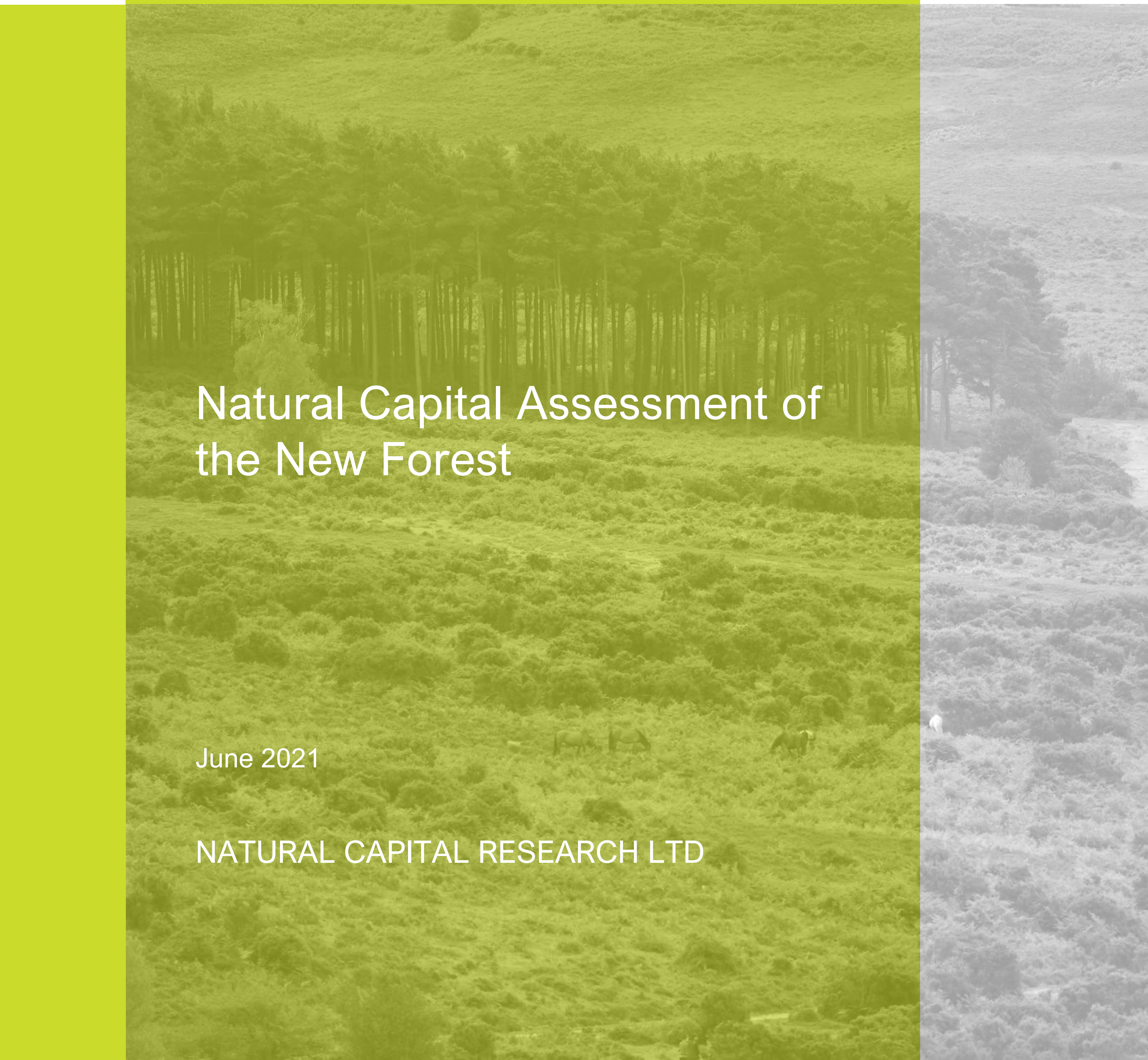

Natural Capital Assessment of the New Forest

June 2021

NATURAL CAPITAL RESEARCH LTD

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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.

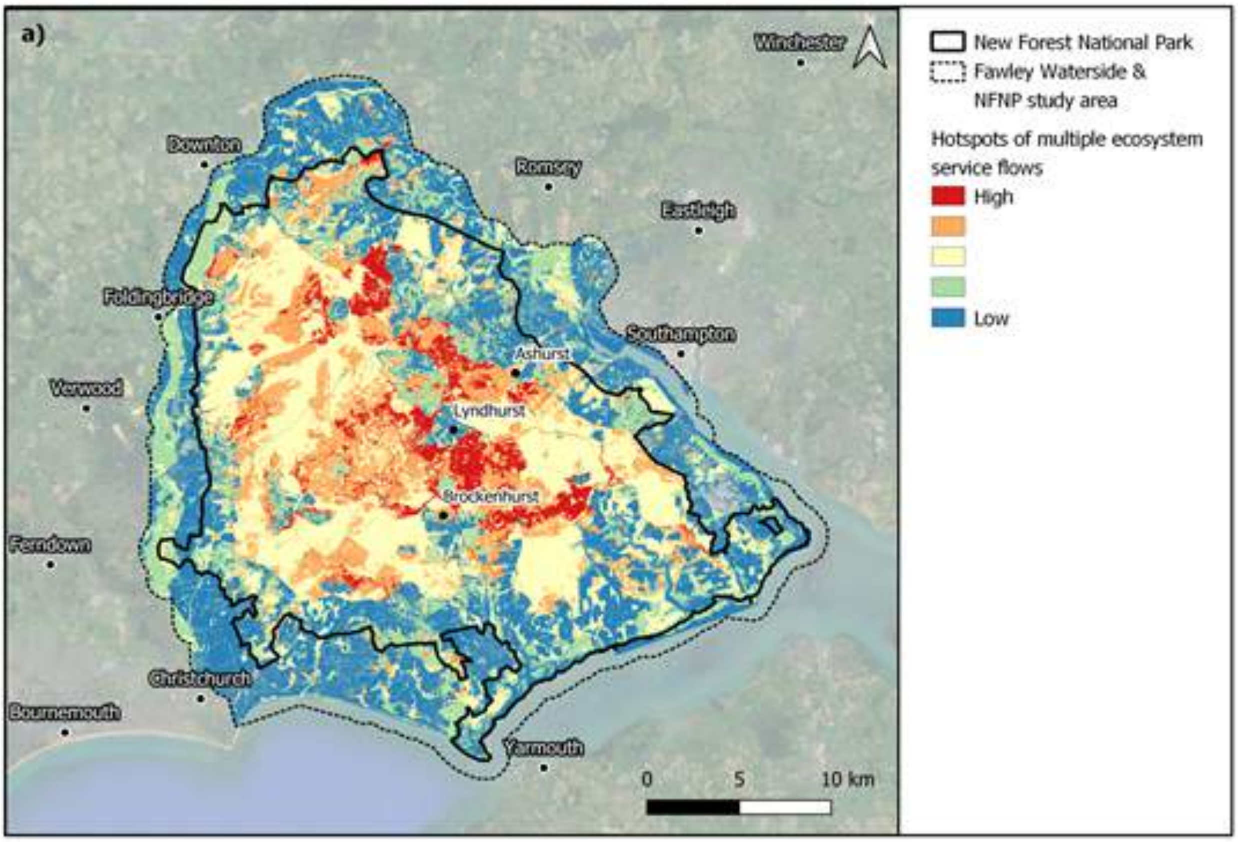
This report details our findings for the New Forest National Park. It presents a series of maps displaying the estimated spatial configuration of these natural capital assets across the reporting areas, the ecosystem service flows from them and the hotspots where multiple benefits occur. It also provides 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

	New Forest National Park				Fawley Waterside & NFNP study area	
Ecosytem Service Flow	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).

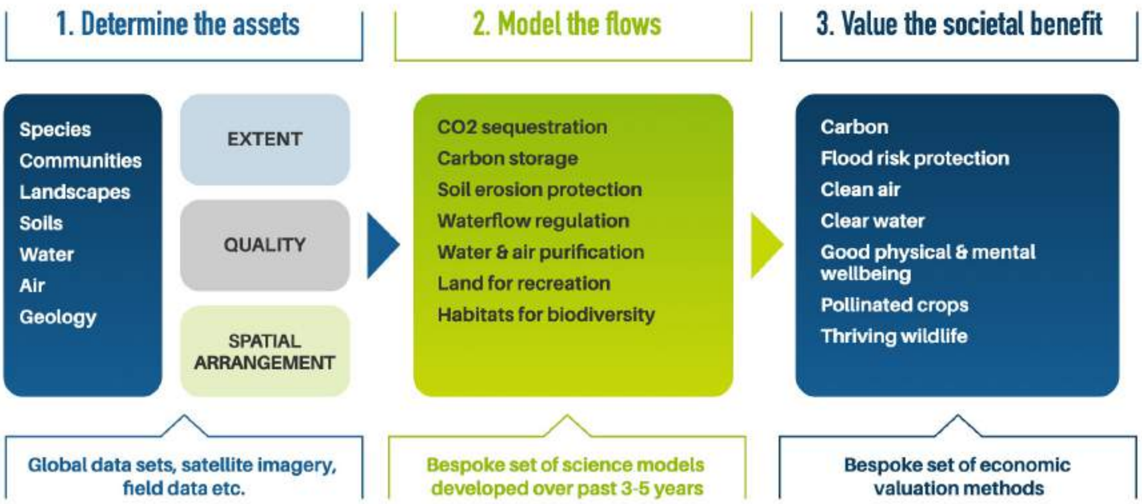


Figure 1: Schematic diagram to illustrate the relationship between natural capital assets (stocks), ecosystem services (flows) and societal benefits. Note that a single asset can provide multiple ecosystems services/positive societal outcomes.

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.

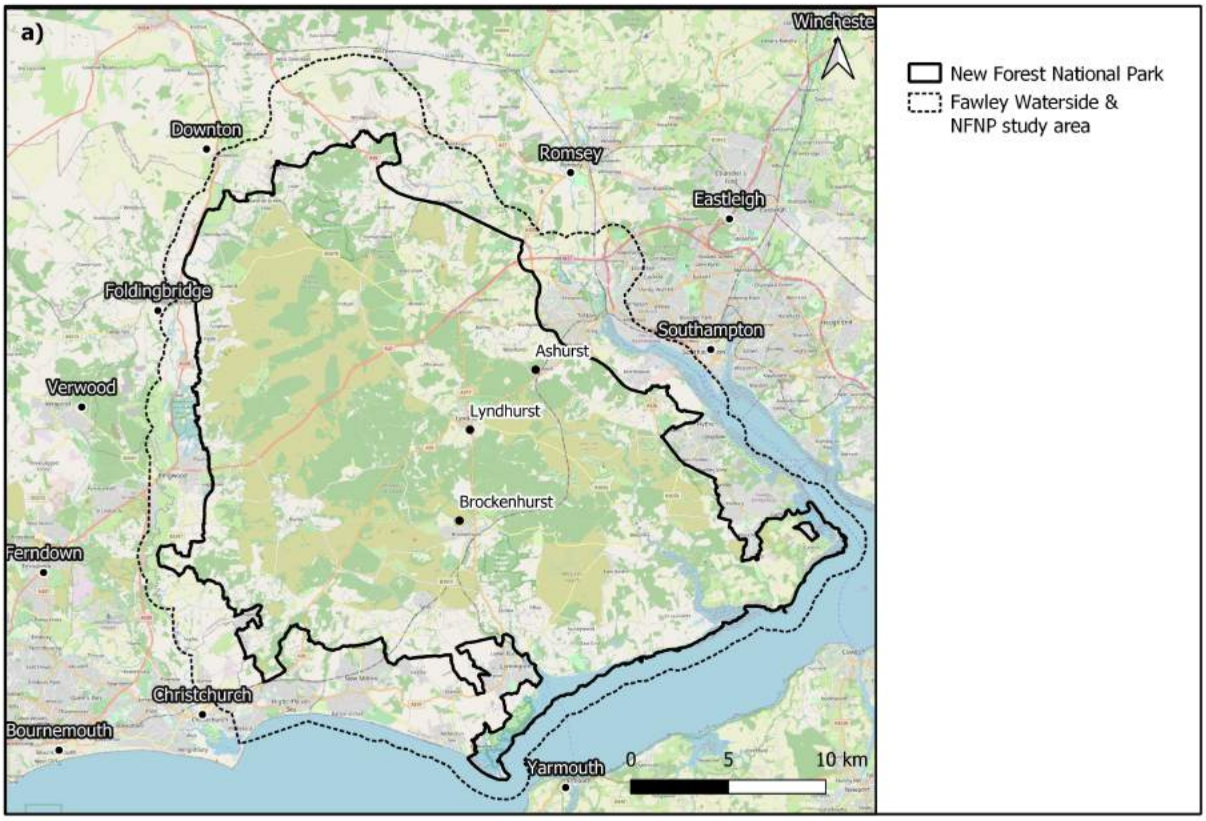


Figure 2: The New Forest National Park

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).

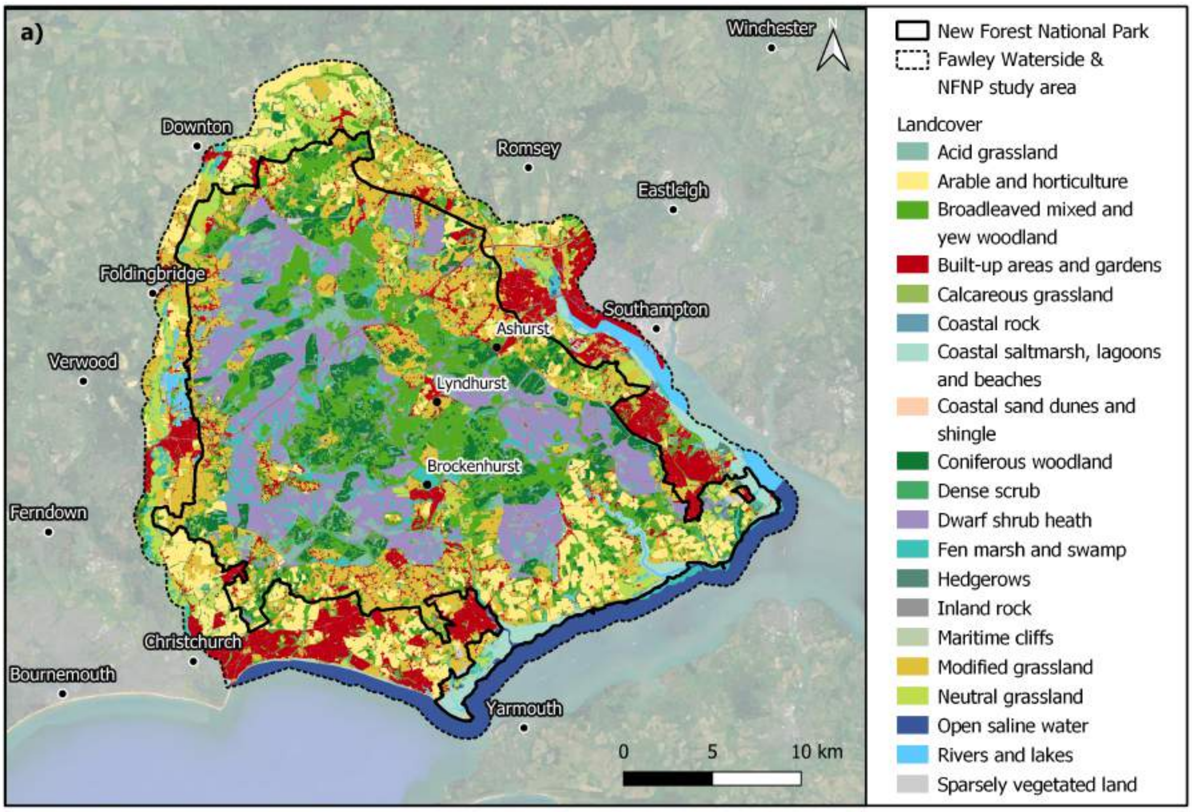


Figure 3: Landcover map for the New Forest National Park.

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).

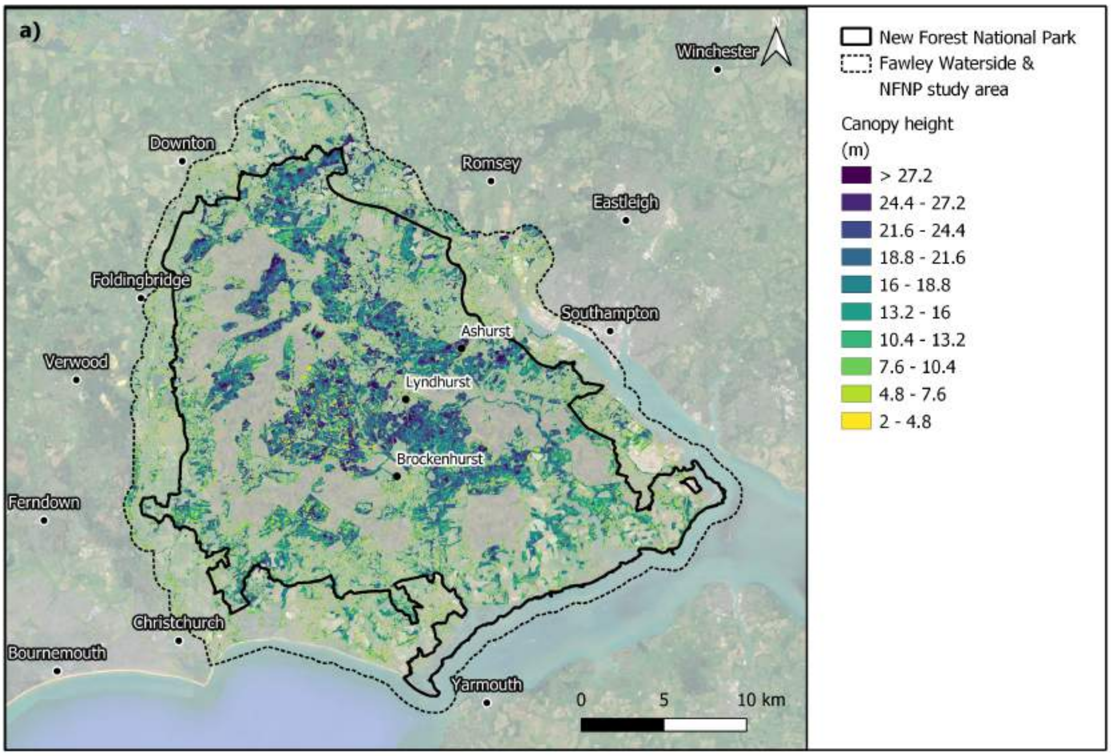


Figure 4: Canopy heights within the New Forest National Park.

[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.

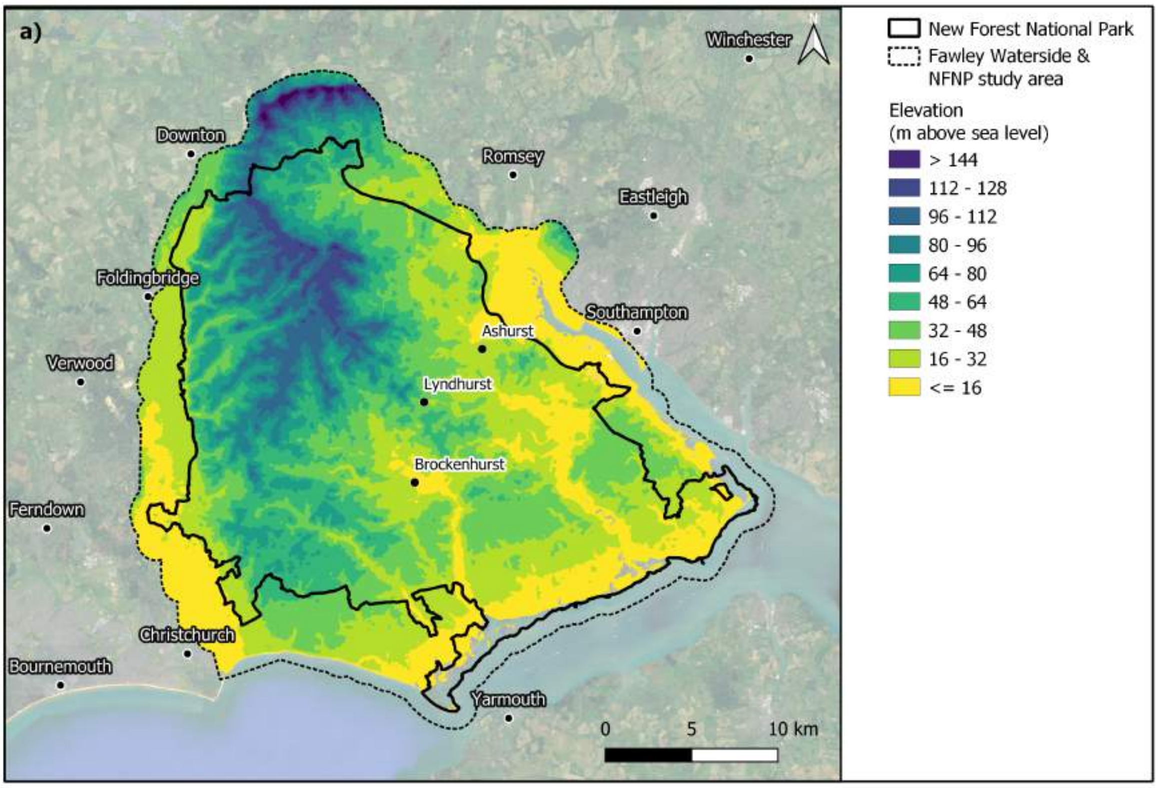


Figure 5: EU Digital Elevation (EU DEM v1.1) of the New Forest National Park. The elevation is shown in metres above sea level.

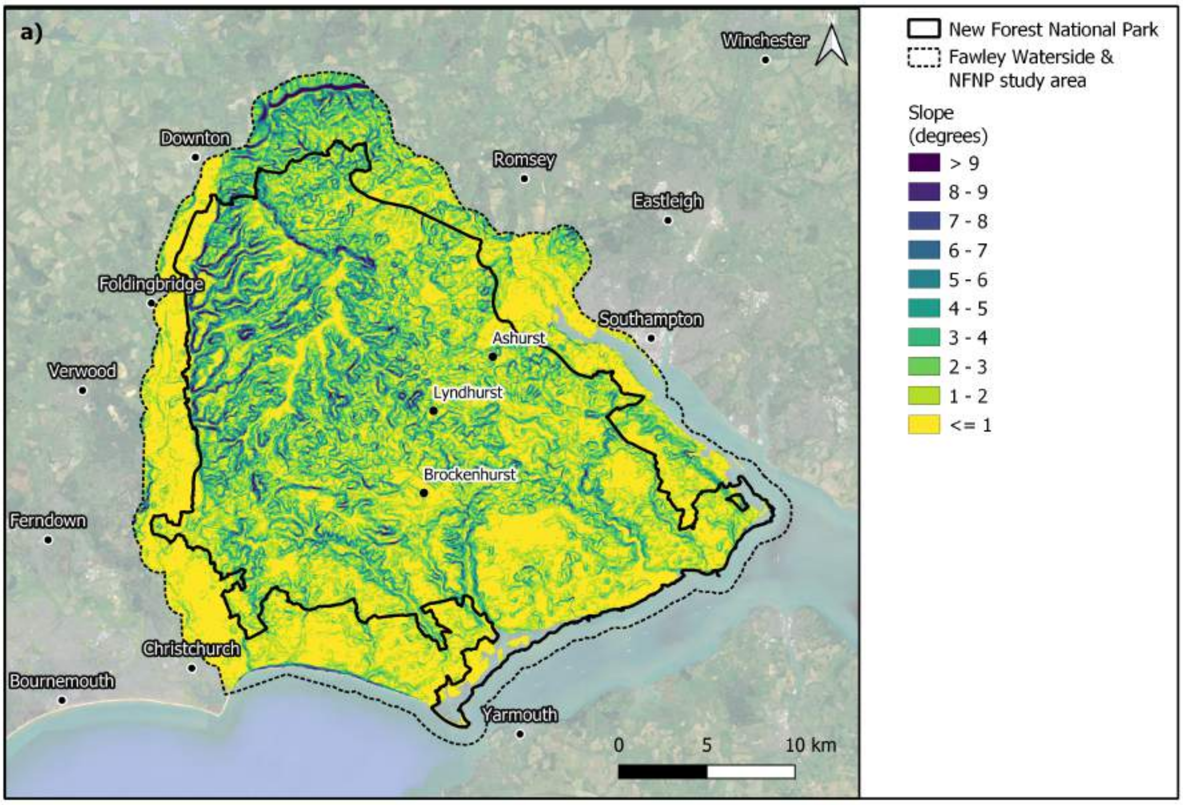


Figure 6: Slope (degrees) within the New Forest National Park. Derived from the EU digital elevation model at 25m.

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).

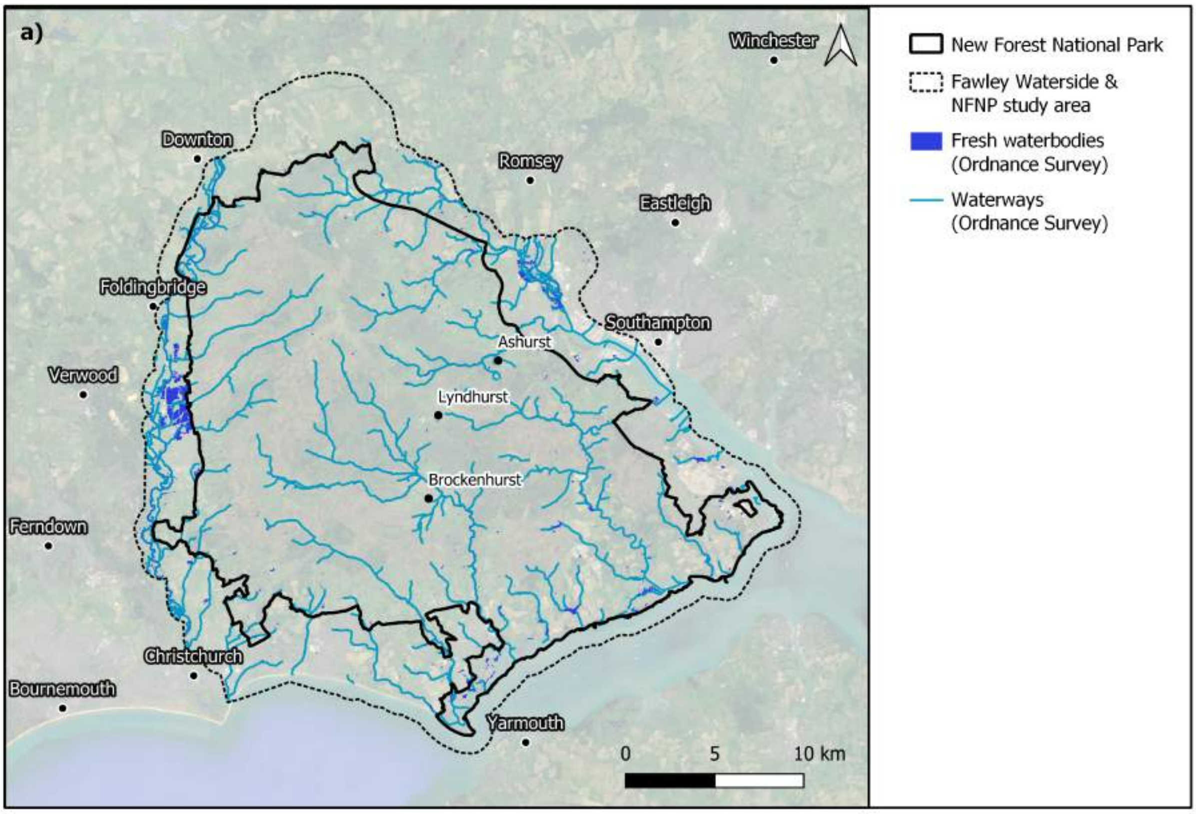


Figure 7: Waterbodies and waterways of the New Forest National Park. Ordnance Survey surface waters and rivers.

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.

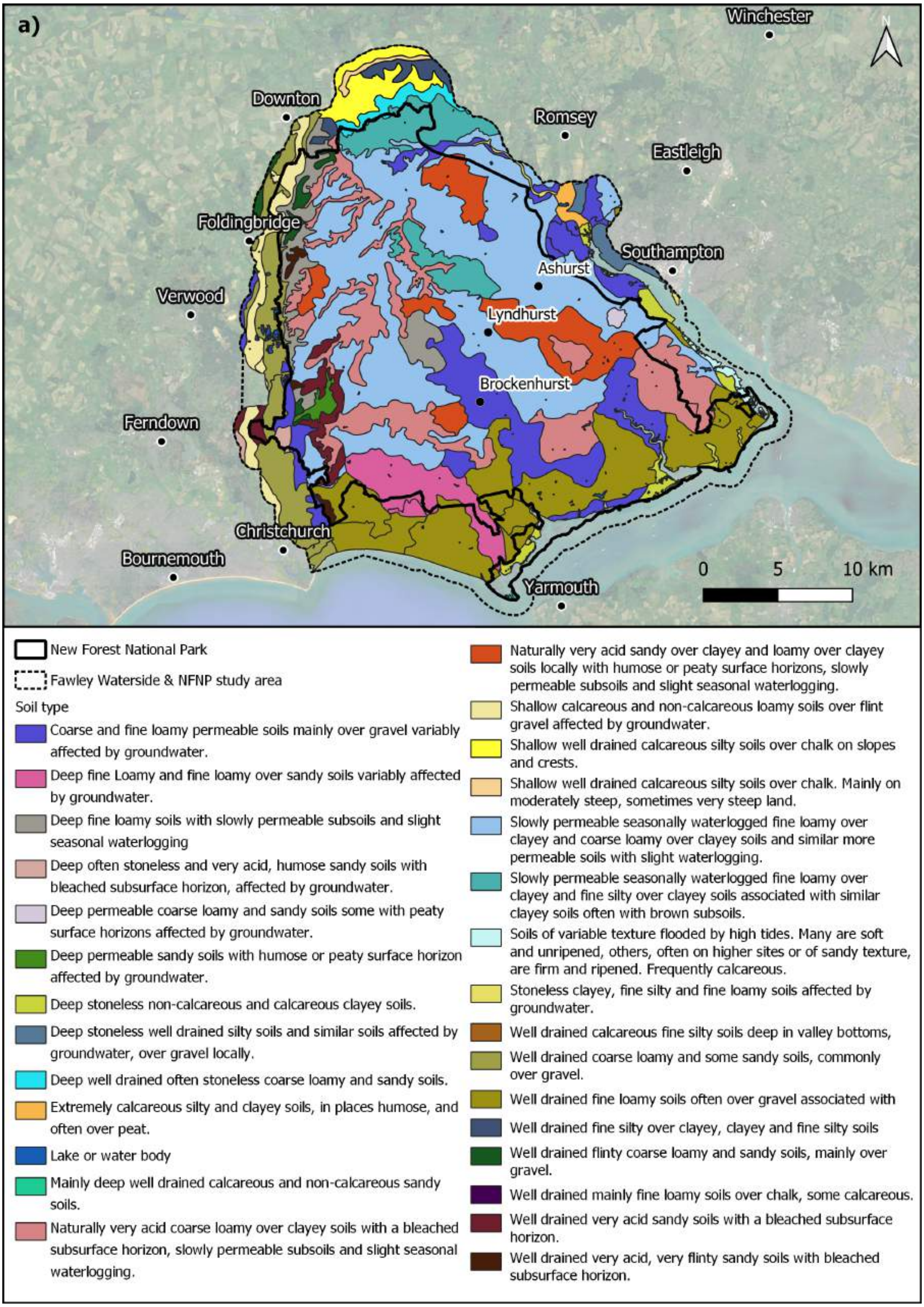


Figure 8: Soil types in the New Forest National Park. Data from the National Soil Map of England and Wales (NATMAP).

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).

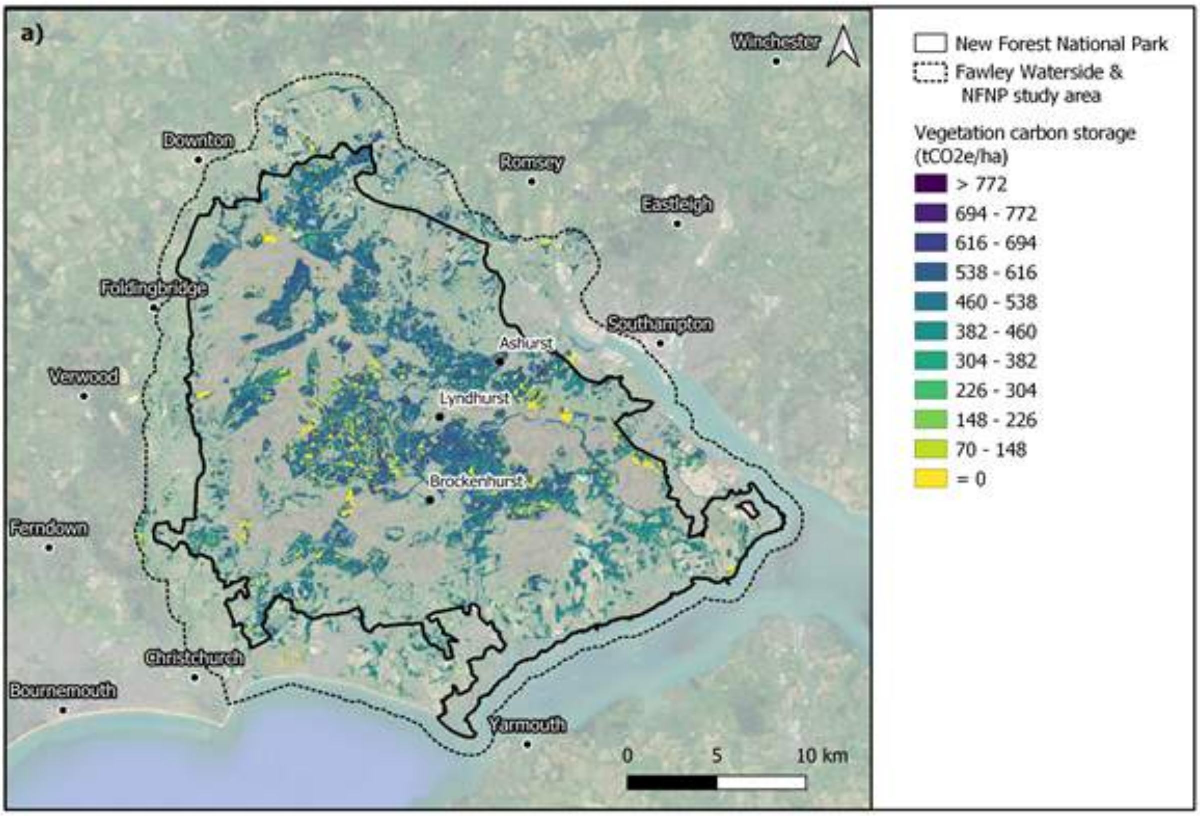


Figure 9: Estimated storage of carbon in trees in woodlands in the New Forest National Park and wider catchment. Units are in tonnes of CO_2e per hectare (tCO_2e/ha).

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_2e (Fig. 10). The majority of this is stored in trees outside of woodlands including hedgerows, which are estimated to store 1,958,718 tCO_2e in total. Grasslands and heathlands store very little carbon in aboveground biomass in comparison. (Appendix 3: Asset register 3a).

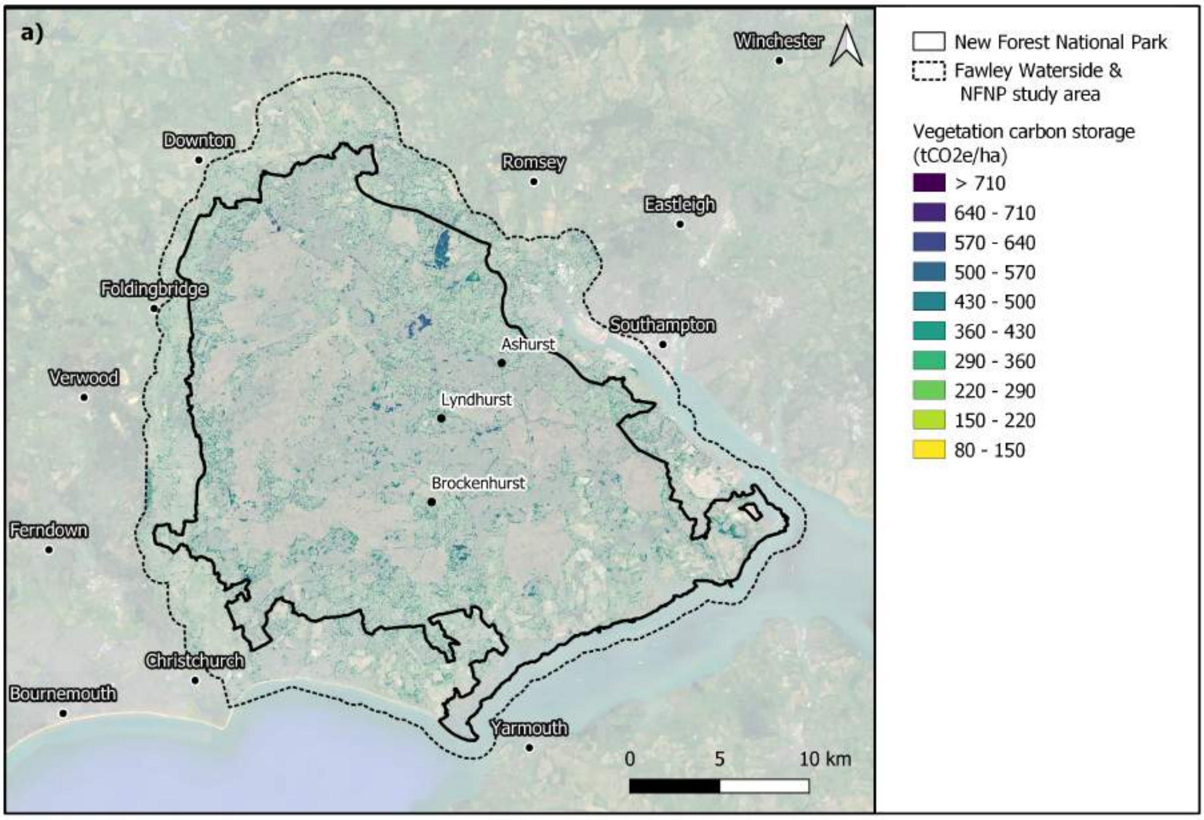


Figure 10: Estimated storage of carbon in trees and vegetation outside of woodlands. Units are in tonnes of CO_2e per hectare.

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.

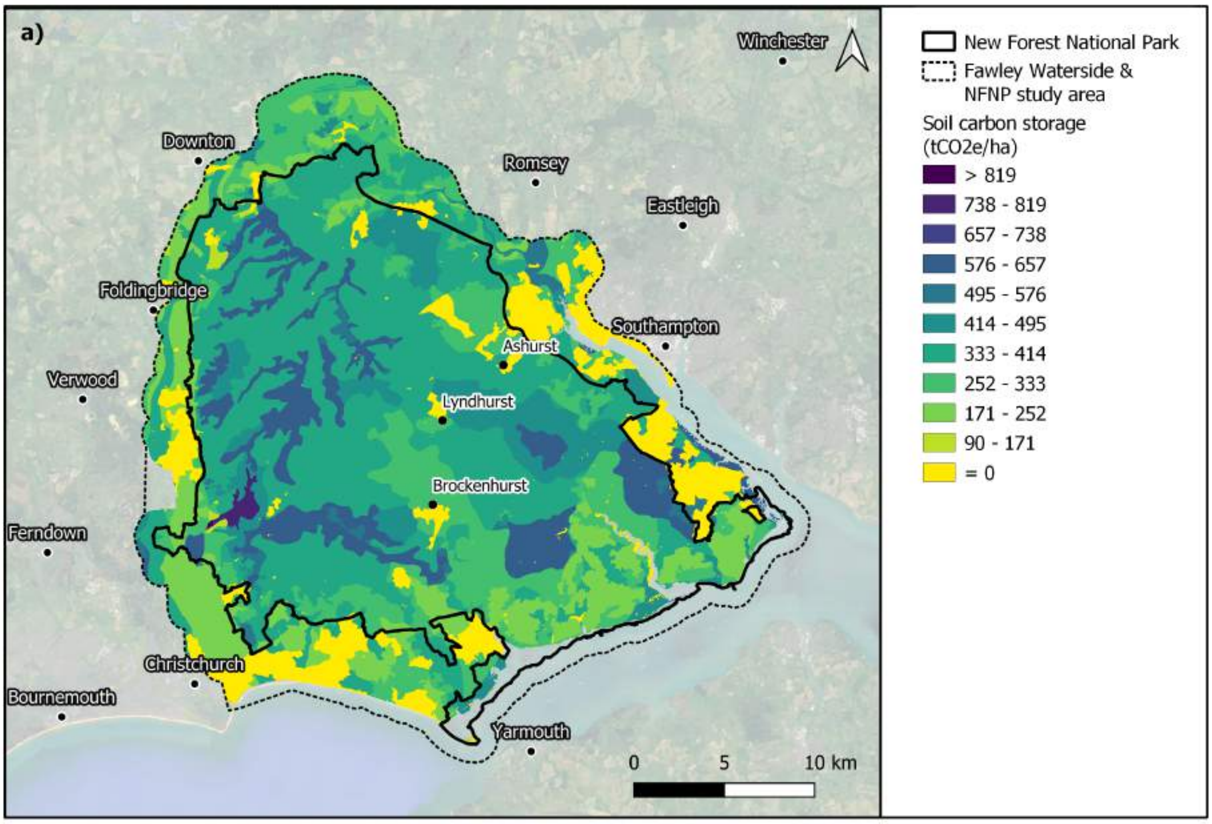


Figure 11: Carbon storage in the top 30 cm of soils in the New Forest National Park (tCO_2e/ha).

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.

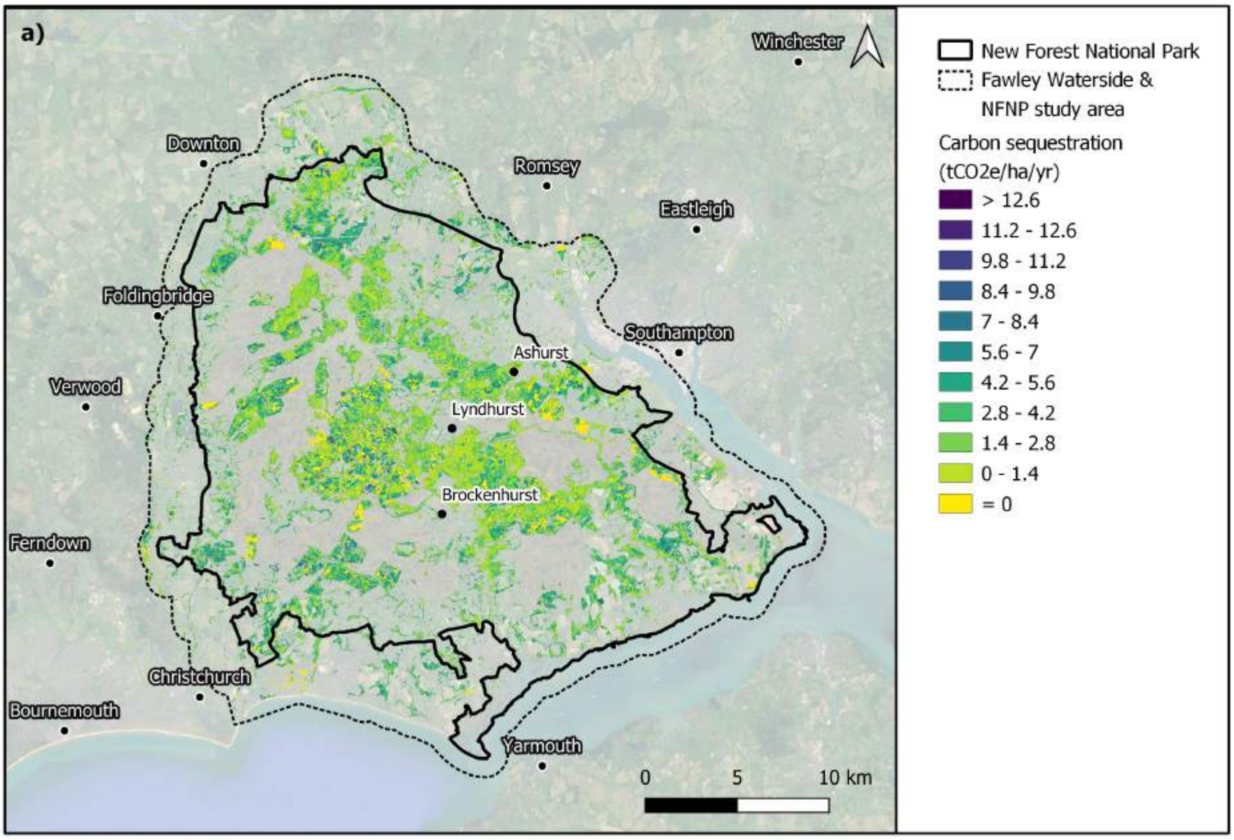


Figure 12: The estimated rate of carbon sequestration by trees within woodlands in the New Forest National Park and catchment. Units are tonnes of CO_2 sequestered/ha/yr.

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).

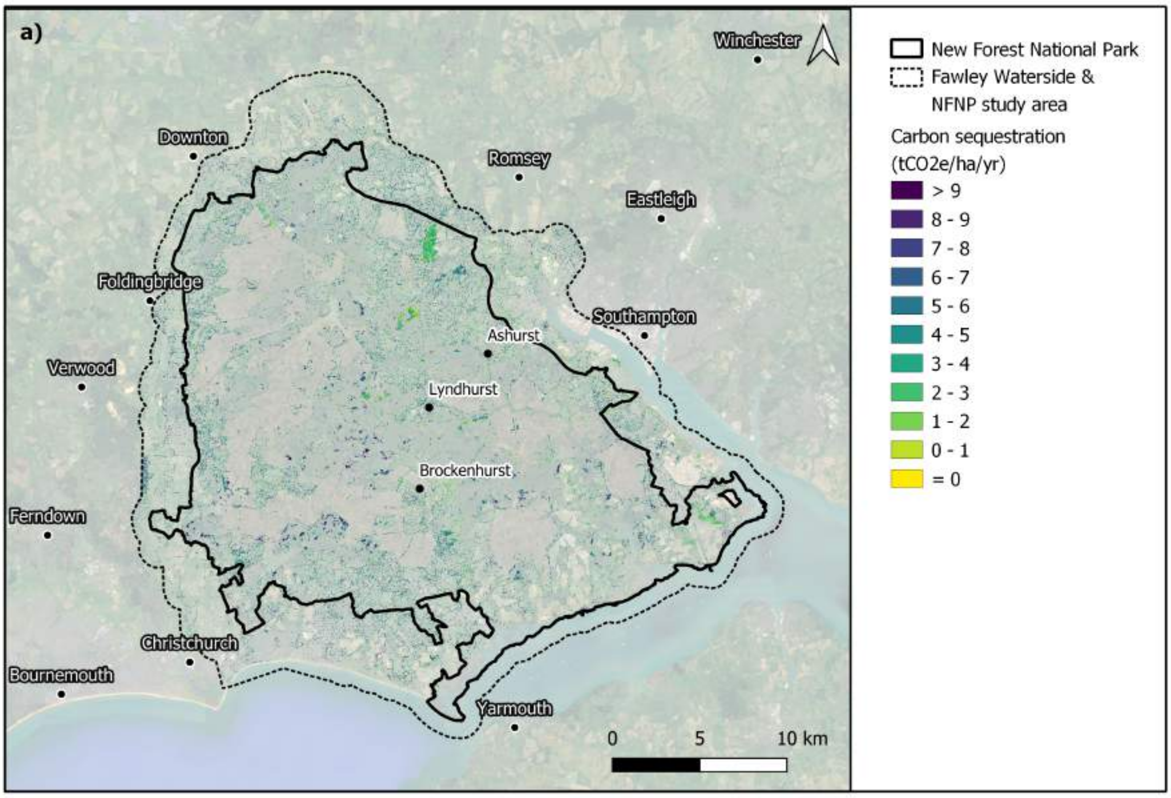


Figure 13: The estimated rate of carbon sequestrated by trees and vegetation outside of woodlands in the New Forest National Park. Units are tonnes of CO_2 sequestered/ha/yr.

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.

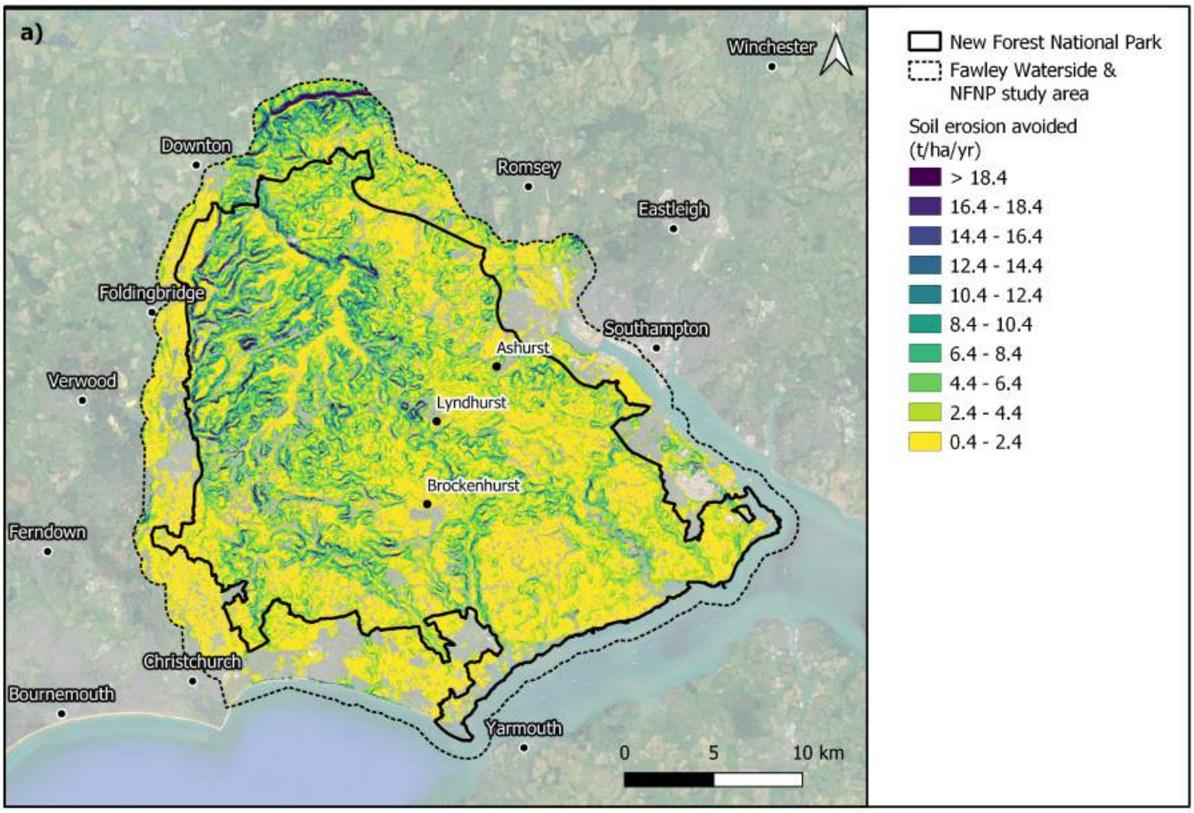


Figure 14: Map of vegetation contribution to soil stabilization in New Forest National Park. The map shows the amount of soil erosion that is avoided due to the type and density of current vegetation, compared with an alternative scenario of bare soil. Units are tonnes of avoided soil loss/ha/yr.

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).

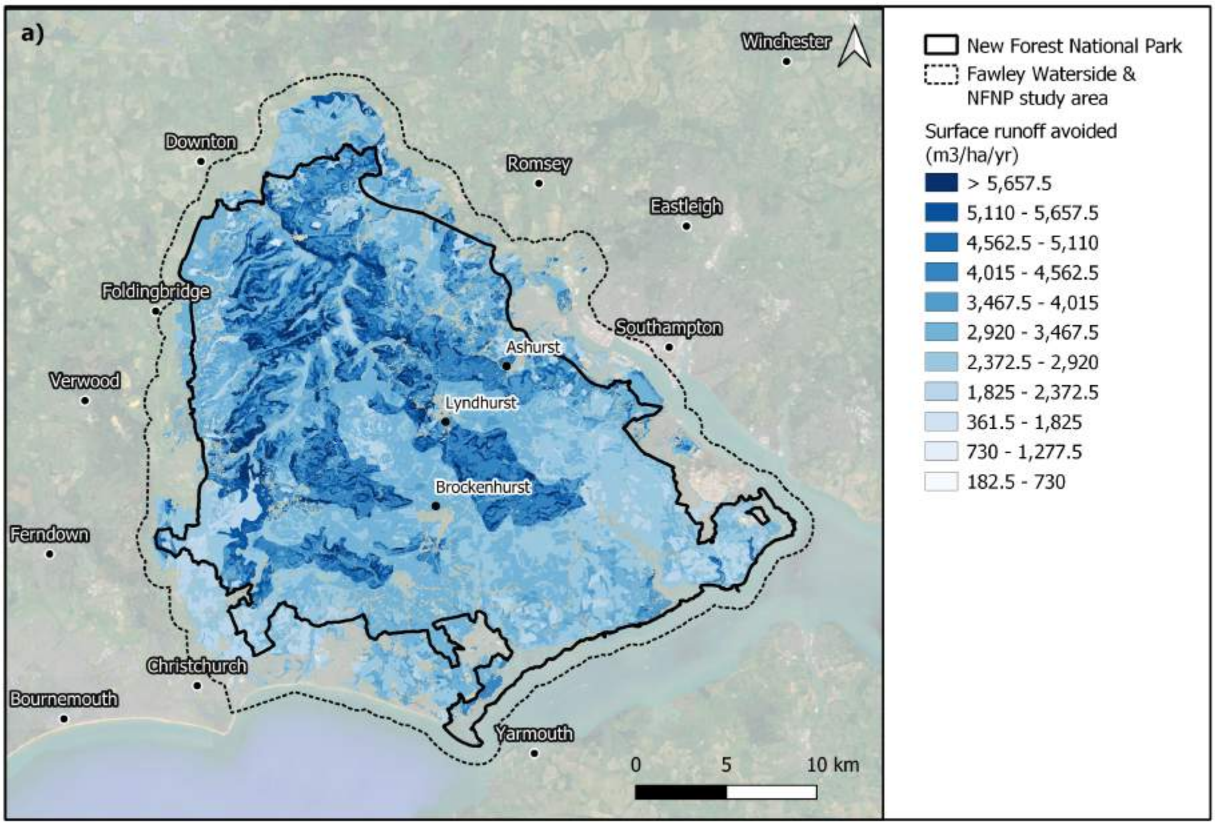


Figure 15: Flood risk reduction by vegetation in the New Forest National Park, estimated as the reduction in surface water runoff from rainfall. High values indicate areas where the current vegetation is estimated to contribute most to reducing the likelihood of flooding downstream, compared with an 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.

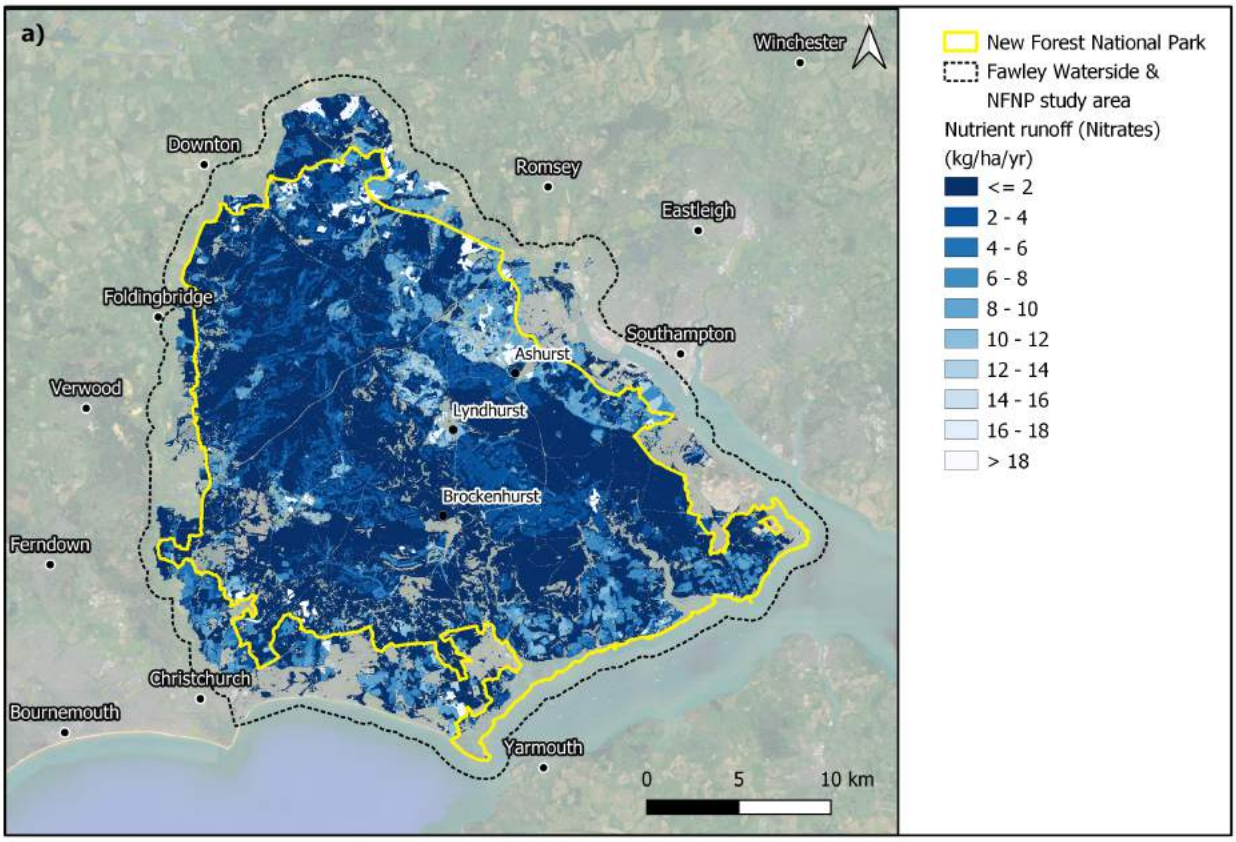


Figure 16: Nutrient runoff within the New Forest National Park. Units are kg of nitrogen (in nitrate) per hectare per year[3].

[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.

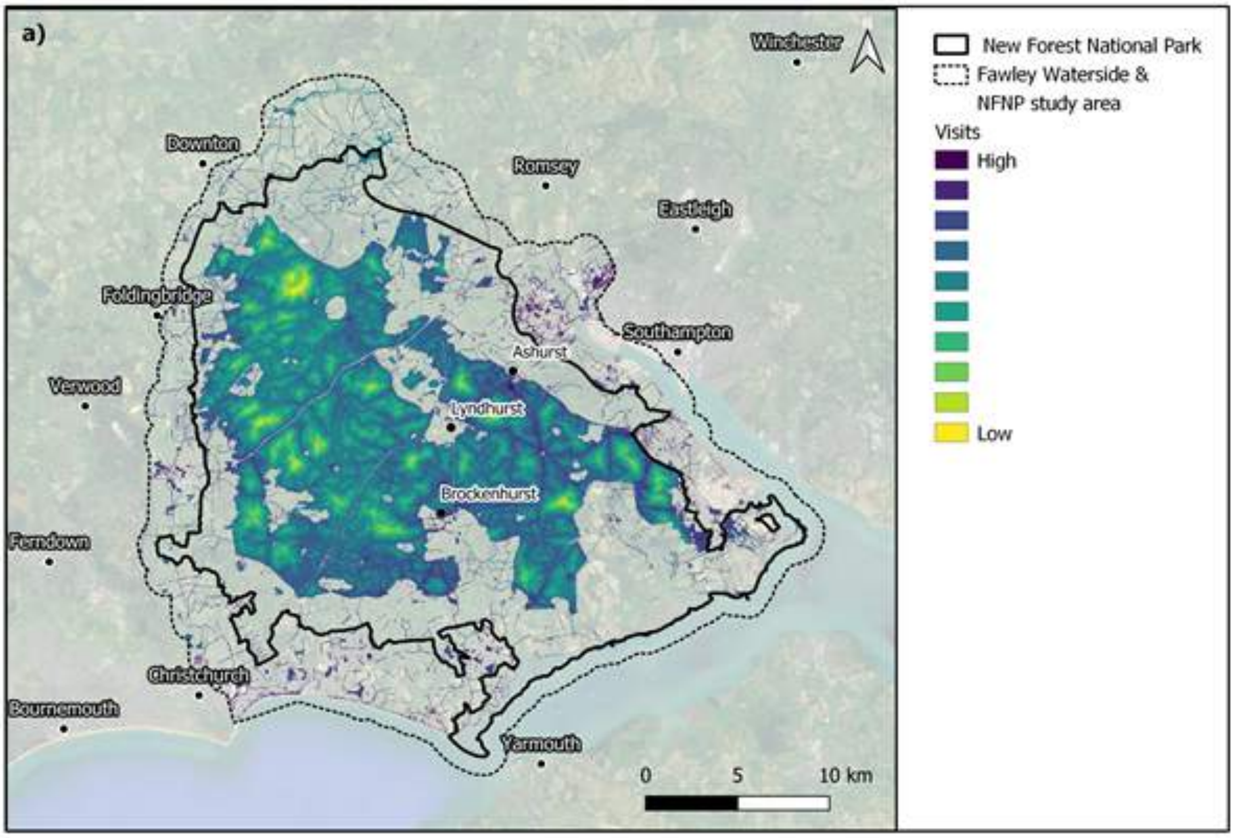


Figure 17: Important areas for recreation in the New Forest National Park. The total number of visits to the New Forest National Park is estimated at 10.4 million per year.

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).

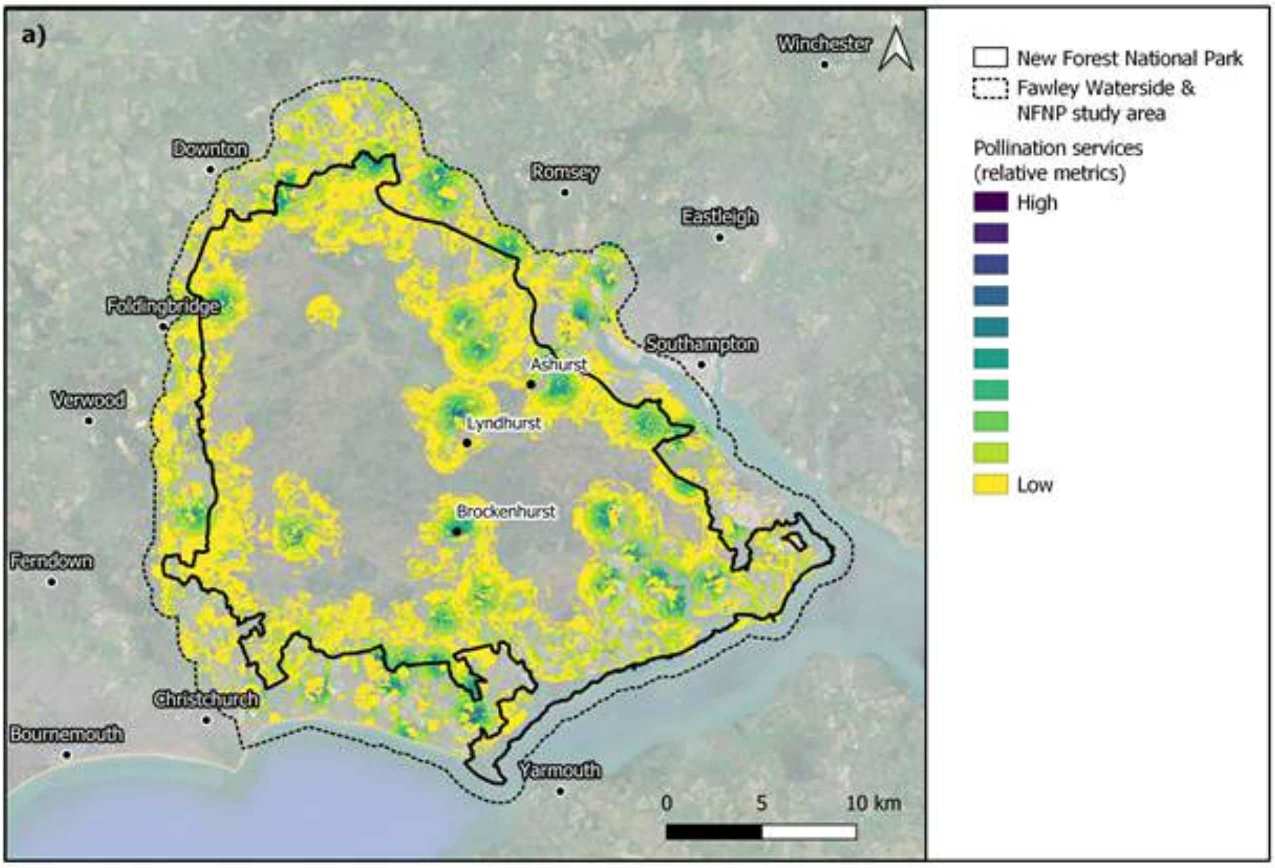


Figure 18a: Distribution of landcover important for pollination services in the New Forest National Park. This is a metric with values between 0 (no pollination service) and 1 (high pollination service).

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.

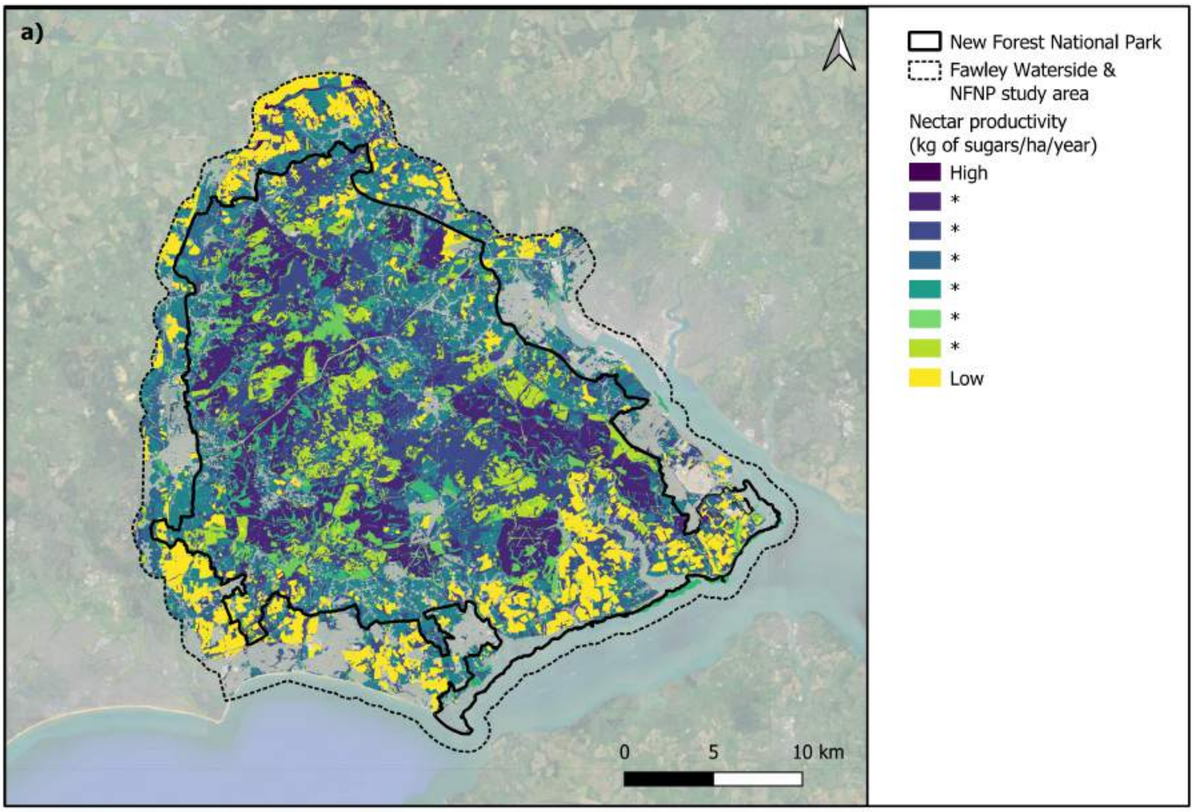


Figure 17b: Distribution of habitat nectar production, which contrbitues to suitability of habitats for pollinating insects, in the New Forest National Park. This is an estimate of nectar production in kg sugars per hectare per year.

[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).

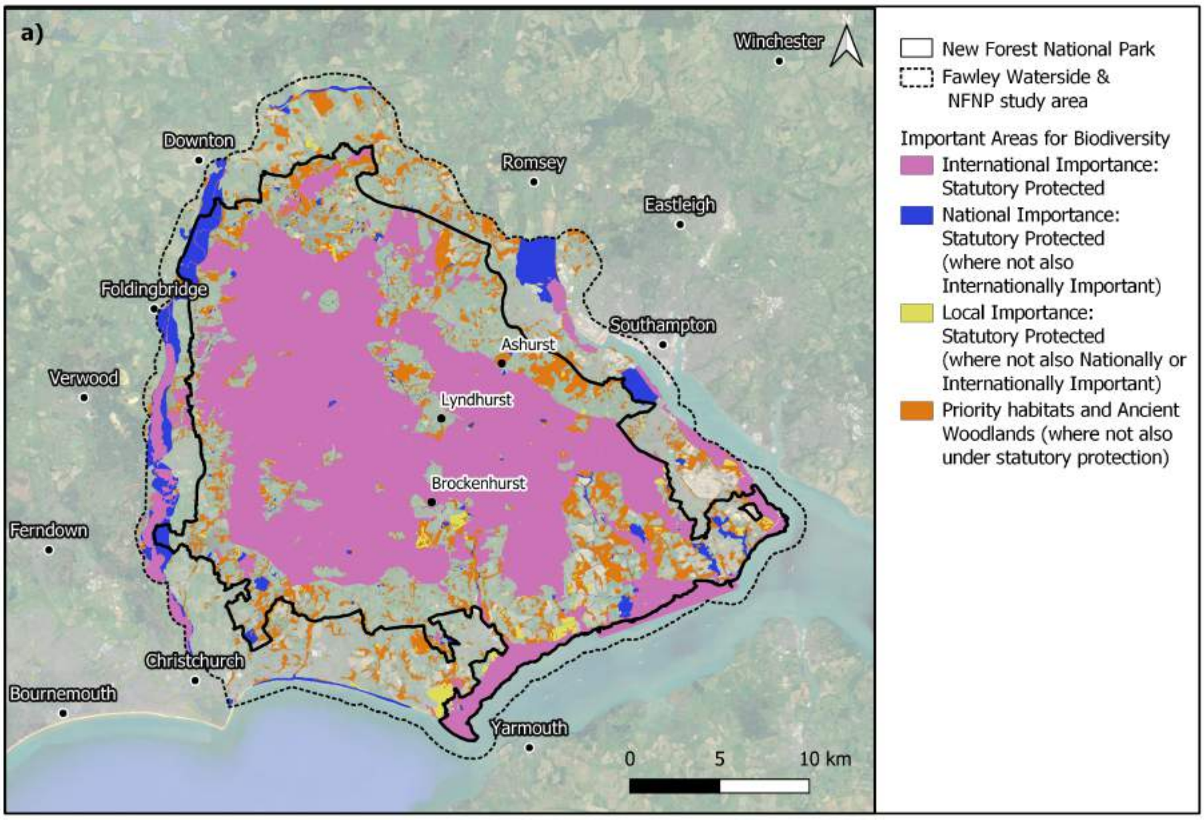


Figure 19: The spatial distribution across the New Forest National Park of important habitats for biodiversity.

[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.

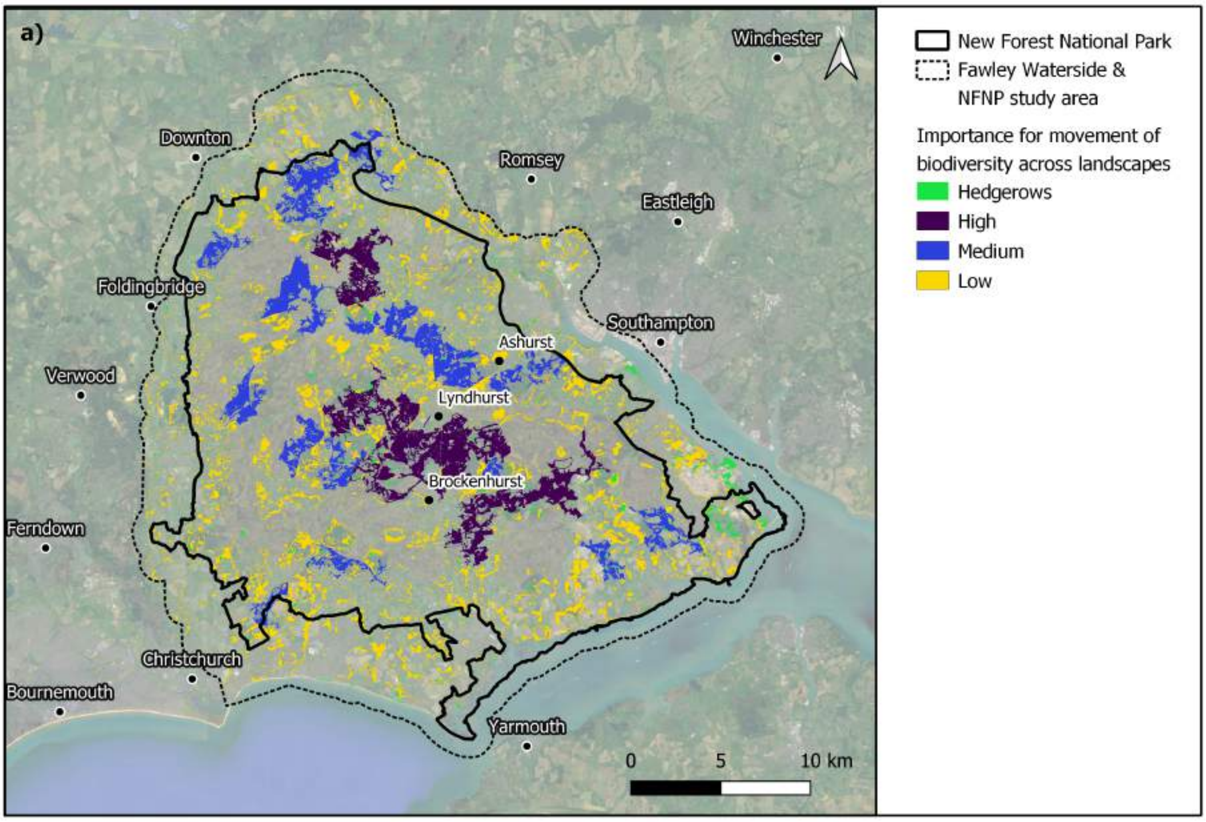


Figure 18: Important broadleaved woodland patches for the movement of biodiversity across landscapes (metric indicating the contribution of patches to overall landscape connectivity, from low to high). The map also displays hedgerows and trees outside of woodlands (mapped from national tree map). The 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.

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[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.

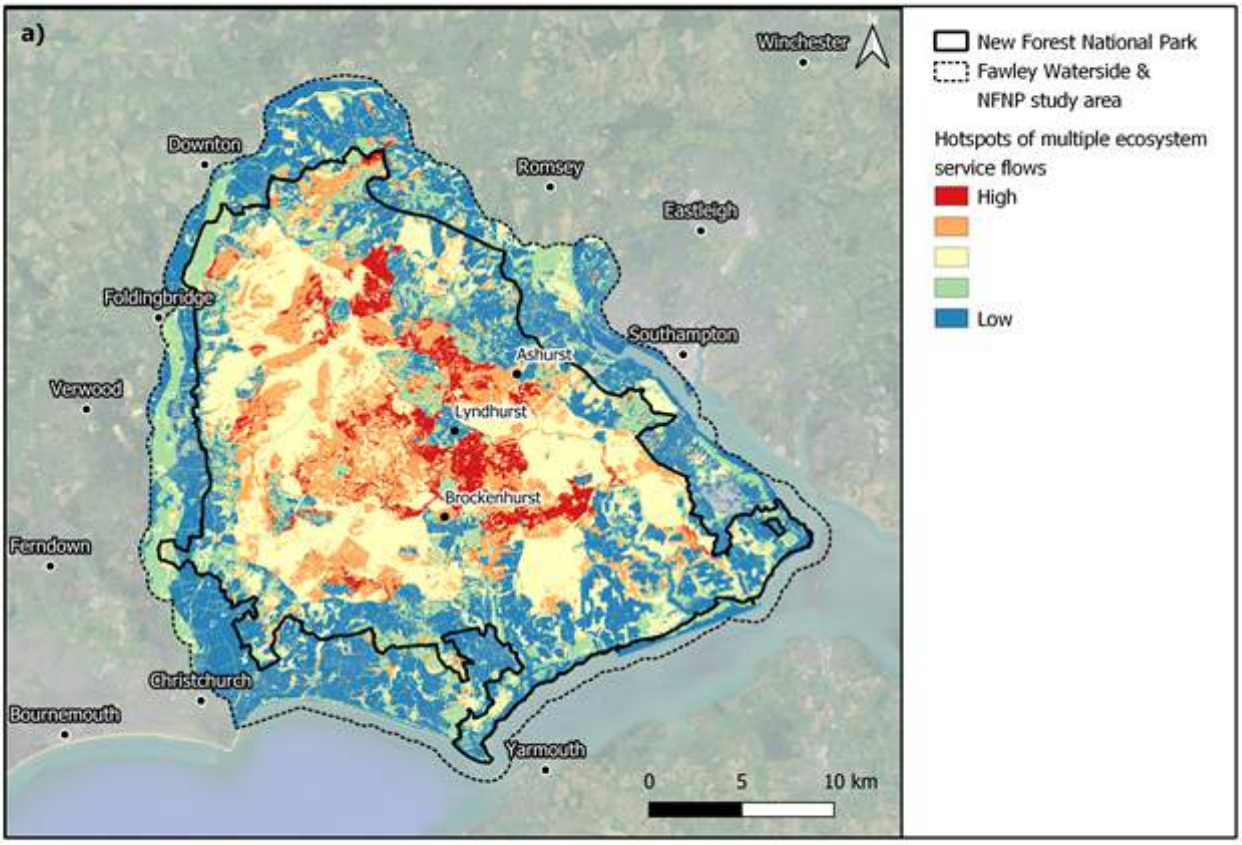

Figure 21: Hotspots of ecosystem services provision for the New Forest National Park where the various ecosystem services displayed in the maps above overlap. The higher the value (red) the more ecosystem services are provided per unit area. All ecosystem services are equally weighted.

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 pollinators (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.

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