Local Natural Capital Accounting: does it deliver useful management information?

A case study of Dartmoor and Exmoor National Parks

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Report to Exmoor National Park Authority and Dartmoor National Park Authority

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1 INTRODUCTION

In the 25 Year Environment Plan the UK government has set out an ambitious program to achieve net improvements in England's environment over the course of this generation. After decades of environmental degradation, resulting often from neglecting natural capital in decision-making, the 25 Year Environment Plan represents an important step towards placing the protection of the environment at the top of the political agenda. The growing consideration of environmental issues in decision-making has been motivated by increasing evidence that environmental preservation is necessary to sustain and contribute to human well-being and economic prosperity. Natural Capital (or natural assets) - the bulk of habitats and ecosystems that underpin our natural environment - provide a variety of ecosystem goods and services (e.g. clean air and water, food, timber, recreation opportunities, biodiversity etc.) that people appreciate. Most of these services, though, are 'invisible' in the sense that they are often overlooked by decision-makers. While there is some ecological knowledge available about the flows of ecosystem goods and services provided by the Natural Capital, evidence is only partial. Furthermore, the monetary value of such ecosystem goods and services is often unknown, due to the fact that only a small part of the goods and services provided by nature are exchanged in formal market settings. One way to make the costs of environmental degradation and the benefits of environmental protection visible is through the development of Natural Capital Accounts. Natural Capital Accounts record changes in the extent and condition of natural assets over time, measure the resulting variation in the flow of ecosystem goods and services provided and, through economic valuation techniques, allow the quantification (in monetary terms) of such changes in service flows.

Reflecting international efforts, since 2011, the UK Government has been working with the Office for National Statistics (ONS) and Defra to produce Natural Capital Accounts for the UK. So far, experimental accounts have been produced for land use and forestry, freshwater assets and services, and scoping studies have been undertaken for peatlands, woodlands, and marine ecosystems, amongst others.[1] Most of the efforts to date have been focused on *national* accounts (accounts which consider the entire country's Natural Capital). However, focus has recently shifted to also include other spatial and organisational scales, with for example the Natural Capital Protocol initiative promoting the adoption of natural capital approaches at the level of individual businesses. Furthermore, the Natural Capital Committee has emphasised the need for more efforts to develop natural capital accounting also *at local and/or organisational* scale. These are accounts which consider smaller spatial extents and, for instance, are developed at the level of those organisations, businesses, NGOs or governmental departments who own and/or manage land on a local or regional scale. This can include for example parks, farms, nature reserves and

[1] For an overview of the Office for National Statistics and Department for Environment, Food, and Rural Affairs natural capital project and related publication, the interested reader should refer to: https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital

National Parks. Please note that such local or organisational Natural Capital accounts conducted at sub-national spatial scale can also include accounts for organisations which operate at a national level (e.g. RSBP), but own or manage various smaller extents of land across the country. This recent shift in focus from national to local, has in part come about through the recognition that much of our Natural Capital is owned or managed by both private and public organisations operating at smaller geographical scales. The role of such businesses and organisations is therefore crucial for the preservation of our natural environment and for the delivery of ecosystem goods and services. This is particularly true in the case of protected landscapes (e.g. National Parks).

It has been argued that Natural Capital accounting at local and/or organisational level can fulfil many purposes. As outlined by Eftec (Eftec 2015)[2] in a report on corporate natural capital accounting prepared for the Natural Capital Committee, the aim of developing natural capital accounts is to "*document an organisation's ownership, liability and assets related to natural capital in a balance sheet format. In the same way that the structured recording of other company assets and liabilities in conventional financial accounts informs and improves an organisation's management decisions, natural capital accounts will enable better decisions to be made about natural capital*". More specifically, as outlined in the Defra report on ecosystem accounts for protected areas in England and Scotland (2015), natural capital accounting can be helpful to guide organisations about resource management decisions, such as balancing competing priorities and identifying opportunities to enhance ecosystem functioning to maximise the delivery of ecosystem services. In addition, natural capital accounting can be used to promote awareness about the importance of natural capital and the interdependencies between the environment and people. By offering a consistent way to monitor and assess change in natural capital over time, natural capital accounts can also help organizations to identify trade-offs between different land uses and/or ecosystem services. Finally, natural capital accounts are helpful in creating clear messages and evidence to influence policy and funding decisions with environmental consequences.

Whilst being increasingly encouraged to produce natural capital accounts, many National Park Authorities, Area of Outstanding Natural Beauty (AONB) partnerships and other organisations often struggle with the task. Although increasingly aware of the extent and value of the ecosystem services provided, these organisations frequently lack the data, expertise and/or resources to comprehensively monitor all the natural capital within their protected landscapes, identify the related ecosystem goods and services, and quantify the wider benefits in economic terms, thereby making the development of natural capital accounts challenging. Several organisations have attempted the development of natural capital accounts at a local and/or organisational scale (see section 2.3). In the absence of any clear methodological guidance and in-house expertise, applications have mostly relied on adaptations of existing methods, primarily developed for

[2] Eftec (2015). Developing Corporate Natural Capital Accounts. Final Report for the Natural Capital Committee. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516968/ncc-research-cnca-final-report.pdf

Natural Capital accounting exercises at international and national scale. These existing methods include approaches outlined in the System of Environmental-Economic Accounting (SEEA) Central Framework and the SEEA Experimental Ecosystem Accounting (SEEA EEA), developed by the United Nations and adapted for the UK by the ONS. In the present document we refer to the local-scale adaptations of such approaches as the "standard practice" in Natural Capital Accounts at organisational scale. Despite the growing number of local scale applications, though, little work has been done to understand the extent to which such international and national approaches are appropriate at a local or organisational scale. One concern is that large-scale approaches, such as those used for national accounts, may not be appropriate at a smaller scale, due to local variation in the delivery of ecosystem services. For example, whilst approaches using national data on agricultural production may be appropriate for the development of accounts at a national scale, agricultural production may be vastly different from the average for smaller areas of interest. The development of a methodology that is suitable for natural capital accounting at organisation level has been outlined as a priority by the Natural Capital Committee in its latest report published in January 2019 (Natural Capital Committee 2019)[3].

National Park Authorities have been specifically encouraged to develop Natural Capital Accounts. For example, the 2019 independent Landscape Review led by Julian Glover[4] advocated for the usefulness of Natural Capital Accounting for National Parks and AONBs. Similarly, in its 2018 annual report, the Natural Capital committee stated that "*England's Nationals Parks contain very significant natural capital, and their powers and duties should be extended to support the objectives of the 25 Year Environment Plan. Where practical, each National Park should quantify and value the main natural capital assets in its area*". For the specific case of National Park Authorities, developing Natural Capital Accounting is related to multiple challenges. Whilst National Park Authorities are encouraged to develop Natural Capital Accounts for the assets in their area, not all land within the National Park area is under ownership or management of the National Park Authority. This can lead to limitations in both the production (e.g. data availability) and usefulness (potential for influencing change) of Natural Capital Accounts produced for the entire National Park area.

In this report we review recent efforts and UK scoping and pilot case studies of natural capital accounts developed for organisations in the environmental sector. This project, part of the NERC-funded programme SWEEP (South West Partnership for Environmental and Economic Prosperity), focuses on critically assessing the advantages and disadvantages (potential limitations) for decision-making of using 'standard approaches' to natural capital accounting at a local or organisational scale. It also discusses possible options to overcome the identified challenges, in order to make the natural capital approach more useful to inform decision-making. For this project, we focused on Dartmoor and Exmoor National Parks as our case study areas and

[3] Natural Capital Committee (2019). State of Natural Capital Annual Report 2019. Sixth report to the Economic Affairs Committee of the Cabinet. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774218/ncc-annual-report-2019.pdf

[4] Landscapes review: National Parks and AONBs (2019). Available at: https://www.gov.uk/government/publications/designated-landscapes-national-parks-and-aonbs-2018-review

considered the entire geographical area within the National Park boundaries. The whole National Park area was selected because, as mentioned earlier, the Natural Capital Committee recommended that "*each National Park should quantify and value the main natural capital assets in its area*"; we therefore interpreted this as a recommendation to consider the entire area of interest which falls under the organisation's remit, i.e. the whole National Park, rather than exclusively the land owned or managed by the National Park Authorities.

2 NATURAL CAPITAL ACCOUNTS IN THEORY

2.1 THE NATURAL CAPITAL APPROACH

The framework underlying Natural Capital Accounting is based on the Natural Capital approach. The natural capital approach is a way of thinking about nature as a production system that provides humans with flows of valuable goods and services. The Natural Capital Approach can be viewed as a 4-step framework, as outlined in Figure 1.

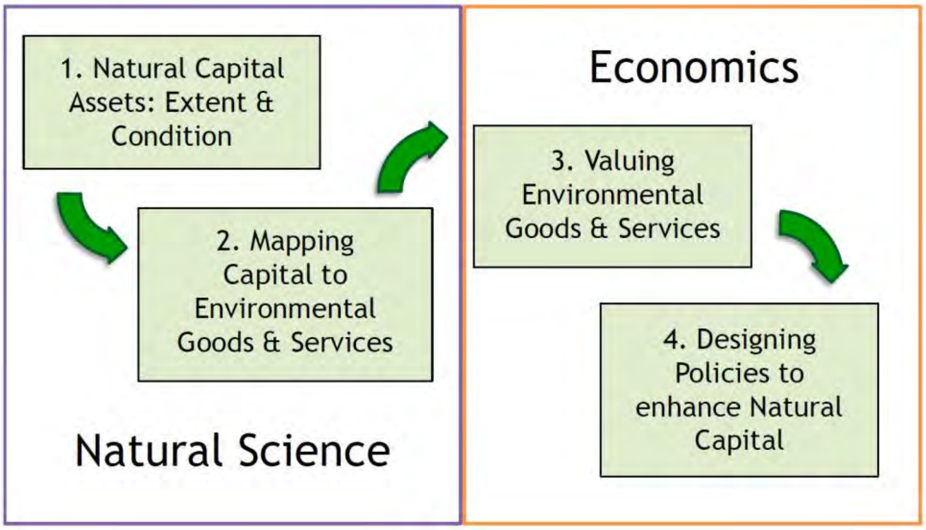


Figure 1. The steps of the Natural Capital approach

The first step in the natural capital approach involves establishing the extent and condition of natural capital assets or stocks - "the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity" (ONS 2017)[5]. For example, a woodland is a natural capital stock.

The second step focuses on mapping the environmental pathways through which changes in natural capital result in changes in the flow of ecosystem goods and services that are valued by people. For example, soil, water and seeds contribute, through complex biophysical or natural processes such as water and nutrient cycles, to the growth of forests, which then provide a wide array of environmental goods and services, such as trees and carbon sequestration. Whilst some of these environmental goods and services are appreciated in their own right (e.g. the wonder

[5] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

inspired by nature), their major value to humans is derived when the environmental goods and services are used in combination with a range of human, social, manufactured and other capital that are part of the economic production system. This yields a plethora of highly valuable goods and services which are crucial to human wellbeing, including stable supplies of food and water, materials and defence from hazards. There are different ways through which a given environmental good or service can generate benefits to people. For instance, trees are an environmental good and they are used to produce timber, using labour input from a forester. Timber is then crafted by a carpenter, using tools to produce furniture, which is then sold on to consumers, who gain welfare from using it. However, there are other possible channels through which individuals may benefit from trees. Trees can enhance the views that people enjoy from their homes and the vicinity to forested areas contributes to improve residents' quality of life.

The next step in the natural capital framework is to establish the economic value of the flows of the identified ecosystem goods and services (step 3). Whilst the flows of goods and services can be assessed through a wide variety of units and metrics (e.g. tonnes of CO_2 sequestered by trees, or numbers of game animals), translating these metrics into something that conveys information about the impacts on human wellbeing is more challenging. By far the most common approach is to apply methods developed by economists to determine the economic values provided by the environment (expressed in monetary terms). For some environmental goods and services (e.g. timber or crop production), information on the value conveyed to individuals is readily available through market prices (which reflect the *private benefits* or value of the good to the buyer). However, for most ecosystem goods and services (e.g. clean air or good water quality) information is not directly available on the value provided to people. These goods and services are not traded in markets, even though they provide benefits that are enjoyed by many individuals (so called *public benefits*). Methods are available to estimate the economic value of changes in the flow of these non-market goods and services.

The last step in the Natural Capital approach consists of using the information about the benefits and values of ecosystem goods and services to inform decision-making, e.g. to design policies and management practices to enhance natural capital (step 4).

2.2 PRODUCING NATURAL CAPITAL ACCOUNTS – THE THEORY

As mentioned in the introduction, Natural Capital Accounts can be produced by following the guidelines developed internationally, e.g. the System of Environmental-Economic Accounting (SEEA) Central Framework and the SEEA Experimental Ecosystem Accounting (SEEA EEA) by the United Nations. At UK level, these guidelines are adopted and adapted by the Office for National Statistics (ONS) and the Department for Environment, Food and Rural Affairs (Defra). In this section, we outline the main concepts and methodologies to produce Natural Capital Accounts in the UK, mostly drawing on the guidelines presented by the ONS in their background paper on the 'Principles of Natural Capital Accounting' (ONS 2017)[6]. The principles and approaches outlined have been developed for national scale accounts. No specific guidelines have yet been issued for more spatially disaggregated accounts, although some methodological guidance is provided in the Natural Capital Committee's Sixth Report (Natural Capital Committee 2019)[7], which is consistent with the recommendations outlined by the ONS (ONS 2017)[8] and in this report.

Natural Capital Accounting was first developed as an expansion of the System of National Accounts (SNA) to provide a more complete picture of the economic wealth of a nation. SNAs rely on the Gross Domestic Product (GDP) to measure value; these focus only on the flows of income and outputs, therefore omitting consideration of the services provided by natural capital. Hence, Natural Capital accounting is a useful (and necessary) addition, as it helps incorporate the value generated by the environment to people into the measurement of welfare/wellbeing.

Natural capital accounting relies on a series of interconnected accounts that provide a structured set of information on natural capital stocks, services and values. Natural capital accounts capture changes in the stock of natural capital, the flows of ecosystem services supplied by them and their value. They are structured in a way that consistently reflects the principles employed in the SNA to make comparison possible. However, a Natural Capital account can consist of a selection or combination of different types of accounts, each emphasising a specific steps (or linking different steps) identified in the Natural Capital framework described in section 2.1. One first distinction is between physical accounts – measuring the extent and condition of the assets and the resulting amount of goods and services produced annually – and monetary accounts – providing information on the monetary valuation of selected services or of a natural asset (see Figure 2). Another important distinction is between asset accounts – focusing on the state of the assets (i.e. volume or extent and its condition or quality) – and service accounts – recording information on the service flows provided by natural assets over a certain time period (typically one year). Both stock (asset) accounts and flow (services) accounts can be in either monetary or physical terms, and can be produced for one or multiple years, to capture how stocks and the provision of services have changed over time.

[6] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

[7] Natural Capital Committee (2019). State of Natural Capital Annual Report 2019. Sixth report to the Economic Affairs Committee of the Cabinet. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774218/ncc-annual-report-2019.pdf

[8] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

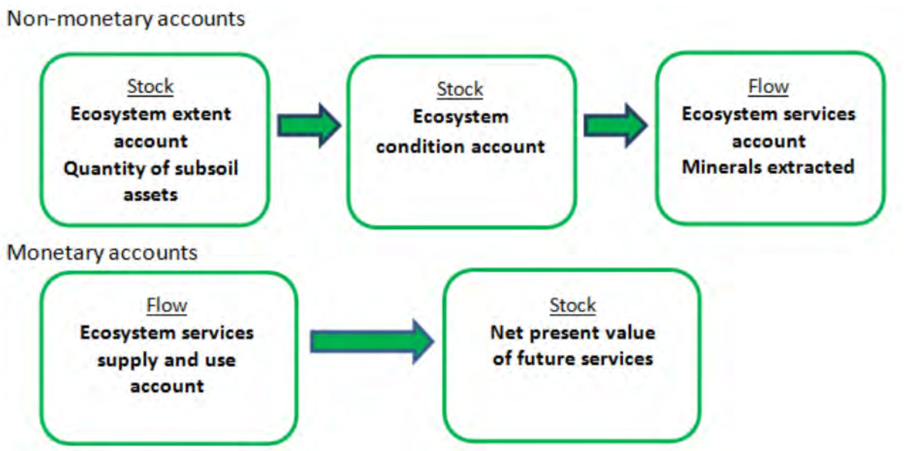


Figure 2. The possible types of Natural Capital accounts (adapted from ONS (2017)[9])

2.2.1 Non-monetary stock accounts

These accounts capture information on the extent and condition of different natural capital stocks within a pre-defined area (e.g. a nation, a region or a park). Typically, the starting point consists of the categorisation of natural capital stocks into land cover classes. In the UK, the ONS and Defra recommend using the Land Cover Map (LCM) data, first released by the Centre for Ecology and Hydrology (CEH) in 1990 and subsequently for the years 2000, 2007 and 2015. These data are deemed to be the best available source of natural capital asset data in the UK for the purposes of natural capital accounting because they are spatially comprehensive and offer information on stock extent over repeated years, although the way in which data are collected varies slightly across years. Inconsistency in methodology can, as we will discuss later, reduce the reliability of stock change detection over time.

In addition to collecting information on the change in asset extent over time, information on the condition or quality of the natural capital stocks is also highly informative. The ONS recommends considering a broad set of condition indicators, including for example volume estimates (e.g. timber biomass.), soil indicators (e.g. carbon or water content), ecological condition (e.g. water quality, level of land degradation) and spatial configuration (fragmentation or connectivity). The condition of ecosystem assets is an important element driving the capacity of natural capital to deliver ecosystem services. Whilst it is acknowledged that information on natural capital stock condition is not always available, it is recommended that when this information is available, it should be reported.

Once the asset accounts are completed, information on stock extent and condition can, if useful, be linked with information on land use, landscape type, land ownership, protected area status

[9] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

and land management practices to have a richer understanding of the drivers of change. An example of an asset account, incorporating extent and condition information on the different stocks, is reported in Appendix 1.

2.2.2 Non-monetary ecosystem service flow accounts

After producing asset accounts, flow accounts are built to record information on the flow of ecosystem goods and services provided by the stock of natural capital and appreciated and valued by people.

The ONS and Defra refer to the Common International Classification of Ecosystem Services (CICES) as one possible standard to be followed in the classification of the ecosystem goods and services in the accounts. This classification system reflects the well-established distinction between provisioning, regulating and cultural services. Provisioning services refer to all those goods and services that can be directly consumed by people (e.g. food, drinking water) or used as inputs in productive activities (e.g. energy, timber). Regulating services are those resulting from well-functioning ecosystem processes (e.g. climate regulation, flood regulation, pollination, etc.). Cultural services are the non-material benefits that people obtain from the enjoyment of ecosystems (e.g. recreation, education).[10] A recommended checklist of ecosystem goods and services suggested by the ONS-Defra for use in Natural capital accounts is reported in Appendix 2.

2.2.3 Monetary accounts

In natural capital accounting, information on both the stock of natural assets and the associated flow of ecosystem goods and services can be reported in both physical and monetary terms. Monetary valuation allows environmental stocks and flows to be integrated and compared with the SNAs using a common metric (money) as a measure of value. The value of stocks is usually calculated as the aggregate value of the flow of ecosystem goods and services that are expected to be produced by the natural capital over a period of time into the future, until the end of the asset life (i.e. when the ecosystem asset is no longer able to supply the ecosystem service in question). This accounting asset life depends on the characteristics of the asset, but also on the management of the asset and the sustainability in the use of natural resources. In the UK Natural Capital monetary estimates published in 2016, the ONS (2017) has considered an asset life of 50 years for all renewable resources, hence adopting a simplified approach. To calculate the aggregate value of the asset over the full asset life, the net present value approach is usually considered. This assumes that the aggregate value of an asset is not simply calculated as the sum of the annual values, but rather as the sum of the discounted flows of values over time. To do so,

[10] http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx

a discount rate is applied. This reflects the weight that people assign to goods and services provided in the future. Discount rates tend to assign a lower value to goods and services being delivered later in time, given that people prefer to enjoy them sooner rather than later. The HM Treasury Green Book currently recommends the use of a Social Discount Rate of 3.5% for flows of services supplied up to 30 years into the future, and 3.0% for 31 to 75 years, although there is ongoing discussion regarding the most appropriate discount rates to apply to environmental goods and services.

In many cases, information on the value of ecosystem goods and services provided by nature is not readily available. For some goods and services (e.g. timber or crops) the market price reveals the value of the good to buyers. However, in most circumstances, environmental goods and services (e.g. clean air, healthy biodiversity, functioning habitats, etc.) do not have a market price, as they are not traded in markets. For these goods, information on the value needs to be inferred using different approaches. To estimate values that are compatible with the SNA, valuation approaches for non-market environmental goods should, where possible, focus on *exchange values*. An exchange value is the monetary amount that would have resulted from a feasible transaction between a supplier and a beneficiary, "if a market existed". Where exchange values cannot be satisfactorily identified, alternative *welfare values* can also be considered, based on an individual's "willingness to pay" for a good or service – this is usually greater than exchange values. To estimate the value of the flow of environmental goods and services, a range of established valuation techniques can be used:

- Market-based methods, including:
    - The market price approach, which relies on the consideration of prices for given marketed ecosystem services (e.g. standing timber, crops, etc.). This approach is consistent with the principles of exchange values.
    - The resource rent approach, which measures the surplus value to the extractor or user of a natural capital asset after all costs and normal returns have been taken into account. Resource rent approaches are particularly suitable to value provisioning services (e.g. drinking water abstraction).
    - The production function approach, which values the importance of ecosystem services (typically regulating services) by studying their contribution to market-based production processes that have a market value. An example of this approach is the role of pollinators in crop pollination. It could be argued that the value of pollinators corresponds to the agricultural profit that would be lost in the absence of insects.

- Revealed preference methods, including:
    - The hedonic pricing method, which focuses on estimating the contribution of environmental services to market-based transactions, typically in the framework

of the housing or the labour markets, where environmental quality is a characteristic of properties or jobs. For example, we can think about the role of sceneries or nice views on residential property prices.

    - Averting behaviour approaches estimate the value of environmental changes through the price that people have to pay for given substitute products that become needed, following a drop in environmental quality or quantity. For instance, the value of clean drinking water can be estimated based on the amount of money that people are willing to spend on bottled water in situations when drinking water is contaminated or of reduced quality.
    - The travel cost method, which measures people's willingness to pay (usually recreational values) is based on information on the visited sites and the costs (in terms of travel costs and time) that individuals are willing to incur to access a given location with given environmental characteristics. The value that people get from visiting a given site generally exceeds the actual access or travel cost incurred and, therefore, the estimated willingness to pay corresponds to a measure of welfare, rather than simply exchange, value.

- Cost-based methods, including:
    - The damage costs avoided method, which estimates the value of a given environmental service (most typically regulating services) by calculating the cost savings incurred because of the existence of the ecosystem service of interest. For example, the value of air pollutant absorption services by trees can be calculated as the health treatment costs not incurred by the NHS as a result of lower health risks attributable to the presence of vegetation.
    - Replacement cost approach, which estimates the value of an environmental service by calculating the investment costs that would be incurred if the ecosystem service under consideration didn't exist or was lost. For example, the flood defence value of coastal margins can be estimated by calculating the costs of flood defence structures in areas which are similar but have no natural flood defences.

- Stated preference methods, including contingent valuation and discrete choice experiments, estimate the value of environmental goods by asking respondents to express their preferences in a survey setting, usually presenting hypothetical environmental scenarios of change. Stated preference methods provide welfare rather than exchange values, but their use is accepted for natural capital accounting purposes when no alternative methods are available.

A summary of the available valuation methods and recommendations regarding the most appropriate approach to use for valuing the different ecosystem services in natural capital accounting, is provided in Appendix 3.

2.3 PRODUCING LOCAL NATURAL CAPITAL ACCOUNTS - IN PRACTICE

Responding to the increasing calls for more efforts to develop natural capital accounts at organisational scale, a wide range of organisations, including those with an environmental and/or conservation focus, have recently started to either produce or commission their own natural capital accounts. For example, the RSPB has produced a Natural Capital Account for the estates that the organization owns and/or manages (RSPB 2017)[11]. Other examples include the work by DEFRA, AECOM and other partners, which have produced Natural Capital Accounts for Protected Areas in England and Scotland.

Overall, whilst alternative approaches and methods are considered by the different organisations for the measurement of natural capital stocks, ecosystem services and valuation, there are also substantial commonalities in the approaches and methods adopted. In this report, we refer to these as the current "standard practice" in natural capital accounting for environmental organizations. "Standard practice" approaches often rely on the use of simplified methodologies and generally use readily available data on natural assets (e.g. land cover maps) and on ecosystem services (e.g. literature on carbon storage by habitat type). Once goods and services are quantified, this information is generally multiplied by per unit values (based on a range of valuation approaches) to compute the total economic value. The "standard practice" approaches frequently adopted are reviewed in more detail in section 3 and Appendices 5 and 6.

Past Natural Capital Accounts at organisational scale have revealed that the "standard practice" approach, based on the multiplication between Price and Quantity, has some clear strengths. It is a useful method for incorporating "Natural Capital thinking" into an organisation's philosophy, and can provide an overview of the interdependencies between the natural world, organisations and society. Using readily available data simplifies the process for the organisation and minimises the resources involved in producing a Natural Capital Account. However, there are also some key limitations and difficulties that need to be considered. A "one size fits all approach" is not appropriate as there are differences in assets and ecosystem services provided by different areas of interest. Hence, generalisations, as used in "standard practice" approaches, are not suitable in many circumstances. In addition, readily available datasets on assets often do not match the level of detail needed to inform management decisions. It is therefore important to ensure a good balance between the ease of simplified approaches and the more in-depth analysis required for comprehensive and informative accounts to guide decision-making.

Given these limitations, there is a concern that currently available approaches to produce Natural Capital accounts at an organisational level may not give the desired information to guide

[11] RSPB (2017). Accounting for Nature: A Natural Capital Account of the RSPB's estate in England

management decisions. In this project, we review "standard practice" approaches, replicate them by developing Natural Capital Accounts for Dartmoor and Exmoor National Parks and evaluate the usefulness of such approaches to inform land management decisions. We also test the sensitivity of the accounts to the use of different data sources and methodologies, and explore potential ways in which organisations can incorporate additional data and expertise into the standard approach to improve the overall accuracy and usefulness of the accounts.

3 METHODOLOGY

The focus of this project is to critically assess the advantages and limitations of applying the current "standard practice" approach to develop accounts at regional or organisational scale. With "standard practice" in this report we mean those efforts which have sought to adapt international and national Natural Capital accounting methodologies and principles to a regional or organisational scale. Dartmoor and Exmoor National Parks are used as case studies for our critical assessment. Our methodology to produce the accounts was based on a review of published natural capital accounting scoping studies/reports and of ecological and environmental economics literature, supported by consultations with management and technical staff from both National Parks. Figure 3 summarises the steps taken in the project.

After identifying Dartmoor and Exmoor National Park Authority's aspirations regarding the use of natural capital accounts to inform their decision-making, we reviewed the approaches adopted by different (scoping) studies, and replicated these for the two National Parks. We next tested the sensitivity of the account results to alternative estimates (obtained from the academic literature or alternative datasets), based on different 'assumptions' regarding the natural assets, flows of ecosystem services and goods and values, and discussed the implications. We concluded this study by critically discussing the usefulness of natural capital accounts for management decisions, by referring to the discussions and consultations with stakeholders at the various stages of the project.

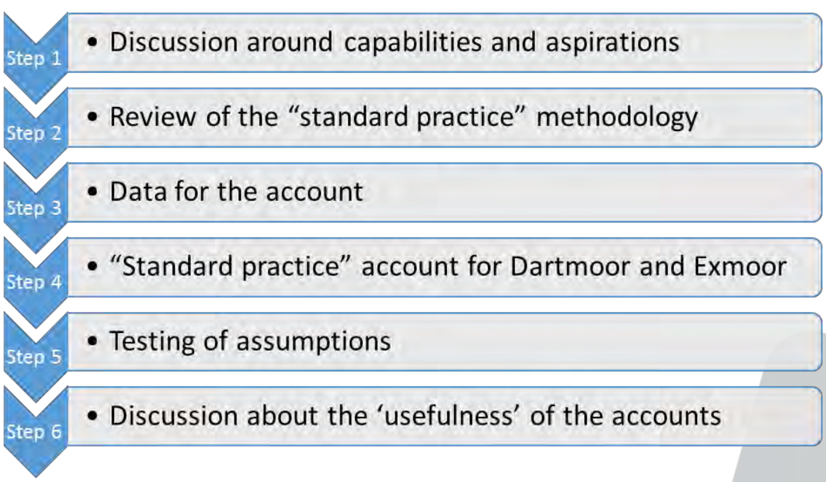


Figure 3. Steps in the production of "standard practice" Natural Capital Accounts for Dartmoor and Exmoor National Parks

3.1 STEP 1: CAPABILITIES AND ASPIRATIONS.

The first step in this project was to establish the National Park Authorities' aspirations as to how a Natural Capital account might inform their decisions. The aim of this step was to set a baseline against which to assess, at the end of the project, whether the produced accounts have met the initial aspirations. In a workshop setting, we held a structured discussion with key staff members from both National Park Authorities (management and ecologists) to identify their expectations regarding what a Natural Capital Account could be useful for within their organisation. The discussion was firstly based on a list of items summarising possible ways in which natural capital accounts can be useful to inform decision-making (based on the Defra report on NCA in protected areas)[12]:

- promote understanding and awareness
- influence policy decisions and secure funding
- support decision-making and management
- identify opportunities to enhance the ecosystem functionality
- explore innovative mechanisms for revenue generation

In addition to presenting these general points, we also displayed a list of specific management ambitions (taken from Dartmoor and Exmoor National Park Authorities' Management Plans[13]) to discuss whether it was felt that Natural Capital Accounting could be a useful tool to provide answers to specific management questions. Based on the discussions with stakeholders, we compiled a list of aspirations regarding how each National Park Authority was hoping to use Natural Capital Accounts to inform decisions.

Exmoor National Park Authority's aspirations:

- Demonstrate how the natural capital approach can be used in the context of the "National Park" designation
- Understand how the Natural Capital approach can be used for post-Brexit farm and environmental support (Exmoor's ambition)[14]
- Guide land management, investment and protection
- Use as a tool to inform:
    - Mires rewetting

[12] White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government.

[13] Available at: www.yourdartmoor.org.uk and https://www.exmoor-nationalpark.gov.uk/about-us/key-documents.

[14] Report on Exmoor National Park's ambition, a transformative proposal for sustaining and enhancing Exmoor's farmed landscapes and communities after Brexit, is available from: https://www.exmoor-nationalpark.gov.uk/__data/assets/pdf_file/0010/1112869/ExmoorsAmbition_Web.pdf

    - Grassland restoration
    - Sustainable construction
    - Winter grazing
    - Land holdings

Dartmoor National Park Authority's aspirations:

- Incorporation of Natural Capital Accounts in the State of the Park Report and Management plan
- Update Natural Capital Accounts on a 5-year basis to see how the stocks/flows/values changed over that period
- Use this to inform which priorities/actions/management changes should be considered in the next management plan review
- Look at how information from accounts may inform future environmental land management schemes
- Use as a tool for informing:
    - The state of air quality
    - Orchard losses
    - Farming Futures
    - Links with management of the Duchy estate
    - Recreation management

Common management ambitions to both Dartmoor and Exmoor National Park Authorities include:

- Woodland management
- Natural Flood Management
- Invasive species control
- Swaling
- Scheduled Monument management

Based on the compiled lists and wider discussions, the following were identified as priority ambitions regarding the potential uses of Natural Capital Accounts:

Exmoor National Park Authority	Dartmoor National Park Authority
• Provide an improved framework for the State of the Park report	• Improved framework for the State of the Park report
• Informing Environmental Land Management Schemes (ELMS)/payment for farming, e.g. by putting value on provided ecosystem services	• Explore the use of Natural Capital accounting for investment decision-making, e.g. when needing to prioritise between two management/restoration options.
• Land ownership/land holdings: understand the best use of land owned by the Exmoor National Park Authority	• Leveraging funding/justifying spending. Understanding the monetary value of e.g. a restoration project, and use this knowledge to leverage funds to cover project costs
• Use to illustrate gaps in decision-making	• Influencing management decision-making, e.g. increasing the size of high value stocks

Despite some aspirations being specific to the context of the Dartmoor and Exmoor National Park Authorities, the identified ambitions generally reflect wider national expectations (summarized earlier in this report) regarding how natural capital accounting is believed to help informing decision-making in environmental organisations.

3.2 STEP 2: REVIEW OF EXISTING “STANDARD PRACTICE"

After discussing the National Park Authorities’ aspirations regarding the use of Natural Capital Accounts, the team focused on reviewing the relevant scoping studies and reports to compile information on the “standard practice” for Natural Capital accounting at an organisational scale. The aim of this step of the work was to review the methodology, datasets and quantitative estimates used by existing scoping studies and reports on Natural Capital accounting, to be able to replicate the “standard practice” in our case study areas. We reviewed a sample of Natural Capital Accounts produced at a local or organisational scale by UK organisations with an environmental remit. Given the limited availability of relevant examples of approaches for selected ecosystem services, we also considered some national case studies to improve accounts’ completeness – mostly focusing on the ONS scoping studies.

The following list of reports was reviewed:

- White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), '**Developing ecosystem accounts for protected areas in England and Scotland'**, Department for Food, Environment & Rural Affairs/The Scottish Government
- RSPB (2017). **Accounting for Nature: A Natural Capital Account of the RSPB's estate in England**
- Rouquette, J.R. (2016). **Mapping Natural Capital and Ecosystem Services in the Nene Valley.** Report for the Nene Valley NIA Project.
- Cryle, P., Krisht, S., Tinch, R., Provins, A., Dickie, I., Fairhead, A. (2015**). Developing UK natural capital accounts: woodland ecosystem accounts.** Economics for the Environment Consultancy Ltd (Eftec) in association with Cascade Consulting for the Department for Environment, Food and Rural Affairs (Defra)
- Office for National Statistics scoping studies:
  - Jones, L., Vieno, M., Morton, D., Cryle, P., Holland, M., Carnell, E., Nemitz, E., Hall, J., Beck, R., Reis, S., Pritchard, N., Hayes, F., Mills, G., Koshy, A., Dickie, I. (2017). **Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts.** Final report for Office of National Statistics, July 2017
  - Richard Smithers, Outi Korkeala, Guy Whiteley, Shaun Brace, Bex Holmes (2016). **Valuing flood-regulation services for inclusion in the UK ecosystem accounts.** Ricardo Energy & Environment for the UK Office for National Statistics
  - Office for National Statistics (ONS) (2016) **Scoping the UK coastal margin ecosystem accounts**

A range of other reports[15] (including Exmoor's "Towards a Register of Exmoor's Natural Capital") were included in the review, but could not be used for the purposes of this project because they either provided only qualitative information, or they provided quantitative figures which were though not readily transferrable to Dartmoor and Exmoor National Parks.

In order to replicate the "standard practice" approach, information had to be derived on: 1) the natural capital stocks and underpinning datasets for stock quantification, 2) the considered

[15] List of reports reviewed but not providing quantitative and easily transferrable information to build standard practice NCAs:
- Deane R and Walker A (2018). Towards a Register of Exmoor's Natural Capital. Report to the Exmoor Society, Dulverton
- Hölzinger, O., Laughlin, P. (2016). Cornwall Area of Outstanding Natural Beauty (AONB) Natural Capital Assessment
- Whiteley, G., Shabb, K., Korkeala, O., Mccullough, A., Smithers, R. (2016). Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimatesReport for Office National Statistics
- Office for National Statistics (ONS) (2017). UK natural capital: developing UK mountain, moorland and heathland ecosystem accounts.
- Dickie I., Evans C., Smyth M.A., Artz, R. (2015). Scoping the Natural Capital Accounts for Peatland, work package 3 of Report NR0165 for Defra.
- Office for National Statistics (ONS) (2018). UK natural capital: developing semi-natural grassland ecosystem accounts.
- Office for National Statistics (2018). UK Natural Capital: Ecosystem service accounts 1997 to 2015
- Office for National Statistics (2016). UK Natural Capital: Monetary estimates 2016

ecosystem goods and service flows, and the data used to quantify these flows and 3) the valuation methodology and values used.

Based on the reviewed reports, we compiled a list of natural capital stocks generally considered in the reviewed Natural Capital accounting approaches. In most of cases, the asset classes considered match with those generally used in publicly available land mapping datasets. Following discussions with the National Park Authorieties, and given the fact that in-house mapping was often dated or did not cover the full extent of the National Park area, it was decided that the project would follow the ONS recommendations and use the CEH Land Cover Map 2015 asset categories and data. This was viewed as the best option, given that it ensures a comprehensive coverage across both National Parks. In addition, using the CEH Land Cover Map data, whose collection is periodically repeated at national scale, allows to potentially replicate Natural Capital accounting exercises for Dartmoor and Exmoor in the future. This approach is also in line with the one used, for example, in the DEFRA report for Protected Areas and in the ONS scoping study focusing on coastal margins, both relying on the 2007 Land Cover map data.

For Dartmoor National Park, park-wide local data on Rhos pasture and Dry Grassland was available. Given the relevance of these habitat classes in Dartmoor, the LCM classification and resulting habitat extent calculations were adapted to incorporate data on Rhos pasture and Dry Grassland. The final list of considered assets for both Dartmoor and Exmoor is included in Appendix 4.

Based on the "standard practice" approaches reflecting the ONS recommendations, reviewed reports and discussions with the National Park Authorities, we then compiled a list of ecosystem goods and services of interest to be included in the National Parks' Natural Capital Accounts. The following ecosystem goods and services are considered in this project:

- Recreation
- Wild food (game)
- Climate regulation (greenhouse gas sequestration)
- Timber
- Crops
- Drinking water
- Air quality regulation
- Minerals
- Biodiversity
- Pollination
- Flood protection
- Livestock
- Plants and seed
- Volunteering

For comparison purposes, we also provide a list (Table 1) of the ecosystem goods and services that were considered (but not always quantified) in the reviewed reports mentioned earlier in this section. The majority of these ecosystem goods and services are in line with the recommendations set out by the ONS (ONS 2017). However, there are also some additional goods and services, including energy production (e.g. hydropower, wind) and waste remediation, that are considered by some reviewed studies but are not frequently included in Natural Capital Accounts. Please, note that we discuss the difficulty of valuing cultural services other than recreation (such as aesthetic value and archaeological heritage) later in this report.

Table 1. The ecosystem goods and services considered in this project and other Natural Capital Accounting projects for organisations with an environmental remit.

Dartmoor & Exmoor	**D**	**R**	**N**	**E**	**Coastal margins**
Recreation	+	+	+	+	+
Wild food	+				
Climate regulation	+	+	+	+	+
Timber	+			+	
Crops	+	+	+		
Drinking water	+	*	*		
Air quality regulation	+	*	*		+
Minerals					
Biodiversity					
Pollination			+		
Flood protection	*		*	+	+
Livestock	+				
Plants & seeds					
Volunteering		+			
	Other water uses				
	Energy (woodfuel)	* (biomass briquettes)			
	Education*	+			
	Heritage*				
	Aesthetic	*			
	Existence*				
		Conservation*			
			Agricultural emissions		
			Noise regulation*		
			Tranquillity*		
			Accessible nature*		
			Green travel*		

Note: A plus symbol (+) indicates the services which were considered in the reviewed reports, an asterisk (*) indicates services that were considered, but were not successfully quantified or estimated. Notes: **D = Defra NCA**

for protected areas (Ref: White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government); **R=accounts for RSPB estate** (Ref: RSPB (2017). Accounting for Nature: A Natural Capital Account of the RSPB's estate in England); **N = Nene Valley report** (Ref: Rouquette, J.R. (2016). Mapping Natural Capital and Ecosystem Services in the Nene Valley. Report for the Nene Valley NIA Project); **E = Eftec woodland NCA for the UK** (Ref: Cryle, P., Krisht, S., Tinch, R., Provins, A., Dickie, I., Fairhead, A. (2015). Developing UK natural capital accounts: woodland ecosystem accounts. Economics for the Environment Consultancy Ltd (Eftec) in association with Cascade Consulting for the Department for Environment, Food and Rural Affairs (Defra)); **O = ONS study valuing coastal areas** (Ref: Office for National Statistics (ONS) (2016) Scoping the UK coastal margin ecosystem accounts).

In addition to the type of ecosystem services provided by natural capital stocks, information also needs to be collated from the reviewed reports about the amount of ecosystem goods and services provided (for example, tonnes of Carbon sequestered per hectare of heather grassland, or tonnes of crops per hectare of agricultural land). Appendix 5 summarises the approaches adopted by the reviewed reports and then used in the preparation of the Natural Capital Accounts for the National Parks. Often, only one approach was available to quantify the ecosystem goods and services, but in several cases multiple options could be considered. In this latter case, the approach that we followed was based on the consideration of the most plausible and practical approach, based on scientific soundness (well-established evidence), local relevance (i.e. applicable to Dartmoor and Exmoor habitats), and feasibility (e.g. the underpinning data being publicly available). When there was uncertainty regarding which approach to use, National Park Authority staff was consulted in the selection process.

The following step in the process consisted of compiling information on the methods employed by the "standard practice" Natural Capital accounts to value (in monetized terms) the benefits provided by the ecosystem goods and services supplied by the natural assets. Generally, the reviewed Natural Capital accounts tended to employ the valuation approaches suggested by the ONS and, in turn, the SEEA (summarised in Section 2.2. of this report). Appendix 6 summarises the valuation approaches employed in our exercise for Dartmoor and Exmoor National Parks. When multiple options were available, expert judgement was used to select the most appropriate (scientifically sound) approach, and stakeholder consultations helped to assess the local relevance and applicability of the proposed method.

An Excel framework was developed to record the quantifications of the natural capital stocks, the ecosystem goods and services and the economic values. The spreadsheet consists of one tab for each ecosystem service. Each tab contains a separate table for each natural capital stock class and sub-class and is used to calculate the value of each ecosystem service provided by each stock type. An example of these tables can be found in Figure 4, which focuses on carbon sequestration services in coniferous woodlands.

							Any other comments:
Stock:	Coniferous woodland						
Stock extent (ha):	10	Unit of measurement:	Source of quantification:	Strengths:	Limitations:	Suggestions for improvements:	
1a. Amount of good produced (per ha):	12	tonnes of CO2e sequestered/ha/year					
1b. Amount of good produced (per ha):							
2a. Value per unit of good (£):	56	£/tonne of CO2e					
2b. Value per unit of good (£):							
Valuation (1a & 2a): (no. ha * amount of good produced/ha * value per unit of good)	10*12*56=£6720						
Valuation (1a & 2b):							
Valuation (1b & 2a):							
Valuation (1b & 2b):							

Figure 4. Example of the Excel table structure used to record information on the reviewed estimates of service flows and values for each stock

From top to bottom, each table records:

i) The stock extent, e.g. the extent of coniferous woodlands in the area under consideration (in blue)

ii) The amount of good or service produced per hectare, e.g. tonnes of carbon sequestered per hectare of coniferous woodland (in pink)

iii) The unit value of the ecosystem services, e.g. the value of carbon (in £) per tonne (in green)

iv) The total value of the ecosystem good or service for this stock (in orange), obtained by multiplying the number of hectares (i) by the amount of goods produced per hectare (ii) and the value per unit of the good (iii).

As reported in Figure 4, ten hectares of coniferous woodlands sequester 12 tonnes of carbon (CO_2 equivalent). Given that the value of a tonne of CO_2 equivalent sequestered is £56 (for 2011), it is easy to calculate the total value of the flow of carbon sequestration services provided by coniferous woodlands, as 10*12*56=£6,720 per year.[16] All calculations were conducted using Excel formulas so that workings could be traced.

In addition, in the white section of the table, we recorded information about the source documents and the unit of measurement used in the quantifications. Where available, we also included information on the strengths and limitations of each approach, suggestions for improvement, and any other relevant comments. In the spreadsheet, we considered one row for each of the reviewed reports and used different letters to be able to link the recorded information to the corresponding source document.

[16] If unit values were available for a different year compared to that considered in the accounts, the values were adjusted to the year of interest by using the GDP deflator formulas, which make it possible to account for the fact that prices changes over time due to inflation. Prices adjusted for the GDP deflator are reported on the left of each table in the Excel spreadsheet.

3.3 STEP 3: DATA FOR THE ACCOUNT

Starting from the list of selected natural capital stocks, ecosystem goods and services and values considered by “standard practice” Natural Capital Accounts, the team worked with the NPAs to assess the quantity and quality of data available to populate the accounts. Information on the extent of each selected natural capital stock (land cover type) was obtained, using ArcGIS, from the CEH Land Cover Map 2015 data. Additionally, for DNPA, data on Rhos pasture and Dry Grassland were also considered (see step 2 of the methodology and Appendix 4). In some cases, quantifications of the values and the flow of ecosystem goods and service provided by the natural capital stocks could be obtained directly from the reviewed reports (step 2). For example, information on the amount of carbon sequestration and air pollution capture per hectare for different habitat types was available directly in the reviewed reports. In other cases, extra calculations were required to quantify the ecosystem services and values for the specific case study area of interest. For example, for Recreation and Volunteering, the annual number of visitors and the number of volunteer hours needed to be obtained specifically for each of the National Parks. See Appendices 5 and 6 for details on the methodologies for valuation and the quantification of ecosystem goods and service flows.

3.4 STEP 4: “STANDARD PRACTICE" NATURAL CAPITAL ACCOUNT

Starting from the list of the most plausible quantifications obtained in Step 2 for selected natural capital stocks, flows of goods and services and values, and the data obtained in Step 3, we drafted a Natural Capital Account for Dartmoor and Exmoor National Parks. The account, reflecting “standard practice” approaches, was produced by combining the information from the individual Excel tables for each ecosystem service and stock into one large table, summarising the total ecosystem service provision and values for a given year. This summary Natural Capital Account table was created as a separate tab in the Excel spreadsheet and was populated by using formulas to ensure that any change introduced elsewhere in the spreadsheet (e.g. a change in a stock extent, a change in the amount of ecosystem service produced, or the value of that service) was automatically updated and reported in the summary table. This sets up a convenient framework for updating the accounts when changes in assets, services or values become available. See Figure 5 below for an example of part of the Natural Capital Account table.

STOCKS		GOODS & SERVICES				TOTALS
		RECREATION				
Natural capital stock	Stock extent	Total amount	Value	Ecosystem service	Value based on	TOTAL VALUE BY
Woodland	11254.00	202572.00	£730,693.06			**£12,285,947.53**
Other broadleaved woodland (not ancient)	7876.00	141768.00	£511,368.27	*all stocks*	*woodland*	
Coniferous	3378.00	60804.00	£219,324.79	*all stocks*	*woodland*	
Open water	234.00	4212.00	£8,263.62			**-£54,068.61**
Freshwater	185.00	3330.00	£6,533.21	*all stocks*	*open water*	
Saltwater	49.00	882.00	£1,730.42	*all stocks*	*open water*	
Mountain/heath/bog	3406.90	61324.20	£333,368.36			**£1,042,458.86**
Bog	26.00	468.00	£2,544.12	*all stocks*	*mountain/heath/bog*	
Heather grassalnd	356.00	6408.00	£34,834.93	*all stocks*	*mountain/heath/bog*	
Heather	3020.00	54360.00	£295,509.83	*all stocks*	*mountain/heath/bog*	
Inland Rock	4.90	88.20	£479.47	*all stocks*	*mountain/heath/bog*	
Improved grassland	34113.00	614034.00	£1,022,729.73	*all stocks*	*semi-natural grassland*	**£1,155,576.83**
Semi-natural grassland	17259.00	310662.00	£517,435.95	*all stocks*	*semi-natural grassland*	**£2,378,681.71**
Neutral	357.00	6426.00	£10,703.09	*all stocks*	*semi-natural grassland*	
Calcareous	0.00	0.00	£0.00	*all stocks*	*semi-natural grassland*	
Acid	16902.00	304236.00	£506,732.86	*all stocks*	*semi-natural grassland*	
Fen/marsh/swamp	0.00	0.00	£0.00	*all stocks*	*semi-natural grassland*	
All stocks	69890.20	1258023.60	£2,762,899.15			**£22,897,518.81**

Figure 4. Example of the Excel table structure used to record the full Natural Capital Account. Incomplete example for illustrative purposes only, only one ecosystem service and a selection of the habitat types are shown.

The Natural Capital Account table also contains information on the stock of natural capital supporting the provision of the flow of ecosystem goods and services valued. In the example above, the number of visitors per hectare was only available at the level of the entire National Park. As a result, information on the rate of visitation was recorded only at an aggregate level for all stocks combined. Similarly, information on the recreational value of each visit was available by habitat type, but not by habitat sub-class. For instance, the same recreational value was considered for broadleaved and coniferous woodland. Recording such information in the account table helps picking up some interesting nuances. We can, for example, observe that the difference in the total value of recreation provided by broadleaved and coniferous woodlands is driven only by differences in woodland extent (hectares of broadleaved and coniferous woodland), given that visitor numbers per hectare and value per visit are the same across both woodland types.

3.5 STEP 5: TESTING OF ALTERNATIVE ESTIMATES

After drafting the accounts, we focused on testing their sensitivity to the use of different estimates regarding the quantification of the underlying components of natural capital accounts, namely the Natural Capital stocks, the flow of ecosystem goods and services and the values. We compared how Natural Capital accounting results can vary when considering "standard practice" estimates versus other available, improved estimates. One of the purposes of the exercise was to highlight limitations in the currently employed approaches to Natural Capital accounting, and to suggest areas for improvement.

We tested several estimates linked to stocks, flows of goods and services and values. The choice of these sensitivity tests was driven by: a) a selection of issues of interest outlined by the National Parks Authorities; b) scientifically-relevant aspects identified by the research team; c) availability of alternative estimates to the ones used in the reviewed reports, offering opportunities for improvement and d) availability of local data to complement the "standard practice" methodology.

Each test of alternative estimates and its justification is presented and discussed in detail in section 4.3 in the Results section.

3.6 STEP 6: DISCUSSION AROUND ACCOUNT 'USEFULNESS'

In the concluding part of the project, we relied on stakeholders' consultation to discuss the usefulness of the produced "standard practice" Natural Capital accounts for decision-making. After presenting the draft accounts to the Chief Executives and other key staff of Dartmoor and Exmoor National Park Authorities, the research team facilitated a discussion (in a workshop setting) in which the merits and the limitations of the accounts were assessed. The discussion was particularly focused on understanding whether the produced Natural Capital accounts met the aspirations and expectations regarding the intended use of this method (as recorded in Step 1), and represent useful tools to better inform management and decision-making.

4 RESULTS AND DISCUSSION

4.1 REPLICATING THE "STANDARD PRACTICE" APPROACH FOR DARTMOOR AND EXMOOR

Starting from the "standard practice" approaches that practitioners have employed in the reviewed Natural Capital accounts, we have drafted a Natural Capital flow account for the year 2015 for Dartmoor and Exmoor National Parks. In Table 2 and 3, benefits are reported by ecosystem good and service (each column) and, where possible and applicable, also by the different natural capital asset classes (each rows). Total values are also provided by ecosystem service (bottom row) and by natural capital stock (right-hand column). A colour coded-approach was employed in each table. Green boxes show instances where ecosystem services could be valued successfully, red boxes where they could not. Orange boxes indicate a partial valuation (not all habitat-subtypes could be included). Grey boxes indicate that the ecosystem service in question is not provided by the corresponding habitat type. Blue boxes show the total values by habitat type (row totals) and by ecosystem service (column totals). The ecosystem services are separated according to whether they provide "private" benefits (obtained by individuals or organisations) or "public" benefits (delivered to the wider society). Please, note that certain ecosystem services (e.g. volunteering) deliver both private and public benefits, but are classed here as private benefits only. This is due to the fact that typical "standard practice" valuation methodology only captures the private benefits of this service (e.g. labour cost saved by an organisation), rather than also the public benefits (e.g. mental health benefits for volunteers). This issue is discussed in more detail later in this report. Appendices 7 and 8 provide full Natural Capital account tables for Exmoor and Dartmoor respectively, displaying annual quantities of ecosystem service delivery and valuation results (broken down by sub-habitat type, where possible). It also needs to be noted that the accounts for the two National Parks are not directly comparable, as different data and assumptions were used to quantify and value some of the ecosystem services (see for example Box 5 on the calculation of recreation values).

Table 2. Natural capital account for Exmoor National Park for 2015 (in 2015 GBP).

	PUBLIC BENEFITS			**PRIVATE BENEFITS**					
	Recreation	Climate regulation	Air quality	Timber	Livestock	Crops	Volunteering	Pollination	**TOTALS**
Woodland	731k	8953k	2175k	427k			X		***12285k***
Open water	8k	-62k					X		-54k
Mountain/heath/bog	333k	685k	23k				X		1042k
Improved grassland	1022k	X	133k				X		1155k
Semi-natural grassland	517k	1732k	129k				X		***2378k***
Arable	82k	-3183k	12k			1613k	X	7k	-1469k
Coastal	68k	31k	1k				X		100k
TOTALS	**2763k**	**8157k**	**2472k**	427k	**7258k**	1613k	199k	7k	**22897k**

Table 3. Natural capital account for Dartmoor National Park for 2015 (in 2015 GBP).

	PUBLIC BENEFITS			PRIVATE BENEFITS				
	Recreation	Climate regulation	Air quality	Timber	Livestock	Crops	Pollination	**TOTALS**
Woodland	3035k	9741k	2356k	456k				***<u>15588k</u>***
Open water	29k	-73k						-44k
Mountain/heath/ bog	4380k	540k	18k					*4939k*
Improved grassland	3337k	X	113k					*3450k*
Semi-natural grassland	4484k	3916k	291k					***<u>8691k</u>***
Arable	251k	-2539k	10k			1287k	6k	-986k
TOTALS	**15516k**	**11585k**	2788k	456k	**8194k**	**1287k**	6k	**39832k**

By replicating the "standard practice" approaches employed in the reviewed natural capital accounts, it was possible to estimate the monetised value of the following ecosystem services:

- Outdoor recreational opportunities;
- Carbon sequestration (from vegetation and plants)
- Air pollution removal (PM_{10} absorbed from the air by vegetation) and avoided related health damages
- Timber production
- Grazing activities (livestock)
- Crop production
- Pollination services (crop dependence on pollinators)
- Volunteering services (for Exmoor)[17]

[17] For Dartmoor, this information was not readily available in the public domain, and this gap was later filled by obtaining additional data directly from Dartmoor National Park Authority (discussed later in this report)

The value of some of the selected goods and services of interest could not be estimated – either because insufficient information was available on the quantity (flow) of ecosystem goods and services produced and/or because of a lack of available monetised estimates of the benefits. For example, no value was estimated for flood protection, wildlife and the provision of water for drinking water purposes - all undoubtedly highly important ecosystem goods and services supplied by National Parks. Incorporating the value of these ecosystem services could significantly increase the relative importance of the "public" compared to the "private" benefits estimated in Tables 2 and 3. For some of the above ecosystem goods and services filling the gaps would be possible by collating additional data, e.g. water extraction information could be obtained from local water companies. However, this process is likely complex and could lead to inaccuracies in the estimates: water companies do not specifically collect water extraction data for National Park areas only. Information is generally collected at specific water abstraction points, which often lie outside the National Parks' boundaries. For this reason, apportioning amounts and values of water to specific sites and catchments can be challenging.

Based on the results of the Natural Capital accounting exercise, we can show that Dartmoor and Exmoor National Parks provide a mixture of both public benefits (accruing to multiple individuals representing the entirety or some groups within society) and private benefits (accruing to single individuals or organizations). Public benefits exceed private benefits in both areas, although in Dartmoor they represent a higher proportion of total benefits estimated (driven largely by differences in the calculated recreation values). For Exmoor, the total benefits (for those ecosystem services which could be successfully valued) are estimated to be £23m, of which £9.5m are private benefits and £13.5m are public benefits; for Dartmoor, the total benefits account for £40m, of which £ 30m are public benefits and £10m are private benefits. It is important to note that this relative balance of private vs. social benefits is driven in large part by limitations in the 'standard practice' methodology, which leads to many public benefits, and therefore a large part of the natural capital value, being fully or partially overlooked. This is discussed in detail in the next section of the report.

In terms of the most valuable ecosystem goods and services provided (based on the results of the natural capital accounts), similar conclusions could be drawn for both National Parks. In both cases, the most valuable goods and services supplied include two public benefits (recreation and carbon sequestration) and one private good (livestock – although see discussion on the limitation of the livestock analysis later in this report). Slight differences exist, though, in terms of which ecosystem services were valued the most. On Exmoor, the highest values were estimated for climate regulation (£8.2m), followed by livestock (£7.3m) and recreation (£2.8m). For Dartmoor, recreational benefits were ranked first (£15.5m), followed by climate regulation services (£11.6m) and livestock (£8.2 – although see the discussion around livestock in section 4 for some important limitations regarding this estimate).

When we look at the total value of all considered ecosystem services by the different natural capital stock types (i.e. LCM land cover classes), again there are similarities and differences across the two case study areas. Both in Dartmoor and Exmoor, woodland habitats provide the highest measured benefits, followed by semi-natural grasslands – in both cases mostly due to the high values associated with carbon sequestration in those habitats. The magnitude of these figures, calculated using a Price x Quantity multiplication, is also driven by the amount of these habitats found within the National Parks (i.e. greater habitat extent contributes to increasing the total value associated with a given ecosystems). Interestingly, open water habitats and arable land are both associated with negative values. For example, in the case of arable land this provides useful insights into the negative impacts (carbon emissions), alongside the benefits provided (crop production).

4.2 LIMITATIONS AND SENSITIVITY OF THE ACCOUNT RESULTS TO ALTERNATIVE ESTIMATES

In this section, we discuss the limitations of producing "standard practice" natural capital accounts. We discuss issues around measuring stock extent and quantifying and valuing ecosystem service flows. We test the sensitivity of the Natural Capital Account results to using alternative estimates and suggest potential improvements to the "standard practice" approaches to overcome some identified limitations.

4.2.1 Measuring stock extent

The first step in the development of Natural Capital Accounts is to collect data on stock extent. Although some local data on Natural Capital assets was available for both National Parks, these data were spatially and temporally patchy. Therefore, in order to obtain information on the Natural Capital assets across the entirety of the National Parks at a set point in time, national data needed to be considered. In this study, we selected the CEH Land Cover Map 2015 (with some adaptations for Dartmoor National Park, see step 2 of the methodology), following the approach used in the DEFRA/AECOM Ecosystem Accounts for Protected areas. Using such national scale data, however, is subject to several limitations, which we discuss in turn in the sections below.

4.2.1.1 Level of detail

In the CEH land cover data, habitats are mapped into relatively broad classes, meaning that some ecologically relevant habitat variables are overlooked. For example, Ancient Woodland is not captured by the Land Cover Map dataset, despite being a habitat with unique features and providing a different flow of ecosystem services from regular broadleaved or coniferous woodlands. Ancient Woodland is not typically used for timber extraction, is particularly attractive for recreational purposes, and is of high biodiversity importance. Another habitat type which is overlooked by the Land Cover Map data is Rhos Pasture. In this study, we were able to merge local data on Rhos pasture with the Land Cover Map data for Dartmoor National Park (see section 2 and Appendix 4). Another example of a habitat feature which is overlooked by Land Cover Map data is Bracken cover. Understanding which areas are dominated by Bracken is important for upland management, as Bracken reduces the amount of foraging area available for livestock on the open moor, whilst having positive effects on certain bird and butterfly species. This potential effect of bracken on Ecosystem Services is currently overlooked in the Natural Capital Accounts and further efforts and data would be needed to identify Bracken-dominated areas across the National Parks, as well as needing a better understanding of the effects on ecosystem service flows. Beyond bracken, other habitat characteristics with management relevance are also not fully captured when using LCM data. This is the case, for instance, of gorse and other scrub on, for example, areas of heather grassland.

4.2.1.2 Classification accuracy

In addition to lacking detail on habitat types, national land cover maps can also present classification problems, and therefore reduced accuracy, when identifying natural capital stocks at finer spatial resolution. Hence, complementing national data with local knowledge is important for ground-truthing and increasing the validity and usefulness of data for management decisions. Box 1 highlights the potential impact of a habitat classification issues on account results.

Box 1. Testing sensitivity of results to classification issues

Exmoor National Park Authority staff highlighted that Land Cover Map data 2015 are subject to a major misclassification problem because they tend to classify Exmoor's open moors as acid grassland. In order to test how this misclassification affects account results, we tested what would happen if the classification was more accurate. To do that, we re-classified all acid grassland extent as "heather". Please note that in order to improve the accuracy further, an estimate would need to be obtained of the proportion of acid grassland which is misclassified. Such data are not available and, hence, we tested the effect of re-classifying the full acid grassland extent into heather. Please note that this is an extreme example, used only to illustrate the effect of habitat misclassifications on Natural Capital Account values; it is highly unlikely that all 100% of acid grassland on Exmoor is in reality heather, and further work would be needed to fully understand the extent of acid grassland misclassification.

The Land Cover Map 2015 data estimates that there are 16,902ha of acid grassland and 3,020ha of heather on Exmoor. After our re-classification, the total amount of heather habitat changed to 19,922ha, with no acid grassland. As a result of the habitat re-classification, the total Natural Capital account value changed from £22.9 million in the original account, to £26 million under the updated assumptions. The table below outlines the implications of habitat re-classification for the estimated amount and value of some ecosystem services. Only some ecosystem services (provided by acid grassland and heather) were affected by the re-classification (recreation, climate regulation and air quality). Other ecosystem services were unaffected, as these services are either not provided by the two habitat types (e.g. timber extraction), or because the ecosystem services flows and values were considered to be the same for both habitat types. The specific reasons explaining the detected changes in values for the affected ecosystem goods and services are outlined in the table below.

Ecosystem service	Original value	Value under new assumption	Reason for change
Recreation	£2.76M	£3.91M	Different value per visit to these habitat types
Climate Regulation	£8.16M	£10.10M	Difference in C capture between habitats
Air Quality	£2.47M	£2.46M	Difference in PM10 capture between habitats

Whilst acid grassland and heather are used as an example here, similar classification issues are likely to be present also for some other habitat types. For example, the Land Cover Map 2015 estimates a total extent of 26ha of blanket bog in Exmoor. Local work suggests that this is a significant underestimate (see https://www.exmoor-nationalpark.gov.uk/Whats-Special/moorland/exmoor-mires-project).

4.2.1.3 Repeatability issues

If the ambition is to produce natural capital accounts over multiple years, a key challenge is related to gathering comparable evidence over time. In order to detect variations over time and allow for the repeatability of the accounting process, data need to be collected using a consistent methodology, which is not always easily achievable in practice. Land Cover Map data are available for multiple years (1990, 2000, 2007 and 2015). However, due to changes in the protocol of satellite data imagery classification and modelling, comparing data over multiple years for the purpose of detecting changes in natural capital stocks is often problematic. Box 2 discusses some issues related to stock detection using 2007 and 2015 Land Cover Map data as an example. Between 2007 and 2015 significant changes were introduced in the training routine for land cover detection, measurement methods and algorithms used.

Box 2. Issues with stock change detection

In this test, we compared Land Cover Map 2007 and 2015 data for Dartmoor and Exmoor National Parks with the purpose of measuring changes in stock extent over time. To illustrate why the data are subject to limitations when the purpose is to repeat Natural Capital Accounts for another year, we focus on two habitats as case studies: broadleaved woodland on Exmoor and arable land on Dartmoor. LCM data appear to show that broadleaved woodlands on Exmoor have changed in extent from 5,764 ha (2007) to 7,821 ha (2015), suggesting an increase by 2,057 ha in less than 10 years. Similarly, data indicate that arable land on Dartmoor has changed from 10,694 ha (2007) to 2,182 ha (2015), signaling a decrease by 8,512 ha. In both cases, based on publicly available data or reports, no evidence could be found of such changes in stocks happening on the ground. A plausible reason for such differences between the two years could therefore be linked to variations in the methodological approach adopted in the Land Cover Map data classification across the two periods. To explore whether this is the case, we compare land cover classification based on Land Cover Map data with Google Earth's imageries (image A and D below), which allows us to see the current true habitat distribution. Based on this comparison, Land Cover Map 2007 data seem to do a better job with the classification of broadleaved woodlands (purple dots in image B) compared to Land Cover Map 2015 data (image C). As image C shows, in the LCM 2015 data, habitats other than broadleaved woodlands tend to be classified as broadleaved woodland (yellow dots). This is likely one of the reasons why broadleaved woodland figures in 2015 are so high relative to 2007. In 2015 LCM data, there is also a higher tendency to classify broadleaved or mixed woodlands as coniferous woodland (red dots), which suggests low accuracy in woodland classification routines.

A

B

C

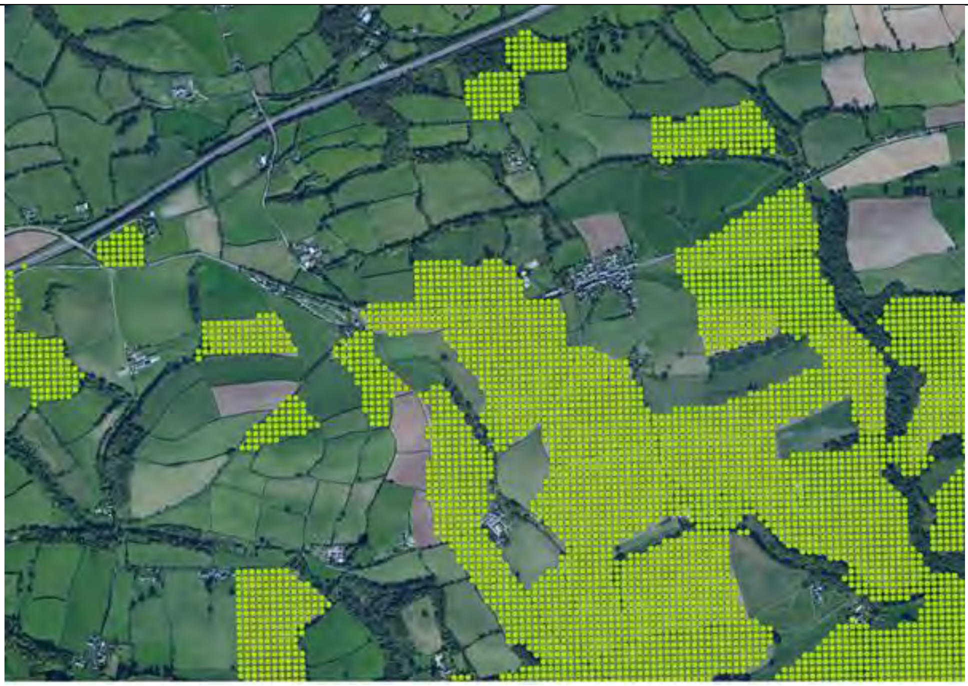
Clear classification problems can also be detected when comparing arable land cover on Dartmoor. Based on the example displayed on the next page, Land Cover Map 2007 data tend to classify other habitat types (especially grassland) as arable land (pink dots in image E). In 2015, the amount of land identified as arable appears to resemble reality more closely (yellow dots in image F). It is of course likely that some change in stock has taken place across time in both National Parks, but based on publicly available reports or data there is no evidence of the significant variations in land cover types suggested by the comparison between 2007 and 2015 Land Cover Map data. Hence, classification problems are apparent across the two years considered. It is possible that factors such as seasonality/timing or field rotation have not been adequately accounted/corrected for during the image acquisition and processing stages, causing these issues. Both factors may play an important role in the classification of arable land based on aerial images as fields might look very different depending on the day and month considered, and field configuration and use can be considerably different under different rotation schemes (Bryan et et al. 2009)[18]. A more accurate classification of Land Cover Map data for arable land could be based on CEH Land Cover plus Crops data, available for the period 2015-2018.

[18] Bryan, B.A., Barry, S., Marvanek, S. (2009). Agricultiural commodity mapping for land use change assessment and environmental management: an application in the Murray-Darling Basin, Australia. Journal of Land Use Science 4(3): 131-155.

D

E

F



To overcome these limitations in the level of detail, classification accuracy and repeatability, the National Parks would need fine-scale, park-wide data on land cover, split into habitat categories of management relevance. These data should also be collected consistently and repeatedly over time (e.g. annually) in order to allow for accounting and monitoring for changes in extents, flows and values over multiple years. Such data do not currently exist due to the time and cost involved in the data collection. However, the recent developments in high-resolution open-source remote sensing technology may help fill this data gap in a cost-effective way in the near future.

4.2.2 Measuring flows of goods and services:

The second step in the development of NCAs is to quantify the flows of ecosystem goods and services. In this section, we discuss factors relating to ecosystem service quantification which may limit the completeness and reliability of Natural Capital Accounts. We focus in particular on i) missing data, ii) the sensitivity of the accounts to using alternative available estimates, iii) the role of incomplete ecological information, iv) the effects of overlooking habitat condition and v) inadequately accounting for temporal dynamics.

4.2.2.1 Missing data

Missing data is a major limitation in the development of Natural Capital Accounts. For the ecosystem services Minerals, Plants and Seeds and Wildlife, no information on both the biophysical flows and valuation could be located. After a search of the literature and discussions with the National Park Authorities, it was decided not to explore Minerals and Plants & Seeds any further in this study, due to both the lack in data and limited management relevance (e.g. mineral extraction is not an activity which is pursued in National Parks). As conservation and enjoyment of the natural world are key purposes of National Parks, incorporating wildlife into the accounts was considered to be of substantial relevance to the National Park Authorities. The valuation of ecosystem services derived from wildlife was not attempted here due to the limited evidence and data availability, but is discussed in Section 4.2.3.1. However, the quantification of key wildlife supported by the different stock types was further explored (see Box 3 below) to help provide a baseline for future account improvements.

Box 3. Incorporating wildlife

Incorporating wildlife and biodiversity is a major challenge in the field of Natural Capital Accounting. The importance of wildlife to humans is widely appreciated, for example through recreational enjoyment, and the provision of ecosystem services such as pollination. Some of these benefits, such as recreation and game provision, can be estimated with current Natural Capital Accounting techniques when sufficient data is available. However, capturing biodiversity more generally is an ongoing challenge, both from an ecological and economic perspective. From an ecological perspective, it first needs to be determined which component of wildlife should be captured; this can include a wide range of measures regarding the abundance or conservation status of individual species, or the diversity of selected species or species groups. It then needs to be determined how such information links to ecosystem services enjoyed by humans, and subsequently how such benefits can be valued (see also section 4.2.3.1). Even when a suitable measure of biodiversity can be identified, data gaps remain a problem, with ecological survey records often patchy across time and space.

Currently, many organisations simply omit an estimate of wildlife from their accounts, or only quantify certain aspects of the wildlife "stock", without attempting valuation. For example, biodiversity was not discussed in the ONS Ecosystem Service Accounts[19], nor was it accounted for in the ONS scoping study for Mountain, Moorland and Heathland.[20] Other reviewed accounts attempt to acknowledge the importance of biodiversity using a wide range of different methodologies. The EFTEC woodland account[21] includes the extent of areas under designation as a proxy for capturing biodiversity, thus assuming that biodiversity is higher in areas subject to conservation action. In the EFTEC report, the limitations of the employed approach are clearly acknowledged. Biodiversity outside of protected areas is overlooked and improved indicators are proposed for the future, such as numbers of invasive species and numbers of native woodland species. The DEFRA/AECOM study on protected areas[22] used a different approach, where biodiversity was used as one of their indicators of ecosystem condition. Bird species diversity and abundance data from the British Trust for Ornithology (BTO) Breeding Bird Survey was reported as a biodiversity indicator for most, but not all, habitat types. Butterfly, fish and deer data were used for semi-natural grassland, open water and wetland, as well as mountain, moors and heath, respectively. Relevant ecosystem services supported by wildlife were discussed, but no attempts at quantifying service flows were made. The Nene valley report also attempted to incorporate estimates of biodiversity, using a broad collection of biodiversity records to produce "hotspot" maps.

[19] Office for National Statistics (2018). UK Natural Capital: Ecosystem service accounts 1997 to 2015

[20] Office for National Statistics (ONS) (2017). UK natural capital: developing UK mountain, moorland and heathland ecosystem accounts

[21] Cryle, P., Krisht, S., Tinch, R., Provins, A., Dickie, I., Fairhead, A. (2015). Developing UK natural capital accounts: woodland ecosystem accounts. Economics for the Environment Consultancy Ltd (Eftec) in association with Cascade Consulting for the Department for Environment, Food and Rural Affairs (Defra)

[22] White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government

However, such data were limited because observer biases were not controlled for and information was not disaggregated by spatial differences in survey efforts. Actual species richness information could therefore not be inferred from these maps, as ecological information is confounded with the survey biases. The RSPB Natural Capital report[23] provides a detailed discussion on the challenges and importance of incorporating biodiversity estimates into an organisation's Natural Capital framework. In their Natural Capital asset register, they annually record breeding numbers and changes in breeding populations for priority bird species on RSPB land, as well as an estimate of the proportion of the total national population that is supported by RSPB land. It is acknowledged that incorporating such information can be used meaningfully, alongside the monetary valuations in the account, to monitor whether the natural environment is being improved over time. One limitation is though that other species groups are not included due to the cost and effort associated with the necessary monitoring. Habitat quality (through measuring variables such as water quality, level of peatland degradation, plant richness and habitat fragmentation) could be used as a proxy for biodiversity (although it needs to be noted that habitat quality data is also often not available).

These examples illustrate that incorporating wildlife into the Natural Capital Accounting remains a challenge, with many different potential methodologies available. Which approach is useful for a Natural Capital Account for National Parks, will depend largely on the management decisions that the account should inform. Given that the statutory aim of National Parks is to conserve wildlife, an approach similar to that used by the RSPB would be a straightforward and informative way to monitor changes in abundance and status of key species year-on-year. Key species for such monitoring could be selected by the National Park Authorities to reflect important local wildlife and conservation aims. This could for example be done by adapting and expanding the current monitoring which takes place as part of the State of the Park reporting. We would recommend that such a list of species includes wildlife from a range of species groups and habitat types, and that species of both local and national conservation importance are considered. Such information can then be used alongside the Ecosystem Service and monetary valuation information in the Natural Capital Account, for example by setting a "net gain" management target with regards to the year-on-year biodiversity numbers in the account.

Whilst, as suggested above, selecting locally relevant wildlife species for monitoring in an organisation's Natural Capital Account is highly useful for management decision-making, this does limit the comparability between Natural Capital Accounts for different areas. In order to ensure that information can be compared across different areas, we would therefore recommend using additional biodiversity indicators obtained from national data. A wide range of national datasets on biodiversity are available from, for example, wildlife charities, however, such data often require further processing before regional or site-specific data can be obtained, and inclusion of these data may therefore not be an efficient and cost-effective option. The online tool NEVO developed by the LEEP institute at the University of Exeter, available at https://www.leep.exeter.ac.uk/nevo (see also box 6 on agriculture) is an example of a publicly available resource which can provide an additional metric of biodiversity. NEVO, which is a map-based tool, brings together spatially explicit data, natural science and economic models to provide insights into the integrated relationships between climate change, land use change, ecosystem service flows and economic values, and includes a dedicated component focusing on biodiversity. The tool allows users to extract a biodiversity index for areas, such as National Parks, in England and Wales. NEVO uses a JNCC species distribution modelling approach to estimate species richness in a given area, based on a comprehensive list of 100 species, covering birds, invertebrates, mammals, herptiles, plants and lichens. More information on the biodiversity emulation used in NEVO can be found at: https://www.leep.exeter.ac.uk/nevo/documentation/. This information can be readily used to explore differences in relative species diversity between different areas. In the table below, we illustrate these data, displayed as "numbers of species present/number of species included" for Dartmoor, Exmoor, the New Forest and the Brecon Beacons. The same 100 species are considered in each area, allowing for direct comparability. The

[23] RSPB (2017). Accounting for Nature: A Natural Capital Account of the RSPB's estate in England

NEVO tool can subsequently be used to explore the effect of future changes in land cover on species richness and a range of ecosystem services.

Species group	Dartmoor	Exmoor	New Forest	Brecon Beacons
Plants	22/38	21/38	26/38	28/38
Invertebrates	15/25	14/25	15/25	15/25
Birds	11/17	10/17	13/17	13/17
Mammals	9/14	9/14	10/14	10/14
Lichen	2/5	2/5	2/5	1/5
Herptiles	1/1	1/1	1/1	1/1
Total	**60/100**	**57/100**	**67/100**	**68/100**

Whilst species richness can be a clear indicator for management purposes, other key indicators (such as the status of key species of interest), also need to be incorporated into Natural Capital Accounts. This is due to the fact that some key habitats may provide a lower diversity of species, but are of substantial conservation value.

In addition to wildlife, other important gaps in the ecosystem services considered in the accounts concern e.g. game, drinking water and flood protection. For these, valuation data was available, but publicly available data to quantify the flow of ecosystem services was missing for both National Parks.

Suitable data on game and deer numbers extracted annually was not available for either of the National Parks – records were either outdated or, in the case of rod catch data for fish, it was not known how many of the caught animals were released back into the water. Following further discussions with the National Park Authorities, it emerged that game provision is of relatively minor importance for Dartmoor and was therefore not explored further due to limited management relevance. For Exmoor, game and deer extraction was not pursued further due to lack of data. Should data on numbers of game caught/shot become available in the future, including this ecosystem service in the Natural Capital Accounts will be very straightforward, as clear value information is available. However, the wider impacts of management for game shooting on other Natural Capital assets would still be overlooked; further work would be needed to incorporate such an assessment of wider costs of management for shooting (see discussion).

Flood Risk Regulation was of interest to the National Park Authorities, and was therefore studied in more detail upon completion of the "standard practice" accounts. However, no suitable methodology could be identified to fill this gap. This is due to the fact that flood risk mitigation is a complex ecosystem service and the extent of flood risk mitigation depends on the local land use, hydrology, geomorphology and wider ecology. Therefore, flood risk mitigation can only be quantified through the use of local, context- specific tools or models which take all these factors into account. This means that generalisable, "standard practice" solutions for quantifying this ecosystem service do not exist. Developing such models would likely be both time-consuming and costly, requiring substantial expert input from a range of sectors and academic disciplines.

Publicly available data on volunteering were missing for Dartmoor. To fill this gap, data on volunteer numbers needed to be obtained. Box 4 below illustrates how complementing publicly available datasets with data held within the organisation can improve account completeness.

Box 4. Filling gaps in "standard practice" accounts using local data

Local data on the number of volunteer days, whilst not available publicly, could be obtained from Dartmoor National Park to improve the account results.

Volunteering

Data on volunteering for Dartmoor could be obtained through information available as part of the National Park Family Indicators. Data show that a total of 2,601 volunteer days were organised or supported by the National Park in 2015/2016. Dartmoor also provided an expert estimate of the number of hours of work per volunteer day (5 hours). This allowed us using the "standard practice" valuation methodology (as used for Exmoor National Park's account) to value volunteering on Dartmoor. We calculated a total volunteering value of £95,048. No information was included on volunteering values in Table 3 for Dartmoor due to a lack of information on volunteering based on publicly available information. This example illustrates how additional local knowledge and/or data can be used to fill some gaps in the accounts when national estimates are not appropriate or when public data are not available. It is important to note that the above estimates of the amount of volunteering are not without limitations. We only include those volunteering days which are organised or supported by the Dartmoor National Park Authority; many other volunteering activities, unrecorded by the National Park, take place within the National Park boundaries, and the estimate of 2,601 volunteering days used here is therefore a lower bound estimate only.

4.2.2.2 Alternative assumptions

In many cases, a range of alternative assumptions regarding the amounts of provided ecosystem services can be considered when building Natural Capital Accounts. For example, based on the review of existing accounts, multiple alternative estimates are available for carbon sequestration and recreation (number of visitors), depending on the specific methodologies used and assumptions made in the source study. Which estimate is selected depends on a range of factors, such as the reliability of the underlying assumptions, the robustness of the data collected (strength of evidence) and the completeness and level of detail of the data for Natural Capital Accounting purposes (e.g. whether the estimates from the data source are available for each habitat type considered in the account). In Box 5 below, we test for the sensitivity of the account results to the use of alternative "standard practice" assumptions regarding climate regulation and recreation services.

Box 5. Alternative "standard practice" assumptions for the quantification of selected ecosystem services

Climate regulation

Measures of the flow of carbon sequestration services provided by natural capital have been found to vary substantially in the reviewed studies. This is because a range of scientific studies were considered and each of them used different habitat classifications, thus providing different estimates. For example, differences in the estimates are due to the inclusion of different plant species in the measurement of sequestration rates. Estimates also differed depending on whether CO_2 or CO_2e (CO_2 equivalent) was considered in the estimates of climate regulation services. CO_2e provides a more complete ecological picture of climate regulation benefits, as it also includes information on the sequestration of other gases in addition to CO_2, such as methane and nitrous oxide. In the "standard practice" account produced for the National Parks, we followed the RSPB Reserves estimates[24], as this was the only reviewed study providing information on CO_2e sequestration across most of the considered habitat types. Such an approach was therefore considered to be the most suitable choice, as it provides a more complete account.

In order to understand how sensitive the account results are to the use of different assumptions about carbon sequestration, we illustrate how the amount of CO_2 sequestration, and the resulting climate regulation value, vary when using different sequestration rates. In the table below, we show an example for Exmoor woodlands.[25] In all cases, the value per tonne of carbon being sequestered was kept the same as in the "standard practice" account and was based on the UK Government non-traded Carbon price. Therefore, all variations displayed are due to changes in the biophysical estimate of Climate regulation, thereby illustrating the sensitivity of the account to different assumptions on carbon sequestration rates.

Broadleaved woodland				
Carbon sequestration (tonnes/ha/year)	**Type**	**Assumption source**	**Total annual sequestration (tonnes/ year)**	**Climate regulation value**
10.71	CO_2e	RSPB Reserves	84,352	£5,263,109
9.37	CO_2e	Nene Valley	73,798	£4,604,606
4.97	CO_2	DEFRA/AECOM	39,142	£2,442,358
4.71	CO_2e	EFTEC UK Woodlands	37,096	£2,314,589

Coniferous woodland				
Carbon sequestration (tonnes/ha/year)	**Type**	**Assumption source**	**Total annual Exmoor sequestration (tonnes/year)**	**Climate regulation value**
17.51	CO_2e	RSPB Reserves	59,149	£3,690,566
12.13	CO_2e	Nene Valley	40,975	£2,556,629
12.66	CO_2	DEFRA/AECOM	42,765	£2,668,336
4.47	CO_2e	EFTEC UK Woodlands	15,100	£942,138

These figures show that when different carbon sequestration rates that are selected, the estimates of total sequestration by woodlands can vary by tens of thousands of tonnes, and the climate regulation value can vary by several million pounds. The RSPB Reserves estimate, based on the median carbon sequestration rates obtained from a review of the scientific literature, provides an adequate starting point for estimating National Park climate regulation benefits. The RSPB estimates are deemed a better choice compared to those presented in the DEFRA/AECOM account[26], as the DEFRA/AECOM account only considered for example the sequestration rates of

[24] RSPB (2017). Accounting for Nature: A Natural Capital Account of the RSPB's estate in England

[25] For additional information on this topic please see a past study conducted on Carbon sequestration in Exmoor woodlands, based on the 1999 Forestry Commission National Woodland Inventory: https://www.exmoor-nationalpark.gov.uk/__data/assets/pdf_file/0027/185418/Exmoor-Woodland-Carbon-Final-Draft-Report.pdf

[26] White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government

one broadleaved and one coniferous species, and overlooked gases other than CO_2 entirely. In the EFTEC[27] and Nene Valley study[28], sequestration rates were only provided for few habitat types, and would therefore not provide account completeness. In order to improve the estimates obtained from the RSPB Reserves Account, local data could be collected on the exact species and age composition of National Park woodlands, in order to derive more locally specific estimates of sequestration rates from the scientific literature.

Recreation

To calculate the number of visitors and recreational value on Exmoor, STEAM data were used (following the methodology outlined in the DEFRA/AECOM report[29] and several others). For Dartmoor, an alternative estimate of recreationists' numbers could be obtained using the ORVal model. We here compare the impact of using different visitor number estimates on the calculated recreational values. The valuation methodology is kept constant.

Data source	Visitors/hectare	Recreational value
ORVal	69	£15,516,527
STEAM	21	£13,687,065

The table shows that these different data sources provide very different visitor numbers and recreational values. Such variations in the numbers and values are due to differences in the modelling methodology. For example, STEAM includes only visits of over four hours, whereas ORVal includes shorter visits also. It is therefore deemed that ORVal provides a more accurate picture of the total recreational numbers, however, STEAM figures can be used to compare Dartmoor visitation rates with those in other National Parks and protected areas which use only STEAM estimates.

In Box 5 above, we test for the sensitivity of the NCA results to the use of different estimates available from national datasets. Occasionally, there may be both national averages and context-specific data available, or accounts can be improved by adapting the national estimates with local information. In Box 6 below, we test how account results can change when locally relevant data or knowledge is incorporated.

Box 6. Incorporating context-specific information

Volunteering

In the accounts presented in Table 2, an 8-hour working day was assumed for volunteers on Exmoor. Subsequent discussions with National Park Authority staff indicated that volunteer working days on Exmoor are generally shorter (5 rather than 8 hours). When we improve the account by taking into consideration this local information, estimates of annual volunteer hours change from 27,288 to 17,055, with the value of volunteering changing from £199,436 to £124,648.

Crop proportions and agriculture

When discussing the initial account findings with National Park Authority staff, it was clear that the national figures on agricultural land use, used to break down the total arable land into crop types, are not readily applicable to

[27] Cryle, P., Krisht, S., Tinch, R., Provins, A., Dickie, I., Fairhead, A. (2015). Developing UK natural capital accounts: woodland ecosystem accounts. Economics for the Environment Consultancy Ltd (Eftec) in association with Cascade Consulting for the Department for Environment, Food and Rural Affairs (Defra

[28] Rouquette, J.R. (2016). Mapping Natural Capital and Ecosystem Services in the Nene Valley. Report for the Nene Valley NIA Project.

[29] White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government

Dartmoor and Exmoor. This is because agricultural land use in the two National Parks is very different from the national average. For example, crops such as beans are generally not found within the National Park boundaries. Based on expert opinions, following discussion with National Park Authority staff, other crop types were also over- or under-represented. Data from the DEFRA June Survey Agricultural cut for National Parks[30] was reviewed in order to identify improved estimates of the proportions of different crop types on DNPA and ENPA arable land. However, the problem with these data is that they are broken down only into a limited number of categories (i.e. "cereals", "other arable crops" and "horticultural crops") and such a breakdown is therefore not sufficient to derive information on yields and values for specific crop types in our case study areas.

In order to test how sensitive the Natural Capital Accounts are to different assumptions on the proportion of different crop types on arable land, we derived information on crop proportions within each National Park using the NEVO tool (https://www.leep.exeter.ac.uk/nevo). NEVO is "a map-based decision support tool to inform decisions that affect the natural environment of England and Wales". NEVO estimates crop types using underpinning data from the Farm Business Survey[31]. For both Dartmoor and Exmoor, we converted the extent of crop types (as provided in NEVO) into percentages and compared these against the national percentages used in our "standard practice" accounts (presented in Tables 2 and 3). The results of this comparison are outlined in the table on the following page. It has to be noted that NEVO uses fewer crop categories, as potatoes were not separated into "early" and "late", and linseed, oats, peas and field beans were not included (and therefore aggregated into the "other" category).

It is important to also note that in the standard practice accounts (Tables 2 and 3), not all crops are included in the valuation of agricultural crop production. For example, during one of the workshops, National Park Authority staff queried why maize was not included. This is due to the fact that following the standard practice approach, yield data were derived from DEFRA publications (cereal and oilseed rape harvest data)[32], and no information on maize yields could be identified in the publicly available DEFRA datasets. As no improved information on maize crop proportion could be derived from the NEVO tool, maize yield was not explored further. However, should more complete information on crop types within the National Park boundaries become available (e.g. through local surveys), information on yields of additional crops could be derived from the scientific literature, for example, or through further exploring DEFRA documentation not currently publicly available.

<table>
<tr><th>Crop type</th><th>% of arable land based on national data</th><th>% of Dartmoor arable land based on NEVO</th><th>% of Exmoor arable land based on NEVO</th></tr>
<tr><td>Wheat</td><td>44.2</td><td>26.7</td><td>21.6</td></tr>
<tr><td>spring barley</td><td>9.7</td><td>13.4</td><td>13.0</td></tr>
<tr><td>winter barley</td><td>9.8</td><td>8.6</td><td>8.3</td></tr>
<tr><td>oilseed rape</td><td>16</td><td>16.9</td><td>13.0</td></tr>
<tr><td>sugar beet</td><td>2.4</td><td>0</td><td>0</td></tr>
<tr><td>potatoes early</td><td>0.3</td><td rowspan="2">0.03</td><td rowspan="2">0</td></tr>
<tr><td>potatoes late</td><td>2.2</td></tr>
<tr><td>Linseed</td><td>0.4</td><td rowspan="5">34.4</td><td rowspan="5">44.0</td></tr>
<tr><td>Oats</td><td>2.6</td></tr>
<tr><td>Peas</td><td>1.1</td></tr>
<tr><td>field beans</td><td>4.3</td></tr>
<tr><td>Other</td><td>7</td></tr>
</table>

[30] DEFRA June Survey statistical data set geographical breakdowns, available at: https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

[31] Further information on the Farm Business Survey: https://www.gov.uk/government/collections/farm-business-survey

[32] Defra Cereal Production survey & Defra Oilseed Rape survey data: https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

This table illustrates that there are some substantial differences between national data and NEVO estimates of crop proportions on arable land. In particular, the estimates of wheat produced on Dartmoor and Exmoor are lower in NEVO, compared to the national averages based on DEFRA data. The proportion of "other", unspecified, crops is significantly higher. To test how different estimates of crop proportions can change the account results, we compare the crop proportions based on NEVO with those based on the national estimates used in the standard practice account.

Dartmoor				
Crop type	**Total production (tonnes) – account proportions**	**Total production (tonnes) – NEVO proportions**	**Value – account proportions**	**Value – NEVO proportions**
Wheat	7804	4719	£1,555,106	£940,310
spring barley	1168	1608	£208,782	£287,580
winter barley	1519	1333	£271,686	£238,310
oilseed rape	1287	1365	£457,778	£485,515
sugar beet	3109	0	£100,393	0

Exmoor				
Crop type	**Total production (tonnes) - account proportions**	**Total production (tonnes) - NEVO proportions**	**Value – account proportions**	**Value – NEVO proportions**
Wheat	9786	4787	£1,949,940	£953,867
spring barley	1464	1958	£261,791	£350,132
winter barley	1905	1612	£340,666	£288,206
oilseed rape	1613	1317	£574,006	£468,664
sugar beet	3898	0	£125,882	£0

As NEVO did not include an estimate for all of the crops considered in the standard practice account, we cannot directly compare the total value of crop production between the two approaches. However, we can compare the estimates of production and value for the five crops (wheat, spring barley, winter barley, oilseed rape and sugar beet) which were included in both the standard practice and NEVO estimates of crop production. For barley, oilseed rape and sugar beet, variations in the figures are relatively minor between the two approaches, with production varying by several hundred tonnes only. However, wheat production amounts, and the resulting values, are very different between the national and NEVO estimates of crop proportion. Wheat production is overestimated when using national estimates of crop proportions. As land allocated to wheat production in uplands on Dartmoor and Exmoor is likely lower compared to the national average, NEVO estimates seem to represent a more realistic picture of true crop production for our case study areas. However, the downside is that using NEVO rather than national estimates only allows to focus on a smaller subset of crop-types. In order to improve the standard practice approach whilst still focusing on a more complete list of crop types, we would recommend replacing national estimates with real data, by collecting information on the exact crop areas within the National Park boundaries.

During the production of the standard practice accounts for Dartmoor and Exmoor, quantifying the value of livestock proved challenging. An additional test that was therefore performed concerning the effect of considering alternative approaches for the quantification of livestock production for natural capital accounting purposes (box 7).

Box 7. Testing for alternative quantifications of livestock

We attempted to replicate the methodology adopted by the reviewed natural capital accounts to quantify the flow of livestock. However, replicating the existing approaches was not possible due to insufficient information provided in the reviewed accounts regarding the adopted methodology. Whilst it was possible to obtain information on the total number of livestock, quantification of the annual flow of livestock as an ecosystem service was not possible (due to insufficient detail provided in the reviewed reports, meaning that calculations could not be replicated). We initially assumed that the annual flow of benefits linked to livestock corresponded to the value (measured in terms of farm gross margins) provided by the sale of the total number of livestock present in a given year on Dartmoor and Exmoor. This is however a poor assumption, given that some livestock takes multiple years to mature, and other adult animals are kept solely for breeding purposes. We therefore tested for the effect on the account numbers and values of excluding livestock that we could assume may not have value (in the accounting sense of the word). In the accounts presented in Tables 2 and 3 the following livestock types were included in the total livestock counts (based on DEFRA June survey data[33]): dairy herd, beef herd, calves, other cattle (no valuation available), breeding pigs, other pigs (no valuation available), breeding ewes, lambs, other sheep (no valuation available), fowl, other poultry (no valuation available), goats (no valuation available) and horses (no valuation available). In our test of assumptions (below), we excluded those animals which are, or assumed to be, breeding animals, namely breeding pigs, breeding ewes and other cattle.

	based on total numbers present		**excluding livestock for (likely) breeding purposes**	
	Total animals	**Value**	**Total animals**	**Value**
Dartmoor National Park	282,088	£8,193,537.42	168,788	£5,093,923.29
Exmoor National Park	362,840	£7,257,878.66	231,523	£3,401,148.79

Excluding the breeding livestock understandably decreased the total number of livestock, and led to a lower value of livestock production. This may be an improvement on the original account values, as it is no longer assumed that all animals produce value each year. We believe that excluding breeding livestock is a more credible and conservative approach, compared to the one initially adopted, which assumes that all livestock on Dartmoor or Exmoor are sold or slaughtered on a yearly basis. However, in the absence of data on the exact number of livestock produced and sold on the market for the year of interest, only including non-breeding livestock, may still lead to an over-estimate of annual production (e.g. by not taking into account that some animals take longer than one year to mature and that some lambs and young cattle may be retained for future breeding rather than marketed).

We can also compare this against the livestock estimates produced by NEVO for beef, dairy and sheep, which incorporates annual livestock yields into the calculations (see box 6 for details on NEVO). In the table below, we therefore look at the Dartmoor and Exmoor account estimates for non-breeding beef, dairy and sheep only, to ensure comparability with NEVO.

	NEVO livestock predictions		**Account predictions**	
National Park	**Total beef/dairy/sheep**	**Farm livestock profits**	**Total beef/dairy/sheep**	**Value**
Dartmoor	161,900	£6.7m	113,679	£5,074,059.21
Exmoor Park	185,300	£5.5m	149,426	£3,388035.73

[33] DEFRA June Survey statistical data set geographical breakdowns, available at: https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

Differences between NEVO and the initial account estimates (Tables 2 and 3) are likely due to differences in the underpinning data and differences in the classification of animals into breeding and non-breeding livestock. However, figures are not dissimilar between NEVO and the "standard practice" approach and are of a similar magnitude.

4.2.2.3 Incomplete ecological information

When reviewing published account studies and reports, it was clear that the methodology for quantifying biophysical flows of ecosystem services is often highly simplified, thereby overlooking ecologically important factors. For example, when calculating climate regulation benefits, current accounts differ in whether they use an estimate of CO_2 or CO_2e (CO_2 equivalent). When considering CO_2 only, the sequestration of greenhouse gases other than CO_2, such as methane (CH_4) and nitrous oxide (N_2O), is overlooked. Box 5 provides an estimate of the sensitivity of the account results to the consideration of different estimates. Similarly, when focusing on air quality, a range of different particles can be considered in the account. For Dartmoor and Exmoor, we only focused on PM_{10}, but ecological completeness could be improved by also considering other air pollutants, such as Nitrous Oxide, $PM_{2.5}$ etc.

As discussed previously, the estimation of flood risk mitigation can only be realistically improved through the development of local or regional, context-specific modelling and tools for flood protection in relation to different land uses and geographical locations. This is another example of an ecosystem service for which incomplete ecological information limits the comprehensiveness of the Natural Capital Account.

It needs to be acknowledged that "standard practice" approaches tend to overlook a wide range of ecologically complex, but nonetheless crucial, interactions between the natural environment and the provision of ecosystem services. Examples include numerous parasitic wasp species, supporting ecosystem service provision through links with a wide range of other organisms, but also potentially acting as crop pests. Another example includes honeybees and heather, which together provide culturally important products such as heather honey.

4.2.2.4 Overlooking ecosystem condition

When developing a Natural Capital Account, ecosystem condition is often partly or completely overlooked. This can lead to substantial limitations and gaps in findings. For example, in our case studies, the Climate regulation services provided by bogs/peatlands could not be estimated. Depending on peat condition, peatlands can range from net carbon emission (when in poor condition) to net carbon sequestration (when in good condition). National Park Authority staff and peatland experts at the University of Exeter were consulted, but appropriate data on peat condition could not be obtained for Dartmoor and Exmoor. For this reason, climate regulation services was data deficient for this specific habitat type.

Other examples of environmental services where different ecosystem conditions can play a role, include: drinking water (susceptible to the level of water quality), recreation (with visitors preferring habitats in better ecological condition) and timber (available timber quantity and quality is driven by woodland quality).

4.2.2.5 Accounting for aspects related to temporal dynamics

When building natural capital accounts, temporal aspects should be taken into consideration. In most cases, the standard practice methodology just focuses on the amount of goods and services that natural assets provide over the period of one year (flow account). Alternatively, if the desire is to produce an asset account, it is necessary to look into the quantity of goods and services that natural capital supplies into the future. Renewable goods and services such as Carbon sequestration could in principle be provided indefinitely as long as the habitat is in existence, whereas "non-renewable" goods, such as oil and gas, can only be supplied for a limited number of years until the stock is depleted. It is therefore necessary to establish the total number of years over which each given habitat will produce the ecosystem services of interest. This timeframe is often challenging to estimate and relies on some approximations. The choice of this time horizon can affect the calculated account values (see section 4.2.3.4.).

Over time, it is not only natural capital stocks which change, but the amount of ecosystem service flows and beneficiaries can also vary. For example, crop yields and timber extraction may differ between years and there may also be changes over time in the number of beneficiaries and users of the environmental goods and services of interest (e.g. due to local population growth). Often, an average or outdated figure is used across years, which may mis-represent the actual ecosystem service flows or number of beneficiaries (see box 8). Therefore, when producing a revised Natural Capital Account for a new year, it is essential not only to revise stock extents, but also to check whether any of the ecosystem service flow quantifications need updating with more recent figures.

Box 8. Testing the effect of population changes over time: the case of recreation

One example where population changes can play a particularly important role is in the case of recreation services. Increases in the number of people that have potential access to a recreational area can translate into an increase in the number of beneficiaries/users/visitors.

In the case of Dartmoor, for example, the total number of visits (modelled using the ORVal tool) is estimated to have increased by almost 3% (from 7,765,103 to 7,991,417) over the period 2014 to 2019, due to increases in the number of houses and local population. Therefore, if a new account was to be produced for a new year, not updating the visitor numbers compared to an earlier account, would lead to an underestimation of total recreational benefits. This is illustrated in the table below by comparing visits between 2014 and 2019 by habitat type.

	Visits 2014	Visits 2019	Variation	
Woodlands	2,455,382	2,520,322	+64,940	+2.64%
Moors and heath	2,186,629	2,262,525	+75,896	**+3.47%**
Managed grassland	1,332,341	1,364,400	+32,059	+2.41%
Natural grassland	1,037,666	1,073,501	+35,835	**+3.45%**
Rivers and lakes	403,807	413,236	+9,430	+2.34%
Graves and cemeteries	180,552	413,236	+4,151	+2.30%
Agriculture	166,477	170,450	+3,974	+2.39%
Allotments	2,250	2,280	+30	+1.33%
	7,765,103	**7,991,417**	**+226,314**	**+2.91%**

4.2.3 Measuring economic values of goods and services:

The "standard practice" methodology has given insufficient or no consideration to certain aspects that can substantially influence the economic values that people derive from the environment. In the following sub-sections, we discuss a series of factors that have to date been overlooked or insufficiently accounted for by the reviewed "standard practice" approaches. Where possible, we use examples to illustrate the consequences of inadequately or limitedly considering such aspects when building Natural Capital Accounts.

4.2.3.1 Missing economic values

Natural Capital accounting practitioners often fail, or are unable, to include a variety of ecosystem good and services that provide important value flows to people. Based on our exercise, for instance, the benefits provided to society in relation to the existence of plants and animal species, beautiful sceneries and unique/diverse landscapes, as well as the appreciation of cultural heritage are completely missing from recent natural capital accounting case studies. This is a particularly significant gap especially if the goal is to develop natural capital accounts for protected natural areas and National Parks, where wildlife, landscape and cultural heritage represent important components of the flows of ecosystem goods and services provided and are significant factors in land management decision-making. As explained in more detail in Box 9, the main reason why such goods and services are not commonly included in standard practice Natural Capital Accounts is that they are difficult to quantify and value. The benefits generated by rare and biodiverse flora and fauna species, beautiful landscapes, historic artefacts or archaeological remains are generally not captured by or connected to any market transaction and therefore is not recorded in the economy. As explained in more details below, the estimation of the economic values associated with biodiversity, scenery or cultural heritage requires tailored valuation approaches and methodologies remain largely under-developed. This means that, with the current state of knowledge, only some of the gaps identified within the "standard practice" natural capital approach can be filled. More research is required in the future to develop appropriate techniques to estimate such under-researched and missing economic values.

Box 9. Missing economic values

Biodiversity: In the System of Experimental Environmental Accounts (SEEA) biodiversity is defined at three different levels: genes, species and ecosystems. Whilst aspects of biodiversity-related services (e.g. game hunting) are sometimes covered in the accounts, this is not the case for other (perhaps less tangible) ecosystem services provided by biodiversity. Biodiversity is important and valued by people for other reasons, such as:

i) the provision of non-consumptive recreational benefits (e.g. wildlife watching);
ii) the maintenance of the functioning of ecological systems and supporting the production of all goods and services that natural capital provides; and
iii) other "non-use value" reasons related to the need to preserve biodiversity and species for their "intrinsic" importance and for future generations.

The above values could be calculated following different routes. Valuing i) could be achieved, for instance, by focusing on the tourist expenditure that visitors are willing to incur to see specific species. For an example of such an approach, we refer to the RSPB report on the value of golden eagles (Molloy (2011)[34] and RSPB (2010)[35]). Alternatively, another, more accurate, approach would consist of using a travel cost recreational demand model with wildlife as one of the attributes of the visited site. Much more complex and contested than estimating the value of i) is the estimation of the value of ii) and iii) (ONS, 2017)[36]. Firstly, as outlined in Box 3, biodiversity refers to a variety of life forms, but it is a complex concept which can be measured in many different ways using a variety of metrics (for example diversity and/or abundance, and considering different levels such as the genes, species, species groups or ecosystems). Previous studies have attempted to estimate the value of specific (keystone or iconic) species, which only represent a sub-set of all species that form biodiversity. Secondly, a further challenge is related to the existence of moral arguments against the valuation of biodiversity. There are some concerns that monetizing biodiversity could lead to an under-appreciation of the intrinsic importance of the environment and to a commodification of nature. For example, valuation is criticised for not being able to account for the critical biodiversity thresholds that should not be passed to avoid undermining the existence and functionality of entire ecosystems (however, as outlined in box 3, a "no net loss" or "net gain" approach could be employed to overcome some of these concerns). In such a framework, where the valuation of biodiversity emerges as a complex and inappropriate task, alternative non-monetary approaches could also be put in place to understand the 'value' that society places upon biodiversity conservation. These include stakeholders' consultations that can help to identify biodiversity conservation targets. This approach does not include monetisation, but is a legitimate alternative expression of societal values (Mace et al. 2019).[37] An alternative view is supported by the SEEA, which recommends estimating the benefits of biodiversity as the value of all goods and services that biodiversity supports. Another possibility is also to consider biodiversity as a characteristic of ecosystem assets and an indicator of asset condition, which determines the flow of goods and services supplied by the natural capital (ONS, 2017)[38]. However, the links between biodiversity, asset condition and ecosystem service flows cannot be easily untangled and low-diversity habitats can still provide key ecosystem services.

Landscape (scenic values): Landscape-related values have also been largely overlooked in natural capital accounts. Complex, unique and/or diverse landscape offer spectacular views that can be enjoyed by recreationists or residents.

[34] Molloy, D, 2011. Wildlife at work. The economic impact of white-tailed eagles on the Isle of Mull. The RSPB, Sandy.
[35] https://www.rspb.org.uk/globalassets/downloads/documents/positions/economics/the-local-value-of-seabirds.pdf
[36] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra.
[37] Mace, G. (2019). The ecology of natural capital accounting. Oxford Review of Economic Policy, 35(1): 54–67.
[38] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra.

To capture this value flow, different approaches could be considered. A travel cost approach could be employed to capture the recreational value of landscape views; information on scenic features (e.g. waterfalls, caves etc.) and viewing points could be employed to explain the choices of visited sites by recreationists and to estimate the extra value that visitors experience from accessing an area with scenic views or viewing points. Similarly, information on viewing points and scenic features can be used as an explanatory variable in hedonic price models. The underlying assumption in these models is that people's choice for a residential location depends on the characteristics of the property, but also on some environmental qualities of the place, which are factored into the price of properties. Hedonic price analyses are, though, data- and resource-intensive. They require a considerable amount of detailed property, geographical and environmental information that is not always easily accessible or available. Furthermore, this approach relies on substantial econometric and statistical work, which requires specific skills and significant amounts of time which is not always available within the scope of most natural capital accounting projects.

Cultural heritage: whilst cultural heritage and archaeological artifacts are appreciated by people, to date, the historic environment has been poorly represented in ecosystem services and natural capital accounts (Historic England, 2017).[39] People can appreciate the historic environment, for example because it enhances their recreational experience, and there are methods available to estimate such value. Cultural heritage could be considered as yet another feature of the visited recreational site which can contribute to enhancing the visitors' experience. Information on the presence of historic buildings (e.g. castles, country houses etc.) and archaeological sites (e.g. standing stones, burial mounds etc.) could be incorporated into travel cost demand models to understand how recreationists choose between different recreational locations and what role the availability of specific archaeological features has in their decision. People might also value historic monuments and artifacts because they symbolise the culture, traditions and sense of place of an area and as something that needs to be passed on to future generations. Estimating these values is admittedly more challenging, even if some studies have attempted to do so,[40] and requires the consideration of welfare, rather than exchange values, not necessarily compatible with natural capital accounting principles.

4.2.3.2 Partially missing economic value components

Whilst recent natural capital accounting case studies have tended to completely overlook the value of some environmental goods and services, they have also managed to value the benefits provided by other goods and services relatively well. In some cases, though, the values considered in the accounts only provide a partial quantification of the benefits that the environment provides to people. This is the case, for instance, with the value of flood risk regulation. The value of reducing flood risks is not often considered in "standard practice" approaches (probably because, as explained previously in this report, quantifying the reduction in flood risk events attributable to the presence of natural capital assets is very difficult). Only one of the reviewed reports (Smithers et al. 2016)[41], reported information on the benefits of reducing flood risks by estimating the avoided costs (flood-related expenditures) resulting from

[39] Historic England (2017). Ecosystem services, natural capital and the historic environment

[40] Kuhfuss, Hanley, Whyte (2016). Should historic sites protection be targeted at the most famous? Evidence from a contingent valuation in Scotland.
Willis et al. (2009). Assessing Visitor Preferences in the Management of Archaeological and Heritage Attractions: a Case Study of Hadrian's Roman Wall. Int. J. Tourism Res. 11, 487–505

[41] Richard Smithers, Outi Korkeala, Guy Whiteley, Shaun Brace, Bex Holmes (2016). Valuing flood-regulation services for inclusion in the UK ecosystem accounts. Ricardo Energy & Environment for the UK Office for National Statistics

the adoption of natural flood mitigation measures. These estimates, though, completely overlook the benefits associated with preventing flooding episodes and avoiding the associated mental health distress and threats to life. Such benefits, researched elsewhere, can be very substantial (Fujiwara et al. 2013)[42]. In this sense, focusing only on avoided flood-related defence costs only provides a lower bound estimate of the total value. Box 10 below focuses on the case of volunteering benefits, which are only partially accounted for in "standard practice" approaches.

Box 10. Partially missing economic values

Volunteering health benefits

Volunteering is not often accounted for in "standard practice" natural capital accounts. However, there are several benefits associated with volunteering. An obvious one is in terms of cost savings for the organisation, which benefits from free labour to carry out tasks which otherwise would have relied on paid workers. To quantify the value of volunteering in those terms, one approach consists of estimating the wage-equivalent value of volunteer work. Practitioners often multiply the hours spent volunteering by some estimate of hourly wage rates (by skill level). This approach is the standard method employed, for example, by the Heritage Lottery Fund (HLF) to cost volunteers' input into projects. The HLF employs different rates to value volunteers depending on the skills: a rate of £6.67/hour (or £50 a day) is considered for unskilled volunteers who, for instance, are in charge of clearing a site or acting as a steward at an event; for skilled workers (e.g. leading a guided walk) a rate of £20/hour (or £150 a day) is used; for professional services (e.g. accountancy or teaching) a rate of £50/hour (or £350 a day) is usually considered.[43]

Following "standard practice", we used the HLF figures for hourly unskilled labour (£6.67/hour) (conservative approach) and have assumed 5 hours of volunteering work per day (improved estimate based on stakeholders' consultations, see box 6). The number of volunteering hours per year were obtained starting from the number of volunteer days provided by Exmoor and Dartmoor National Parks[44], multiplied by 5.

	Exmoor National Park	Dartmoor National Park
Total volunteering days (per year)	3,411	2,601
Total number of volunteer hours	17,055	13,005
Value of volunteering (2015)	£124,648	£95,048

There are some discrepancies, though, between the above approach and the one usually employed by the National Park Authorities to value volunteering activities. This latter is based on the assumption that half of volunteering days should be valued at £100/day and the other half at £50/day. Such figures only approximate the official HLF figures and there is no particularly strong argument to justify the use of those numbers (sources could not be traced, the £100/day figure possibly represents an out-of-date proxy for the £150/day HLF figure for skilled volunteering). For comparative purposes, we report below the value of volunteering based on the approach commonly employed by National Park Authorities.

[42] Fujiwara, D., Oroyemi, P., McKinnon, E. (2013). Wellbeing and civil society. Estimating the value of volunteering using subjective wellbeing data. A report of research carried out by the Department for Work and Pensions and the cabinet Office.

[43] http://www.cavs.org.uk/wp-content/uploads/2012/04/4.19.pdf
https://www.heritagefund.org.uk/sites/default/files/media/attachments/HF%20Application%20Guidance_C_LARGE_0.pdf

[44] It's important to note that the estimate of the number of volunteer days for both National Parks should not be compared, as for Dartmoor the figure provided only includes volunteering that is organised by the National Park, which underrepresents the actual level of volunteers on Dartmoor.

	Exmoor National Park	Dartmoor National Park
Total volunteering days (per year)	3,411	2,601
Value of volunteering (2015)	£255,825	£195,075

Both approaches considered in this Box provide a lower bound estimate of the value of volunteering. It is well-known that a considerable portion of the benefits of volunteering accrue to the volunteers themselves in term of health and well-being benefits (Casiday et al. 2008).[45] There is not much literature available on these benefits, but some studies found that volunteering reduces the incidence of depression, stress, hospitalisation, pain and psychological distress. It is difficult to put precise numbers on those benefits. However, some estimations have been attempted. New Economy Manchester (2014)[46] estimate that the average cost of treating those suffering from depression or anxiety is around £956 per year. Volunteering could reduce or fully prevent depression or anxiety problems. Hence, the provided figure, which is an estimate of the yearly avoided costs for the NHS to treat mental health problems, could be viewed as an additional estimate of volunteering benefits. As well as reducing treatment costs for the NHS, spending time outdoor volunteering also provides mental health benefits to volunteers that translate into additional wellbeing. These benefits have been found to account for a large component of the value of volunteering. As reported in Haldane (2014)[47], some studies (Fujiwara et al. 2013; Fujiwara et al. 2014) have estimated that the increased life satisfaction and wellbeing resulting from frequent volunteering is worth around £13,500 per year (2011 prices) and the relief from depression and anxiety as a result of volunteering is worth around £37,000 per year. Such estimates could be considered as an upper bound value of the health benefits of volunteering. Despite the uncertainty around those figures, it is clear that the health benefits of volunteering account for large numbers and more should be done to improve their consideration for accounting purposes.

4.2.3.3 Accounting for spatial heterogeneity

Spatial aspects have received only limited attention in natural capital accounting. Some of the reviewed studies have provided maps of the spatial distribution of the different natural capital assets or ecosystem goods and services provided by a given area, but have generally not considered the effect of spatial aspects on the economic values. Whilst, in some cases, the value of the flow of ecosystem services is likely to be insensitive to the spatial configuration of natural capital, in many other cases, there may be important spatial elements to account for (Schaafsma, 2015)[48]. For example, the benefits of climate regulation are expected to be insensitive to the location where carbon is sequestered (regardless of where carbon is sequestered, the related benefits in terms of climate regulation services will be experienced by population around the world). On the other hand, people might for example experience different recreational benefits depending on where recreational opportunities are provided (e.g. closer or far away from home, in a certain habitat (e.g. woodlands) rather than others (e.g. coastal paths).

[45] Casiday, R., Kinsman, E., Fisher, C., Bambra, C. (2008). Volunteering and Health. What impact does it really have? Project report. Volunteering England.

[46] For further details see http://neweconomymanchester.com/stories/832-unit_cost_database

[47] Haldane, A. (2014). In giving, how much do we receive? The social value of volunteering. A Pro Bono Economics lecture to the Society of Business Economists, London

[48] Schaafsma M. (2015) Spatial and Geographical Aspects of Benefit Transfer. In: Johnston R., Rolfe J., Rosenberger R., Brouwer R. (eds) Benefit Transfer of Environmental and Resource Values. The Economics of Non-Market Goods and Resources, vol 14. Springer, Dordrecht

Based on the literature, the key spatial issues to consider when applying economic valuation methods for natural capital accounting purposes include:

- Distance (distance-decay)

The valuation literature has found evidence that the distance between the ecosystem good/service and the beneficiary plays an important role in determining how valuable a good or service is to the person. Based on the distance-decay paradigm, people's willingness to pay is assumed to diminish linearly as a function of the distance separating respondents from a given environmental resource of interest (Johnston et al., 2015)[49]. While distance is probably the most well-known spatial driver of values, many other factors are though also expected to drive spatial heterogeneity of individuals' preferences.

- Substitutes/complements

In addition to distance, another spatial factor that is expected to play a role is the availability of "substitute" and "complement" ecosystem goods and services. Substitutes refer to those ecosystem goods or services that are perceived to provide the same level of wellbeing, compared to another specific good or service of interest. For example, a broadleaved woodland can be viewed as a substitute for mixed forests by recreationists if visitors are indifferent to the woodland type when choosing the location for their trip. Complements, on the other hand, are those ecosystem goods or services that provide more wellbeing to people when consumed jointly with something else. For example, the value of an urban greenspace is higher when a pond is also present. Ignoring the existence of substitute or complements for given ecosystem goods and services of interest affects the measurement of the values that people obtain from the environment. Based on the above, when substitutes are overlooked the economic value of a given ecosystem good/service should be over-estimated, while the reverse should be true when complements are ignored.

- Distance and substitutes/complements effects

The effect of distance can be mediated by the availability of substitutes/complements, such that it does not only matter how far individuals are from a given environmental good, but also how this distance relates to the location of other substitute/complement sites (Schaafsma et al., 2012; 2013)[50]. In this case, distance-decay effects also depend on the geographical distribution of substitute or complement sites.

- Type of habitat and endowment

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[49] Johnston, R.J. & Ramachandran, M. Environ Resource Econ (2015). Modeling Spatial Patchiness and Hot Spots in Stated Preference Willingness to Pay 59 (3): 363-387.

[50] Schaafsma, Marije, Brouwer, R., Rose, J. (2012) "Directional Heterogeneity in WTP Models for Environmental Valuation." *Ecological Economics* 79: 21–31.

Schaafsma, M., Brouwer, R., Gilbert, A., van der Bergh, J., Wagtendonk, A. (2011). Estimation of Distance-Decay Functions to Account for Substitution and Spatial Heterogeneity in Stated Preference Research. Land Economics 89(3): 514-537.

The value of ecosystem services has been proved to differ depending on the habitats or ecosystems supplying them (Christie et al., 2011[51]; Interis and Petrolia, 2016[52]). For example, individuals may have preferences regarding which habitats to visit for recreational reasons, e.g. prefer a recreational visit to coastal areas than to intensive grasslands.

Similarly, the value of a good or service depends on how of it much there is already available. For instance, an extra unit of an already abundant good in a given area should be valued less compared to an extra unit of a relatively scarce good (Sagebiel et al., 2017[53]; Bateman et al., 2011[54]).

- Similarity of the socio-economic context

The characteristics of the population of beneficiaries are also important and can contribute to spatially-defined effects. For example, differences in income across beneficiaries, with higher-income respondents displaying higher willingness to pay (Bateman et al., 2011[55]), are likely to be spatially heterogeneous.

To illustrate the above points, in box 11 below, we test for the role of spatial factors on recreational values.

Box 11. Testing the role of spatial factors on recreational values

To monetise the value of recreational visits, the reviewed natural capital accounts have commonly relied on the results of the meta-analysis regression estimated by Sen et al. (2014)[56], which considers around 300 UK valuation studies focusing on recreation. The Sen et al. (2014) meta-analysis specifically controls for information on the visited habitat type. The study provides information on the recreational value (per person and per trip) of visiting a woodland or forest; enclosed farmland; semi-natural grassland; a river, lake or canal; mountain, hill or moorland; and coastal margins. However, no other spatial factor (among those mentioned above) is accounted for in the Sen et al. (2014) meta-analysis. An improvement in this sense is offered by considering the recreational value estimates provided by the Outdoor Recreation Valuation (ORVal) Tool (https://www.leep.exeter.ac.uk/orval/), developed by researchers at the University of Exeter and focusing on the calculation of the welfare value of a recreational day visits to greenspaces in England and Wales.

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[51] Christie, M., Hyde, T., Cooper, R., Fazey, I., Dennis, P., Warren, J., Colombo, S., Hanley, N. (2011). Economic Valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan. Final Report to Defra

[52] Interis, M., Petrolia, D.R. (2016). Location, location, habitat: How the value of ecosystem services varies across locations and by habitat. Land Economics 92: 292-307.

[53] Sagebiel, J., Glenk, K. and Meyerhoff, J. (2017) Spatially explicit demand for afforestation. Forest Policy and Economics, 78, pp.190-199.

[54] Bateman, I., Brouwer, R., Ferrini, S., Schaafsma, M., Barton, D.N., Dubgaard, A., et al. (2011). Making benefit transfer work: deriving and testing principles for value transfer for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe. Environmental and Resource Economics. 50(3): 365-387.

[55] Bateman, I., Brouwer, R., Ferrini, S., Schaafsma, M., Barton, D.N., Dubgaard, A., et al. (2011). Making benefit transfer work: deriving and testing principles for value transfer for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe. Environmental and Resource Economics. 50(3): 365-387.

[56] Sen. A., Harwood, A.R., Bateman, I.J., Munday, P., Crowe, A., Brander, L., et al. (2014). Economic Assessment of the Recreational Value of Ecosystems: Methodological development and National and local application. Environmental and Resource Economics 57(2): 233-249.

The published literature acknowledges that sites with similar land cover types can be valued differently depending on the accessibility of such locations and the distance that recreationists have to travel to visit those sites. Locations which are more accessible to people tend to be valued more, and people willing to travel a longer distance to visit a particular site are placing a greater value on the visit. These aspects, overlooked in the Sen et al. (2014) meta-analysis regression, are accounted for in the ORVal tool. In the calculation of the welfare measures, ORVal accounts for heterogeneity in the accessibility of different sites and considers the distance travelled by visitors to reach the destination from their place of residence (as well as incorporating the use of different modes of transport, i.e. car versus walking).

In addition to accounting for habitat-specific differences in recreational values, the ORVal model also employs a flexible econometric specification which controls for the availability of substitute sites that individuals could have considered for their visit (i.e. the degree of similarity between types of recreational sites). Respondents may for example consider recreational paths as being more similar to each other than to other types of recreational sites, such as parks. In addition, it can be expected that greenspaces with similar land covers, e.g. two woodlands, are perceived as closer substitutes than recreational sites with different habitats, e.g. a woodland and a moorland. It is also assumed that sites which can be reached by the same mode of transport are perceived as being more similar (e.g. two parks within walking distance) compared to two sites that need to be accessed using a different mode of transport (e.g. a local neighbourhood park vs a park that is driving distance away). The underlying idea in the model is to allow respondents to place a greater value on visiting unique sites with fewer alternative/substitutes locations available. Accounting for alternative substitute and complement sites has been acknowledged to play an important role to estimate more accurate values. However, this is not something that is generally incorporated into standard practice Natural Capital Accounting, due to the challenges related to the incorporation of such complex spatial patterns into the valuation analysis.

To illustrate the importance of accounting for spatial factors (beyond habitat-specific differences), we have calculated and compared the recreational values of Dartmoor and Exmoor National Parks using the Sen et al. (2014) and the alternative ORVal-based approaches. The ORVal figures for Dartmoor and Exmoor where taken from the online version of the tool, available at: https://www.leep.exeter.ac.uk/orval/.

	Sen et al. (2014) estimates	**ORVal estimates**
Dartmoor National Park	£15,516,528	£20,260,274
Exmoor National Park	£2,762,899	£8,023,928

From the above comparison, it emerges that the Sen et al. (2014) approach appears to undervalue the recreational values of both Dartmoor and Exmoor National Parks. Differences, though, could be driven by a variety of factors, which we will discuss below with the help of a series of illustrative case studies.

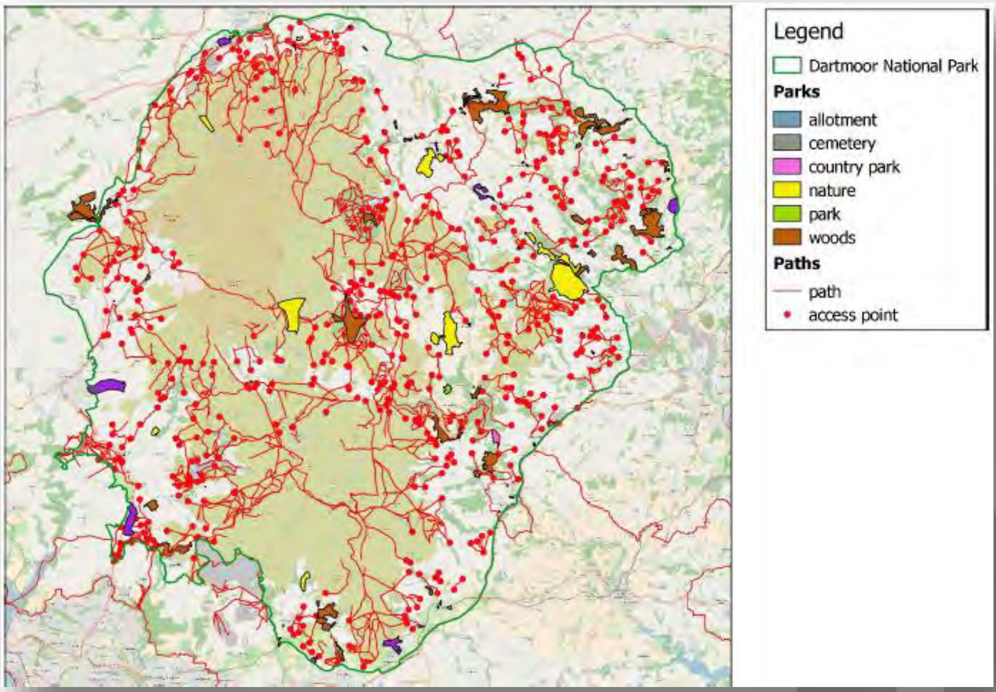
The first difference that can be detected across the two studies concerns the estimates of values per habitat. As described earlier, ORVal provides more accurate estimates of recreational values by considering a more behaviourally realistic model of recreational demand which accounts for distance, location and the availability of substitute sites, as recommended by the literature. Recreational values per habitat in ORVal are estimated by assuming that a visit to a given habitat site is not constant (as assumed by the Sen et al. (2014) meta-analysis), but can vary depending on the distance of the site from the recreationist and the availability of alternative sites with similar characteristics. Compared to the Sen et al. (2014) study, the ORVal model tends to estimate higher values per visits for most of the habitat classes considered. Based on the table provided below, this means that some habitats (i.e. woodlands and mountains, moors and heathlands) tend to be overvalued when using the "standard practice" approach based on the Sen et al. (2014) estimates of recreational values, whilst others (i.e. freshwater ecosystems, natural and semi-natural grassland and farmland habitats) tend to be undervalued.

Value per visit per habitat: comparing the standard practice with a more sophisticated approach

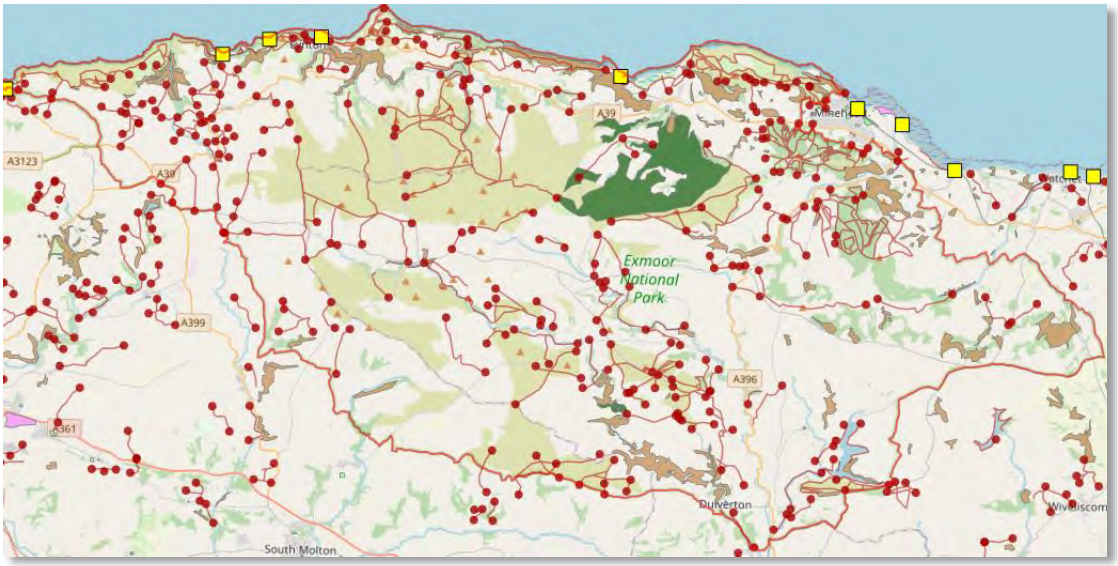
	Sen et al. (2014) 2015 prices	ORVal model 2015 prices
Woodlands	£ 3.61	£ 2.99
River, lake or canal	£ 1.96	£ 3.67
Mountains, moors heathlands	£ 5.44	£ 4.55
Semi-natural grassland (Sen) Natural grassland (ORVal) Managed grassland (ORVal)	£ 1.67	 £ 3.42 £ 2.78
Enclosed farmland (Sen) Agriculture (ORVal)	£ 1.67	 £2.78
Graveyards and cemeteries		£ 3.36
Allotments		£6.24

The second effect of spatial aspects that we want to illustrate here, is that recreational values are also sensitive to accessibility. Recreational values are likely higher in locations with more access points. For this reason, the assumption of homogeneous visitation rates across the area of interest that is assumed in "standard practice" natural capital accounts is often not realistic. Based on the ORVal map of access points for Dartmoor and Exmoor shown below, for instance, it is clear that some areas of the National Parks are more accessible than others, and, as illustrated for Dartmoor, some areas are visited more heavily than others. Therefore, assuming homogeneous visitation rates can substantially misrepresent the recreational values of certain portions of the National Park, with important implications in terms of spatial planning and decision-making.

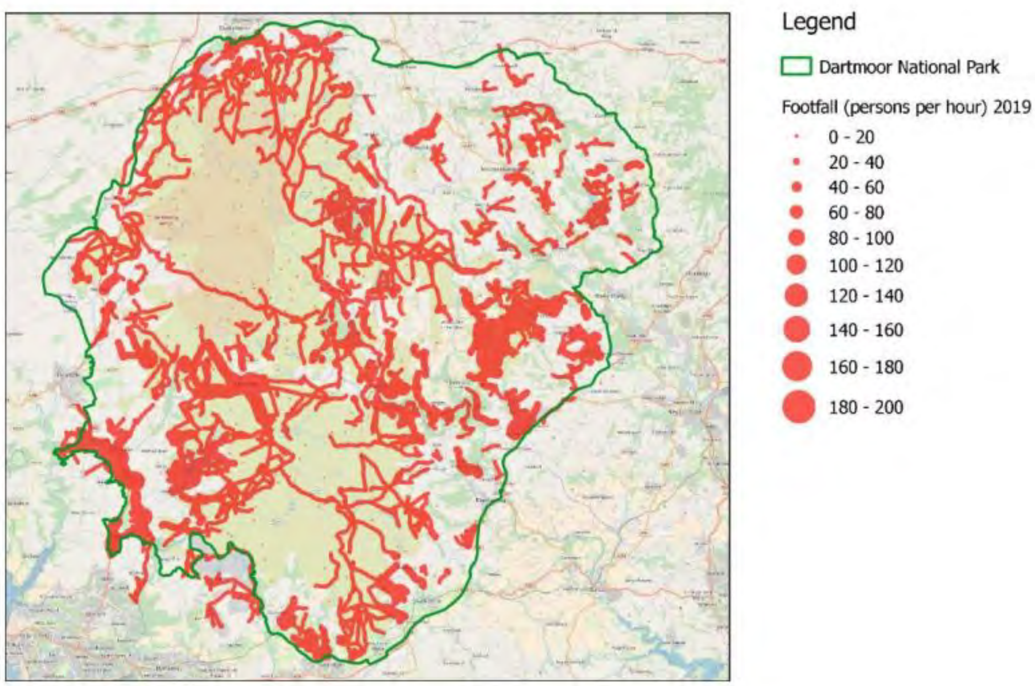
Dartmoor access points



Exmoor access points

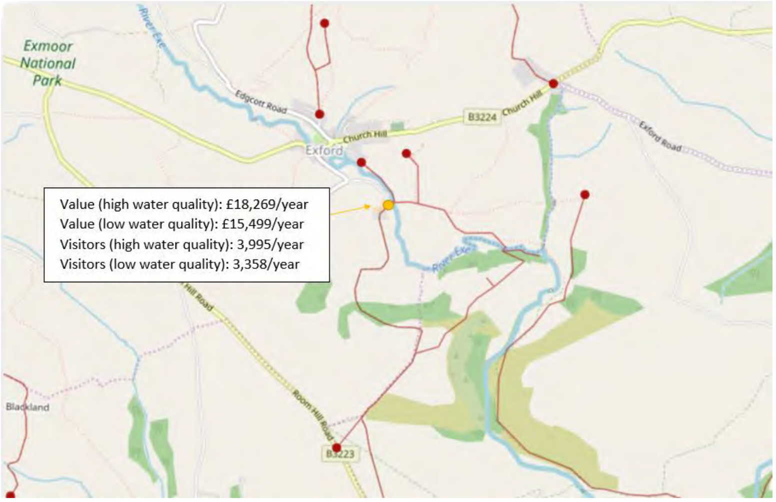


Dartmoor visitation hotspots



To understand how accessibility of sites can affect values and management decision making, we here give a hypothetical example for woodland creation. Creating a new woodland will create additional opportunities for recreation and we want to test how recreational values are affected by different degrees of accessibility. We simulate the creation of a new broadleaved forest of 20 hectares north of Princetown in Dartmoor National Park. In the map illustrated below, the yellow dot is the location where the woodland creation was originally proposed. ORVal then provides information on the welfare value and number of visits not only for the proposed new woodland site (yellow dot), but also for alternative nearby locations (11 purple dots). Larger dots indicate a larger recreational value. As the map illustrates (through the relative size of the purple dots), the recreational benefits associated with such broadleaved woodland creation are greater the closer the site is to accessible areas (in this example, the location with the largest value is the point located closest to the road network and access points from Princetown). The highest value (£136,296/year) and visitation rate (41,525/year) would be associated with placing the woodland close to Princetown. However, creating a new woodland close to an already existing woodland is associated with lower welfare benefits (£39,576/year) and visitation rates (12,485/year), even if the woodland is located close to an accessible location. The implication of the above is that if a constant recreational value is assumed for all sites, it is likely that recreational areas that are more attractive for visitors are undervalued, whilst areas which are of less importance for recreationists are overvalued. Such information has important implications for decision-making and planning, as not considering spatial effects would likely lead to suboptimal amounts of habitat creation efforts being implemented in areas that are potentially more valuable for recreationists.

Lastly, we illustrate the role of spatial variation in ecological features on the economic value of recreational visits. We consider the effect of a change in the water quality of a river in an area with recreational interest; looking at a decrease from high to low water quality in the River Exe close to Exford in Exmoor National Park.



The 2016 value associated with visiting a location placed closed to the river is £18,269/year and the number of annual visits accounts for 3,995/year. Under the assumption that water quality went down from high to low, the same recreation site would experience a decrease by £2,770 (per year) in terms of recreation values and a decrease by 637 estimated visits (per year). This example illustrates that the quality (or condition) of the natural capital has a significant effect on the estimation of the economic value of greenspace. This is because for recreationists, a degradation in the condition of the natural environment (in this case water quality) negatively affects their visitors' experience (hence, why the reduction in value). Overlooking the role of the ecological condition of the site on the recreational experience of visitors (as in the standard practice approach to natural capital accounting) can provide very different results with implications for decision-making and planning. Recreational values might be substantially undervalued if the valuation process ignored the fact that the ecological condition (e.g. water quality) at the visited site is high, while the reverse would be true if degraded ecological conditions were overlooked and instead assumed to be average or higher. Taking these factors into account in the valuation is essential to ensure that natural capital results can informatively underpin environmental policies regarding the maintenance or improvement of habitat condition.

4.2.3.4 Accounting for aspects related to temporal dynamics

Natural capital accounting focuses on recording information on natural capital assets, ecosystem goods/services and the related monetised values at a given point in time, and monitoring how these change over time. Indeed, time is a crucial dimension. To account for temporal issues, the reviewed natural capital accounts have tended to present flow accounts, showing the value of the ecosystem goods and services provided for one year of reference, as well as stock accounts, by calculating the net present value of the flow of ecosystem goods and services that the natural assets are expected to provide over a period of time into the future. With this respect, as described in sub-section 4.2.2.5, a first assumption that needs to be made concerns the length of time over which an asset is expected to provide goods and services. Another decision that needs to be taken at this stage concerns the most appropriate discount rate for the calculation of the net present value. A discount rate reduces the value of a good or service that is delivered later in the future. The idea is that a good is more valuable if it can be enjoyed in the present, while it is valued less if it can be enjoyed only at a later stage. If we think about money, £10 earned today are preferred to £10 earned in a year's time, £10 earned in a year's time are therefore worth less. Following the above reasoning, for example, a woodland planted this year and providing recreational opportunities should be valued more (providing more happiness or utility in economic terms) than the same woodland planted at a later time. Following this logic, discount rates are typically numbers bigger than zero. However, the higher the number the more the future is discounted in favour of present generations and at the expense of future generations. It is acknowledged that environmental goods and services should not be discounted following the same rates as financial markets. The Government periodically issues recommendations regarding the most appropriate discount rates to use for environmental goods and services. However, the debate around which discount rate is the most appropriate is still ongoing, and several alternative choices of discount rates are available. In box 12, we explore the use of alternative assumptions regarding discount rates.

Box 12. Alternative assumptions regarding the discount rate

Generally, the guidelines for discounting the flow of environmental goods and services that are produced over time rely on the Government guidelines as set in the HM Green Book document. Recommendations are generally that a discount rate of 3.5% is employed for flows projected out to 30 years, with discount rates declining to 3% for longer periods of time. This decline (to the so called 'reduced' discount rate) is justified by the fact that for significantly long periods into the future (i.e. exceeding 30 years) it is not ethically defensible not to employ a lower discount rate, given the irreversible wealth transfers that is otherwise implied from the future generations to the present generation. The table below summarizes various long-term discount rates that the Green Book considers for different ranges of time:

Period of years	0-30	31-75	76-125	126-200	201-300	301+
Standard rate as published in the Green Book	3.5%	3.00%	2.50%	2.00%	1.50%	1.00%
Reduced rate where 'pure STP' = 0	3.00%	2.57%	2.14%	1.71%	1.29%	0.86%

Alternative discount rates for the valuation of the flows of environmental goods and services taking place in the very long term are recommended elsewhere (e.g. Drupp et al. 2018)[57]. Drupp et al. (2018) report the results of a survey to a poll of experts who were asked about acceptable estimates of the social discount rate for very long-term environmental problems. The median value estimated from this exercise was 2%, ranging from a lower bound of 1% to an upper bound of 3.5%. The minimum value provided in the survey was 0% and the maximum was 10%. This shows that there can be huge variation in the figures that we can considered for the social discount rate.

To illustrate the sensitivity of the account values to the choice of the discount rate we consider the case of carbon sequestration as an example. As set out in the Defra/ONS (2014) document[58] focusing on principles of ecosystem accounting, the time period for valuing timber production is assumed to be 50 years and, as such, the asset value of other woodland-related services (including carbon sequestration) should also be capitalised over the same period of time.

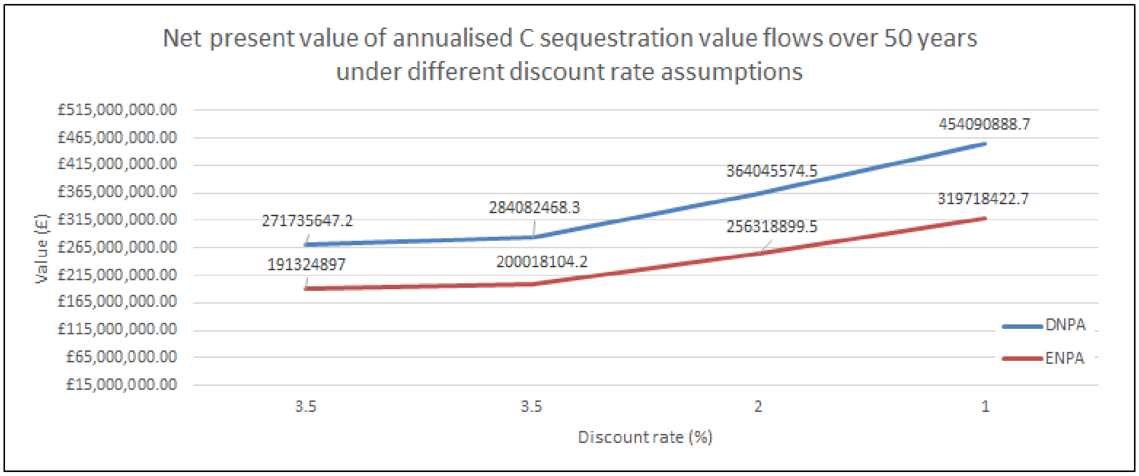
Below we compare the value of the flow of carbon sequestration services over the assumed period of time (50 years) for Dartmoor and Exmoor, by considering different discount rates, to show how sensitive results are to the choice of the discount rate:

[57] Drupp, M., Freeman, M., Groom, B, Nesje, F. (2015). Discounting disentangled: an expert survey on the determinants of the long-term social discount rate. Centre for Climate Change Economics and Policy working paper no. 195 https://www.cccep.ac.uk/wp-content/uploads/2015/10/Working-Paper-172-Drupp-et-al.pdf

[58] Defra/ONS (2014), Principles of ecosystem accounting. Paper for Natural Capital Accounting Steering Group.

	Discount rate			
	3.5%	HM 3.5% + 3%	2%	1%
Dartmoor National Park	£271,735,647.16	£284,082,468.36	£364,045,574.53	£454,090,888.69
Exmoor National Park	£191,324,896.96	£200,018,104.19	£256,318,899.51	£319,718,422.66

Results of this exercise (reported in the above table and the figure below) show that the total net present value figures for the annualised flows of carbon sequestration values vary considerably depending on the discount rate, with much higher net present values calculated when lower discount rates are considered.



4.2.3.5 Testing for the effects of using alternative economic value estimates

The reviewed "standard practice" natural capital accounts have shown, in some cases, consistency in the use of approaches and values to quantify the economic benefits provided by specific goods and services. This has been the case, for instance, for the valuation of carbon regulation services and recreation, which have consistently relied on the abatement cost approach for the former and the values estimated from the Sen et al. (2014) meta-analysis for the latter (as illustrated in Appendix 6).

However, for some ecosystem goods and services the reviewed natural capital accounting studies have employed different/alternative valuation approaches and figures. The availability of multiple valuation options raises the question of which approach is most appropriate for the purposes of compiling a natural capital account, and should therefore be selected. Sometimes the choice of one approach over another is justified by strong arguments (i.e. alignment with the accounting principles as set out in the System of Experimental Environmental Accounts (SEEA)). However, in some other cases, it is less clear what valuation approach should be favoured.

In most of the reviewed examples of natural capital accounts developed for protected areas or organisations with an environmental remit, the "standard practice" methodology employs economic values that proceed from national statistics or generic literature reviews. In some cases, such national or generic values can be appropriate, for example, in the case of carbon sequestration values, which should be the same regardless of the specific settings. However, in other circumstances this is not the case and local knowledge and expertise can be important in identifying which valuation approach is most appropriate in the development of a robust Natural Capital Account. In Box 13 below, we illustrate the implications of using local knowledge to inform the most appropriate value estimates for crops.

Box 13. Testing alternative assumptions using local knowledge: crop values

In the reviewed natural capital accounts, the most frequent approach to value the benefits from agricultural crop production is based on the consideration of resource rents or farm gross margins. One useful reference source for this purpose is the John Nix Pocketbook for farm management 2018 (Redman 2017)[59]. For certain crops (i.e. wheat and barley) different values are presented depending on the final use of the crops (whether the crops are primarily used for human-related consumption (e.g. milling or malting activities) or whether they are primarily used for animal feeding).

In the draft account for Dartmoor National Park, it was naively assumed that all produced wheat and barley is used for human-related consumption. However, stakeholder consultation and local knowledge of the farming system on Dartmoor, revealed that most of the wheat and barley produced on Dartmoor (2,687 tonnes/year for barley and 7,804 tonnes/year for wheat) is used for animal feed. Based on this, the figures used for crop valuation were edited (to reflect feeding rather than milling/malting prices – as reported in the table below):

	Malting and milling prices (2015£/tonne)	**Feed prices (2015£/tonne)**
Barley	82	72
Wheat	80	82

The total value of agricultural production (including all crops, not just wheat and barley) before and after the above change is summarised below. Feed price for barley is smaller than the malting and milling price, while the reverse is true for wheat prices. Overall, it is possible to observe a decrease in the value of agricultural crop production in the accounts when moving from malting/milling to feed prices for the two selected crops. Without introducing the above-mentioned adjustments, informed by local knowledge and expertise, the conclusions of the accounts wouldn't have dramatically changed, but crop values would have been overestimated.

	Malting and milling prices	**Feed prices**
Total value of agricultural crop production on Dartmoor for 2015	£1,286,865.37	£1,285,825.53

[59] Redman, G. (2017). The John Nix Pocketbook for Farm Management 2018. 48th Edition. Melton Mowbray: Agro Business Consultants

4.3 DISCUSSION OF THE USEFULNESS OF "STANDARD PRACTICE" ACCOUNTS

Upon completion of the accounts, following the "standard practice" approaches, we discussed with the National Park Authorities the usefulness of the produced natural capital accounting to inform their decision-making. The discussion was guided by the list of aspirations identified by Dartmoor and Exmoor staff in a meeting at the beginning of the project (see step 1 of the methodology section).

The table below reports the main aspirations identified by the National Park Authorities' staff at the start of the project. A colour code was assigned to each aspiration at the end of the project to indicate whether the produced Natural Capital Accounts were perceived to meet the initial aspirations and are useful for decision-making. Green indicates that initial aspirations were met; orange that aspirations were only partially met and red that aspirations could not be met.

	Exmoor National Park	Dartmoor National Park	
	Provide improved information to feed into the State of the Park report	Provide improved information to feed into the State of the Park report	
	Provide input into the Environment Land Management Schemes (ELMS)/payment for farming, e.g. by putting value on provided ecosystem services	Explore the use of Natural Capital accounting for investment decision-making, e.g. when needing to prioritise between choice of two management/restoration options	
	Land ownership/land holdings: understand best use for land owned by Exmoor National Park	Leveraging funding/justifying spending. Understanding the monetary value resulting from e.g. a restoration project, and use this knowledge to leverage money for cost of project	
	Use to show where (data) gaps are in decision-making	Influencing management decision-making, e.g. increasing amounts of stocks which are shown to have high value	

As shown by the colour-coding in the above table, it was perceived that, in most cases (red boxes), "the standard practice" natural capital accounting could not satisfy initial expectations. Both National Park Authorities felt that current approaches in "standard practice" natural capital accounting are only of limited usefulness to inform decision-making. It was highlighted that the accounts can be useful to provide some improved information to feed into the State of the Park report (a document which all National Park Authorities are required to prepare, providing a nontechnical overview of the status and trends of a park's natural resources and highlighting possible issues and challenges for the future). At present, no standard and rigorous methodology is employed for the preparation of such reports. It was felt that the natural capital accounting framework presented as part of this project could provide improved structured information on the Natural Capital stocks, ecosystem services and value flows for the State of the Park reports. It was also felt that the project was helpful to identify knowledge gaps and data shortages (amber box).

It was concluded that the remaining aspirations could not be met using Natural Capital Accounting (red boxes). Dartmoor and Exmoor National Park Authority staff felt that the information from the accounts could not be used to help influence management decision-making. The gaps in the account and the illustrated sensitivity to the underpinning data were perceived to be a major barrier to the employment of the account results to guide management decisions. It was also concluded that the produced accounts could not guide Exmoor's decisions regarding the best use of NPA-owned land and the design of farming payment schemes. This is due to a scale issue; accounts covering the full National Park area are not helpful to inform decisions concerning, for example, specific farms or NPA-owned parcels of land. Finally, the National Park Authorities concluded that the accounts could not be used for leveraging and justifying spending, or to inform investment decision-making. Natural Capital Accounts are not designed specifically with these purposes in mind, and the fact that these ambitions were outlined but not met, may represent a mismatch between the actual uses and applications of Natural Capital Accounts, and the perceptions of organisations regarding what Natural Capital Accounts can be used for.

While it was felt that the underlying idea behind natural capital accounting could prove useful, there has been a consensus that Natural Capital Accounting is still in its early days, and that the methodology and framework need to be improved substantially before the approach can become useful to inform management decision-making for environmentally-facing organisations such as National Parks. Whilst developing Natural Capital Accounts at organisational level is increasingly encouraged by the Government, there are still considerable gaps in relation to how accounts can be implemented in a way which is useful for decision-making. In the specific case of National Park Authorities, the development of natural capital accounts for the whole parks' area has limited direct management relevance, as these organisations do not have ownership or management control over all land within the National Park boundaries. Therefore, a Natural Capital Account for an organisation such as a National Park Authority will, by definition, have limited management usefulness, as decision-making on the natural capital assets and land-use is not always within the organisation's control. One possible solution would be to create accounts focused exclusively on the Natural Capital owned or managed by the National Park Authorities, but this would mean that the full benefits flowing from the UK's National Parks are not adequately captured as many areas would be excluded from the account.

One of the major concerns raised by stakeholders was regarding the reliability of the Natural Capital Accounting approach and the resulting total value estimates. As shown in section 4.2., account results are highly sensitive to the underpinning data sources used to measure natural assets, flows of ecosystem goods and services and values. Such variability makes current standard practice for Natural Capital Accounting at an organizational scale an unreliable instrument for decision-making. Based on discussions with Dartmoor and Exmoor National Park Authority representatives, it was clear that Natural Capital Accounting can only be as good as the underlying data employed in the process. If, as we have shown, the underlying data are subject to limitations and are inaccurate or incomplete at the spatial scale of interest, natural capital accounting will misrepresent the value of the natural environment. For these smaller-scale, organisational Natural Capital Accounts to be informative in the future, more support is needed to supply or collect fit-for-purpose data. This includes in particular repeatable high-resolution land cover datasets for vegetation categories of management interest, as well as comprehensive, National Park-wide data on, for example, ecosystem condition, livestock numbers, water extraction and other measures needed to quantify ecosystem service flows.

In addition, ensuring consistency in the accounting methodology used by different organisations with similar characteristics is essential for comparison purposes. One additional suggestion going forward is to agree on a standard selection of datasets that all National Park Authorities should hold and monitor over time (in addition to any other organisation-specific data and monitoring). This would be helpful to address existing concerns about the repeatability of the accounting process over time, which is now difficult due to the patchiness of data available.

The review of standard practice revealed that Natural Capital Accounts are often skewed in favour of private (or market-based) goods and only partially include public (or non-market) goods. In the case of organisations such as National Park Authorities, whose remit is to ensure a sustainable use and appropriate conservation of the natural environment, the exclusion of important environmental public goods from the accounts is one of the biggest limitations of Natural Capital Accounting in its present format. This is particularly true in relation to ecosystem goods and services such as biodiversity, wildlife, landscapes and cultural heritage, upon which National Park Authorities focus much of their management efforts. The fact that current "standard practice" cannot value these goods and services means that National Park Authorities cannot appropriately compare the value of these ecosystem services (of key organisational importance) with those of other ecosystem services produced by the National Park. This is a severe limitation for the management usefulness of the Natural Capital Approach. It also means that the accounts cannot be used to provide evidence on the full value of management interventions implemented to benefit biodiversity (for example, increasing habitat extents of known biodiverse habitat sites). This is a major limitation also when it comes to justifying the request for extra funding. It was hoped that the Natural Capital Accounts could be used to help make the case for additional investment in the natural environment. However, what emerged from the conversations with the National Park Authorities is that, compared to existing knowledge, information from the "standard practice" Natural Capital Accounts provides less leverage than originally hoped to justify funding requests.

The standard approach adopted by practitioners to produce Natural Capital Accounts is also of limited relevance for building an understanding of specific local issues. For example, one of the aspirations initially identified by Exmoor National Park Authority was to use Natural Capital Accounts to better understand the various benefits and impacts of farming for separate land holdings and ownership types. This is not an issue generally addressed by "standard practice" Natural Capital Accounts, revealing a possible mismatch between organisations' expectations and the actual capabilities of "standard practice" Natural Capital Accounts. Whilst in theory (see section 2.2), Natural Capital Accounts could be further customised to present results by groups of users or beneficiaries of interest to reflect specific management issues, this is rarely done in practice. Another topic of interest, which "standard practice" Natural Capital Accounts fail to address, is related to the role of a range of ecosystem services that are very specific to the local area, but often of substantial cultural value. These include, for example, the importance of: i) bees and heather, contributing to local heather honey production, and ii) Dartmoor and Exmoor ponies, which are unique and charismatic species, contributing to the recreational enjoyment of the area and to conservation grazing. These values are not captured using the "standard practice" approach in Natural Capital Accounting. Further understanding of the above benefits would therefore require comprehensive, National Park-wide data, resources and expertise to go beyond the "standard practice" approach and create tailored Natural Capital Accounts which better meet the organisation's expectations.

We can conclude that whilst there are broad expectations regarding what a Natural Capital Account can and cannot do, the current "standard practice" Natural Capital Accounts do not deliver the management tool which both our case study organisations (DNPA and ENPA) may need. From discussions with the National Park Authorities, a common theme was related to the perceived complexities and challenges associated with Natural Capital Accounting for environmental organisations. Frequent concerns raised were in relation to the limited time, resources and expertise that National Park Authorities would have in-house to design and maintain natural capital accounts, which may limit the feasibility and uptake of this approach. Based on discussions with the National Park Authorities it was felt that perhaps Natural Capital Accounting is not the most useful approach to inform decision-making. When specific management questions arise, for examples when organisations are faced with the choice between alternative management or investment decisions, a cost-benefit analysis could be a more appropriate tool. This approach provides a side-by-side comparison of the total costs and benefits (in monetary terms) of alternative options, which is something a Natural Capital Account cannot provide. An additional approach which could be considered is the development of a risk register of natural capital assets. A risk register identifies the risk of changes to the assets (i.e. habitat quality) and delivery of ecosystem services, and could be more informative than an annual Natural Capital Account to understand which natural assets are in need of management changes or additional protection. However, it is important to acknowledge that both of the above approaches (cost benefit analysis and risk registers) can suffer from similar methodological issues and data shortages as Natural Capital Accounts. These alternative options are therefore likely only appropriate in specific instances, such as smaller case studies, when the management question, staff expertise and data availability allow the application of such approaches.

5 LESSONS LEARNT AND RECOMMENDATIONS

Based on the insights gathered through this project, there are a number of valuable lessons learnt and recommendations that we believe can help practitioners, policymakers and organisations in the development of more useful Natural Capital Accounts.

1. **More clarity is needed about what a Natural Capital Account is and what it is not.** Whilst there is a general understanding that "natural capital thinking" is about placing the environment (and the related benefits to people) at the heart of decision-making, several misconceptions regarding Natural Capital Accounting still exist. The stakeholder consultations in our project revealed that more clarity is needed on the underlying principles and methods, as well as the types of questions that Natural Capital Accounting can feasibly answer. Natural Capital Accounts are designed to monitor changes in natural capital stocks, ecosystem services and values over time. They can be helpful to identify priority (valuable) habitats and can evidence and communicate the value of nature when areas are considered for human development (e.g. housing or infrastructure). They are, however, not a tailored decision-making tool to answer all the wide-ranging management questions faced by environmentally facing organisations. National Park-wide accounts alone will generally not provide answers regarding the optimal use of smaller parcels of land or help select the optimal management or restoration options. There is a need for more awareness regarding the capabilities and potential applications of this approach, particularly in the context of management decision-making. Based on discussions with the National Park Authorities, it emerged that Natural Capital Accounts are often mistakenly perceived as project appraisal tools to support decisions regarding alternative investment options. This raises the question of whether alternative decision-support approaches (such as cost-benefit analyses or Natural Capital risk registers) could represent more useful tools to guide management decisions of organisations with an environment remit. The results of stakeholders' discussions held within our project, have highlighted that, whilst providing a useful overview of the National Parks' natural capital and the related key ecosystem services, in its present form, the Natural Capital Accounting approach is only of limited wider management usefulness to National Park Authorities. The production of Natural Capital Accounts for only those areas where National Park Authorities have management control (as opposed to the whole National Park area), may help improve the management usefulness of Natural Capital Accounts. This may mean that the accounts can be more informatively used to, for example, monitor the effects of land management interventions. However, the limitations regarding the underpinning data and estimates, as outlined in this report, would still be an issue that would need to be taken into consideration regardless of the approach considered.

2. **Guidelines are needed to support the development of Natural Capital Accounts for local and regional scales**. Alongside clarifying what a Natural Capital Account is and is not, more recommendations are needed on the practical steps that need to be followed in order to implement Natural Capital Accounting. Step-by-step guidelines for the development of local Natural Capital Accounts are currently not available but encouraged by the Natural Capital Committee. Clear guidance on the methodology would prevent different environmental organisations using different approaches and it would be beneficial for the development of a consistent and robust approach across organisations, which would be useful for comparability purposes.

3. **Tools for natural capital assessment and monitoring, ecosystem service quantification and valuation are needed to support the development of Natural Capital Accounts and collaborations with experts should be encouraged.** Based on our stakeholder discussions, Natural Capital Accounting was perceived as an onerous task. Overall, it was felt that the development of Natural Capital Accounts for organisations such as Dartmoor and Exmoor National Park Authorities is challenging due to the limited availability of both resources and expertise to develop and update the accounts. Whilst this report focused on the entire National Park area, the same limitations would be present if smaller areas were considered (e.g. only the areas under National Park Authority ownership and management). Developing a Natural Capital Account can be highly time-consuming and requires interdisciplinary knowledge and a range of technical and analytical skills, often not available in-house. Publicly available tools, developed by academics or other specialists, but tailored for use by non-specialists, need to be encouraged to help support the development of Natural Capital Accounts. In this project, for example, we have used publicly available online tools such as ORVal and NEVO, which are sophisticated but user-friendly integrated valuation tools. Such tools can provide organisations with easily obtainable, scientifically underpinned estimates of ecosystem services and values to be used in the natural capital accounting process. If organisations don't have the necessary resources or skills to develop Natural Capital Account themselves, collaborations with specialists should be encouraged.

4. **Data availability is a major issue and fit-for-purpose data collection for Natural Capital Accounting should be promoted**. We showed in this study that when the underpinning data are subject to limitations, Natural Capital Accounts will misrepresent the values of the natural environment. Despite the availability of nation-wide information on some natural capital assets, ecosystem services and values, there is an overall lack of data to consistently and reliably measure natural assets over multiple years to detect change. Data on asset condition is also often not available across the entirety of the area of interest. In addition to this, data gaps also exist regarding the quantification of a range of ecosystem goods and services (e.g. flood protection or wildlife), which are of key importance to National Parks. With respect to the above, there is therefore a need to support National Park Authorities and similar

organisations with fit-for-purpose data collection for Natural Capital Accounting purposes. At a minimum, this should include multi-year data on assets across the whole of the National Park, as well as ecosystem service measures which cannot typically be derived from national data (e.g. water extraction, game harvesting and volunteer numbers). The frequency of data collection, and therefore of the accounts, depends on organisational interests, as well as the anticipated speed of environmental change. In addition, the collection of National Park-wide data on locally important assets (e.g. ancient woodland) or ecosystem services (e.g. Dartmoor/Exmoor pony numbers) should be promoted. Otherwise, there is a risk of overlooking or inappropriately accounting for such assets and services when national data are used. One promising opportunity to fill data gaps regarding natural assets lies in the use of remote sensing data (such as Sentinel data collected by the European Space Agency), which offer several advantages: the information is publicly available, collected regularly, and it allows for fine-scale detailed detection of changes in natural asset extent and potentially condition. Some specialist GIS expertise is needed to process remote sensing data into a useable land cover map. However, expert collaborations can be used to aid this process and open access tools are increasingly becoming available.

5. **Valuation methods need to be further progressed to be fit-for-purpose for Natural Capital Accounting**. Based on the results of our Natural Capital Accounts developed for Dartmoor and Exmoor, it emerged that the economic values of private goods provided by areas such as National Parks are relatively well represented, whilst some important public goods supplied are either completely or only partially included in the accounts. Importantly, no established methodology seems to be available to fully value the benefits of flood protection, cultural heritage, landscape values and biodiversity, which are crucial for organisations such as National Park Authorities. To include these and other currently overlooked goods and services into Natural Capital Accounts, more efforts are therefore needed to develop sound valuation methodologies.

6. **Uncertainties need to be made explicit**. Gaps in data and the limitations in the available methodologies need to be explicitly acknowledged when developing Natural Capital Accounting exercises, otherwise there is a risk of account results being open to misinterpretation. Sensitivity tests need to be more systematically performed in accounting exercises and the related estimates of uncertainties need to be reported. Narratives around the reliability of the results and any apparent gap or downsides in the approach need to be explained to ensure appropriate interpretation and use of the results.

7. **The quantification of the flow of ecosystem goods and services should be better linked to the ecological condition of natural assets.** Typically, the reviewed Natural Capital Accounting exercises have assumed that natural capital stocks supply constant rates of ecosystem goods and services. However, the capability of natural assets to provide goods and

services that benefit people heavily depends on the ecological condition of the stock. In this report, this is for example discussed in relation to the effect of water quality on recreation and the role of peatland condition on carbon sequestration. Wherever possible, data on asset condition, as well as evidence on the effects of condition on ecosystem service provision, should be included in the accounting process. However, data on asset condition across the entire area of interest is often lacking, and incorporating ecological condition would therefore often only be possible after extensive data collection efforts.

8. **The sustainability of extraction and/or use of natural capital stocks needs to be better considered.** Related to the above, the ecological condition of natural capital stocks also depends on the sustainability (or lack thereof) of resource extraction and natural capital stock use over time. Unless natural assets are sustainably managed, the assumption of constant flows of ecosystem services is inaccurate, as over-exploited natural capital stocks tend to supply declining rates of goods and services over time. For example, if the rate of logging in woodlands exceeds the rate of re-growth or plantation, a declining rate of timber production is to be expected. Better understanding of the implications of sustainable or unsustainable uses of natural capital stocks is crucial if Natural Capital Accounting is to be used to inform decision-making in the longer term. Flow accounts which only focus on annual ecosystem service supply (e.g. annual sequestration of carbon, annual timber extraction) only provide a partial picture and are often not sufficient to inform sustainable decision-making. Stock accounts, which measure the total ecosystem goods and services that are expected to be produced by a given natural capital until the end of its asset life, could instead be used to provide useful additional insights when there are sustainability concerns. Given that stock accounts provide a picture of the long-term availability of natural capital stocks and ecosystem goods and services, they can give an indication of the sustainability of natural resource use and extraction.

9. **Spatial aspects need to be better incorporated into Natural Capital Accounting**. Based on the reviewed Natural Capital Accounting approaches and wider literature, we can conclude that only limited consideration has been given so far to spatial aspects. No specific guidelines are available regarding whether Natural Capital Accounts should be spatially explicit and only a few case studies provided maps of the geographical distribution of natural assets or ecosystem services and goods. In this study, we have tested how spatial dimensions - including site accessibility, distance from the beneficiary, availability of substitutes and types of habitats – can affect the recreational values experienced by people. Given that for the majority of ecosystem goods and services, the location of the natural asset and the associated goods and services is important to drive economic values, spatially explicit natural capital accounting methodologies should be encouraged wherever possible, if decisions about spatial planning are to be made based on the results of the Natural Capital Accounting exercise.

10. **More consideration should be given to the costs of maintaining natural capital stocks for the provision of ecosystem goods and services**. In addition to considering the benefits and values of the ecosystem goods and services provided by natural assets, the costs that need to be incurred to support the provision of such goods and services, should also be taken into explicit consideration. These can include, for example, the costs of habitat management (e.g. woodland management), of provision of recreational opportunities (e.g. footpath maintenance and infrastructure for visitors) and of managing volunteering. Typically, cost accounts are not provided in the reviewed Natural Capital Accounts, but their inclusion could increase the management usefulness of the approach.

6 APPENDICES

Appendix 1. The general structure of an asset account (ONS-Defra, 2017)[60]

	Extent of ecosystem (area)	Volume (volume)	Biodiversity (indicator)	Soil (index)	Ecological condition (indicator)	Access (indicator)	Management practice (area)
Examples	Woodland, Freshwater	timber biomass; carbon stock; water quantity	Farmland Birds Index	carbon content, water content	water quality	proximity to areas of population	conservation status, organic farming
Opening stock							
Additions to stock[3]			Net change	Net change	Net change		
Reductions in stock							
Closing stock							

Source: Office for National Statistics

[60] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

Appendix 2. List of ecosystem services to be considered in UK accounts (ONS 2017)[61]

Provisioning services

	Description of service	Notes
Biomass	Cultivated crops including horticulture (tonnes)	For example wheat; can include residues used as animal fodder.
	Grass (tonnes)	Livestock is excluded as the production of grass fodder is taken as the service.
	Wild fish (tonnes)	Aquaculture is treated in the same way as livestock.
	Woody biomass (cubic metres)	Production of timber
	Wild produce (tonnes)	Nuts, berries, mushrooms, wild animals
	Peat (tonnes)	For either horticulture or energy
Water (cubic metres)	Water (cubic metres)	Water abstracted, including groundwater and collected water Naviagation Possibly
Energy	Hydropower (joules)	Energy from hydropower
	Other renewable sources (joules)	Energy from wind, solar, tidal etc.

Source: Office for National Statistics

Regulating services

	Description of service	Notes
Mediation of wastes and nuisances	Air pollutant absorption by vegetation (tonnes)	Deposition of pollutants on bare soil is excluded
	Other waste remediation (tonnes /cubic metres)	Solid waste e.g. manure spreading
		Liquid waste e.g. effluent deposition/dilution /remediation (may be a supporting service to water provisioning)
	Noise mitigation (decibels)	Shelter belts along motorways
	Mediation of visual impacts	Shelter belts around industrial structures
Mediation of flows	Flood protection (cubic metres/ reduced risk of flooding)	Water absorption and attenuation by vegetation
		Control of sediment
		Provision of storage for excess water
	Maintaining baseline flows for water supply (reduced risk of drought)	Supporting service for water provisioning
	Storm protection (reduced risk of damage)	Properties protected by natural sea defences (wetlands, dunes, shelter belts)
	Erosion protection (reduced risk of loss of soil)	Mass stabilisation and control of erosion rates
Biophysical Maintenance	Greenhouse gas sequestration (tonnes)	Excludes carbon storage
	Local climate regulation	Vegetation that enables air circulation
	Pollination	Commonly seen as a supporting or intermediate service

Source: Office for National Statistics

[61] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

Cultural values

	Description of service	Notes
Physical interactions with nature	Setting for outdoor recreation (No. of visits, or time spent at site)	Walking, hiking, climbing, boating. Note that health is generally viewed as a benefit rather than as a service
	Nature-related tourism (No. of visits, time spent at site)	Bird watching, snorkelling
	Amenity (experiential interactions with nature)	Overlaps with recreation; can include an element of option value.
Intellectual interactions with nature	Educational interactions (No. of visits)	School trips
	Subject matter for scientific research (No. of publications)	Research related to ecosystems
	Heritage preservation (cultural archive)	
	Ex situ entertainment viewing	Documentaries on UK ecosystems
	Sense of place / artistic representations	
Spiritual interactions with nature	Symbolic (emblematic plants, animals etc.)	No obvious measures within the UK
	Sacred and religious	
	Existence and bequest	

Source: Office for National Statistics

Appendix 3. Summary guidance for valuing selected services in ecosystem accounting (ONS 2017[62])

PROVISIONING SERVICES	
Woody biomass	Unit resource rent (stumpage prices). Although stumpage prices may include some management overheads and return to capital, these amounts are not expected to be significant.
Wild fish (marine)	Residual resource rent – however this can be low or negative depending on market structure. It may be possible to base estimates on quotas, this would need to be further explored.
Cultivated crops and grass	Residual resource rent. The approach commonly produces quite low values for ecosystem services, but this is not wholly unexpected as anthropogenic inputs into the production are so significant. Different estimates may be possible for different sectors of the industry. Agricultural land valuations, suitably adjusted, may be another option.
Peat	Market prices or residual resource rent.
Water	Residual resource rent for public water supply – but can be low or negative depending on market structure. The residual value method has in our experience to date generated a relatively high resource rent for public water supply which could be considered inconsistent with the concept of a price regulator and normal returns. In future water may be traded between water companies although the prices charged may depend more upon covering the overheads of delivery than on the value of the resource in situ. It is also possible that abstraction licence charges may provide an estimate of the amount of resource rent captured by the Government. Requires further research.
Hydropower and other renewable energy sources	Residual resource rent. Unit resource rent factors used in the national accounts may be transferable to local levels.

REGULATING SERVICES	
Air pollutant absorption	The main challenge is to estimate the physical service provided by the ecosystem. To value the quantity estimated, the relevant Defra health damage costs (depending upon type of pollutant and habitat) offer a simplistic means of valuing a physical service. A more sophisticated method would relate pollution absorbed to population exposure as set out in Defra guidance. Each method assumes that the estimated cost is one that recipients, or society, would be prepared to pay. Damage costs reflect increased mortality, and applied to ecosystem vegetation the benefit is the reduced mortality of pollutant absorption. This is an area of further research.
Noise mitigation	This is an area for further research.
Flood protection	Damage costs avoided from reduced flood risk. This is an area of further research. A particular challenge is that the probability of the service being provided varies across catchments depending on the risk.
Greenhouse gas sequestration	The UK "non-traded" carbon price schedule published by BEIS can be roughly interpreted as (simulated) exchange values in that they are based on the marginal abatement cost (supply) of meeting UK policy targets (demand). The nature of such a market however remains unclear. Existing fledgling ecosystem carbon markets (e.g. based on UK Woodland Carbon Code) are not suitable because they are sensitive to the wider institutional framework around carbon markets. The price of carbon in existing markets should become more representative of the value of carbon sequestration in the future as the institutional setup of markets becomes more established. This should be kept under review.

[62] ONS (2017). Principles of Natural Capital Accounting. A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

CULTURAL SERVICES	
Setting for outdoor recreation	Observed travel costs based on MENE can be interpreted as the price of access, together with admission and membership fees. Imputed value required to capture "free" trips.
Nature-related tourism	This is the Resource Rent captured by the tourism sector by taking advantage of the attractions of the natural environment. It could be measurable for an area using ONS micro-data sources. This service would be in addition to the service received by visitors to the natural environment.
Amenity (value of green and blue space)	UK NEA demonstrated substantial natural capital values embedded in property prices, but further work is needed to derive accounting values, based on hedonic pricing methods. May have some overlap with recreational values which will need untangling.
Amenity (value of private gardens)	UK NEA demonstrated substantial ecosystem values embedded in property prices, including domestic gardens, but further work is needed to derive accounting values, based on hedonic pricing methods.
Educational interactions	Some variation of travel cost or opportunity cost approach for educational trips (distinct from recreational). This is an area of further research.
Mental and physical health	This is an area for further testing and research; a key issue is potential overlap with other service values. See discussion of physical services in section 5.

Appendix 4. List of the Natural Capital asset classes and sub-classes used to produce Natural Capital Accounts for Dartmoor and Exmoor National Parks. For Exmoor, LCM 2015 classifications were used. For Dartmoor, LCM classifications were adapted with additional local data on Rhos pasture and dry grassland, adaptations are detailed below.

Exmoor	Dartmoor	Adaptations made to Dartmoor classes
Woodland	Woodland	
Broadleaved	Broadleaved	30% of DNPA Rho pasture extent was subtracted from total LCM broadleaved extent
Coniferous	Coniferous	
Open water	Open water	
Freshwater	Freshwater	
Saltwater	Saltwater	
Mountain/heath/bog	Mountain/heath/bog	
Bog	Bog	
Heather grassland	Heather grassland	
Heather	Heather	
Inland Rock	Inland Rock	
Improved grassland	Improved grassland	Total DNPA dry grassland extent and 25% of Rhos pasture extent was subtracted from total LCM improved grassland extent
Semi-natural grassland	Semi-natural grassland	
Neutral	Species-rich dry	LCM Neutral and Calcareous grassland extents were merged, and DNPA dry grass extent added
Calcareous	Species-rich wet (Rhos pasture)	Based on DNPA Rhos pasture extent (subtracted from LCM extents of acid grassland (45% of Rhos extent), improved grassland (25% of Rhos extent) and broadleaved woodland(30% of Rhos extent))
Acid	Acid	45% of DNPA Rhos pasture extent want subtracted from LCM acid grassland extent
Fen/marsh/swamp	Fen/marsh/swamp	
Arable/horticulture	Arable/horticulture	
Coastal		
Saltmarsh		
Supra-littoral rock		
Supra-littoral sediment		
Littoral rock		
Littoral sediment		

Appendix 5. List of approaches used for quantifying flows of ecosystem goods and services (based on the review of current approaches)

Ecosystem good/service	Quantification	Approach	Comments	Reviewed report(s) using this approach	Alternatives available from reviewed reports?
Recreation (outdoor visit)	Number of environment-related visitors/hectare/year. *Obtained from DNPA/ENPA reports using same approach as reviewed NCA studies.*	STEAM visitor models* were used to obtain visitor number data, and responses from visitor surveys were used to extract proportion of visits related to the Natural Environment.	*For Dartmoor, we used information on visitor numbers obtained from the ORVal model (calibrated for DNPA in a previous project) as these estimates were deemed more reliable. Differences between ORVal and STEAM estimates are outlined in the report. To extract environment-related visit numbers for Dartmoor and Exmoor, 85% of all visits were used, as ENPA visitor survey showed that 85% if all respondents listed "landscape/scenery" as primary reason for visit. Similar data was not available for DNPA. Resulting environmental visitors/hectare/year: Dartmoor: 69, Exmoor: 18	D	Y – MENE (see report for comparison between STEAM and ORVal – which uses MENE data)
Wild food	-	The DEFRA protected areas report used data on numbers of game/deer extracted in each protected area	Whilst in theory possible to replicate this approach to the NPs, data is needed on game and deer numbers extracted within the National Park boundaries each year. Such information was not available.	D	N
Carbon sequestration	Tonnes of CO2/CO2e sequestered/ha/year. Broadleaved woodland: 10.71 Coniferous woodland: 17.51 Open water: -5.4 Bog: NA Heather grassland: 1.61 Heather: 3.45 Improved grassland: NA Acid/calcareous grassland: 1.61 Fen/Marsh/Swamp: 3.91 Species-rich dry grassland: 1.61 Rhos pasture/neutral grassland: 1.55 Arable: -18.65 Saltmarsh: 4.2 Supralittoral sediment: 1.14	Using Carbon sequestration rates based on published studies of sequestration of different habitat types	Estimates used in the RSPB accounts were used for the NPs, as the RSPB study provided comprehensive information across a wide range of habitat types, and sequestration rates were based on a comprehensive literature review. Sequestration rates for bog are unknown, as sequestration is highly dependent on bog condition, for which information was unavailable. Data on improved grassland was unavailable from the reviewed reports. +Data on littoral sediment was unavailable from the RSPB study, estimate from the ONS coastal margin scoping study was used instead.	All	Y

Timber	m³ of overbark harvested/year/ha Broadleaved woodland: 0.5 Coniferous woodland: 7.4	Timber production was estimated by dividing total UK production of softwood and hardwood (Forestry Commission data) by total UK area of coniferous and broadleaved woodland.		D,E	N
Livestock	Numbers of livestock *Obtained for NPs from DEFRA data, not obtained from reviewed reports*	Data on number of livestock was obtained from DEFRA surveys. Livestock yield information was then obtained from other sources to provide estimate of annual production of livestock.	Whilst livestock numbers could be obtained from DEFRA surveys for Dartmoor and Exmoor, information on livestock yield could not be located. Therefore, only "total livestock numbers" within the National Park could be estimated. This does not take into account that some animals take multiple years to mature, and some animals are used only as breeding stock and not used for marketing. The estimates provided for Dartmoor and Exmoor therefore represent the total livestock in the park, not an annual value flow, and estimates are therefore inflated (see report for further detail).	D	N
Crops	Tonnes of yield/ha/year for various crop types oats: 6 oilseed rape: 3.7 spring barley: 5.5 winter barley: 7.1 wheat: 8.1 linseed: 1.5 sugar beet: 60.7 Peas & beans: 2.4 Potatoes (early): 15 Potatoes (main crop): 33	Obtained from DEFRA agricultural datasets ("Agriculture in the United Kingdom", "Cereal production survey" and "oilseed rape survey"	For some of these crops, regional yield data was available (oats, oilseed rape, spring barley, winter barley, wheat). When this was the case, figures for the southwest were used.	D,N	N
Drinking water	-	In the DEFRA study for protected areas, data was used on annual m³ of freshwater extracted from surface and ground within the area of interest.	Estimates of water extraction volumes in the National Parks could not be extracted within the timeframe of this project. However, the approach outlined here could easily be replicated for the National Parks should extraction data become available.	D	N
Air quality purification	kg of absorbed PM10/ha/year Woodland: 11.91 Bog: NA	The ONS scoping study on air quality shows pollutants capture by broad UK habitat type, dividing by UK habitat	Pollutants other than PM10 could also be considered. Estimates displayed here are obtained by dividing ONS approach used here, DEFRA protected area study also calculated air pollution benefits, but sources underpinning	O	Y

	Heather grassland: 0.64 Heather: 0.42 Improved grassland: 0.24 Semi-natural grassland: 0.46 Arable: 0.27 Coastal margins: 0.67	type extents gives estimates per hectare displayed here.	absorption calculations could not be traced, and this is therefore not available as an alternative approach.		
Minerals	-		Generally not considered by the reviewed NCA studies		
Plants and seeds	-		Generally not considered by the reviewed NCA studies		
Wildlife	-		No current developed methodology for incorporating wildlife into Natural Capital Accounts		
Pollination	Proportion of crop production (and agricultural value) dependent on pollinators Beans: 0.25 Linseed: 0.05	Using worldwide coefficients of pollinator dependence	Oilseed rape and peas have a varied pollinator dependence and could therefore not be quantified. Not all crops of interest for the NP study were included in the pollinator dependency estimates from the Nene Valley study. Oats, Barley, Wheat, Sugar Beet and Potatoes are all not pollinator dependent.	N	N
Flood protection	-	No methodology for quantifying links between assets and levels of flood protection	The Eftec woodland study quantified the amount of woodland positioned in/upstream from flood risk zones. The ONS study on coastal areas provided a value for wetland flood protection, but no data based on which to estimate extent of flood protective wetlands in Exmoor.		
Volunteering	Number of volunteer hours per year *Obtained from DNPA/ENPA reports using same approach as reviewed NCA study.*	Data on the number of hours of volunteering work within the area of interest	For Dartmoor and Exmoor, obtained from in-house data	R	N

Notes: **D = Defra NCA for protected areas** (Ref: White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government); **R=accounts for RSPB estate** (Ref: RSPB (2017). Accounting for Nature: A Natural Capital Account of the RSPB's estate in England); **E = Eftec woodland NCA for the UK** (Ref: Cryle, P., Krisht, S., Tinch, R., Provins, A., Dickie, I., Fairhead, A. (2015). Developing UK natural capital accounts: woodland ecosystem accounts. Economics for the Environment Consultancy Ltd (Eftec) in association with Cascade Consulting for the Department for Environment, Food and Rural Affairs (Defra)); **N = Nene Valley report** (Ref: Rouquette, J.R. (2016). Mapping Natural Capital and Ecosystem Services in the Nene Valley. Report for the Nene Valley NIA Project); **O = ONS studies (air quality, valuing flood regulation and valuing coastal areas)** (Ref: Jones, L., Vieno, M., Morton, D., Cryle, P., Holland, M., Carnell, E., Nemitz, E., Hall, J., Beck, R., Reis, S., Pritchard, N., Hayes, F., Mills, G., Koshy, A., Dickie, I. (2017). Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts. Final report for Office of National Statistics, July 2017; Richard Smithers, Outi Korkeala, Guy Whiteley, Shaun Brace, Bex Holmes (2016). Valuing flood-regulation services for inclusion in the UK ecosystem accounts. Ricardo Energy & Environment for the UK Office for National Statistics; Office for National Statistics (ONS) (2016) Scoping the UK coastal margin ecosystem accounts)**.**

Appendix 6. List of the economic valuation assumptions employed (based on the review of current approaches)

Ecosystem good/service	Value (2015£)	Valuation Approach	Comment	Reviewed report(s) using this approach	Alternatives available?
Recreation (outdoor visit)	Woodlands: £3.61/visit River, lake or canal: £1.96/visit Mountains, moors, heathlands: £5.43/visit Semi-natural grassland: £1.67/visit Enclosed farmland: £1.67/visit Coastal: £4.28/visit	Meta-analysis of valuation studies	The values per visit were taken from the Sen et al. (2014) study. This is a meta-analysis based on about 300 estimates of the value of recreational visits to different habitats. Reviewed studies drew on a mix of stated and revealed preference studies providing WTP information. This is a standard approach employed by the reviewed reports.	all	NO
Wild food	-	Resource rent, assumed to be equal to wholesale market prices	Wild food, game and fish were not included in the natural capital accounts developed for Dartmoor and Exmoor because of insufficient availability on the quantification of this ecosystem good/service.	D	NO
Carbon sequestration	£62.39/tonne of CO_{2e} sequestered	Abatement cost approach	The value of carbon sequestration is based on DECC non-traded carbon prices (central estimate) for 2015. This is a pretty standard approach employed by the reviewed reports	all	NO
Timber	£14.74/m³ standing hardwood £ 14.07/m³ overbark softwood	Literature review Resource rent, approximated by using FC sales prices of harvested timber	For softwood timber production, standing price per cubic meter of overbark (or stumpage price) is used (Forestry Commission data). In the absence of equivalent prices for hardwood, information was extracted from a review of the literature	D E	YES
Livestock	Dairy cows: £1021.44/cow Finishing cattle: £157.36/head Calves (<1 year): £94.23/head Breeding pig: £24.23/pig Breeding ewe: £31.10/ewe Lamb (<1 year): £2.83/ewe Poultry: £0.45/head	Resource rent approach (farm gross margins based on John Nix Pocketbook for Farm management 2018)	The Defra report considered market prices for livestock and then applied some resource rent ratios to estimate the resource rents for livestock. We opted for considering a more readily applicable but equivalent approach based on the farm gross margins (which, similarly to resource rents are also calculated starting from market prices, after subtracting variable costs).	D	YES
Crops	Wheat (milling, winter): £80.09/tonne Wheat (feed, winter): £81.98/tonne Barley (malting, winter): £81.98/tonne Barley (feed, winter): £71.61/tonne Spring barley: £94.61/tonne Oats (winter): £78.21/tonne	Resource rent approach (farm gross margins based on John Nix Pocketbook for Farm management 2018)	The Defra report considered market prices for livestock and then applied some resource rent ratios to estimate the resource rents for livestock. We opted for considering a more readily applicable but equivalent approach based on the farm gross	D	YES

	Oil seed rape (average price, winter): £178.09/tonne Linseed (spring): £219.55/tonne Sugar beet (average price): £9.42/tonne Field peas (marrowfats): £111.19/tonne Field beans (winter): £102.71/tonne Field beans (spring): £103.65/tonne Potatoes (early potatoes): £97.06/tonne Potatoes (maincrop potatoes, based on all potatoes): £63.13/tonne		margins (which, similarly to resource rents are also calculated starting from market prices, after subtracting variable costs).		
Drinking water	0.15/m^3 of abstracted water	Resource rent approach	The value provided for the abstraction of drinking water for public use are calculated by subtracting human input from the market price of water (set by Ofwat).	D	YES
Air quality purification	£16.23/kg of PM_{10} absorbed	Damage cost avoided	Information on the value of air quality improvement is estimated by considering the health benefits (in terms of damage avoided) resulting from lower concentrations of PM_{10} in the air. The figure of £15,041/tonne of PM_{10} absorbed (2010 prices) was derived from the Interdepartmental Group on Costs and Benefits (IGCB) report and specifically refers to rural areas	D	YES
Minerals	-	-	Generally not considered by the reviewed NCA studies	none	NO
Plants and seeds	-	-	Generally not considered by the reviewed NCA studies	none	NO
Wildlife	-	-	No information available on the monetary value of wildlife preservation	none	NO
Volunteering	£7.31/hour of volunteering (lower bound)	Costs avoided	Heritage Lottery Fund value of work per hour for unskilled workers	R	NO
Pollination	oilseed rape: mixed response field beans: 0.25 linseed: 0.05 apples (dessert apples): 0.45 apples (culinary apples): 0.28 pears: 0.09 plums: 0.08 cherries: 0.04 oats: 0 barley: 0 wheat: 0 sugar beet: 0 peas: mixed response	Pollinator dependency	Pollinator-dependency coefficients are applied to the farm gross margins calculated for agriculture (crop) to determine the value of crop production attributable to the existence of pollinators (the value that, in the absence of pollinators, would be lost).	N	NO

	potatoes: 0				
Flood protection	Reducing flood risks in woodlands: Lower bound: £22.48/ha Upper bound: £27.18/ha	Replacement cost approach	Estimates of avoided expenditures on flood-related defenses due to reduced flood risks	O	NO
	For coastal areas: Lower bound: £1679.18/meter Upper bound: £1740.95/meter		Average costs avoided – savings (per km) in terms of not needing to replace coastal margin habitats with man-made sea walls due to lower flood risks	D	NO
	For saltmarshes: £1.775/metre of saltmarsh (year unknown)	Avoided costs	Cost savings in seawall investments that should be otherwise incurred in the absence of flood protection services provided by saltmarshes	O	NO

Notes: **D = Defra NCA for protected areas** (Ref: White, C., Dunscombe, R., Dvarskas, A., Eves, C., Finisdore, J., Kieboom, E., Maclean, I., Obst, C., Rowcroft, P. & Silcock, P. (2015), 'Developing ecosystem accounts for protected areas in England and Scotland', Department for Food, Environment & Rural Affairs/The Scottish Government); **R=accounts for RSPB estate** (Ref: RSPB (2017). Accounting for Nature: A Natural Capital Account of the RSPB's estate in England); **E = Eftec woodland NCA for the UK** (Ref: Cryle, P., Krisht, S., Tinch, R., Provins, A., Dickie, I., Fairhead, A. (2015). Developing UK natural capital accounts: woodland ecosystem accounts. Economics for the Environment Consultancy Ltd (Eftec) in association with Cascade Consulting for the Department for Environment, Food and Rural Affairs (Defra)); **N = Nene Valley report** (Ref: Rouquette, J.R. (2016). Mapping Natural Capital and Ecosystem Services in the Nene Valley. Report for the Nene Valley NIA Project); **O = ONS studies (valuing flood regulation and valuing coastal areas)** (Ref: Richard Smithers, Outi Korkeala, Guy Whiteley, Shaun Brace, Bex Holmes (2016). Valuing flood-regulation services for inclusion in the UK ecosystem accounts. Ricardo Energy & Environment for the UK Office for National Statistics; Office for National Statistics (ONS) (2016) Scoping the UK coastal margin ecosystem accounts)**.**

Appendix 7. Natural Capital Account table for Exmoor National Park. Stock extents are based on Land Cover Map 2015.

STOCKS		GOODS & SERVICES																TOTAL
		Recreation		Climate regulation		Timber		Livestock		Crops		Volunteering		Air quality		Pollination		
Natural capital stock	Stock extent (ha)	Annual visitors	Value	Annual tonnes of CO2e sequest.	Value	Annual m3 overbark	Value	Total livestock no.	Value	Annual tonnes	Value	Annual hours	Value	Annual kg PM10 absorbed	Value	Annual pollinator-depedent tonnes	Value	
Total goods & services	69890	1258024	£2,762,899	130731	£8,156,890	28935	£426,677	362840	£7,257,879	21589	£1,613,595	27288	£199,436	155495	£2,472,710.48	71	£7,432	£22,897,519
Woodland	11254	202572	£730,693	143501	£8,953,676	28935	£426,677			0	£0			134035	£2,174,901.42	0	£0	£12,285,948
Broadleaved	7876	141768	£511,368	84352	£5,263,109	3938	£60,443			0	£0			93803	£1,522,083.13	0	£0	
Coniferous	3378	60804	£219,325	59149	£3,690,566	24997	£366,234			0	£0			40232	£652,818.29	0	£0	
Open water	234	4212	£8,264	-999	-£62,332	0	£0			0	£0			0	£0.00	0	£0	-£54,069
Freshwater	185	3330	£6,533	-999	-£62,332	0	£0			0	£0			0	£0.00	0	£0	
Saltwater	49	882	£1,730			0	£0			0	£0			0	£0.00	0	£0	
Mountain/heath/bog	3407	61324	£333,368	10992	£685,852	0	£0			0	£0			1496	£23,238.73	0	£0	£1,042,459
Bog	26	468	£2,544			0	£0			0	£0					0	£0	
Heather grassalnd	356	6408	£34,835	573	£35,762	0	£0			0	£0			228	£2,657.23	0	£0	
Heather	3020	54360	£295,510	10419	£650,090	0	£0			0	£0			1268	£20,581.51	0	£0	
Inland Rock	5	88	£479	0	£0	0	£0			0	£0			0	£0.00	0	£0	
Improved grassland	34113	614034	£1,022,730			0	£0			0	£0			8187	£132,847.09	0	£0	£1,155,577
Semi-natural grassland	17259	310662	£517,436	27766	£1,732,422	0	£0			0	£0			10982	£128,823.28	0	£0	£2,378,682
Neutral	357	6426	£10,703	553	£34,526	0	£0			0	£0			164	£2,664.69	0	£0	
Calcareous	0	0	£0	0	£0	0	£0			0	£0			0	£0.00	0	£0	
Acid	16902	304236	£506,733	27212	£1,697,896	0	£0			0	£0			10817	£126,158.59	0	£0	
Fen/marsh/swamp	0	0	£0	0	£0	0	£0			0	£0			0	£0.00	0	£0	
Arable/horticulture	2736	49248	£82,027	-51026	-£3,183,773	0	£0			21589	£1,613,595			739	£11,986.73	71	£7,432	-£1,468,733
oats	70									420	£32,817					0	£0	
oilseed rape	436									1613	£287,312							
spring barley	266									1464	£137,949					0	£0	
winter barley	268									1905	£156,176					0	£0	
wheat	1208									9786	£783,807					0	£0	
linseed	11									16	£3,525					1	£176	
sugar beet	64									3898	£36,735					0	£0	
peas	30									72	£7,998							
field beans	118									283	£29,025					71	£7,256	
potatoes (early)	7									107	£10,389					0	£0	
potatoes (main crops)	61									2025	£127,860					0	£0	
other	196																	
Coastal	887	15971	£68,381	498	£31,046	0	£0	0	£0	0	£0			56	£913.22	0	£0	£100,340
Saltmarsh	84	1512	£6,474	353	£22,013	0	£0	0	£0	0	£0			56	£913.22	0	£0	
Suppra-littoral rock	471	8478	£36,298	0	£0	0	£0	0	£0	0	£0			0	£0.00	0	£0	
Suppra-littoral sediment	3	59	£254	4	£235	0	£0	0	£0	0	£0			0	£0.00	0	£0	
Littoral rock	90	1620	£6,936	0	£0	0	£0	0	£0	0	£0			0	£0.00	0	£0	
Littoral sediment	239	4302	£18,419	141	£8,798	0	£0	0	£0	0	£0.00			0	£0.00	0	£0.00	

Appendix 8. Natural Capital Account table for Dartmoor National Park. Stock extents are adapted from Land Cover Map 2015 (see Appendix 4)

STOCKS		GOODS & SERVICES														TOTAL
		Recreation		Climate regulation		Timber		Livestock		Crops		Air quality		Pollination		
Natural capital stock	Stock extent (ha)	Annual visitors	Value	Annual tonnes of CO2e seques.	Value	Annual m3 overbark	Value	Total livestock no.	Value	Annual tonnes	Value	Annual kg PM10 absorbed	Value	Annual pollinator-dependent tonnes	Value	
All stocks	**94322**	**6508218**	**£15,516,528**	**185675**	**£11,585,099**	**32000**	**£455,630**	**282088**	**£8,193,537**	**17218**	**£1,286,865**	**171888**	**£2,788,461**	**57**	**£5,928**	**£39,832,048.46**
Woodland	**12194**	**841386**	**£3,034,945**	**156125**	**£9,741,358**	**32000**	**£455,630**			**0**	**£0**	**145231**	**£2,356,562**	**0**	**£0**	**£15,588,495.40**
Broadleaved	8440	582360	£2,100,618	90392	£5,640,000	4220	£64,771			0	£0	100520	£1,631,079	**0**	**£0**	
Coniferous	3754	259026	£934,327	65733	£4,101,358	27780	£390,859			0	£0	44710	£725,482	**0**	**£0**	
Open water	**217**	**14973**	**£29,376**	**-1172**	**-£73,114**	**0**	**£0**			**0**	**£0**	**0**	**£0**	**0**	**£0**	**-£43,738.15**
Freshwater	217	14973	£29,376	-1172	-£73,114	0	0			0	£0	0	£0	**0**	**£0**	
Saltwater	0	0	£0	0	£0	0	0			0	£0	0	£0	**0**	**£0**	
Mountain/heath/bog	**11679**	**805851**	**£4,380,738**	**8654**	**£539,991**	**0**	**0**			**0**	**£0**	**1153**	**£18,055**	**0**	**£0**	**£4,938,783.57**
Bog	8928	616032	£3,348,851			0	0			0	£0			**0**	**£0**	
Heather grassland	224	15456	£84,021	361	£22,502	0	0			0	£0	143	£1,672	**0**	**£0**	
Heather	2404	165876	£901,729	8294	£517,489	0	0			0	£0	1010	£16,383	**0**	**£0**	
Inland Rock	123	8487	£46,137	0	£0	0	0			0	£0	0	£0	**0**	**£0**	
Improved grassland	**29035**	**2003415**	**£3,336,871**			**0**	**0**			**0**	**£0**	**6968**	**£113,072**	**0**	**£0**	**£3,449,942.46**
Semi-natural grassland	**39015**	**2692035**	**£4,483,830**	**62761**	**£3,915,970**	**0**	**0**			**0**	**£0**	**17947**	**£291,213**	**0**	**£0**	**£8,691,012.99**
Acid	36595	2525055	£4,205,710	58918	£3,676,164	0	0			0	£0	16834	£273,150	**0**	**£0**	
Fen/marsh/swamp	11	759	£1,264	43	£2,684	0	0			0	£0	5	£82	**0**	**£0**	
Species-rich dry grassland	1107	76383	£127,223	1782	£111,204	0	0			0	£0	509	£8,263	**0**	**£0**	
Rhos pasture	1302	89838	£149,633	2018	£125,919	0	0			0	£0	599	£9,718	**0**	**£0**	
Arable/horticulture	**2182**	**150558**	**£250,768**	**-40694**	**-£2,539,106**	**0**	**0**			**17218**	**£1,286,865**	**589**	**£9,560**	**57**	**£5,928**	**-£985,985.23**
oats	56					0	0			335	£26,172			0	£0	
oilseed rape	348					0	0			1287	£229,135					
spring barley	212					0	0			1168	£110,017			0	£0	
winter barley	214					0	0			1519	£124,553			0	£0	
wheat	964					0	0			7804	£625,098			0	£0	
linseed	9					0	0			13	£2,811			1	£141	
sugar beet	51					0	0			3109	£29,297			0	£0	
peas	24					0	0			57	£6,379					
field beans	94					0	0			225	£23,148			56	£5,787	
potatoes early	6					0	0			85	£8,285			0	£0	
potatoes main crop	49					0	0			1615	£101,970			0	£0	
remainder (other)	157					0	0									