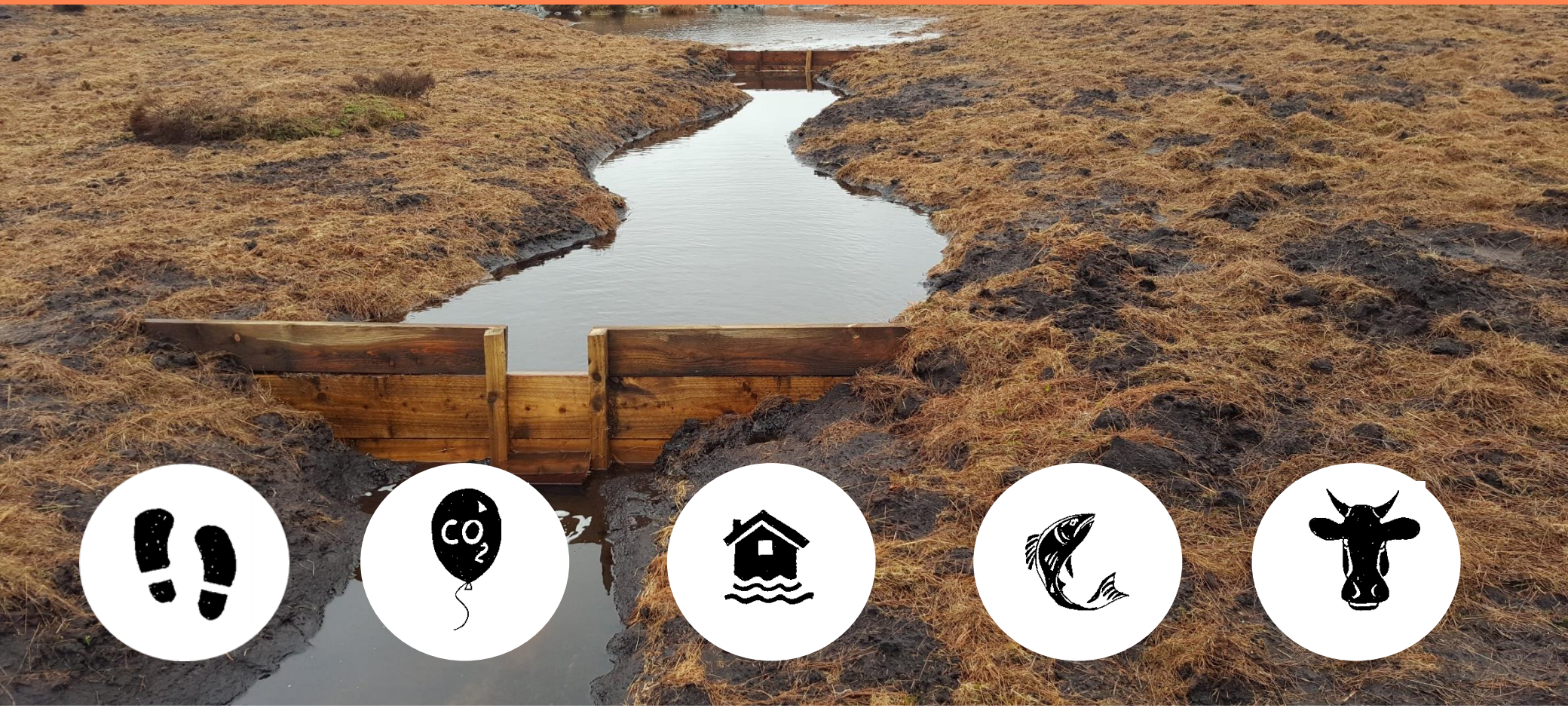
FOREST OF BOWLAND
Area of Outstanding Natural Beauty

Mapping Natural Capital and Ecosystem Services in the Forest of Bowland AONB



PENDLE HILL LANDSCAPE PARTNERSHIP

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heritage lottery fund
LOTTERY FUNDED

Natural Capital Solutions

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Acknowledgements

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Mapping supplied by Natural Capital Solutions.

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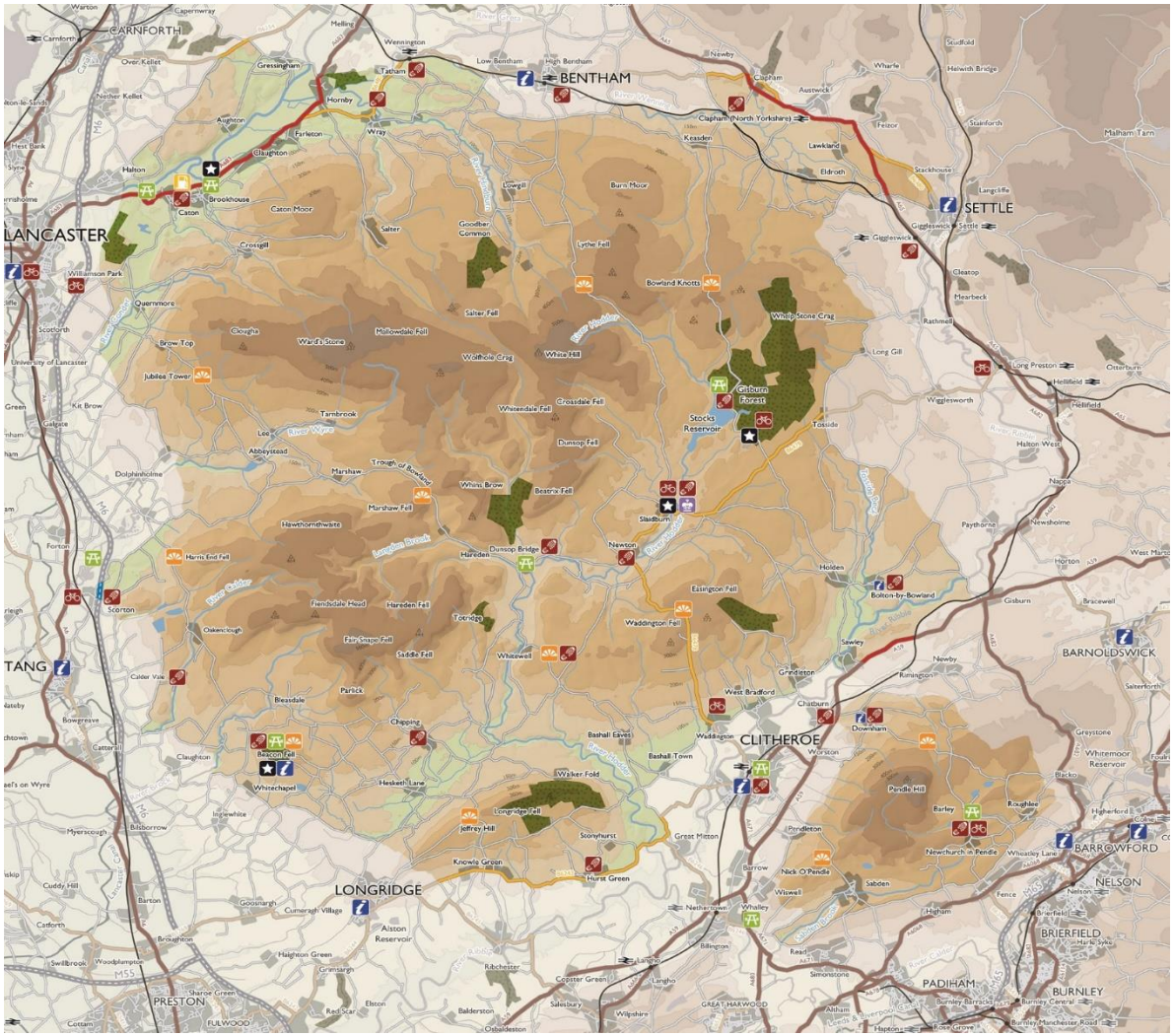
Context

The Forest of Bowland was designated as an Area of Outstanding Natural Beauty (AONB) in 1964 under the National Parks and Access to the Countryside Act (1949). It covers 803 km2 and it's boundaries encompass six district councils within the counties of Lancashire and North Yorkshire, namely Craven, Lancaster, Pendle, Preston, Ribble Valley and Wyre.

The Bowland fells are internationally important for their expanse of blanket bog and heather moorland providing habitats for breeding bird communities such as hen harrier, merlin and peregrine.

The Forest of Bowland also has 21 Sites of Special Scientific Interest (SSSIs), covering 16,382ha or 20.4% of the AONB's area.



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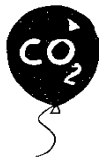
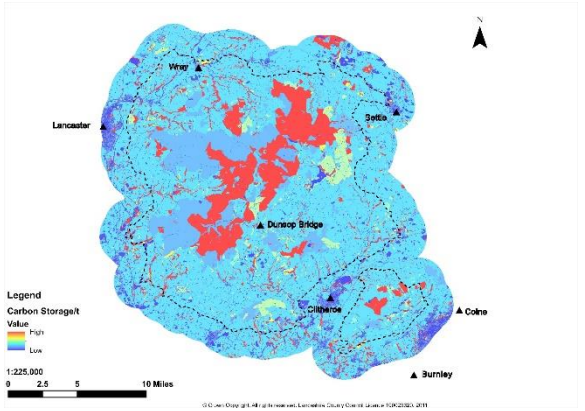
Executive Summary

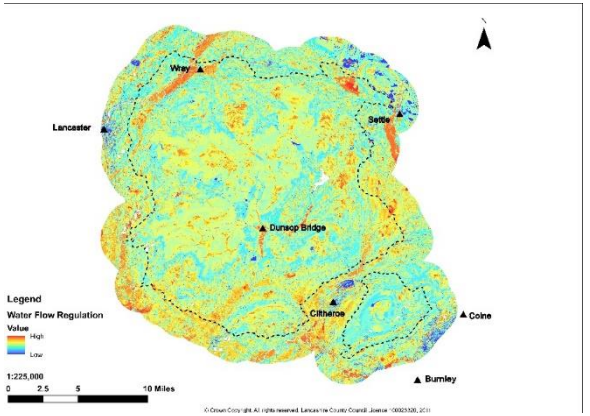
The value that the landscape of the Forest of Bowland AONB provides for people reaches far beyond its boundaries. This landscape is vital for goods and services like water, food and places for recreation.
***Ecosystem Services** are the services provided by nature and landscape that benefit people, and they provide a particular focus for valuing the environment. Services identified include:*



Carbon storage : Upland soils are the largest carbon store in England. 300 million tonnes of carbon are stored in English peatlands, mostly in the uplands. The Forest of Bowland has around 20,000 hectares of peatland soils. As well as soils, carbon is also stored in vegetation particularly in woodland and trees.



Water Flow Regulation: The Forest of Bowland has steep topography and narrow floodplains which combine with waterlogged moorland soils and high rainfall to produce watercourses that respond rapidly to rainfall. The resultant increased fluvial flood risk occurs mainly downstream in the valleys of the Ribble, the Lune and the Hodder, impacting communities such as Lancaster and Churchtown in the east, and Padiham and Whalley in the west.



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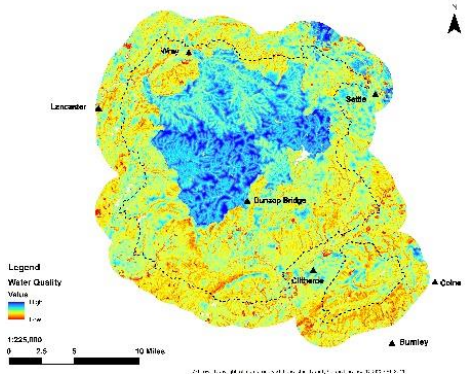
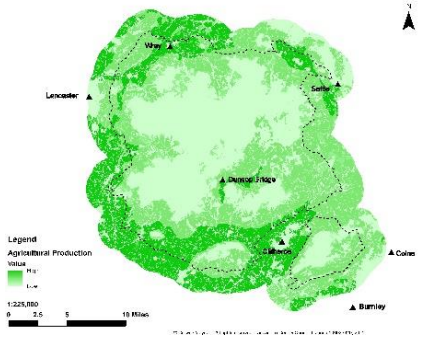
Water Quality : Upland river catchments of the AONB provide water for thousands of homes and businesses in Lancashire and the North West of England. The sustainable management of catchment land by the water utility company helps to improve water quality; reducing the need for more costly 'end-of-pipe' water treatment.
65.5% of rivers are in good ecological condition, a further 27.5% are in moderate condition (State of Nature Report)



Agricultural production : 67% of farmers are hill farmers: predominantly extensive beef and sheep on the fells with more intensive beef and sheep within the valleys and lowland fringes. 12% of farms are dairy farms. Hill farming systems concentrate on the production of suckler beef and store lambs. In addition, the western fringes of the AONB also support a number of other farming enterprises including pig, poultry and horticulture.



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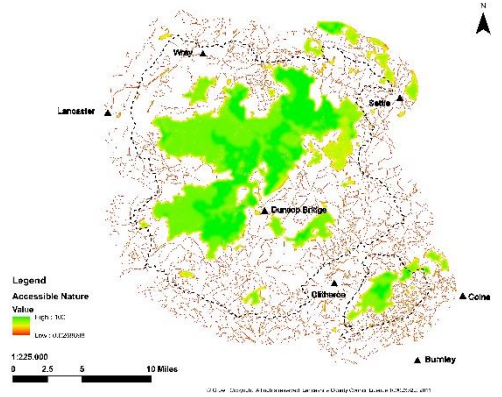
Accessible nature: The AONB has an estimated resident population of 16,000 with over one million people living within a 30-minute journey of the area. The extensive rights of way network and access land areas within the AONB, offers access to nature, provides excellent recreational opportunities and supports the health and well-being of both residents and visitors.



Air and noise regulation: Further mapping shows the AONB is a source of clean air, tranquillity, and freedom from noise and light pollution.
Other benefits : The production of timber, the dispersal and cycling of nutrients, pollination and, with the appropriate technology in the correct location, a source of renewable energy (such as micro-hydro, small-scale wind, solar and biomass).

As part of a wider Natural Capital Approach, mapping ecosystem services assists decision-making with a common framework for evidence and analysis. By mapping ecosystem services the AONB Partnership can begin to see synergies where areas of work deliver on multiple objectives. Simply put, it helps us all to know what to value and where to target investments in the future.

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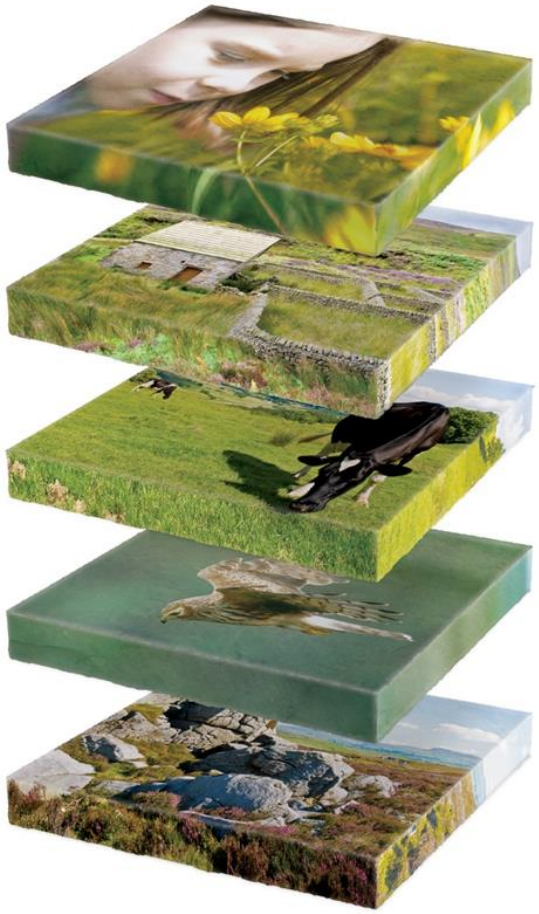
The Natural Capital Approach



Figure#1: Natural Capital Assets in the AONB landscape

This report aims to identify and summarise the natural capital assets for the AONB, establishing a current baseline for biodiversity and habitats, and to identify the supply and demand of relevant Ecosystem Services that exist within the Forest of Bowland.

The report has been produced thanks to funding from the AONB and the National Lottery Heritage Fund through the Pendle Hill Landscape Partnership as part of the 'What's a Hill Worth?' project. Mapping and analysis was carried out by Alison Holt & Jim Roquette at Natural Capital Solutions principally using the Ecoserv-GIS mapping model. This report was then compiled by the Forest of Bowland AONB team.

What is Natural Capital?

"The elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions." Natural Capital Committee

Natural Capital is those elements of the natural world from which flow a series of services to society. The environment's contribution to these benefits are referred to as ecosystem goods and services. For example, woodland, species rich grassland, wetlands, peatland and other soils are all aspects of natural capital, whilst carbon storage, clean air and water and opportunities for recreation are some of the ecosystem services which flow from them. These services are also influenced by financial and social capital, but at their root is the natural capital that makes their delivery possible.

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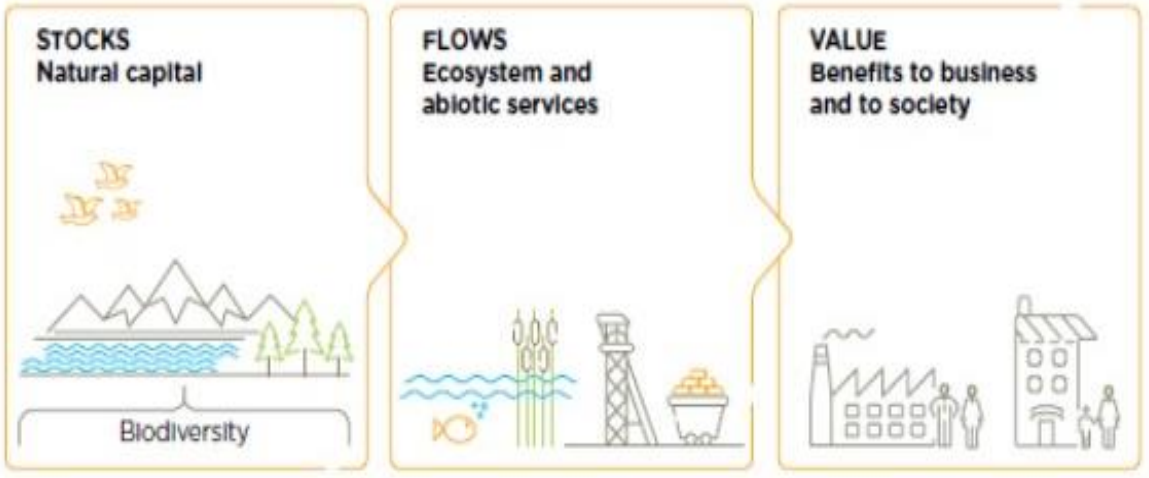
The Natural Capital Approach

What are Ecosystem Services?

Ecosystem services are the benefits which flow from Natural Capital. They include a wide range of benefits such as food, energy, clean air and water, regulation of risks (floods, droughts, erosion), recreation and spiritual benefits.

People's wellbeing can depend upon the quality and quantity of the natural environment. The structures and processes that make up healthy functioning landscapes provide us with ecosystem services, all of which contribute to our health, wealth and wellbeing.

Figure#2: The Natural Capital Logic Chain shows the relationship between 'natural capital' and 'ecosystem services' derived from the Natural Capital Coalition Protocol 2016



Reproduced from the Natural Capital Coalition, 2016. "Natural Capital Protocol"
naturalcapitalcoalition.org/protocol/

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The Natural Capital Approach

Applications

Decisions in the public and private sectors are often based on the expected economic costs and benefits of different options. The environment provides a wide range of important benefits, but without quantification these are difficult to include in this decision making. Some products like timber have a known financial value, but in other cases, such as the role of bees in pollinating crops or the storage of carbon in peatland, we are only just beginning to fully understand their role and their value to society and the economy. Thus the natural environment can be forgotten about.

"At the core of valuing natural capital is an assessment that highlights both risks and opportunities of change."

The concept of ecosystem services captures the dependence of human well-being on natural capital and on the flow of services it provides. This development has occurred alongside a progression in science, policy and management over the last two decades, shifting from a relatively simple framing in purely conservation terms focusing mostly on species and habitats, to a framing in terms of conservation, sustainable uses and benefit sharing and a more systemic approach in terms of socio-ecological systems. For example, carbon is increasingly being given a monetary value and is beginning to form the basis of Payments for Ecosystem Services (PES) schemes such as the Woodland Carbon Code and the Peatland Code.

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The Natural Capital Approach

How can this approach be used?

- Create a baseline for evidence over time.
- Highlight ecological 'risk' and 'opportunity'
- Assist partners in working towards programmes that maximise multiple benefits.
- Inform decision makers on the intangible value of environmental assets within the AONB
- A basis for natural capital accounting and innovative approaches to nature-based solutions

Specifically the AONB will use this approach to:

- Assist the AONB in prioritising action as part of its Management Plan delivery.
- Assist in delivering Government policy such as the proposed 'Environmental Land Management System', which prioritises support for the supply of public goods such as biodiversity, carbon, natural flood management, water quality and access to the countryside; or delivering on Environmental Net Gain.

Note : Biodiversity is at the heart of natural capital, as the living component of the stock. Yet, the lack of visibility of biodiversity within Natural Capital approaches has been identified as a key issue. Indeed, implementing a Natural Capital approach can present potential risks to nature conservation when incompletely or incorrectly applied. In practice, the scientific and practical challenges mean that it is not always possible to measure all of nature's values. For example, while we can estimate and value the carbon sequestered by a woodland, it is not possible to value England's woodlands reverberating with birdsong. Put simply, economic valuation will only ever be a partial reflection of nature's values and is unable to reflect the value of retaining the wonder of nature, for its own sake and for future generations to enjoy

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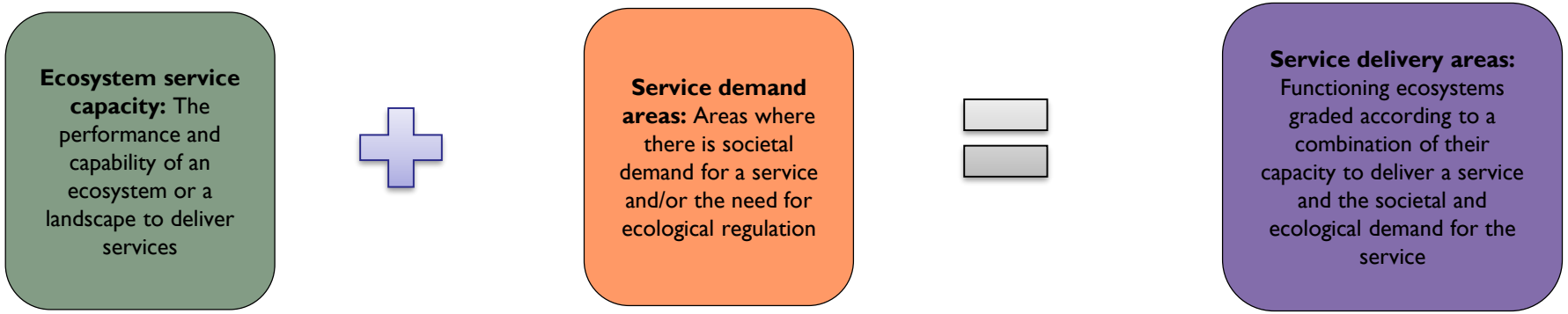
Methodology

EcoServ GIS, a toolkit developed by the Wildlife Trusts, with a number of bespoke modifications, was used to map ecosystem services across the AONB area. The EcoServ-GIS toolkit generates fine scale maps illustrating the human requirement (need or demand) for ecosystem services as well as the capacity of the natural environment to provide each service, using scientifically informed, standardised methods and widely available datasets. It provides users with the facility to overlay these maps to show how well demand and capacity coincide in space. This highlights those natural areas providing high levels of service delivery, that should be conserved, as well as those that are most in need of actions to improve single or multiple service delivery. These are illustrated by maps of service "benefiting areas" as well as identified "management zones". These maps can be used over a range of scales informing policies across a landscape, catchment or regional scale.



Figure#3: Defining Service Flow
Adapted from: Winn, J.P. (2015) Eco-Serv Natural England Publications, p. 14.

Modelling and mapping ecosystem services

Before the physical flow or value of ecosystem services can be calculated and mapped, it was necessary to obtain an accurate assessment of the natural capital assets currently present in the Forest of Bowland AONB. The most important component of this was to create a **habitat basemap** for the area. This was created using OS MasterMap polygons as the underlying mapping unit, and then used a series of different data sets to classify each polygon to a detailed habitat type and to associate a range of additional data with each polygon. The data that was used to classify habitats in the basemap is shown below:

- **OS Mastermap topography layer**
- **OS VectorMap District data**
- **OS Mastermap Greenspace**
- **CORINE European land cover data**
- **Priority habitats and phase 1 habitat survey data**
- **Public Rights of Way data**
- **Digital Terrain Model**
- **Hydrology of Soil Types (HOST)**

Polygons were classified into **Phase 1 habitat types** and were also classified into broader habitat groups. Multiple modifications were made to the EcoServ GIS programme code to enable improved classification of habitats. Furthermore, upon initial completion the basemap was carefully checked and manual alterations were made in a number of places where misclassifications had occurred. The basemap was produced to cover the whole of the Forest of Bowland AONB area, plus an additional buffer zone of 3 km to ensure that all maps were accurate right to the edge of the main study area.

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Methodology

Ecosystem Service Models

Once a detailed habitat basemap was created, it was then possible to quantify and map the benefits that these habitats (natural capital) provide to people. The following benefits (ecosystem services) have been assessed for this project:

- Carbon storage and sequestration
- Agricultural production
- Water flow
- Water quality
- Accessible nature
- Air quality regulation: capacity & demand
- Noise regulation: capacity & demand

(the above two services are not included in this report)

In all cases the models were applied at a 10m by 10m resolution to provide fine scale mapping across the area. The models are based on the detailed habitat information determined in the habitat basemap, together with a variety of other relevant external data sets (e.g. digital terrain model, UK census data 2011, open space data) and many other data sets and models mentioned in the methods described for each ecosystem service.

For all of the ecosystem services listed ***Natural Capital Solutions*** mapped the **capacity** of the natural environment to deliver that service – or the current supply. Where there is a local **demand** (beneficiaries) these have also been mapped for the ecosystem service (eg air quality). This has not, however, been possible for services where the demand is considered to be national or international, such as carbon storage or food production.

Limitations

These models are indicative (showing that certain areas have higher capacity or demand than other areas) and are not process-based mathematical models.

In all cases the capacity and demand for ecosystem services is mapped relative to the values present within the Forest of Bowland and buffer zone on a scale from 0-100.

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

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. The Priority Habitat Inventory (PHI) from Natural England can be used to identify the distribution of some of the peatland habitats This includes blanket bog, grass moorland, upland flushes, fens and swamps, lowland raised bog, lowland fens and reedbeds. However, this does not necessarily identify the geographic extent or condition 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. The final map was not ground truthed for accuracy, hence some misclassifications are inevitable.

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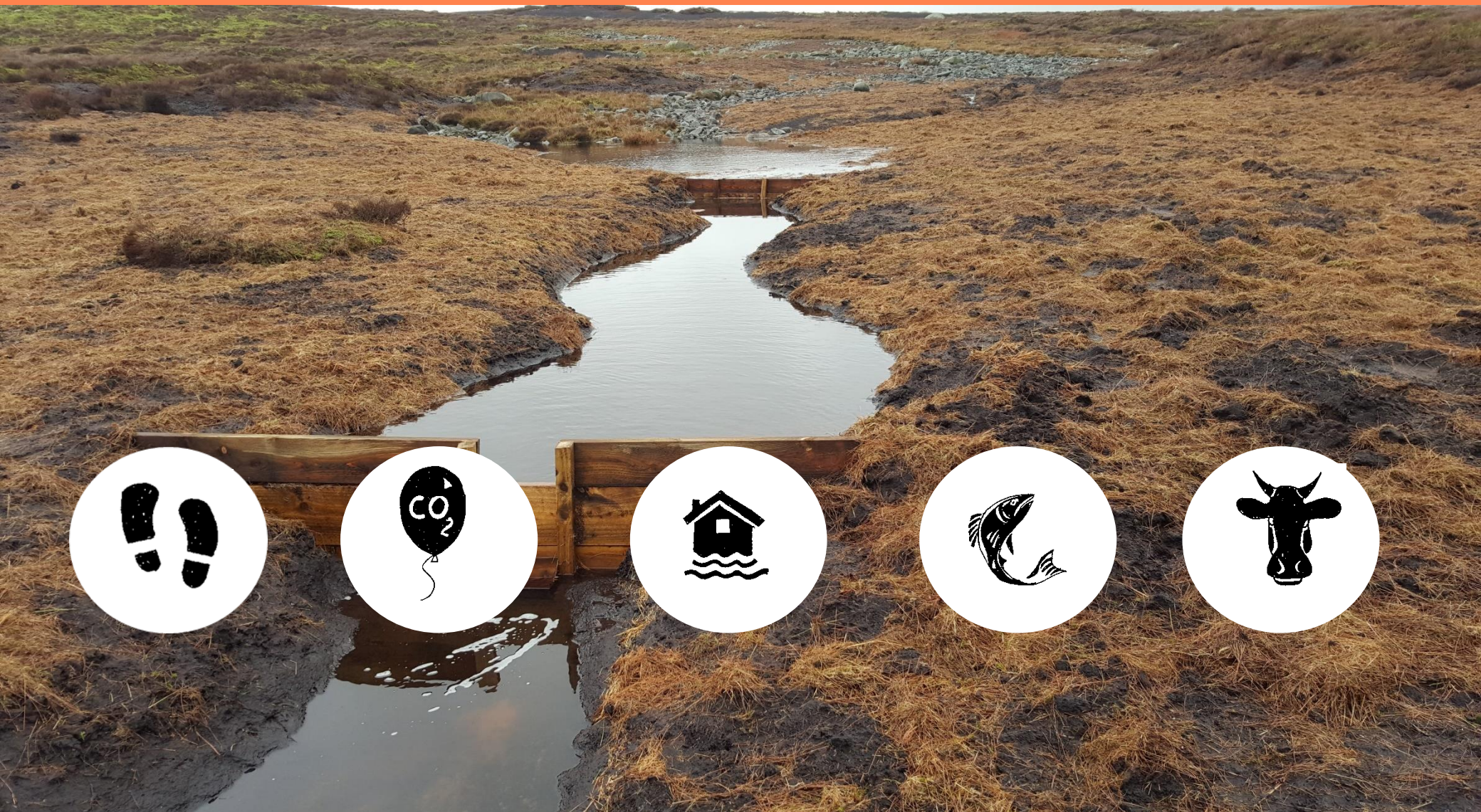
Ecosystem Service Maps



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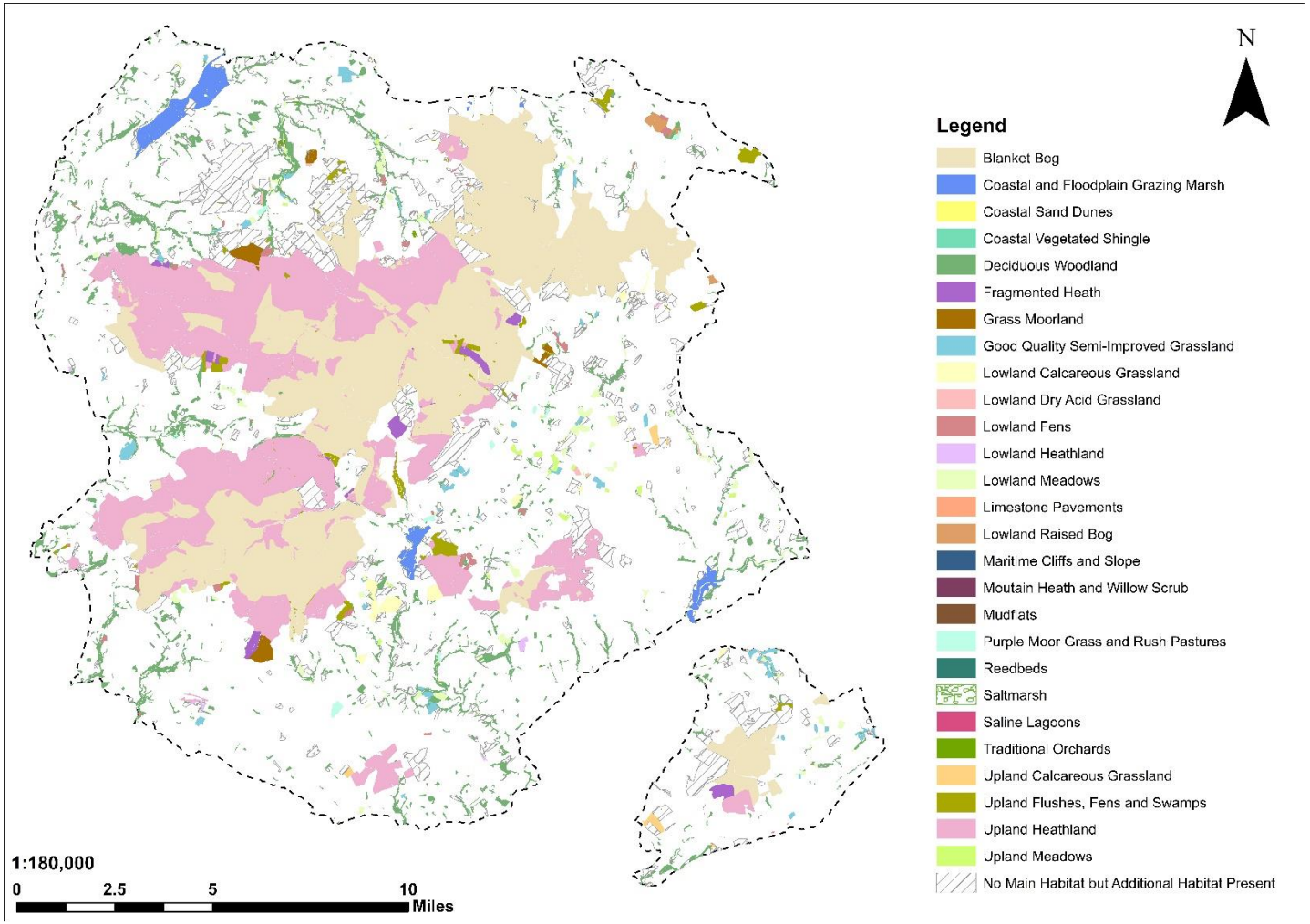
Habitat Basemap

Habitat Basemap

The Eco-Serv GIS Toolkit created a habitat basemap, or natural capital asset register, for the Forest of Bowland by combining a variety of habitat mapping data. This generated a detailed map identifying the main habitat type of each 10 x 10m polygon which is too large and fine detailed to include here.

Instead, for illustrative purposes, here is the **Priority Habitat map** for the AONB area. This shows that blanket bog, upland heath and other peatland habitats occupy around 25% of the total area; with woodland/forestry covering 8%. Improved and semi-improved grasslands cover the majority of the remaining area. Many of these priority habitats, including blanket bog, have been in unfavourable condition and they are currently the focus for work to bring back into favourable condition.



Figure#4: Priority Habitats in the Forest of Bowland

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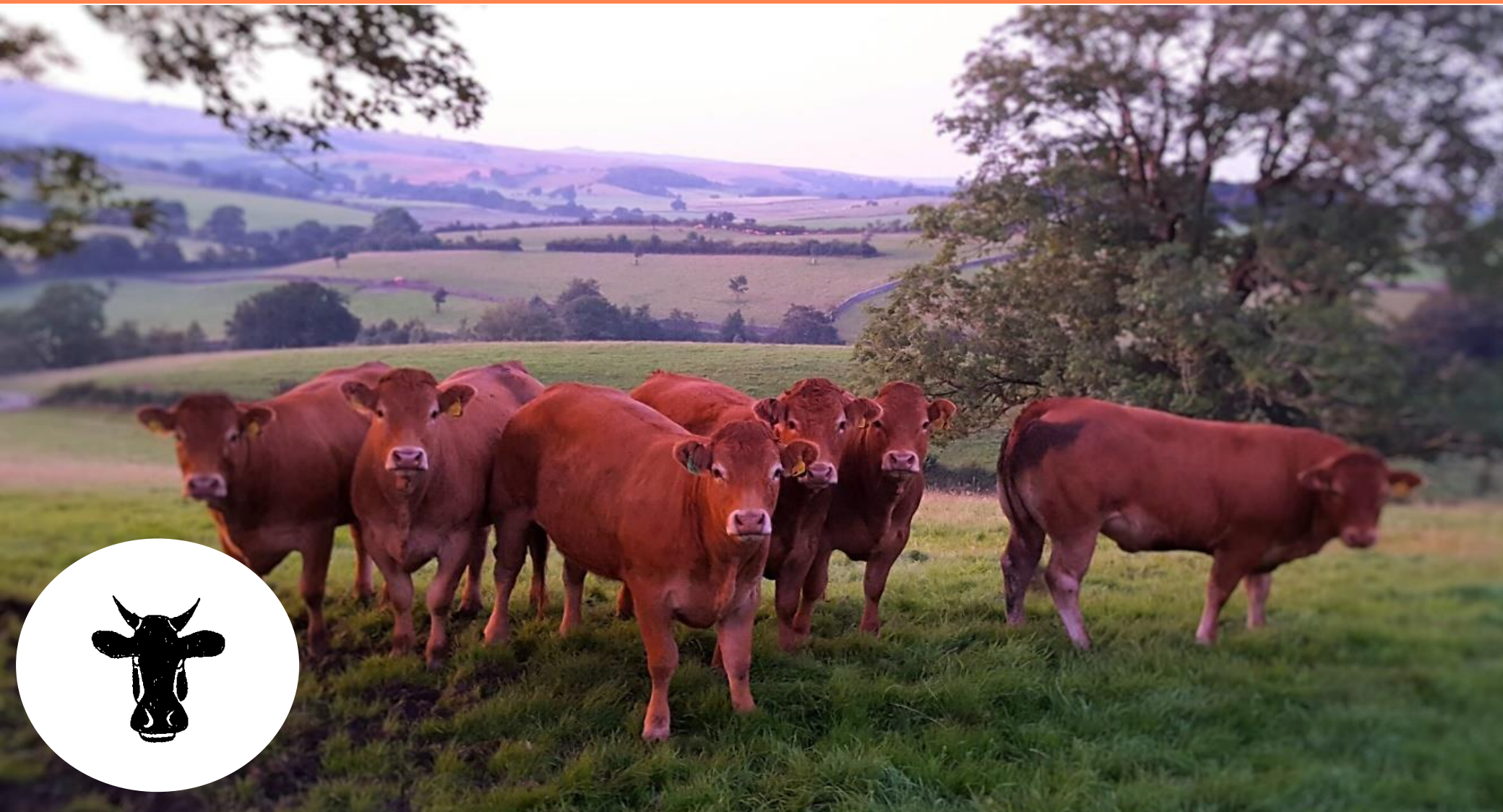
Agricultural Production



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Agricultural Production

Although much of the Forest of Bowland is marginal for agriculture, farming remains important in terms of the rural economy here and sustains not just family farms but other rural livelihoods. This 'social capital' needs to be considered in the context of any land use change. Food production includes more than just the natural capital but also the human capital and investment represented by machinery, labour, tradition, knowledge and experience in local farmers.

Methodology

'Agricultural production' models the capacity of the land to produce food under current farming practices. The ability of habitats to provide food, accounting for the Agricultural Land Classification, was mapped. Each broad habitat was assigned a score based on its ability to provide food. This was then weighted by the Agricultural Land Class in which it occurred (graded 1 to 5, decreasing in quality). This methodology has been taken from the 'eco-metric tool' that is being developed for Natural England, and features in the report Smith, A. (2019) Natural Capital in Oxfordshire Short Report. The data was projected across the study area, resampled at a 1 ha resolution and normalised on a 0 to 100 scale relative to values present within the study area

ALC grade	Multiplier
1	3.03
2	2.40
3a	1.83
3	1.33
3b	1.00
4	0.67
5	0.50

Habitat	Score
Arable, horticulture, improved grassland, intensive orchards	10
Allotments	7
Semi-natural rough grassland	6
Wood pasture, traditional orchard	5
Marshy grassland	4
Bog/heath, domestic gardens, woodlands, hedges	1

Opportunities: linking to the Forest of Bowland AONB Management Plan

Work with the local farming community to achieve appropriate grazing regimes to produce food and other multiple benefits.
Encourage the development and promotion of supply chains and markets for high quality local produce.
Encourage sustainable grazing regimes on permanent pasture with a low input of artificial fertilizer.

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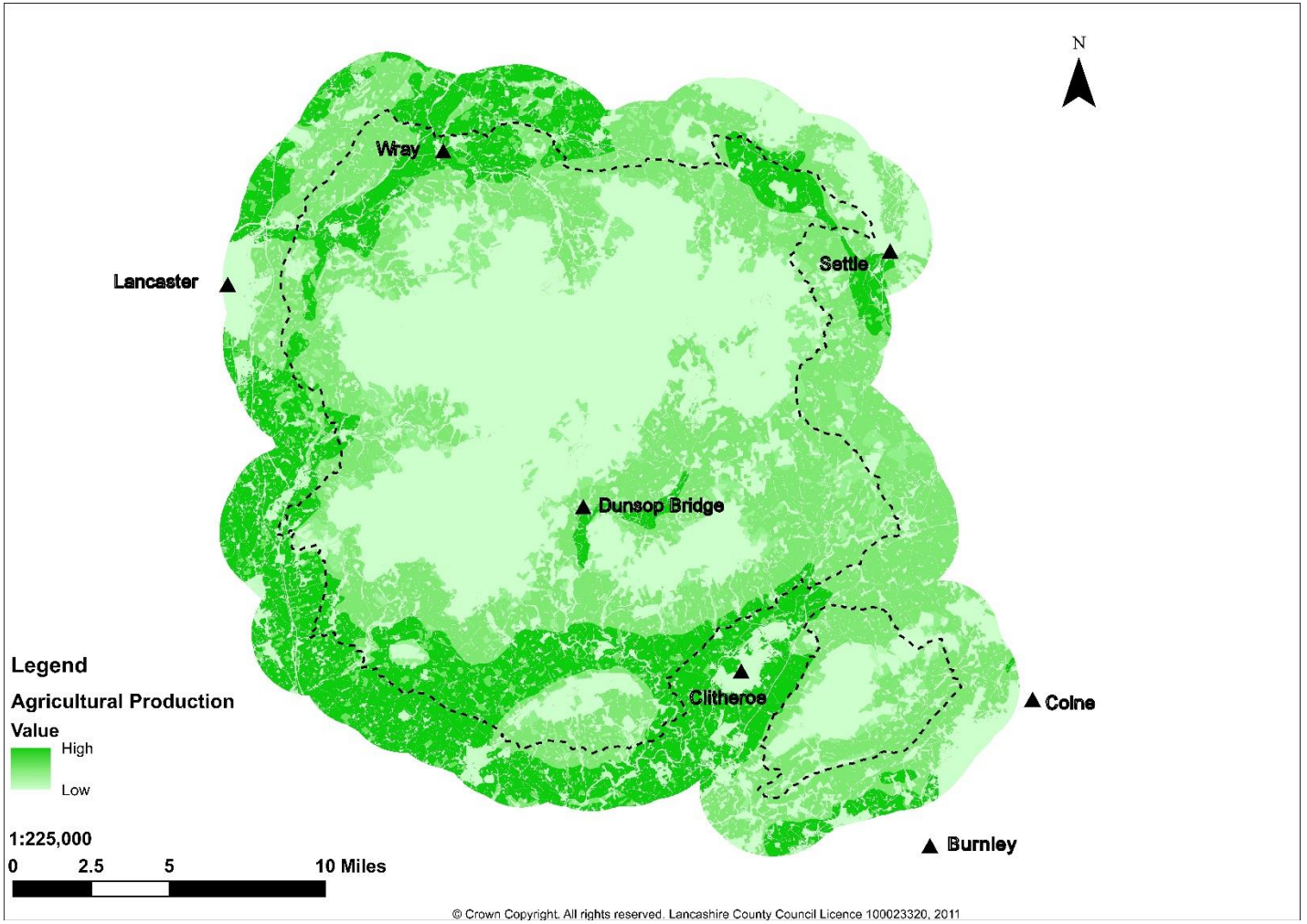
Agricultural production

What does it show ?

- Food production is dominated by cattle and sheep farming. This is an important area for rearing livestock.
- Soils are poor and there is little opportunity for arable crops.
- Most land is Agricultural Grade 4 or 5. The Bowland Fells are dominated by extensive sheep farming on the hills, where output per hectare, and value, is low.
- In many locations well managed livestock production systems have the potential to increase the overall food provision however inappropriate stocking regimes, may have significant detrimental effects on many key environmental services including biodiversity, soil erosion, water quality and climate regulation.
- The highest values occur in the pasture that fringes the Bowland Fells: these are predominantly areas of intensive dairy farming.



Figure#5: Agricultural production in the Forest of Bowland

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Carbon Storage

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Carbon Storage

"Improving the condition of 130,000 hectares of degraded peat throughout the Northern Upland Chain Local Nature Partnership will provide £460 million net benefit over forty years, just from reducing the amount of carbon being released into the atmosphere" (Northern Upland Chain, 2013).

Carbon storage capacity indicates the amount of carbon stored naturally in soil and vegetation. Carbon storage and sequestration is seen as increasingly important as we move towards a low-carbon future. The importance of managing land as a carbon store has been recognised by the UK government, and land use has a major role to play in national carbon accounting. Changing land use from one type to another can lead to major changes in carbon storage, as can the restoration of degraded habitats.

Peat and peatland soils are the biggest terrestrial store of carbon on the planet. Britain and Ireland hold over 20% of the world's blanket bog, the habitat associated with deep peat. These soils store significant carbon; however when degraded they release stored gases into the atmosphere and through water run-off. Soil carbon is also high under areas of woodland, and carbon storage and sequestering is also provided by the woodland itself.

Methodology

The EcoServ GIS carbon storage model was used. This model estimates the amount of carbon stored in the vegetation and top 30cm of soil. It applies average values for each habitat type taken from a review of a large number of previous studies in the scientific literature. As such it does not take into account habitat condition or management, which can cause variation in amounts of carbon stored. It is calculated for each 10m by 10m cell across the study area. Scores are scaled on a 0 to 100 scale, relative to values present within the mapped area.

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Carbon Storage

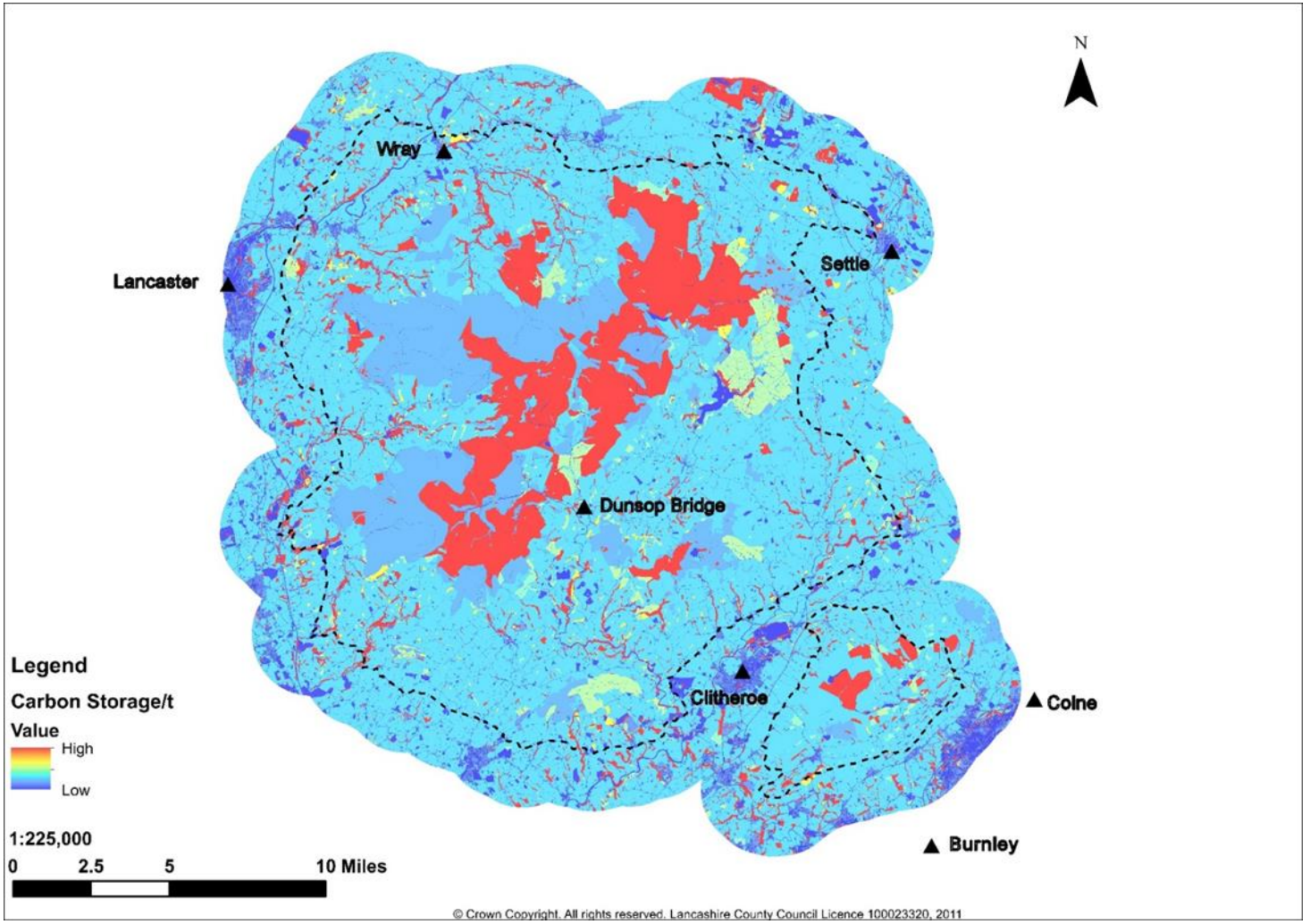
What does it show ?

In the Forest of Bowland AONB carbon levels in the soil are generally high, reflecting the large bodies of deep peat and peat rich soils associated with extensive tracts of wet-heath and blanket bog habitat on the fells.

The highest amounts of carbon stored (hotspots) are shown in red, with blue showing the lowest amounts (coldspots). Woodland largely shows up as light green.

Upland peatland such as those in blanket bog, or the very acid loamy upland soils in the Forest of Bowland in good biological condition, can retain high quantities of stored carbon which might otherwise become greenhouse gases.

When peatland is functioning well, (active) they are also able absorb (sequester) the greenhouse gas carbon dioxide from the atmosphere. Degraded peat bogs release these stored gases into the atmosphere (carbon emissions) through water and wind erosion.



Figure#6: Carbon storage in the Forest of Bowland

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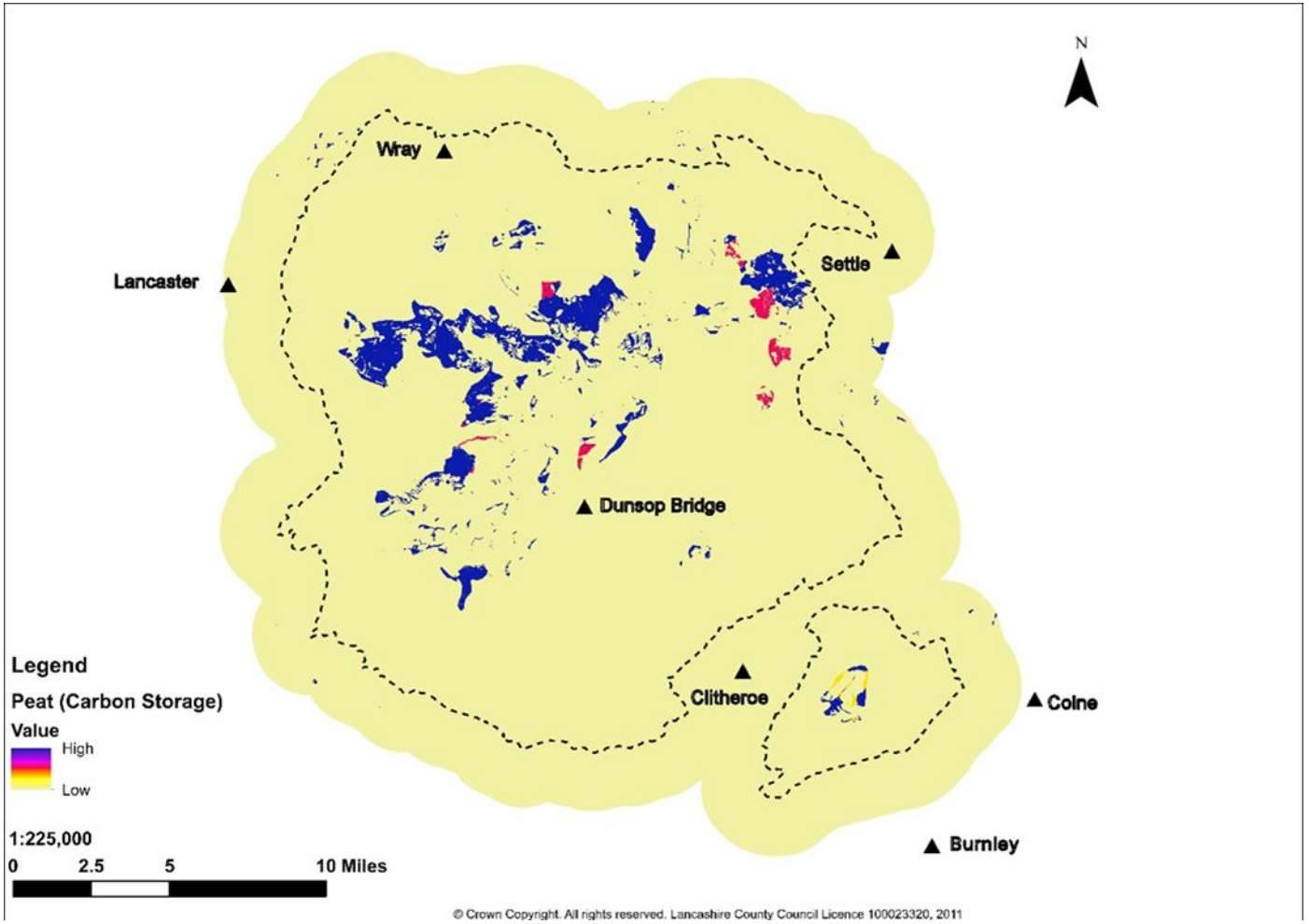
Carbon Storage from deep peat soils

What does it show?

This map shows how closely the service of carbon storage in peat reflects the habitat map in terms of the extent of peatland soils namely those areas of blanket bog within the Bowland Fells SSSI.

Alongside the ecosystem services generated by water quality and water flow there is a need to restore these priority habitats not just for their biodiversity value but for other ecosystem services they provide.



Figure#7: Carbon storage from deep peat soils in the Forest of Bowland

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Carbon storage from deep peat soils

Opportunities: linking to the Forest of Bowland AONB Management Plan

- Restoration and sustainable management of blanket bog and other moorland habitats to provide opportunities to safeguard existing stores of greenhouse gases while aiming to sequester increased volumes of carbon dioxide from the atmosphere.
- Ensure that all areas of blanket bog are under good environmental management which improves the habitat's ability to actively sequester carbon dioxide from the atmosphere, while retaining significant volumes in storage of greenhouse gases.
- Prioritise the restoration of bare and eroded peatland habitats.

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Carbon storage from woodland

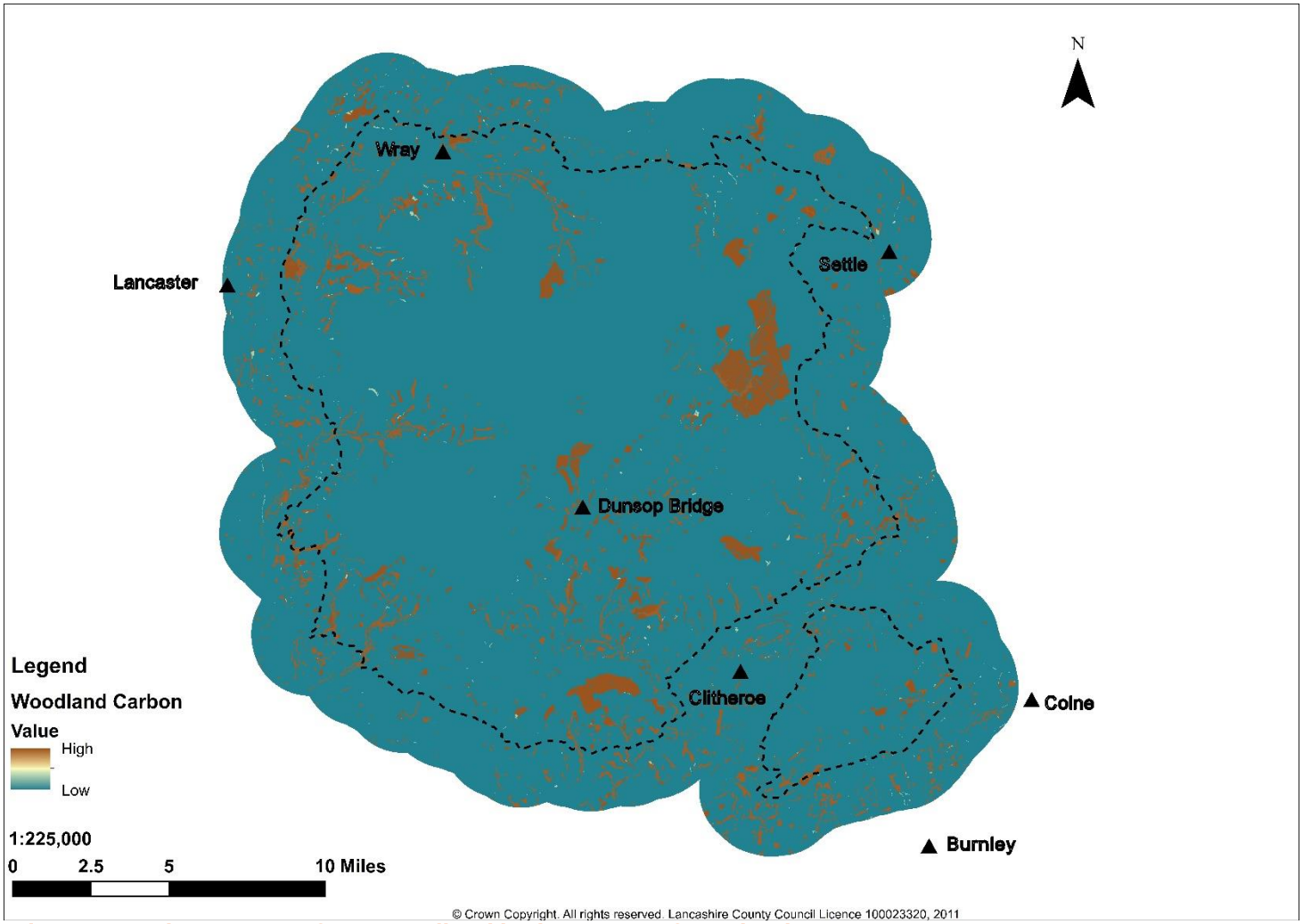
What does it show?

The map basically reflects woodland cover across the Forest of Bowland and does not distinguish between the conifer plantations of Stocks Reservoir and Longridge and the native broad leaf woodland in terms of carbon capture.

In the medium term conifers are a better choice than hardwoods, but in the long term (100+ years) oak and beech store as much as conifers (Dewar and Cannell, 1992).

Although it should be noted that these rapid growing plantations may not supply the other ecosystem services around landscape and biodiversity and indeed may have negative impacts upon water flow and biodiversity.

Carbon storage will be high both in woodland soils and the woodland itself. If woodland and forest are managed in a sustainable way, they perform a vital role both as carbon stocks and sinks, representing an important means of removing carbon dioxide from the atmosphere.



Figure#8 Carbon storage from woodland in the Forest of Bowland

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Carbon Sequestration from woodland

The accumulation or capture of carbon is referred to as 'carbon sequestration'.

The rate of carbon capture is closely related to the growth rate of the trees, and UK forests are among the most productive in northern Europe. Woodland has an additional benefit for climate change mitigation in that wood fuel and forest products can substitute fossil fuels and reduce the need for materials such as concrete, the production of which produces substantial greenhouse gas emissions. While naturally-regenerating forest in the shrub phase may only store 0.6 tonnes of carbon/ha/year, this rises to 2.4 tonnes/ha/year by 2050 as woodland becomes established and 4.1 tonnes/ha/year thereafter. Maximum sequestration rates in fast-growing British forests can be as high as 6-10 tonnes/ha/year, though this is more likely to be in lowland woodlands (Lamb et al, 2016).
At one extreme, minimal intervention can allow carbon stocks to build up and there are fewer emissions from forestry operations. On the other hand, if the objective is to store carbon rapidly, then choosing fast growing species on fertile land could be the best option.

The overall total sequestration of carbon from woodland in the Forest of Bowland is 42,545 TCO2/ha/year

Methodology

Carbon sequestration from woodland areas were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2018a,b). Coniferous woodland sequestration rates were averaged over an 80-year period and deciduous woodland sequestration rates were averaged over a 100-year period, as this is the length of a typical forestry cycle for deciduous woodland. Information on species composition was taken from the Forestry Commission 'National Inventory of Woodland and Trees, England, Regional Report for the NW' (Forestry Commission 2002) and AONB information sources. The annual sequestration rate for each woodland type were then multiplied by the area of each and added together to give the total annual sequestration estimate for woodland at the site. Parkland areas were included assuming a sequestration capacity of 20% of woodland, and dense continuous scrub was assumed to be 50%. Maps of the sequestration rate scaled from 0 to 100 were produced.

Further opportunities: linking to the Forest of Bowland AONB Management Plan

- Ensure existing woodlands are under good management.
- Create new woodland where this sits well alongside landscape, biodiversity and historic environment interests.
- Minimise the soil disturbance necessary to secure management objectives, particularly on organic soils.
- Avoid establishing new forests on soils with peat exceeding 50 cm in depth and on sites that would compromise the hydrology of adjacent bog or wetland habitats

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Carbon Emissions from deep peat soils

Methodology

The data sets of deep peat soils and deep peat soils over 50cm depth were merged. The shallow peat soils data were not included, as these are not considered to meet national definitions of peat: they are either shallower than true peat soils or have a lower density of carbon. (Evans, E. (2017))

Emissions factors were assigned to the areas of deep peaty soils based on their broad habitat type (e.g. woodland, bog, improved grassland, heathland), and these were derived from the work of Evans, et al (Evans, 2017). The quality of bog/mire habitats were broken down further by habitat type (e.g. dry modified bog, wet modified bog, raised and blanket bog) and assigned an emission factor taken from the Peatland Code Field Protocol (2017). According to the Peatland Code pristine peat, which can sequester rather than emit carbon, is very rare in Britain.

The total carbon emissions from deep peaty soils in the AONB = 73,419 tco2/ha/yr.

This means, as sequestration is lower than emissions, that there is a net emission of CO_2 for the AONB area.

Habitat	Emissions (tCO_2/ha/year)
Woodland	7.34
Cropland	26.42
Extensive grassland (incl. heathland)	13.21
Intensive grassland	23.49
Bog habitats	
Drained peat (e.g. dry modified bog)	4.5
Degraded peat (e.g. wet modified bog)	2.5
Near natural condition (e.g. raised blanket bog)	1.1

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Water flow capacity

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Water flow capacity

Water flow capacity is the capacity of the land to slowdown the run-off of water and thereby potentially reduce flood risk downstream. Following a number of recent flooding events in the UK and the expectation that these will become more frequent over the coming years due to climate change, there is growing interest in working with natural process to reduce downstream flood risk. These projects aim to “slow the flow” and retain water in the upper catchments for as long as possible. Maps of water flow capacity can be used to assess relative risk and help identify areas where land use can be changed.

Methodology

A bespoke model was developed, building on an existing EcoServ model and incorporating many of the features used in the Environment Agency’s catchment runoff models used to identify areas suitable for natural flood management. Runoff was assessed based on the following two factors and mapped for each 10m by 10m cell across the study area:

i) Roughness score – Manning’s Roughness Coefficient provides a score for each land use type based on how much the land use will slow overland flow.

ii) Slope score – based on a detailed digital terrain model, slope was re-classified into a number of classes based on the British Land Capability Classification and others.

iii) Standard % runoff – was obtained from soil data and modified to reflect soil hydrological properties and their sensitivity to structural degradation from agricultural use (from Broadmeadow et al 2013). This was integrated with a layer showing impermeable areas where no soil was present (sealed surfaces, water and bare ground)

Each indicator was normalised from 0-1, then added together and projected on a 0 to 100 scale, as for the other ecosystem services. Note that this is an indicative map, showing areas that have generally high or low capacity and is not a hydrological model.

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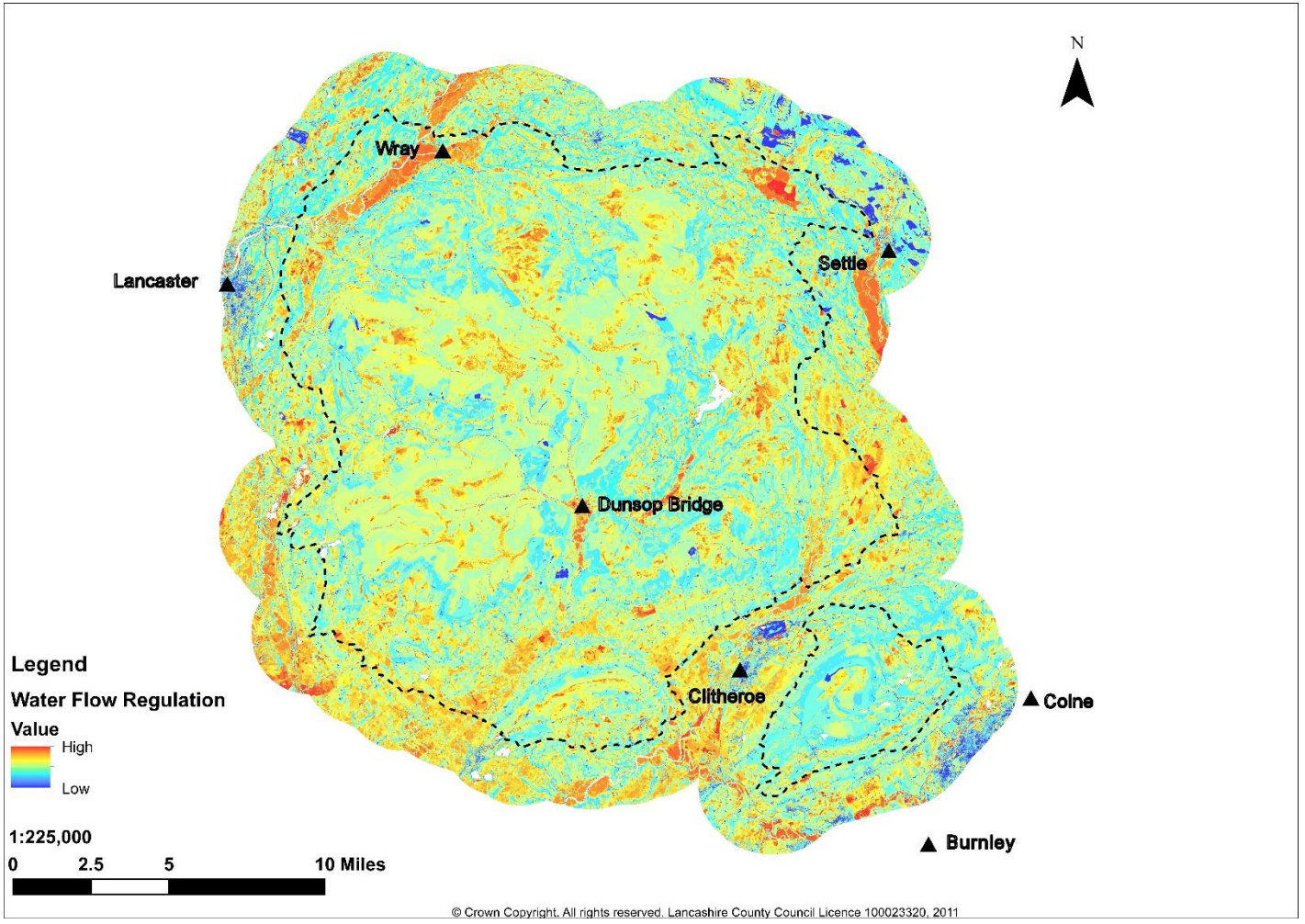
Water flow capacity

What does it show?

The areas with greatest potential for water flow capacity (orange/red) are either those floodplains immediately adjacent to the Rivers Lune (Wray – Lancaster) and Ribble (Settle - Clitheroe area) with potential for storage. And also those habitats with least hydrological connectivity (most hydrological 'roughness' as measured by Manning's equation) ie the moorland plateaux of the Bowland Fells SSSI.

Conversely those areas that 'amplify' flow (blue) are clearly urban areas and those steeper slopes of the moorland escarpment or in-bye land, which appear to shed water in response to extreme rainfall.



Figure#9 Water flow capacity in the Forest of Bowland

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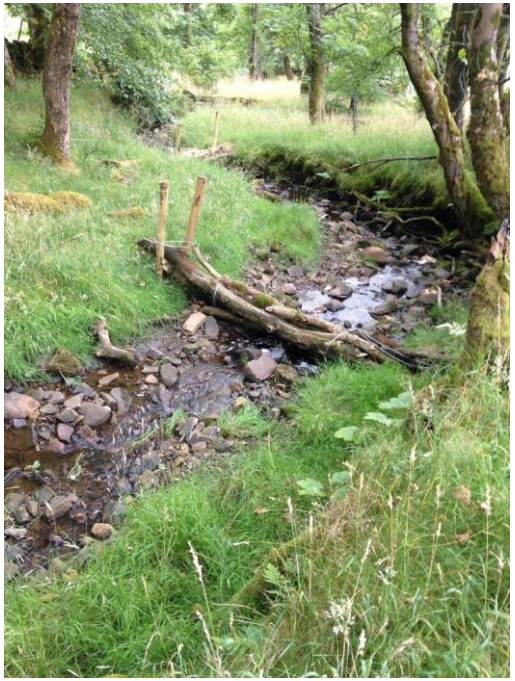
Water flow capacity

Opportunities: linking to the Forest of Bowland AONB Management Plan

- Reduce the degree of overland flow associated with moorland habitats by blocking grips and restoring the bryophyte community to increase storage capacity and reduce run off rates.
- Seek opportunities to expand areas of wetland habitats e.g. reedbeds, wet pastures and woodlands along valley bottoms
- Seek opportunities which allow rivers to follow natural courses and re-engage with their floodplains
- Increase the capacity of areas with existing low capacity by increasing surface roughness and run-off using natural flood management techniques



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Water quality capacity

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Water quality capacity

Water quality capacity maps show the risk of surface runoff water becoming contaminated with high pollutant and sediment loads before entering a watercourse, with a higher water quality capacity indicating that water is likely to be less contaminated. Although urban diffuse pollution is partially captured in the model at catchment scale, the focus is on sedimentation risk from agricultural diffuse pollution, hence built-up areas are not particularly well accounted for in the existing model.

Methodology

There is a strong link between the percentage cover of these land uses and pollution levels, with water quality particularly sensitive to the percentage of sealed surfaces in the catchment. At a fine scale, a modification of the Universal Soil Loss Equation (USLE) was used to determine the rate of soil loss for each cell. Over two thirds of the Forest of Bowland is in a Nitrate Vulnerable Zone: 55,000 hectares. (Natural England, 2010). This is based on the following three factors:

Distance to watercourse – using a least cost distance analysis, taking topography into account.

Slope length – using a flow accumulation grid and equations from the scientific literature. Longer slopes lead to greater amounts of runoff.

Land use erosion risk – certain land uses have a higher susceptibility to erosion and standard risk factors were applied from the literature. Bare soil is particularly prone to erosion.

Each of the three fine scale indicators and the catchment-scale indicator were normalised from 0-1, then added together and projected on a 0 to 100 scale.

A modified version of an EcoServ model was developed, which combines a coarse and fine-scale assessment of pollutant risk. At a coarse scale, catchment land use characteristics were used to determine the overall level of risk. The percentage cover of sealed surfaces and arable farmland in each sub-catchment was calculated and the values were re-classified into a number of risk classes.

Opportunities linked to the Forest of Bowland AONB Management Plan

Many of the land management proposals relating to flow (riparian planting strips, managing upland habitats riverine restoration) also have benefits for water quality, more specifically, woodland and trees next to water courses can provide a level of shade that support river ecology.

- Promoting the management of nutrient inputs to farmland, targeting applications to maximise uptake and minimise run-off.
- Managing fells, river banks, flood plains and wetlands for a robust vegetation cover that reduces soil erosion and water run-off, through appropriate grazing regimes.

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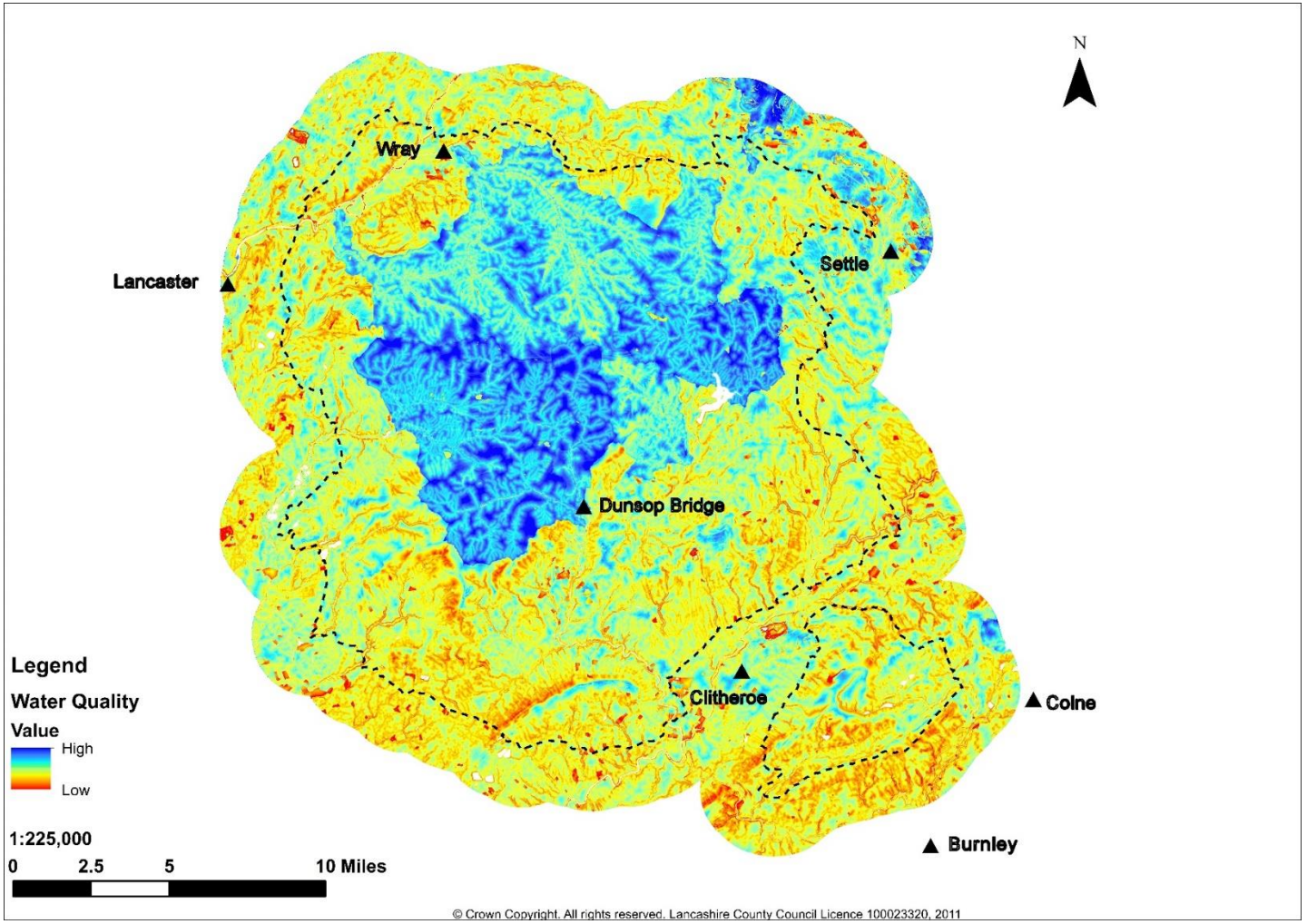
Water quality capacity

What does it show ?

Note : This is an indicative map, showing areas that have generally high or low capacity and is not a process-based model.

High values (blue) indicate areas that have the greatest capacity to deliver high water quality, coincidentally this is largely local water catchment land, managed by United Utilities.

Low values (red) indicate areas with a low capacity to improve water quality: this value can be increased by reducing the risk of run off and erosion through changing land cover and management.



Figure# 10 Water quality in the Forest of Bowland

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Accessible nature

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Accessible nature

Recent evidence shows that access to natural greenspaces for fresh air, exercise and quiet contemplation has benefits for both physical and mental health. Research provides good evidence of reductions in levels of heart disease, obesity and depression where people access greenspace.

Nature supports stress recovery by evoking positive feelings, reducing negative emotions, effectively holding attention/interest, and blocking or reducing stressful thoughts, thereby improving health outcomes (Ulrich, 1979; 1981; 1986; Ulrich *et al.,* 1991).Natural England and others have published guidelines that promote the enhancement of access, naturalness and connectivity of greenspaces. The two key components of accessible nature capacity are therefore public access and perceived naturalness. Both of these components are captured in the model, which maps the availability of natural areas and scores them by their perceived level of "naturalness".

Relating this to what we understand about how residents and visitors interact with the Forest of Bowland, in research undertaken by Lorraine Ritchen-Stones at the University of Lancaster in a study of 89 respondents with an awareness of the forest of Bowland, 11.8% of respondents use Forest of Bowland's landscape for the mental and physical health benefits it provides. Language used to describe positive mental health benefits included: *"healing, tranquil, peace, quiet, relax, play, inspiration, re-energise and escape".*
Physical activities predominantly include, hiking, walking, cycling, bird watching, and fishing. The qualitative analysis also shows that 23.4% of respondents demonstrated aesthetic appreciation of the Forest of Bowland.

Methodology

An EcoServ model was used to map accessible nature capacity. In the first step, accessible green spaces were mapped. These were determined from OS Mastermap Greenspace data, and data sets on public rights of way, access land, local nature reserves, accessible woodlands and others. Greenspaces that did not have full public access (e.g. golf courses, institutional grounds) were removed from further analysis. The retained areas were then scored for their perceived level of naturalness, with scores taken from the scientific literature. Naturalness was scored in a 300m radius around each point, representing the visitors' experience within a short walk of each point.
The resulting map shows accessible areas, with high values representing areas where habitats have a higher perceived naturalness score. Scores are on a 1 to 100 scale, relative to values present within the study area. White space shows built areas or areas with no public access.

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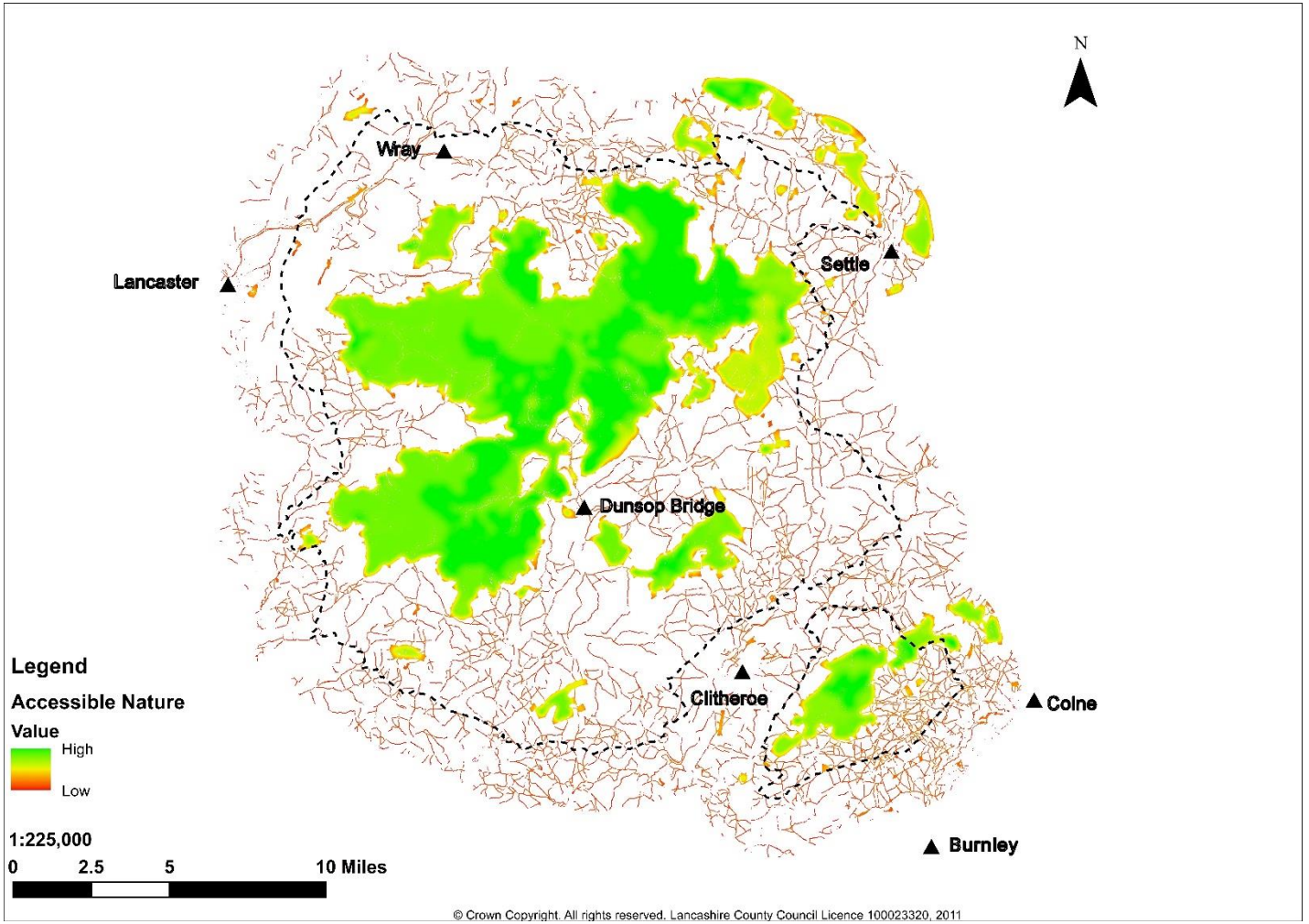
Accessible nature

What does it show?

This is not a very useful model for this ecosystem service as it does not include 'accessibility' ie the ease and frequency of access.
Larger continuous blocks of more natural habitat types will have higher scores than smaller isolated sites of the same habitat type.
The access land in the centre of the Forest of Bowland scores highly (despite it being remote and not heavily used) as does the extensive accessible woodland such as Gisburn Forest (which is a popular destination.)
There is an extensive network of paths and linear routes throughout the AONB which appear low scoring (this may be due to the use of 300m focal buffers around each point).



Figure#11:Accessible nature in the Forest of Bowland

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Conclusion and Next Steps

Whilst the Forest of Bowland can feel remote it is also on the doorstep of the towns and cities of Lancashire and North and West Yorkshire. The AONB supplies essential services whether this is the supply of clean drinking water, the need to alleviate downstream flooding in the upper reaches of the catchment, and to continue providing recreational opportunities and maintain the cultural heritage for a growing population.

It is vital to ensure that these natural capital assets are managed to ensure provisioning and regulating services, but cultural services are extremely important to the Forest of Bowland too. Work carried out by the AONB identifies how important the area is to residents and visitors and how this manifests in a sense of wellbeing.

There is a perceived need to manage the landscape for multiple-benefits. The key is to understand which habitats can be ecologically restored, extended or created, and where these should be located, to ensure that benefits are maximised and risk reduced. The report provides evidence to focus on how to restore habitats that deliver multiple services.

Next Steps

There is further work that could be done to create a more comprehensive baseline of the ecosystem services provision. Only a subset of services has been measured. There is much more work to be undertaken on the cultural services, recreation, health and well-being. There are also opportunities to map timber production, renewable energy and soil erosion control.

It would be useful to express any increases (or losses) in ecosystem services in monetary terms. Placing a value on ecosystem services has been undertaken in other designated areas such as Dorset AONB. This should be seen as making these 'services' more visible rather than necessarily placing a price tag on these services. This is a subject area where the AONB may wish to work with outside partners in developing a basis for natural capital accounting and innovative approaches to nature-based solutions. Indeed this is an area that the Northern Upland Chain Local Nature Partnership has sought to develop under its Natural Capital Investment Plan. Payments for Ecosystem Services (PES) have been identified as a measure that can encourage changes in land management, for example, in promoting natural food management through woodland planting there are other potential benefits in terms of biodiversity and water quality.

Appendix 1: Ecosystem Services

ECOSYSTEM SERVICES IN THE FOREST OF BOWLAND AONB	
Provisioning Services	**RELEVANT OBJECTIVES IN MANAGEMENT P**LAN
Food:	Suckler beef, diary, sheep
Water:	United Utilities extracting water from the headwaters of the main rivers and via key reservoirs at Stocks, Barley and Barnacre
Timber:	Gisburn
Energy:	Wind, woodfuel
Rock and minerals:	Aggregate
Supporting Services	
Wildlife habitats and species:	16,000 ha of nationally important Sites of Special Scientific Interest (23 sites, covering 13% of the AONB The area is important for breeding birds especially raptors including hen harrier, peregrine and merlin; and waders such as lapwing, curlew, redshank and snipe.
Geodiversity:	
Nutrient cycling:	
Cultural Services	
Sense of place:	The 'Forests' , the fells , the sense of wildness and local distinctiveness
Heritage:	the area holds almost 900 listed buildings and designated heritage assets (818 Listed Buildings, 48 Grade I and II* Listed Buildings, 20 Scheduled Monuments
Tranquillity:	The Bowland Fells also offer some of the darkest skies in England with low levels of pollution. Tranquillity and 'dark skies' can add to the tourism offer of the area as well as to residents' health and well being.
Recreation	Beacon Fell country Park Gisburn Forest An excellent network of public rights of way and over 25,000 ha of open access land
Tourism:	European Charter for sustainable tourism in protected areas in both 2005 and 2010 ……the 'food' offer
Knowledge and education:	school visits to farms, arts workshops and performances, bird watching safari's, field studies for students; and opportunities for volunteering in traditional countryside skills. In 2013 the Festival Bowland programme offered over 120 events and attracted in excess of 1300 participants
Health & wellbeing:	On the doorstep of East Lancashire where need to improve health outcomes
Regulating Services	
Regulating climate change:	carbon dioxide is absorbed by farmland and woodland and perhaps most importantly by blanket bog. Restoring blanket bog and eroding peat so that it can become an active carbon store is a vital contribution to mitigating against climate change.
Regulating soil erosion:	the risk of soil erosion in the AONB is high; due to the high peat content, steep slopes and high rainfall of the area.
Regulating soil quality:	Loss of organic matter
Regulating water quality:	Reducing Dissolved Organic Carbon (ie SCaMP with United Utilities)
Flood control:	Mitigating surface water run-off - Assisting 'Slow the Flow' Reconnecting with floodplains

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Appendix 2: Sources of data

Spatial Dataset	Source
OS MasterMap topography layer (Vector)	OS website - https://www.ordnancesurvey.co.uk/business-and-government/products/topography-layer.html
Other topographic base layers [1:25000 / 1:50000] (Raster)	https://www.ordnancesurvey.co.uk/business-and-government/products/25k-raster.html. 2. https://www.ordnancesurvey.co.uk/business-and-government/products/50k-raster.html.
BAP habitat (Vector)	National BAP dataset. Required pre-processing to determine if each polygon was BAP quality or not, and to classify each habitat to fit with Eco-Serv requirements
Broad Habitats (Vector)	Magic [Natural England Datasets] http://www.natureonthemap.naturalengland.org.uk/dataset_download_summary.htm.
Local wildlife sites (Vector)	
Landcover 2007 [although Landcover 2015 now available] (Raster 25m / Vector)	Centre for Ecology and Hydrology (CEH) website: https://www.ceh.ac.uk/services/land-cover-map-2007.
Corrine European habitat data (CLC 2006)	European Environment Agency modified and used to identify quarries, industry and golf courses, and to distinguish arable from pasture.
Urban Land Use (Landcover 2007 Vector / Raster)	Landcover 2007 (from CEH website)
Designations	Magic [Natural England Datasets] http://www.natureonthemap.naturalengland.org.uk/dataset_download_summary.htm.
Agricultural Land Classification (ALC)	Magic [Natural England Datasets] http://www.natureonthemap.naturalengland.org.uk/dataset_download_summary.htm.
Ancient Woodland	Ancient Woodland Data Inventory [Natural England Dataset] http://www.gis.naturalengland.org.uk/pubs/gis/tech_aw.htm. OR http://www.natureonthemap.naturalengland.org.uk/dataset_download_summary.htm.

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Appendix 3: Glossary of terms

Ecosystem services The direct and indirect (intrinsic) contribution of ecosystems to human wellbeing.

Natural Capital: The parts of the natural environment that produce value to people.

Natural Capital Approach: A means for identifying and quantifying natural resources and associated ecosystem goods and services that can help integrate ecosystem-oriented management with economic decision-making and development.

Natural Capital Asset register: A catalogue of the significant assets which includes data on the asset extent, condition, services and benefits delivered. A register of natural capital can therefore be defined as a "way of making natural assets and their benefits explicit."

Habitat opportunity mapping: A Geographic Information System (GIS) based approach used to identify potential areas for the expansion of key habitats. It aims to identify possible locations where new habitat can be created that will be able to deliver particular benefits, whilst taking certain constraints into account.

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