Natural Capital Assessment of the New Forest

June 2021

NATURAL CAPITAL RESEARCH LTD

NATCAP
RESEARCH

The Team

Professor Dieter Helm – Director

Dieter Helm CBE is Professor of Economic Policy at the University of Oxford and a Fellow in Economics at New College, Oxford. Dieter is Chair of the UK Government's Natural Capital Committee and has been actively involved in the development of the 25 Year Environment Plan, the new agricultural policy and ELMs, the Agricultural and the Environment Bills, including the net biodiversity gains planning policies. He chairs the Environment Group and is a Vice President of BBOWT. He is the author of Natural Capital and, most recently, his new book Net Zero: How We Stop Causing Climate Change. Dieter guides the company's research and analysis on the economics and accounting of natural capital, including valuation, environmental markets notably in carbon, green finance and investments, and land management assessments.

Professor Kathy Willis – Director

Katherine Jane Willis CBE is a Professor of Biodiversity at the University of Oxford. Until recently she was the Director of Science at the Royal Botanic Gardens, Kew. She is also a member of the UK Government's Natural Capital Committee. She has over 30 years of research experience focusing on modelling and remotely determining important landscapes for biodiversity and ecosystem services across the world. Most recently she has been leading a team in Oxford to develop new and emerging technologies to assist land managers in decision-making to ensure the best outcomes for business and biodiversity. Over the past 10 years, Kathy has also been closely involved in the scrutiny of International, UK and local government policies associated with biodiversity, wildlife trade, and nature/climate change. Most recently she has been involved in providing detailed analysis and scrutiny of the scientific evidence-base underpinning the Government's 25 Year Environment Plan, the Biodiversity Net Gain Bill, ELMs scheme and the Environment Bill (in its second reading) and the Natural Capital Committee's advice on Using nature-based interventions to reach net zero greenhouse gas emissions by 2050. She guides the company's scientific research and analysis on Natural Capital and nature-based interventions and enhancements.

Julian Metherell - Director

Julian Metherell is a partner of MW&L Capital, a private investment firm he co-founded in 2018. MW&L has investments in the energy, shipping, agriculture and fintech sectors. In addition, Julian farms in East Anglia where he is investing to restore the habitat and ecology of an Estate which includes an important SSSI. Julian spent the majority of his career in investment banking. He was a partner of Goldman Sachs and served as Chief Executive of the UK Investment Bank from 2006 - 2011 advising clients in the natural resources and utility sectors on M&A and financing. He currently sits on the board of Gaslog, a leading international LNG shipping business where he chairs the Sustainability Committee. In addition, he is chair of the Advisory Board, at the Cambridge Judge Business School and a Trustee of the Royal Opera House

Dr Abigail Barker – Chief Operations Officer

Abigail Barker is the COO of Natural Capital Research with responsibility for establishing and growing the company. Prior to this, Abigail spent over 10 years at the Royal Botanic Gardens, Kew where she was the Head of Science responsible for Biodiversity Informatics and Spatial Analysis. At Kew, Abigail oversaw a team tasked with applying modern IT and spatiotemporal techniques to maximise the potential of Kew's collections. Abigail, together with Prof. Kathy Willis, led the delivery of the groundbreaking *State of the Worlds Plants* reports and was responsible for delivering the Plants of the World Online portal. Abigail has a PhD in spatial and statistical modelling of heathland ecosystems and has over 20 years hands-on experience of big data, socio-demographic and spatial analysis and modelling.

Dr Beccy Wilebore – Head of Research

Beccy Wilebore leads the natural capital research (team) at NCR with responsibility for setting the science vision and overseeing model development. She is a quantitative ecologist with 10+ years of experience at the interface between natural sciences and economics. During her postdoctoral research at the University of Oxford and Royal Botanic Gardens, Kew, she used large-scale geospatial and hydrological models to map and quantify ecosystem services from natural capital. She also specialises in data analysis from earth observation and remote sensing. Beccy was previously a NERC Knowledge Exchange Fellow on natural capital and holds a PhD in forest ecology and REDD+ from the University of Cambridge.

Dr Carole Adolf

Carole Adolf is a plant ecologist and climate scientist specialising in the impact of climate change, land-use and disturbances, such as wildfire, on plant distributions and biodiversity across space and time. She focuses on statistical and spatial models, while also incorporating long-term data into her analyses to identify the full range of natural variability in ecosystem responses to climatic and land-use change. Carole is an associated researcher at the Oxford Long-Term Ecology Laboratory at University of Oxford and has a PhD in Climate Sciences from the University of Bern, Switzerland.

Lorna Burnell

Lorna Burnell is in the process of submitting her PhD thesis, which focuses on the risks to global water resources from geoengineering the climate with solar radiation management. She specialises in hydrological modelling at the global scale, with a particular focus on water scarcity and drought assessment. Lorna has a BSc (First Class) in Geography from the University of Nottingham where she won the McGuckin Physical Geography Prize for best dissertation (Building and testing a fuzzy inference system to assess local flood risk perception in Burnham-on-Sea) and the University Prize for Geography for best undergraduate student.

Katey Fisher

Katey Fisher graduated with a BSc (Hons) in Zoology from the University of Liverpool where her final year project focussed on the biological traits contributing to encephalization in pinnipeds in comparison to cetaceans. Katey's previous roles include research in terrestrial and marine conservation, and she is committed to sustainable social and environmental change. Katey previously worked as part of the research team at Estación Biológica de Doñana, Sevilla, researching the functional links in avian, microbial, macrophyte, and invertebrate greenhouse gas output stimulation. Katey is also experienced in international operations and sales, having recently left a role with Operation Wallacea where she worked on worldwide field research programmes.

Dr Sophie Flack-Prain

Sophie Flack-Prain is an ecosystem modeller who explores biosphere-climate interactions. Her research focuses on understanding ecosystem functioning through a combination of process-driven and data-driven models. Her work on tropical crops addresses key issues around future production and the vulnerability of crops to climate extremes. Sophie has a PhD in Atmospheric and Environmental Sciences; her thesis looked at the role of carbon allocation and trait optimality in driving Amazon forest responses to changing water availability.

Joel Footring

Joel Footring recently graduated with BA Biological Sciences (First Class) from the University of Oxford. His final year project contributed to the Gates Foundation Humbug project and the development of the MozzWear app. He used specimens from the Oxford University Natural History Museum and the Natural History Museum (London) to identify the morphological determinants of the acoustic signatures of five mosquito species. He has also spent time doing practical ecological work with Derbyshire Wildlife Trust and the University of Nottingham.

Dr Rhosanna Jenkins

Rhosanna is an interdisciplinary scientist with extensive experience of spatial analysis and modelling. Her academic background ranges from climate change impact analysis and nature recovery to low carbon energy innovation and sustainable tourism. She holds a PhD in Environmental Sciences from the University of East Anglia. Her thesis modelled projected changes to the water resources, biodiversity and agriculture of southern Kenya as a result of climate change and development plans.

Associate Prof. Marc Marcias-Fauria

Marc Macias-Fauria is an ecologist who focuses on cold environments, he is an Associate Professor in Physical Geography at the University of Oxford and a NERC Fellow. His research focuses on understanding the coupling of physical and biological systems (biogeoscience). He employs long-term ecological records and modelling to understand ecological and biogeographic processes as they are constrained by the physical environment. He gained a degree in Biology at the University of Barcelona, an MSc at the Department of Biological Sciences, University of Calgary, and a PhD at the Department of Geology (now Department of Geosciences & Geography), University of Helsinki, where he studied the climate controls on boreal forest wildfires, tree-growth, and insect outbreaks

Dr Thea Piovano

Thea is an environmental modeller, specialising in hydrology. As a PhD student in the University of Aberdeen, she worked on hydrological modelling at the catchment scale, with a focus on spatially distributed tracer-aided rainfall-runoff models to investigate water storage and fluxes in cold region catchments. She has experience in mapping and geospatial data analysis. She has a master's degree in Environmental Engineering from Politecnico di Torino.

Dr Anna Zanchetta

Anna is a researcher specialised in geospatial data analysis. Her academic background ranges from physics of the atmosphere to water management in developing countries and engineering. During her PhD she focused on remote sensing techniques for desertification studies in the Middle East region and has recently completed a PostDoc in Technion about equity in transport. Anna is a true believer and promoter of free and open source software and its application for social and environmental benefit. She holds a PhD in Geomatics and Environmental Engineering from Bologna University.

Dr Florian Zellweger

Florian Zellweger is an environmental scientist whose research uses high-resolution remote sensing and large field databases to understand how forests and natural capital are responding to global change drivers such as climate and land management change. Florian's current research focuses on developing detailed spatial models to quantify and monitor carbon stocks and sequestration, as well as biodiversity, for the sustainable management and conservation of natural resources. His work furthers the understanding of how biodiversity and ecosystem functioning are changing in an increasingly human-dominated world. Florian has a PhD in forest ecology and remote sensing from ETH Zurich and was a Postdoctoral Fellow at the University of Cambridge.

Executive Summary

The Solent Local Enterprise Partnership (LEP), together with the Fawley Waterside Partnership and a range of stakeholders, comissioned Natural Capital Research Ltd to develop a natural capital baseline assessment for four sites: Associated British Ports' (ABP) waterside landholdings, the Barker Mill Estate, the Cadland Estate, and the New Forest National Park (NFNP).

To quantify the natural capital assets for each study site, we followed a four-step process:

1) Mapping the extent and quality of current natural capital assets (**stocks**) for each study site. We determined the stocks of natural capital in the following assets:
    i) Landcover (for example woodlands and grasslands)
    ii) Woodlands, trees and hedge composition (height and species)
    iii) Water and wetlands
    iv) Topography
    v) Soil type

2) Calculation of the ecosystem services (or **flows**) from these stocks. We determined, in physical units where possible, the flows of the following ecosystem services:
    i) Carbon storage in vegetation and soils
        (a) Carbon storage in woodlands
        (b) Carbon storage in trees and vegetation outside of woodlands
        (c) Carbon storage in topsoils
    ii) Carbon sequestration in vegetation
        (a) Carbon sequestration in woodlands
        (b) Carbon sequestration in trees and vegetation outside of woodlands
    iii) Soil erosion prevention
    iv) Flood risk reduction
    v) Nutrient runoff (areas contributing the least to nitrate runoff through vegetation and land management practices)
    vi) Recreation (areas that are estimated to have high numbers of visits per year)
    vii) Pollination (important areas for supporting insect pollinators of crops)
    viii) Important biodiversity habitats
    ix) Nature networks

3) Creation of **summary maps** displaying the distribution of these services across each study site

4) Creation of **a total combined service provision** for each study site, and a full asset register.

This report details our findings for the New Forest National Park. It presents a series of maps displaying the estimated spatial configuration of these natural capital assets across the reporting areas, the ecosystem service flows from them and the hotspots where multiple benefits occur. It also provides the results in tabular form comprising a set of asset registers detailing the baseline quantity of services provided across the sites.

A summary of the key findings is set out below. The baseline asset register details the total ecosystem service flows that are estimates from natural capital in the National Park and wider study area. The summary heatmap combines multiple services to show the areas from which the largest concentrations of ecosystem services flow.

Register detailing the total ecosystem service flows for the NFNP

Ecosytem Service Flow	New Forest National Park					Fawley Waterside & NFNP study area	
	Total		Relative value			Relative value	
Carbon storage in vegetation and soils	31,848,330	tCO2e	562.2	tCO2e/ha		467.0	tCO2e/ha
Trees in Woodlands	8,442,295	tCO2e	444.4	tCO2e/ha		138.8	tCO2e/ha
Trees and vegetation outside of woodlands	2,155,113	tCO2e	58.0	tCO2e/ha		41.0	tCO2e/ha
Topsoils	21,250,922	tCO2e	375.1	tCO2e/ha		307.4	tCO2e/ha
Carbon sequestration in vegetation	72,101	tCO2e/yr.	1.3	tCO2e/ha/yr		1.3	tCO2e/ha/yr
Trees in woodlands	51,425	tCO2e/yr.	0.9	tCO2e/ha/yr		1.0	tCO2e/ha/yr
Trees and vegetation outside of woodlands	20,677	tCO2e/yr.	0.4	tCO2e/ha/yr		0.3	tCO2e/ha/yr
Soil erosion prevention	186,929	tonnes soil loss avoided/yr	3.3	tonnes soil loss avoided/ha/yr		2.8	tonnes soil loss avoided/ha/yr
Flood risk reduction	179,400,020	m3 runoff avoided/yr	3,166.7	m3 runoff avoided/ha/yr		2,408.8	m3 runoff avoided/ha/yr
Recreation	10,381,300	number of visits/yr		n/a			n/a
Important areas for supporting insect pollinators of crops	22,919	ha	40.5	% of total area		40.3	% of total area
Important biodiversity habitats	39,317	ha	69.0	% of total area		55.0	%

Nature networks reflect spatial configurations of habitats so are not summarised in this table

Hotspots of ecosystem services provision for the New Forest National Park showing where the multiple ecosystem services overlap. The higher the value (red) the more ecosystem services are provided per unit area. All ecosystem services are equally weighted.

Introduction

Natural capital is the term used to describe those parts of the natural environment (species, habitats, communities, landscapes, soils, water, air) that provide essential ecosystem services, such as carbon dioxide (CO_2) sequestration and carbon storage, waterflow regulation, soil erosion protection, pollination and important areas for biodiversity. These services in turn underpin key societal benefits including, for example, equable climates, flood risk reduction, clean water, clean air, physical and mental wellbeing and thriving wildlife.

In describing natural capital assets, it is usual practice to view them in terms of the natural capital assets (stocks), the ecosystem services (flows) from these stocks, and their societal benefits (Fig. 1).
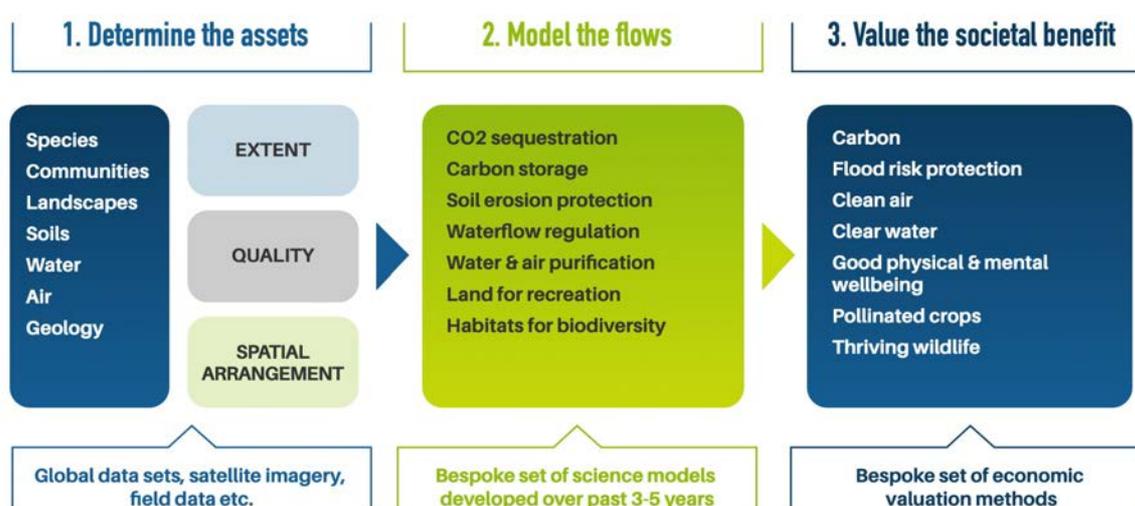
Figure 1: Schematic diagram to illustrate the relationship between natural capital assets (stocks), ecosystem services (flows) and societal benefits. Note that a single asset can provide multiple ecosystems services/positive societal outcomes.

Natural Capital Research Ltd.

The need to determine natural capital stocks, flows and societal benefits, is moving rapidly up the global political agenda, not least because nature-based interventions are now widely recognised by individuals, businesses and governments as key to achieving net-zero greenhouse gas emissions. Since its inception in September in 2018, Natural Capital Research Ltd (NCR) has been working with a large number of clients, from individual Estate owners to service industries, local governments and conservation organisations, to help them understand and quantify their natural capital.

Our natural capital baseline assessments are tailored specifically to the client's requirements but usually include: i) a detailed quantitative understanding of the spatial configuration of natural capital assets on their land and the flows from them (e.g. tonnes/ha CO_2 sequestered, tonnes/ha of carbon stored etc.); ii) modelled output indicating where the greatest opportunities exist on their land holdings to further enhance natural capital assets (e.g. where further planting of trees will provide the greatest benefit); iii) a natural capital asset register; and iv) analysis of the client's business activities/outputs to assess their impact on natural capital through their activities. These assessments allow our clients to understand what they already possess in terms of natural capital assets (baseline), what they could do to enhance them further, how to reduce the impacts of their activities on natural capital, and how to

ultimately achieve net-zero emissions. In addition, we provide bespoke methodological frameworks to enable our clients to measure and assess progress towards their environmental sustainability targets each year.

This project

The objective of this study was to create a baseline natural capital asset register (stocks and flows) for four sites within the Fawley Waterside Partnership area which also are key sites in the Solent LEP.

The Solent LEP is a coastal LEP, with an economy that is intrinsically linked to and influenced by the coast and maritime activities. The LEP includes three Islands, three peninsulas, and 340 miles of coastline. The mainland part of the Solent is the most urbanised area of southern England, outside of London, and is home to a range of nationally and internationally significant industrial assets such as the Port of Southampton, the ExxonMobil Refinery, HM Naval Base in Portsmouth, and an international airport. These industrial assets sit adjacent to an outstanding and internationally recognised natural environment - covering both land and sea - that includes the Solent Waterway, the New Forest National Park and the Isle of Wight Biosphere. Although the scope of this project was limited to the areas directly impacted by the planned development of the Fawley Waterside, it is important to recognise the wider economic and natural landscape in which they are situated and the value of the Natural Capital of the New Forest National Park area to the wider Solent economy.

One of the seven priorities for the Solent LEP set out in the Delivery Plan for 2021 is to pioneer approaches to climate change adaptation and decarbonisation with a specific objective to "utilise the Solent's geography and industrial strengths to enhance economic resilience and become a leading hub for environmentally friendly innovation". This natural capital baseline is core ot the delivery of this objective.

The four sites for which a natural capital baseline was produced are the Associated British Ports' (ABP) waterside landholdings, the Barker Mill Estate, the Cadland Estate, and the New Forest National Park (NFNP). All fall within the Fawley Waterside area, with the NFNP area covering a wider area outside of Fawley Waterside. This baseline was designed to provide a clear and comprehensive evidence base on the state of natural capital at each site for the year 2020, and quantification of the flows of important environmental services from those assets in physical units. The results are presented in maps and tabular form in the sections below.

The results in this report give a thorough representation of the stocks and service flows from terrestrial aboveground natural capital, freshwater and topsoils. The models used in this report are sensitive to the role of vegetation in providing ecosystem services. Littoral habitats such as coastal saltmarsh and mudflats, as well as areas of deeper peat in the national park, have been highlighted as areas for future work to further extend the understanding of natural capital in the region.

Study Site

New Forest National Park

The New Forest National Park was designated in 2005 and covers 56,658 hectares (220 square miles) on the central south coast of England, within the counties of Hampshire and Wiltshire. It is home to more than 35,000 people.

National Parks are protected landscapes recognised to be of the highest national importance for the natural beauty of their landscapes, the value of their wildlife habitats and cultural heritage and the opportunities they give for many people to enjoy these qualities.

The New Forest is uniquely special, representing the remarkable survival of an unenclosed lowland landscape. It hosts wild species and traditional management practices at a scale that has long disappeared from the rest of western Europe. This gives the area global significance for its biodiversity, cultural continuity and public appreciation.

The New Forest National Park Authority has statutory purposes and socio-economic responsibilities as specified in the Environment Act of 1995:

- To conserve and enhance the natural beauty, wildlife and cultural heritage of the area
- To promote opportunities for the understanding and enjoyment of the special qualities of the National Park by the public.

Working in partnership with other organisations it is also the Authority's duty in furthering Park purposes, to seek to foster the economic and social well-being of the local communities within the National Park.
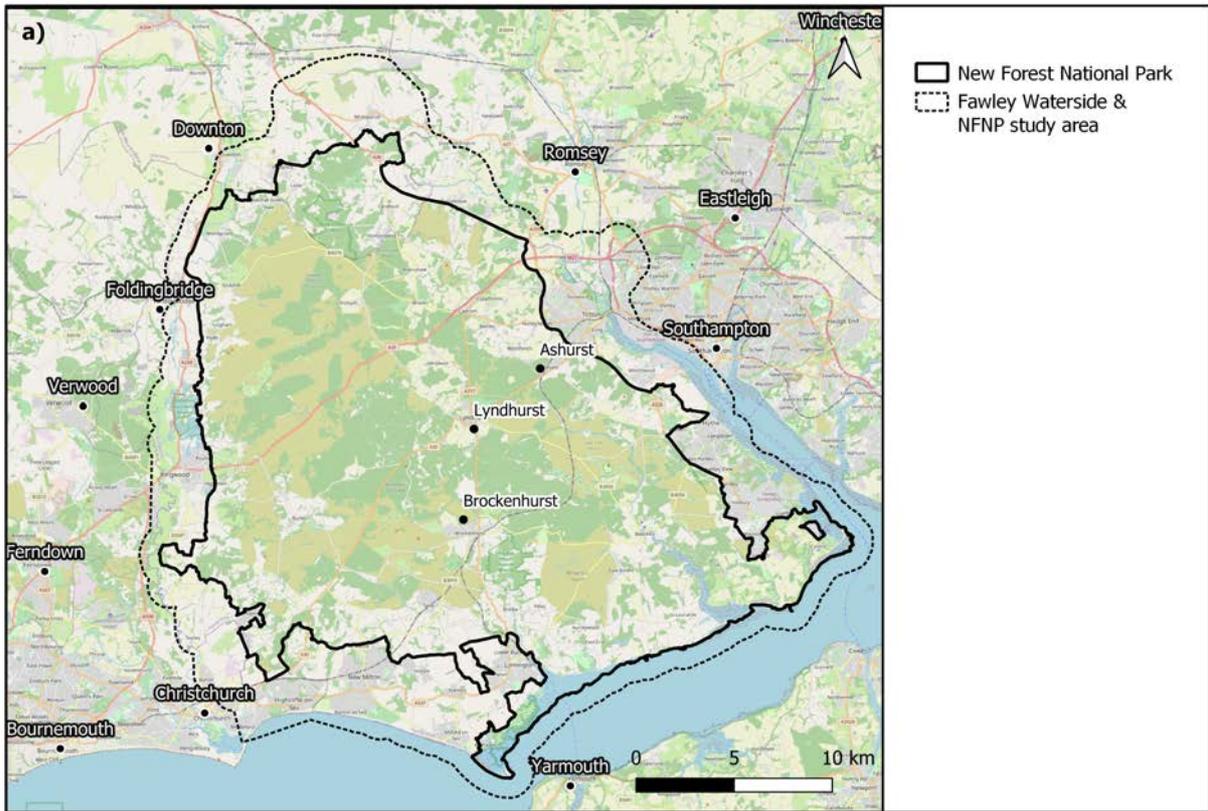
Figure 2: The New Forest National Park

Determining the Natural Capital Assets (Stocks) of New Forest National Park

Natural capital assets are those biotic and abiotic features of the environment that underpin important ecosystem services flows. These features include the type of landcover, species of trees, height of the tree canopy, topography and angle of slopes of the drainage basin catchments, the presence of freshwater bodies and rivers, and soil type.

Methodological approaches and data sources used to determine the natural capital assets in the New Forest National Park are provided in Appendix 1 and results from our mapping of these assets are as follows:

Landcover

Figure 3 displays the estimated landcover across the New Forest National Park (NFNP). Around a third of the NFNP is classified as woodland, with 13,307 ha (23% of the site) classified as broadleaved mixed and yew woodland and another 5,690 ha (10% of the site) as coniferous woodland. Almost a fifth (18%, 9,935 ha) of the NFNP is dwarf shrub heath. Significant areas of farmed land exist around the edges of the NFNP, including 15% (8,219 ha) modified grassland (Appendix 2: Asset register 2a). Surrounding the National Park are high densities of built-up areas and gardens, both along the waterside and across the water in Southampton (partially mapped).
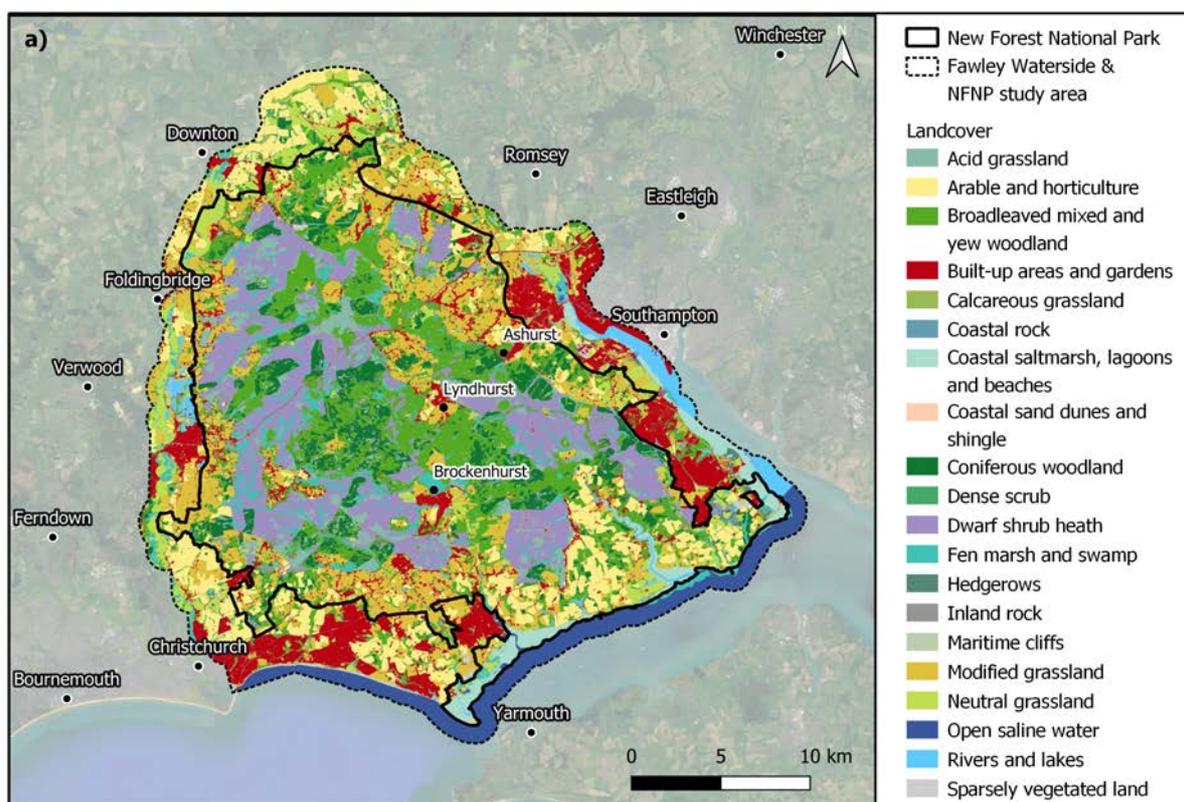
Figure 3: Landcover map for the New Forest National Park.

Forest, Trees and Hedges Composition (height and species)

Woodlands within the New Forest National Park are dominated by broadleaf species (13,307 ha). The broadleaved mixed and yew woodland has an average canopy height of approximately 17.2 m (Fig. 4) whereas the coniferous woodland has a slightly lower average canopy height of 14.5 m (Appendix 2: Asset register 2b). This likely reflects the age and management of the respective woodland types. Trees outsides of woodlands and hedgerows[1] in the NFNP are estimated as an average of 1.2m tall. Canopy height estimates are utilised in the carbon storage and sequestration model (and the supporting age and yield class models).
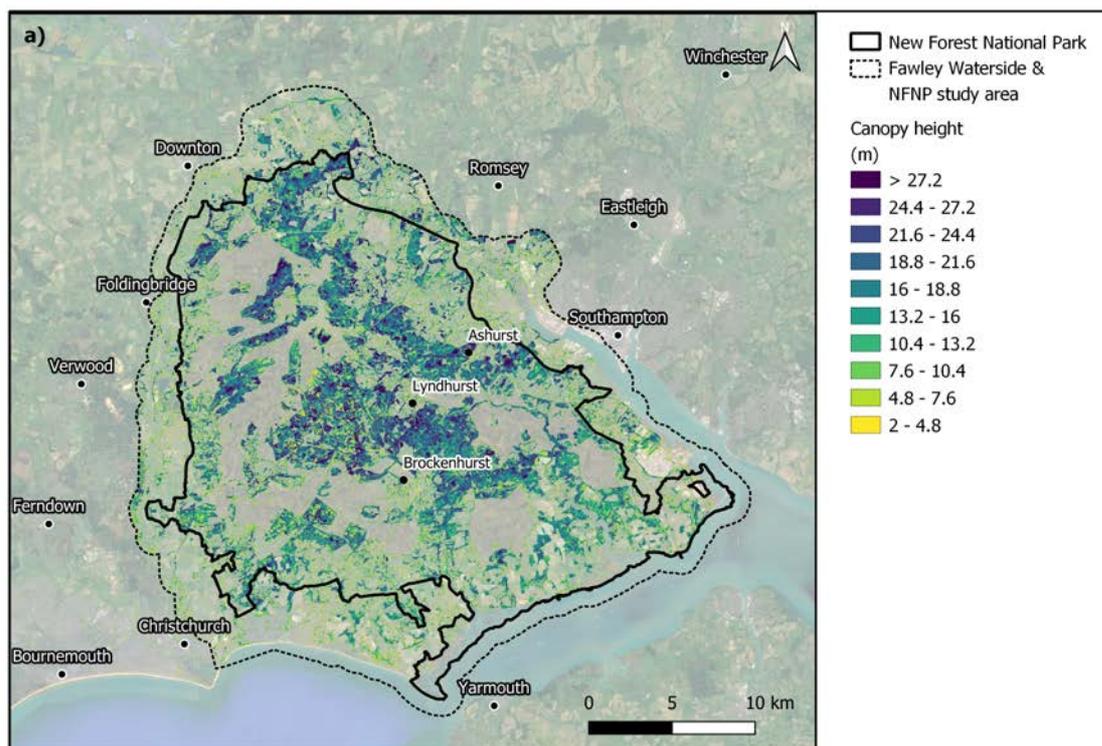
Figure 4: Canopy heights within the New Forest National Park.

---

[1] Mapped using the National Tree Map (NTM)

Topographical variation of the land

A digital elevation model of the New Forest National Park (Fig. 5) indicates that the study area has a variable range of elevations from sea-level to 145m. The greatest elevations found in the north of the National Park, with acid grassland, dwarf shrub heath and woodlands (both coniferous and broadleaf) associated with the highest land.

Similarly, the slope of the land shows considerable variation across the National Park (Fig. 6). (Appendix 2: Asset register 2c). Coniferous and broadleaved woodlands are associated with the steepest slopes, as well as maritime cliffs. Arable and horticultural land and neutral grasslands are associated with shallow slopes.
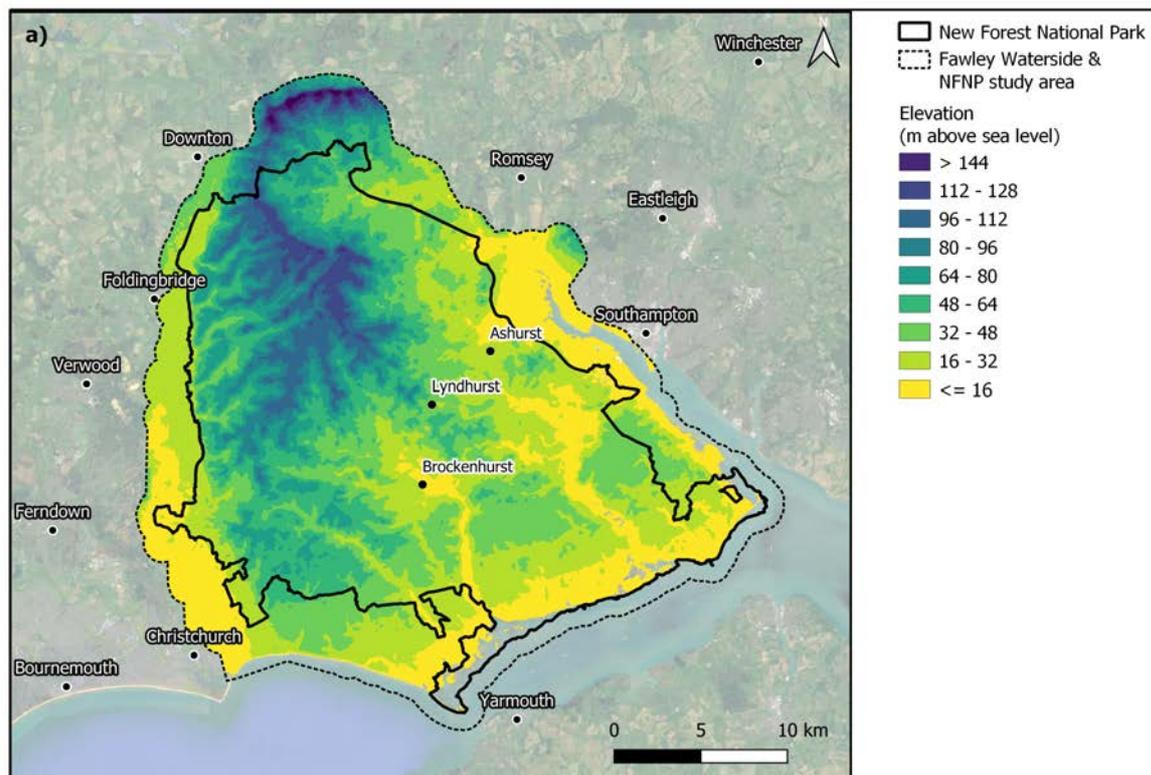
Figure 5: EU Digital Elevation (EU DEM v1.1) of the New Forest National Park. The elevation is shown in metres above sea level.
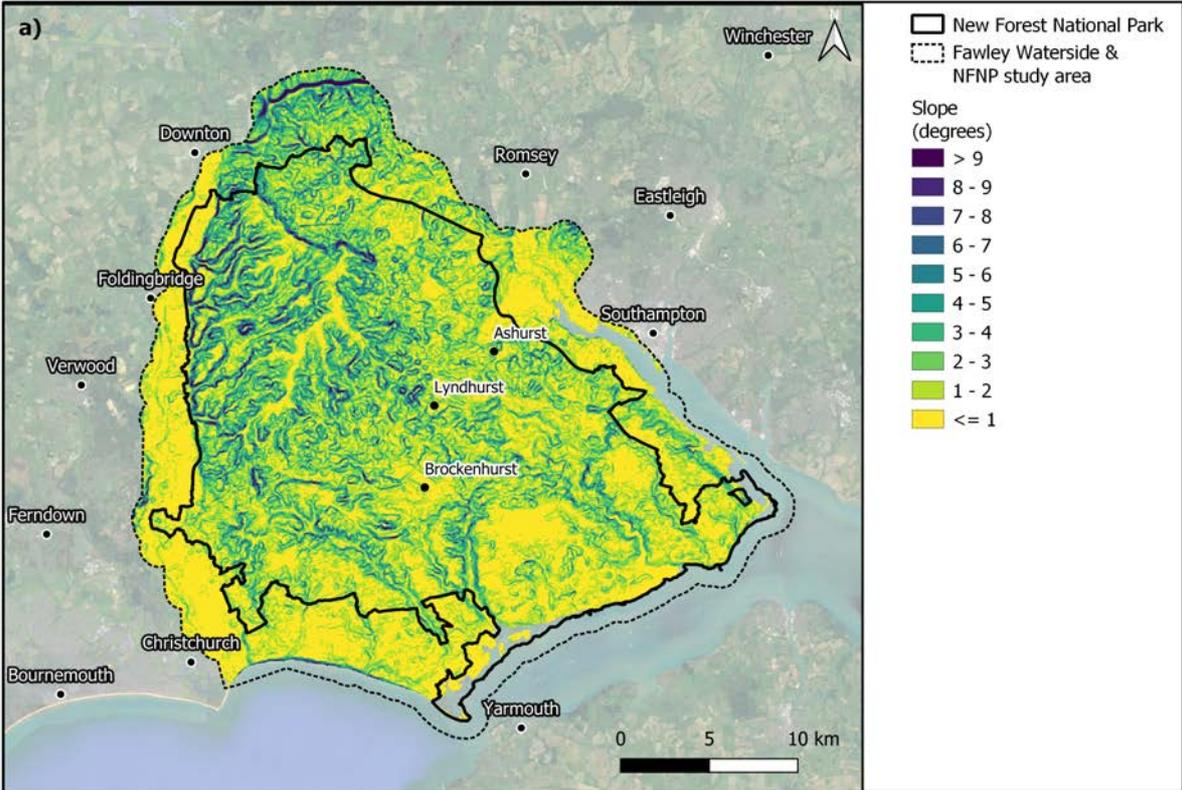
Figure 6: Slope (degrees) within the New Forest National Park. Derived from the EU digital elevation model at 25m.

Freshwater (rivers, lakes, ponds, and wetlands)

There are 407.4 km of rivers and streams within the New Forest National Park (Fig. 7). Of these, 25 rivers (totally nearly 250km) have been assessed under the EU Water Framework Directive where 5 achieved a good overall status in 2019, 19 achieved a moderate status and only 1 river was classified as poor (Ripley Brook). In addition, 3,127 ha (2% of the total area of the NFNP) is covered with fen, marsh and swamp (Appendix 2: Asset register 2d).
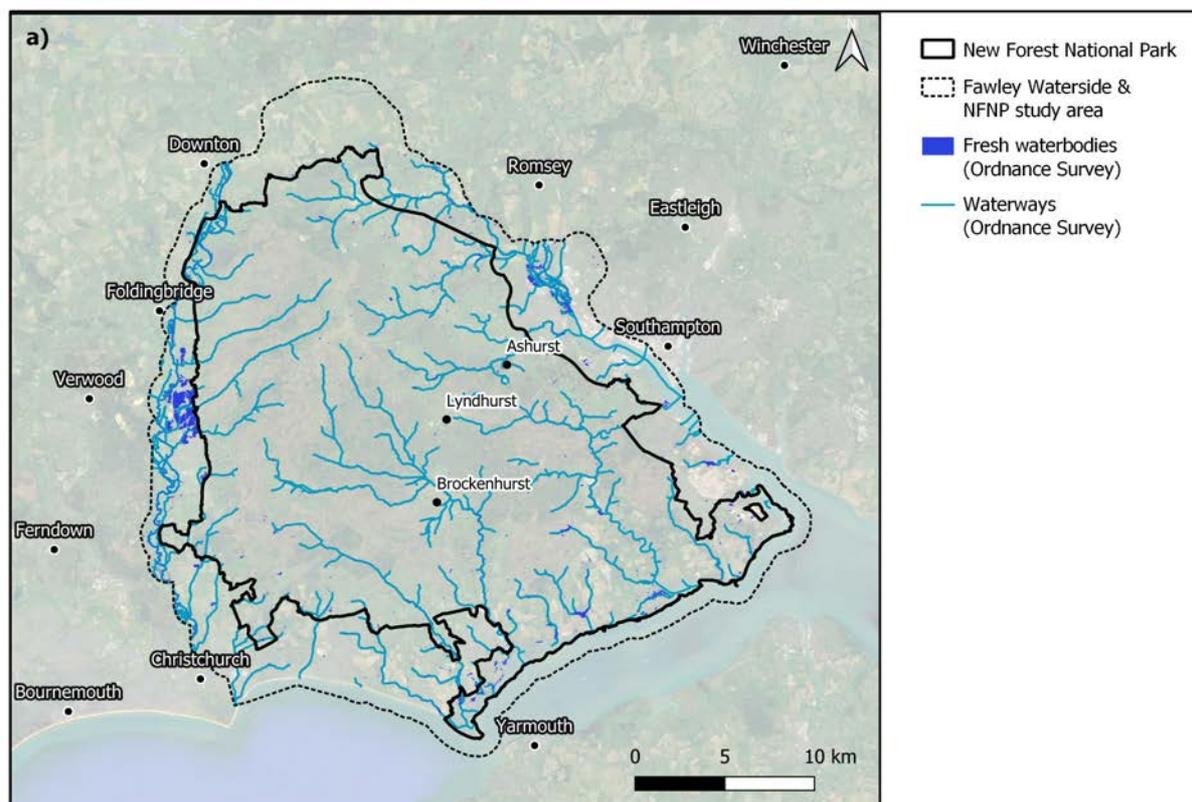
Figure 7: Waterbodies and waterways of the New Forest National Park. Ordnance Survey surface waters and rivers.

Soil type

There are over 20 different soil types within the New Forest National Park, as classified by the National Soil Map for England (NATMAP) (Fig. 8). The most common soil type within the National Park (19,938 ha) is slowly permeable seasonally waterlogged fine loamy over clayey and coarse loamy over clayey soils and similar more permeable soils with slight waterlogging (Appendix 2: Asset register 2e). The soil type of naturally very acid coarse loamy over clayey soils is most commonly associated with the wet and dry heaths in the National Park, indicating the important relationship between these habitats and their soils. Well drained fine loamy soils over gravel are most commonly found towards coastal areas.
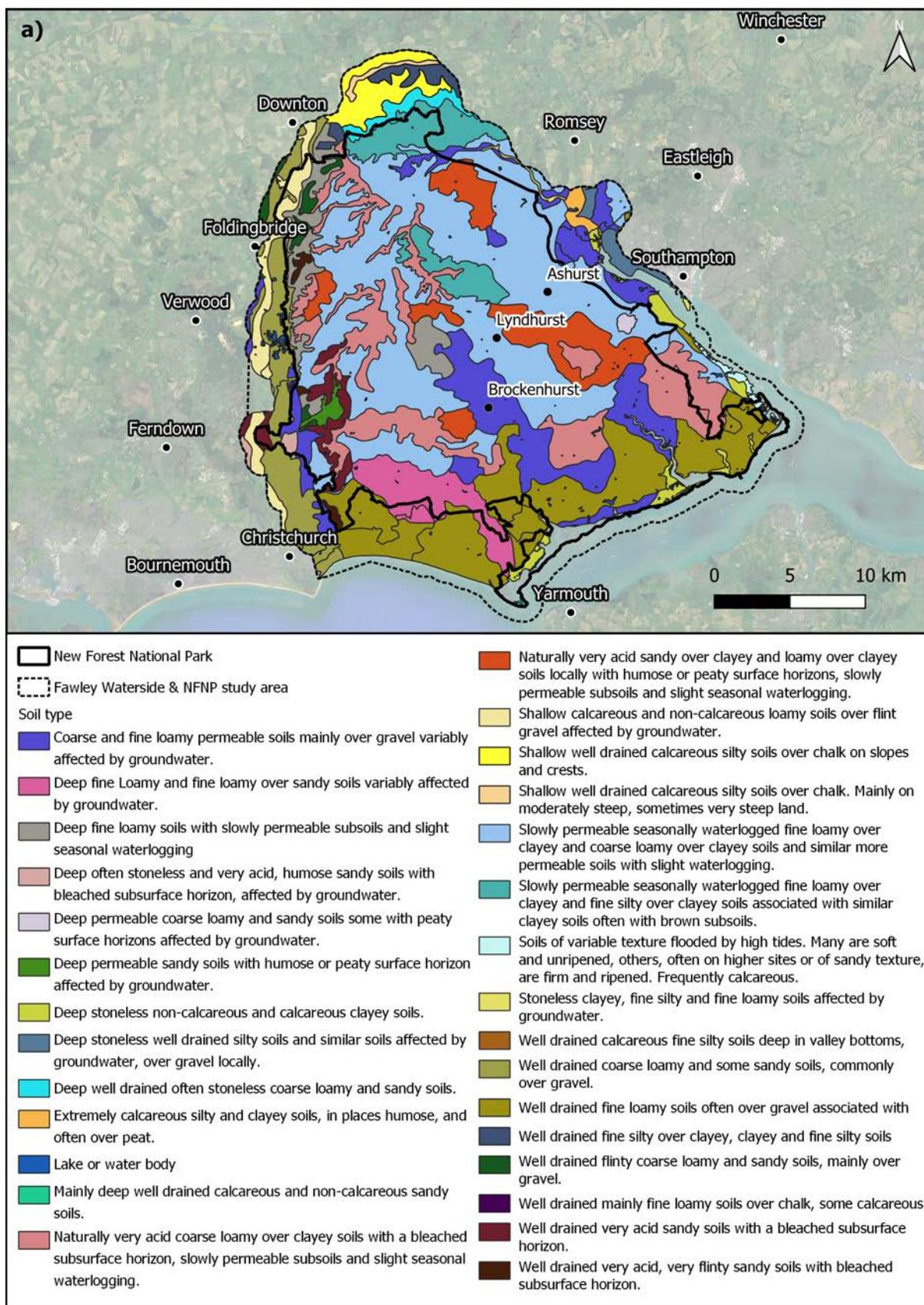
Figure 8: Soil types in the New Forest National Park. Data from the National Soil Map of England and Wales (NATMAP).

Determining the Natural Capital Flows (Ecosystem Services)

We used the data described above in a variety of modelling approaches to determine key ecosystem service flows provided by these natural capital assets. Our methodological approaches are described in Appendix 1. Specifically, we estimated: carbon stored in vegetation and soils; carbon sequestration in vegetation, soil erosion prevention, flood risk reduction; nutrient runoff; recreation; pollination; important biodiversity habitats and nature networks. These ecosystem services were selected to give a broad representation of the services provided by natural capital in the National Park, including the key services of carbon and recreation and biodiversity. The outputs from the modelling are provided in the following section and detailed according to area/landcover type in the asset registers in Appendix 3.

Carbon stored in vegetation and soils

The quantity of carbon storage in vegetation (aboveground biomass and belowground coarse roots) was estimated for woodlands (Fig. 9), trees and vegetation outside of woodlands (Fig. 10) and topsoils (Fig. 11).

Carbon storage in trees in woodlands

Our results estimate that broadleaved mixed and yew woodland on average store around 463 tCO_2e/ha. In comparison coniferous woodlands in the Park store around 402 tCO_2e/ha (Appendix 3: Asset register 3a). This is due to the management of the woodlands, with large areas of very mature, ancient broadleaved woodlands storing high densities of carbon per hectare compared with relatively younger managed coniferous plantations. In total, trees in woodlands in the New Forest National Park store an estimated 8,442,295 tCO_2e in the baseline year (Fig. 9).
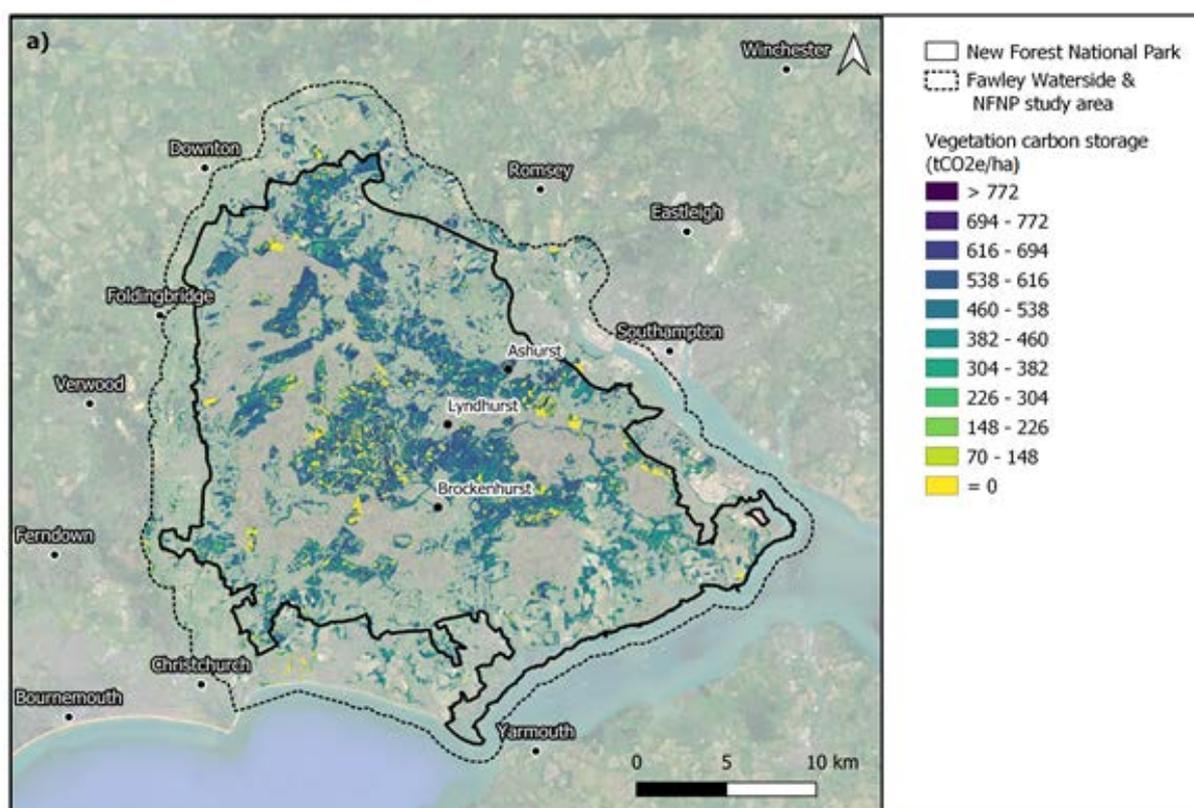
Figure 9: Estimated storage of carbon in trees in woodlands in the New Forest National Park and wider catchment. Units are in tonnes of CO_2e per hectare (tCO_2e/ha).

Trees and vegetation outside of woodlands

Trees and vegetation outside of woodlands within the New Forest National Park store an estimated 2,155,113 tCO$_2$e (Fig. 10). The majority of this is stored in trees outside of woodlands including hedgerows, which are estimated to store 1,958,718 tCO$_2$e in total. Grasslands and heathlands store very little carbon in aboveground biomass in comparison. (Appendix 3: Asset register 3a).
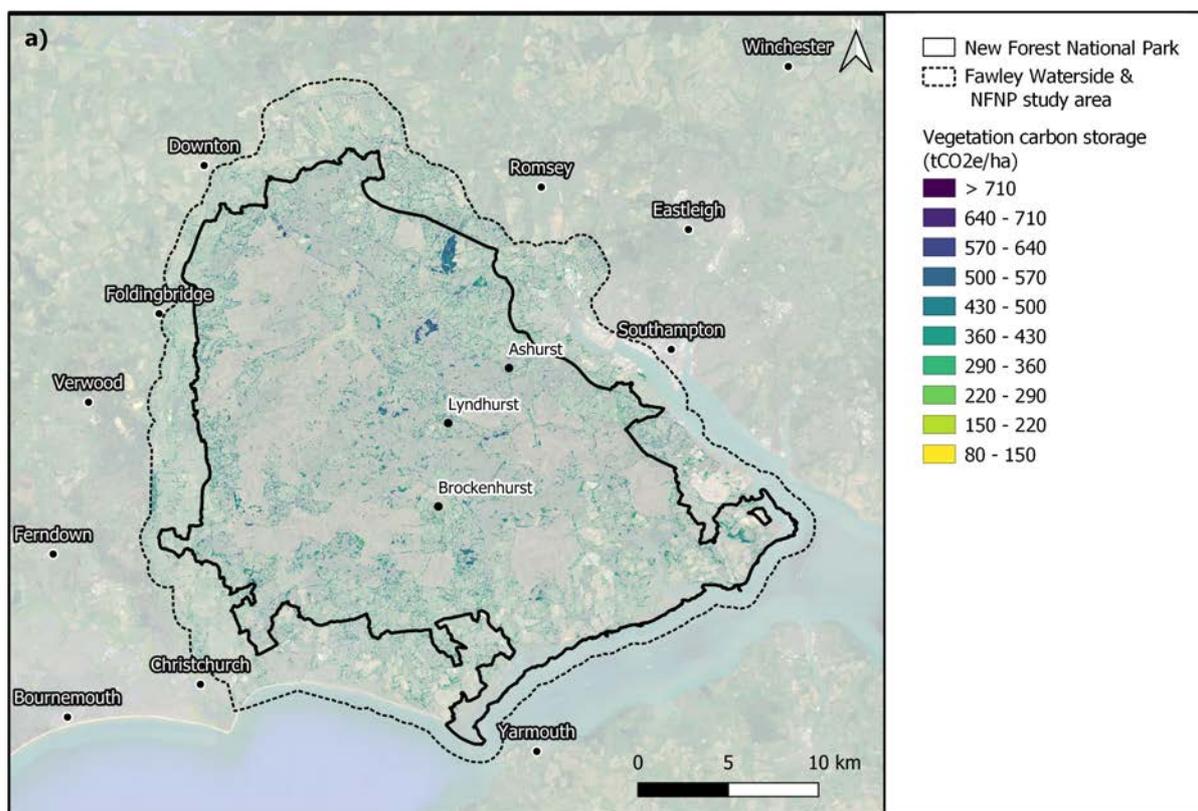
Figure 10: Estimated storage of carbon in trees and vegetation outside of woodlands. Units are in tonnes of CO$_2$e per hectare.

Carbon storage in topsoils

We estimated soil carbon storage for the top 30 cm of soil from the National Soil Map for England (NATMAP). Our results indicate that these topsoils within the New Forest National Park store a total of 21,250,921 tCO_2e (Fig. 11). The soils that hold the most carbon are situated beneath dwarf shrub heath (501 tCO_2e/ha) due to their high organic matter content. Forest soils (those associated with broadleaf woodlands and coniferous woodlands) are somewhat higher in carbon stores, while the lowest carbon stores are broadly associated with grassland and other landcovers. See Appendix 3: Asset register 3a.

Data were only available for topsoils in this study. However, areas of deep peat are known to exist through the National Park. Peatlands can store large volumes of carbon and deep peats can typically store more carbon per hectare than the equivalent area of woodland. A lack of data on the extent and depth of peatlands prevented us from including this asset in the baseline assessment, however this is a significant limitation for the New Forest National Park and has been identified as a key data gap to be targeted in future work.
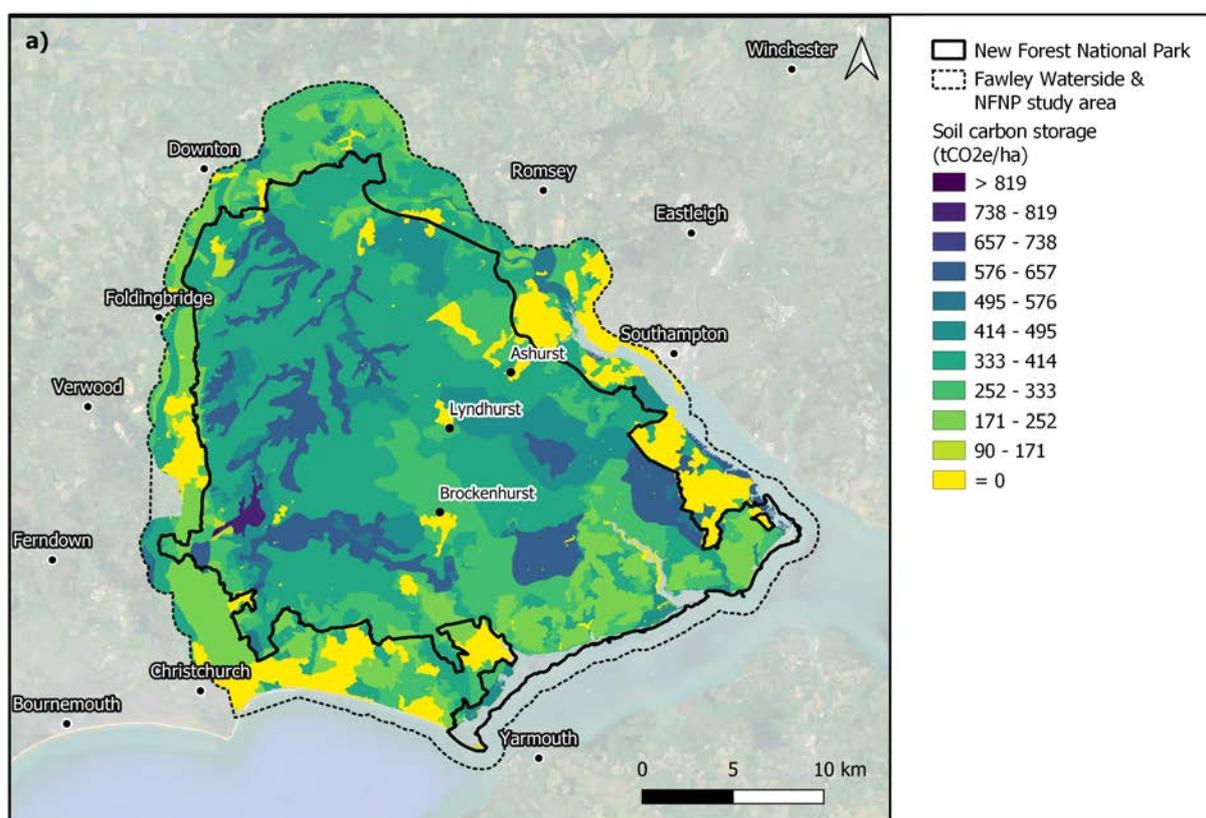
Figure 11: Carbon storage in the top 30 cm of soils in the New Forest National Park (tCO_2e/ha).

Carbon Sequestration

In addition to the standing stock of carbon in vegetation and soils, we estimated the rate of CO_2 sequestration (or emission) by vegetation. Rates of carbon sequestration were estimated for woodlands, and for trees and vegetation outside of woodlands. Unfortunately, there is currently insufficient data available to estimate rates of carbon exchange in soils as this would require information on historical land use and management or additional soil sampling across the study area.

Carbon sequestration in trees in woodlands

In total, trees in woodlands within the New Forest National Park sequester an estimated 55,281 tCO_2e per year (Fig. 12). Over 50% of the total carbon sequestration by vegetation comes from trees in woodlands. Broadleaved woodlands are estimated to sequester 3 tCO_2e per hectare per year, while coniferous woodlands are estimated to sequester 4 tCO_2e per hectare per year (Appendix 3: Asset register 3b). Many of the mature broadleaved woodlands in the National Park are estimated to sequester little or no carbon as they are fully mature. The greatest rates of sequestration are found in the younger and more highly managed woodlands.
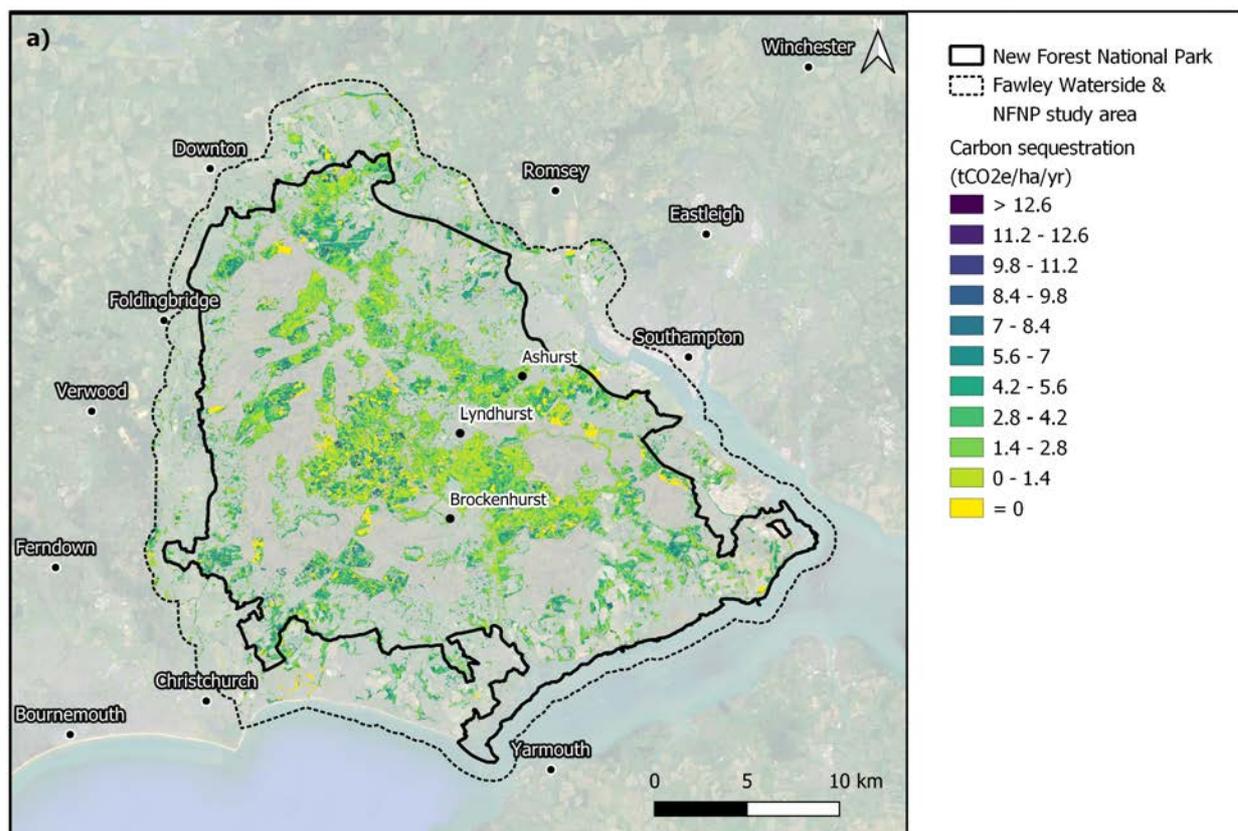
Figure 12: The estimated rate of carbon sequestration by trees within woodlands in the New Forest National Park and catchment. Units are tonnes of CO_2 sequestered/ha/yr.

Carbon sequestration in trees and vegetation outside of woodlands

In total, trees and vegetation outside of woodlands within the New Forest National Park sequester an estimated 20,677 tCO_2e/yr (Fig. 13). We estimate that the greatest per hectare service comes from hedgerows and trees outside of woodlands (0.5 tCO_2e/ha/yr). Other vegetation such as grassland, arable and heathland are assumed not to be sequestering additional carbon aboveground (Appendix 3: Asset register 3b).
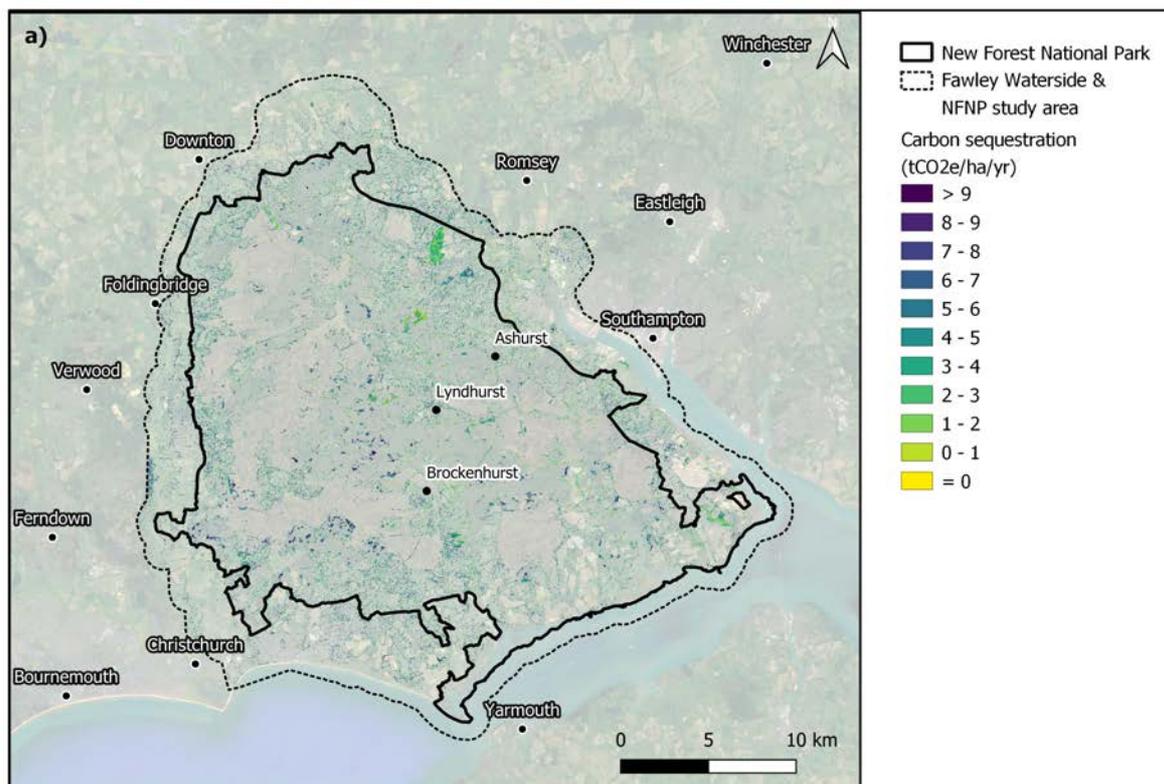
Figure 13: The estimated rate of carbon sequestrated by trees and vegetation outside of woodlands in the New Forest National Park. Units are tonnes of CO_2 sequestered/ha/yr.

Soil erosion prevention

The vegetation across the New Forest National Park contributes to reducing soil loss from rainfall, by stabilising soils and preventing the loss of topsoils through erosion. In total, vegetation across the New Forest National Park reduces an estimated 186,929 tonnes of soil loss per year, in comparison to a scenario in which there is no vegetation (note: all reported values are a comparison to this no-vegetation scenario). Figure 14 displays those areas of landcover across the New Forest National Park that provide the greatest protection from soil erosion from rainfall.

There is variation even within areas of the same vegetation type due to differences in model inputs that encompass: rainfall and runoff; soil types and erodibility; and the underlying terrain (including slope). When these areas are analysed for their landcover type it becomes apparent that the greatest proportion of this service is provided by broadleaved woodlands (approximately 34% of the total), reducing soil erosion by approximately 5 tonnes of soil per ha per year (Appendix 3: Asset register 3c). This is due to the location of broadleaved woodlands on steeper slopes, and the large extent of broadleaved woodlands within the National Park.
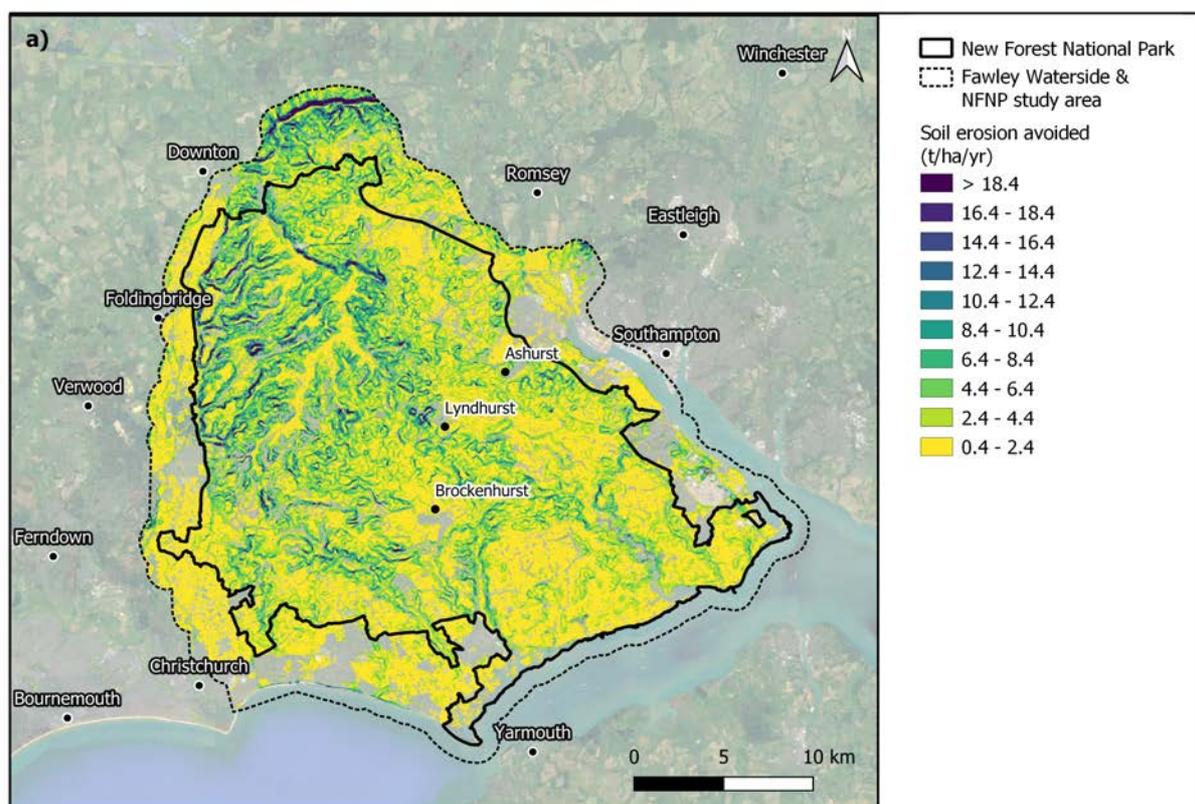
Figure 14: Map of vegetation contribution to soil stabilization in New Forest National Park. The map shows the amount of soil erosion that is avoided due to the type and density of current vegetation, compared with an alternative scenario of bare soil. Units are tonnes of avoided soil loss/ha/yr.

Flood risk reduction

The contribution of vegetation to flood risk reduction is a function of the vegetation characteristics and the location of the vegetation (soil type, topography and position with the catchment). Vegetation, particularly trees, aid in the reduction of surface water through a number of means. Leaves in the tree canopy intercept rainfall, holding it on the leaves to either evaporation or fall through more slowly, as well as directing rainfall down the trunk/stem to enter the soil at the base of the tree. All of these responses help to delay the amount of water initially reaching the soil, providing a chance for this to drain away, as well as increasing the soil's ability to store water and thus reduce the amount of surface water generated.

Within the New Forest National Park, the vegetation type that contributes most to reducing flood risk is found predominantly in areas covered in woodland, with broadleaved and coniferous woodlands reducing 3,937 m^3 per hectare per year and 3,959 m^3 per hectare per year respectively (Fig. 15). Overall, vegetation in the national park reduces surface runoff by over 179,400,020 m^3 per year (Appendix 3: Asset register 3d).
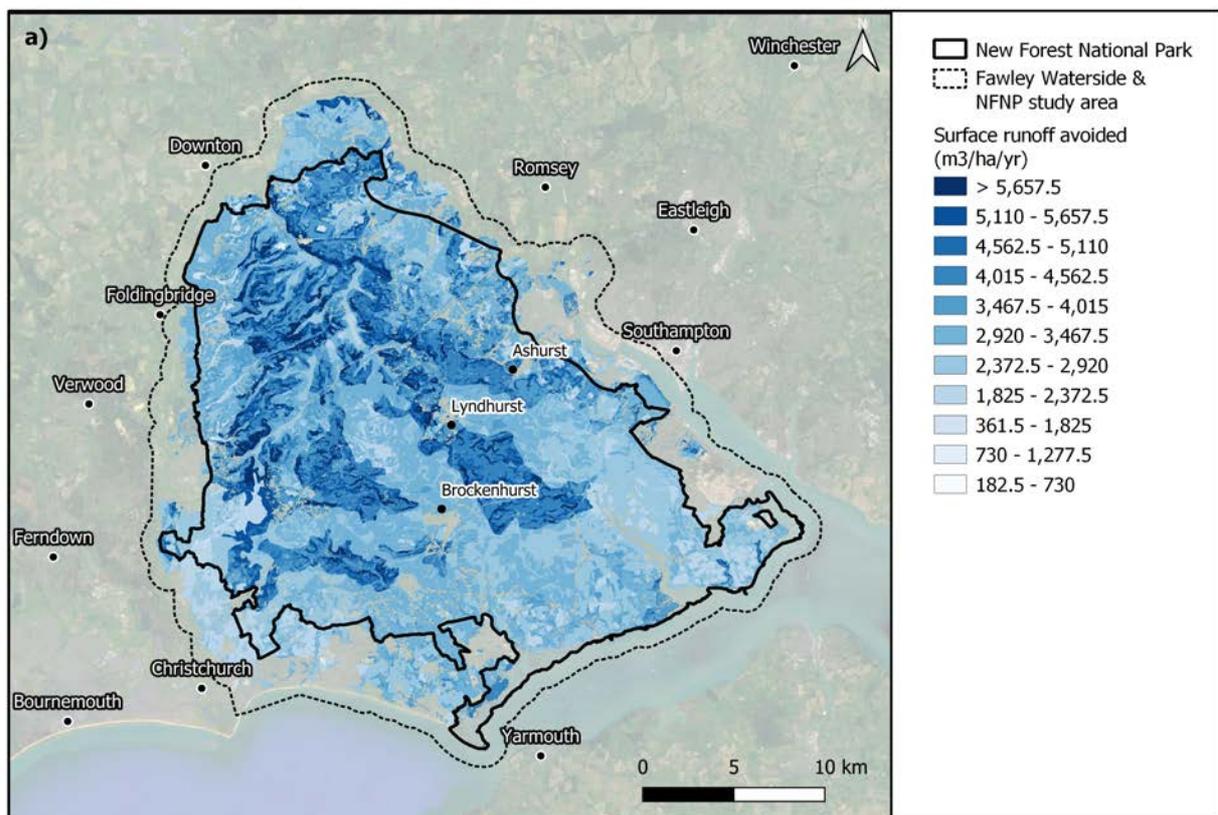
Figure 15: Flood risk reduction by vegetation in the New Forest National Park, estimated as the reduction in surface water runoff from rainfall. High values indicate areas where the current vegetation is estimated to contribute most to reducing the likelihood of flooding downstream, compared with an alternative scenario of bare soil.

Nutrient runoff

Nitrate runoff contributes to the pollution of freshwater habitats and can be exacerbated by the application of organic and inorganic fertiliser, especially to soils with high rates of surface runoff. We estimated areas of land where nutrient runoff (nitrates) are lowest due to current vegetation and land management practices[2].

In the New Forest National Park, 155,081 kg of N in nitrate is estimated within surface runoff each year. When analysed by landcover type, over 44% of this is estimated to come from arable and horticultural land, with 17 kg of nitrogen (in nitrate) in surface runoff per hectare per year. It is estimated that another 22.8% comes from modified grassland. Coniferous woodland and dwarf shrub heath have the lowest average levels of nitrate runoff (Appendix 3: Asset register 3e).

The levels of nitrate in runoff as displayed here are determined both by the volume of surface water runoff that occurs and the amount of fertiliser applied, meaning that direct comparison between different areas is not always clear. Modelled streamflow concentrations of nitrate were compared to Environment Agency point sampling values were correct in both range and magnitude.
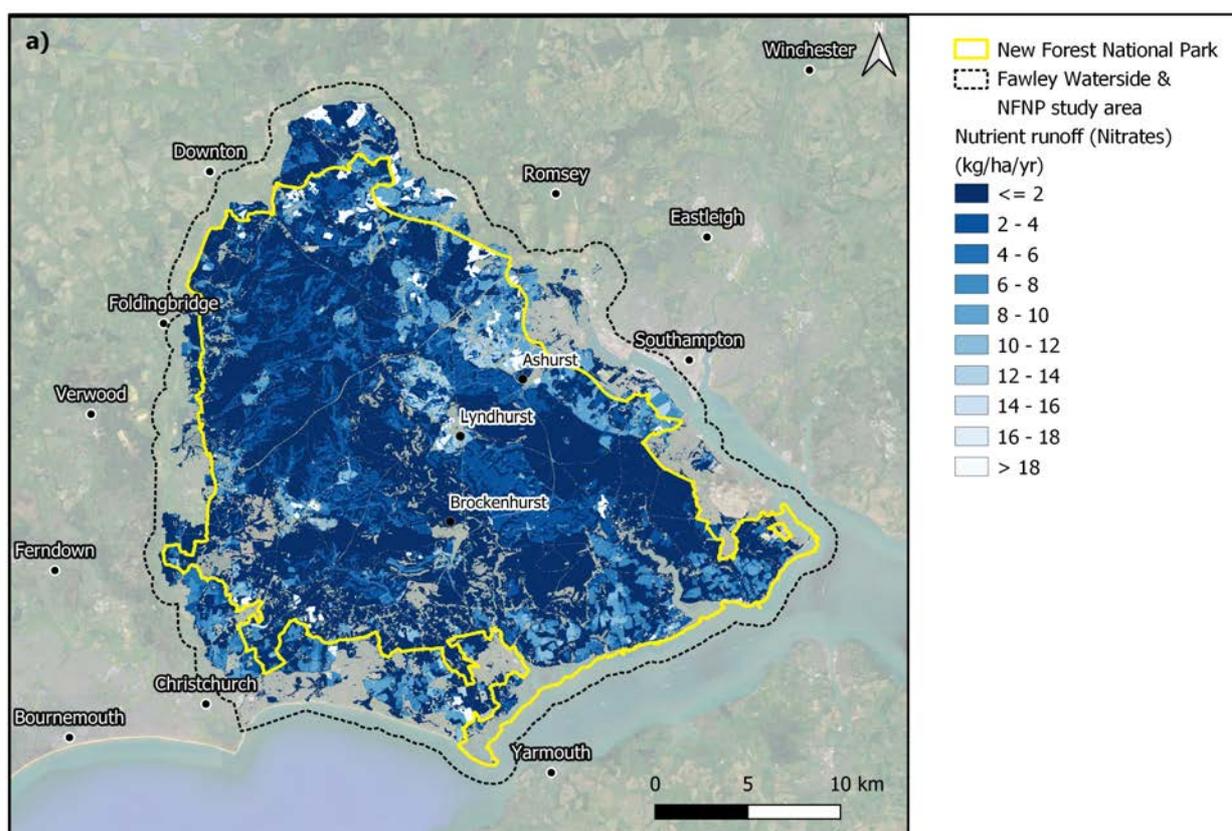
Figure 16: Nutrient runoff within the New Forest National Park. Units are kg of nitrogen (in nitrate) per hectare per year[3].

---

[2] Nutrient inputs were set according to client-supplied information for pasture and arable rotations, and from information adapted from Taylor et al. (2016). Nutrient inputs are likely to vary between farms and land managers in the study area, there results are therefore indicative of average practices in the study area.

[3] High runoff of nutrients is a disservice (it has a negative impact on freshwater natural capital assets). High rates of N runoff are therefore displayed in pale colours for consistency with other maps.

Recreation

To calculate important areas for recreation in the New Forest we used a variety of datasets that record geographic information, within a machine learning model that assesses the probability of a visit occurring based on characteristics of the environment, to determine the suitability of areas for recreation, and calibrated the numbers based on observed visitor numbers (see also Methodology in Appendix 1).

Our results estimate that there are distinct areas that attract higher visitor numbers each year (Fig. 17) and these are concentrated around paths and trails. Areas of broadleaved woodland account for an estimated 28% of total visits and dwarf heath shrub (31% of total visits). These two landcover classes alone account for an estimated 6 million visits a year. In total, our results estimate that the New Forest National Park receives approximately 10.4 million visits per year. The highest numbers of visitors are found in the southern half of the national park, often close to amenities and along trails and paths.

This estimate is lower than the figures given by other reports on recreational use of the New Forest National Park, such as the recent RJS Associates report (2018), which estimated the number of visitor days in 2017 as 15.2 million. However, the difference between these estimates can be explained by the fact that our method does not take into account the visits to villages within the National Park boundary. All built-up areas are excluded from our model, leaving only greenspaces that are publicly accessible within these landcovers.
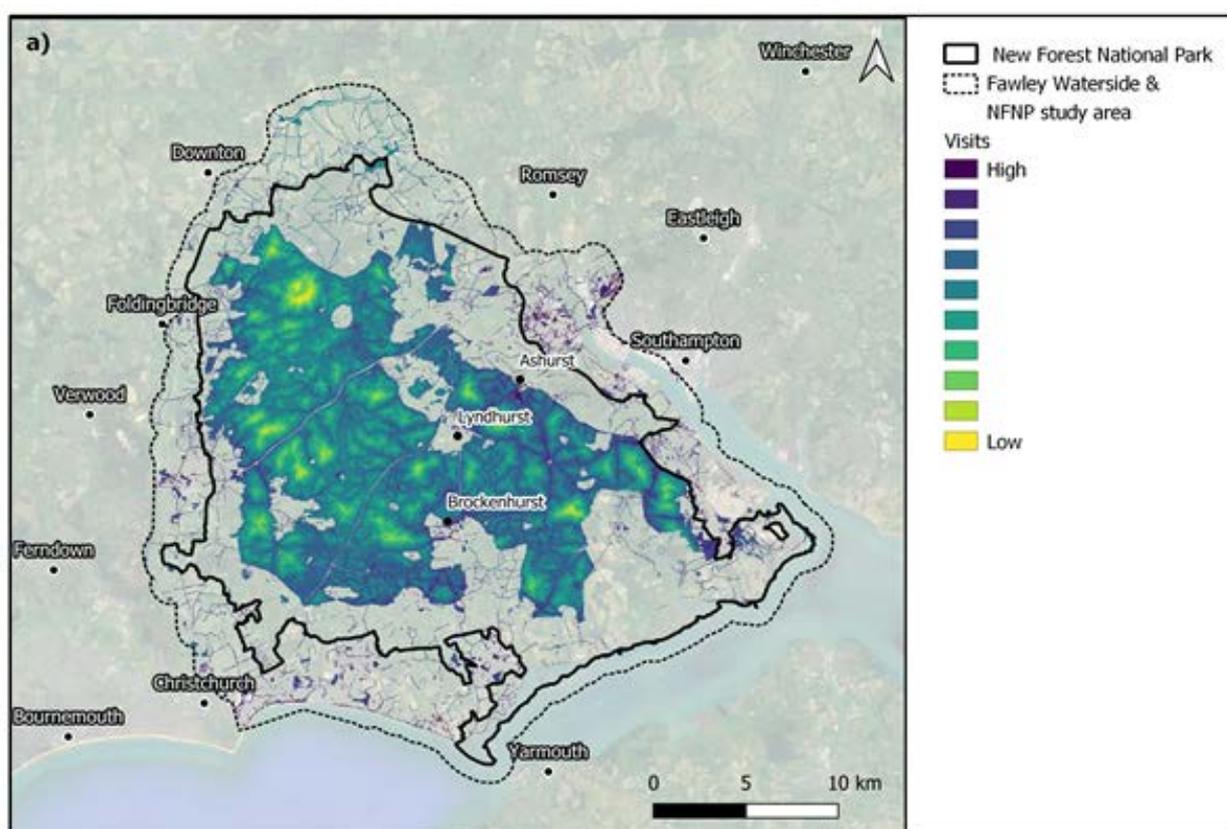
Figure 17: Important areas for recreation in the New Forest National Park. The total number of visits to the New Forest National Park is estimated at 10.4 million per year.

Pollination

The degree of importance for pollination depends on the presence of suitable nesting and foraging sites for pollinating insects, as well as these being located within foraging distance of crops dependent on pollinators. This model only includes crops dependent on pollinators and does not include honey production due to lack of data on the precise location of beekeepers or hives within the New Forest. Our results show a metric with values between 0 (no pollination service) and 1 (high pollination service). Areas with a pollination score of 0.1 or higher are classified as high importance for pollinating insects and are shown in Figure 18a.

Within the New Forest National Park, our results estimate there are 22,919 ha (40% of the total site) landcover that is of high importance for pollinating insects for crops. Around half of this is classified as broadleaved woodland. However, the landcover with the highest average pollination service per hectare is dense scrub (Appendix 3: Asset register 3g).
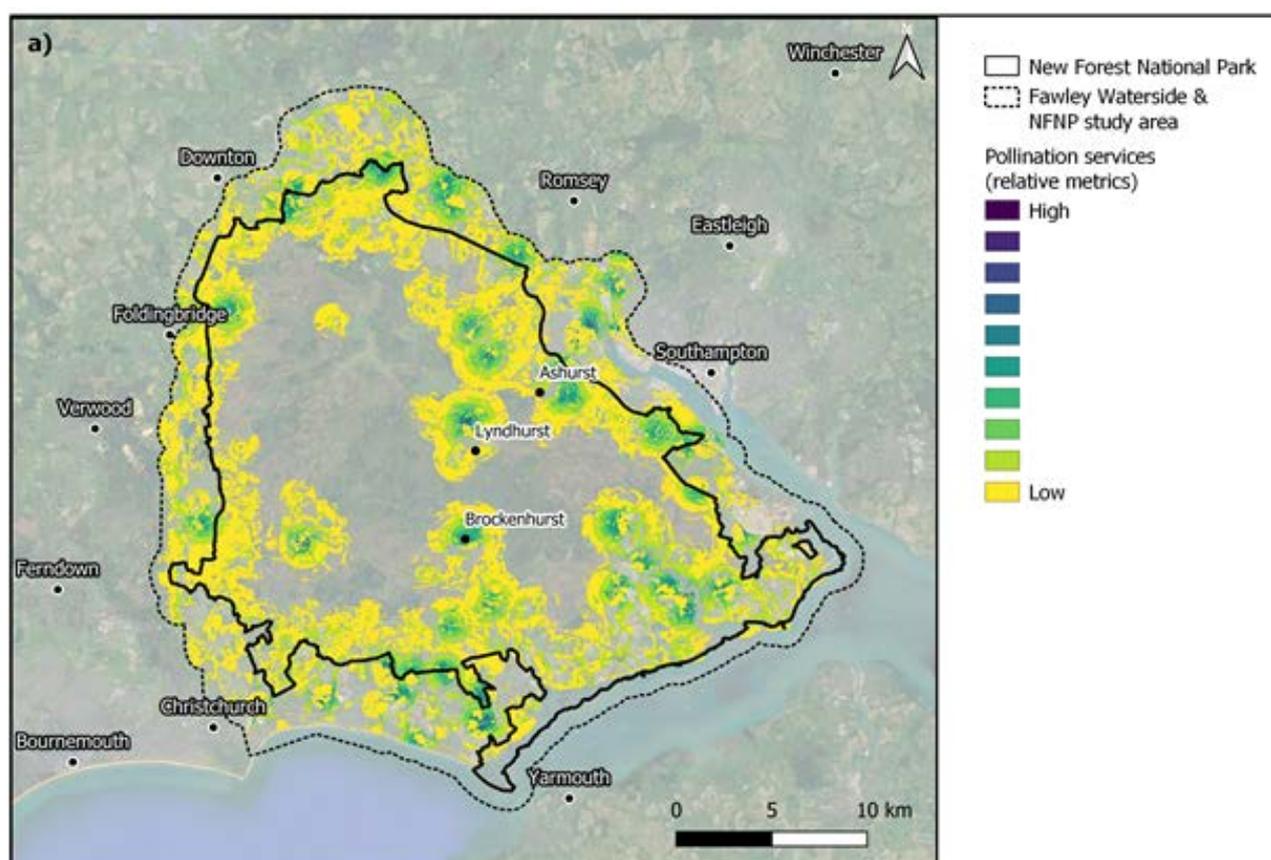
Figure 18a: Distribution of landcover important for pollination services in the New Forest National Park. This is a metric with values between 0 (no pollination service) and 1 (high pollination service).

To provide further insight into the importance of habitats in the study area for pollinating insects, we also show the estimated production of nectar by habitat type within the National Park (Map 18b). Nectar availability is a component of site suitability for insect pollinators of crops, as well as an indicator of the potential for habitats to contribute to honey production, which is an important crop in the area. Calcareous grasslands and shrub heath produce the most nectar per hectare (97.5 and 82.4 kg sugar/ha/yr. respectively[4]), with broadleaf woodland also contributing greatly to nectar production (70.0 kg sugar/ha/yr.). We were not able to include honey production in the pollination model as the distribution of bee hives was not available for this study. This has been highlighted as a key data gap to be addressed in future work.
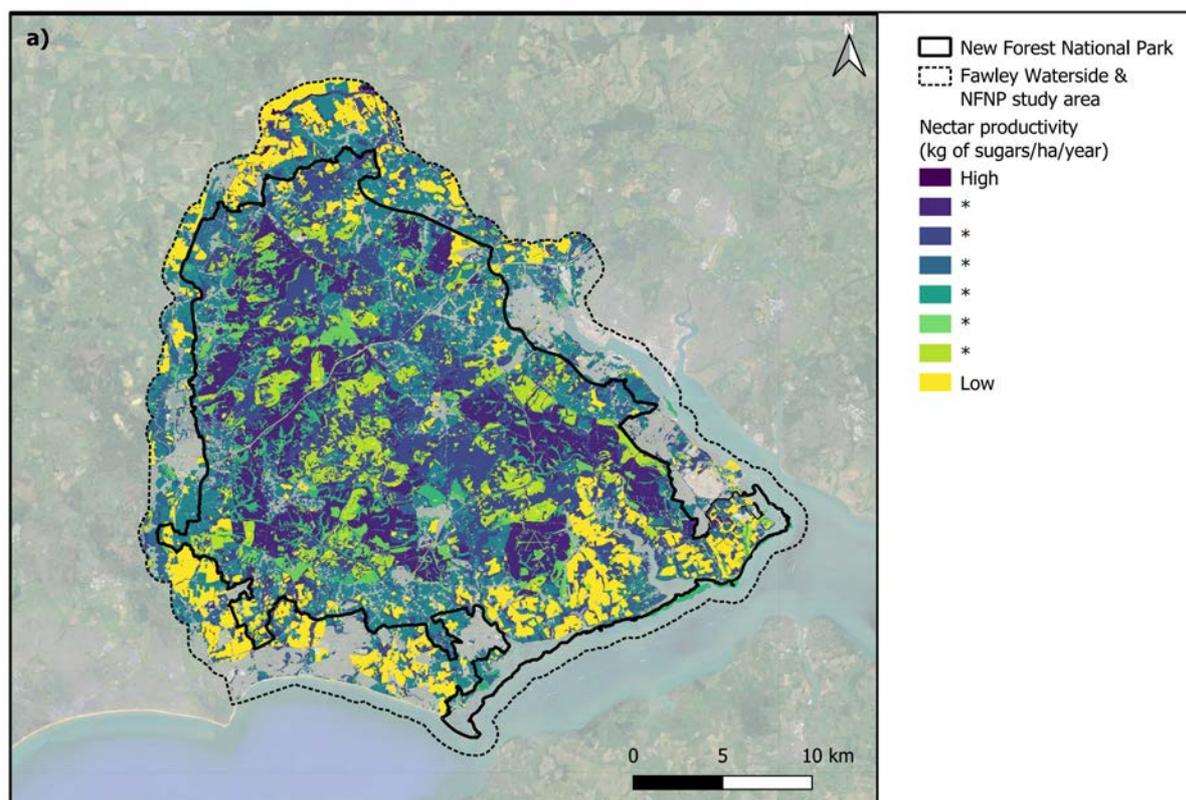
Figure 17b: Distribution of habitat nectar production, which contrbitues to suitability of habitats for pollinating insects, in the New Forest National Park. This is an estimate of nectar production in kg sugars per hectare per year.

---

[4] Assigned from estimates in Baude et al., 2016

Important biodiversity habitats

Figure 19 shows the distribution of important areas for biodiversity across the New Forest National Park. Over half of the land within the New Forest National Park (69%, 39,317 ha) is protected at the international level for its importance for biodiversity. Another 2% is protected at the national level and 1% is protected at the local level. 5,907 ha (10%) of land within the National Park boundary is priority habitat[5] or ancient woodlands, which is not also under other levels of protection (Appendix 3: Asset register 3h).
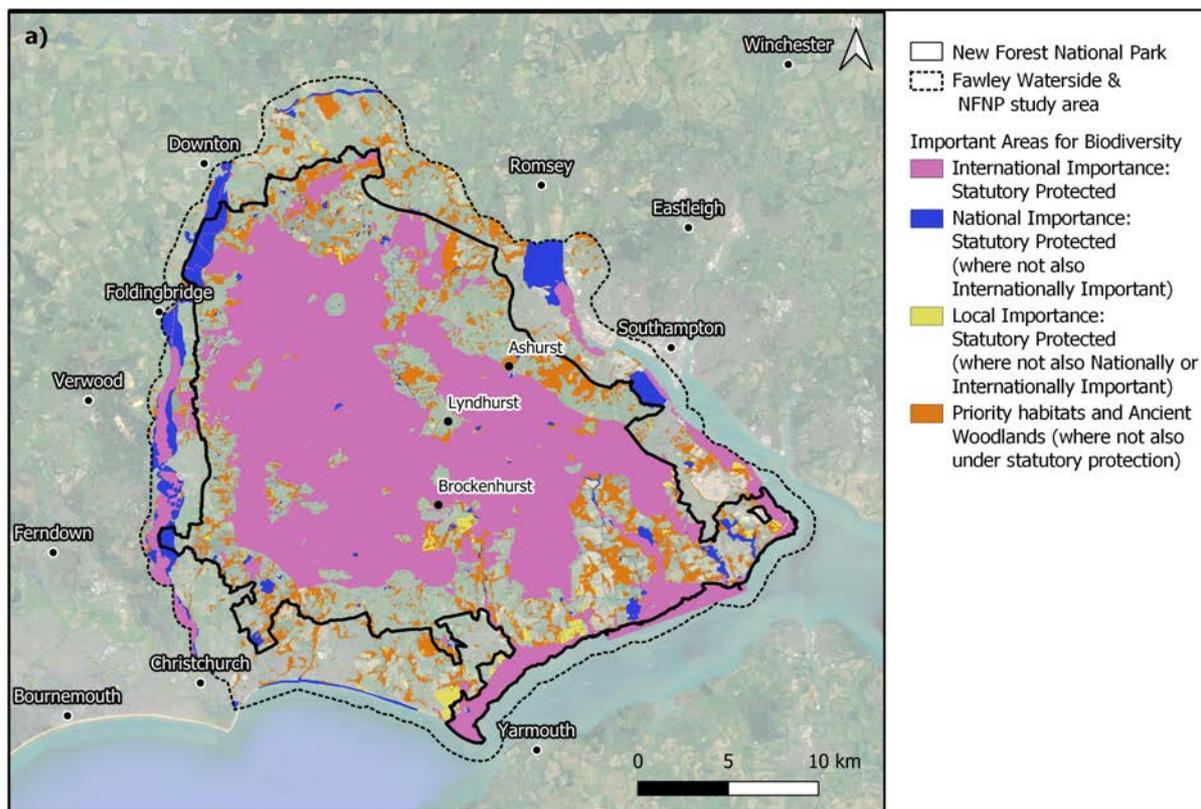
Figure 19: The spatial distribution across the New Forest National Park of important habitats for biodiversity.

---

[5] These data are based on Natural England's Priority Habitat Inventory and do not represent an up to date, exhaustive list of priority habitats. Others may also be present but could not be mapped.

Nature networks

Figure 20 displays the relative importance of patches of woodland habitat for movement of biodiversity in the New Forest National Park within the context of the wider study area. Our estimation is based on a model that identifies patches of broadleaved woodlands and then uses graph theory models to work out the contribution of each patch to the overall connectivity of the study area. A low dispersal distance was used in the modelling to account for a range of species. At this scale, the most important patches for connectivity are those with the largest core areas or those that act as key stepping stones for species between other patches. Roads are included are barriers to movement between patches. We do not include coniferous woodlands, scrub or trees outside of woodlands in this calculation.

From our modelling of fragments of different woodland patches within the New Forest National Park, we estimate that there is 3,760 ha of woodlands that are of the greatest importance for the movement of biodiversity across the landscape. The majority of these important woodlands for connectivity are located in the centre of the national park. An additional 3,793 ha (7% of the study area) is classified as medium importance and 5,755 (10% of the study area) is classified as low importance for the movement of biodiversity (Appendix 3: Asset register 3i). Trees outside of woodlands and scrub areas can be seen in green in the map. These were not classified as woodlands in the landcover map, but they provide important corridors between woodland patches.
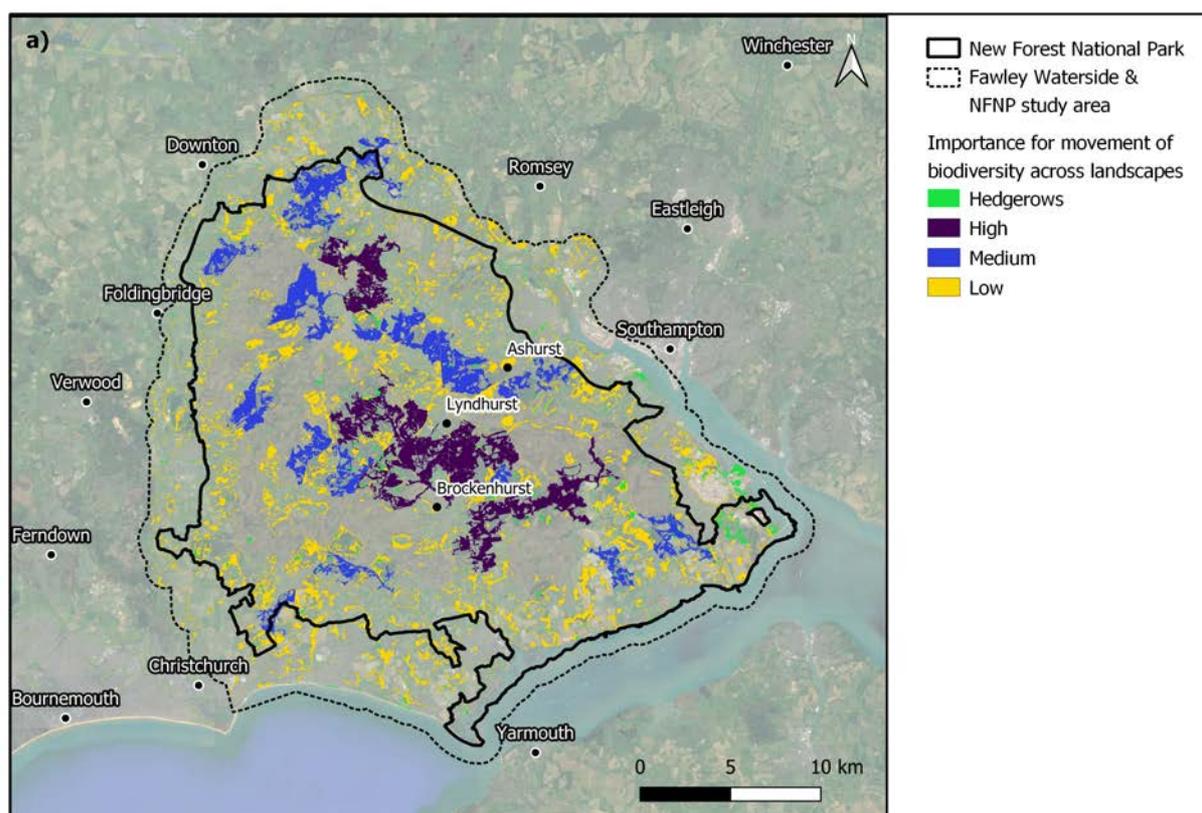
Figure 18: Important broadleaved woodland patches for the movement of biodiversity across landscapes (metric indicating the contribution of patches to overall landscape connectivity, from low to high). The map also displays hedgerows and trees outside of woodlands (mapped from national tree map). The individual importance of hedgerows is not modelled but these are displayed to show the connectivity of the land between woodland patches.

Total combined ecosystem service flow

Hotspots of multiple ecosystem service flows were calculated across carbon storage in vegetation and soils, carbon sequestration in vegetation, vegetation contribution to soil stabilisation, vegetation contribution to reducing flood risk, important habitat for supporting insect pollinators of crops, important area for movement of biodiversity, and important areas for biodiversity, important areas for recreation. All ecosystem services are given equal weighting. Values can range from a minimum of 0 to a maximum of 8.[6] The resulting hotspot map (Fig. 21) indicates those areas which provide the greatest value across multiple ecosystem services.

The landcover that provides the greatest combined service per hectare within the New Forest National Park is broadleaved mixed and yew woodland, with coniferous woodland also important due to its role in carbon storage and sequestration, and water flow regulation. Dwarf shrub heathland also important for the flow of multiple services, especially for biodiversity and recreation. Note that peatlands below the top 30cm of soil were not included in this assessment due to a lack of data, and these areas may score even more highly if these belowground stocks were accounted for. Appendix 3: Asset register 3j).

The models used in this report are sensitive to the role of vegetation in providing ecosystem services. Unvegetated or sparsely vegetated habitats such as coastal saltmarsh and sand dunes are not as well-represented in these terrestrial models but, nonetheless, provide important ecosystem services. Low values for coastal areas are not indicative of unimportant habitats.

---

[6] Nutrient runoff is not included in the map of combined ecosystem service flow as this map only shows beneficial ecosystem services. Nutrient runoff is considered a disservice.
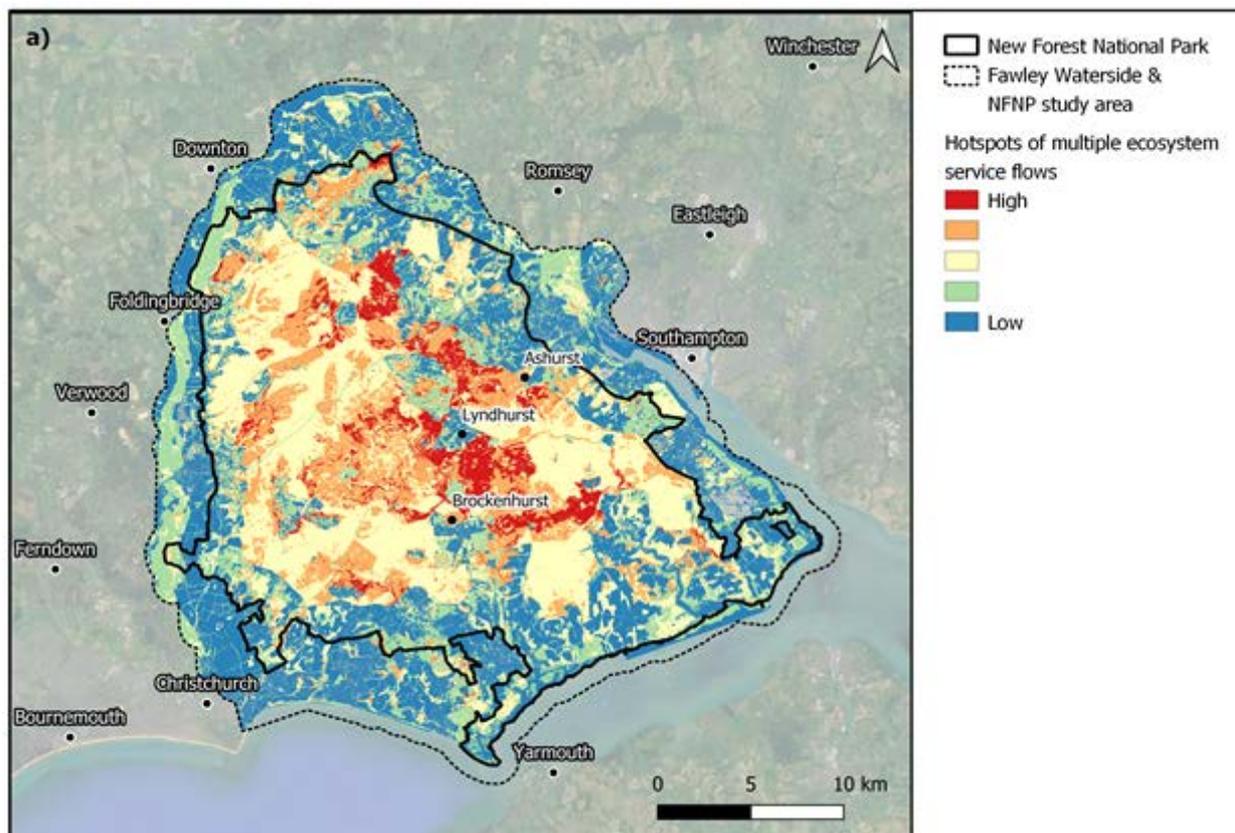
Figure 21: Hotspots of ecosystem services provision for the New Forest National Park where the various ecosystem services displayed in the maps above overlap. The higher the value (red) the more ecosystem services are provided per unit area. All ecosystem services are equally weighted.

Recommendations & Conclusions

Conclusions

Within the New Forest National Park, we estimate that:

- The landcover that provides the greatest combined service per hectare within the New Forest National Park is broadleaved mixed and yew woodland, with dwarf shrub heathland also important for the flow of multiple services, especially for biodiversity and recreation.

- The woodland in the New Forest National Park stores large volumes of carbon, especially the mature broadleaved woodlands which store more carbon per hectare than coniferous plantations.

- The National Park is an area of high biodiversity importance, with almost 70% of its area recognised as important for biodiversity conservation, and most of this (55.6% of the total area) designated as internationally important as a Special Protected Area (SPA).

- Recreation is also a key service provided by the National Park, due to its accessible location close to large population centres such as Southampton. We estimate that more than 10 million visits per year to the National Park occur specifically within the natural capital of the park.

Recommendations

- Areas of deep peat are known to exist through the National Park from previous studies, but insufficient data were available to include them fully in this baseline. Peatlands can store large volumes of carbon and deep peats can typically store more carbon per hectare than the equivalent area of woodland. This omission is, therefore, an important gap in the understanding of natural capital assets in the New Forest National Park and has been identified as a key area to be targeted in future work.

- The results in this report give a thorough representation of the stocks and service flows from terrestrial aboveground natural capital. The models used in this report are sensitive to the role of vegetation in providing ecosystem services. Littoral habitats such as coastal saltmarsh and sand dunes, as well as marine habitats, are not well represented here but nonetheless provide important ecosystem services. Further assessment of these intertidal and marine habitats is recommended in future work to give a true reflection of the benefits of these areas.

- The pollination model presented in this report accounts for crops that are dependent on pollinatiors (arable crops and horticulture, including allotments and orchards). Bee-keeping and honey production is another important activity that is dependent on suitable habitats and nectar production, but was not included here due to a lack of data on the location of bee hives around the national park. The inclusion of bee hives in the model would give a fuller representation of ecosystem services in the region and is recommended as a future refinement.

Next Steps

This baseline provides a solid evidence base for the current state of natural capital. From here, a number of options are available:

1) Repeated baselines at regular intervals to monitor changes to natural capital over time.

This baseline can be repeated at regular intervals in future to measure and report on the progress of enhancement activities, and to track changes to natural capital assets through time. The frequency of repeated baselines will be dependent on how often the data underlying the models in the report are updated. In this assessment, we have used landcover data provided by Hampshire Biodiversity Information Centre (HBIC) so baseline frequency should be informed by their policy on data collection and updates.

2) Enhancement modelling to identify areas where improvement of natural capital assets (stocks) will achieve the greatest increase in services flow, with a focus on what is both practical and realistic to implement.

This baseline can be used as the starting point to explore and plan for a range of alternative enhancement options. Opportunity maps can be used to target realistic scenarios of potential changes to natural capital assets, and these can be combined with our ecosystem service models to explore strategies for natural capital enhancement and to identify the areas where changes would result in the greatest improvement in multiple ecosystem benefits overall. The results of this work would be specific to the study area and provide the basis on which to form a natural capital plan. The outputs, whilst guided by the outcomes of the baseline assessment, would also depend on the specific aims and objectives of the project and would therefore be tailored to the priorities of the client and the intervention/impact they are seeking to assess.

Appendix 1 Data sources and methodological approaches

We developed a consistent methodology to first acquire the data and then map the key natural capital assets (stocks) across each site (described in Table a). We then developed a series of models and approaches to calculate the ecosystem service flows from these assets (described in Table b). Finally, we combined these ecosystem services to create a hotspot map of ecosystem services (described in Table c).

a) Methodological approaches and data sources used to determine natural capital assets (stocks)

Input data	Methodology	Citation
Landcover		
IHS	A landcover map was generated from multiple open source data layers across England, Wales and Scotland. All input datasets are harmonized using the UK Hab classification (Butcher et al., 2018) to generate a landcover map with approximately 100 classes of terrestrial, freshwater and marine assets. UK Hab methodology provides correspondence guidance for most input data, but where necessary additional landcover codes were created to maintain detailed information from the input data, such as specific crop types. In each location, multiple estimates of landcover may be available; sources are prioritised based on their resolution (higher spatial or habitat resolution is prioritized) and source date (more recent prioritised over older data).	HBIC, 2020
Surface water bodies and reservoirs		OpenStreetMap contributors, 2017
Trees crops (orchards, vineyards, allotments)		OpenStreetMap contributors, 2018
National Forest Inventory 2017		Forestry Commission, 2018
Ancient Woodlands (England)		Natural England, 2020
Priority Habitat Inventory		Natural England, 2020
RPA Crop Map of England (CROME) 2018		RPA, 2018
Surface waterbodies		Ordnance Survey Zoomstack, 2020
Corine Landcover Map 2018		Copernicus, 2018
Copernicus Sentinel-2 mission. Level 2-A data		European Space Agency (ESA), 2016
Forest, trees and hedges compostion (height and species)		
National Tree Map (NTM)	Canopy height of woodlands and trees in non-woodlands	BlueSky Ltd, 2020
Topographical variation of the land		
European digital elevation model v1.1	DEM (m above sea level) reprojected to British National Grid	Copernicus, 2016
European digital elevation model v1.1	Slope (percentage) calculated from DEM in QGIS	Copernicus, 2016
Water and wetlands		
Ordnance Survey Zoomstack (surface water bodies and rivers)	Length of rivers calculated in QGIS	Ordnance Survey, 2020
Landcover map	Surface waters, wetlands and transitional waters	Copernicus, 2018
Soil type and physical properties		
National Soil Map of England and Wales (NATMAP)	Soil types and physical properties mapped and summarised	Cranfield University, 2020

b) Methodological approaches and data sources used to determine ecosystem service flows

Ecosystem Service	Input data	Methodology
Carbon stored in vegetation and soils		
Trees in woodlands	National Tree Map (BlueSky Ltd)	Carbon storage is estimated using a statistical model relating canopy height from NTM data and biophysical variables derived from Sentinel satellite products to stand-level carbon storage estimates from the National Forest Estate. This model is then applied across the entire study area at 25m resolution. Predictor variables include canopy height from the National Tree Map, NDVI summer, NDVI winter, and estimations of stand age and yield class. Estimates of carbon storage in the National Forest Estate were calculated from forest inventory data (2019) and methods from the Woodland Carbon Code (2020). Carbon storage is predicted at 25m resolution.
	National Forest Estate England and Scotland (2019, Forestry Commission)	
	Sentinel Satellite Observations (NDVI summer, NDVI winter); European Space Agency (ESA), 2016 Digital Elevation Model (DEM, EU-DEM v1.1). Copernicus, 2016 Woodland Carbon Code Lookup Tables (2020, Forestry Commission)	
Trees and vegetation outside of woodlands	National Tree Map (BlueSky Ltd)	Carbon storage is estimated using a statistical model relating canopy height from NTM data and biophysical variables derived from Sentinel satellite products to stand-level carbon storage estimates from the National Forest Estate. This model is then applied across the entire study area at 25m resolution. Predictor variables include canopy height from the National Tree Map, NDVI summer, NDVI winter, and estimations of stand age and yield class. Estimates of carbon storage in the National Forest Estate were calculated from forest inventory data (2019) and methods from the Woodland Carbon Code (2020). Carbon storage is predicted at 25m resolution. Carbon storage for non-woodland landcovers such as heathland and grassland are taken from published values for UK habitats.
	National Forest Estate England and Scotland (2019, Forestry Commission)	
	Sentinel Satellite Observations (NDVI summer, NDVI winter); European Space Agency (ESA), 2016 Digital Elevation Model (DEM, EU-DEM v1.1). Copernicus, 2016 Woodland Carbon Code Lookup Tables (2020, Forestry Commission)	
Carbon storage in topsoils	National Soil Map of England and Wales (NATMAP). Cranfield University, 2020	Soil carbon is mapped by the National Soil Map of England and Wales.
Carbon sequestered in vegetation		
Trees in woodlands	National Tree Map (BlueSky Ltd)	Carbon sequestration was mapped based on the statistical relationship between woodland types and stand-level carbon sequestration estimates for National Forest Estate forests. Sequestration estimates for the National Forest Estate were calculated using forest inventory data and methods from the Woodland Carbon Code. This relationship was then applied across the entire study area. The predictor variables included canopy height from the National Tree Map, NDVI summer, NDVI winter, elevation, and estimations of stand age and yield class. Estimates of carbon sequestration in the National Forest Estate were calculated from forest inventory data (2019) and methods from the Woodland Carbon Code (2020).
	National Forest Estate England and Scotland (2019, Forestry Commission)	
	Woodland Carbon Code Lookup Tables (2020, Forestry Commission) Sentinel Satellite Observations (NDVI summer, NDVI winter); Digital Elevation Model (DEM, EU-DEM v1.1) European Space Agency (ESA), 2016	
Trees and vegetation outside of woodlands	National Tree Map (BlueSky Ltd)	Carbon sequestration is estimated using a random forest machine learning model. The model is calibrated by relating a series of predictor variables to stand-level carbon sequestration estimates from the National Forest Estate. Predictor variables used include canopy height estimates from the National Tree Map, summer and winter Normalised Difference Vegetation Index from Sentinel, Forest Research ESC based climate estimates and model generated estimates of stand age and yield class. Estimates of carbon sequestration in the National Forest Estate were calculated by applying the Woodland Carbon Code (2020) to forest inventory data (2019) . The model is applied across the study area at 10m resolution. Model outputs are masked to separate woodland versus non woodland areas. Estimates then undergo resampling and are presented at 5m resolution. Carbon sequestration into non-woody landcovers such as grasslands and heathlands were assumed to be nill.
	National Forest Estate England and Scotland (2019, Forestry Commission)	
	Woodland Carbon Code Lookup Tables (2020, Forestry Commission) Sentinel Satellite Observations (NDVI summer, NDVI winter) European Space Agency (ESA), 2016	

Vegetation contribution to soil stabilisation		
	R factor	Rates of soil erosion are estimated using the Revised Universal Soil Loss Equation (RUSLE) model. The method is based on the combination of several spatially-dependent factors, including soil susceptibility to erosion, topography, rainfall intensity, land cover and vegetation density. We create a bespoke landcover-management factor (C-factor) based on landcover map and published parameters for landuse categories in the UK and Europe. K-factor is calculated from NATMAP soil data in England and Wales, and taken from LUCAS-topsoil dervied K-factor (Panagos et al.) for Scotland. The soil erosion model is applied to two different scenarios: a) the baseline land cover map to estimate current rates of soil erosion, and b) a scenario with natural vegetation converted to arable land. We report the difference in the soil erosion rates between these models to give an understanding of the contribution of current vegetation to stabilising soils and reducing rates of soil loss from rainfall.
	K factor derived from NATMAP data (Cranfield University, 2020)	
	E factor	
	LS Factor	
	C factor derived from Landcover map	
	Fractional vegetation cover dervied from Sentinel-2 satellite data. European Space Agency (ESA), 2016	

Vegetation contribution to reducing flood risk		
	Daily rainfall data from National River Flow Archive (2020)	SWAT+ a semi-distributed, physically based hydrological model, has been applied in order to quantify the affect of vegetation on reducing surface runoff. Input data for the model includes landcover map, elevation, soil properties, weather data (temperature, wind speed, relative humidity, incoming solar radiation) from CFSR, and daily rainfall data from UK National River Flow Archive dataset. The model also allows for incorporation of land management practices. By comparing two scenarios, one estimating surface runoff under current landcover and one estimating surface runoff if the vegetation were removed, an assessment of the contribution of vegetation on flood regulation can be made. The model takes into account a unique combination of slope, soil and landcover to estimate the hydrological response at daily timesteps.
	National Soil Map for England and Wales (NATMAP) Cranfield, 2020	
	EU DEM v1.1 (Copernicus, 2016)	
	Landcover map (Copernicus, 2018)	
	OS rivers (Ordnance Survey Zoomstack, 2020)	
	Weather data from Climate Forecast System Reanalysis (CFSR)	

Nutrient runoff		
	Daily rainfall data from National River Flow Archive	The model SWAT+ was applied (as described above) to quantify where nutrient runoff (nitrates) is lowest due to current vegetation and land management practices. Land management practices for agriculture and pasture land were applied. Crop rotations were developed using client knowledge and Taylor et al. (2016). Fertiliser application amounts and N-P-K ratios for pasture land were determined based on client knowledge, current fertiliser products on sale from major manufactures and Crofts and Jefferson (1999).
	EU DEM v1.1	
	Landcover map	
	OS rivers (Ordnance Survey Zoomstack, 2020)	
	Weather data from Climate Forecast System Reanalysis (CFSR)	

Important areas for supporting insect pollinators of crops		
	drawn from the Rural Payments Agency (RPA) Crop Map of England (CROME)	Demand for pollinators is mapped using the distribution of crops dependent on pollinators in the UK and reviews of published studies assessing the impact of pollinators on crop yields (Aizen et al. 2009; Klein et al. 2007). The pollinator demand map is weighted based on the distance from pollinator-dependent crops and degree of pollinator-dependence of those crops. The demand and supply maps are combined to create a relative index of pollination service provision, scaled between 0 and 1. Important habitat for supporting insect pollinators of crops are those areas that score 0.2 or higher.
	Corine Landcover 2018 (perennial crops of berries, orchards and vineyards)	
	Open Street Map (Orchards, vineyards)	
	Landcover map	

Important areas for biodiversity		
	Special Protection Areas (SPAs)	Areas of importance for wildlife or conservation are determined based on different types of designated protected areas and conservation sites together with data for habitats that are recognised as important for biodiversity but are not under statutory protection. These are then classified by their designation, either as 'internationally protected', 'nationally protected', 'locally protected' or 'priority habitat or ancient woodlands'.
	Special Areas of Conservation (SACs)	
	Ramsar sites	
	Biosphere reserves	
	SSSIs	
	National Nature Reserves	
	Nature Improvement Areas	
	Environmentallly Sensitive Areas	
	Priority habitats	
	Ancient woodlands	
	County Wildlife Sites	
	Sites of Importance for Nature Conservation	

Areas important for recreation		
	Flickr records (Flickr API 2020)	The model combines volunteered geographic information from Flickr (2020), eBird (GBIF, 2020) and iNaturalist (GBIF, 2020) records with 9 environmental variables (landcover, landcover diversity, viewshed, elevation, slope, proximity to waterbodies, presence of protected areas, distance to recreation assets, and presence of trails and paths) within a machine-learning technique called maximum entropy modeling (Phillips et al., 2017) to determine potential recreation supply. Maximum entropy models estimate the probability of an event occurring (such as a photo being taken at a particular location) based on characterstics of the area (in this case, the environmental variables listed above). The output of this model - a probability map showing potential recreation supply - is combined with data on potential demand for recreation, based on weighted travel time from population centres of different size, and calibrated based on existing visitor data from previous reports on recreational use of the New Forest National Park to estimate the number of visitors each year.
	eBird records (GBIF, 2020)	
	iNaturalist (GBIF, 2020)	
	Landcover (composite product, see stocks): broad habitat types and landcover diversity	
	Elevation (25m EU DEM v1.1) (Copernicus, 2016)	
	Slope (derived from 25m EU DEM v1.1)	
	Cumulative viewsheds (dervied from 25m EU DEM v1.1)	
	Roads (national regional and local, OS Zoomstack, 2020)	
	Public footpaths, bridleways and trails (OS Zoomstack + National Forest Estate Recreation Routes + National Trails England + OSM paths)	
	Waterways (OS Zoomstack, 2020)	
	Recreation assets (National Forest Estate Amenities + World Heritage Sites + Registered Parks and Gardens + Registered Battlefields)	
	Countryside and Rights of Way (CRoW)	
	Greenspaces (Ordnance Survey Zoomstack, 2020)	
	Protected areas (NNR, LNR, SSSI, SAC, SPA, Ramsar)	
	Visitor numbers (Footprint Ecology, 2020)	
	Population density (UK Gridded Population 2011; Reis et al. (2017). UK Gridded Population 2011 based on Census 2011 and Land Cover Map 2015. NERC Environmental Information Data Centre.)	

Important woodland patches for maintaining movement of species across landscapes.		
	Landcover map	Patches of broadleaved woodland habitat are extracted from the landcover map. The distances between the centre of each patch are calculated and used to calculate the Integral Index of Connectivity (IIC) using the R package *lconnect* . Patches are considered to be connected if their distance is less than a given threshold distance (=dispersal distance). We use a consevative dispersal distance of 20m. The dIIC for each patch can be subdivided into three fractions dIIC Intra: (i) a measure for intra-patch connectivity, mainly referring to the patch area and the available habitat therein (ii) dIIC Flux: this shows how well a patch is connected to other patches in the landscape when regarding the dispersal flux of species (iii) dIIC Connector: this shows the importance of a given patch for the connectivity of other patches, when this given patch acts as a connecting element or stepping stone between these other patches.

c) Methodological approaches and data sources used to determine combined services

Ecosystem Service	Input data	Methodology	Output resolution and units
Hotspots of multiple services	Carbon storage in trees in woodlands Carbon storage in trees and vegetation outside of woodlands Carbon storage in topsoils Carbon sequestration in trees in woodlands Carbon sequestration in trees and vegetation outside of woodlands Vegetation contribution to reducing flood risk Vegetation contribution to soil stabilisation Important habitat for supporting insect pollinators of crops Important areas for recreation Important habitats for biodiversity Important vegetation patches for movement of biodiversity across landscapes	Carbon storage in the top 30cm of soil and carbon storage in vegetation (within and otuside of woodlands) are combined to produce total carbon storage. Carbon sequestration within and outside of woodlands are combined to produce a total carbon sequestration. Each of these total results is standardised to values between 0 (low) and 1 (high). Results for other ecosystem sevices are also standardised in this way. The standarised ecosystem services maps are summed to create a map of ecosystem services hotspots. The final map of multiple services can take values from 0 (no ecosystem services) to 8 (maximum across all ecosystem services).	5m Hectares

Appendix 2: Asset Registers of natural capital stocks

a) Asset register of estimated landcover types

Landcover	New Forest National Park Area (ha)	% of total	Fawley Waterside & NFNP study area Area (ha)	% of total
Acid grassland	3,478.9	6.1	3,587.2	4.2
Arable and horticulture	4,070.9	7.2	8,954.7	10.5
Broadleaved mixed and yew woodland	13,307.3	23.5	15,507.5	18.1
Built-up areas and gardens	3,261.6	5.8	10,004.7	11.7
Calcareous grassland	0.2	<0.1	70.7	0.1
Coastal rock	1.0	<0.1	6.8	<0.1
Coastal saltmarsh, lagoons and beaches	1,278.6	2.3	1,890.7	2.2
Coastal sand dunes and shingle	59.6	0.1	94.1	0.1
Coniferous woodland	5,689.9	10.0	5,947.1	6.9
Dense scrub	46.3	0.1	324.1	0.4
Dwarf shrub heath	9,935.2	17.5	9,950.5	11.6
Fen marsh and swamp	3,127.5	5.5	3,797.8	4.4
Hedgerows	514.1	0.9	778.2	0.9
Inland rock	-	-	<0.1	<0.1
Maritime cliffs	0.6	<0.1	46.8	0.1
Modified grassland	8,218.7	14.5	12,190.3	14.2
Neutral grassland	2,964.6	5.2	6,284.4	7.3
Open saline water	59.3	0.1	3,652.6	4.3
Rivers and lakes	280.5	0.5	1,625.5	1.9
Sparsely vegetated land	357.8	0.6	871.5	1.0
Total	56,653	100	85,585	100

b) Asset register of estimated canopy heights for trees situated on the different landcover types

Landcover	New Forest National Park Area (ha)	Average height (m)	Fawley Waterside & NFNP study area Average height (m)
Trees in woodlands			
Broadleaved mixed and yew woodland	13,307.3	17.2	16.8
Coniferous woodland	5,689.9	14.5	14.5
Trees and vegetation outside woodlands			
Hedgerows and trees outside of woodlands	n/a	1.2	1.7
Total	56,652.6	6.7	5.2

c) Asset register of topographical variation

Landcover	Area (ha)	New Forest National Park Average elevation (metres above sea level)	Average slope (degrees)	Fawley Waterside & NFNP study area Average elevation (metres above sea level)	Average slope (degrees)
Acid grassland	3,478.9	58.8	2.3	57.7	2.3
Arable and horticulture	4,070.9	25.6	1.4	35.4	1.6
Broadleaved mixed and yew woodland	13,307.3	50.9	2.8	49.3	2.8
Built-up areas and gardens	3,261.6	42.1	2.0	29.5	1.5
Calcareous grassland	0.2	1.2	0.5	95.5	8.4
Coastal rock	1.0	0.1	0.2	0.4	1.3
Coastal saltmarsh, lagoons and beaches	1,278.6	0.2	0.4	0.2	0.4
Coastal sand dunes and shingle	59.6	0.6	0.7	1.6	1.8
Coniferous woodland	5,689.9	51.7	2.7	51.7	2.7
Dense scrub	46.3	33.9	2.1	63.8	2.8
Dwarf shrub heath	9,935.2	55.0	2.1	55.0	2.1
Fen marsh and swamp	3,127.5	46.1	2.3	39.5	2.0
Hedgerows	514.1	36.5	2.2	29.8	2.1
Inland rock	-	-	-	-	-
Maritime cliffs	0.6	5.5	3.8	12.0	6.4
Modified grassland	8,218.7	37.6	2.0	33.6	1.8
Neutral grassland	2,964.6	32.5	1.9	35.0	1.8
Open saline water	59.3	-	-	-	-
Rivers and lakes	280.5	11.4	0.9	6.8	0.3
Sparsely vegetated land	357.8	46.0	2.2	36.1	1.9
Overall	56,652.6	45.1	2.2	38.7	1.9

d) Asset register of freshwater

Asset	New Forest National Park Quantity	units	Fawley Waterside & NFNP study area Quantity	units
Water and Wetlands				
Freshwater bodies	429.8	ha	1,394.6	ha
Open saline water	59.3	ha	3,652.6	ha
Rivers and lakes	280.5	ha	1,625.5	ha
Fen marsh and swamp	3,127.5	ha	3,797.8	ha
All rivers and streams	407.4	km	657.3	km

* Ordnance Survey surface waters and rivers.

e) Asset register of soil types

Asset	National Park Quantity	Area
Soils		
Deep fine loamy soils with slowly permeable subsoils and slight seasonal waterlogging	2,136	ha
Well drained flinty coarse loamy and sandy soils, mainly over gravel.	420	ha
Mainly deep well drained calcareous and non-calcareous sandy soils.	32	ha
Coarse and fine loamy permeable soils mainly over gravel variably affected by groundwater.	6,197	ha
Deep permeable coarse loamy and sandy soils some with peaty surface horizons affected by groundwater.	126	ha
Well drained fine loamy soils often over gravel associated with	6,103	ha
Lake or water body	123	ha
Deep well drained often stoneless coarse loamy and sandy soils.	66	ha
Deep stoneless non-calcareous and calcareous clayey soils.	597	ha
Well drained coarse loamy and some sandy soils, commonly over gravel.	334	ha
Slowly permeable seasonally waterlogged fine loamy over clayey and coarse loamy over clayey soils and similar more permeable soils with slight waterlogging.	19,938	ha
Well drained very acid, very flinty sandy soils with bleached subsurface horizon.	255	ha
Shallow calcareous and non-calcareous loamy soils over flint gravel affected by groundwater.	420	ha
Slowly permeable seasonally waterlogged fine loamy over clayey and fine silty over clayey soils associated with similar clayey soils often with brown subsoils.	2,497	ha
Deep permeable sandy soils with humose or peaty surface horizon affected by groundwater.	295	ha
Well drained very acid sandy soils with a bleached subsurface horizon.	1,061	ha
Soils of variable texture flooded by high tides. Many are soft and unripened, others, often on higher sites or of sandy texture, are firm and ripened. Frequently calcareous.	67	ha
Well drained fine silty over clayey, clayey and fine silty soils	<1	ha
Naturally very acid coarse loamy over clayey soils with a bleached subsurface horizon, slowly permeable subsoils and slight seasonal waterlogging.	7,997	ha
Deep fine Loamy and fine loamy over sandy soils variably affected by groundwater.	2,090	ha
Deep often stoneless and very acid, humose sandy soils with bleached subsurface horizon, affected by groundwater.	128	ha
Naturally very acid sandy over clayey and loamy over clayey soils locally with humose or peaty surface horizons, slowly permeable subsoils and slight seasonal waterlogging.	4,585	ha

Appendix 3: Asset Registers of Natural capital flows

a) Register of carbon stored in NFNP vegetation and soils

| Landcover | New Forest National Park | | | | Fawley Waterside & NFNP study area |
	Area (ha)	Total (tCO2e)	% of total	Per hectare (tCO2e/ha)	Per hectare (tCO2e/ha)
Trees in woodlands					
Broadleaved mixed and yew woodland	13,307.3	6,155,606	19.3	463	453
Coniferous woodland	5,689.9	2,286,689	7.2	402	402
Trees and vegetation outside woodlands					
Hedgerows and trees outside of woodland	n/a*	1,958,718	6.2	n/a*	n/a*
Acid grassland	3,478.9	12,756	<0.1	4	4
Arable and horticulture	4,070.9	29,854	<0.1	7	7
Built-up areas and gardens	3,261.6	11,959	<0.1	4	4
Calcareous grassland	0.2	1	0.0	4	4
Coastal rock	1.0	-	-	-	-
Coastal saltmarsh, lagoons and beaches	1,278.6	4,688	<0.1	4	4
Coastal sand dunes and shingle	59.6	-	-	-	-
Dense scrub	46.3	339	<0.1	7	7
Dwarf shrub heath	9,935.2	72,858	0.2	7	7
Fen marsh and swamp	3,127.5	22,935	<0.1	7	7
Inland rock	-	-	-	-	-
Maritime cliffs	0.6	-	-	-	-
Modified grassland	8,218.7	30,135	<0.1	4	4
Neutral grassland	2,964.6	10,870	<0.1	4	4
Open saline water	59.3	-	-	-	-
Rivers and lakes	280.5	-	-	-	-
Sparsely vegetated land	357.8	-	-	-	-
Topsoils					
Broadleaved mixed and yew woodland	13,307.3	4,994,486	15.7	375	361
Dwarf shrub heath	9,935.2	4,980,424	15.6	501	501
Modified grassland	8,218.7	2,623,153	8.2	319	304
Coniferous woodland	5,689.9	2,266,529	7.1	398	395
All other landcovers	19,501.5	6,386,330	20.1	327	206
Total of vegetation and soil	56,653	31,848,330	100	562	467

*Hedgerows and trees outside of woodlands mapped from National Tree Map data. Many of these trees are found in other mapped landcovers such as grasslands and parks

b) Register of carbon sequestered in NFNP vegetation

Landcover	Area (ha)	New Forest National Park Total (tCO2e/yr)	% of total	Average per hectare (tCO2e/ha/yr)	Fawley Waterside & NFNP study area Average per hectare (tCO2e/ha/yr)
Trees in woodlands					
Broadleaved mixed and yew woodland	13,307.3	31,836.6	44.2	2.4	2.5
Coniferous woodland	5,689.9	19,588.2	27.2	3.4	3.4
Trees and vegetation outside woodlands*					
Hedgerows and trees outside of woodlands	37,655.4	20,676.5	28.7	0.5	0.4
Overall	56,653	72,101	100	1.3	1.3

c) Register of NFNP vegetation that contributes to soil stabilization*

Landcover	Area (ha)	New Forest National Park Total (tonnes of soil/yr)	% of total	Average per hectare (tonnes of soil/ha/yr)	Fawley Waterside & NFNP study area Average per hectare (tonnes of soil/ha/yr)
Acid grassland	3,478.9	13,103	7.0	3.8	3.7
Arable and horticulture	4,070.9	8,400	4.5	2.1	2.5
Broadleaved mixed and yew woodland	13,307.3	63,036	33.7	4.7	4.8
Built-up areas and gardens	3,261.6	-	-	-	-
Calcareous grassland	0.2	<0.1	<0.1	0.3	19.5
Coastal rock	1.0	-	-	-	-
Coastal saltmarsh, lagoons and beaches	1,278.6	690	0.4	0.5	0.5
Coastal sand dunes and shingle	59.6	92	<0.1	1.5	2.8
Coniferous woodland	5,689.9	26,203	14.0	4.6	4.6
Dense scrub	46.3	160	0.1	3.5	5.2
Dwarf shrub heath	9,935.2	32,634	17.5	3.3	3.3
Fen marsh and swamp	3,127.5	4,037	2.2	1.3	1.1
Hedgerows	514.1	1,817	1.0	3.5	3.5
Inland rock	-	-	-	-	-
Maritime cliffs	0.6	-	-	-	-
Modified grassland	8,218.7	27,311	14.6	3.3	3.0
Neutral grassland	2,964.6	9,446	5.1	3.2	3.2
Open saline water	59.3	-	-	-	-
Rivers and lakes	280.5	-	-	-	-
Sparsely vegetated land	357.8	-	-	-	-
Total	56,653	186,929	100	3.3	2.8

* Results are the estimated increase in soil erosion that would occur if the current vegetation were removed, leaving only bare soil.

d) Register of areas of vegetation in the NFNP that is important for flood risk reduction*

| Landcover | New Forest National Park | | | | Fawley Waterside & NFNP study area |
	Area (ha)	Total surface water runoff avoided (m3/yr)	% of total	Average surface water runoff avoided per hectare (m3 avoided/ha/ yr)	Average surface water runoff avoided per hectare (m3 avoided/ha/yr)
Acid grassland	3,478.9	11,402,119.5	6.4	3,277.5	3,232.1
Arable and horticulture	4,070.9	9,741,009.5	5.4	2,392.8	1,898.1
Broadleaved mixed and yew woodland	13,307.3	52,385,926.4	29.2	3,936.6	3,659.3
Built-up areas and gardens	3,261.6	-	-	-	-
Calcareous grassland	0.2	3.8	<0.1	22.2	160.3
Coastal rock	1.0	-	-	-	-
Coastal saltmarsh, lagoons and beaches	1,278.6	-	-	-	-
Coastal sand dunes and shingle	59.6	-	-	-	-
Coniferous woodland	5,689.9	22,525,370.5	12.6	3,958.8	3,857.5
Dense scrub	46.3	128,687.9	0.1	2,780.2	1,873.5
Dwarf shrub heath	9,935.2	34,557,723.7	19.3	3,478.3	3,476.1
Fen marsh and swamp	3,127.5	11,041,046.6	6.2	3,530.3	2,979.3
Hedgerows	514.1	1,761,702.6	1.0	3,426.7	2,705.7
Inland rock		-	-	-	-
Maritime cliffs	0.6	-	-	-	-
Modified grassland	8,218.7	26,454,056.9	14.7	3,218.8	2,827.3
Neutral grassland	2,964.6	9,402,372.8	5.2	3,171.5	2,353.4
Open saline water	59.3	-	-	-	-
Rivers and lakes	280.5	-	-	-	-
Sparsely vegetated land	357.8	-	-	-	-
Total	56,653	179,400,020	100	3,167	2,409

* Estimates are the increase in surface water runoff from rainfall that would be expected if the current vegetation were removed, leaving only bare soil. Surface runoff contributes to pluvial flooding, and fluvial flooding where responses in rivers and streams are flashy.

e) Register of areas contributing the least to nutrient runoff (nitrates) in the NFNP

| Landcover | | New Forest National Park | | | Fawley Waterside & NFNP study area |
	Area (ha)	Total (kg N in nitrate in surface runoff per year)	% of total	Per hectare (kg N in nitrate in surface runoff/ha/yr)	Per hectare (kg N in nitrate in surface runoff/ha/yr)
Acid grassland	3,478.9	7,330	4.7	2.1	2.1
Arable and horticulture	4,070.9	69,161	44.6	17.0	11.7
Broadleaved mixed and yew woodland	13,307.3	16,006	10.3	1.2	1.1
Built-up areas and gardens	3,261.6	-	-	-	-
Calcareous grassland	0.2	-	-	-	0.0
Coastal rock	1.0	-	-	-	-
Coastal saltmarsh, lagoons and beaches	1,278.6	-	-	-	-
Coastal sand dunes and shingle	59.6	-	-	-	-
Coniferous woodland	5,689.9	6,737	4.3	1.2	1.1
Dense scrub	46.3	72	<0.1	1.6	0.7
Dwarf shrub heath	9,935.2	6,384	4.1	0.6	0.6
Fen marsh and swamp	3,127.5	5,833	3.8	1.9	1.6
Hedgerows	514.1	424	0.3	0.8	0.8
Inland rock	-	-	-	-	-
Maritime cliffs	0.6	-	-	-	-
Modified grassland	8,218.7	35,287	22.8	4.3	3.6
Neutral grassland	2,964.6	7,848	5.1	2.6	1.8
Open saline water	59.3	-	-	-	-
Rivers and lakes	280.5	-	-	-	-
Sparsely vegetated land	357.8	-	-	-	-
Total	56,653	155,081	100	2.7	2.4

Nutrient inputs were set according to client-supplied information for pasture and arable rotations. Nutrient inputs are likely to vary between farms and land managers in the study area, there results are therefore indicative of average practices in the study area.

f) Register of recreational visits related to natural capital in the NFNP

The total number of visits to the NFNP is estimated as 10,381,300 per year

g) Register of different landcover types in the NFNP that are important for pollination services*

Landcover	New Forest National Park		Fawley Waterside & NFNP study area	
	Area of habitat important for pollinating insects for crops (ha)	% of total area	Area of habitat important for pollinating insects for crops (ha)	% of total area
Acid grassland	635.0	1.1	703.0	0.8
Arable and horticulture	386.5	0.7	878.0	1.0
Broadleaved mixed and yew woodland	7,536.8	13.3	9,651.3	11.3
Built-up areas and gardens	363.6	0.6	1,506.4	1.8
Calcareous grassland	-	-	70.5	0.1
Coastal rock	-	-	-	-
Coastal saltmarsh, lagoons and beaches	-	-	-	-
Coastal sand dunes and shingle	0.2	<0.1	0.2	<0.1
Coniferous woodland	1,894.8	3.3	2,086.9	2.4
Dense scrub	43.7	0.1	321.5	0.4
Dwarf shrub heath	1,094.7	1.9	1,106.6	1.3
Fen marsh and swamp	1,395.3	2.5	1,739.2	2.0
Hedgerows	138.8	0.2	255.5	0.3
Inland rock	-	-	-	-
Maritime cliffs	-	-	-	-
Modified grassland	6,921.2	12.2	10,742.8	12.6
Neutral grassland	2,508.1	4.4	5,401.6	6.3
Open saline water	-	-	-	-
Rivers and lakes	-	-	-	-
Sparsely vegetated land	-	-	-	-
Total	22,919	40	34,463	40

* Pollination service is a metric with values between 0 (no pollination service) and 1 (high pollination service). Areas with a pollination score of 0.1 or higher are classified as high importance for pollinating insects.

h) Register of areas important for biodiversity within the NFNP

Area important for biodiversity	National Park Area (ha)	National Park % of total area	Fawley Waterside & NFNP study area Area (ha)	Fawley Waterside & NFNP study area % of total area
Protected area (internationally important)	31,491.6	55.6	33,892.8	39.6
Protected area (nationally important)	1,306.1	2.3	3,466.9	4.1
Protected area (locally important)	612.3	1.1	954.0	1.1
Priority habitat for biodiversity and ancient woodlands	5,907.4	10.4	8,422.6	9.8
Total	39,317.3	69.0	46,736.2	55.0
Other areas	17,335.2	30.6	38,849.0	45.4

International importance statutory = SPA/SAC/Ramsar/Biosphere Reserve; National importance statutory = SSSI/National Nature Reserve/Environmentally Sensitive Areas/Nature Improvement Areas; Local importance = SINC; National importance non-statutory = Priority habitat/ancient woodlands

i) Register of woodland patches in the NFNP that are important for movement of biodiversity across landscapes.

	New Forest National Park Area of low importance for movement of biodiversity (ha)	% of study area	New Forest National Park Area of medium importance for movement of biodiversity (ha)	% of study area	New Forest National Park Area of greatest importance for movement of biodiversity (ha)	% of study area	Wider area % of land in the region of low importance	Wider area % of land in the region of medium importance	Wider area % of land in the region of greatest importance
Woodlands									
Broadleaved mixed and yew woodland	5,755	10	3,793	7	3,760	7	9	5	4

j) Register of landcover types which support greatest combined ecosystem service flow in the NFNP

| Landcover | New Forest National Park | | | Fawley Waterside & NFNP study area |
	Area (ha)	Combined ecosystem services per ha (0-8)	Percentage of combined ecosystem services	Combined ecosystem services per ha (0-8)
Acid grassland	3,478.9	2.7	7.1	2.7
Arable and horticulture	4,070.9	0.8	2.5	0.7
Broadleaved mixed and yew woodland	13,307.3	3.6	35.6	3.4
Built-up areas and gardens	3,261.6	0.7	1.7	0.4
Calcareous grassland	0.2	1.2	<0.1	1.8
Coastal rock	1.0	1.1	<0.1	0.9
Coastal saltmarsh, lagoons and beaches	1,278.6	1.0	1.0	1.1
Coastal sand dunes and shingle	59.6	1.2	0.1	1.1
Coniferous woodland	5,689.9	2.9	12.5	2.9
Dense scrub	46.3	1.3	<0.1	1.0
Dwarf shrub heath	9,935.2	2.7	20.3	2.7
Fen marsh and swamp	3,127.5	2.7	6.4	2.5
Hedgerows	514.1	2.5	1.0	2.2
Inland rock	-	-	-	1.0
Maritime cliffs	0.6	1.8	<0.1	1.3
Modified grassland	8,218.7	1.2	7.3	1.2
Neutral grassland	2,964.6	1.7	3.9	1.5
Open saline water	59.3	1.1	<0.1	0.1
Rivers and lakes	280.5	1.0	0.2	0.4
Sparsely vegetated land	357.8	1.1	0.3	0.8
Total	56,653	2.3	100	1.8

k) Register detailing the total ecosystem service flows for the NFNP

Ecosytem Service Flow	New Forest National Park				Fawley Waterside & NFNP study area	
	Total		Relative value		Relative value	
Carbon storage in vegetation and soils	31,848,330	tCO2e	562.2	tCO2e/ha	467.0	tCO2e/ha
Trees in Woodlands	8,442,295	tCO2e	444.4	tCO2e/ha	138.8	tCO2e/ha
Trees and vegetation outside of woodlands	2,155,113	tCO2e	58.0	tCO2e/ha	41.0	tCO2e/ha
Topsoils	21,250,922	tCO2e	375.1	tCO2e/ha	307.4	tCO2e/ha
Carbon sequestration in vegetation	72,101	tCO2e/yr.	1.3	tCO2e/ha/yr	1.3	tCO2e/ha/yr
Trees in woodlands	51,425	tCO2e/yr.	0.9	tCO2e/ha/yr	1.0	tCO2e/ha/yr
Trees and vegetation outside of woodlands	20,677	tCO2e/yr.	0.4	tCO2e/ha/yr	0.3	tCO2e/ha/yr
Soil erosion prevention	186,929	tonnes soil loss avoided/yr	3.3	tonnes soil loss avoided/ha/yr	2.8	tonnes soil loss avoided/ha/yr
Flood risk reduction	179,400,020	m3 runoff avoided/yr	3,166.7	m3 runoff avoided/ha/yr	2,408.8	m3 runoff avoided/ha/yr
Recreation	10,381,300	number of visits/yr		n/a		n/a
Important areas for supporting insect pollinators of crops	22,919	ha	40.5	% of total area	40.3	% of total area
Important biodiversity habitats	39,317	ha	69.0	% of total area	55.0	%

Nature networks reflect spatial configurations of habitats so are not summarised in this table

References

Aizen, M. A., Garibaldi, L. A., Cunningham, S. A. and Klein, A. M. (2009) 'How much does agriculture depend on pollinators? Lessons from long-term trends in crop production', Annals of botany, 103(9), pp. 1579–1588.

Alonso, I., Weston, K., Gregg, R. and Morecroft, M. (2012) 'Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources.', Natural England Research Reports, Number NERR04, 17(10), pp. 55–59.

Arnold, J. G., Srinivasan, R., Muttiah, R. S. and Williams, J. R. (1998) 'Large area hydrologic modeling and assessment part I: Model development', Journal of the American Water Resources Association, 34(1), pp. 73–89.

Axe, M. S., Grange, I. D. and Conway, J. S. (2017) 'Carbon storage in hedge biomass – A case study of actively managed hedges in England', Agriculture, Ecosystems and Environment, 250, pp. 81–88.

Ballabio, C., Panagos, P. and Monatanarella, L. (2016) 'Mapping topsoil physical properties at European scale using the LUCAS database', Geoderma, 261, pp. 110–123.

Baude, M., Kunin, W. E., Boatman, N. D., Conyers, S., Davies, N., Gillespie, M. A. K., Morton, R. D., Smart, S. M. and Memmott, J. (2016) 'Historical nectar assessment reveals the fall and rise of floral resources in Britain', Nature, 530(7588), pp. 85–88.

Beven, K. J., Kirkby, M. J. and Kirkby, A. J. (1979) 'A physically based, variable contributing area model of basin hydrology / Un modèle à base physique de zone d'appel variable de l'hydrologie du bassin versant) A physically based, variable contributing area model of basin hydrology / Un modèle à base physique de zone d'appel variable de l'hydrologie du bassin versant A physically based, variable contributing area model of basin hydrology', Hydrological Sciences Journal, 24(1), pp. 43–69.

Bieger, K., Arnold, J. G., Rathjens, H., White, M. J., Bosch, D. D., Allen, P. M., Volk, M. and Srinivasan, R. (2017) 'Introduction to SWAT+, A Completely Restructured Version of the Soil and Water Assessment Tool', JAWRA Journal of the American Water Resources Association, 53(1), pp. 115–130.

BlueSky Ltd (2020) National Tree Map. Available at: https://www.bluesky-world.com/.

Brauman, K. A., Daily, G. C., Ka'eo Duarte, T. and Mooney, H. A. (2007) 'The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services', Annual Review of Environment and Resources, 32(1), pp. 67–98.

Chapman, S. J., Bell, J., Donnelly, D. and Lilly, A. (2009) 'Carbon stocks in Scottish peatlands', Soil Use and Management, 25(2), pp. 105–112.

Chaudhary, A., Burivalova, Z., Koh, L. P. and Hellweg, S. (2016) 'Impact of Forest Management on Species Richness: Global Meta-Analysis and Economic Trade-Offs', Scientific Reports, 6(1), pp. 1–10.

Chow, V. (1959) Open Channel Flow. Singapore: McGraw-Hill Book Company.

Climate Change Committee (CCC) (2018) Land use: Reducing emissions and preparing for climate change report.

Commission, F. (2019) 'National Forest Estate Ownership England'.

Coomes, D. A., Dalponte, M., Jucker, T., Asner, G. P., Banin, L. F., Burslem, D. F. R. P., Lewis, S. L., Nilus, R., Phillips, O. L., Phua, M. H. and Qie, L. (2017) 'Area-based vs tree-centric approaches to mapping forest carbon in Southeast Asian forests from airborne laser scanning data', Remote Sensing of Environment, 194, pp. 77–88.

Copernicus (2016) European Digital Elevation Model (EU-DEM), version 1.1. Available at: ttps://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1?tab=download

Copernicus (2018) Corine Land Cover (CLC) 2018. Version 20b2. Available at: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

Cranfield University (2020) National Soil Map of England and Wales - NATMAP, LandIS - Land Information System . Available at: http://www.landis.org.uk/data/natmap.cfm.

Cummins, R., Donnelly, D., Nolan, A., Towers, W., Chapman, S., Grieve, I. and Birnie, R. V (2011) Peat erosion and the management of peatland habitats. Scottish Natural Heritage Commissioned Report No. 410.

Defra (2000) Countryside and Rights of Way Act (CRoW). Available at: https://www.legislation.gov.uk/ukpga/2000/37/contents

ESDBv2 Raster Library (2006) A set of rasters derived from the European Soil Database distribution v2.0, European Commission and the European Soil Bureau Network, CD-ROM, EUR 19945 EN). Available at: https://esdac.jrc.ec.europa.eu/content/european-soil-database-v2-raster-library-1kmx1km.

European Soil Data Centre (ESDAC) (2015) EU LUCAS topsoil (500m), European Comission, Joint Research Centre. Available at: https://esdac.jrc.ec.europa.eu/

European Space Agency (ESA). (2018) Copernicus Sentinel-2 mission. Level 2-A data.

Falloon, P., Powlson, D. and Smith, P. (2004) 'Managing field margins for biodiversity and carbon sequestration: a Great Britain case study', Soil Use and Management, 20(2), pp. 240–247.

Food and Agriculture Organization of the United Nations (FAO) (no date) Global Soil Organic Carbon (GSOC) Map, Global Soil Partnership . Available at: http://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data-new/global-soil-organic-carbon-gsoc-map/en/.

Forbes, H., Ball, K. and McLay, F. (2015) Natural Flood Management Handbook. Scottish Environment Protection Agency.

Forestry Commission (2017) National Forest Inventory Woodland GB.

Forestry Commission (2018) Woodland Carbon Code (WCC) Carbon Lookup Tables v2.0. Available at: https://www.woodlandcarboncode.org.uk/

Forestry Commission (2020) Woodland Carbon Code (WCC) Carbon Lookup Tables v2.3.

Godínez-Gómez, O. and C. A. C. A. (2020) 'Makurhini R package: Analyzing landscape connectivity.'

Graves, A. R., Morris, J., Deeks, L. K., Rickson, R. J., Kibblewhite, M. G., Harris, J. A., Farewell, T. S. and Truckle, I. (2015) 'The total costs of soil degradation in England and Wales', Ecological Economics, 119(1), pp. 399–413.

Hiederer, R. (2013) Mapping Soil Properties for Europe-Spatial Representation of Soil Database Attributes, Luxembourg: Publications Office of the European Union.

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. and Tscharntke, T. (2007) 'Importance of pollinators in changing landscapes for world crops', Proceedings of the Royal Society B: Biological Sciences, 274(1608), pp. 303–313.

Levatich, T., Ligocki, S. (2020) 'EOD - eBird Observation Dataset.', Cornell Lab of Ornithology.

Lilly, A., Baggaley, N. and Donnelly, D. (2012) 'Map of soil organic carbon in top soils of Scotland.', Map prepared for EU project GS-SOIL -Assessment and strategic development of INSPIRE compliant Geodata-Services for European Soil Data. ECP-2008- GEO-318004.

Lonsdorf, E., Kremen, C., Ricketts, T., Winfree, R., Williams, N. and Greenleaf, S. (2009) 'Modelling pollination services across agricultural landscapes', Annals of Botany, 103(9), pp. 1589–1600.

Maetens, W., Poesen, J. and Vanmaercke, M. (2012) 'How effective are soil conservation techniques in reducing plot runoff and soil loss in Europe and the Mediterranean?', Earth-Science Reviews, 115(1–2), pp. 21–36.

Met Office; Hollis, D.; McCarthy, M.; Kendon, M.; Legg, T.; Simpson, I. (2019) HadUK-Grid Gridded Climate Observations on a 1km grid over the UK, v1.0.1.0 (1981-2010)., Centre for Environmental Data.

Met Office (2019) Climate. Available at: https://www.metoffice.gov.uk/weather/climate.

Miller, J. D. and Hutchins, M. (2017) 'The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom', Journal of Hydrology: Regional Studies. Elsevier B.V., pp. 345–362.

National River Flow Archive (2020) Daily rainfall data. Available at: https://nrfa.ceh.ac.uk/data/search.

Natural England (2020a) Ancient Woodland (England) . Available at: https://naturalengland-defra.opendata.arcgis.com/datasets/ancient-woodland-england/data?geometry=-13.447%2C59.134%2C13.140%2C66.163.

Natural England (2020b) Priority Habitat Inventory . Available at: https://data.gov.uk/dataset/4b6ddab7-6c0f-4407-946e-d6499f19fcde/priority-habitat-inventory-england (Accessed: 8 December 2020).

NCAR - Climate Data Guide (no date) Climate Data Sets . Available at: https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr.

O'Connell, P. E., Ewen, J, O'Donnell, G., Quinn, Philip, O'connell, E., Ewen, John, O'donnell, G. and Quinn, Paul (2007) 'Is there a link between agricultural land-use management and flooding?', Hydrol.Earth Syst.Sci, 11(1), pp. 96–107.

OpenStreetMap contributors (2018) Water bodies and water courses. Available at: http://planet.openstreetmap.org.

Palmer, R. C. and Smith, R. P. (2013) 'Soil structural degradation in SW England and its impact on surface-water runoff generation', Soil Use and Management, 29(4), pp. 567–575.

Panagos, P. (2006) 'The European soil database', GEO: connexion, 5(7), pp. 32–33.

Panagos, P., Meusburger, K., Ballabio, C., Borrelli, P. and Alewell, C. (2014) 'Soil erodibility in Europe: A high-resolution dataset based on LUCAS', Science of the Total Environment, 479–480(1), pp. 189–200.

Panagos, P., Borrelli, P., Meusburger, K., Alewell, C., Lugato, E. and Montanarella, L. (2015) 'Estimating the soil erosion cover-management factor at the European scale', Land Use Policy, 48, pp. 38–50.

Panagos, P. et al. (2015) 'Rainfall erosivity in Europe', Science of the Total Environment, 511, pp. 801–814.

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L. and Alewell, C. (2015) 'The new assessment of soil loss by water erosion in Europe', Environmental Science and Policy, 54, pp. 438–447.

Panagos, P., Standardi, G., Borrelli, | Pasquale, Lugato, E., Luca Montanarella, | and Bosello, F. (2018) 'Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models', Land Degradation and Development, 29(3), pp. 471–484.

Panagos, P., Borrelli, P. and Meusburger, K. (2015) 'A new European slope length and steepness factor (LS-factor) for modeling soil erosion by water', Geosciences (Switzerland), 5, pp. 117–126.

Phillips, S. J., Anderson, R. P., Dudík, M., Schapire, R. E. and Blair, M. E. (2017) 'Opening the black box: an open-source release of Maxent', Ecography, 40(7), pp. 887–893.

Powney, G. D., Carvell, C., Edwards, M., Morris, R. K. A., Roy, H. E., Woodcock, B. A. and Isaac, N. J. B. (2019) 'Widespread losses of pollinating insects in Britain', Nature communications, 10(1), pp. 1–6.

Price, B., Waser, L. T., Wang, Z., Marty, M., Ginzler, C. and Zellweger, F. (2020) 'Predicting biomass dynamics at the national extent from digital aerial photogrammetry', International Journal of Applied Earth Observation and Geoinformation, 90, p. 102116.

Reis, S., Liska, T., Steinle, S., Carnell, E., Leaver, D., Roberts, E., Vieno, M., Beck, R. and Dragosits, U. (2017) 'UK gridded population 2011 based on Census 2011 and Land Cover Map 2015', NERC Environmental Information Data Centre. (Dataset).

Ricketts, T. H., Regetz, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S. S., Klein, A. M., Mayfield, M. M., Morandin, L. A., Ochieng', A. and Viana, B. F. (2008) 'Landscape effects on crop pollination services: are there general patterns?', Ecology Letters, 11(5), pp. 499–515.

Robertson, A. D., Davies, C. A., Smith, P., Stott, A. W., Clark, E. L. and McNamara, N. P. (2017) 'Carbon Inputs from Miscanthus Displace Older Soil Organic Carbon Without Inducing Priming', BioEnergy Research, 10(1), pp. 86–101.

Saura, S. and Pascual-Hortal, L. (2007) 'A new habitat availability index to integrate connectivity in landscape conservation planning: Comparison with existing indices and application to a case study', Landscape and Urban Planning, 83(2–3), pp. 91–103.

Saura, S. and Rubio, L. (2010) 'A common currency for the different ways in which patches and links can contribute to habitat availability and connectivity in the landscape', Ecography, 33(3), pp. 523–537.

Schulze, E. D. (2018) 'Effects of forest management on biodiversity in temperate deciduous forests: An overview based on Central European beech forests', Journal for Nature Conservation. Elsevier GmbH, pp.

Treweek, Jo, Butcher, B., Treweek, J, Carey, P. and Norton, L. (2018) 'Introducing the UK Habitat Classification - Updating Our Approach to Habitat Survey, Monitoring and Assessment', In Practice: Bulletin of the Chartered Institute of Ecology and Environmental Management.

Ueda, K. (2020) 'iNaturalist Research-grade Observations', iNaturalist.org.

UK National River Flow Archive (2020) Daily rainfall data. Available at: https://nrfa.ceh.ac.uk/content/uk-water-resources-portal.

Williams, I. H. (1994) 'The dependence of crop production within the European Union on pollination by honey bees', Agricultural Zoology Reviews (United Kingdom).

Wischmeier, W. H. and Smith, D. D. (1978) 'Predicting rainfall erosion losses: a guide to conservation planning', United States. Dept. of Agriculture. Agriculture Hdbook, 537(1), pp. 285–291.