 'Habitat Network' outside the existing PHI; this study uses the Network Enhancement Zone 1 (NEZ1) and Fragmentation Action Zone (FAZ) around existing priority habitats as the best areas to expand priority habitats. One example is the creation of blanket bog or upland heathland (priority habitats) on existing 'grass moorland' (a non-priority habitat). Another example might be the creation of new reedbeds (priority habitat) on land in a floodplain in NEZ1.

3. Outside existing habitats and adjacent areas (outside the ‘Habitat Network’); for example, creation of new woodland on land outside NEZ1 or FAZ, or re-wetting of lowland peat soils currently under arable cultivation to reduce loss of carbon.

The government’s targets are not articulated in terms of the Habitat Network expansion zones, nor in terms of carbon storage and sequestration. This study examines how the targets deliver against the total extent of opportunity for expansion of ‘high-carbon, high-nature’ habitats.

In practice many other objectives and constraints will also play a role in shaping future land use as is recognised in the recent Land Use Framework consultation (Defra, 2025). This project takes a scenario-based approach that can inform this wider discussion by estimating the potential carbon storage and sequestration if all the most suitable land that can deliver these outcomes is restored to nature rich ecosystems.

Peatland Restoration Targets

Table 1. Peatland Targets - Stated Aims with notes on possible locations for delivery

EIP Target	In existing priority habitat inventory	In Habitat Network expansion zones	Outside the Habitat Network	Notes
Restore 280,000 hectares of peatland by 2050	Yes	Yes	No	Peatland priority habitats currently cover 512,000 hectares, of which 361,000 hectares lies within SSSIs. Peatlands are in varying condition. Degraded habitats are significant carbon emitters. EIP also aims for 75% of all SSSIs to be in favourable condition by 2042. This study also identifies 350,000 hectares of non-priority habitat in Habitat Network Enhancement Zone 1 and Fragmentation Action Zone, mostly in uplands, that could be restored or re-created to priority peatland habitat. EIP also states that peatland restoration will contribute to the 500,000 hectare wildlife-rich habitat restoration / creation target.
Fund the restoration of over 35,000 hectares of peatlands by 2025	Yes	Yes	No	See notes above for extent of peatlands. This is an interim target.
Halt the continuing degradation and carbon emissions of lowland peat soils used for agriculture, principally by re-wetting them	No	No	Yes	This study identifies 203,000 hectares of deep and shallow lowland peat soils outside the priority habitat inventory and network enhancement zones.

Woodland Creation Targets

Table 2. Woodland Creation Targets with notes on possible locations for delivery

EIP Target	In existing priority habitat inventory	In Habitat Network expansion zones	Outside the Habitat Network	Notes
Increase tree and woodland canopy cover from 14.5% to 16.5% by 2050, of which at least 12% will be in woodland	No	Yes	Yes	This equates to about 250,000 hectares, or 9,000 hectares per year. It is not all expected to be biodiverse priority deciduous woodland. EIP states that biodiverse woodland creation will contribute 20% (100,000 hectares) of the 500,000 hectare wildlife-rich habitat creation target.
Increase tree and woodland canopy cover by 0.26% by January 2028	No	Yes	Yes	This is an interim target which equates to around 34,000 hectares.

Wildlife-rich habitat creation and restoration targets

Table 3. Wildlife-rich habitat restoration or creation targets with notes on delivery

EIP Target	In existing priority habitat inventory	In Habitat Network expansion zones	Outside the Habitat Network	Notes
Restore or create >500,000 hectares of a range of wildlife-rich habitats outside protected sites by 2042	Yes	Yes	Yes	EIP states this is expected to include 100,000 hectares of biodiverse woodland and also peatland restoration schemes outside protected sites, but no estimated area is given for peatland restoration schemes that can count towards this target.
Restore or create 140,000	Yes	Yes	Yes	See notes above.

EIP Target	In existing priority habitat inventory	In Habitat Network expansion zones	Outside the Habitat Network	Notes
hectares of a range of wildlife-rich habitats outside protected sites by 2028				This is an interim target

Targeting 'High-Carbon' Habitats and Landscapes

These nature recovery targets offer an opportunity to increase carbon storage and sequestration in habitats, at the same time as increasing biodiversity.

The study is concerned with expansion of habitats and associated carbon benefits within the Habitat Network, consistent with the Making Space for Nature Review (Lawton et al. (2010) principles of bigger, better, more, and more connected areas of priority habitat.

This study provides:

- Habitat and carbon scenarios in five habitat groups; (1) peat-based habitats, (2) woodlands, (3) coastal habitats, (4) grassland and heathland, and (5) wetlands.
- For each scenario, the following were identified: the extent of habitat creation or restoration opportunity in the Habitat Network, total carbon storage, total carbon sequestration, carbon storage estimates per hectare, and carbon sequestration per hectare.
- Comparison of the opportunities for carbon storage and sequestration
- Consideration of timescales for habitat creation or restoration
- Assessment of land availability for habitat and carbon delivery

The study examines which types of landscapes would be most effective in delivering carbon and biodiversity outcomes. England's 3,000 "Landscape Description Units" (LDU's), provide a more granular picture of the landscape than the 159 National Character Areas (NCA's), and are more precise for targeting delivery of agri-environment and other natural capital investment to achieve the targets.

England's LDU's were ranked in terms of the area of habitat they could deliver under each of the habitat and carbon scenarios. A national 'top ten' of LDUs is given for each scenario, and the detailed data, available in supplementary Excel workbooks, allows regional ranking and targeting.

Key findings

Maximum Peat (Scenario 1)

Conserving and Restoring existing PHI peatland habitats

There is currently 512,000 hectares of peatland in the PHI; defined as blanket bog, lowland raised bog, lowland fen, upland flushes, fens and swamps, upland heathland and mountain heaths and willow scrub. About 361,000 hectares lie within SSSI's, and 151,000 hectares outside SSSI's.

Degraded peatlands are significant GHG emitters and are highly sensitive to climate change, principally from higher temperatures and lower precipitation in summers. There is no reliable data on the overall condition of existing peatlands.

Part 1 of this research has shown that the existing peatland PHI stores approximately 203 million tonnes carbon, just under 40% of total carbon stored in the PHI as a whole. About 147 million tonnes of this is in SSSI peatlands.

A 'maximum peat scenario' to safeguard the existing PHI store of 203 million tonnes would require all the peatland PHI to be under restoration management, which goes beyond the EIP targets of a) 280,000 hectares peatland restoration by 2050 and b) 75% of SSSI's to be restored to favourable condition by 2042.

Abatement i.e. reductions in GHG emissions, compared to baseline, would commence shortly after restoration starts.

Restoration and / or re-creation to priority peatland habitat elsewhere in the Habitat Network

A maximum peat scenario offers a further opportunity for restoration to priority status of an additional 350,000 hectares of peatland in Habitat Network enhancement 1 and fragmentation action zones; as follows:

Table 4. Breakdown of Peatland Habitat Network restoration opportunity by area and carbon storage

Habitat Network	Total Opportunity Area in Network Enhancement Zone 1 and Fragmentation Action Zone (hectares)	Future Carbon Storage if Ecosystem restoration delivered (t C)
Blanket bog *235,641ha existing*	181,789	37,423,695
Lowland fen *19,934ha existing*	66,021	54,099,501

Habitat Network	Total Opportunity Area in Network Enhancement Zone 1 and Fragmentation Action Zone (hectares)	Future Carbon Storage if Ecosystem restoration delivered (t C)
Lowland raised bog *12,445ha existing*	2,948	4,745,570
Upland flushes, fens and swamps *12,883ha existing*	50,102	10,829,799
Upland heathland *230,086ha existing*	48,103	6,113,342
Total	**348,962 hectares**	**113,211,907 tonnes**

This peatland restoration has the highest potential to protect stored carbon (113 million t C), although timescales to achieve this will be at least 40 years. However, abatement i.e. reductions in emissions, compared to baseline, would commence at a much earlier date. This scenario would see these habitats still being a net emitter of greenhouse gases in the medium term, although emissions would be much less than experienced from the pre-restoration habitats.

313,312 hectares of this peatland restoration is in the uplands, including about 79,000 hectares of carbon-rich non-priority habitats, such as grass moorland and fragmented heath which can often be restored to peatland habitat using widely-practiced techniques such as drain-blocking and alteration to livestock grazing practices.

About 10% of the peatland restoration opportunity (35,650 hectares) is in the lowlands.

Restoration to blanket bog, raised bog and lowland fen offer the greatest opportunity for building carbon store; and lowland fen over peat is notably more ‘carbon-dense’ than blanket bog.

Given the widespread potential for blanket bog restoration outside the protected site and PHI network, it would be useful to introduce criteria for identification of ‘degraded blanket bog still capable of natural regeneration’, similar to the JNCC definition of habitat H7120 as ‘degraded raised bog still capable of natural regeneration’ (JNCC, undated).

Lowland raised bog is the most carbon-dense peatland habitat, with peat depths often 10m or more. However, it has only small network enhancement and fragmentation action zones, hence it has a limited total restoration opportunity, in terms of carbon storage.

Halting Degradation of Lowland Peat Soils used in agriculture

A maximum peat scenario also considers the third EIP target which relates to peaty soils in the lowlands currently used for agriculture. The EIP does not quantify this target.

This study shows that outside existing priority peatland habitats and the associated Habitat Network, an additional 203,000 hectares of lowland is underlain by deep and shallow peats, typically on higher-grade agricultural land such as the Fens[1].

Whilst this EIP target does not require restoration to priority habitat, it would involve re-wetting of peat soils and safeguarding of current carbon stores. Abatement i.e. reductions in emissions, compared to baseline, would commence at an early date following re-wetting. This scenario will still be a net emitter of CO_2, in the medium term, although emissions would be much less than experienced on the pre-restoration habitats.

Summary

This study shows that the EIP targets for restoration of 280,000 hectares of peatland and restoration of 75% of SSSI's to favourable condition are unlikely to secure the safeguarding of habitat carbon in the 512,000 hectares of existing peatland PHI. Thus at least some of the 203 million tonnes of carbon stored in the peatland PHI is at risk.

The EIP targets would not deliver the possible restoration or re-creation of 350,000 hectares of non-priority habitats that could be turned into priority peatland habitats, mostly in the uplands. If implemented, this additional opportunity could result in the future realisation of up to 113 million tonnes carbon storage.

This study shows that the separate EIP target for responsible land management to safeguard the carbon stored in lowland peats through re-wetting would require action outside the Habitat Network. The EIP target is not quantified. This study shows that about 200,000 hectares of lowland land over deep and shallow peat falls outside the Habitat Network and would be included in this EIP target. This target is undated, although the EIP notes that actively degrading lowland peat is responsible for 3% of UK carbon emissions, a problem which must be tackled to meet legally binding net zero 2050 obligations.

Maximum Woodland (Scenario 2)

There is currently 920,820 hectares of priority deciduous woodland habitat and wood pasture and parkland habitat in the PHI. Our estimates suggest it stores approximately 231 million tonnes of carbon and may sequester approximately 8.1 million t CO_2e per year.

This study indicates there is the potential for creation of up to 255,000 hectares of new priority deciduous woodland in Habitat Network enhancement zone 1 (NEZ1) and fragmentation action zone (FAZ) for ancient semi-natural woodland (ASNW) and wood pasture and parkland (WPP). The term 'Maximum Woodland' is perhaps misleading because Habitat Network mapping is not available for deciduous woodland as a class of priority habitat; it is only available for ancient woodland and wood pasture and parkland.

[1] https://nationalcharacterareas.co.uk/the-fens/

If habitats were expanded by planting of deciduous woodland and agroforestry (wood pasture-style groupings of trees), and based on this narrowly-defined opportunity, the future carbon store in new young woodland could be some 26 million tonnes, although it would take several decades to achieve this.

Dependent on the baseline habitat, abatement in carbon emissions might occur within five to ten years, with notable sequestration occurring after 30 years to some 891,000 t CO_2e y-1.

The EIP target is for creation of 250,000 hectares of new woodland with an expectation that 100,000 hectares would be biodiverse i.e. priority habitat. This study shows that the EIP target would deliver at least 26 million tonnes of future carbon storage and increase sequestration by at least 891,000 t CO_2e per year.

If Habitat Network maps are developed for deciduous woodland priority types, it is likely that several hundred thousand hectares of additional opportunity would emerge. As an illustration of what this might mean, the NEZ1 for traditional orchards would add 543,000 hectares of new tree and woodland opportunity, resulting in a potential additional 51 million tonnes of carbon store and annual sequestration of up to 1.5 million tonnes of carbon dioxide equivalent.

Research by the Forestry Commission shows there is over 3 million hectares of relatively unconstrained land suitable for woodland establishment.

Maximum Coastal Habitat (Scenario 3)

Currently there is 64,000 hectares of coastal priority habitat in the grouping of coastal saltmarsh, sand dunes, vegetated shingle and maritime cliff and slope. It currently stores about 16 million tonnes of ‘blue carbon’ and sequesters 211,000 tonnes CO_2e per year, primarily in saltmarsh. It is a habitat particularly vulnerable to coastal squeeze associated with sea-level rise. Most of this habitat is already in the SSSI network. Although there is an EIP target for favourable conservation management of SSSI’s, this cannot prevent the loss of blue carbon from coastal squeeze.

There is a total opportunity to create up to 119,000 hectares of coastal priority habitats in the Habitat Network, largely outside the SSSI network. It is not possible to disaggregate this to estimate the specific opportunity for coastal saltmarsh, which is one of the ‘top ten’ priority habitats for carbon storage and sequestration. As coastal areas are dynamic systems that are driven by natural process, there will always be uncertainties around which coastal habitat develops and stays in the longer term.

However, it is possible to estimate the total carbon store from the coastal habitat opportunity at approximately 29 million t C, much of which would come from new coastal saltmarsh. In terms of total carbon sequestration, the coastal habitat group has a significant total rate (-395,000 t CO_2e y^{-1}). It is also capable of rapidly achieving good condition (15 years) and would generally be achieved in agricultural habitats that have a relatively low baseline carbon store and are probably emitting carbon.

The EIP does not have a specific target for creation or restoration of coastal habitats; it falls into the general target of >500,000 hectares of wildlife-rich habitats outside protected sites.

This study shows that there is considerable carbon value in promoting the delivery of up to 119,000 hectares of new coastal habitats in the EIP. It would also deliver compensatory habitat to make up for the likely loss of SSSI saltmarsh due to sea-level rise and offers other ecosystem services such as coastal flood attenuation.

Maximum Grassland and Heathland (Scenario 4)

There is currently 418,000 hectares of grassland and heathland priority habitat in the PHI. The grassland and heathland PHI currently stores about 65 million tonnes of carbon, although upland heathland forms the majority of this and is already partly considered in the peatland scenario.

Based on Habitat Network maps for eight grassland and heathland priority habitats, the total opportunity for creation of new priority grasslands and heathlands is 890,000 hectares, 75% of which would be in lowland habitats.

This would achieve an eventual carbon store of 69 million tonnes and the typical period to achievement of good habitat condition would be 15 to 20 years.

Annual carbon sequestration would not be significant once habitats had achieved good condition. However, where baseline habitats are currently significant emitters, the abatement achieved by transformation to permanent grassland would reduce net emissions rapidly, although this cannot be quantified with current evidence.

This group of habitats also has Favourable Conservation Status data available. Using this, the total opportunity area is lower (641,000 hectares, rather than 890,000 hectares).

The EIP does not have a specific target for creation or restoration of grassland and heathland habitats; it falls into the general target of >500,000 hectares of wildlife-rich habitats outside protected sites.

This study shows that, compared to other scenarios, there is a lower carbon benefit in promoting the creation of new priority grassland and heathland habitats in the EIP, unless the existing grasslands overlie drained peats. For grasslands and heathlands on drained peat, habitat creation and restoration measures would safeguard existing carbon stores; for example by the transformation of non-priority ‘grass moorland’ or ‘fragmented heath’ to upland heathland.

Maximum Wetland (Scenario 5)

There is currently 24,000 hectares of priority lowland fen and reedbed and 221,000 hectares of priority coastal and floodplain grazing marsh in the PHI. Collectively these store 41 million tonnes of carbon, although there is an overlap with the peat scenario as a proportion of the lowland fen PHI overlies deep and shallow peats.

Of the total area of 245,000 hectares in the PHI, 47,000 hectares is in SSSI's.

Based on Habitat Network maps for reedbeds and lowland fen, and removing lowland fens over peat which are included at scenario 1; the opportunity area for creation of new priority wetland habitat is 156,000 hectares. This would achieve an eventual carbon store of approximately 26 million t C.

It would remain as a net carbon emitter, but dependent on the baseline habitat, emissions would rapidly reduce. These habitat types are considered capable of achieving good condition in 12 to 15 years.

This opportunity understates the potential for wetland priority habitat creation and associated carbon storage, because there is no Habitat Network map for coastal floodplain grazing marsh, a widespread category of habitat which is in the 'top ten' of high carbon habitats.

The EIP does not have a specific target for creation or restoration of wetland habitats; it falls into the general target of >500,000 hectares of wildlife-rich habitats outside protected sites.

This study shows that there is considerable carbon value in promoting the delivery of at least 156,000 hectares of new wetland habitats in the EIP. This opportunity would also help deliver other ecosystem services, notably flood attenuation and water quality improvement.

Delivery of habitat creation and restoration for carbon in nature

Table 5 below shows opportunities for expanding the priority Habitat Network with high-carbon habitats in mind. Important notes relevant to this table are:

- For all scenarios, the opportunity area is for expansion of the Habitat Network in Network Enhancement Zone 1 and Fragmentation Action Zone. There will be many other expansion opportunities outside the Habitat Networks.
- The opportunity area is for creation of new priority habitats on land that is currently not a priority habitat.
- For the peat scenario, the opportunity relates to land that overlies peat soils and where the habitat is currently not a priority type; for example transformation of grass moorland on drained peat to blanket bog or upland wet heath is classed as habitat expansion.
- For woodland and wetland scenarios there are no Habitat Network zones for deciduous woodland in general or coastal and floodplain grazing marsh. If these had been defined, they would add considerable opportunity.
- The Habitat Networks overlap, so some of the opportunity areas also overlap.
- The figure for future carbon storage is based on what the habitat would store in its final steady-state once habitat creation, establishment and restoration works were complete. It is not the uplift in carbon storage from the baseline as the baseline will differ in each location but indicates the total potential carbon possible in the habitat network if full restoration is enacted.
- The timescales for good habitat condition are based on the statutory biodiversity metric and do not relate precisely to when habitats achieve ultimate carbon storage or steady-state in terms of carbon sequestration.

Further information about opportunity areas and timescales is given in the detailed narratives at Chapter 5.

Table 5. Summary of opportunities for restoration and creation of high-carbon habitats

Habitat Opportunity	Current Extent of PHI (hectares)	Opportunity Area in Habitat Network (hectares)	Future Carbon Storage if Ecosystem restoration delivered (t C)	Future Total Carbon Sequestration t CO_2e y^{-1}	Timescale to Good Habitat Condition (years)	Notes
Scenario 1 – Peat	510,989	348,962	113,211,907	1,024,275	>30	Current PHI extent includes 'Upland Heathland' over peat. Overlaps with scenario 4 have been removed. There is an additional 203,000 hectares deep and shallow lowland peats outside any Habitat Network – relevant to a separate EIP target for responsible management of lowland peats
Scenario 2 – Woodland	920,820	254,639	26,323,990	-890,704	>30	Opportunity area significantly understates total potential, because no Habitat Network is currently defined for deciduous woodland, a very widespread PH
Scenario 3 – Coastal Habitats	63,956	119,306	29,048,715	-394,643	15	
Scenario 4 – Grassland and Heathland	417,921	890,354	69,415,840	12,753	15 to 20	Current PHI extent includes 'Upland Heathland'. Overlaps with scenario 1 have been removed from this opportunity.
Scenario 5 – Wetland	244,788	155,799	26,174,239	225,675	12	Opportunity area significantly understates total potential, because no Habitat Network is currently defined for coastal and floodplain grazing marsh which is a very widespread PH.

Note: In Future Total Carbon Sequestration: a negative figure is carbon sequestration, a positive figure is carbon loss (emission) to the atmosphere

The vast majority of land for all the five opportunity scenarios in the Habitat Network is outside the SSSI network. This is consistent with the Environment Improvement Plan (EIP) targets to expand at least 500,000 hectares of wildlife-rich habitat outside protected sites.

Analysis of Targets

The EIP's nature recovery targets are not currently articulated in terms of quantifiable activity in high-carbon habitats. The evidence produced here demonstrates that there is considerably more opportunity to focus on 'high-carbon, high-nature' habitats than is currently articulated in the EIP. Commentary is provided below.

Peat

The target to ensure 75% of SSSI's are in favourable condition by 2042 could focus on SSSI's with peatland habitats as they store 147 million tonnes of carbon but are currently emitting rather than sequestering carbon.

The target to restore 280,000 hectares of peatland habitats by 2050 could be clarified so that it goes beyond the commitment to restore SSSIs. There are about 150,000 hectares of PHI peatland outside SSSIs and a further 350,000 hectares of opportunity in Habitat Network Enhancement Zone 1 and Fragmentation Action Zone. 90% of this opportunity is in the uplands where there is at least 80,000 hectares of carbon-rich non-priority habitat, such as grass moorland, which can readily be restored to peatland priority habitat. This offers the opportunity for large carbon benefit and good cost – benefit investment ratios.

Taken together the above actions would safeguard the 203 million tonnes of carbon in peatland PHIs and protect an additional 113 million tonnes in peat soils outside of the PHI.

The separate EIP target to bring lowland agricultural peat soils into responsible management to reduce emissions can be quantified at around 200,000 hectares on deep and shallow lowland peats. This goes significantly beyond the above opportunities and whilst it may not result in creation of actively-building peatland habitats, it would deliver very significant abatement of current carbon dioxide emissions.

Woodland

The target to create 250,000 hectares of woodland with an expectation of 100,000ha being biodiverse could deliver a future carbon store of at least 26 million tonnes.

This study shows that this could all be delivered in the Habitat Network Enhancement Zone 1 and Fragmentation Action Zone for ancient woodland and wood pasture and parkland.

There is very considerable opportunity to create further new deciduous woodland in many other areas that are not constrained by, or targeted for, other priority habitats.

Coastal

The opportunity to create up to 119,000 hectares of coastal habitat in network enhancement and fragmentation action zones would fall within the EIP target of creating at least 500,000 hectares of wildlife-rich habitat outside protected sites. Although the evidence base is incomplete, some estimates suggest salt marsh could deliver carbon sequestration more rapidly than peatland restoration or woodland creation and would also help offset the inevitable loss of carbon and priority habitat in coastal SSSIs from sea level rises and ‘coastal squeeze’. Shoreline Management Plans are important delivery mechanisms and it would be beneficial for these to identify and prioritise locations for creation of high-carbon coastal habitats.

Grassland and Heathland

There is considerable opportunity to create and/or restore up to 890,000 hectares of grassland and heathland in network enhancement and fragmentation action zones. This would fall within the EIP target of creating at least 500,000 hectares of wildlife-rich habitat. However, this offers lower carbon benefits than the other scenarios.

Wetland

The opportunity to create up to 156,000 hectares of wetland habitat in network enhancement and fragmentation action zones would fall within the EIP target of creating at least 500,000 hectares of wildlife-rich habitat outside protected sites. This opportunity can deliver carbon storage and offers other ecosystem services such as flood attenuation and water quality regulation. A focus on restoring natural processes with a functioning floodplain wetland mosaic is a key requirement for effective restoration.

When the priority habitat map for Floodplain Wetland Mosaic (FWM) is released, developing an associated Habitat Network Map would enable the identification of opportunities for the creation of this carbon-rich habitat.

Integrated Habitat Summary

There is a major opportunity to deliver more for carbon and nature recovery. The government’s nature recovery and land management targets understate the very considerable opportunity to safeguard and increase habitat carbon.
This could be addressed by:

- Protecting our carbon stores, making them more prepared for a future climate.
- Including more spatial direction towards creation of high-carbon wildlife-rich habitats at an ecosystem scale in key landscapes and areas.
- Setting out a carbon and nature approach to peat-based ecosystems to deliver habitats restoration across significantly more of the 1.2 million ha of Peatlands in England.
- Clearer targeting on the locations that would be ideal for restoration and creation of new habitats (that have habitat potential) to achieve both nature and carbon restoration at an ecosystem scale.

- Focussing the restoration of peatland habitats (280,000 hectares) outside of protected sites onto areas adjacent to existing high-quality areas. Our study finds that there is a total of 860,000 hectares of land that is already peatland habitat, often in degraded condition, or land that could be restored to peatland habitats from carbon-rich non-priority habitats.
- Recognising the 203,000 hectares of lowland agricultural peat soils that could be brought into ‘responsible management’ through a targeting approach for early improvement.
- Focussing the 500,000 hectare target for creating wildlife-rich habitats outside protected sites, on areas of habitat expansion. This will help to capture more opportunity for coastal and wetland habitat creation to reduce climate impact.
- Ensuring 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 to support the Net Zero goal.

Additionally early investment in expansion of high-carbon habitats will bring early benefit and better value for money in terms of:

- abatement of current emissions
- improved resilience of habitats to future unavoidable climate change
- slowing current habitat degradation and loss of peaty soils making restoration easier with lower costs when restoration does occur.
- delivery of other societal benefits such as improved resilience to flood, drought and improved water quality.

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 relates to Part 3 and its aims were to assess:

i. What is the maximum area of habitat expansion that could be delivered for each habitat?
ii. What is the range of possibilities for delivering government targets for expansion of wildlife-rich habitats, deciduous woodland and peatland habitats?
iii. What is the potential expansion of the 'top ten' habitat types for carbon i.e. those identified in Part 1?
iv. How much carbon could be delivered through expansion of 500,000 hectares of wildlife-rich habitat?
v. Can priority habitats be ranked in terms of habitat expansion and carbon outcomes?
vi. Which types of landscape and which areas of England can deliver specific habitat and carbon outcomes?

2. Background

The government's targets to restore nature and protect the environment are set out in the Environment Improvement Plan (DEFRA, 2023) and enshrined in The Environmental Targets (Biodiversity) (England) Regulations 2023.

The habitat restoration and creation targets are area-based and include peatland, deciduous woodland and other 'wildlife-rich' habitats, a term defined by s10 of the Regulations, which includes s41 priority habitats and other habitats listed at Schedule 1 of the Regulations (S1 habitats).

Natural England has also published Environment Act Habitat Target – Definitions and Descriptions which sets out how the habitat targets will be defined and measured. It includes definitions for restoration and creation, the list of wildlife-rich habitats, and the actions that will count toward the target.

The targets can be summarised as follows:

- By the end of 2042, restore or create in excess of 500,000 hectares of a range of wildlife-rich habitats outside protected sites, compared to 2022 levels.
    - With an interim target by 2028, restore or create 140,000 hectares of wildlife-rich habitats outside protected sites.
- Increase tree canopy and woodland cover from 14.5% to 16.5% of total land area in England by 2050. Although this target is not expressed in terms of hectarage, based on standard stocking densities, this is about 250,000 hectares, or 9,000 hectares per year.
    - with an interim target to increase this by 0.26% (equivalent to 34,000 hectares) by 31 January 2028.
- Restore approximately 280,000 hectares of peatland by 2050
    - With an interim plan to fund the restoration of over 35,000 hectares of peatlands by 2025 through the Nature for Climate Peatland Grant Scheme
- Support responsible management measures to improve lowland peat

Separately, the England Peat Action Plan (UK Government, 2021) sets out the government's long-term vision for the management, protection and restoration of English peatlands, which cover 1.42 million hectares.

These commitments for habitat creation and restoration offer significant opportunities for future carbon storage and sequestration. Part 1 of the Nature Net Zero project gives a carbon-ranking for all priority habitats and identifies a shortlist of 'high-nature, high-carbon' habitats which includes woodlands, peat-based habitats, coastal saltmarsh and some heathlands.

When creating and restoring 500,000 of wildlife-rich habitats, a decision about which habitats to prioritise has carbon implications. The purpose of this study is to provide carbon-related data to inform the prioritisation.

We explore how much carbon storage and sequestration could be achieved whilst delivering the environmental targets. To help focus the task, five scenarios were constructed; (1) peat-based habitats, (2) trees and woodlands, (3) coastal habitats, (4) grassland and heathland, and (5) floodplain and wetland.

The feasibility of creating or restoring specific habitats is determined by the ecological requirements of the habitat, specifically influenced by underlying soils and geology, land availability and the need to secure appropriate long term management. In practice it will also be shaped by wider decisions about land use and management, for example the needs of food production, but these are not addressed in this study.

In order to estimate the extent of opportunity, we used Natural England's Habitat Network maps to take account of underlying soils and geology. In particular the Network Enhancement Zone 1 (NEZ1) and Fragmentation Action Zone (FAZ) illustrate areas of theoretical opportunity for creation and restoration of many types of priority habitats.

In addition, the peaty soils dataset identifies theoretical opportunity for creation of peat-based habitats beyond the reach of NEZ1/FAZ.

3. Data Sources

Potential areas for the restoration and expansion of priority habitats were identified using Natural England's open source Habitat Networks (Individual) dataset, providing a national coverage (Edwards et al, 2020). Datasets are publicly available from www.data.gov.uk.

Natural England has also commissioned the Centre for Ecology and Hydrology (CEH) to produce potential habitat maps, which displays the biological and physical (biophysical) suitability of land to support a particular habitat. However this was unpublished at time of study and therefore not available for use in this study.

Coastal data from the Restoring Meadows, Marshes and Reefs (ReMeMaRe) initiative was also reviewed (MMO 2019), principally for salt marsh expansion. However this data only provided a high level indication where managed realignment or Regulated Tidal Exchange (RTE) may be feasible and contained areas already subject to industrial development. As such it was not utilised for this study.

Natural England's peaty soils data was also employed to enhance the identification of habitat opportunities linked with high carbon areas, as detailed in the Methodology section, as well as the Priority Habitat data.

Table 6. 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
Landscape Description Units*	27-03-2024	18-02-2003

*Data provided directly by Natural England and is not publicly available online.

Habitat Network Map

The Habitat Network describes the geographic extent and location of 18 priority habitats, based primarily, but not exclusively, on the Priority Habitat Inventory (PHI). The network data identifies four zones for habitat enhancement and expansion in the vicinity of existing priority habitats. Most of the priority habitats included in the network have their own specific set of zones, although some habitats are aggregated and some habitats do not have certain zones.

Network Enhancement Zone 1 (NEZ1)

Land connecting existing patches of primary and associated habitats, likely suitable for creation of the primary habitat. Its focus is to expand and join up the existing patches of habitat, targeting the improvement of connections.

Network Enhancement Zone 2 (NEZ2)

Land connecting existing patches of primary and associated habitats which is less likely to be suitable for creation of the primary habitat. Its focus is to improve the biodiversity value where land management changes and/or green infrastructure provision can be targeted.

Fragmentation Action Zone (FAZ)

Land within NEZ1 which connects the existing patches of primary and associated habitats that are currently highly fragmentated and where fragmentation could be reduced by creation of the specific habitat. Its focus to address the most fragmentated areas of habitats to create bigger habitat patches.

Network Expansion Zone (NEZ)

Land beyond the Network Enhancement Zones with potential for expanding, linking and/or joining networks across the landscape. Action in this zone to improve connections between existing Habitat Networks can be targeted here.

Favourable Conservation Status Habitat Targets

Natural England's Favourable Conservation Status (FCS) habitat targets (that were published before January 2024) were used as a reference to compare the areas identified for habitat enhancement and expansion in the Habitat Network Maps described previously.

Natural England interprets FCS as the situation in which a habitat, or species, is thriving throughout its natural range and is expected to continue to thrive into the future. To meet FCS status the habitat across its favourable range and distribution needs to be sufficiently large for the necessary structures and functions to exist in a landscape setting and to promote the recovery of any threatened species associated with that habitat (Moulsey and others, 2023).

Data for S41 Habitats of Principal Importance with area figures (in hectares) for current, favourable and proposed habitat increase were provided by Natural England (pers. comm. Sally Mousley). The figures were provided in a Word format with no related spatial GIS datasets, which reflected progress on the FCS habitat targets as of 23rd November 2023.

Landscape Description Units

Natural England's Landscape Description Unit (LDU) dataset was used as the geographical frame of reference for quantifying habitat opportunities and exploring their relationships with different landscape typologies.

LDUs are of varying size, and form the building blocks of National Character Areas (NCAs). England has 159 NCA's which are mostly too large to allow granular analysis of opportunities for increases in habitat carbon at an ecosystem or landscape recovery scale. There are about 3,000 LDU's which represent Landscape Types in a specific location. These are the basic building blocks of the landscape and are defined by a combination of six key characteristics relating to geology, topography, soils, tree cover character, land use and historic settlement pattern.

The LDU dataset includes information about landscape character in addition to environmental and socio-economic characteristics. For each LDU, its Landscape Character Type (LCT) is denoted by a 3 letter code based on physiography, landcover and cultural pattern – see Table 7. Full details of LCTs can be accessed here: National Landscape Typology - Definitive Attributes (defra.gov.uk).

For example, an LDU with LCT code of 'HAD' is a landscape with:

- High hills (H)
- Heath and moorland (D)
- Wooded – ancient woods (A)

Landscape Description Units (LDU) do not have unique names; they only have a unique identification number. For the purposes of this study, a unique naming convention was developed for each LDU based on:

- the National Character Area (NCA) the LDU sits within, or mostly sits within
- the LDU's unique identification number
- the LDU Landscape Character Type (LCT).

Thus LDUs were assigned unique names for this study as follows:

- Dominant National Character Area (eg Bodmin Moor)
- LDU unique identification number (eg 163)
- LDU LCT (eg UDO means Low Hills, Heath and Moorland, Unsettled / Open Land)

Thus 'LDU 163' is named as 'Bodmin Moor LDU163 UDO' for this study.

Note: The LDU physiographic code 'L' proved useful for identification of lowlands that could be targeted for 'Responsible Management' of lowland peat under agriculture, one of the EIP targets.

Table 7. Landscape Character Type codes and translations

	Code	Translation
Physiography	H	High hills
	U	Low hills
	V	Upland vales and valleys
	R	Intermediate
	L	Lowlands
Landcover	W	Wetland
	D	Heath and moorland
	L	Chalk and limestone
	B	Other light land
	C	Clayland
	P	Other heavy land
Cultural pattern	A	Wooded – ancient woods
	E	Wooded – estate land
	S	Wooded - secondary
	D	Dispersed unwooded
	N	Nucleated unwooded
	W	Wetland/waste unwooded
	O	Unsettled/open land
	C	Coalfields
	Urban	Urban

Timescales for Habitat Creation and Restoration

The Statutory Biodiversity Net Gain User Guide defines ‘time to target condition’. Time to target condition is measured in years. It is defined as ‘the average time taken between starting creation or enhancement of habitats and that habitat reaching its target condition or distinctiveness’.

Time to target a ‘good’ condition was extracted from the statutory biodiversity metric (February 2024 issue), for all the priority habitat types considered in this report.

4. Methodology

This study followed six methodological stages:

Stage 1: Scenario building

Stage 2: Data selection, cleansing and ordering

Stage 3: Quantification of maximum habitat expansion opportunity per scenario

Stage 4: Estimation of carbon storage and sequestration per scenario

Stage 5: Analysis of habitat and carbon opportunities in differing landscape types

Stage 6: Estimation of timeframes for achieving carbon outcomes per habitat type

Scenario building

Creation and restoration opportunities for priority habitats were grouped into five scenarios, based on different ways of delivering the governmental targets listed at Chapter 2. All scenarios are based on habitat expansion within the Habitat Network:

- Scenario 1: Maximum Peat - focused on maximising restoration of peat-based habitats
- Scenario 2: Maximum Woodland - focused on maximising woodland planting opportunities, not on peat
- Scenario 3: Maximum Coastal - focused on maximising creation of coastal habitats
- Scenario 4: Maximum Grassland and Heathland - focused on maximising creation and restoration of grassland & heathland habitats not on peat
- Scenario 5: Maximum Wetlands - focused on maximising creation of wetlands

Data selection, cleansing and ordering

The maximum potential expansion for each priority habitat was quantified using Natural England's Habitat Network Map, specifically the Network Enhancement Zone 1 (NEZ1) and the Fragmentation Action Zone (FAZ).

The habitat expansion ranges were also compared against the Favourable Conservation Status expansion figures for the S41: Habitats of Principal Importance in England.

Areas of existing Priority Habitat were removed from the NEZ1 and FAZ data, to maintain the study's focus on maximising opportunity for creation or restoration of new habitats. Where Priority Habitat currently exists, carbon retention is likely to be moderate to good.

For example, the NEZ1 for blanket bog overlies parcels of existing upland heathland (another priority habitat). The area of upland heathland was subtracted from the area of

blanket bog enhancement zone for the purpose of quantification of new habitat opportunity.

The Habitat Network Mapping data also contains overlaps between possible habitats, so a habitat hierarchy was set up for each scenario based on factors such as geology/soils and carbon value. The principle purpose of the hierarchy was to eliminate incompatibilities in habitat outcome.

Quantification of maximum habitat expansion opportunity per scenario

Having cleansed and ordered the data, the maximum possible extent of habitat expansion was quantified for each scenario. For example, Figure 1 shows the location of all opportunity areas for grassland and heathland expansion. The map aggregates all the NEZ1 and FAZ areas for all priority grassland and heathland types.

The dataset is capable of subdivision for detailed analysis, in respect of:

- Priority habitat types
- Habitat opportunity in NEZ1
- Habitat opportunity in FAZ
- Other habitat opportunities – specific to peat-based habitats, as described below for Scenario 1
- Different priority habitats within the aggregated scenario. For example, Scenario 1 comprises opportunities for blanket bog, lowland raised bog, lowland fen etc
- Geographical location

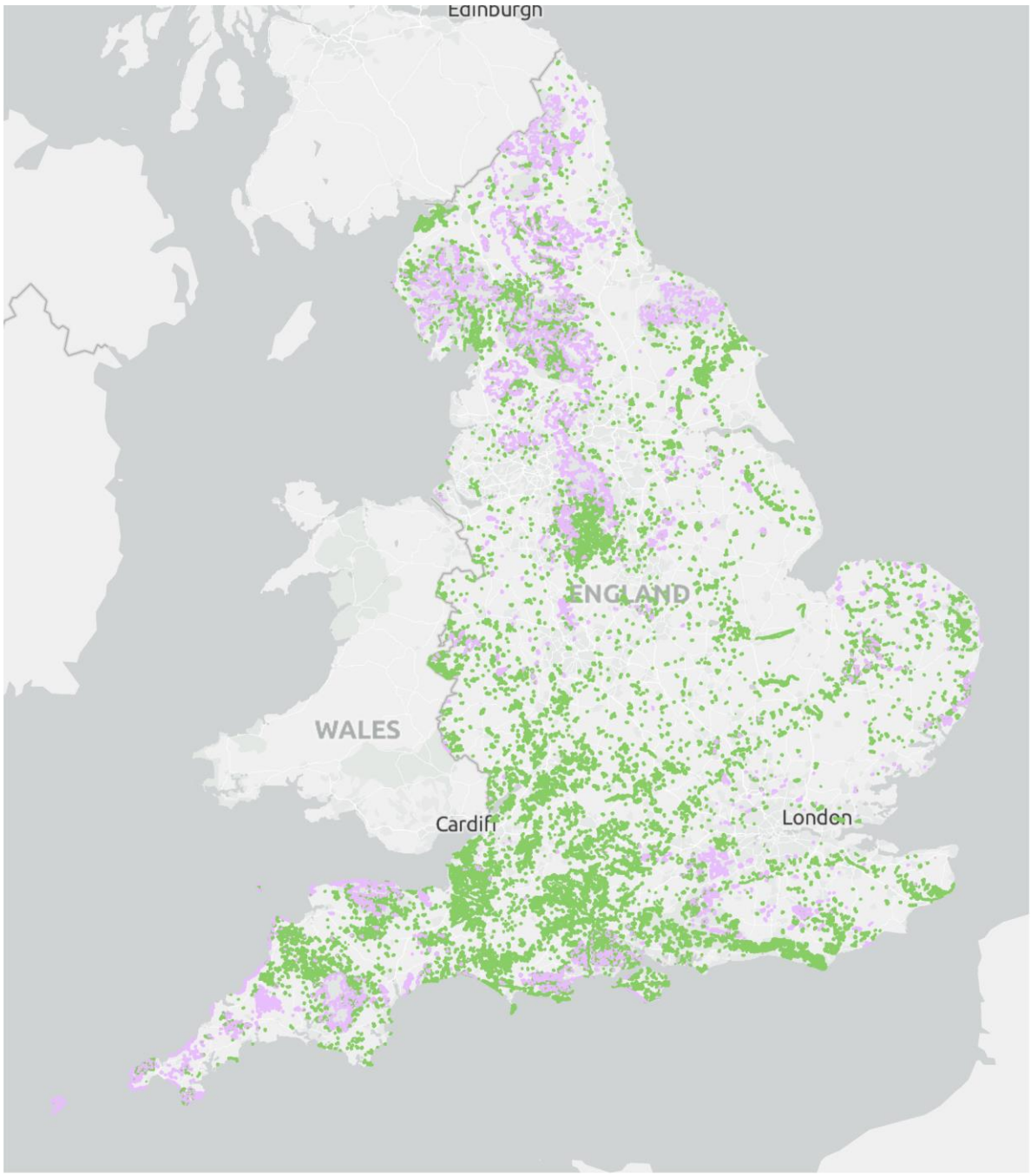

Figure 1. Map showing the maximum grassland (green) and heathland (purple) expansion scenario.

Estimation of carbon storage and sequestration per scenario

The potential carbon storage and sequestration rates were calculated for each scenario based on the typical carbon storage and sequestration estimates for each priority habitat (identified at Part 1) multiplied by the hectarage of potential habitat expansion within the Habitat Network.

The carbon storage values represent the final ‘steady-state’ condition of the habitat, which will not be achieved for some time; depending on the baseline habitat type and its condition.

The estimates for carbon store do not account for the pre-expansion carbon store; which again depends on the baseline habitat type. Thus, the estimates for post-expansion carbon storage must not be interpreted as the increase in carbon store arising from the habitat expansion. Nevertheless, the total carbon store value is useful for comparative purposes when considering the carbon ‘end-point’ associated with different habitat scenarios.

The estimates for carbon sequestration do not account for the pre-expansion sequestration rates; which depends on the baseline habitat type. Thus, the estimates for post-expansion carbon sequestration cannot be interpreted as an increase in carbon sequestration arising from the habitat expansion. Nevertheless, the total carbon sequestration rate is useful for comparative purposes when considering the carbon ‘end-point’ associated with different habitat scenarios.

That said, the carbon sequestration rates for deciduous woodland do provide a reasonable estimate of total net increase in sequestration, since the new woodland would be planted on grassland or cultivated land, and not on peaty soils.

Note: Negative values in sequestration rates indicate sequestration from the atmosphere back into the vegetation or soil by the ecosystem, and positive values indicate emissions to the atmosphere.

Analysis of habitat carbon opportunities in differing landscapes

Each scenario was considered in terms of the Landscape Description Units (LDU) within which they sit. The aim was to identify LDUs with the greatest opportunities for habitat expansion. This report presents a national ranking of LDUs but the detailed dataset may be interrogated at regional geographies to identify priority LDUs for particular habitat interventions.

Figure 2 shows an example of the LDU mapping for the Bodmin Moor National Character Area. LDU naming and referencing protocols are described at Chapter 3. For example Bodmin Moor LDU163 UDO means the LDU lies within Bodmin Moor NCA, it has a unique numerical reference of 163 and its landscape character is ‘Low Hills (U), Heath and Moorland (D), Unsettled / Open Land (O)’.

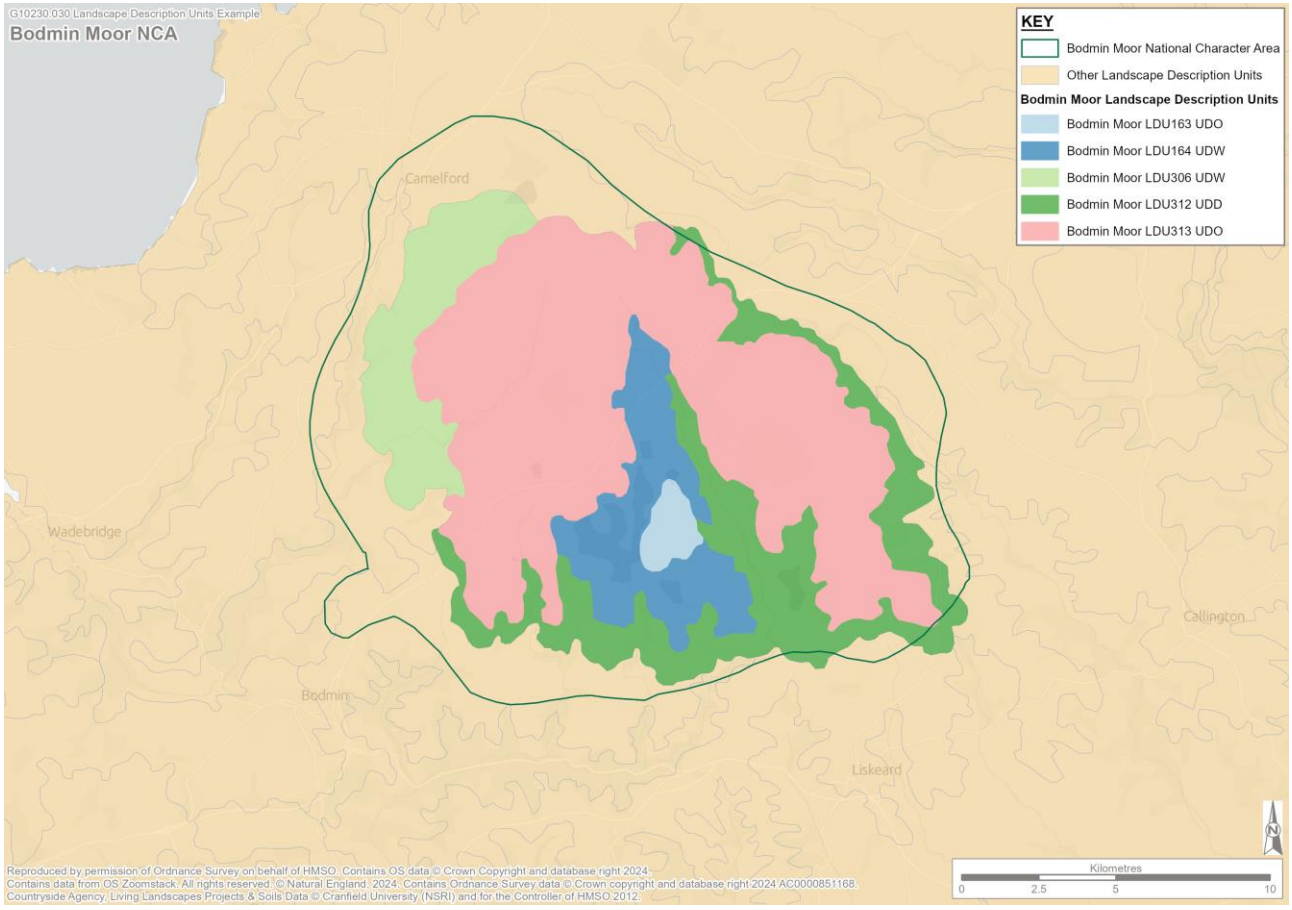

Figure 2. Bodmin Moor National Character Area and the Landscape Description Units that sit within.

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Estimation of timeframes for achieving carbon outcomes per habitat type

The timescales needed to achieve satisfactory habitat and carbon outcomes will vary depending on habitat type, management and prevailing environmental factors such as climatic exposure.

For the purpose of this study, the timescales for satisfactory habitat creation or restoration to meet governmental targets were derived from the “Time to ‘Good’ target condition” used in the Statutory Biodiversity Net Gain Metric (Defra, 2024) – see Table 8.

The statutory metric covers most of the targeted habitats except upland heath and upland flushes, fens and swamps. Based on professional judgement, these would sit in the 30+ category as they are peat-based habitats.

In practice, the time to achieve good condition will depend on the baseline habitat type and condition.

The achievement of good habitat condition is not linked to achievement of eventual carbon storage values or sequestration rates per hectare, particularly for peat-based habitats. In terms of restoring the carbon sink function of a peatland, Lindsay (2010) suggests a timeframe of around four decades before restoration to a fully functional blanket bog can achieve net carbon gain, although emissions reduction – abatement - will occur much earlier.

However, for the purpose of the study, it is assumed that once a habitat is in good condition, it is then capable of continually increasing its carbon storage and sequestration until it reaches the upper limit for these variables. In other words, the study assumes the carbon benefits are ‘baked in’ when habitat restoration commences.

Table 8. Timescales to achieve 'Good' Habitat Condition

Time to Good Condition (years)	Priority Habitats
30+	Blanket bog, Lowland raised bog, priority Deciduous Woodland types, Wood pasture and parkland, Lowland dry acid grassland, Lowland heathland
30	Fens (lowland and upland), Traditional orchard,
25	Upland calcareous grassland
20	Coastal sand dunes, Lowland calcareous grassland, Purple moor grass and rush pastures, Upland hay meadow
15	Coastal salt marsh, Lowland meadows
12	Reedbed

Scenario-specific Methodologies

The standard methodological approach described above is explained in more detail for each scenario below, including specific notes on methodological adaptations.

Scenario 1 - Maximum Peat

The peatland habitats included in this scenario include blanket bog, lowland fen, lowland raised bog; upland flushes, fens and swamps, and upland heathland. Reedbeds were not included as they have a limited total expansion area and because a relatively low percentage of existing reedbed priority habitats actually overlies deep or shallow peat. Mountain heaths and willow scrub were also excluded, as Habitat Network mapping is not

available for this priority habitat. They cover a very limited area (1,502 hectares) and are mostly already within SSSI's, so outside the scope of this study.

As most peat-based habitats have specific NEZ1 and FAZ and these often overlap, a dataset hierarchy was set up with the following order to assign overlaps to an individual Habitat Network:

1. Blanket bog
2. Lowland raised bog
3. Lowland fen
4. Upland flushes, fens and swamps
5. Upland heathland
6. Deep and shallow peat, outside any Habitat Network Mapping

To enhance carbon calculations, each opportunity area was analysed in terms of its location relative to underlying peat. For example, an opportunity area of Upland heathland in the Fragmentation Action Zone may sit on either deep peat; shallow peat; soils with peaty pockets; or not currently sit on peat. Different typical carbon storage values are available for each scenario, using the outputs from Part 1 of this project.

This scenario was further expanded to quantify the area of deep and shallow peats outside the PHI and the Habitat Network Expansion Zones, in order to inform the consideration of the EIP target for 'responsible management of agricultural lowland peat'. The areas of deep and shallow peats were taken from the peaty soils dataset and 'clipped' to:

- Exclude any areas already under a priority habitat
- Exclude any areas covered by the peatland Habitat Network NEZ1 and FAZ described above
- Quantify peat in lowland areas by reference to the LDU physiographic code L – Lowlands

This resulted in the quantification of deep and shallow peaty soils outside the PHI and the peatland habitat networks, with separate values for lowland and other areas.

Scenario 2 – Maximum Woodland

There is no Habitat Network map for deciduous woodland, nor any of its constituent types, such as lowland mixed deciduous woodland, upland birchwood, wet woodland etc.

The Habitat Network maps available for this scenario are ancient semi-natural woodland (which is a subset of deciduous woodland), wood pasture and parkland, and traditional orchard.

Any areas of NEZ1 and FAZ for these habitats overlying peat were removed from analysis as new woodland creation over existing peaty soils is not consistent with nature recovery targets (with localised exceptions in the case of some wet woodlands).

A hierarchy was set up to assign any overlapping areas to an individual Habitat Network, using the following order:

1) Ancient semi-natural woodland
2) Wood pasture & parkland
3) Traditional orchard

The aggregated NEZ1 and FAZ for Traditional Orchards is extremely large, primarily because the core habitat parcels are small but dispersed very widely across the English landscape, so their associated NEZ1 and FAZ (in 'buffer zones' around the core parcels) are disproportionately large and do not help with focussing habitat expansion opportunity, which is the purpose of this study. In agreement with Natural England, the habitat and carbon analysis focussed on ancient woodland and WPP Habitat Networks. Figures for Traditional Orchard were included in the detailed results for completeness and to provide an indication of the extent of woodland opportunity.

For the ancient semi-natural woodland scenario, the carbon benefits of creating new deciduous woodland were quantified using the typical storage and sequestration values for young (<100 years) deciduous woodland.

For the wood pasture and parkland (WPP) scenario, the carbon benefits of creating new open canopy and dispersed woodlands akin to wood pasture were quantified using the typical storage values for WPP. As there is no typical sequestration rate available for WPP, the rate for traditional orchard was used as a proxy as it has scattered trees in a grassland setting.

Scenario 3 – Maximum Coastal

As there is only a single, aggregated, dataset for the coastal habitats group in the NEZ1 and FAZ spatial layers, an estimate of the extent of NEZ1/FAZ for each component habitat was derived from the nationwide percentage composition of coastal priority habitats, using data from Part 1.

Table 9 shows the composition and associated carbon storage value and sequestration of existing coastal priority habitats.

Table 9. Composition of existing coastal habitats and their typical carbon storage values and sequestration rates

Coastal Habitat	Area (ha)	Share of Coastal Habitat (%)	Carbon Storage t C ha^{-1}	Carbon Sequestration t CO_2e y^{-1} ha^{-1}
Coastal saltmarsh	36,341	57%	393	-5.19
Coastal sand dunes	10,525	16%	14.50	-2.18

Coastal Habitat	Area (ha)	Share of Coastal Habitat (%)	Carbon Storage t C ha^{-1}	Carbon Sequestration t CO_2e y^{-1} ha^{-1}
Coastal vegetated shingle	4,016	6%	0	0
Maritime cliff and slope	13,074	20%	87	0
Total	**63,956**	**100%**	**243.48**	**-3.31**

The values for carbon storage and rates of sequestration for the aggregated coastal habitat group are calculated from the relative share of each component coastal habitat type.

These values and rates were then used as the basis of estimating the carbon storage and sequestration potential of habitats in the coastal NEZ1 and FAZ.

Scenario 4 – Maximum Grassland and Heathland

As there are several overlaps between the NEZ1 and FAZ for these habitat types, a hierarchy was set up (based on consideration of geology and soils) to assign land to a single priority habitat opportunity:

1) Lowland calcareous grassland
2) Upland calcareous grassland
3) Lowland heathland
4) Upland heathland*
5) Lowland dry acid grassland
6) Purple moor grass and rush pastures
7) Lowland meadows
8) Upland hay meadow

* Upland heathland has also been included in Scenario 1: Maximum Peat. Areas captured in Scenario 1: Maximum Peat were therefore excluded from the opportunity areas for Scenario 4: Maximum Grassland and Heathland.

The estimates of potential area for habitat expansion were compared with the estimates from Natural England's Favourable Conservation Status (FCS) habitat targets for grassland and heathland. As the FCS targets have no spatial GIS data they could not be included in the spatial analysis of carbon opportunities using the Landscape Description Units.

Scenario 5 – Maximum Wetland

Coastal floodplain and grazing marsh is included in the Habitat Network Map as a restoration layer for other priority habitats – however due to its current poor habitat quality

it is deemed not viable to use as the basis for habitat expansion. It has therefore been excluded by Natural England as a standalone Habitat Network Map, and therefore does not have a bespoke NEZ1 or FAZ.

When the Floodplain Wetland Mosaic (FWM) habitat inventory is released, the creation of a habitat network map for it should be a high priority, which will then enable quantification of the carbon benefits of FWM expansion.

Thus, only lowland fen and reedbed habitats are included in this scenario, which means that a potentially significant area of FWM habitat expansion is not included in the analysis.

Where there are overlaps, the following hierarchy was used to assign land to a single habitat type:

1) Lowland fen
2) Reedbed

Lowland fen was excluded where it was included in Scenario 1: Peat, or if it sits on top of the existing deep or shallow peaty soils data.

Limitations

There are several limitations arising from the age and uncertainty of priority habitat and Habitat Network mapping. There are also caveats on the use and interpretation of carbon storage and sequestration data.

These limitations are outlined below, and some have been referenced in the narrative above.

These mean that the results cannot be taken as a precise estimate for total habitat opportunity, and in particular the carbon storage and sequestration estimates must not be used to quantify the carbon increases that would follow habitat expansion.

However, the purpose of the study is to provide indicative scenarios for the possible expansion of high carbon habitats to meet government targets. It is clear that there is sufficient opportunity to meet and exceed these targets, and the results allow decision-makers to gain a sense of the different habitat carbon outcomes that could be achieved.

Despite the caveat on quantification of carbon uplifts, the results can still be used to compare carbon outcomes across different scenarios, since the method uses the same datasets to derive carbon estimates.

Age and/or lack of priority habitat or Habitat Network data

The Priority Habitat Inventory is updated over time, although not on a nationwide basis. Thus some habitats may have changed, for example, woodlands may have been planted. The PHI contains little data on habitat condition, just presence or absence of the habitat, so the current status of conservation efforts outside protected sites is not known. Thus

some habitats listed as opportunities for enhancement may already be in active conservation restoration/management.

Some priority habitats are not included in the Natural England Habitat Network Mapping dataset, for example Coastal and Floodplain Grazing Marsh (CFGM) and mountain heaths and willow scrub. These therefore could not be included in the assessment, which therefore understates the extent of opportunity, particularly for floodplain wetland expansion with CFGM being a widespread habitat, with 18.59% sitting on deep and shallow peats and identified as one of the 'top ten' high carbon habitats in Part 1.

All the coastal habitats are merged into one singular NEZ1 and FAZ within the Natural England datasets. TEPs findings at Part 1 generated carbon values for individual priority habitats (coastal saltmarsh; coastal sand dunes; coastal vegetated shingle; maritime cliffs and slopes); of which saltmarsh is one of the 'top ten' high-carbon habitats. As the coastal Habitat Network maps are combined, it is difficult to pick out the potential for saltmarsh expansion and associated carbon increases. A work-around has been described in the detailed methodology.

The Natural England datasets do not include network enhancement and expansion layers for deciduous woodland. Therefore for scenario 2, only the dataset for ancient woodland, traditional orchards and wood pasture and parkland could be used to calculate opportunity using this methodology.

A review of the available Favourable Conservation Status (FCS) targets for S41: Habitats of Principal Importance identified only grassland and heathland habitat expansion targets were currently assessed. Others are not available, either because they had not been published, or had not yet been set, or were grouped at a broad habitat level. Due to this limitation, only the grassland and heathland FCS was compared with the Habitat Network data.

Limitations on habitat carbon data

The carbon storage values reported in this study are for the eventual target habitat but do not take account of the baseline carbon stored in existing habitats prior to restoration or creation works. This is unavoidable since the baseline habitat is not knowable.

This means that the carbon storage values presented in this report cannot be taken as the increase in carbon store arising from habitat works; rather they represent the end-point for carbon once the habitats have been restored which may take significant time in the case of woodland and peat-based habitats.

Nevertheless, for the purpose of this study, the reported carbon storage values allow comparison between different scenarios.

The carbon sequestration rates for different habitats also reflect the typical estimates generated at Part 1, and do not factor in baseline sequestration and overstate the amount of carbon sequestration. For some habitats the evidence base is poor with relatively few

measurements, especially of sequestration and emissions. Nevertheless the results allow a nationwide comparison of habitat scenarios.

The carbon figures do not take into account the emissions associated with habitat creation works, for example from machinery, transport, plant nurseries.

5. Results

Scenario 1: Maximum Peat

Nationwide Opportunity

A breakdown of opportunity by peatland priority habitat is presented in Table 10. The total area of existing peatland priority habitat is 511,000 hectares with a further opportunity area for restoration of these peatland habitats of 348,962 hectares in the Habitat Network NEZ1 and FAZ. Restoration of this area would eventually lead to a future carbon store of 113,211,907 t C, through safeguarding the existing store, reducing current emissions, and increasing sequestration.

For this scenario, peatland habitats are defined as blanket bog, lowland fen, lowland raised bog, upland flushes, fens and swamps and upland heathland. It is recognised that reedbeds, coastal and floodplain grazing marsh and purple moor grass and rush pasture are priority habitats that can often overlie peat, but to a much lesser proportion than the above habitats.

Most of this opportunity is in the uplands. Only 35,650 hectares lies within lowlands, defined in terms of the LDU physiographic code 'L' – Lowlands.

By hectarage the priority habitat zone with the largest opportunity is blanket bog. With an opportunity of 182,000 hectares, it accounts for 52% of the peatland habitat opportunity.

In terms of carbon storage, restoration of lowland fen provides the greatest opportunity at 54,099,501 t C. This is about 48% of the total theoretical carbon store, achieved on 19% of the peat opportunity area. This is due to the significant 'carbon density' of lowland fen that lies over peat.

Lowland raised bogs are the deepest peats with the highest carbon density on a per hectare basis. This study shows that 12,445 hectares are already in the PHI and there is 2,948 hectares opportunity in NEZ1 and FAZ. However, there is understood to be around 37,500 hectares of deep peat of raised bog derivation nationally, much of which is in agricultural use. There is clearly more potential to expand the present PHI area and protect these very significant carbon stores.

Delivery of all peat-based opportunities in peatland NEZ1/FAZ would result in a theoretical emission of 1,024,275 t CO_2e y^{-1}. This figure must be taken in the context of the significant limitations on this data. It indicates a net emission of carbon at a rate of 2.93 t CO_2e y^{-1}, but this will likely be a significant reduction from current emissions i.e. 'abatement' compared to the baseline habitats prior to intervention. As new peat-based habitats mature, the net emissions will reduce and net sequestration may commence. Part 1 (see Appendix 2 Table 9), shows emissions from blanket bog can be around zero when in good condition, but as high as 18.86 t CO_2e y^{-1} ha^{-1} when in degraded condition.

Table 10. Peat based habitat opportunities. Total carbon storage based on typical values with a consideration for peat. Total carbon sequestration based on typical rates.

Habitat Network	Fragmentation Action Zone (ha)	Network Enhancement Zone 1 (ha)	Total Opportunity Area (ha)	Total Carbon Storage t C	Total Carbon Sequestration t CO_2e y^{-1}
Blanket bog *235,641ha existing*	16,806	164,983	181,789	37,423,695	621,718
Lowland fen *19,934ha existing*	10,228	55,793	66,021	54,099,501	218,529
Lowland raised bog *12,445ha existing*	578	2,369	2,948	4,745,570	10,081
Upland flushes, fens and swamps *12,883ha existing*	4,418	45,684	50,102	10,829,799	171,350
Upland heathland *230,086ha existing*	6,195	41,907	48,103	6,113,342	2,598
Total	**38,226**	**310,737**	**348,962**	**113,211,907**	**1,024,275**

The NEZ1 and FAZ for the upland peatland opportunities (blanket bog, upland flushes, fens and swamps and upland heathland) currently include a significant proportion of grass moor, fragmented heath and good quality semi-natural grassland and no main habitat but other habitats present, which are non-priority habitats identified at Part 1 of this study as being important carbon stores in their own right, but capable of being enhanced and restored to priority status.

In summary, of the 279,994 hectares of upland peat NEZ1/FAZ opportunity, 79,546 hectares is currently comprised of these non-priority habitats.

Table 11 quantifies the significant areas of deep and shallow peat outside the PHI and peatland FAZ and NEZ1 opportunity areas. This represents a further theoretical restoration opportunity of 424,280 hectares, although carbon storage value and sequestration rates cannot be estimated since it is not knowable what specific habitats could be created on these areas.

203,075 hectares (47.9%) of these deep and shallow peat soils lie in the lowlands, defined as any Landscape Description Units with a physiographic coding of ‘L’ – Lowlands. It is likely that most of these are used for agriculture and thus fall within the scope of the EIP

target for responsible management of lowland agricultural peat to safeguard carbon store and reduce emissions.

Table 11. Areas of deep and shallow peat outside the PHI and habitat networks

Deep and shallow peaty soils outside the PHI and Habitat Networks	Total Area (hectares)	Area in lowlands (hectares)	Proportion in lowlands (%)
Outside PHI and peatland habitat network NEZ1 and FAZ	424,280	203, 075	47.9%
Outside PHI and all habitat networks of all types	152,000	125,419	82.5%

A subset of the above figure is the amount of deep and shallow peats that is located outside any habitat network expansion zones for any habitat type – 152,000 hectares, most of which is also in the lowlands.

Landscape Types

LDUs are assessed in terms of their total area of opportunity for the restoration and enhancement of peat-based habitats. This includes opportunities in Network Enhancement Zone 1, Fragmentation Action Zone, and other deep or shallow peat not currently located in any Habitat Network Map. The ‘top five’ LDUs for peat-based opportunity are listed at Table 12.

The Fens LDU22334 LWW is a notable outlier, containing about 98,000 hectares of peat-based opportunity. However, about 88,000 hectares is made up of deep and shallow peat areas outside the Habitat Network, typically on high-grade agricultural land. Opportunity to restore lowland fen would require a significant trade-off with current levels of food production, although ongoing soil losses combined with increasing summer droughts and winter floods are likely to render current cropping patterns increasingly unproductive.

Another LDU with significant opportunity is Yorkshire Dales LDU1804 HDO, containing about 15,500 ha of opportunity.

Figure 3 presents the national picture for peat-based opportunity, with the ‘top ten’ LDUs, by area, highlighted.

The results from this landscape analysis, found in Supplementary Excel 1, can be analysed on a habitat-specific basis. For example, Table 13 and Figure 4 show LDUs with opportunity for blanket bog restoration in Network Enhancement Zone 1. The Yorkshire Dales NCA holds 3 of the top 5 LDUs for this specific opportunity – with Yorkshire Dales LDU1804 HDO having about 12,000 hectares of opportunity for blanket bog expansion.

Table 12. The top 5 Landscape Description Units with the greatest opportunity for restoration of peat-based habitats (scenario 1).

Landscape Description Unit	Total Opportunity Area (ha)	Deep and Shallow Peat Area (ha)
The Fens LDU2234 LWW	98,050	88,200
Yorkshire Dales LDU1804 HDO	15,761	0
Cumbria High Fells LDU1655 HDO	12,117	1,717
Dartmoor LDU292 HDO	11,639	2
Yorkshire Dales LDU1805 HDO	9,972	0.12

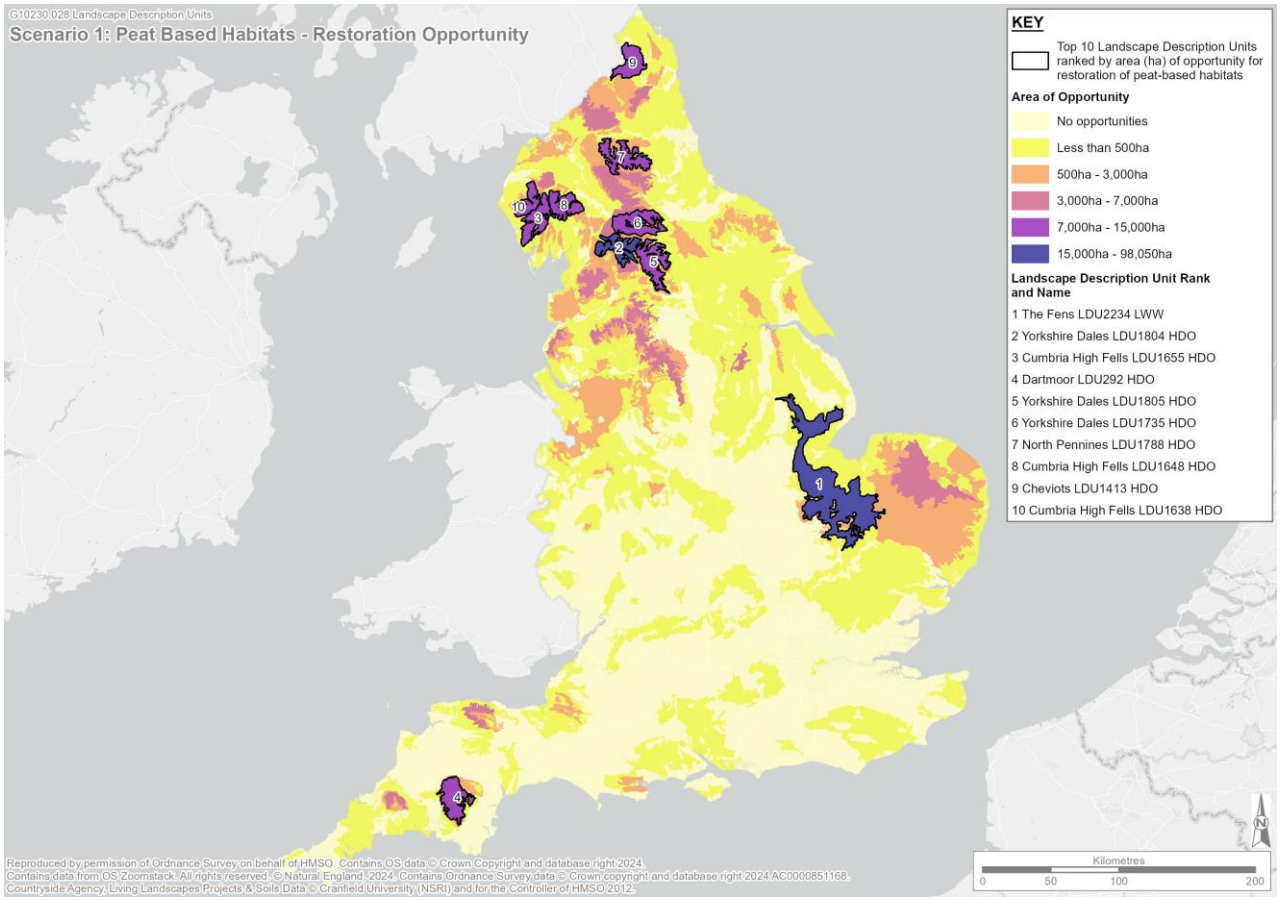

Figure 3. Landscape Description Units (LDU) showing extent of opportunity for restoration and enhancement of peat-based habitats, highlighting top 10 LDUs.

Table 13. The top 5 Landscape Description Units with the greatest opportunity for blanket bog restoration in Network Enhancement Zone 1.

Landscape Description Unit	Total Opportunity Area (ha)
Yorkshire Dales LDU1804 HDO	12,301
Yorkshire Dales LDU1805 HDO	8,131
North Pennines LDU1788 HDO	7,316
Yorkshire Dales LDU1735 HDO	6,279
Bowland Fells LDU1675 HDO	5,110

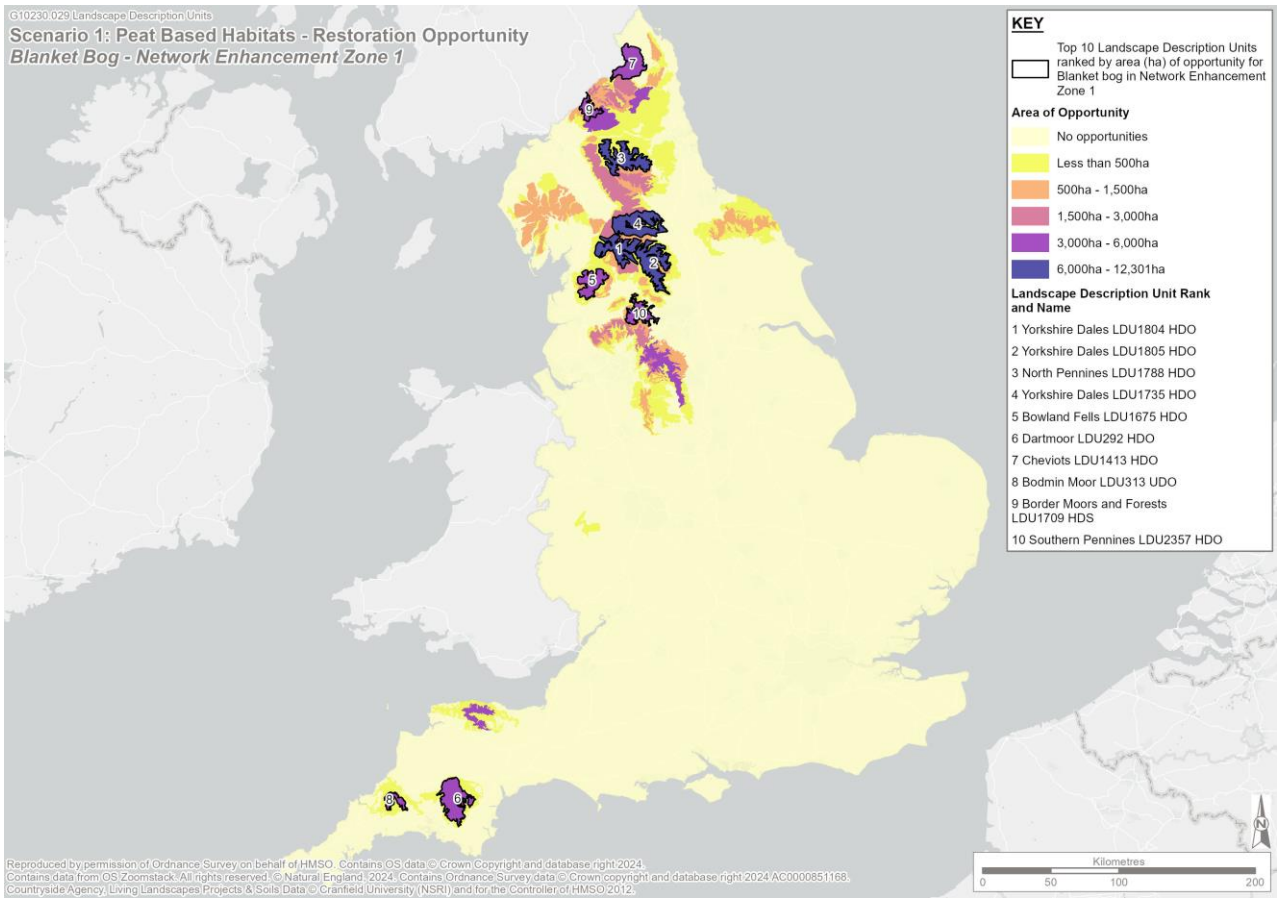

Figure 4. Landscape Description Units (LDU) and their opportunities for blanket bog restoration in Network Enhancement Zone 1, with the top 10 LDUs highlighted.
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Landscape Character Types

About 75% of blanket bog restoration opportunity is found in Landscape Character Types HDO and HDS – as shown at Table 14 and Figure 5. LDU's which fall into these LCTs could be targeted for creation of upland high-carbon habitats – it is likely that other allied priority habitats such as Upland heathland and Upland fens, flushes and swamps will also be found alongside blanket bogs in a mosaic of habitats.

Table 14. Top 5 Landscape Character Types for Landscape Description Units containing opportunities for Blanket bog restoration and expansion

Landscape Character Type	Total Opportunity* Area - hectares	Total Opportunity Share	Total Opportunity Rank
HDO	117,199	64.47%	1
HDS	17,052	9.38%	2
UDW	9,195	5.06%	3
UDS	7,892	4.34%	4
UDO	6,057	3.33%	5

* Includes Fragmentation Action Zone (FAZ) and Network Enhancement Zone 1 (NEZ1).

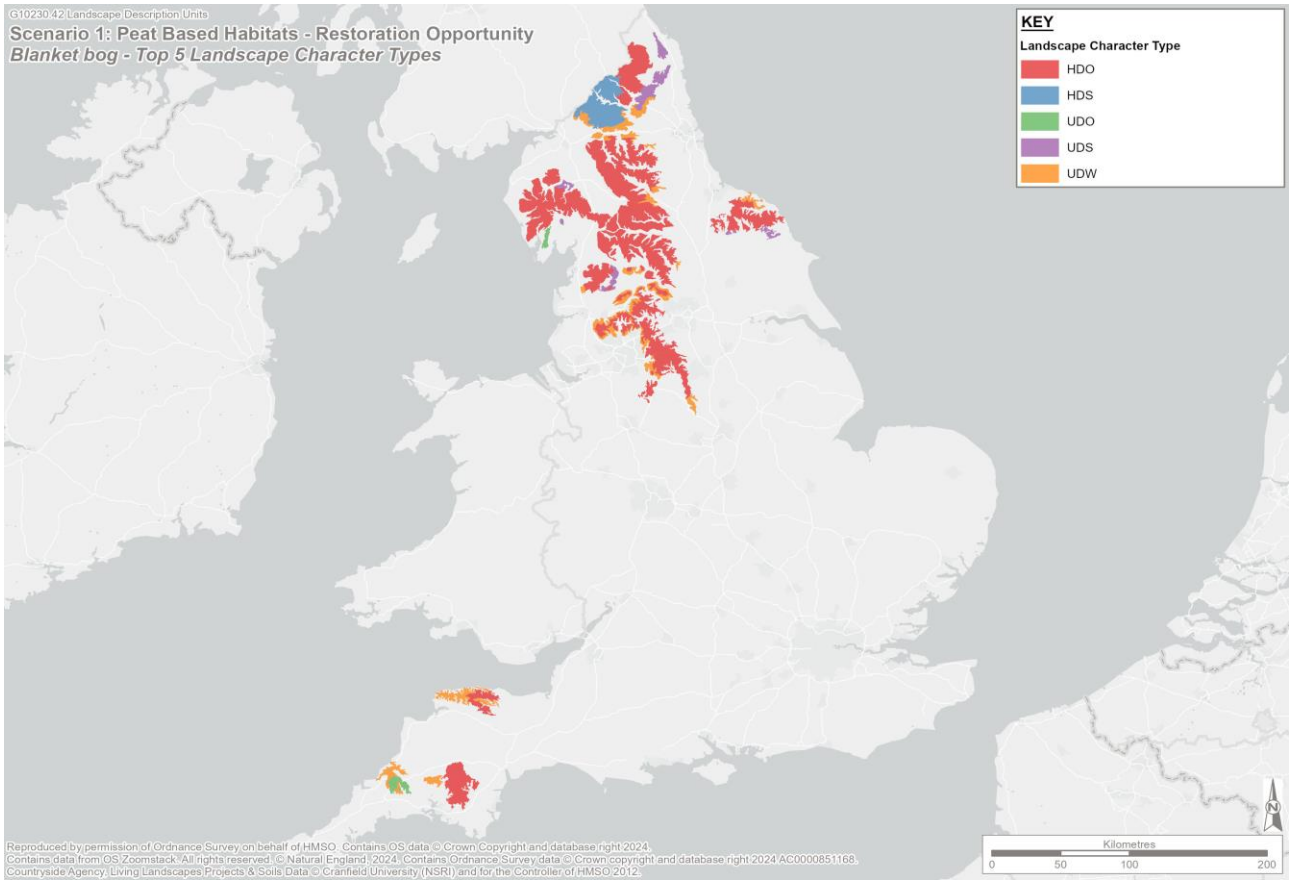

Figure 5. Landscape Description Units with opportunities for Blanket bog, consisting of the top 5 Landscape Character Types for total opportunity.

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Scenario 2: Maximum Woodland

Nationwide Opportunity

A breakdown of deciduous woodland opportunities by priority habitat is presented in Table 15. The total opportunity area is 798,255 ha.

The priority habitats with the largest opportunity are traditional orchards. However, as described in Chapter 4, the Habitat Network data for traditional orchards results in extensive areas being identified in large buffer zones around numerous small core areas. As it would not be realistic to prioritise habitat expansion on this basis, the bottom row of Table 15 excludes traditional orchards, indicating an opportunity area of 254,638 hectares within Habitat Networks for ancient woodland and wood pasture and parkland.

Collectively these two woodland opportunity types could offer total carbon storage of 26 million t C in an expanded Habitat Network. This is based on the carbon store of younger woodland (up to 100 years old) but storage value would increase beyond 100 years age.

Expansion of deciduous woodland in the ancient semi-natural woodland FAZ, and wood pasture style planting in the WPP network could provide a sequestration rate of about 891,000 t CO2e y-1.

Table 15. Woodland habitat network opportunities and carbon implications

Habitat Network	Fragmentation Action Zone (ha)	Network Enhancement Zone 1 (ha)	Total Opportunity Area (ha)	Total Carbon Storage t C	Total Carbon Sequestration t CO_2e y^{-1}
Ancient semi-natural woodland	13,333	No data, not possible to recreate this habitat	13,333	3,399,915	-193,330
Wood pasture and parkland *161,298ha existing*	8,723	232,583	241,306	22,924,047	-697,371
Traditional orchard *18,544ha existing*	No data	543,616	543,616	51,643,518	-1,571,050
Total	22,056	776,199	798,255	77,967,481	-2,461,754
Total excluding Traditional orchard	22,056	232,583	254,638	26,323,990	-890,704

Landscape Types

LDUs are assessed in terms of their total area of opportunity for the creation and restoration of deciduous woodland habitats. This includes opportunities in Network Enhancement Zone 1 and Fragmentation Action Zone for ancient semi-natural woodland and wood pasture and parkland. The 'top five' LDUs for woodland opportunity are listed at Table 16 and illustrated at Figure 6.

The High Weald LDU1221 RBA holds the greatest area of opportunity, totalling about 12,500 hectares – followed by South Downs LDU745 ULA with about 4,000 hectares of opportunity. The average area for opportunity across the top 10 LDUs is 3,598 hectares.

Table 16. The top 5 Landscape Description Units with the greatest opportunity for creation and restoration of woodland priority habitats.

Landscape Description Unit	Ancient semi-natural woodland opportunity area (ha)	Wood Pasture and Parkland opportunity area (ha)	Total Opportunity Area (ha)
High Weald LDU1221 RBA	1,101	11,263	12,364
South Downs LDU745 ULA	76	4,084	4,160
Low Weald LDU965 LCA	330	3,459	3,789
Thames Basin Heaths LDU1178 LCA	91	2,595	2,686
Hampshire Downs LDU980 RCA	222	2,161	2,383

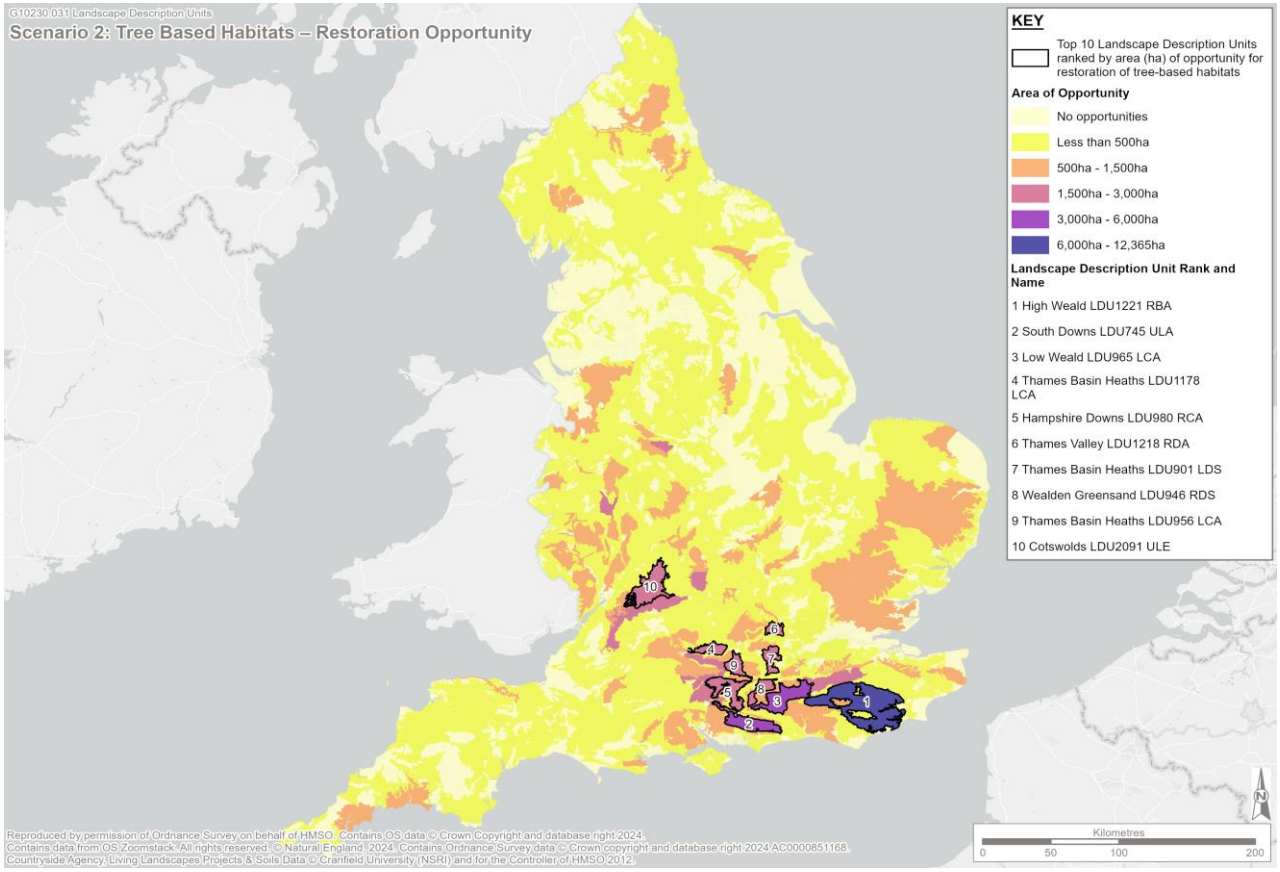

Figure 6. Landscape Description Units (LDU) and their opportunities for creation and restoration of priority woodland habitats, with the top 10 LDUs highlighted.
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Landscape Character Types

Around 20% of woodland restoration and expansion opportunity is found in Landscape Character Types RBA and RCA – as shown at Table 17 and Figure 7. LDUs which fall into these LCTs could be targeted for the expansion and restoration of existing woodland.

As expected given that this analysis used datasets for ancient woodland and wood pasture and parkland expansion, all the top 5 LCTs across the LDUs containing opportunities for woodland have a cultural pattern of ‘Wooded – ancient woods’ (A).

As can be seen at Figure 7, prioritisation of woodland expansion in these LDU’s would have a widespread benefit across much of central and southern England; areas which have been shown in the Part 2 research to be particularly at risk of adverse effects from rapid climate change.

Table 17. Top 5 Landscape Character Types for Landscape Description Units containing opportunities for woodland restoration and expansion

Landscape Character Type	Total Opportunity Area - hectares	Total Opportunity Share	Total Opportunity Rank
RBA	26,121	10.26%	1
RCA	25,719	10.10%	2
LCA	21,602	8.49%	3
ULA	16,961	6.66%	4
RDA	11,720	4.60%	5

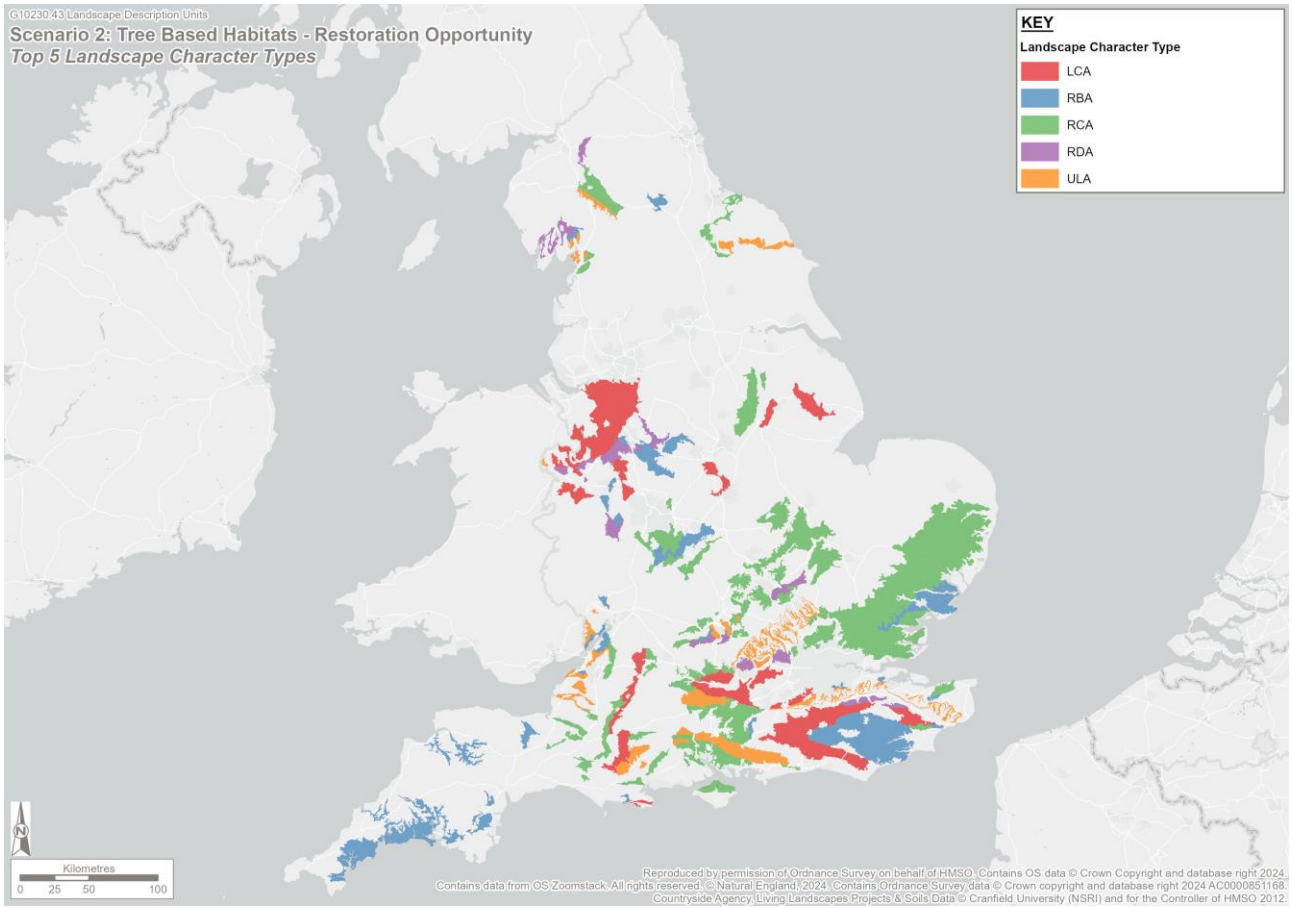

Figure 7. Landscape Description Units with opportunities for woodland, consisting of the top 5 Landscape Character Types for total opportunity.

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Scenario 3: Maximum Coastal Habitats

Nationwide Opportunity

Coastal habitat creation opportunity is presented in Table 18. This is a grouping of habitats consisting of coastal saltmarsh, coastal sand dunes, coastal vegetated shingle and maritime cliff and slope. In total there is about 119,000 hectares of opportunity.

In terms of high carbon habitats, coastal saltmarsh is one of the 'top ten' nationwide, but as the dataset is aggregated it is not possible to estimate how much of the 119,000 hectares opportunity would be suitable for saltmarsh creation.

Saltmarsh creation can however be presumed to be the majority opportunity, given that the scope for creation of dunes, cliffs and shingle will be strictly limited to certain geologies and topography.

The estimation of carbon storage and sequestration is derived from a proportionate distribution of the make-up of existing coastal habitats priority habitats, as described at Table 9 in Chapter 4 (Methodology). This indicates a total carbon storage value of 29,048,715 t C, and a total carbon sequestration rate of -394,643 t CO_2e y^{-1}.

Table 18. Coastal priority habitat expansion opportunity

Habitat Network	Fragmentation Action Zone (ha)	Network Enhancement Zone 1 (ha)	Total Opportunity Area (ha)	Total Carbon Storage** t C	Total Carbon Sequestration t CO_2e y^{-1}
Coastal habitats *63,956ha existing*	22,378	96,928	119,306	29,048,715	-394,643

Landscape Types

LDUs are ranked for their total area of opportunity for the restoration and enhancement of coastal habitats, inclusive of Network Enhancement Zone 1 and Fragmentation Action Zone. Table 19 lists the 'top five' LDUs for coastal opportunity and Figure 8 illustrates the national distribution of opportunity.

The Greater Thames Estuary LDU1057 LWO contains the greatest area of opportunity, with c.3,500ha, followed by Humberhead Levels LDU3073 LWW with c.2,500 hectares. The average area of opportunity across the top 10 LDUs is 1,893 hectares.

Table 19. The top 5 Landscape Description Units with the greatest opportunity for creation and restoration of priority coastal habitats.

Landscape Description Unit	Total Opportunity Area (ha)
Greater Thames Estuary LDU1057 LWO	3,631
Humberhead Levels LDU3073 LWW	2,386
The Fens LDU2001 LWO	1,891
The Fens LDU1892 LWO	1,752
West Penwith LDU191 RDD	1,740

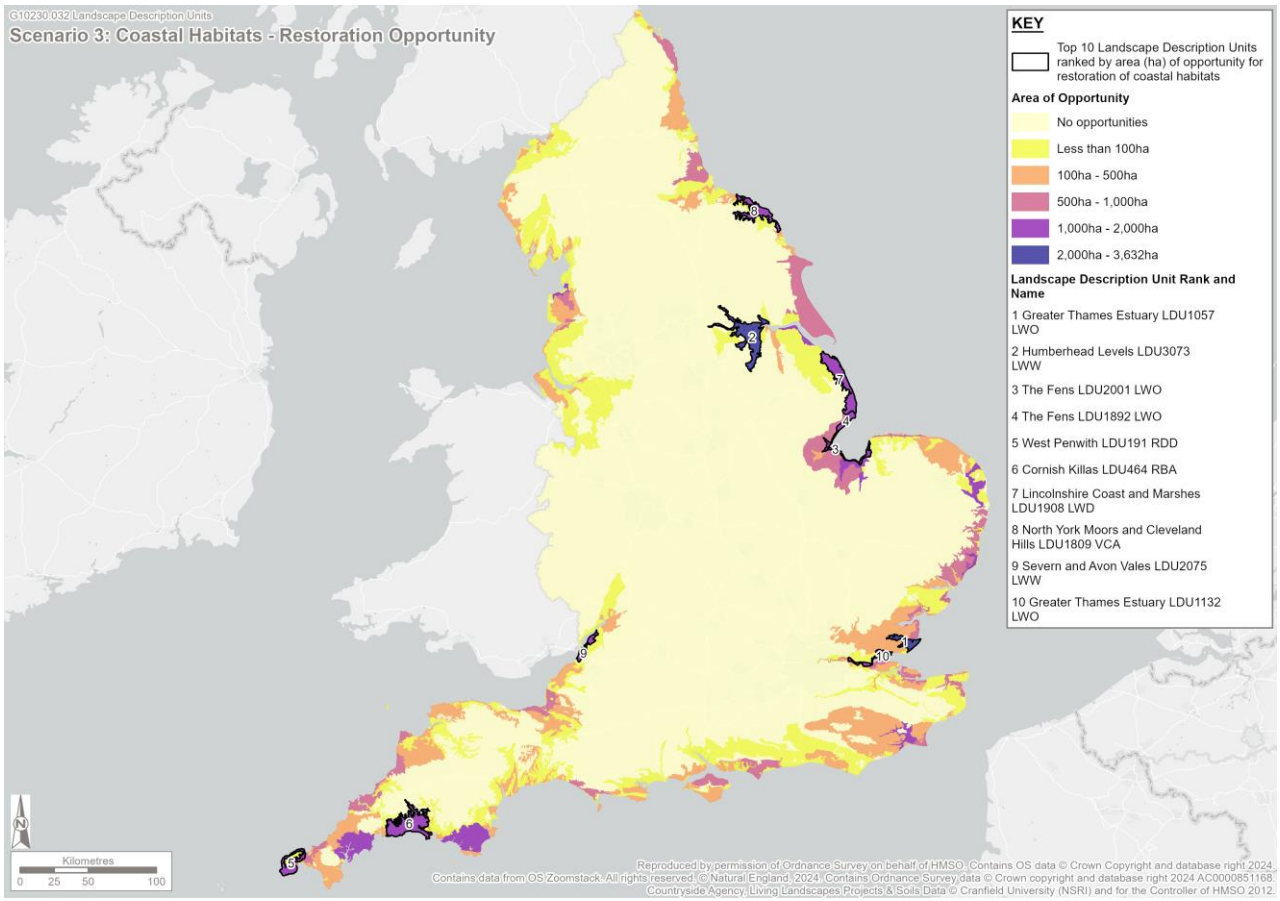

Figure 8. Landscape Description Units (LDU) and their opportunities for priority coastal habitat creation and restoration, with the top 10 LDUs highlighted.

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Landscape Character Types

Coastal habitat creation opportunities are found in a range of Landscape Character Types, so there is not an obvious means of using the LDU system to prioritise the creation of coastal-based high-carbon habitats i.e. saltmarsh. Table 20 shows the top 5 LCT's with coastal opportunity, as illustrated by Figure 9. When studying Figure 9, it should be recognised that LDU's are primarily for terrestrial landscape assessment, so many LDU's include only a relatively small proportion of coastline.

Table 20. Top 5 Landscape Character Types for Landscape Description Units containing opportunities for coastal-based habitat restoration and expansion

Landscape Character Type	Total Opportunity Area - hectares	Total Opportunity Share	Total Opportunity Rank
LWO	19,395	21.27%	1
LWW	18,197	19.95%	2
RBD	10,068	11.04%	3
RBA	4,638	5.09%	4
LWD	3,969	4.35%	5

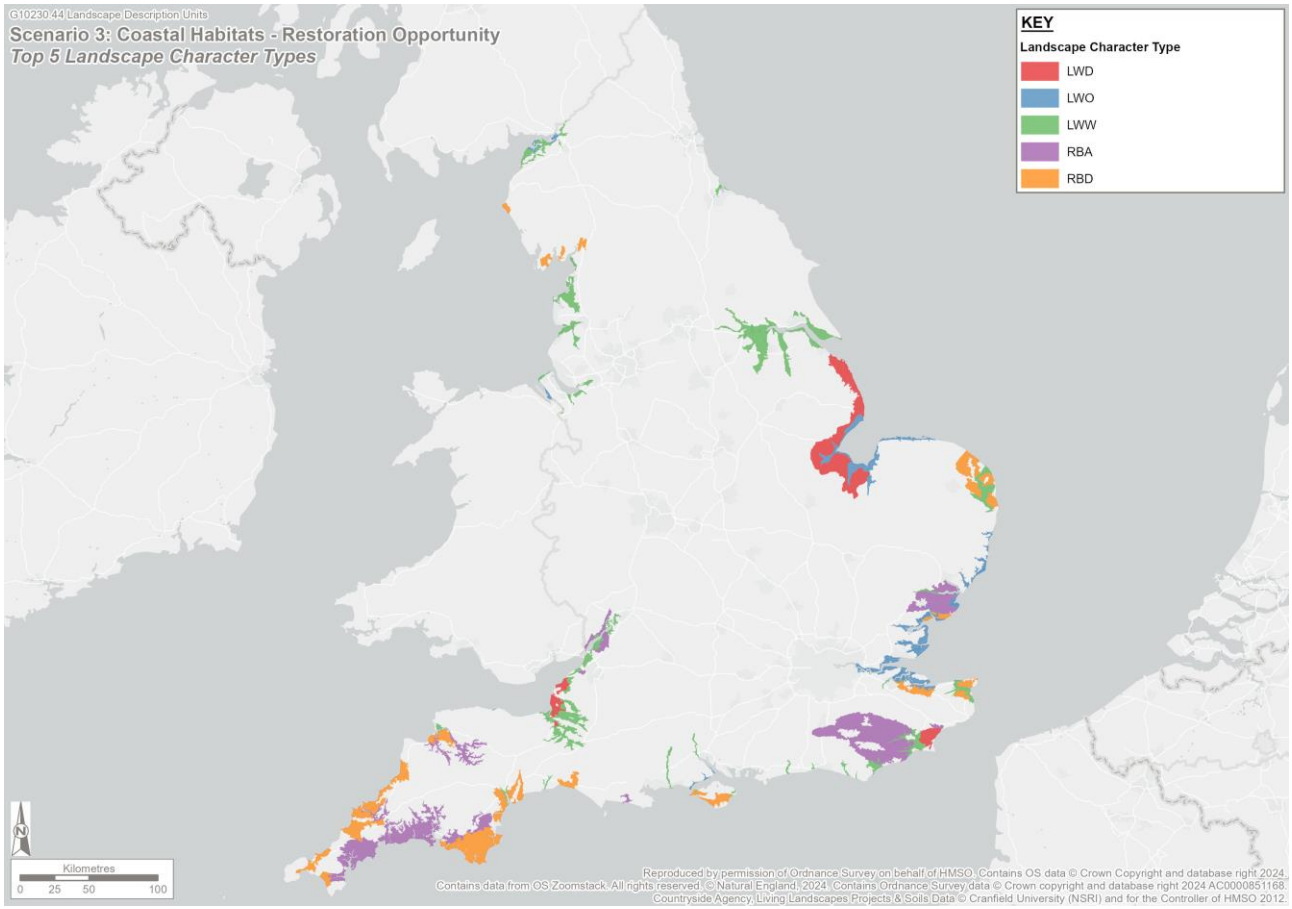

Figure 9. Landscape Description Units with opportunities for coastal-based habitats, consisting of the top 5 Landscape Character Types for total opportunity.

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Scenario 4: Maximum Grassland and Heathland Habitats

Nationwide Opportunity

A breakdown of grassland and heathland opportunities by priority habitat is presented in Table 21. The total opportunity area is c.890,000 hectares with the share across individual priority habitats shown in Figure 10. Grassland habitats account for 73% of this opportunity, of which lowland meadow contributes 27%.

The total grassland and heathland habitat opportunity areas would deliver a total carbon storage value of c.70,000,000 t C, and a total sequestration rate of c.12,500 t CO_2e y^{-1}.

The three largest contributors to potential carbon store are lowland calcareous grassland, lowland heath and lowland meadows, each of which have an estimated store of 14 to 15 million t C - see Figure 11.

Table 21. Grassland and heathland priority habitat opportunities. Total carbon storage and total carbon sequestration based on typical values and rates.

Habitat Network	Fragmentation Action Zone (ha)	Network Enhancement Zone 1 (ha)	Total Opportunity Area (ha)	Total Carbon Storage t C	Total Carbon Sequestration t CO_2e y^{-1}
Lowland calcareous grassland *65,662ha existing*	38,756	176,512	215,268	14,853,492	0
Lowland dry acid grassland *17,723ha existing*	6,241	60,304	66,545	5,789,410	0
Lowland heathland *54,461ha existing*	32,507	114,875	147,381	14,738,122	7,959
Lowland meadows *27,143ha existing*	15,931	219,932	235,863	14,151,759	0
Purple moor grass and rush pastures *10,647ha existing*	11,938	86,861	98,799	8,595,511	0
Upland calcareous grassland *9,617ha existing*	1,938	14,348	16,287	1,123,780	0
Upland hay meadow *2,581ha existing*	1,138	20,298	21,436	1,286,155	0

Habitat Network	Fragmentation Action Zone (ha)	Network Enhancement Zone 1 (ha)	Total Opportunity Area (ha)	Total Carbon Storage t C	Total Carbon Sequestration t CO_2e y^{-1}
Upland heathland *230,086ha existing*	9,381	79,395	88,776	8,877,611	0
Total	**117,830**	**772,525**	**890,354**	**69,415,840**	**12,753**

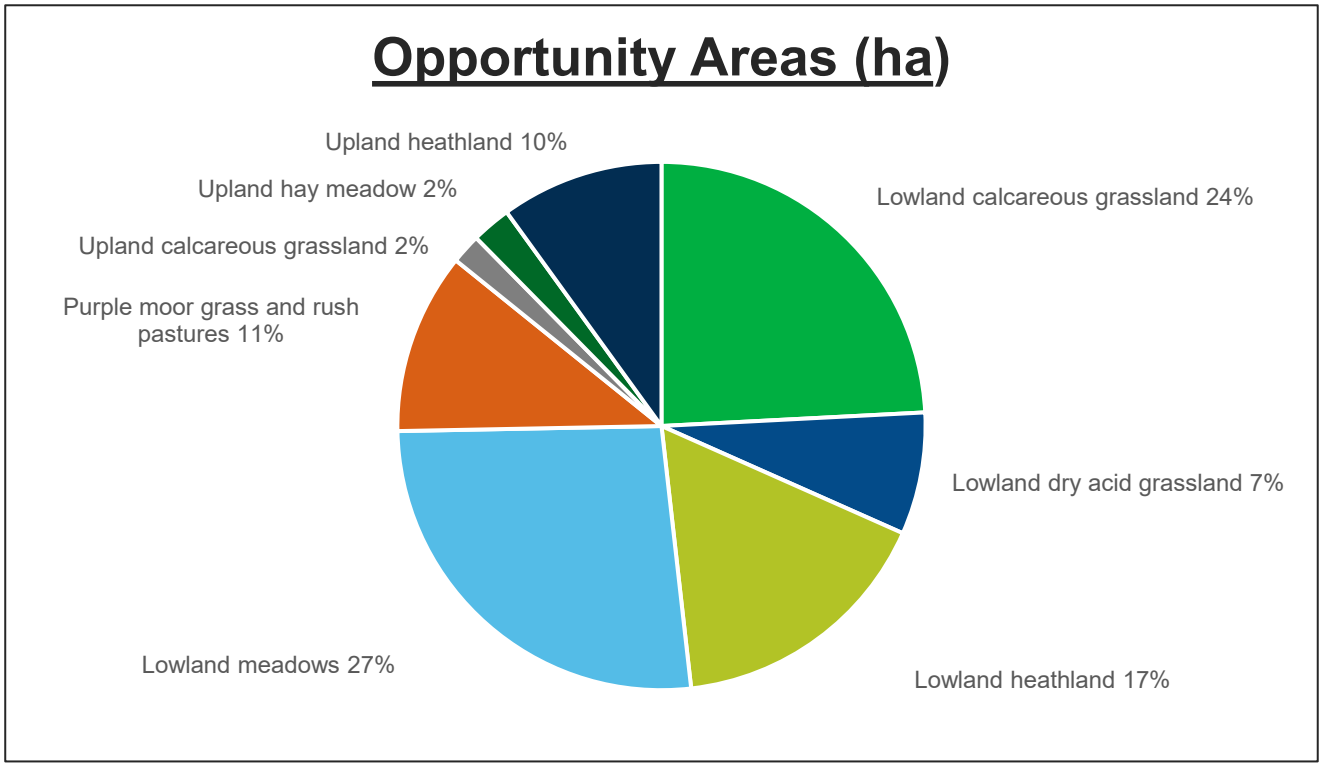

Figure 10. Total share of all grassland and heathland opportunities per habitat, made up of both Fragmentation Action Zone and Network Enhancement Zone 1 data from Natural England's Habitat Network Map.

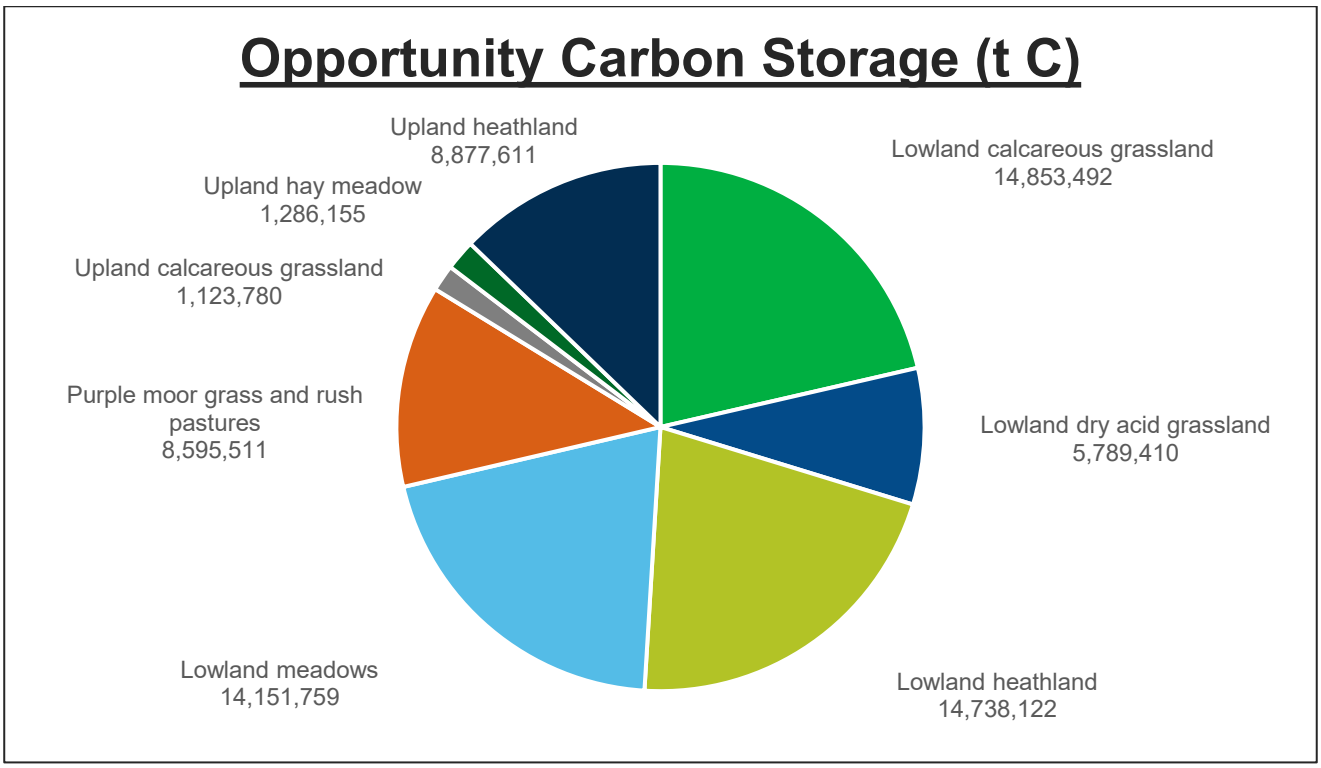

Figure 11. Total carbon storage per habitat opportunity area, made up of both Fragmentation Action Zone and Network Enhancement Zone 1 data from Natural England's Habitat Network Map. Values based on typical carbon storage value.

Habitat increases for grassland and heathland habitat are available in the Favourable Conservation Status (FCS) data and these are provided for comparison in Table 22.

There are some significant differences between the extent (in hectares) identified as opportunities within the NEZ1 and FAZ data and the FCS habitat targets, notably for lowland calcareous grassland and lowland and upland heath. This is a result of Natural England terrestrial habitat specialists providing professional judgement to produce the FCS figures (pers. comm. Ian Crosher Natural England Senior Specialist Climate Change). The FCS expansion largely fits within and aligns with the NEZ1 and FAZ opportunity, but reflects a tighter focus on opportunity.

Table 22. Grassland and heathland based habitat opportunities. Comparison between Total Opportunity Area and FCS figures with Total carbon storage based on typical values

Habitat Network	Total Opportunity Area (ha)	Total Carbon Storage t C		FCS expansion area (ha)	Total Carbon Storage t C
Lowland calcareous grassland	215,268	14,853,492		149,000	10,281,000
Lowland dry acid grassland	66,545	5,789,410		49,000	4,263,000
Lowland meadows	235,863	14,151,759		219,000	13,140,000
Purple moor grass and rush pastures	98,799	8,595,511		65,500	5,698,500
Upland calcareous grassland	16,287	1,123,780		FCS statement not published yet	No data
Upland hay meadow	21,436	1,286,155		24,000	1,440,000
Lowland and Upland heathland*	236,157	23,615,733		135,000	13,500,000
Total	**890,355**	**69,415,840**		**641,500**	**48,322,500**

* The FCS figures for lowland and upland heaths are combined in the FCS data and therefore combined above.

Landscape Types

LDUs can be ranked for their total area of opportunity for the creation and restoration of all grassland and heathland based habitats, inclusive of Network Enhancement Zone 1 and Fragmentation Action Zone. Table 23 lists the top five in terms of the area of opportunity, and this is mapped at Figure 12.

The White Peak LDU2931 HLN is the LDU that holds the greatest area of opportunity with about 14,500 hectares. The average opportunity area per LDU for the top 10 LDUs is about 10,000 hectares.

Table 23. The top 5 Landscape Description Units with the greatest opportunity for creation and restoration of grassland and heathland priority habitats.

Landscape Description Unit	Total Opportunity Area (ha)
White Peak LDU2931 HLN	14,748
Salisbury Plain and West Wiltshire Downs LDU635 ULW	12,412
Yorkshire Wolds LDU1233 RLE	10,836
Dorset Downs and Cranborne Chase LDU395 ULN	10,580
Cotswolds LDU2091 ULE	9,196

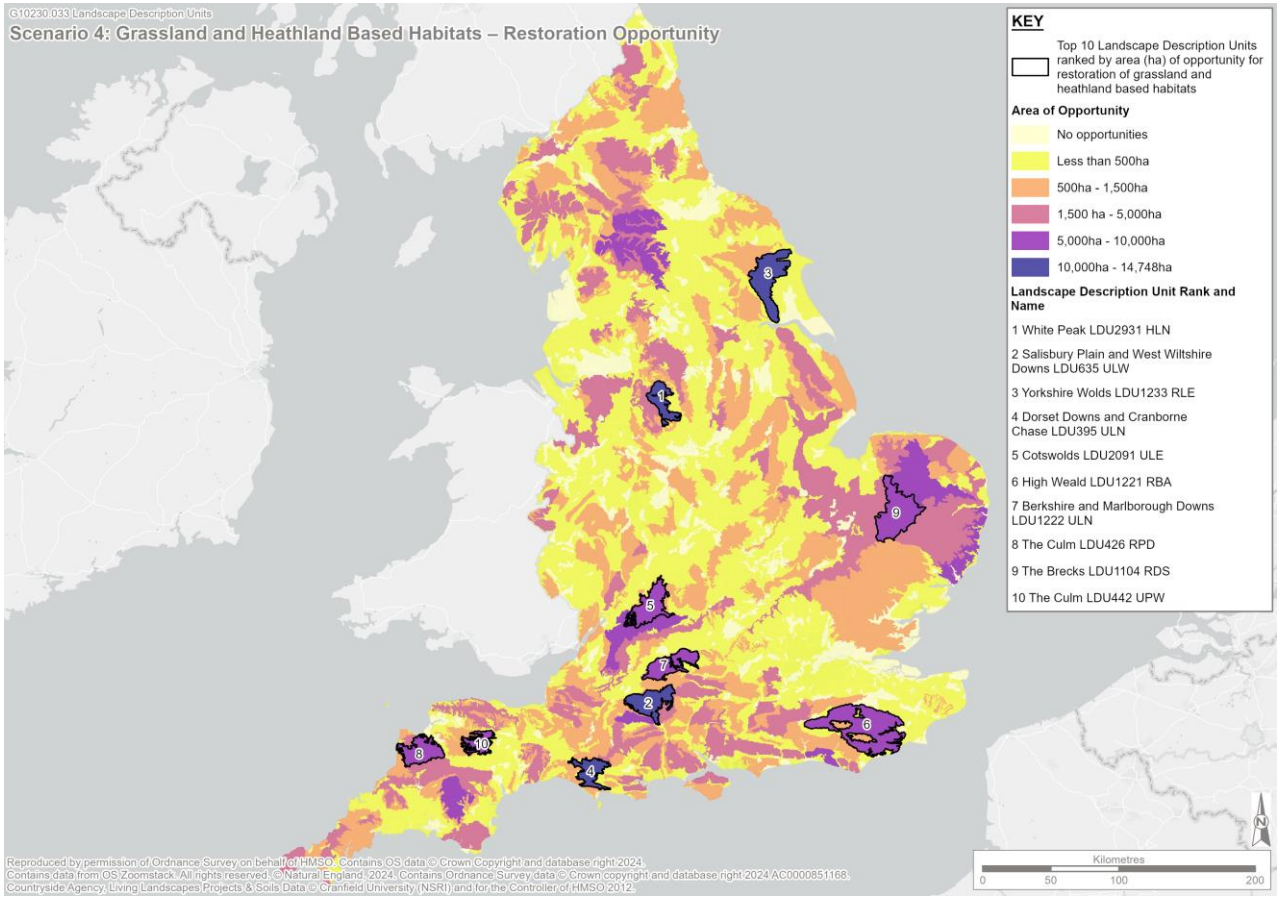

Figure 12. Landscape Description Units (LDU) and their opportunities for creation of grassland and heathland priority habitats, with the top 10 LDUs highlighted.

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The results from this landscape analysis, found in Supplementary Excel 4, can be further scrutinised to identify specific opportunities per habitat. For example, Table 24 and Figures 13 and 14 show areas of opportunity for:

- Lowland calcareous grassland, Network Enhancement Zone 1 (NEZ1) (Figure 13)
- Lowland heathland, Network Enhancement Zone 1 (NEZ1) (Figure 14)

The data could also be interrogated at regional level to identify and map LDU's with most opportunity. This might assist with targeting of local nature recovery strategies.

Table 24. The top 5 Landscape Description Units with the greatest opportunity for Lowland calcareous grassland, Network Enhancement Zone 1, and Lowland heathland, Network Enhancement Zone 1.

Data Filter	Landscape Description Unit	Total Opportunity Area (ha)
Lowland calcareous grassland - NEZ1	White Peak LDU2931 HLN	10,411
	Salisbury Plain and West Wiltshire Downs LDU635 ULW	9,832
	Yorkshire Wolds LDU1233 RLE	9,334
	Cotswolds LDU2091 ULE	7,599
	Berkshire and Marlborough Downs LDU1222 ULN	7,108
Lowland heathland - NEZ1	Suffolk Coast and Heaths LDU1124 RDS	3,528
	New Forest LDU665 RDO	3,060
	West Penwith LDU191 RDD	2,513
	The Brecks LDU1104 RDS	2,051
	Dorset Heaths LDU357 LDS	2,016

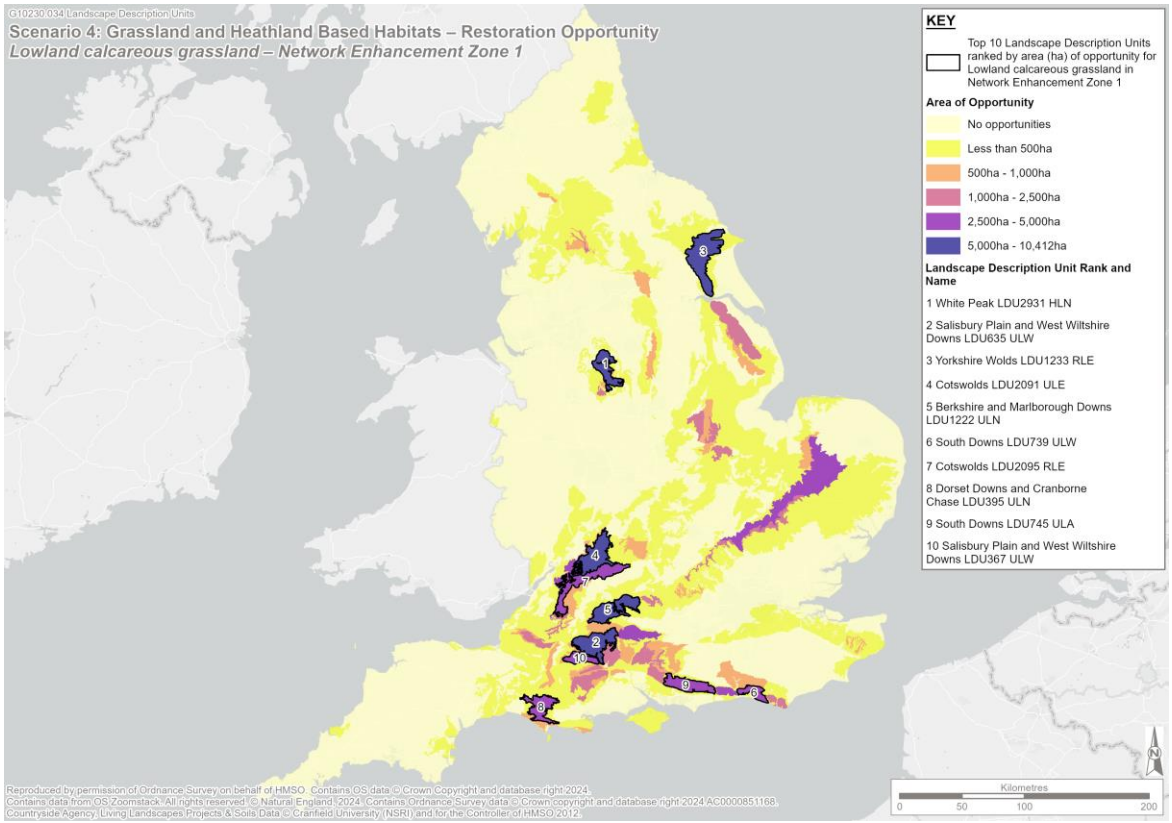

Figure 13. Landscape Description Units (LDU) and their opportunities for lowland calcareous grassland, Network Enhancement Zone 1.

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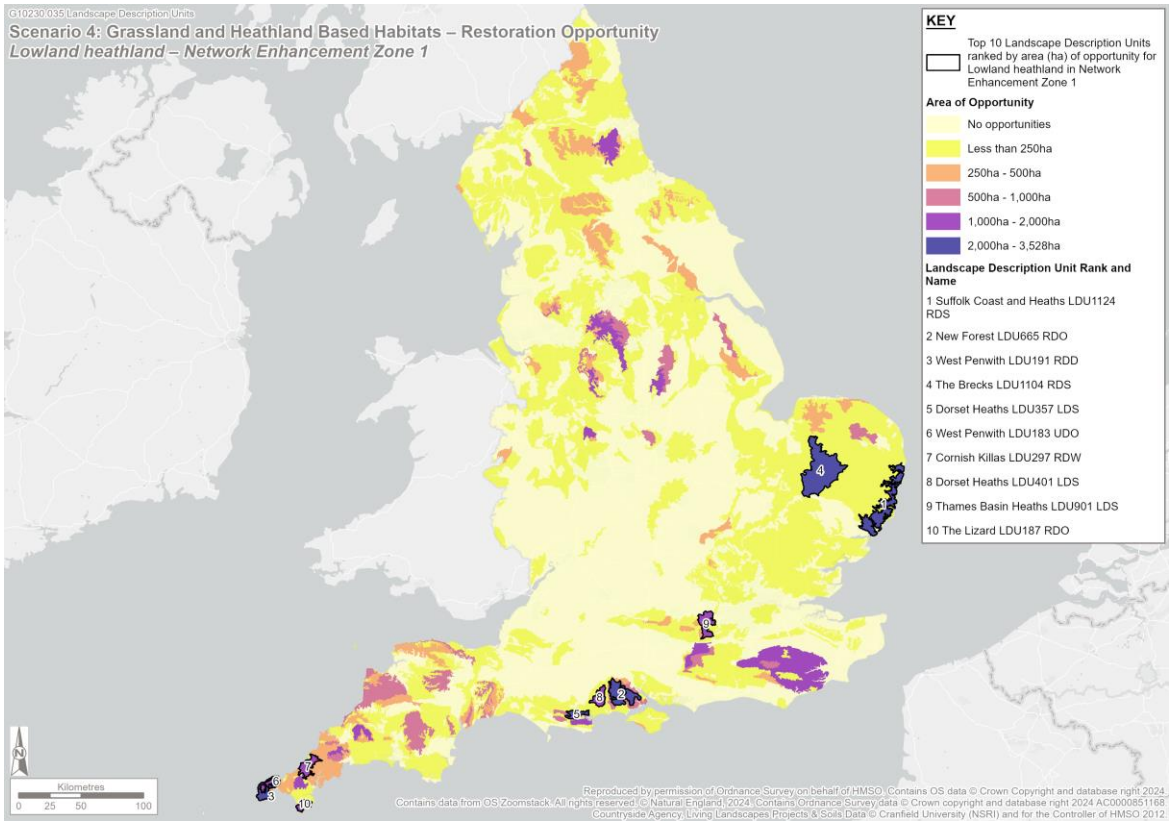

Figure 14. Landscape Description Units (LDU) and their opportunities for lowland heathland, Network Enhancement Zone 1.

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Landscape Character Types

About 30% of lowland calcareous grassland opportunities are found in the Landscape Character Types ULW and ULA, as shown in Table 19 and Figure 15. The LDUs with such LCTs share both the same physiography (Low hills (U)) and landcover (Chalk and limestone (L)). Thus, LDUs containing these LCTs could be realistically targeted for the expansion and restoration of existing Lowland calcareous grassland across the landscape.

Looking at lowland heathland opportunities, around 25% are found in the Landscape Character Types RDS and LDS, as shown in Table 25 and Figure 16. All the top 5 LCTs with lowland heathland opportunity contain the same existing landcover descriptor, Heath and moorland (D); again showing the potential for using the LCT system as a targeting system for agri-environment investment. However the presence of the HDO type (High Hills Physiography) is unexpected and may reflect the plasticity of the identification of lowland heathland priority habitat and its associated network enhancement zone.

Table 25. Top 5 Landscape Character Types for Landscape Description Units containing opportunities for the restoration and expansion of Lowland calcareous grassland and Lowland heathland

Landscape Character Type	Total Opportunity Area - hectares	Total Opportunity Share	Total Opportunity Rank
Lowland calcareous grassland			
ULW	35,587	16.53%	1
ULA	29,339	13.63%	2
RLE	26,989	12.54%	3
ULN	26,104	12.13%	4
HLN	14,709	6.83%	5
Lowland heathland			
RDS	19,779	13.51%	1
LDS	14,100	9.63%	2
HDO	11,116	7.59%	3
UDW	10,342	7.07%	4
UDS	8,904	6.08%	5

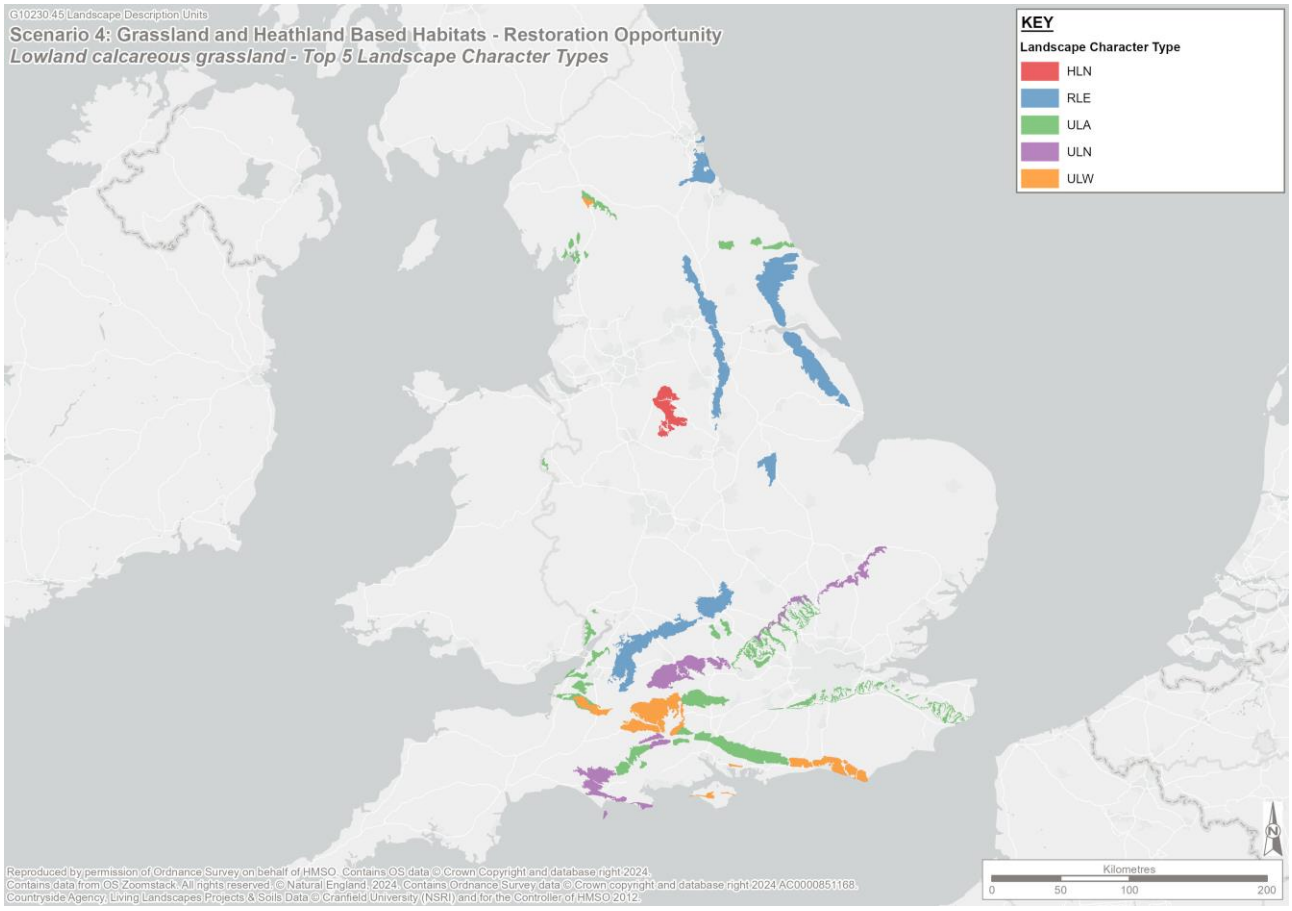

Figure 15. Landscape Description Units with opportunities for Lowland calcareous grassland, consisting of the top 5 Landscape Character Types for total opportunity.
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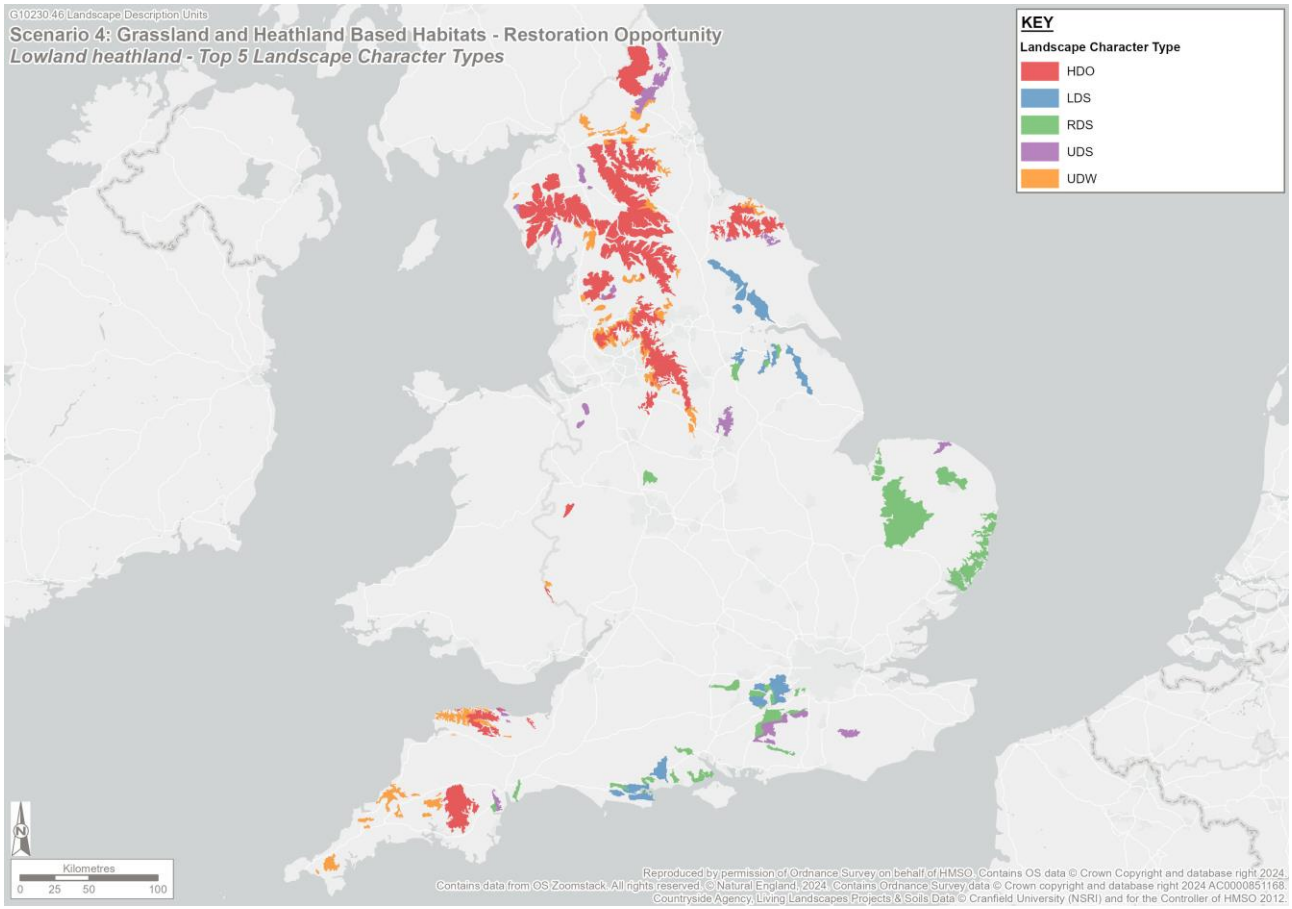

Figure 16. Landscape Description Units with opportunities for Lowland heathland, consisting of the top 5 Landscape Character Types for total opportunity.

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Scenario 5: Maximum Wetland Habitats

Nationwide Opportunity

A breakdown of wetland priority habitat opportunities is presented in Table 26. The total opportunity area for these habitats is c.156,000 hectares, equating to a total carbon storage value of c.26,000,000 t C, and a total sequestration of 230,000 t CO_2e y^{-1} (net emission).

Reedbed accounts for 56% of the habitat opportunities and the potential total carbon storage.

As noted previously a notable limitation is the absence of Coastal and Floodplain Grazing Marsh (CFGM) as there is no data in the Natural England Habitat Network Mapping dataset for this habitat. CFGM is in the 'top ten' of high carbon habitats and there will be widespread opportunity for creation or restoration of Floodplain Wetland Mosaic habitats.

Table 26. Floodplain and wetland based habitat opportunities. Total carbon storage and total carbon sequestration based on typical values and rates

Habitat Network	Fragmentation Action Zone (ha)	Network Enhancement Zone 1 (ha)	Total Opportunity Area (ha)	Total Carbon Storage t C	Total Carbon Sequestration t CO_2e y^{-1}
Lowland fen *19,934ha existing*	10,756	57,424	68,180	11,454,200	225,675
Reedbed *4,283ha existing*	5,826	81,794	87,619	14,720,039	No data
Total	*16,582*	*139,217*	*155,799*	*26,174,239*	*225,675*

Landscape Description Units

LDUs have been ranked for their total area of opportunity for the creation and restoration of wetland habitats, inclusive of Network Enhancement Zone 1 and Fragmentation Action Zone.

The Broads LDU1093 LWW is the LDU which holds the greatest area of opportunity, c.4,000ha – see Table 27 and Figure 17.

Table 27. The top 5 Landscape Description Units with the greatest opportunity for creation and restoration of priority wetland habitats.

Landscape Description Unit	Total Opportunity Area (ha)
The Broads LDU1093 LWW	4,051
Suffolk Coast and Heaths LDU1124 RDS	3,491
Humberhead Levels LDU3073 LWW	3,309
The Fens LDU2234 LWW	2,585
New Forest LDU665 RDO	2,316

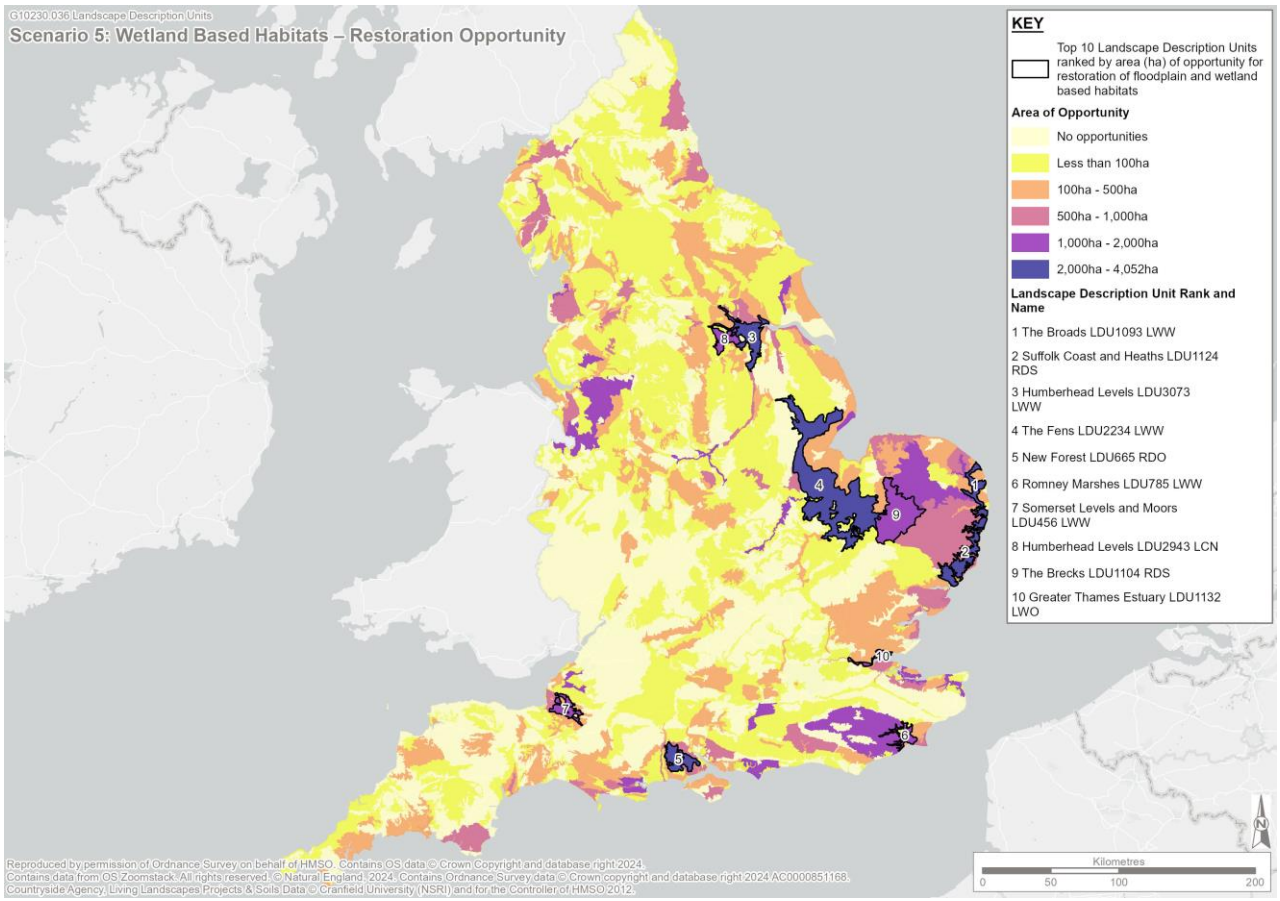

Figure 17. Landscape Description Units (LDU) and their opportunities for creation and restoration of priority wetland habitats, with the top 10 LDUs highlighted.
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The results from this landscape analysis, found in Supplementary Excel 5, can be further scrutinised to identify specific opportunity focus areas per habitat and per LDU. For example, Table 28 and Figure 18 focus on reedbed habitat opportunity within Network Enhancement Zone 1.

Table 28. The top 5 Landscape Description Units with the greatest opportunity for reedbeds, Network Enhancement Zone 1.

Landscape Description Unit	Total Opportunity Area (ha)
The Broads LDU1093 LWW	3,526
Suffolk Coast and Heaths LDU1124 RDS	3,272
Humberhead Levels LDU3073 LWW	2,398
The Fens LDU2234 LWW	2,004
Romney Marshes LDU785 LWW	1,834

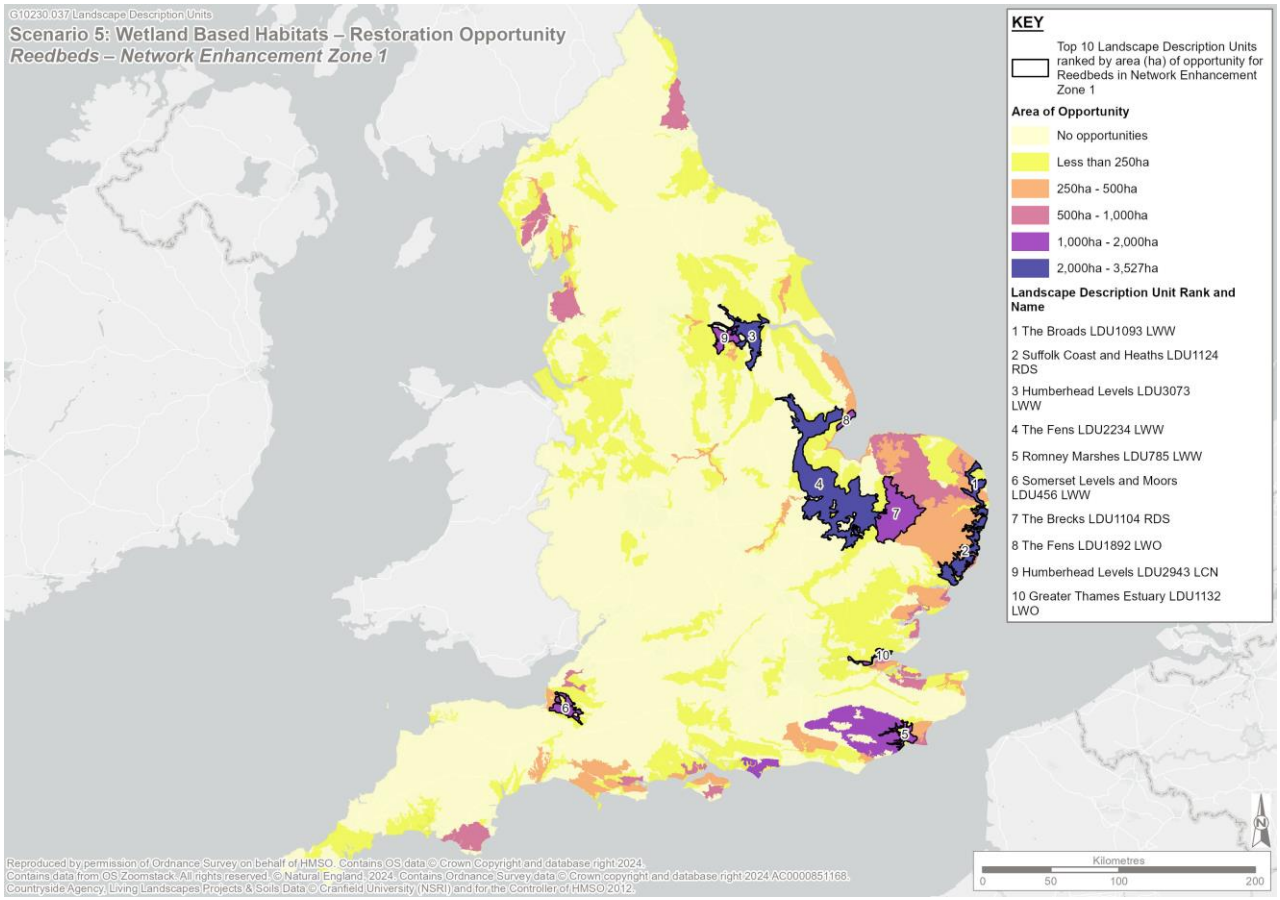

Figure 18. Landscape Description Units (LDU) and their opportunities for reedbeds, Network Enhancement Zone 1.

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Landscape Character Types

About 40% of Reedbed opportunities are found in the Landscape Character Types LWW and LWO, as shown in Table 29 and Figure 19. The LDUs with such LCTs share both the same physiography (Lowlands (L)) and current Landcover (Wetland (W)).

Thus, LDUs which fall into these LCTs could be realistically targeted for the expansion and restoration of reedbed across the landscapes – rather than a complete change of the existing landscape(s).

Table 29. Top 5 Landscape Character Types for Landscape Description Units containing opportunities for the restoration and expansion of reedbed

Landscape Character Type	Total Opportunity Area - hectares	Total Opportunity Share	Total Opportunity Rank
LWW	18,371	23.21%	1
LWO	11,734	14.82%	2
RDS	6,204	7.84%	3
RBD	4,858	6.14%	4
LWS	3,823	4.83%	5

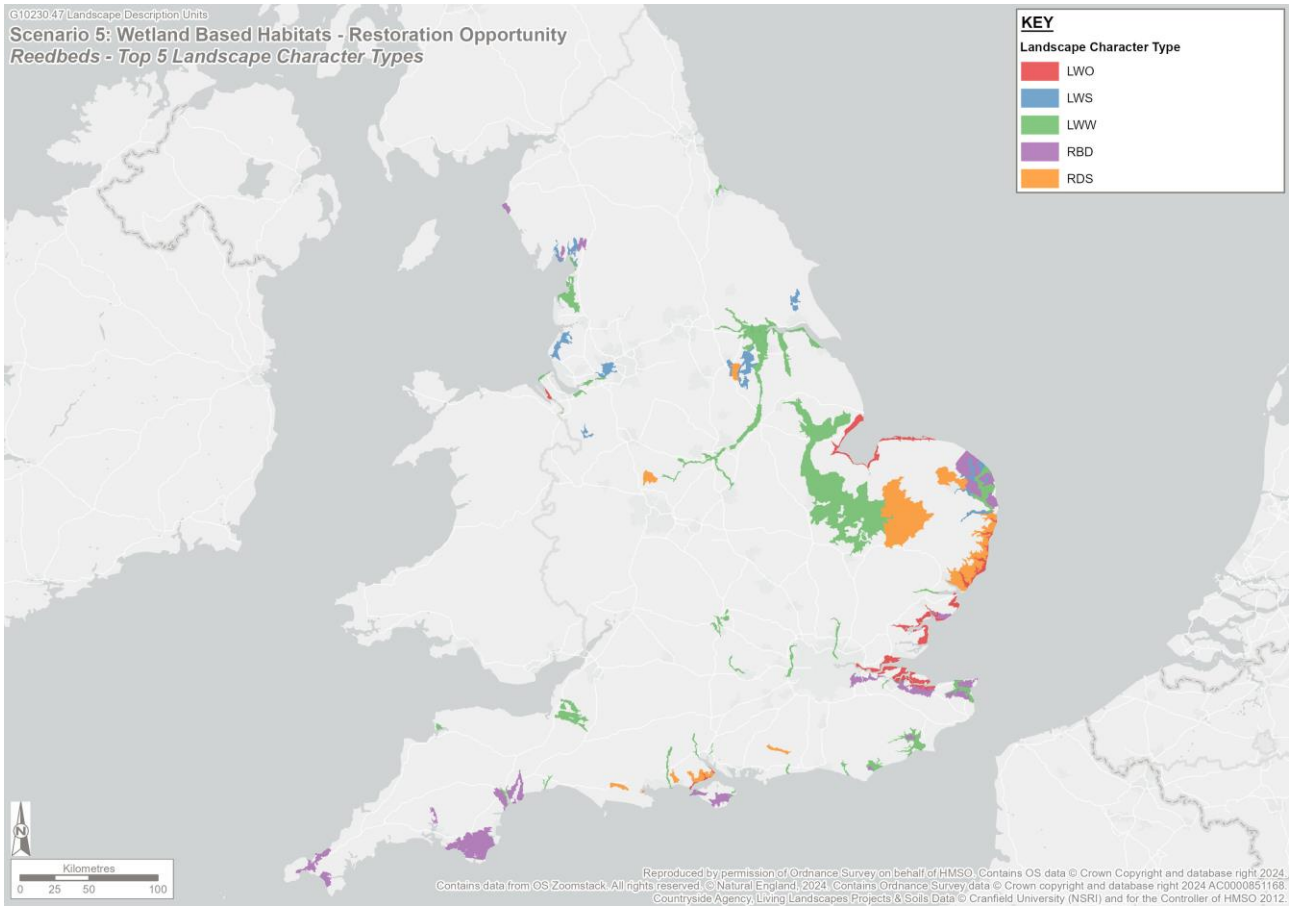

Figure 19. Landscape Description Units with opportunities for reedbed, consisting of the top 5 Landscape Character Types for total opportunity.
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Scenario comparison

The five scenarios are summarised at Table 30. The following notes should be read alongside the table to ensure it is interpreted correctly.

The opportunity area is based on Natural England's Habitat Network map and is the amount of land in Network Enhancement Zone 1 and Fragmentation Action Zone that could lend itself to creation or restoration of the specific priority habitat. There will be many other opportunities outside the Habitat Network which would deliver similar carbon improvements, but they will offer less benefit for nature recovery goals especially against the Lawton principles of "bigger, better and more connected" priority habitats.

The carbon storage and sequestration figures reflect the eventual future state of the habitat, and do not factor in the baseline carbon stored or sequestered by the existing habitats. They should not be read as the net increase in carbon associated with habitat

restoration, although improvements in carbon store, sequestration and abatement of baseline emissions can be assumed.

The detailed calculations for each scenario should be read to understand specific inclusions and exclusions. Woodland and wetland priority habitat opportunities are significantly understated by Table 30, due to network enhancement zones not being available for deciduous woodland and coastal floodplain grazing marsh.

Carbon values for the woodland opportunity is based on a mix of woodland and wood pasture style planting, the latter having lower storage and sequestration values than closed canopy woodland. Also the woodland opportunity uses carbon values for young woodland (<100 years).

There are some overlaps between habitat networks so there will be some overlaps between the various scenarios and their outcomes; for example the wood pasture and parkland habitat network NEZ1 may overlap with lowland meadow NEZ1. Some overlaps have been removed, as noted in the methodology; for example the upland heathland NEZ1 has been split between Scenarios 1 and 4 depending on whether the opportunity overlies deep and shallow peat, or not.

The table also includes a row showing the area of lowland peat outside the PHI and peatland habitat network – this area could be eligible for ‘responsible management’ by re-wetting of lowland agricultural peats as set out in the EIP. This is not a nature recovery measure as it does not target a priority habitat outcome.

Table 30. Summary of Priority Habitat Expansion opportunities with associated carbon values and timescales to achieve good condition

Habitat	Opportunity Area (hectares)	Future Carbon Storage if Ecosystem restoration delivered t C	Future Carbon Storage per hectare t C ha^{-1}	Future Total Carbon Sequestration t CO_2e y^{-1}	Timescale to Good Habitat Condition (years)
Scenario 1 – Peat Restoration	348,962	113,211,907	324	1,024,275	>30
Lowland Agricultural Peat 'Responsible Management'	203,075	N/A the purpose of this measure is to safeguard existing carbon store	N/A	N/A the purpose of this measure is to reduce current emissions	N/A the purpose of this measure is not habitat-oriented
Scenario 2 – Woodland Creation	254,639	26,323,990	103	-890,704	>30
Scenario 3 – Coastal Habitat Creation	119,306	29,048,715	243	-394,643	15
Scenario 4 – Grassland and Heathland Creation or Restoration	890,354	69,415,840	78	12,753	15 to 20
Scenario 5 – Wetland Creation	155,799	26,174,239	168	225,675	12

Table 31 presents more detailed information, including potential carbon storage values and carbon sequestration rates on a per hectare basis, and a breakdown of the total opportunity area into Network Enhancement Zone 1 (NEZ1) and Fragmentation Action Zone (FAZ). It includes rankings of total opportunity in terms of carbon storage and sequestration.

For all five scenarios the NEZ1 (land connecting existing patches of primary and associated habitats, and likely suitable for creation of the primary habitat) are the largest in extent/area and provide the greatest potential for carbon storage and sequestration.

Maximum Peat (Scenario 1)

There is currently 512,000 hectares of peatland in the PHI; defined as blanket bog, lowland raised bog, lowland fen, upland flushes, fens and swamps, upland heathland and mountain heaths and willow scrub. About 361,000 hectares lies within SSSI's, and 151,000 hectares outside SSSI's.

Part 1 of this research has shown that the existing peatland PHI stores 203 million tonnes carbon, just under 40% of total carbon stored in the PHI as a whole. About 147 million tonnes of this is in SSSI peatlands.

Degraded peatlands are significant GHG emitters and are highly sensitive to climate change, principally from higher temperatures and lower precipitation in summers.

A maximum peat scenario offers a further opportunity for restoration to priority status of an additional 350,000 hectares of peatland in Habitat Network enhancement 1 and fragmentation action zones.

This peatland restoration has the highest potential future carbon store of the five scenarios (113 million t C), although timescales to achieve this will be at least 40 years. However, abatement i.e. reductions in emissions, compared to baseline, would commence at a much earlier date. This scenario will still be a net emitter of CO_2, although emissions would be less than experienced on the pre-restoration habitats.

313,312 hectares of this peatland restoration is in the uplands, including about 79,000 hectares of carbon-rich non-priority habitats, such as grass moorland and fragmented heath which can often be restored to peatland habitat using widely-practiced techniques such as drain-blocking and amendment to livestock grazing practices.

Restoration to blanket bog, raised bog and lowland fen offer the greatest total opportunity for building carbon store. Lowland fen over peat is notably more 'carbon-dense' than blanket bog.

Lowland raised bog is the most carbon-dense peatland habitat, with peat depths often 10m or more. However, it has only small network enhancement and fragmentation action zones, hence it has a limited total restoration opportunity, in terms of carbon storage.

A maximum peat scenario also considers an EIP target which relates to peaty soils in the lowlands currently used for agriculture. Although the EIP does not quantify this target, this study shows that 203,000 hectares of lowland is underlain by deep and shallow peats outside existing priority peatland habitats and the associated Habitat Network, typically on higher-grade agricultural land such as the East Anglian Fens.

Whilst this EIP target does not require restoration to priority habitat, it would involve re-wetting of peat soils and safeguarding of current carbon stores. Abatement i.e. reductions in emissions, compared to baseline, would commence at an early date following re-wetting. This scenario will still be a net emitter of CO_2, although emissions would be much less than experienced on the pre-restoration habitats.

Maximum Woodland (Scenario 2)

There is currently 920,820 hectares of priority deciduous woodland habitat and wood pasture and parkland habitat in the PHI. It stores 231 million tonnes of carbon and sequesters 8.1 million t CO_2e per year.

This study indicates there is opportunity for creation of 255,000 hectares of new priority deciduous woodland in Habitat Network enhancement zone 1 (NEZ1) and fragmentation action zone (FAZ) for ancient semi-natural woodland (ASNW) and wood pasture and parkland (WPP). The term 'Maximum Woodland' is perhaps misleading because Habitat Network mapping is not available for deciduous woodland as a class of priority habitat; it is only available for ancient woodland and wood pasture and parkland.

If habitats were expanded by planting of deciduous woodland and agroforestry (wood pasture-style groupings of trees), and based on this narrowly-defined opportunity, the future carbon store in new young woodland would be some 26 million tonnes, although it would take several decades to achieve this.

Dependent on the baseline habitat, abatement in carbon emissions might occur within five to ten years, with notable sequestration occurring after 30 years to some 891,000 t CO_2e y-1.

Maximum Coastal Habitat (Scenario 3)

Currently there is 64,000 hectares of coastal priority habitat in the grouping of coastal saltmarsh, sand dunes, vegetated shingle and maritime cliff and slope. It currently stores about 16 million tonnes of 'blue carbon' and sequesters 211,000 tonnes CO_2e per year, primarily in saltmarsh. It is a habitat particularly vulnerable to coastal squeeze associated with sea-level rise. Most of this habitat is already in the SSSI network. Although there is an EIP target for favourable conservation management of SSSI's, this cannot prevent the loss of blue carbon from coastal squeeze.

There is a total opportunity to create up to 119,000 hectares of coastal priority habitats in the Habitat Network, largely outside the SSSI network. It is not possible to disaggregate this to estimate the specific opportunity for coastal saltmarsh, which is one of the 'top ten' priority habitats for carbon storage and sequestration. As coastal areas are dynamic systems that are driven by natural process, there will always be uncertainties around which coastal habitat develops and stays in the longer term.

However, it is possible to estimate the total carbon store from the coastal habitat opportunity at 29 million t C, much of which would come from new coastal saltmarsh. In terms of total carbon sequestration, the coastal habitat group has a significant total rate (-395,000 t CO_2e y^{-1}). It is also capable of rapidly achieving good condition (15 years) and would generally be achieved in agricultural habitats that have a relatively low baseline carbon store and are probably emitting carbon.

Maximum Grassland and Heathland (Scenario 4)

There is currently 418,000 hectares of grassland and heathland priority habitat in the PHI. The grassland and heathland PHI currently stores about 65 million tonnes of carbon, although upland heathland forms the majority of this and is already partly considered in the peatland scenario.

Based on Habitat Network maps for eight grassland and heathland priority habitats, the total opportunity for creation of new priority grasslands and heathlands is 890,000 hectares, 75% of which would be in lowland habitats.

This would achieve an eventual carbon store of 69 million tonnes and the typical period to achievement of good habitat condition would be 15 to 20 years.

Annual carbon sequestration would not be significant once habitats had achieved good condition. However, where baseline habitats are currently significant emitters, the abatement achieved by transformation to permanent grassland would reduce net emissions rapidly, although this cannot be quantified with current evidence.

This group of habitats also has Favourable Conservation Status data available. Using this, the total opportunity area is lower (641,000 hectares, rather than 890,000 hectares).

Maximum Wetland (Scenario 5)

There is currently 24,000 hectares of priority lowland fen and reedbed and 221,000 hectares of priority coastal and floodplain grazing marsh in the PHI. Collectively these store 41 million tonnes of carbon, although there is an overlap with the peat scenario as a proportion of the lowland fen PHI overlies deep and shallow peats.

Of the total area of 245,000 hectares in the PHI, 47,000 hectares is in SSSI's.

Based on Habitat Network maps for reedbeds and lowland fen, and removing lowland fens over peat which are included at scenario 1; the opportunity area for creation of new priority wetland habitat is 156,000 hectares. This would achieve an eventual carbon store of 26 million t C.

It would remain as a net carbon emitter, but dependent on the baseline habitat, emissions would rapidly reduce. These habitat types are considered capable of achieving good condition in 12 to 15 years.

This opportunity understates the potential for wetland priority habitat creation and associated carbon storage, because there is no Habitat Network map for coastal floodplain grazing marsh, a widespread category of habitat which is in the 'top ten' of high carbon habitats.

Table 31. Summary table for all scenarios and opportunity areas. Total carbon storage and total carbon sequestration based on typical values and rates

Scenario	Action Zone	Total Area (ha)	Total Carbon Storage t C	Total Carbon Sequestration t CO_2e y^{-1}	Total Carbon Storage t C ha^{-1}	Total Carbon Sequestration t CO_2e y^{-1} ha^{-1}	Carbon Storage ha^{-1} Rank	Carbon Sequestration ha^{-1} Rank
Scenario 1 – Peat	FAZ	38,226	17,420,733	108,753	456	2.84	1	9
Scenario 1 – Peat	NEZ1	310,737	95,791,174	915,522	308	2.95	2	10
Scenario 2 – Woodland	FAZ	22,056	5,548,604	-93,332	192	-9.91	5	1
Scenario 2 – Woodland	NEZ1	232,583	22,095,363	-672,164	95	-2.89	8	4
Scenario 3 – Coastal	FAZ	22,378	5,448,655	-74,023	243	-3.31	3=	2=
Scenario 3 – Coastal	NEZ1	96,928	23,600,060	-320,620	243	-3.31	3=	2=
Scenario 4 – Grassland and Heathland	FAZ	117,830	9,602,367	2,262	81	0.02	9	6
Scenario 4- Grassland and Heathland	NEZ1	772,525	59,813,473	10,491	77	0.01	10	5
Scenario 5 – Wetland	FAZ	16,582	2,785,726	35,602	168	2.15	6=	8
Scenario 5 - Wetland	NEZ1	139,217	23,388,512	190,073	168	1.37	6=	7

Note: In Future Total Carbon Sequestration: a negative figure is carbon sequestration, a positive figure is carbon loss (emission) to the atmosphere

Range of Carbon Outcomes

Taking the EIP target for creation and restoration of at least 500,000 hectares of wildlife rich habitat, including its assumption that 100,000 hectares would be biodiverse trees and woodland, it is possible to use the above analysis to model high and low carbon outcomes.

A low-carbon outcome would see 100,000 hectares of new woodland and trees and 400,000 hectares of grassland and heathland.

A high carbon outcome would see the 100,000 hectares of new woodland and trees, along with maximisation of coastal (119,000 hectares) and wetland (156,000 hectares) opportunities in the habitat network, with the balance (125,000 hectares) being grassland and heathland.

Table 32 demonstrates the difference in carbon outcomes. The carbon storage values and sequestration rates are derived from Tables 30 and 31, using the typical carbon values generated at Part 1 of this research.

Table 32. High and Low Carbon Outcomes for the 500,000 hectare habitat creation and restoration target (rounded figures)

Carbon Outcome	Assumed breakdown of newly-created habitats	Future Carbon Storage if Ecosystem restoration delivered t C	Future Total Carbon Sequestration t CO_2e y^{-1}
Low Carbon	100,000 hectares trees and woodlands 400,000 hectares grasslands and heathlands	41,500,000	-350,000
High Carbon	100,000 hectares trees and woodlands 119,000 hectares coastal habitats 156,000 wetland habitats 125,000 hectares grasslands and heathlands	75,000,000	-518,000

Note: In Future Total Carbon Sequestration: a negative figure is carbon sequestration, a positive figure is carbon loss (emission) to the atmosphere.

6. Delivery

Timescales

The five scenarios identify the potential amount of land within Habitat Networks that could be available to deliver new habitats and increased carbon storage and sequestration. The timescale for new habitats to achieve good and stable condition depends on the baseline habitat type, site conditions and factors such as soil type, previous land use and the technical difficulty of habitat creation and restoration.

As Table 30 shows, many habitats with high carbon storage and sequestration potential require a minimum of 30 years to reach a condition where the habitats are functioning sufficiently well that carbon storage is increasing and sequestration is occurring at predicted rates.

Some high carbon habitats such as saltmarsh and lowland fens could be brought to good condition in shorter timescale, typically less than 20 years.

Nevertheless, in many situations the baseline habitats are net carbon dioxide emitters, so the initiation of creation or restoration works to generate high carbon habitats will reduce emissions from an earlier date – abatement of current emissions being particularly important in the period to 2035.

Land availability

The amount of land available is a key factor in the ability to deliver the government's targets to restore nature and protect the environment set out in the Environment Improvement Plan (DEFRA, 2023), as articulated at Chapter 2.

The targets for expansion of 'wildlife-rich habitat' and deciduous woodland are for land outside protected sites. The vast majority of opportunities identified in this report are outside the SSSI network, ranging from 86% for scenario 3 (coastal habitats) to nearly 99% for scenario 2 (woodland habitats) – refer to Table 33.

This provides confidence that these opportunities could deliver the Environment Improvement Plan targets.

The Forestry Commission has identified about 3 million hectares of land that has no obvious environmental or societal protections that would be adversely affected by woodland creation (Forestry Commission, 2024). This far exceeds the 254,638 ha identified as opportunity areas for woodland habitats in Network Enhancement Zone 1 and Fragmentation Action Zones for ASNW and WPP. Nevertheless, woodland planting in the Scenario 2 opportunity areas would deliver against the Lawton principles of bigger, better and more connected networks of priority habitats.

Table 33. Areas of opportunity within or outside of SSSIs

Habitat	Area of NEZ1 & FAZ within SSSI (ha)	Area of NEZ1 & FAZ within SSSI %	Area of NEZ1 & FAZ outside SSSI (ha)	Area of NEZ1 & FAZ outside SSSI %
Scenario 1* = Peat	42,713	9	457,249	91
Scenario 2# = Woodland	2925	1.15	251,714	98.85
Scenario 3 = Coastal	16,726	14	102,579	86
Scenario 4 = Grass & Heath	38,067	4	852,288	96
Scenario 5 = Wetland	21,256	14	134,541	86

* Also includes areas of peaty soils outside of NEZ1 and FAZ

Excludes traditional orchard NEZ1 and FAZ

7. Conclusions and Recommendations

This assessment builds on Part 1 of the Nature Net Zero study which quantifies typical carbon storage and sequestration rates for priority habitats. By using Natural England's National Habitat Network and the Peaty Soils Dataset, we can estimate the carbon implications of expansion of the Habitat Network and delivery of the nature recovery targets in the Environmental Improvement Plan (Defra, 2023).

It is appreciated that this study has limitations arising from the fact that it has not involved any field measurements, and use of typical carbon storage values has been internally tested, rather than externally peer-reviewed. Opportunities for certain priority habitats could not be generated due to a lack of national habitat data.

Nevertheless, accepting these limitations, the assessment enables the quantification of carbon in habitats and landscapes at an England-wide scale.

Comparison of Carbon Outcomes associated with Nature Recovery Scenarios

The study seeks to identify habitats that make the best return on investment to achieve long term functional recovery of carbon in ecosystems, using five habitat scenarios. There are several factors that influence investment decisions:

- Extent of Opportunity – a large area offers opportunity to deliver against the legal target and provides a strong focus for research and knowledge-sharing effort
- Safeguarding of existing soil carbon stores – prevention of ongoing degradation of carbon-rich soils is key to meeting legal Net Zero targets
- Creating new carbon stores
- Creating habitats that will sequester atmospheric carbon as soon as possible
- Abatement of existing emissions at an early date
- Sensitivity to climate change – some habitats are particularly vulnerable as set out at Part 2 of this research
- Timeframes to achieve good habitat condition

Table 34 is a matrix that summarises the habitat and carbon opportunities arising from the five expansion scenarios. Notes on the matrix are:

The total opportunity area relates to expansion within Habitat Network Enhancement Zones 1 and Fragmentation Action Zone – other opportunities will of course be available, particularly for woodland where the Network opportunity is known to be understated.

Carbon Store is assessed on a qualitative basis, using the figures from Table 30. Each '+' represents 100 tonnes C per hectare either safeguarded or created. The allocation of '+' across the columns for safeguarding existing carbon and creating new stores by 2100 is based on professional judgement.

Net sequestration is based on expected time for a new habitat to achieve net sequestration. Some high-carbon habitats do not achieve this.

Abatement of existing emissions is based on a 2-step scale from baseline to future habitat with high-emission habitats being cultivated croplands and degraded peatlands, low emission habitats being grasslands, wetlands and peatlands in recovering condition and zero/sequestering habitats being woodland and saltmarsh. Thus a change from degraded to recovering peatland would be one step and creation of saltmarsh through shoreline realignment taking in arable land would be 2 steps, whereas creation of a priority grassland on an existing grassland would not involve significant abatement (i.e. no step change). A 2035 timeframe is used, and again professional judgement about typical baselines is used.

Sensitivity to climate change is taken from work by Staddon and others (2023), tabulated at Part 2 of the research. Where two figures are given, the lower figure represents the sensitivity of the habitat in good condition, and the higher figure represent its sensitivity in degraded condition.

Table 34 does not consider trade-offs and synergies with other ecosystem services such as food and hay production, regulation of water quality and flood attenuation or cultural services such as a sense of place and wellbeing. Some of these trade-offs and synergies are considered at Part 4 of this Nature Net Zero study.

Table 34. Comparator Matrix for carbon and climate resilience outcomes associated with different habitat expansion scenarios

Scenario	Creation or Restoration of priority habitats	Total Extent of Opportunity in Habitat Network '000 hectares	Safeguarding existing soil carbon stores	Creating new carbon stores by 2100	Net Sequestration by 2050 / 2100	Abatement of existing emissions by 2035	Sensitivity to climate change (1 – low, 5 – high)	Good Habitat Condition by 2035 / 2050 / 2100
Peatland Habitats	Restoration	349	+++	Possible	Uncertain	+	3-5	2100
Responsible Management of Lowland Agricultural Peat	No	203 (not in habitat network)	+++	Possible	No	++	N/A	N/A
Trees and Woodland	Creation	255	+	+	2050	+	2-3	2100
Coastal Habitats	Creation	119	No	++	2050	+	5	2050
Grasslands and Heathlands	Creation and some restoration	890	+	Possible	No	Possible	2-4	2035 / 2050
Wetland Habitats	Creation	156	+	+	No	+	4-5	2050

Analysis of Nature Recovery and EIP Targets

The evidence produced here demonstrates that the EIP's nature recovery targets are not currently articulated in terms of quantifiable activity in high-carbon habitats and that there is considerably more opportunity for focussing on 'high-carbon, high-nature' habitats than currently articulated in the EIP. Some commentary is provided below.

Peat

The target to ensure 75% of SSSI's are in favourable condition by 2042 could focus on those with peatland habitats as they store 147 million tonnes of carbon but are currently emitting rather than sequestering carbon.

The target to restore 280,000 hectares of peatland habitats by 2050 could be clarified so that it goes beyond the commitment to restore SSSIs. There are about 150,000 hectares of PHI peatland outside SSSIs and a further 350,000 hectares of opportunity in Habitat Network Enhancement Zone 1 and Fragmentation Action Zone. 90% of this opportunity is in the uplands where there is at least 80,000 hectares of carbon-rich non-priority habitat, such as grass moorland, which can readily be restored to peatland priority habitat.

Taken together the above actions would safeguard the 203 million tonnes of carbon in peatland PHIs and secure a future carbon store of up to 113 million tonnes.

The separate EIP target to bring lowland agricultural peat soils into responsible management to reduce emissions can be quantified at around 200,000 hectares on deep and shallow lowland peats. This goes significantly beyond the above opportunities and would deliver very significant abatement of current carbon dioxide emissions.

Woodland

The target to create 250,000 hectares of woodland with an expectation of 100,000 hectares being biodiverse would deliver a future carbon store of at least 26 million tonnes.

This study shows that this could all be delivered in the Habitat Network Enhancement Zone 1 and Fragmentation Action Zone for ancient woodland and wood pasture and parkland.

There is very considerable opportunity to create further new deciduous woodland in many other areas that are not constrained by, or targeted for, other priority habitats.

Coastal

The opportunity to create up to 119,000 hectares of coastal habitat in network enhancement and fragmentation action zones would fall within the EIP target of creating at least 500,000 hectares of wildlife-rich habitat outside protected sites. This 'blue carbon' opportunity can deliver carbon sequestration more rapidly than peatland restoration or woodland creation and would also help offset the inevitable loss of blue carbon and priority habitat in coastal SSSIs threatened by sea level rise and coastal squeeze.

Grassland and Heathland

There is considerable opportunity to create and/or restore up to 890,000 hectares of grassland and heathland in network enhancement and fragmentation action zones. This would fall within the EIP target of creating at least 500,000 hectares of wildlife-rich habitat. However, this offers lower carbon benefits than the other scenarios.

Wetland

The opportunity to create up to 156,000 hectares of wetland habitat in network enhancement and fragmentation action zones would fall within the EIP target of creating at least 500,000 hectares of wildlife-rich habitat outside protected sites.

This opportunity can deliver carbon storage and offers other ecosystem services such as flood attenuation and water quality regulation. A focus on restoring natural processes with a functioning floodplain wetland mosaic is a key requirement for effective restoration.

When the priority habitat map for Floodplain Wetland Mosaic (FWM) is released, developing an associated Habitat Network Map would enable the identification of opportunities for the creation of this carbon-rich habitat.

Collectively for all habitat groups

There is a major opportunity to deliver more for carbon and nature recovery. There is a considerable opportunity to safeguard and increase habitat carbon beyond the government's current nature recovery and land management targets
This could be addressed by:

- Protecting our carbon stores, making them more prepared for a future climate.
- Including more spatial direction towards creation of high-carbon wildlife-rich habitats at an ecosystem scale in key landscapes and areas.
- Setting out a carbon and nature approach to peat-based ecosystems to deliver habitats restoration across significantly more of the 1.2 million ha of Peatlands in England.
- Clearer targeting on the locations that would be ideal for restoration and creation of new habitats (that have habitat potential) to achieve both nature and carbon restoration at an ecosystem scale.
- Focussing the restoration of peatland habitats (280,000 hectares) outside of protected sites onto areas adjacent to existing high-quality areas. Our study finds that there is a total of 860,000 hectares of land that is already peatland habitat, often in degraded condition, or land that could be restored to peatland habitats from carbon-rich non-priority habitats.
- Recognising the 203,000 hectares of lowland agricultural peat soils that could be brought into 'responsible management' through a targeting approach for early improvement.

- Focussing the 500,000 hectare target for creating wildlife-rich habitats outside protected sites, on areas of habitat expansion. This will help to capture more opportunity for coastal and wetland habitat creation to reduce climate impact.
- Ensuring 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 to support the Net Zero goal.

Additionally early investment in expansion of high-carbon habitats will bring early benefit and better value for money in terms of:

- abatement of current emissions
- improved resilience of habitats to future unavoidable climate change
- slowing current habitat degradation and loss of peaty soils making restoration easier with lower costs when restoration does occur.
- delivery of other societal benefits such as improved resilience to flood, drought and improved water quality.

Landscapes for Investment

The study demonstrates which landscapes and which areas of England are best placed to deliver each scenario. Landscape Description Units (LDU's) are an invaluable tool for highlighting opportunity and can be used to target investment in nature recovery to achieve high-carbon habitats.

For example, to achieve restoration to blanket bog and allied upland priority habitats. investment in LDU's with the landscape character coding of HDO should be targeted – see Table 14 and Figures 4 and 5. Regional and national priorities can be identified – for example investment in several LDUs in the Yorkshire Dales would deliver significant joined-up delivery of upland habitats and investment in Dartmoor and Bodmin Moor (and Exmoor) is also a priority given the extreme vulnerability of southwestern moors to climatic heating – see Figure 4.

For restoration of lowland fens, lowland raised bogs, lowland wetlands and also for 'responsible management' of lowland agricultural peat (a separate EIP target), LDUs with the first and second LCT nominals of 'LW' – Lowland Wetlands, would be a priority for investment that would deliver nature recovery and carbon safeguarding.

For woodlands, the expansion opportunity does not need to be so focussed, but this study shows that creation of deciduous woodland for carbon could offer particular habitat networking benefits in LDUs with the third LCT nominal of 'A' – Wooded – ancient woods. Figure 7 shows LDU's with greatest opportunity.

For coastal habitats, the expansion opportunity is less closely correlated with the LDU system, and opportunities for creation of new saltmarsh will most likely be identified at a local level, taking account of shoreline management plans, known vulnerability to coastal squeeze and technical feasibility. Giving shoreline management plans scope to identify opportunity areas for habitat expansion may well help.

For grasslands and heathlands, the opportunity for expansion of specific habitats will vary across LDU's but the system can be used to highlight the largest area of opportunity for specific types – for example Figure 16 shows the LDU's with the greatest opportunity for lowland heathland creation.

Recommendations for Mapping, Data and Inventory

Arising from this study, we have identified several possible improvements in relation to mapping and data associated with the Priority Habitat Inventory and the Habitat Network in order for practitioners to understand the carbon value of particular habitats and implications of investment decisions. These recommendations for future refinement are:

- Annually invest in improving the Priority habitat inventories to continue to improve the quality of the data.
- Update and evolve our habitat classification system & Priority Habitats as this framework is nearly 30 years old, so that greater understanding around broad nature recovery goals can be linked to carbon and other integrated outcomes, such as including habitat categories like 'degraded blanket bog capable of restoration'.
- Ensure habitat condition is included in future iterations of the PHI
- Split out the Deciduous woodland PHI into the individual woodland types as the grassland, heathland and peatland PHI habitats already do.
- Create a wider habitat inventory framework that also includes degraded habitat components that are currently non-priority but capable of restoration – for example map grass moorland more comprehensively and denote areas of grass moorland that are likely to be heavily degraded blanket bog areas, capable of restoration
- Review the 'fragmented heath' inventory (a non-priority habitat) as the vast majority is on shallow peat soil and may well be wrongly mapped and classified.
- Consider a habitat carbon dataset as part of baseline information provided for each priority habitat
- Update the national Habitat Network datasets, in particular provision of Habitat Network layers for Deciduous woodland and Coastal and Floodplain Grazing Marsh and/or replacement with Floodplain Wetland Mosaic habitat & corresponding Habitat Network.
- Provision of a national Deciduous Woodland Habitat Network dataset, divided into the separate component priority habitat woodland types to refine the habitat areas, carbon storage values and sequestration rates.
- Refine coastal habitat data using information from the Restoring Meadows, Marshes and Reefs (ReMeMaRe) initiative.
- Advocacy of the value of Landscape Description Units and their landscape character typologies as a means of targeting habitat recovery.

Gaps in Knowledge about carbon in habitats

The significant knowledge gaps evident from this Nature Net Zero project are as follows. More information on typical carbon storage values and sequestration rates would be useful in the following habitats in order to estimate baseline carbon and potential for increases.

Some research is already commissioned through Natural England's Nature Returns programme.

Priority Habitats with lack of Carbon Storage data

- Purple Moorgrass & Rush Pasture (PMGRP)
- Lowland Fens, not on deep peat
    - on shallow peat soils
    - on Mineral soils
- Alkaline Fens (where there is a good PHI that lends itself to field-sampling)
- Reedbeds
    - on shallow peat
    - on mineral soils
- Upland Flushes, Fens & Swamps
- Mountain Heath & Willow Scrub
- Wet Heathland, separated between upland and lowland
- Wood pasture & Parkland

Non-Priority High-Carbon Habitats

- Grass Moorland
- Fragmented Heath

Timescales to achieve carbon outcomes

Just as the statutory biodiversity metric provides a framework for estimating the timescales for a given habitat to achieve 'good' condition, it would be useful to understand timeframes for the functional recovery of carbon in habitats:

- Abatement of existing emissions from baseline to future habitat
- Net sequestration commencing (where relevant)
- Safeguarding of existing stored carbon
- Increase in carbon store for restored peatland habitats by, say, 2100

This information would help inform investment decisions using a matrix such as that shown at Table 34.

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Appendices

Supplementary Excel Sheets

1 Habitat Expansion and Restoration Opportunities
2 Scenario 1 – Peat and Landscape Description Units
3 Scenario 2 – Trees and Woodlands and Landscape Description Units
4 Scenario 3 – Coastal Habitats and Landscape Description Units
5 Scenario 4 – Grasslands and Heathlands and Landscape Description Units
6 Scenario 5 – Wetlands and Landscape Description Units

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