England's peatlands

Carbon storage and greenhouse gases

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Peatland habitats, such as Ebblake Bog in Dorset, create diverse and attractive landscapes rich in wildlife

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Our peatlands are important stores of carbon, but have been damaged by recent management leading to increased emissions of greenhouse gases

Foreword

England's peatlands have been 10,000 years in the making, but our recent activities mean that their future is under threat. This should come as no surprise – they have always played an important part in people's lives. Symbolic sites of ritual burial in ancient times, they have been widely drained for grazing, cultivation and grouse moors in modern times, as well as being degraded as a result of the demand for peat as a growing medium.

Natural peatlands are home to a unique array of wildlife – from bitterns, swallowtail butterflies and fen violets in our lowland fens to nesting waders, cranberry and colourful bog mosses and cotton-grass in our raised and blanket bogs. The peat contains an irreplaceable record of human history in the artefacts it preserves, and the more remote, rugged uplands, where most of our peatlands are found, form stunning wilderness landscapes where people can experience nature on a grand scale.

To add to this already impressive list of roles, our peatlands can either help or hinder us as we grapple with a changing climate. They are natural carbon reservoirs. Globally peatlands store approximately double the amount of carbon that is stored in all the world's forests[1], an estimated 550 billion tonnes. This means peatlands are a vital and irreplaceable part of regulating the climate.

By storing such huge stocks of carbon in the soil, they prevent it from being emitted to the air as carbon dioxide (CO_2). If all that carbon was to be lost to the atmosphere, it would be nearly eighty times more than annual global CO_2 emissions from our burning of fossil fuels*.

Around the world, our historical and current management threatens this vital carbon store. The drainage, burning, cultivation and extraction of peatlands cause approximately 2 billion tonnes CO_2 to be lost to the atmosphere every year – around 10% of total global carbon emissions from all human activities.

England's peatlands are no exception to this global picture. They store some 580 million tonnes of carbon, but over the last 300 years – a fraction of the life of these peatlands – they have become widely degraded. Around three quarters of them are visibly damaged, while a larger area is affected by atmospheric pollution. Today this unique and invaluable resource is under threat, and emitting the equivalent of ~3 million tonnes of CO_2 into the atmosphere each year.

Restored peatlands generally have lower greenhouse gas emissions, and contribute less to global warming, than degraded peatlands. The clear message is that peatland restoration is generally beneficial for combating climate change.

In this report we detail the State of England's peatlands today and examine how this nationally important carbon store can be managed so that it continue deliver a range of vital services long into the future.

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* 550 billion tonnes of carbon is equivalent to 2,017 billion tonnes of CO_2. Average annual global CO_2 emissions from the consumption of fossil fuels was 26.4 billion tonnes between 2001–2005 (IPCC, 2007).

Executive summary

Peat is organic material that has built up in waterlogged conditions over thousands of years, and represents a large store of carbon captured from the atmosphere. Peatlands damaged by drainage can rapidly lose their stored carbon as carbon dioxide (CO_2), but re-wetting these peatlands could increase emissions of other greenhouse gases (methane and nitrous oxide). Carbon storage and greenhouse gas emissions from peatlands are therefore of increasing relevance to the UK government in leading our efforts to address climate change.

This report describes the extent and current management of England's peatlands. It estimates the amount of carbon stored in our peatlands and the scale of greenhouse gas emissions from a range of peatlands subject to different land uses and pressures. It then evaluates the costs and benefits of peatland restoration, and estimates the potential greenhouse gas benefits that this could deliver. Finally, the report describes current policy and restoration activity and sets out ideas for further progress.

Peatlands cover 11% of England's land area, and have long been considered places to tame and convert to 'productive' use for agriculture or forestry. Other vital services they provide have only recently been acknowledged. In their undamaged state they play an important role in managing water quality and flooding. They are among our most valuable areas for biodiversity and are integral components of many of our most treasured landscapes. They are also among England's most important terrestrial stores of organic carbon. Over the past 300 years, however, our peatlands have been significantly degraded, and in some cases destroyed, by human activity.

Natural England has evaluated the extent of damage to peatlands from a range of causes, including agriculture, pollution, drainage, burning and peat extraction. Less than 1% of our deep peat has been mapped as undamaged, while over 70% of peatlands show on-the-ground degradation. Almost a quarter of our deep peat area is cultivated, including almost 40% of our lowland fen peat. Burning for grouse moor management occurs on almost a third of our blanket bog peats, and moorland grips (drains) are found across a fifth of these upland peatlands.

English peatlands are estimated to contain around 584 million tonnes of carbon, based on the limited information available on peat depth and quality. If this were all to be lost to the atmosphere, it would be equivalent to 2.14 billion tonnes of CO_2, which is around five years of England's total annual CO_2 emissions. The peatland degradation described above threatens this nationally important store of carbon and can release it as CO_2, but rewetting peatlands can also increase emissions of methane. Methane and nitrous oxide are more powerful greenhouse gases than CO_2. Emissions of these gases are expressed in terms of the tonnes of CO_2 that would have the equivalent effect (CO_2-equivalents), and are combined with data on CO_2, to give an overall measure of emissions. Natural England estimates that in their current state English peatlands are responsible for the emission of ~3 million tonnes of CO_2-e a year, which is a similar to emissions from around a third of a million British households.

The evidence suggests that, overall, peatland restoration delivers greenhouse gas benefits by protecting stored carbon and drastically reducing the amount of carbon dioxide emitted, even after accounting for the increased emissions of methane following re-wetting.

Restoration of key types of degraded peatlands could deliver emissions reductions of up to 2.4 million tonnes of CO_2-e each year, with 1.1 million tonnes of this reduction delivered by rewetting cultivated deep peatlands. The capital costs of peatland restoration vary according to the type of peatland and the nature of restoration work. Natural England has

generated a 40-year cost-benefit analysis by comparing the costs of restoration and of changing land use with emissions benefits, valued using the Shadow Price of Carbon.

Even at the lowest shadow carbon value, restoration of cultivated or agriculturally-improved deep peat generates net economic benefits of up to £19,000 a hectare after 40 years. Restoration and management costs associated with blocking moorland grips are repaid by the value of emissions reductions over this period. If the mid-range shadow carbon values are used, all the peatland restoration techniques considered deliver net economic benefits after 40 years. This makes most peatland restoration options a cost-effective means to reduce greenhouse gas emissions.

Current policies and initiatives broadly support peatland restoration but there is scope for improvement. Existing advice and regulation promote some elements of sustainable peatland management, and incentives are available to encourage more demanding restoration activities. This policy framework needs further improvement. The mapping data suggests that active peatland restoration covered only 2% of our deep peat resource in late 2008. The Government, Natural England and others are now working together to review policy support for peatland restoration, and to identify opportunities for improvement and priorities for action.

Over the past 20 years, a number of successful voluntary restoration projects and partnerships have been established where restoration for biodiversity and landscape benefits has been the primary objective. Natural England and its predecessors have supported many of these projects, such as Moors for the Future and Peatscapes, through providing expertise, direct funding and through the delivery of the agri-environment schemes such as Environmental Stewardship. These projects have pioneered techniques for restoring damaged peatlands, formed successful partnerships with a wide range of stakeholders, and successfully communicated new knowledge and ideas.

The challenge now is to support the expansion of the successful restoration projects and partnerships to deliver wider peatland restoration and more successful management for all our major peatlands.

There are many different options to be examined. There is much current interest in enabling the private sector to invest in peatland restoration to help meet their own voluntary carbon targets while contributing to national carbon commitments. There are appreciable policy and evidence issues to overcome before this could be realised, but the approach demonstrates a potentially innovative way to reward well-managed peatlands.

The possibility for generating revenue from reducing peatland emissions through restoration is based on the likely effects of restoration indicated by recent European research. However, research is still needed to establish the relationships between peatland restoration and GHG emissions for UK peatlands, to enable the emissions benefits to be valued confidently.

Natural England is helping fund and manage a JNCC-led partnership project to design a UK-wide research programme to identify the research sites and measurements that will provide the evidence required to support national decision-making. We are also part-funding monitoring of the emissions impacts of grip blocking, undertaking research into the impacts of lowland peatland restoration on food production and security, and working with the Environment Agency and others to explore the impact of peatland restoration on water movement and quality.

We have badly mistreated our peatlands over the last three centuries, and in many places that damage continues today. The peatlands of the future should represent a better balance of land uses which reflects their true value to society and seeks to integrate carbon storage, water management, wildlife habitats and the range of other benefits we gain from living, healthy peatland landscapes.

Drainage of lowland peatlands for agriculture has resulted in millions of tonnes of peat carbon being emitted to the atmosphere as greenhouse carbon dioxide

Introduction

Peat is the remains of wetland plants and animals that build-up in more or less permanently saturated conditions, and represents an important store of carbon. Peat soils in England have been accumulating carbon since the retreat of the last glaciers approximately 10,000 years ago. In an undamaged state, peat usually remains wet at the surface all year round and will continually accumulate organic matter as carbon, every hectare building up between 0.1–0.2 tonnes of carbon for each year the peatland remains active. In this manner, some of our peat soils have reached depths of 8 metres of more.

There are three main types of peatland, distinguished by the vegetation that forms them: fen, blanket bog and raised bogs. In England, all these habitats are nationally or internationally important for wildlife and they include six Biodiversity Action Plan Priority Habitats. These are described on page 6.

There have been many attempts to quantify the amount of carbon stored in the UK's peatlands. Estimates range widely from 3 billion to more than 16 billion tonnes. Despite the range of these estimates, the common finding is that peatlands are the single most important soil type for carbon storage, containing more than half of total UK total soil carbon.

The benefits of peatlands as carbon stores, and for a wide range of other important factors, depend crucially on how we manage them. Our past management has left us a legacy of peatlands in a wide range of conditions. Natural England has been gathering data on the state of our peatlands, which has allowed us to make a more informed estimate not only of the amount of carbon they store but also of how much carbon degraded peatlands are losing.

Our planned *State of England's Peatlands* report will set out in more detail the approach we have taken to estimate and map the extent and status of our peatlands. It will describe the wide range of important services peatlands provide, including their rich biodiversity and role in water quality and flood management. This report summarises the key findings of the *State of England's Peatlands* report in relation to their role as carbon stores and the contribution their restoration can make to meet our climate change goals.

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Lowland fens are among our most diverse habitats for wildlife, but most have been lost to drainage and agriculture

© Natural England / Dave Key

Blanket bog peatlands still define the landscape on many of our upland plateaux

© Natural England / Iain Diack

Raised bogs are now among the rarest habitats in the country

Fen peatlands form where groundwater meets the surface – at springs, hollows or at the edge of open water. The type of fen vegetation depends greatly on the quality of the water and ranges from a diverse mix of reeds, sedges and tall herbs to mosses and insectivorous plants like sundews, as well as including wet woodland. The incredibly diverse animal life of fens includes bitterns, bearded tits, curlew and snipe and a wide range of invertebrates such as the swallowtail butterfly and white faced darter dragonfly.

Blanket bog peatlands literally blanket our upland landscapes. They form where rainfall is very frequent and cloud cover is high. Rainfall, snow and mist are the sole source of scarce nutrients; the plants that can tolerate these conditions include bog mosses and cotton grasses, along with heathers. Golden plover and dunlin nest in these remote areas, as do hen harriers and short-eared owls.

Raised bogs also receive their surface water only from precipitation, but often start off as fens. Once fen peat has built up, rainwater begins to dominate the nutrient supply and bog mosses begin to lay down a dome of wet acidic peat. Rare plants of raised bogs include bog rosemary and cranberry, and rare invertebrates of these habitats include the large heath butterfly, bog bush cricket and bog pill beetle.

The state of our peatlands

Mapping Peatlands

Using a range of different data sources[2, 3, 4] Natural England has collated a map showing the extent of peatlands in England. For the purposes of this project, peatlands have been classified into three types based on the source of the information but assumed to have the following general characteristics:

- Deep peaty soils: Areas covered with a majority of peat >40cm deep
- Shallow peaty soils: Areas with a majority of soils with peat 10–40cm deep
- Soils with peaty pockets: Areas of mostly non-peat soils, supporting smaller pockets of deep peat (such as flushes or exposures of buried peat) too small to map at a national scale.

The areas covered by each of these peatland types, as suggested by this mapping approach, are presented in Table 1 and shown in Map 1. Based on this estimate, peatlands make up around 11% of England's total land area. Just under half of these peatlands support significant areas of deep peat. The deep peaty soils were further subdivided into the broad peatland habitat types that formed them and are presented in Table 2 and shown in Map 2.

Our most extensive peatlands are blanket bog which, with upland valley mires, are found mainly on the high plateaux and valleys of the Pennines, North York Moors, parts of the Lake District, and in the uplands of the South West. In the lowlands deep fen peats are principally found in the Fens of Cambridgeshire and Lincolnshire, around the Broads and Fens of East Anglia, the Somerset Levels, and the Lancashire Mosslands. Lowland raised bogs include those of the West Midlands, Manchester Mosslands, the Humberhead Levels, the Somerset Moors, Solway Mosses, and small areas of the Fens.

Table 1: Areas of different peatland types in England derived from soils, geological and habitat maps.

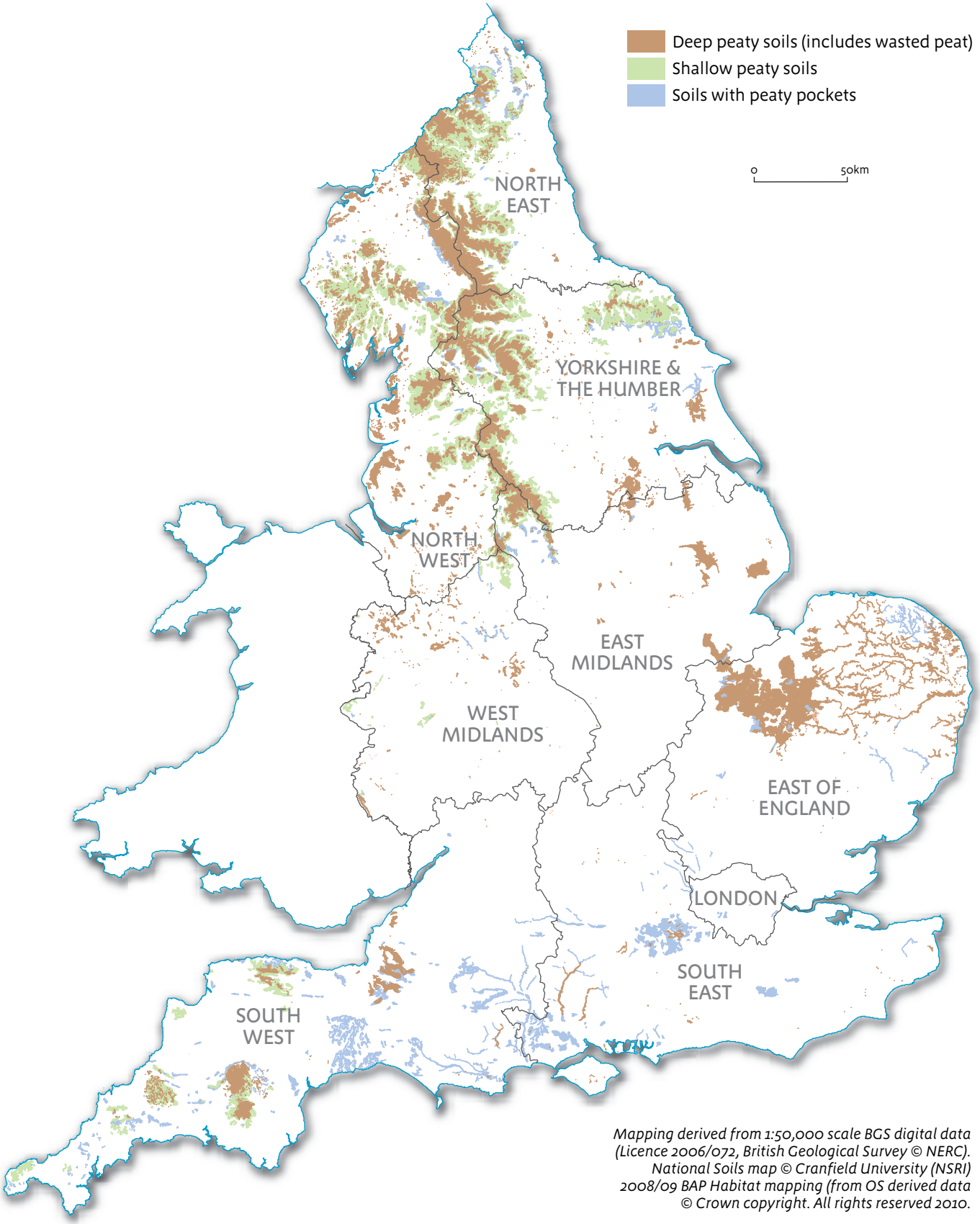
Peat Mapping Class	Area (km^2)
Deep Peaty Soils	6,799*
Shallow Peaty Soils	5,272
Soils with Peaty Pockets	2,114
Total	**14,185**

*Includes 1,922 km^2 of lowland 'wasted' peat – a technical term for deep peat that has been substantially degraded following years of drainage and cultivation so that the peat is now more dominated by underlying mineral material.

Table 2: Areas of deep peaty soils in England derived from main peatland habitats, and separated to indicate area of wasted lowland fen peat.

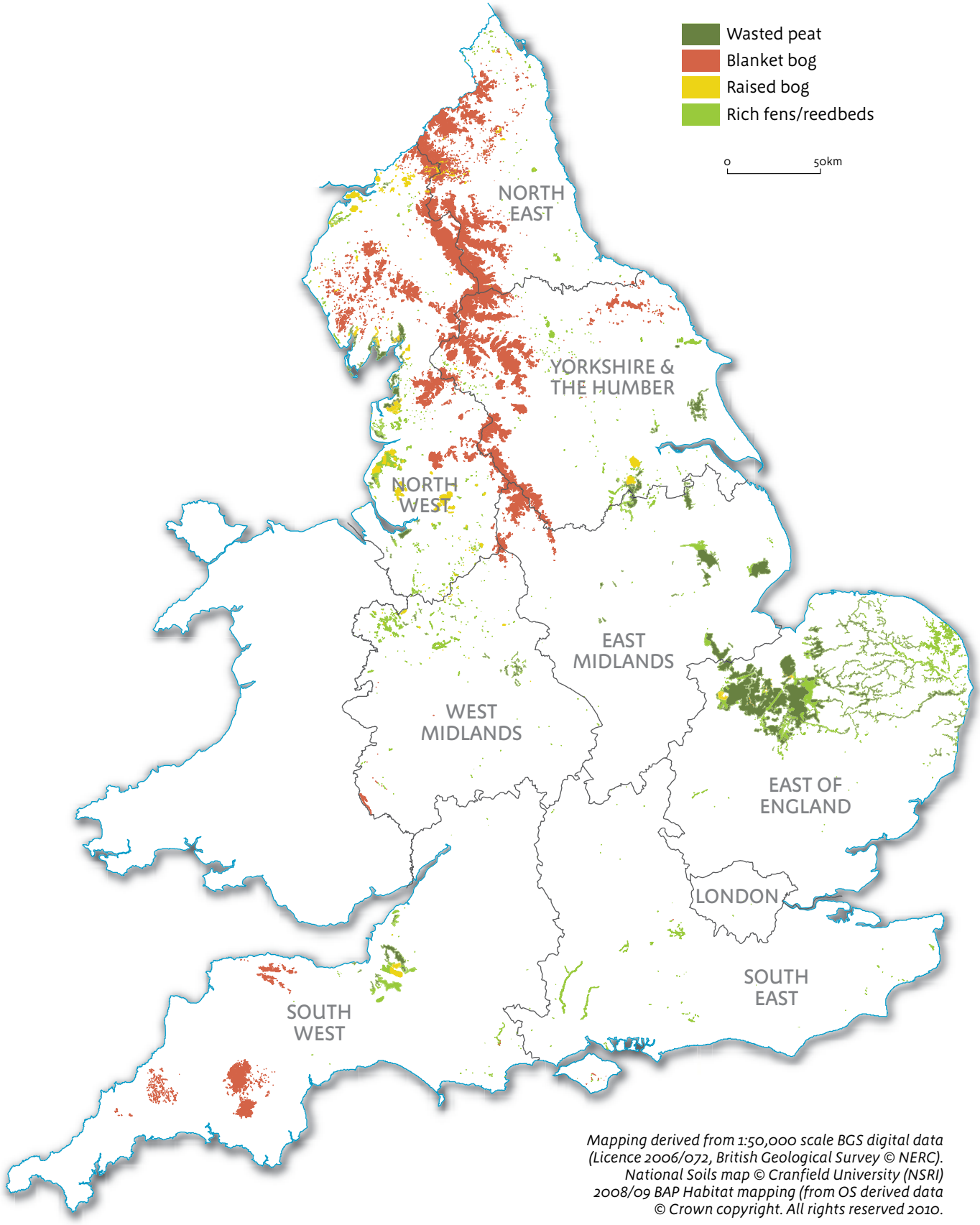
Deep Peat Habitat of Origin	Area (km^2)
Blanket bog and Upland Valley Mire	3,553
Raised bog (upland and lowland)	357
Lowland Fens/Reedbeds (deep)	958
Lowland Fens/Reedbeds (wasted)	1922
No data	9
Total area of deep peat	**6,799**

Map 1: England's deep peatlands cover much of our uplands, but also include large lowland areas. Shallower peaty soils fringe our uplands.



Mapping derived from 1:50,000 scale BGS digital data (Licence 2006/072, British Geological Survey © NERC). National Soils map © Cranfield University (NSRI) 2008/09 BAP Habitat mapping (from OS derived data © Crown copyright. All rights reserved 2010.

Map 2: Blanket peat is the most extensive peatland type. Large areas of fen peatland remain but the majority has become wasted through drainage and cultivation. Raised bogs are mainly found in the lowlands of the north and west.



Mapping derived from 1:50,000 scale BGS digital data (Licence 2006/072, British Geological Survey © NERC). National Soils map © Cranfield University (NSRI) 2008/09 BAP Habitat mapping (from OS derived data © Crown copyright. All rights reserved 2010.

The shallow peaty soils are principally associated with gentle hill slopes around our upland plateaux, and are associated with wet heaths and grasslands. Soils with peaty pockets are found associated with springline mires in the Blackdown Hills, steep upland slopes with wet flushes in the Eden Valley, among the heathlands of Surrey and the New Forest, and in wet valley bottoms across southern England. They also represent outcrops of buried peat in Somerset, East Anglia and other low lying areas.

Condition and Use of Peatlands

Having analysed the extent of England's peatlands, we have collated the available evidence on the condition and use of this valuable resource across the country. Our analysis has highlighted the degree of damage that our peatlands have suffered from a wide range of sources including agriculture, pollution, drainage, burning and extraction.

Only 1% of England's deep peats have been mapped as being in an **undamaged** state where they remain substantially waterlogged and actively continue to form peat and therefore sequester carbon.

Around 30% of deep peats support **semi-natural** vegetation which is not normally associated with formation of deep peat. On these deeper peatlands this vegetation may mean that peat formation has slowed or stopped, but on shallow peatlands this vegetation can represent an undamaged state, maintaining a high wildlife interest and maintaining the soil carbon store in a steady state. These areas are generally managed through extensive, low-input activities such as livestock grazing. They include species rich grasslands and heathlands as well as vegetation such as bracken. Around half (51%) of our blanket bog peatlands are in this state.

Around 4% of deep peats are dominated by **scrub**, and a further 3% have developed further into **woodland**. While some of these areas are of high value for wildlife (wet woodland, for example, is a BAP priority habitat) many are associated with peatland drainage, and invasive non-native scrub such as *Rhododendron* that can threaten peatland biodiversity and carbon storage.

Just under a quarter (24%) of deep peat is under **cultivation**. From around 400 years ago huge areas of wetland were drained for agriculture. The drained peat of the Fens, for example, became some of the most productive agricultural land in the country. We estimate that 39% of deep fen peats are currently under cultivation. This drainage and cultivation not only destroyed diverse fen habitat, but also degraded the peat itself. No longer waterlogged, the accumulated peat material literally wasted away – it shrank, decomposed and became eroded by the wind or carried away on harvested crops, and the land surface typically subsided at around 2 cm a year[5]. This has left a lower-lying **wasted** peatland over 28% of our deep peatland area. These wasted areas are now more dominated by the underlying mineral material with little deeper peat remaining. Map 3 shows the extent of cultivation and peat wastage in the East Anglian Fens.

Agricultural improvement and drainage, liming and fertilizer application have enabled wet grassland and heath to be converted into species-poor **improved grassland** for livestock farming. Some 9% of all deep peats are in this state, including 22% of deep fen and 15% of raised bog habitats. Improved grassland is another frequent land use in the shallow peaty soils in our upland fringes such as those around the Forest of Bowland, shown in Map 4.

Agriculture has impacted less on our high upland peatlands; conditions here are often too harsh to reward intensive agricultural practices. However, after World War II upland peatlands were targeted to intensify livestock production. Subsidy payments encouraged farmers to stock upland areas more heavily, often with hardy breeds which could withstand longer periods on the moors or stay there permanently. This led to many upland peatlands becoming **overgrazed**, resulting in changes in the vegetation, and erosion and compaction of the peat. Although grazing intensity has been since reduced in many areas, in part as the result of incentives provided through agri-environment payments,

The washlands of the River Nene are an island of grassland surrounded by cultivated and wasted peatlands

we estimate that 5% of all deep peats are still in this state (9% on upland blanket bog).

Moorland burning is a widespread land management practice in the uplands for the management of game. While peatlands have always been used for hunting, the late 19th and early 20th century saw a switch from walked-up shoots with gun dogs to driven grouse shoots. This change was accompanied by new land management by gamekeepers, involving **rotational burning** of the moorland vegetation to encourage a pattern of young and older heather for feeding and nesting grouse. Some 16% of all deep peats are rotationally burnt, including 30% of blanket bog. This management encourages heather to support high grouse populations, but when done poorly it can kill or damage the bog mosses that form the peat.

In the post-war agricultural intensification land managers were also grant-aided to drain moorland with many thousands of kilometres of shallow drains called **grips**. These gripped peatlands drain water more quickly away from the peat's mossy surface layer which thins or disappears completely. Bog mosses become scarcer and this changes how water moves through the peatland; instead of trickling through and across the upper peat surface, the grips provided channels for rapid passage of water, affecting downstream flood risk. Grips dry out the peat on both sides (especially down the slope) and the peat, exposed to oxygen in the air, decomposes into CO_2. Our mapping has found that 11% of deep peats are gripped, mostly on blanket bog (21%). Gripping and burning often coincide in the same area, as shown in Map 5, of the North Pennines.

Gripping, along with overgrazing, wildfires and pollution, also encourages the development of **haggs and gullies**. Gullies are branched erosion features that extend into the peat mass to form a network of channels. These often erode down to the mineral material under the peat and lose peat material from their bare sides through the action of wind, water and frost heave. Where gullies meet, blocks of peat (haggs) become isolated from the peat mass. We estimate that 7% of deep peats are hagged and gullied, again primarily on blanket bog (14%).