Catchment Based Approach

PROTECTING PEATLANDS & CARBON RICH SOILS

GUIDANCE DOCUMENT

Interreg North-West Europe
Carbon Connects
European Regional Development Fund
EUROPEAN UNION

THE PRINCE OF WALES'S CHARITABLE FUND

Executive Summary

This report provides guidance for the Catchment Based Approach (CaBA) Partnerships on peatland protection and restoration, describing the availability of mapped data to determine extent and type of peatland, the provision of information to determine the reduction in emissions from restoration projects, explanation of associated ecosystem service benefits and, examples of business models. The report is not intended to provide exhaustive detail on each aspect but instead aims to highlight some key general points and provide useful sources of information.

The IUCN UK Commission on Peatlands reports that approximately **80% of UK peatlands have been damaged**, largely as a result of drainage for agriculture, forestry, track building or peat extraction. As a result of decades of these unsuitable management practices, the majority of the UK's peatlands are no longer storing and sequestrating carbon. Instead, **they are now a significant net source of GHG emissions**. Arable cropland occupies just 7% of the UK's peat area but has the highest GHG emissions per unit area of any land-use, with high rates of both CO_2 and N_2O emissions as a result of drainage and fertilisation.

The UK Natural Capital Accounts report that the net benefits, in terms of climate change emissions, of **restoring 55% of UK peatlands to near natural condition are estimated to have a present value of approximately £45 billion to £51 billion**. Asides from their critical role in climate regulation, there has been a growing recognition of the range of other ecosystem services peatlands provide including drinking water, flood risk management and recreational value.

Public, European and Heritage Lottery funds have been directed at peatland restoration but there is a growing recognition that restoration and protection that fully realises the climate regulation and other ecosystem services provided by UK peatlands is only likely to be achieved through the additional attraction of private investment. Both carbon credit schemes and corporate and social responsibility (CSR) initiatives can play a role, although the former requires significant rigour. **CaBA Partnerships can play a role in securing business investment in peatland restoration** through various means including undertaking an intermediary role between landowners and investors, providing the evidence base for investment and in the monitoring and quantification of all ecosystem service benefits arising.

Securing funding for a restoration project will typically require that an estimate of the anticipated reduction in emissions arising from the interventions be made. Differing approaches are available to undertake this estimation that vary considerably in their rigour and cost. Emissions factors for differing land uses are available but considerable uncertainty remains, particularly with respect to cultivated peatlands. Addressing damage to upland peat typically focuses on restoration of the natural water balance through blocking drains and channels, coupled with re-seeding. Certain management interventions e.g. use of cover crops and minimum tillage, can lead to the sequestration of carbon in agricultural soils, although quantifying the change in soil organic carbon arising from these remains uncertain.

Several economic sectors offer the potential to secure investment for peatland restoration, including airport authorities and airlines seeking to offset emissions and energy

companies looking to compensate for infrastructure development. Food and drink manufacturers may have interest in improving the sustainability of supply chains on both upland and lowland peatlands, whilst Local Governments are increasingly looking to offset carbon. Niche markets may include the harvesting of biofuels such as reeds, wetland plants as building materials, and the growing of sphagnum moss for use as a growing medium.

Contents

1 Introduction

Whilst they occupy only 3% of the terrestrial area of the world, peatlands contain 500 gigatonnes of carbon, twice that held within the biomass of all the world's forests and, sequester 0.37 gigatonnes of carbon dioxide (CO_2) a year. Peatlands are preserved by water saturation and if they remain wetted, their carbon stores are not only conserved but continue to slowly accumulate as plant material steadily decomposes. Whilst this storage and sequestration is offset by the release of methane to the atmosphere, the net long-term climate effect (in part because methane decays much more rapidly in the atmosphere than CO_2) is beneficial. However, when drained peatlands turn into significant sources of greenhouse gases (GHG) as aerobic decomposition of the peat drives the emission of CO_2 and gullying and erosion contribute to the loss of particulate carbon.

An estimated 500,000 km^2 of peatlands worldwide have been drained and emit approximately 2 gigatonnes of CO_2 per year, contributing 5% of global anthropogenic CO_2 emissions. The major hot spots of these emissions are Indonesia, the European Union, Russia, China and the United States. In the UK, the IUCN UK Commission on Peatlands reports that approximately 80% of UK peatlands have been damaged, largely as a result of drainage for agriculture, forestry, track building or peat extraction (Bain et al. 2011). As a result of decades of these unsuitable management practices, the majority of the UK's peatlands are no longer storing and sequestrating carbon. Instead, they are now a significant net source of GHG emissions, currently estimated to emit 23,100 Kt CO_2 equivalent (e) per year (Evans et al. 2017).

Arable cropland occupies just 7% of the UK's peat area but has the highest GHG emissions per unit area of any land-use, with high rates of both CO_2 and N_2O emissions as a result of drainage and fertilisation. As a result, cropland is estimated to emit ~7,600 kt CO_2 e per year, 32% of total UK peat GHG emissions. Around two thirds of the cropland area is on 'wasted' peat - shallow residual organic soils where much of the original peat has already been lost - predominantly in the Fenlands of East Anglia. Indeed, approximately 80% of England's peatland emissions comes from agricultural lowland peatlands used for cropland and grassland (Evans et al. 2017).

Asides from GHG emissions, the loss of carbon rich soil from cropland also diminishes soil quality that, in turn, can reduce crop yields. Additionally, eroded soil transports with it a range of particulate pollutants, detrimentally impacting upon water quality and aquatic ecosystems. Soils with diminished organic matter also hold less water, exacerbating runoff and reducing their resistance to drought and erosion. Compaction and drainage of agricultural soils also enhance rapid runoff, increasing flood risk downstream.

The UK Natural Capital Accounts for Peatlands reports that the net benefits, in terms of climate change emissions, of restoring 55% of UK peatlands to near natural condition are estimated, conservatively, to have a present value of approximately £45 billion to £51 billion over the next 100 years (Office for National Statistics, 2019). Asides from their critical role in climate regulation, there has been a growing recognition of the range of other ecosystem services peatlands provide including drinking water, flood risk management and recreational value.

Various funding sources have provided investment in the restoration of UK peatlands including public funds from both national and European sources, water companies and Heritage Lottery Funds, with 95,000 hectares actively restored since 1990 (Evans et al. 2017). Nationwide restoration and protection that fully realises the climate regulation and other ecosystem services provided by UK peatlands is, however, only likely to be achieved through the additional attraction of private investment. This, to date, has been relatively modest but, from April 2019, all UK quoted companies and all large companies were legally required to measure and report their greenhouse gas emissions, whilst all other companies are encouraged to do so voluntarily. This requirement is beginning to drive greater interest in certified carbon credit schemes.

Important too, however, is the increasing inclusion of 'carbon' within corporate and social responsibility (CSR) objectives and a growing appreciation of the additional ecosystem service benefits afforded by peatlands. These developments indicate that there is significant potential for private investment for peatlands to grow over the coming years via not just certified credit schemes but also through agreements that are less onerous and require less rigour, potentially providing an opportunity for CaBA Partnerships.

CaBA Partnerships can play a role in securing business investment in peatland restoration through various means, including undertaking an intermediary role between landowners and investors, providing the evidence base for investment and in the monitoring and quantification of all ecosystem service benefits. In doing so, CaBA will also play a role in contributing to efforts to meet the UK's national targets for reducing emissions of greenhouse gases and the Governments Clean Growth Strategy (BEIS 2017).

This report provides guidance on this potential role for CaBA Partnerships, describing how peatlands can be protected, the availability of maps to determine extent and type of peatland, the provision of data to determine the reduction in emissions from restoration projects, explanation of associated ecosystem service benefits and, examples of potential and proven business models. The report is not intended to provide exhaustive detail on each aspect but instead aims to highlight some key general points and provide useful sources of information.

2 Protection & Restoration of Peatlands

2.1 Upland (non-cultivated) Peat

Drainage of upland peat 'bogs' has led to them drying, damaging plant life such as mosses that cover the peat. This loss of vegetation exposes bare peat rendering it susceptible to erosion and gullying. Addressing this damage requires that the natural water balance of the peatland is restored, typically through blocking channels with 'leaky dams' made from peat, coir, heather bales, stones or wood (Pennine PeatLIFE 2020). Where gullying has led to the creation of steep banks, reprofiling to a shallower slope can help vegetation regrowth. The addition of brash, from heather and other blanket bog plant species, on to bare areas, helps to prevent further drying and erosion. It also provides material for sphagnum mosses to grow on (Pennine PeatLIFE 2020). Seeding and the addition of small amounts of fertilizer can speed the revegetation process. As a final stage, the addition of sphagnum mosses to the wetter areas of a site can help water retention and prevent the exposure of bare peat.

Figure 1: Coir rolls used to block gullies in upland raised peat bog.

2.2 Cultivated Peat

The top metre of the world's soils contains three times as much carbon as the entire atmosphere, making it a major carbon sink alongside forests and oceans. Since humans started farming land around 12,000 years ago, however, an estimated 133 billion tons of carbon have been lost globally – both to the atmosphere and through erosion - with the rate of loss increasing dramatically since the start of the industrial revolution (Sanderman et al. 2017). As much of the UK's lowland peat is on prime arable land, restoring it to a natural or semi-natural state has a high opportunity cost associated with lost agricultural production. Improved soil management practices can, however, help to store more soil organic carbon (SOC) on cultivated land, with additional benefits for drainage and moisture holding capacity (helping build resilience to droughts and floods), pollutant attenuation and crop yield. These practices include minimising or conservation tillage (Holland 2004), winter cover crops, use of farm-yard manure and the inclusion of grass leys in arable rotations (Soil Association 2018) and residue management (Smith et al. 2007). Additionally, organic farming provides for the sequestering of carbon, in part, through a greater soil microbial biomass. Other wholescale changes to land use will also lead to an increase in sequestration, including conversion to permanent pasture.

Other measures can be employed on-farm to prevent the further transport of soil – and hence carbon - once it is eroded. These include riparian buffer strips, sediment traps and ponds and wetlands. Many of these types of interventions also function as flood risk management measures as they aim to slow the flow of water and allow material to deposit.

Figure 2: Cultivation of lowland carbon rich soil

3 Carbon Credit Schemes

3.1 Schemes & their requirements

Re-wetting and regeneration of peatlands reduces emissions of GHG and hence provides the potential to implement carbon credit schemes, whereby credits are sold to Governments, organisations or individuals to offset emissions and the funds used to finance the re-wetting. Carbon credits are permits for GHG emissions that can potentially, therefore, be traded on markets as part of a 'cap and trade' system. Several peatland restoration projects globally are trading carbon under carbon markets; however, these are challenged by a weak carbon price and high costs associated with the rigorous accreditation systems.

Given the challenges associated with adhering to the strict criteria associated with globally valid standards, there is growing interest in local, regional and national approaches to carbon credit schemes. Such schemes provide scientific rigour but with costs associated with validation and verification minimised through the involvement of independent experts. Credits from such schemes are not tradeable on markets but they can be bought by companies who wish to support their environmental performance and/or seek to achieve Corporate and Social Responsibility (CSR) goals.

One such scheme is the UK's Peatland Code (IUCN-UK, 2020), a voluntary standard established by the IUCN UK National Committee that is applicable to both blanket and raised bog with a baseline condition of 'actively eroding or drained'. The code establishes the principles for a peatland scheme and hence provides a framework for buyers and sellers to work together for peatland restoration. Both baseline and the net change in GHG emissions as a result of the project are calculated using the Peatland Code Emissions calculator. Other such schemes exist elsewhere in Europe, including MoorFutures (MoorFutures 2015) established in the German state of Mecklenburg-Western Pomerania in 2010 as the first carbon credits issued for peatland rewetting in the world. The credits are currently sold in the German federal states of Brandenburg and Mecklenburg-Western Pomerania and Schleswig-Holstein.

Both mandatory and voluntary carbon credit schemes require adherence to and avoidance of several requirements (MoorFutures 2015) including, in brief;

- Additionality – whereby the reduction in GHG emissions would not have occurred without the funding from the sale of credits;
- Measurability – that requires that emissions reductions are quantified in a transparent and agreed way
- Verifiability - through an independent third party and based upon previously agreed criteria
- Conservativeness – emission reductions arising from interventions should be underestimated to ensure that they can be guaranteed.
- Reliability – carbon credits must have a contractually established owner with purchasing and sales registered by an independent institution
- Sustainability – meaning in this sense to contribute to improved socioeconomic conditions

- Permanence – whereby emission reductions from a project cannot be reversed, for example, through land use change
- Reference – Each emission reduction project must be evaluated through reference to baseline or historical condition
- Project Crediting Period – this refers to the timetable over which carbon credits will be generated. Tree planting, for example, accrues credits more quickly whilst the trees are young and growing. On maturity their carbon stocks reach equilibrium.
- Leakage – refers to a situation whereby negative effects occur outside the project area but as a result of the project. For example, in response to restoration a farmer may shift detrimental activities to a hitherto natural peatland, negating the impact of the project.

CaBA Partnerships may be able to secure investment for restoration through CSR mechanisms where the rigour required is not as onerous as a recognised credit scheme. Nevertheless, an understanding of the various requirements listed above will be of value and the closer they can be adhered to, the stronger the case for investment is likely to be. CSR driven investment will still require, for example, a measure of permanence.

3.2 The role for CaBA Partnerships

The rise in corporate awareness with respect to carbon emissions, coupled with the availability of codes to facilitate private investment, potentially provides an opportunity for Catchment Partnerships to become more actively involved in peatland restoration. This may not necessarily, however, include the full rigour of a credit scheme but instead could encompass private investment where some agreed level of carbon sequestration will suffice.

Regardless of the level of rigour applied, CaBA Partnerships can; undertake the role of intermediary between businesses and peatland landowners within restoration projects; be directly involved in the delivery of interventions to protect peat; undertake monitoring of outcomes and; provide expertise with respect to one or more of the range of ecosystem services that peatlands provide - as interest in these services beyond climate regulation grows, codes and frameworks for investment are beginning to embrace and explore ways in which they too can become part of the package of private investment.

4 Additional Ecosystem Services

The inclusion of other peatland ecosystem services - water quality, flood risk management, biodiversity etc - alongside climate regulation, can help to strengthen the business case for investment. In some recognised carbon credit schemes these additional ecosystem services are sold separately through 'layering' where they can attract a distinct credit, or through bundling where they combined with other services into a single package. Asides from credit schemes, however, the case for investment for peatland restoration may well be strengthened with the inclusion of additional ecosystem services.

4.1 Flood Risk Reduction

Natural undegraded peatlands can contain as much as 98% water by mass and hence their ability to reduce flood risk downstream is likely to be limited unless a storm event occurs at a time when the peatland water table is low enough to provide sufficient storage capacity. In contrast, damaged and eroded peatlands exacerbate the volume and speed at which surface runoff occurs. Alderson et al. (2019) report that peatland restoration through vegetation and gully blocks slows the flow of water across the landscape by increasing surface roughness. This delays the release of water from the uplands and reduces peak stream flow (relative to the degraded state). Restoration of damaged peatlands, therefore, provides reduced downstream flood risks compared to damaged peatlands (Committee on Climate Change, 2013).

4.2 Water Quality

Peatlands provide over a quarter of the UK's drinking water, approximately 1,900 million m^3 per annum, valued at £888 million in 2016 (Office for National Statistics, 2019). Peatlands play an important role in attenuating atmospheric pollutants and, where in near-natural state, provide water of high quality. Upland areas, however, have experienced an increase in dissolved organic carbon in watercourses due, in part, to recovery from acidification. Degradation of upland peat has also released particulate organic carbon further diminishing water quality and increasing the cost of treatment where such sources are used for public supply. Water Companies invest in peatland restoration to decrease the burden of water treatment. Improved water quality may also have beneficial impacts upon priority species downstream, such as salmon.

4.3 Other

The Office for National Statistics (2019) estimated that recreational time spent on UK peatlands in 2016 was 179.9 million hours with an expenditure of £273.6 million. Peatlands also have archaeological and education value with iron age objects and the ability to explore past climates through cores, being two such examples.

4.4 Valuing the Economic Benefits of Peatland Restoration

Valuation of peatland ecosystem services helps to establish an economic case for investment and provides a means to communicate the wider benefits to society. Monetisation provides a challenge, however, not least because it can be viewed as putting a price on nature, but also because the various techniques involved each have their limitations. From a CaBA perspective, however, an understanding of these techniques and knowledge of their application elsewhere can help to strengthen a business case for restoration, even if the supporting economic evidence is uncertain and not fully quantitative.

The Yorkshire Integrated Catchment Solutions Programme (iCASP) has recently produced a user guide to value the benefits of peatland restoration (iCASP 2019). The guide encompasses measurement of the benefits that peatlands produce in the form of carbon sequestration through using the abatement (or mitigation) cost method. This is based on the idea that if carbon is sequestered by peatlands, there would be cost savings from not having to abate that carbon by other means. The guide also addresses the benefits that peatlands provide by reducing flood risk downstream using the avoided-cost method that quantifies the cost-savings from not having to provide compensation for the losses and damages caused by flooding. Water Quality benefits are also included through the avoided cost approach associated with reduced drinking water costs and a contingent valuation method (willingness to pay) approach to ecological water quality. The guide also includes a range of useful supporting references including Moxey and Moran (2014) and Sakai et al. (2016).

5 Estimating GHG emissions

5.1 Background

Securing funding for a restoration project will typically require that an estimate of the anticipated reduction in emissions arising from the interventions be made. Differing approaches are available to undertake this estimation that vary considerably in their rigour and cost. Quantification with a view to establishing a formally recognised and validated carbon credit scheme obviously requires considerable rigour. Less onerous methods are, however, available that may well be sufficient to fulfil the requirements of a CSR-led approach to restoration. Regardless of the method used, an estimate of baseline (current situation) and future emissions (under restoration) is likely to be required. Such an approach means that some estimate of the monetised benefits of carbon sequestration through restoration can be made through the abatement method, whereby sequestration means that there are costs savings from not having to abate that carbon by other means.

The most precise means of quantifying emission fluxes over small areas is using closed chambers, however, spatial and temporal variation in water table, vegetation and soil carbon content, mean that such precise measurement at a site requires an array of chamber measurement in space and time. Eddy covariance techniques offer an alternative approach for larger scale estimates but both approaches are complex, time-consuming and costly. As a result, they are largely limited to research projects.

Other, simpler, approaches to estimating GHG emissions exist that may well be rigorous enough to satisfy the requirements of a CSR funded project. These are briefly described below with supporting data held in Tables 1 and 2. Its important to note that such data account not just for CO_2 emissions but also methane (CH_4) – particularly important on saturated sites - and Nitrous Oxide (N_20), which arises from cultivated peatland, subject to fertiliser input. Addressing only CO_2 emissions in isolation does not provide an adequate estimate of net GHG emissions.

5.2 Peatland Code – Emissions Factors

The Peatland Code (IUCN-UK, 2020) provides standard emissions factors for four peatland conditions; ‘Near-Natural’; ‘Modified’; ‘Drained’ and ‘Actively Eroding’ based on a review and statistical analysis of available flux data. These are captured in a Peatland Code Emissions Calculator that is applicable to ‘upland’ peatlands. The emissions are summarised in Table 1.

5.3 Greenhouse Gas Emission Site Types

The Greenhouse Gas Emission Site Types (GEST) method (Couwenberg et al. 2011; MoorFutures 2015) offers another indirect approach to estimating emissions. GEST uses two factors, water table and vegetation type, to estimate net emissions. Initially developed to be able to assess GHG fluxes across Central Europe, the catalogue of available GEST values is being expanded as new GEST types are validated through research projects, including those in other regions.

Table 1: The Peatland Code emission factors (t CO2eq/ha/yr) for each of 4 conditions categories (Smyth et al. 2015).

Peatland Code Condition Category	Descriptive Statistic	CH4	CO2	N2O	DOC	POC	Emission Factor
Pristine*	-	-	-	-	-	-	Unknown
Near Natural	Mean (±StE)	3.2 (1.2)	-3.0 (0.7)	0.0 (0.0)	0.88	0	1.08
	Median	1.5	-2.3	0.0			
Modified	Mean (±StE)	1.0 (0.6)	-0.1 (2.3)	0.5 (0.3)	1.14	0	2.54
	Median	0.2	0.1	0.5			
Drained	Mean (±StE)	2.0 (0.8)	1.4 (1.8)	0.0 (0.0)	1.14	0	4.54
	Median	1	-0.9	0.0			
Actively Eroding	Mean (±StE)	0.8 (0.4)	2.6 (2.0)	0.0 (0.0)	1.14	19.3 (avg of 14.67 and 23.94)	23.84
	Median	0.1	0.4	0.0			

5.4 IPCC – Emission Factors

The Intergovernmental Panel on Climate Change (IPCC) provides a 3-tiered approach to estimating emissions from 'Land Use, Land Change and Forestry' (LULUCF). Tier 1 methods reflect the simplest approach whereby typical default emissions factors are provided for particular land use categories. These are intended to be applicable across broad categories of peatland globally and, therefore, fail to reflect the variation found nationally and regionally. The Tier 2 methodology uses country specific emission factors based on national data whilst Tier 3 uses more complex models to reflect more detailed variation in conditions within a country.

Evans et al. (2017) used the IPCC Tier 2 approach, in part, to develop a comprehensive set of emission factors for a range of UK land use types. The classification scheme devised was developed in collaboration with the Department for Business, Energy and Industrial Strategy (BEIS), Defra, devolved administrations and conservation agencies. Derivation of the emissions factors drew upon data captured within the IPCC Wetlands Supplement (IPCC 2014) and from more recent research studies. In total 2232 individual observations from 214 sites with direct measurement of CO_2, CH_4 and N_2O losses, as well as other emission pathways (such as DOC and POC leaching and burnt or harvested biomass) from 300 publications were included in the meta-analysis. The collated data provides the most comprehensive UK dataset of emissions factors to date and has been used to implement an inventory that estimates that the UK's peatlands to be emitting approximately 23,100 kt CO_2e yr-1 of GHG emissions. The data also suggest that almost all the 'Tier 2' peat condition categories included in the assessment are net sources of GHG emissions. The only exception is near-natural fen, where the high rate of CO_2 sequestration from the atmosphere outweighs CH_4 and N_2O emissions

The final emission factors derived from Evans et al. (2017) are reproduced in Table 2, expressed in t CO_2e ha^{-1} yr^{-1}. They provide a resource from which both emissions under baseline and restored conditions can be estimated. They also enable the impact of land use change upon emissions to be estimated.

Table 2: Emissions factors for peat condition types from Evans et al. (2017). All fluxes are shown in tCO2e ha^{-1} yr^{-1}. Note that a positive EF indicates net GHG emission, and a negative EF indicates net GHG removal.

Peat condition category	Drainage status	Direct CO2	CO2 from DOC	CO2 from POC	Direct CH4	CH4 from ditches	Direct N2O	Indirect N2O	Total
Data source		*Evans 2017*	*IPCC (2014)*	*Evans et al. (2016)*	*Evans 2017*	*IPCC (2014)*	*Evans 2017*	*IPCC (2006)*	
Tier		*2*	*1*	*2*	*2*	*1*	*2*	*1*	
Forest	Drained	7.39	1.14	0.30	0.12	0.14	0.65	0.17	9.91
Cropland	Drained	26.57	1.14	0.30	0.02	1.46	8.97	0.54	38.98
Eroded modified bog	Drained	0.85	1.14	0.89	1.19	0.66	0.06	0.06	4.85
	Undrained		0.69	0.71		0.00		0.05	3.55
Heather dominated modified bog	Drained	-0.14	1.14	0.30	1.36	0.66	0.05	0.03	3.40
	Undrained		0.69	0.10		0.00		0.02	2.08
Grass dominated modified bog	Drained	-0.14	1.14	0.30	1.36	0.66	0.05	0.03	3.40
	Undrained		0.69	0.10		0.00		0.02	2.08
Extensive grassland	Drained	13.33	1.14	0.30	1.82	0.66	1.50	0.29	19.02
Intensive grassland	Drained	23.37	1.14	0.30	0.37	1.46	2.80	0.48	29.89
Rewetted bog	Rewetted	-2.23	0.88	0.10	2.02	0.00	0.04	0.00	0.81
Rewetted fen	Rewetted	0.86	0.69	0.10	4.24	0.00	0.24	0.04	6.37
Near natural bog	Undrained	-3.54	0.69	0.00	2.83	0.00	0.03	0.00	0.01
Near natural fen	Undrained	-5.44	0.69	0.00	3.88	0.00	0.24	0.00	-0.61
Extracted domestic	Drained	4.73	1.14	0.89	0.20	0.68	0.14	0.13	7.91
Extracted industrial	Drained	6.44	1.14	5.00	0.20	0.68	0.14	0.24	13.84

5.5 Emissions from Cultivated Land

Certain management interventions (e.g. use of cover crops and minimum tillage) can lead to the sequestration of carbon in agricultural soils and quantifying the change in soil organic carbon (SOC) arising from these is necessary to underpin any associated offsetting scheme. SOC is quantified through laboratory analysis and, whilst the analysis of SOC at any one location is precise, large spatial variation is likely to be evident due to a range of factors including soil texture, drainage and topography, and fully capturing this spatial variation will be costly. These costs will be exacerbated by the need to sample over time as any changes in SOC may take some years to manifest themselves. Additionally, changes in SOC arising from management interventions are likely to be small relative to the large SOC soil stock, providing the challenge of a low signal to noise ratio (Conant et al. 2011).

Alternatives to soil sampling and analysis of SOC exist, including the use of models, for example, the CENTURY model (Parton 1996) and the use of published studies on how managed practices affect SOC, although these are relatively limited in number and not necessarily able to capture the local soil type(s) involved in any offsetting scheme.

Tools are also available, for example, the Farm Carbon Calculator (2020) that in addition to quantifying sequestration from interventions to increase soil organic carbon, also addresses that from planting of woodland and hedgerows, and uncultivated field margins. The calculator also addresses emissions per species of animal reared and from fertiliser and diesel usage.

6 Potential Investment Opportunities

Several economic sectors offer the potential to secure private investment for peatland restoration, including airport authorities and airlines seeking to offset emissions. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA, 2020) is an emissions mitigation approach for the global airline industry with its measures primarily including offsetting and 'alternative' fuels. CORSIA has driven funding from Heathrow Airport to Lancashire Wildlife Trust to protect and restore peatland sites (Lancashire, Manchester, North Merseyside Wildlife Trusts, 2020). Several airlines have recently pledged to offset emissions e.g. Easyjet (2020).

A range of other industrial sectors, including cement manufacturers, may seek to offset emissions whether voluntarily or through a mandatory requirement. Food and drink manufacturers and supermarkets may have interest in improving the sustainability of supply chains on both upland and lowland peatlands. Upland interest may lie, for example, with spring water sources and the rearing of lamb, whilst lowland may encompass improved land management of a range of arable crops grown on carbon-rich soils.

There is growing evidence of a willingness to explore other ecosystem service benefits and 'blue-credits' associated with peatland restoration that address improved water quality and flood risk reduction. For water companies, organic carbon in raw water supplies represents an economic burden, requiring treatment to remove.

A substantial number of Local Authorities have declared a climate emergency with aspirations to attain net-zero carbon emissions. There may, therefore, be opportunities to work with local Authorities to establish offsetting schemes whilst some Local Enterprise Partnerships have developed Energy Strategies that encompass the drive towards a low carbon economy.

Niche markets may include the harvesting of reeds and other plant species for biofuels and the use of e.g. cattails for fodder. In addition to its use as thatch, reed can also be pressed into fibrous building board, whilst rushes can be used to create matting. There may also be a market for farmed sphagnum moss both to regenerate peatland and as a source of ethical 'peat' growing medium for horticulture.

7 Data & Evidence

Underpinning any initiatives focused on the protection or restoration of peatlands is knowledge of the peat resource itself. An important consideration, given the ambitious government targets for emissions reduction and habitat restoration, is to consider where peatland conservation and restoration may be most desirable. Using data and evidence to develop a catchment plan for peatland initiatives will allow CaBA partnerships to target their actions and finds where they will have the multiple benefits. In this section, we will introduce the existing data and identify opportunities to build on the local evidence base and enable smarter decision making.

7.1 Peatland locations & carbon stocks

Unlike the soils data for Scotland and Northern Ireland, the National Soil Map of England and Wales held by the National Soils Research Institute (NSRI) at Cranfield University is not open data and it is a restricted dataset. Licencing currently costs £500 per 1000km^2 (discounts may apply for larger areas) and a corporate licence for commercial use with full coverage for England and Wales is £75,350 + VAT. These costs are a considerable barrier to most CaBA Partnerships and the licensing restricts the publishing of any derived products, which means that information and knowledge gained cannot be made available for wider decision making. For more information or to request a quote, visit the Land Information System (LandIS) at www.landis.org.uk.

However, the Soilscapes dataset is freely available through the CaBA data package as an OGC Web Mapping Service (WMS) to all CaBA partnerships for non-commercial use only (see Figure 3). This is a simplified soils dataset covering England and Wales and is based on the far more detailed National Soil Map. The mapping service allows users to make a simple query by clicking on the map to open a pop-up with a simple soil description. Unfortunately, as it is a WMS, the dataset only has limited functionality for analysis and visualisation. It

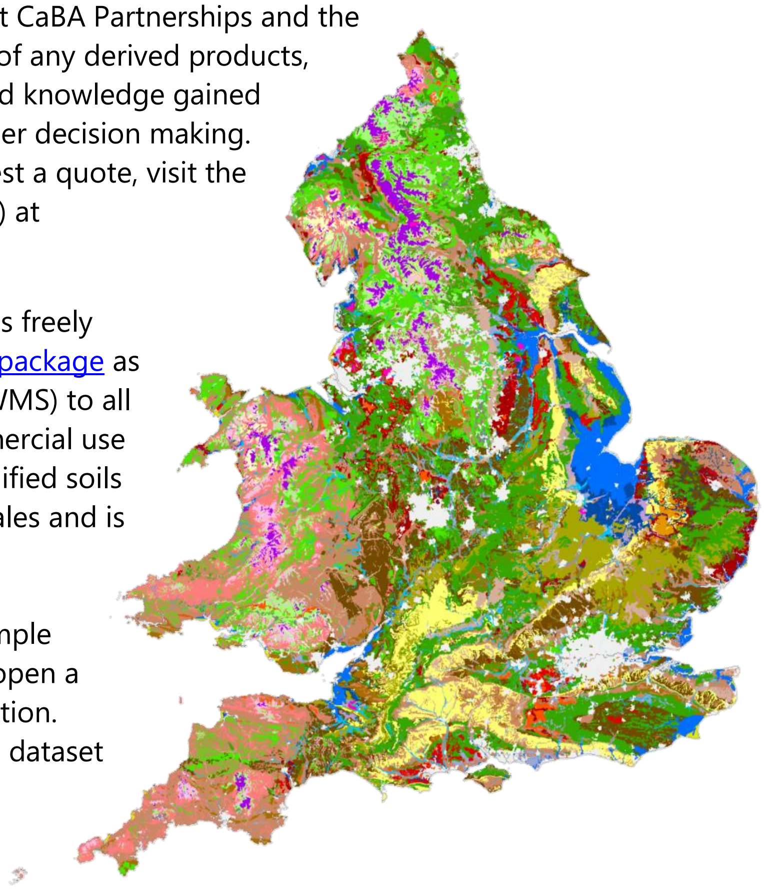

Figure 3: Soilscapes (© Cranfield University (NSRI) used with permission)

is not possible to use the data for analysis in any modelling or geoprocessing tasks, to filter the data or change the symbology to show only peat soil types. Being able to clearly interpret maps is something we often take for granted, but it is also worth noting that the data is symbolised using a multi-coloured design and is not easily accessible to users with colour blindness, or Colour Vision Deficiency (CVD) as it's more accurately known. CVD affects approximately one in 12 men and one in 100 women in the UK.

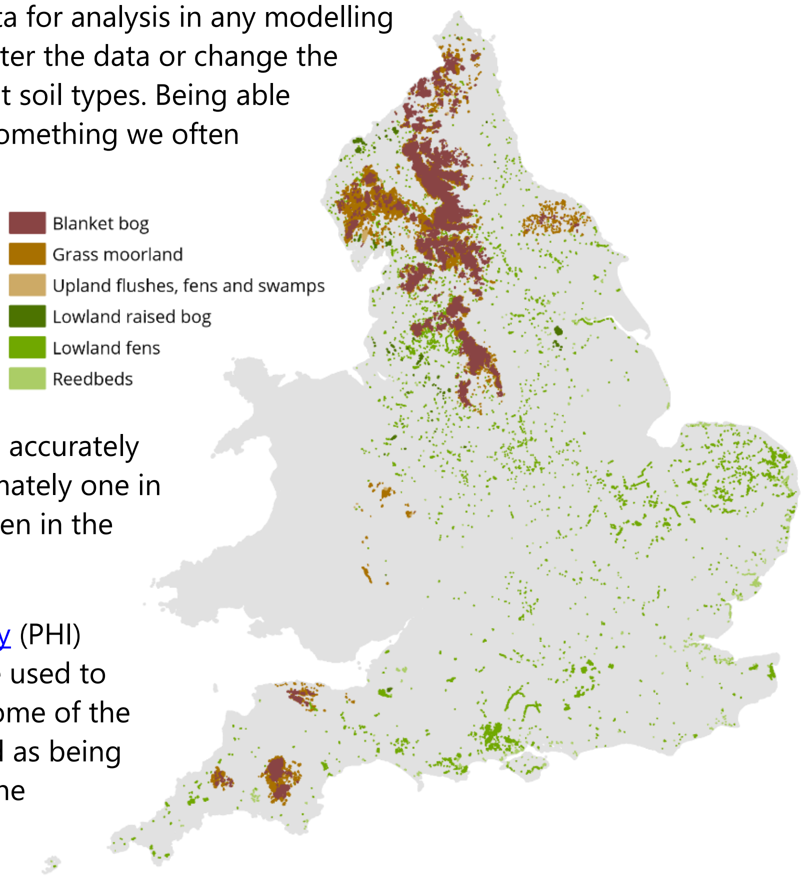

Figure 4: Priority Habitat Inventory (© Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right 2020)

The [Priority Habitat Inventory] (PHI) from Natural England can be used to identify the distribution of some of the peatland habitats recognised as being of principle importance for the conservation of biological diversity in England under section 41 of the Natural Environment and Rural Communities Act 2006. Note, this replaces the Biodiversity Action Plan (BAP) priority habitat inventories. This includes Blanket Bog, Grass Moorland, Upland flushes, fens and swamps, Lowland raised bog, Lowland fens and Reedbeds (see Figure 4). However, this does not necessarily identify the geographic extent of all carbon rich peaty soils. A quick comparison against the NSRI soils data shows that it potentially underestimates the geographic extent of lowland peat significantly and fringe areas surrounding blanket bog. This is likely due to the fact that lowland peat soils and fringe areas have been heavily degraded over many years as a result of unsuitable land use practices. As a result, they are no longer likely to be classified as peatland habitat due to land use change or poor condition. Nevertheless, this dataset is suitbale for identifying the extent of existing peatland habitats that should be protected and enhanced to increase carbon sequestration and maximise the benefits of other ecosystem services. The PHI can be accessed through the CaBA data package or is available for downloaded from the Natural England Open Data portal. This is a very large dataset and has been split into three regions (North, Central & South) to make it easier to manage.

Estimates of soil carbon for peatlands are difficult to obtain at a national scale and local soil sampling and surveys are the most effective way to determine carbon stocks. However, mean estimates of carbon density in topsoil (0-15 cm depth) in tonnes per hectare are available from Natural England's natural capital maps and is also included in the CaBA data package (see Figure). The map was produced using measurements of carbon from soil collected in the Centre for Ecology & Hydrology Countryside Survey (2007) which were extrapolated up to a national level using a statistical model and combining habitat and geological information. This is a coarse resolution (1 km) layer and should be used in an indicative manner, but it is a good guide for protecting all carbon rich soils, not just peatland.

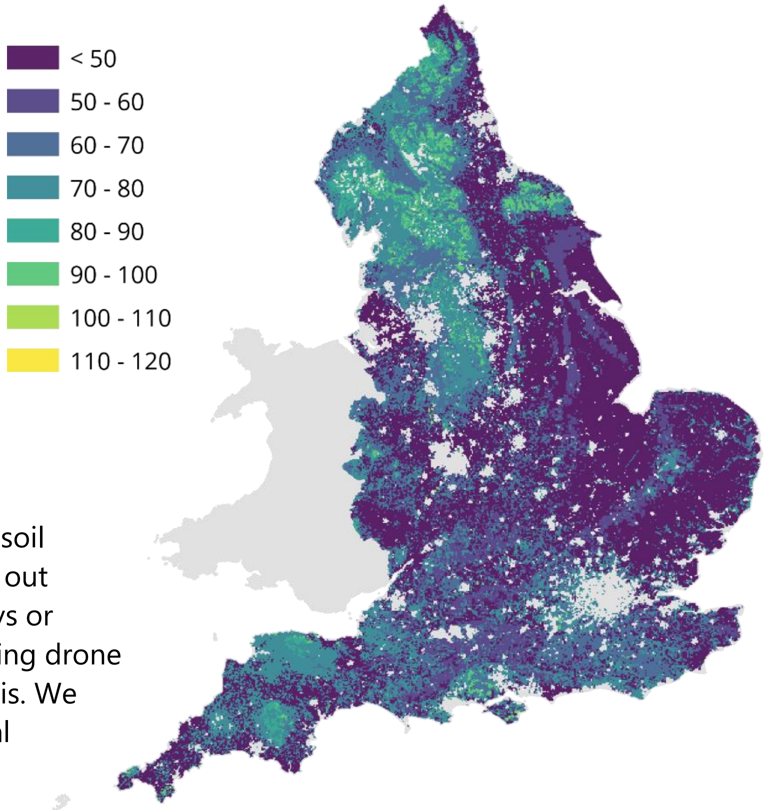

Figure 5: Mean estimates of carbon density in topsoil (0-15cm depth) (Henrys et al. 2012)

In some areas, local peatland and soil carbon mapping has been carried out using soil sampling, habitat surveys or remote sensing techniques including drone surveys or satellite imagery analysis. We recommend speaking to your local authority, public agencies and conservation organisations, such as the National Park Authority, Natural England, National Trust, RSPB, AONB etc. High resolution terrain mapping can also be highly beneficial when mapping the extent and condition of peatland, as well as for long-term monitoring of restoration activities. The Environment Agency provides lidar survey data free of charge for some areas in England that can be download from the Defra Data Services Platform. Historically, LIDAR surveys have focused on areas at risk of flooding, including flood plains, urban areas and the coastal zone. The Environment Agency's geomatics team aims to deliver a full national 1m LIDAR height dataset for England by mid-2021, which will include the difficult to reach upland areas.

7.2 Targeting restoration & multi-benefits

Peatland condition is often used as a proxy for the likely greenhouse gas emissions from peatlands. Establishing a baseline of peatland condition and soil carbon levels at a catchment scale is therefore important before delivering any project. A primary goal of peatland assessment should be to identify areas of high-quality peat, with valuable carbon stocks, that need to be protected to prevent future carbon emissions, as well as areas of erosion and degradation that have the potential to be restored. It is also important to emphasise the associated ecosystem services that peatland provides. These are the benefits provided by the regulation of natural processes. Including climate regulation, water quality and natural hazard regulation, such as flooding (Bonn et al., 2014).

There is no publicly available dataset on the national state of peatland condition in England or Wales. A national overview is made available in Natural England's report on England's peatlands: carbon storage and greenhouse gases, but the underlying data is not available under an Open Government Licence. This research shows that an estimated 74% of our deep peatlands show visible peat degradation or are subject to damaging land management practices, which has significant implications for how much carbon our peatlands can store and greenhouse gas emissions. To get a high-level overview of a catchment or region, we can sometimes infer peatland condition from proxy data sources. For example, using water quality monitoring data, habitat maps or land use information. This weight of evidence approach can be adopted where it is not possible to determine the extent of peatland degradation from maps. Remote sensing techniques, combined with modelling, can also provide potentially powerful tools to assess peatland condition at a range of spatial scales and can be useful in the decision-making process for the selection of sites for restoration.

Land use

Different land management practices on peatlands can have a significant impact on the condition. Land uses that require peatland to be drained have the greatest impact on condition and greenhouse gas emissions, as drainage allows air to penetrate deeper into the peat and enables stored carbon to oxidise. This is likely to be exacerbated by climate change, as warmer summers may speed up decomposition and more extreme storm events will leave exposed peat more vulnerable to physical erosion by wind and water (Natural England, 2010).

The historic and current reclamation of peatland for drainage-based agriculture (horticulture, arable and intensive grassland) has caused significant damage to these ecosystems and the services they provide (Chapman et al. 2003, Graves and Morris, 2013). Identifying permanent pasture and arable land use on peatlands or carbon rich soils may help to target changes in agricultural practices that would protect or restore peat soils. For example, rewetting soils by blocking drainage ditches or changes in crop management. The Corine Land Cover dataset from the European Environment Agency is a freely available land cover dataset covering the whole of the UK. CaBA partnerships also have access to the CEH Land Cover Map through the CaBA data package, however, this is licenced for partnership use only and further licencing is need for commercial work. Both datasets have classes to identify arable and pasture/improved grassland.

This is especially important in lowland peat, where drainage and arable farming is leading to significant losses of carbon. A report found that 380,000 tonnes of soil carbon is being lost from peat soils each year in the East Anglian Fens; 9 per cent of the total carbon loss from soils across England and Wales despite the peat soils of the Fens making up only 0.12 per cent of the landmass (Cranfield University, 2009).

In upland peat, we often find that the raised bogs are well protected and agricultural practices are carefully managed. However, it is the often the periphery of these bogs that are under increased pressure from sub-optimal farming practices. This can result in a 'fried egg' effect, where degradation occurs around the fringes of an otherwise well protected peat bog. For example, the Dartmoor National Park in Figure 6.

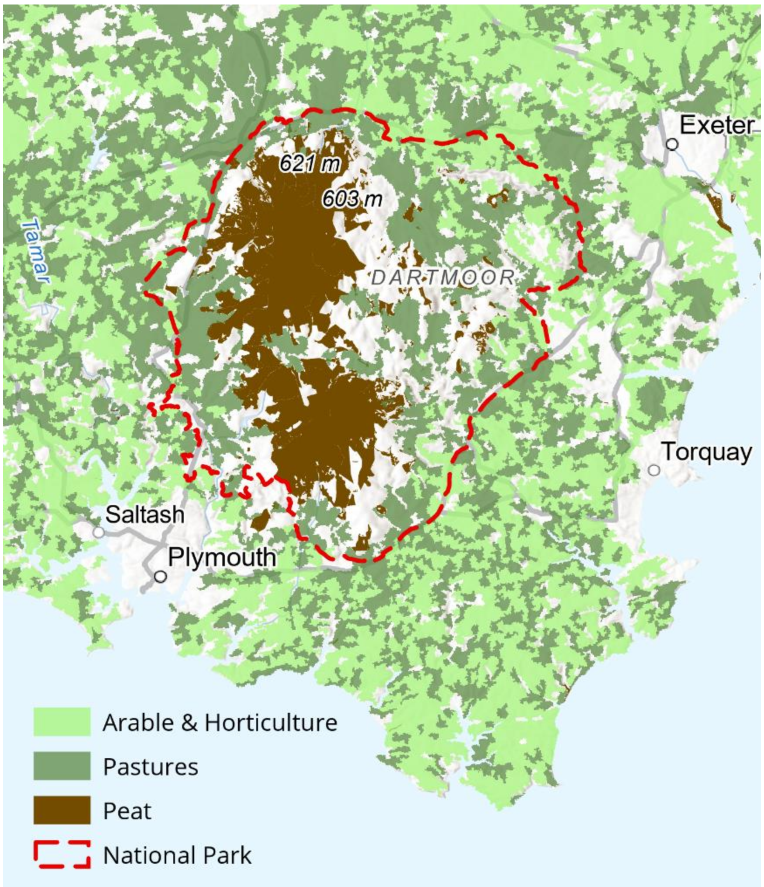

Figure 6: 'Fried Egg' effect in the Dartmoor National Park

Water quality

Colour in drinking water sources could be used as a proxy for peat condition in upland catchments. When peat soils become degraded it can result in colouration (discoloured with sediment and dissolved compounds) which makes the raw water harder to treat, and there is an EU Directive requirement to remove the by-products. Although it should not be assumed that colour issues are solely attributable to peat degradation, protecting and restoring peat in drinking water catchments will help to reduce colouration and the need for expensive, energy intensive water treatment processes.

Drinking Water Safeguard Zones (Surface Water) are catchment areas that influence the water quality for their respective Drinking Water Protected Area and are at risk of failing the drinking water protection objectives of the Water Framework Directive (WFD). Figure 7 shows catchments at risk of failing to meet good standards due to colour issues. There is an opportunity for targeting peatland restoration and protection measures within or upstream of these drinking water catchments to reduce colouration and improve raw water quality. Due to the exceptionally high costs of water treatment to remove colour from drinking water, this would be of benefit to water companies and their customers. In the Bamford catchment (West England/East Wales), Severn Trent Water has been known to spend at least £2000 per week during the summer, increasing to as much as £4000 per week in the winter months to remove peaty sediment from drinking water. Restoring peatland functionality is key to reducing colouration and improving raw water quality.

Nature-based solutions, like peatland restoration, are a worthwhile and appealing investment for water companies. As well as reducing the costs of water treatment for businesses and their customers, investment in peatland restoration also delivers multiple benefits. It enhances biodiversity, reduces their GHG emissions and creates healthy, natural landscapes for leisure and recreation. Numerous water companies in the UK are already undertaking restoration projects within their catchments. For example, United Utilities (North West England) Sustainable Catchment Management Plans during 2005 to 2010 led to the restoration of 20,000ha of upland water catchments. The conservation improvements were considerable, with 96.6% of the 13,000ha of SSSI restored to favourable or recovering status. Monitoring of these areas is starting to show that improved peatland habitat condition is beginning to reduce turbidity and colouration of raw water from these restored catchments.

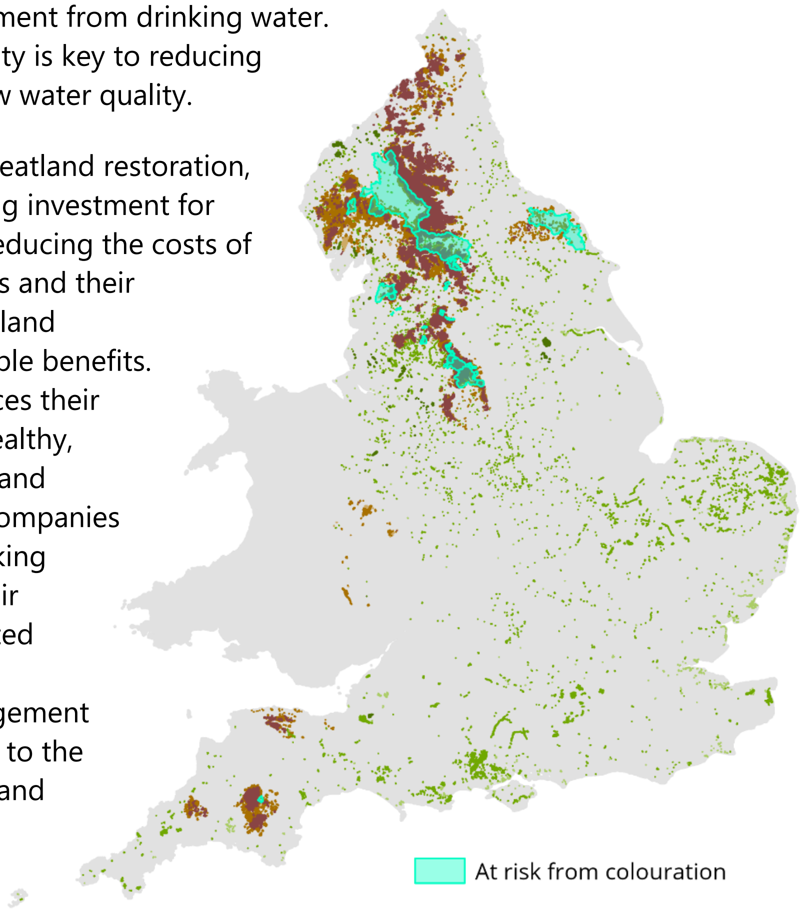

Figure 7: Drinking Water Safeguard Zones (Surface Water) at risk from colour (© Environment Agency copyright and/or database right. All rights reserved. Derived from BGS digital data under licence from British Geological Survey ©NERC. Derived from Centre of Ecology and Hydrology data ©CEH)

Flood risk

The impact of peatlands in good condition on flood regulation is complex and not fully understood. Healthy peatlands can store large volumes of water – as much as 90% water by mass when fully saturated - but it should not be assumed that this can significantly diminish the impacts of flooding during large storm events. For a reduction in flooding, the water level needs to be low enough to allow enough capacity to store water rapidly. If a bog is already close to saturation, then it is unlikely to be able to attenuate flow and store water during a storm event (Acreman and Holden, 2013).

However, the condition of peatland can have a significant impact on the speed of surface runoff, as well as the size and timing of peak flows, thus influencing the severity of flooding (Smyth et al. 2015). As dried peat is very difficult to re-wet, damaged peatlands will increase the rate of surface runoff. There is reduced infiltration into ground water and erosional gullies are formed by wind and water, channelling surface water flows. Natural and restored peatlands provide reduced downstream flood risks compared to damaged peatlands (Committee Climate Change, 2013). Natural Flood Management can help to hold water in the headwaters of the catchment and 'slow the flow' to communities at risk downstream.

To identify opportunities for peatland restoration to reduce flood risk, it may be useful to explore the Communities at Risk data from the Environment Agency. The [Indicative Flood Risk] blue square map, shown in Figure 8, is modelled based on the number of properties that fall within the flood risk area (1 in 100 and 1 in 1000 annual probability rainfall). Areas identified exceed the risk threshold which is defined as:

1. People >200
2. Critical services >1
3. Non-residential properties >20

Targeting peatland restoration in the headwaters of their upstream catchments would reduce the flood peak and mitigate the risk of flooding to communities, critical services and businesses downstream. This dataset is only to be used as an indicator and more in-depth modelling is recommended to inform any natural flood mitigation measures or interventions.

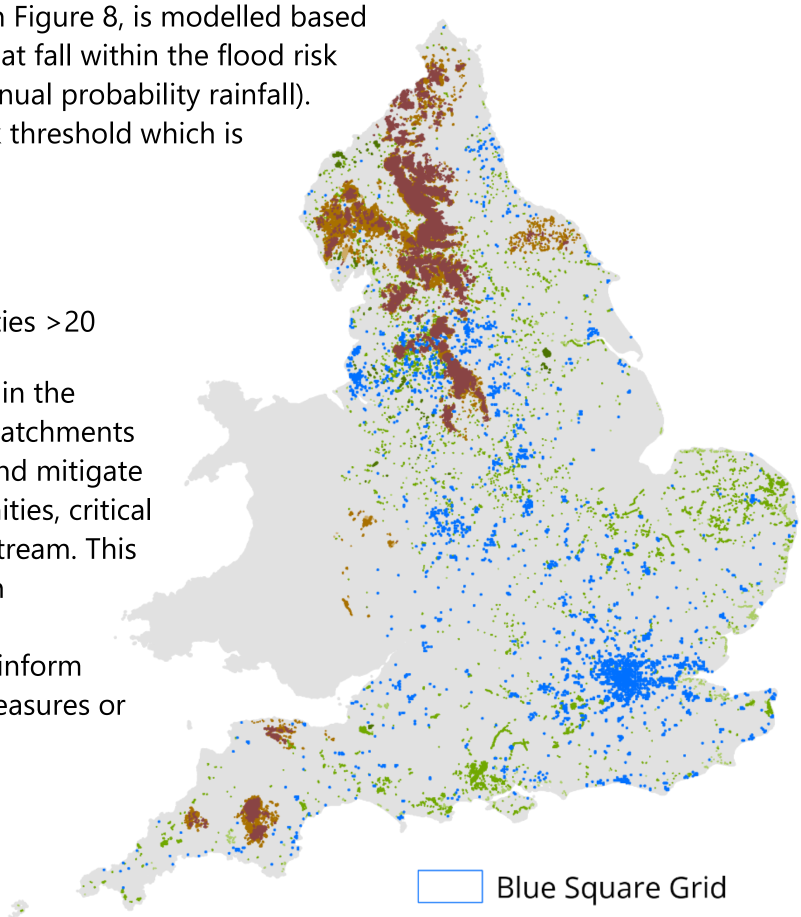

Figure 8: Blue Square Grid - Indicative Flood Risk © Environment Agency

Water resources

Peatlands in upland areas play a significant role in the supply of drinking water and the condition of the peatlands has an impact on the downstream catchments for the quantity of water supplied. It is estimated that in the UK, 72.5% of the storage capacity of reservoirs is peatlands-fed water, supporting the equivalent of 28.3 million people or more than 43% of UK population (Xu et al. 2018). Peatlands are vital to UK water security and must be protected to preserve the UK's water supply. Threats to peatlands could mean a significant threat to our water supply, especially with increasing instances of prolonged drought as a result of climate change.

The [Water Resource Availability and Reliability] maps developed through the Catchment Management Abstraction Strategy (CAMS) can be used an indicator to identify catchments that are water stressed and at risk from over abstraction. Peatland restoration in catchments that are already being over abstracted, or are at risk of being over abstracted, may help to increase infiltration into groundwater and raise the water table, creating additional water resource storage in the catchment or upstream catchments. Increasing the availability and reliability of water resources in the catchments to our abstractions will help to build climate resilience. This will ensure we continue to have a reliable drinking water supply, as well as essential water for irrigation and industry.

Acknowledgments

This report has been written under Workstream LT of the Interreg North West Europe project 'Carbon Connects' (NWE 615) with the support of 'The Prince of Wales's Charitable Fund'.

Authors

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