Northern Upland Chain Natural Capital Account

Final report

Yorkshire Dales National Park Authority

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Disclaimer

Document evolution

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Final report	21/10/2021	Reviewed by Ian Dickie

This report is based on eftec's Version 2 – January 2020 report template.

Executive summary

This is the final report for the project to develop a natural capital account for the area covered by the Northern Upland Chain (NUC) Local Nature Partnership (LNP). The scope of this account is all the natural capital assets in the NUC boundary, and assessment of the benefits from them, which aligns with the scope of the UK's national ecosystem accounts. The results give a consistent picture of the NUC's natural capital: the extent and condition of natural capital assets and the benefits they provide to businesses in the region and the rest of the society. The results can input to both the NUC LNP and protected landscapes strategy and operational decision-making.

An outline of the accounting process is provided in Figure S1. Spatial data are used to build the asset register, from which benefits are assessed using further data from Government and robust academic sources. Physical and monetary values of benefits are calculated. The account does not cover the costs of managing and maintaining natural capital assets, so does not conform to the full scope of an organisational natural capital account defined in the British Standard (BS8632).

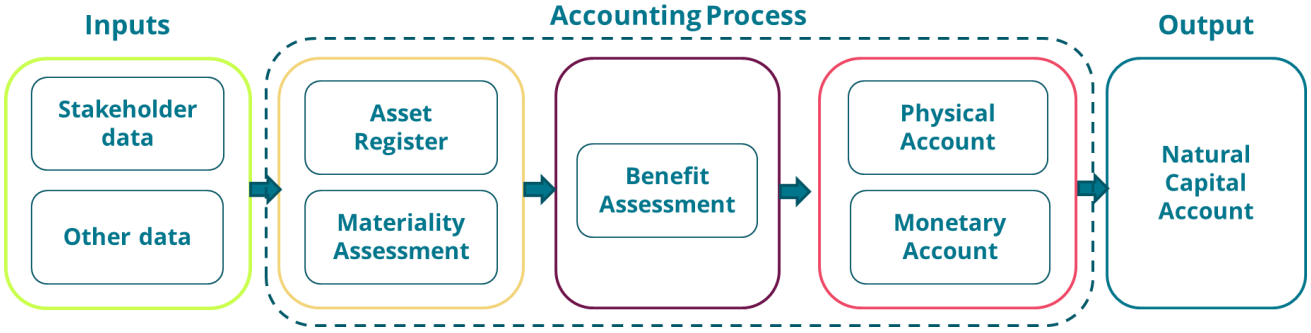
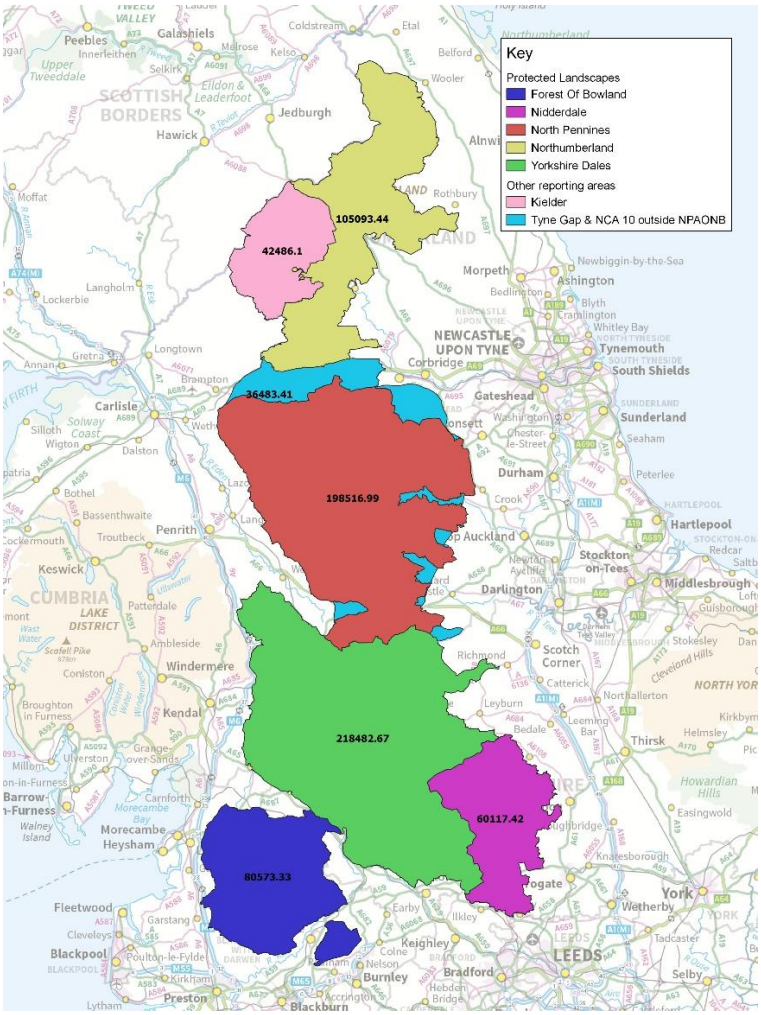


Figure S 1: Outline of accounting process

The methods used in the project are based on published evidence from Government and robust academic sources. Their application, including identification of material benefits to include in the account, was developed in partnership with the five protected landscapes that makeup the NUC (see Figure S2), in particular staff from the Yorkshire Dales NPA. The asset and benefit assessment for the NUC is broken down for the five protected landscapes and can also be used at a finer spatial scale.

Account results

The NUC asset value account results in Figure S3 and Table S1 quantify assets in detail and measure and value a wide range of benefits – this is believed to be one of the most complete natural capital accounts developed in the UK, in terms of the large regional area covered, and range of benefits valued. The results identify large benefits from natural capital to wider society that are nearly as large as the direct benefits to business.



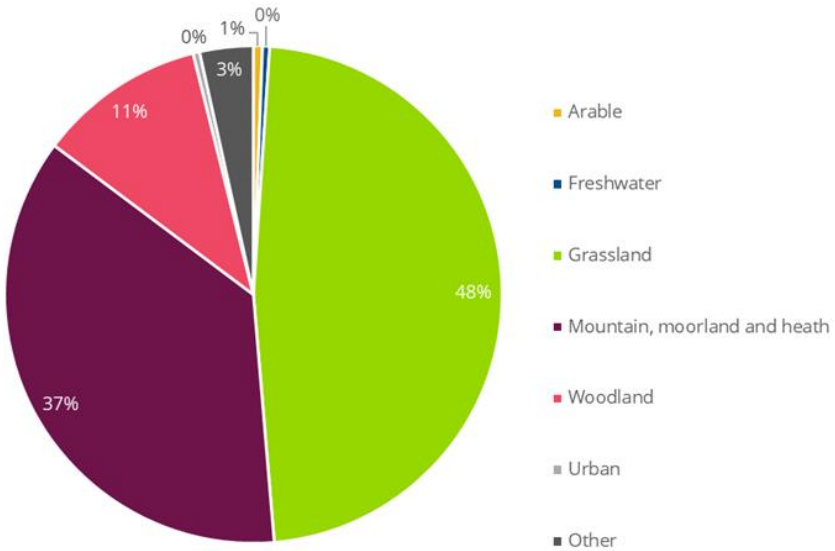


Figure S 2: NUCLNP account boundary and habitat breakdown

Table S1. NUC Natural Capital Asset Valuation, PV60 £m

	Valuation metric	Value to businesses	Value to the rest of society	Total
Asset values (monetised)				
Food provision	Arable income	109		**109**
	Livestock income	2,066		**2,066**
Timber	Value of softwood removals	179		**179**
Other fibres and materials	Value of wool	7		**7**
Renewable energy	Resource rent value of onshore wind	3		**3**
	Resource rent value of hydropower	9		**9**
Minerals	Ex-works value of mineral production	1,045		**1,045**
Carbon sequestration	Value of CO_2e sequestered in habitats		5,089	**5,089**
	Value of CO_2e emitted by habitats		(15,524)	**(15,524)**
	Value of CO_2e emitted by livestock		(2,558)	**(2,558)**
Air quality regulation	Value of PM2.5 removal by woodland		183	**183**
Recreation	Adult recreation welfare value (under 3 hours)		1,864	**1,864**
Physical health	Avoided medical treatment costs		1,159	**1,159**
Education	Value of educational visits		1	**1**
Volunteer	Value of volunteer days		31	**31**
Tourism	Domestic tourism expenditure attributed to natural capital		2,236	**2,236**
Water quality	Welfare of avoiding deterioration in rivers		1,433	**1,433**
	Welfare of avoiding deterioration in lakes		6	**6**
Total gross asset value		**3,418**	**(6,080)**	**(2,662)**
Asset values (non-monetised)				
Flood risk management	Volume of water held back by woodland: 11 million m^3			
Biodiversity	Total SSSI area: 216,000 hectares			
Other material unquantified benefits				
Water supply				
Mental health				

The data for the NUCLNP account can be broken down to generate accounts for specified reporting areas. Seven reporting areas, based on protected landscape boundaries and the remaining areas within the NUC boundary, are used in the account. These data demonstrate how the account allows comparisons between different areas.

Account results for other reporting areas in the region can be efficiently generated from the spatial data and account calculation processes developed. This requires spatial analysis habitats and land uses to generate an asset register for the reporting area. From the asset register benefits calculations can be made to provide a natural capital asset value - some benefits calculations then occur automatically, whereas others require manual data processes. Not all data breaks down neatly at a finer scale (e.g., minerals data is organized by planning authority boundary).

The account data supports analysis at a finer spatial scale and provides a baseline against which to measure change over time, and to undertake scenario analysis to help understand the impacts of

different land use options. Such an analysis has been undertaken for a hypothetical but realistic high nature value (HNV) livestock farm within the NUC. This compares the HNV to a conventional farming approach, identifying the reduction in income (opportunity cost) and the increase in natural capital value from the HNV system.

This analysis can inform the development of ELMS payments. However, it should be noted that not all benefits are valued (see the bottom rows of Table S1), so natural capital values are only one factor in determining payment design.

Further work

The results are considered to provide a robust and detailed baseline of natural capital evidence for the NUC LNP. Further engagement with stakeholders is recommended to discuss how to share, use, update and manage the account results going forward. There are still details in the methods that could be improved, and the methods need to be kept up to date with UK Government approaches to measuring and valuing ecosystem services and environmental impacts, in particular Defra's ENCA guide.

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Abbreviations & Acronyms

AONB	Area of Outstanding Natural Beauty
BEIS	Department for Business, Energy and Industrial Strategy
CEH	Centre for Ecology and Hydrology
CNCA	Corporate Natural Capital Account
CO_2e	Carbon dioxide equivalent
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
ELMS	Environmental Land Management Scheme
ENCA	Enabling a Natural Capital Approach
HNV	High Nature Value
MENE	Monitoring of Engagement with the Natural Environment
MWh	Megawatt hour
NCA	Natural Capital Account
NCC	Natural Capital Committee
NUCLNP	Northern Upland Chain Local Nature Partnership
ONS	Office for National Statistics
ORVal	Outdoor Recreation Valuation tool
PM2.5	Particulate Matter less than 2.5 microns in diameter
QALY	Quality Adjusted Life Year
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive
YDNPA	Yorkshire Dales National Park Authority

1.Introduction

This is the final report for the development of a baseline natural capital account for the Northern Upland Chain Local Nature Partnership (NUCLNP). It reports the work undertaken to produce the draft baseline account for the LNP and presents the results for a defined high nature value (HNV) farming scenario.

1.1 Project objective

Systematic and consistently generated evidence is what distinguishes accounting from one-off assessments. Accounting thus offers comparability across space and time, bringing rigour to the presentation of data on natural capital assets, the services they support, the value of the benefits they provide to people, and the distribution of those benefits across society into the future.

The project aims to create a set of replicable natural capital accounts for:

- The whole area covered by the Northern Upland Chain Local Nature Partnership.
- Each of the five protected landscapes within the NUCLNP, for the 'Tyne Gap'[1] and National Character Area 10[2] area and Kielder[3].

A key part of the project is to support and encourage 'High Nature Value' farming. As part of this project, the Partnership is keen to develop evidence that can demonstrate the value of the natural capital of the area covered by the NUCLNP. Therefore, a scenario that models the absence of HNV farming in the Yorkshire Dales National Park has been developed, to help quantify:

- The current role of HNV farming in providing natural capital benefits.
- What it costs to maintain natural capital assets through HNV farming.
- What it would cost to maintain/restore/recreate natural capital assets.

1.2 Project outputs

The outputs of this project include this report documenting the approach taken, and the key results, including key data gaps and uncertainties for the NUCLNP baseline account. This report should be read in conjunction with the Excel™ natural capital account workbooks developed by eftec and populated Yorkshire Dales National Park Authority (YDNPA) partners (NUCLNP-NCA-workbook-final.xls). Finally, this report provides recommendations on the interpretation of, and future updates to, the accounts.

In addition to the baseline natural capital account for the NUCLNP boundary, a natural capital account has been produced comparing a defined HNV farming scenario to conventional farming practices. The result and interpretation are presented within this report.

[1] This is the area between the North Pennines AONB and Northumberland National Park.
[2] Refers to the area of the National Character Area 10 that extends beyond the North Pennines AONB.
[3] Comprised of the National Nature Reserves of Kielderhead, Whitelee Moor and Kielder Forest and Water.

1.3 Structure of this report

The structure of the report is as follows:

- **Section 2: Approach** – provides an overview of the natural capital accounting method and its application to the NUCLNP baseline and HNV farming scenario.
- **Section 3: Scope of the natural capital benefits account** – defines the spatial boundary, asset register, benefits and presentation of results.
- **Section 4: Summary of the NUCLNP benefits account** – presents the analysis used to build the natural capital benefits account for the NUCLNP
- **Section 5: Summary of the High Natural Value farming benefits account** – presents the analysis used to build the natural capital benefits account for the defined farming scenarios.
- **Section 6: Results and next steps** – final results of the natural capital benefits accounts for the NUCLNP and HNV farming scenario, with interpretation of the results and next steps.
- **Appendix A: Benefit methodologies** – details the quantification and economic valuation methods used to produce the results reported within this report and in the accompanying accounting excel workbook.
- **Appendix B: Example NUCLNP reporting area account** – presents the natural capital benefits account for Yorkshire Dales National Park as an example of additional outputs that can be extracted from the accompanying accounting excel workbook.
- **Appendix C: High Nature Value farming methodology** - details the quantification and economic valuation methods used to produce the results reported here within.

2. Approach

This section provides a description of the natural capital accounting method used and the approach taken to develop an account for the NUCLNP and the HNV farming scenario.

2.1 Natural capital accounting

Natural Capital is "the stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people"[4]. A natural capital approach can be defined as distinguishing between the natural capital stocks and the flows of benefits they provide; projecting benefits into the future and linking the provision of benefits to the extent and condition of assets. The intention is to ensure that business decisions prioritise maintaining the assets to maintain benefits, and not to maximise one of the benefits at the expense of others or the natural capital asset itself.

Systematic and consistently generated evidence and repeated updates are what distinguish accounting from one-off assessments. Accounting offers comparability across space and time, bringing rigour to the presentation of data on natural capital assets, the services they provide, the benefits and hence value of those services, and the distribution of those benefits across society and into the future.

The approach to developing the NUCLNP baseline and HNV farming scenario account is based on the Corporate Natural Capital Account (CNCA) framework for the Natural Capital Committee in 2015 (eftec, RSPB and PWC, 2015). This framework is also the basis of BSI:8632 on Natural Capital Accounting for Organizations[5]. Natural capital accounting involves producing a natural capital balance sheet and a natural capital income statement mirroring traditional financial accounting. The intention is to present information to the decision makers in a format they are familiar with so that the organisation's impacts and dependencies on the natural capital is considered more explicitly and in conjunction with other forms of capital.

The **natural capital balance sheet** has two parts: asset values (of the benefits natural capital produce for the business and the wider society) and liabilities (of what the business legally or voluntarily spends to maintain natural capital). The natural capital balance sheet and its supporting schedules answer five key questions:

I. What assets do we own and/or manage?
II. What benefits do they provide and to whom?
III. What are these benefits worth?
IV. What does it cost to maintain the assets?
V. How do costs compare to benefits over time?

The following supporting schedules hold the information gathered to answer the above questions:

- **Natural Capital Asset Register –** which records the stock of natural capital assets in terms of their extent, condition and spatial configuration (e.g., size and status of designated sites). These indicators

[4] Source: Natural Capital Protocol *https://naturalcapitalcoalition.org/natural-capital-protocol/*
[5] Available at: *https://shop.bsigroup.com/products/natural-capital-accounting-for-organizations-specification?pid=000000000030401243*

help determine the health of natural capital assets and their capacity to provide benefits[6].

- **Physical Flow Accounts –** which quantifies the benefits that the assets deliver in physical terms. The changes in the quantity / quality of the assets and their benefit provision over time are also shown.
- **Monetary Flow Accounts –** which estimates the economic value of the benefits in monetary terms and discounts the projected future flow of these benefits to provide the present value for the assets. This uses data from actual markets and other (non-market) values. The value of the benefit should be net of the cost of producing the benefit.
- **Natural Capital Liabilities Account –** which details the costs of activities required to sustain the capacity of the natural capital assets to provide benefits over the long term, including management actions for the habitats identified in the asset register.

The monetary flow and cost accounts distinguish private values to the organisation(s) from external values to the rest of society. These supporting schedules provide all the data required for the balance sheet which compares the asset values to cost of maintaining those values.

Where understanding and evidence allow, calculation of assets and liabilities can take account of expected changes to future costs and benefits of management, and external factors such as population growth or climate change. Otherwise, caution is needed when interpreting the bottom line of natural capital balance sheet – as BSI 8632 states, a positive net asset value is not necessarily an indication of sustainable asset management.

2.2 Preparing natural capital benefits account for the Northern Upland Chain

YDNPA was the main project partner, however other protected landscapes have been consulted in the accounting process to provide data and insight to the reporting areas within the NUCLNP. A natural capital liabilities account has not been produced as part of this project (question IV in the CNCA framework). In this project a **natural capital benefits balance sheet** has been produced, which relates to Steps I – III and as such has a similar scope to the UK national natural capital accounts[7] than an organisational account.

This structure of the account allows the benefit assessment to be designed so that some of the benefits are automatically calculated when asset register information is inputted, for others, asset and benefit data need to be linked manually. These calculations link data on the extent and condition of the assets identified in the asset register, to value data on flows of ecosystem services, through the process shown in Figure 2.1. The product of quantity and unit value gives an estimate of annual value. Asset values are calculated by summing the expected future annual values of benefits over 60 years, discounted according to HM Treasury (2020) Green Book Guidance.

[6] The natural capital asset register is also the basis for scoping the natural capital risk register, and for a materiality assessment (see Section 4.2) to determine the content of the flow and liabilities accounts.

[7] Natural Capital - Office for National Statistics (ons.gov.uk)

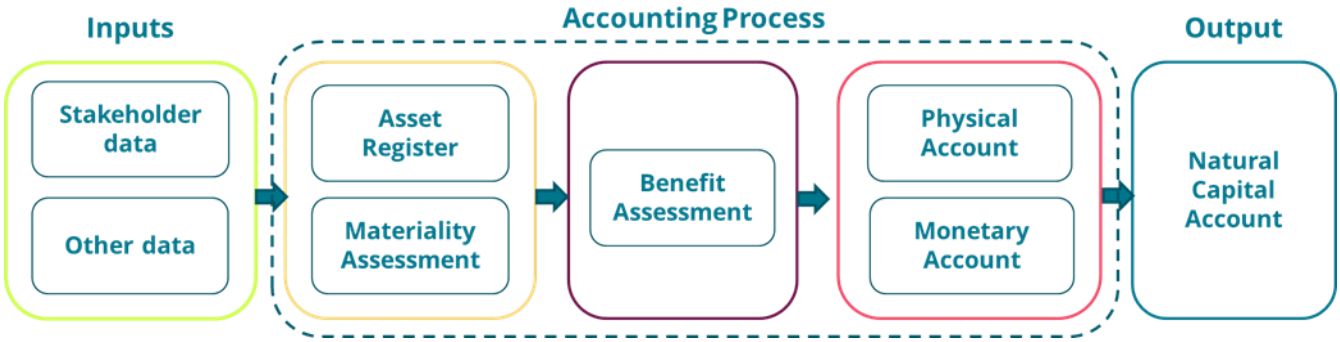

Figure 2.1: Outline of accounting process

The account workbook (NUCLNP-NCA-workbook-final.xls) contains all supporting schedules and the balance sheets for the Northern Upland Chain LNP overall and individual reporting areas. The assumptions and evidence used have been integrated into the natural capital accounting workbook, with further details provided in Appendix A. The project was conducted in three phases:

- **Phase 1: Inception and scoping**. eftec developed a template accounting workbook in Excel™ which was used to provide a structure for gathering data to produce the natural capital account. The project start-up meeting confirmed the objectives of the project and provided an opportunity for the demonstration of the workbook to the YDNPA project partners, as an important first step in understanding the structure of the account.
- **Phase 2: Support to building the account.** Following the start-up meeting, ongoing support was provided through regular update calls and web-meetings on how to use the workbook. This included:
  - Engagement with the remaining four protected landscape partners
  - Data collection and processing for each of the supporting schedules and the balance sheet
  - To assist protected landscape partners in choosing appropriate data and methods throughout.

  The work required use of internal data (e.g., on assets) and to identify external data (e.g., on some monetary valuation methods) which could be used in the account, with eftec advising on the correct calculation processes for quantifying benefits and expressing the values in monetary terms (answer questions II and III above).
- **Phase 3: Review of output**. In line with eftec's quality assurance processes, the NUCLNP natural capital accounting workbook and report have been reviewed internally. This includes a review of the structure and the boundary of the account (to be consistent with the CNCA framework), the quality of the input evidence, and consistent application of calculation processes.

2.3 High nature value farming scenario analysis

The baseline natural capital account provides data that can be applied at different scales, and also used as a basis to assess the impacts of land management options. A scenario has been developed of a representative upland livestock farm, comparing a 'high-nature value' farming system to a more intensive commercial farm. The analysis aims to inform potential Environmental Land Management Scheme (ELMS) funding, based on the opportunity costs and public goods value of HNV farming, compared to the commercial alternative. Full details of the scenario are in Appendix C.

3.Scope of the natural capital benefits account

Scoping of the account defines the spatial boundary of the account, the natural capital assets and the benefits covered and presentation of results.

3.1 Spatial boundaries and asset register

The spatial boundary for the NUCLNP benefits account is based on the NUCLNP boundary. This includes including Northumberland National Park, North Pennines AONB, Yorkshire Dales National Park, Nidderdale AONB and the Forest of Bowland AONB. It also includes the extensive National Nature Reserves of Kielderhead and Whitelee Moor as well as Kielder Forest and Water (i.e., aggregated to form the 'Kielder' reporting area), and the 'Tyne gap' between the North Pennines AONB and Northumberland National Park and the National Character Area 10 beyond the North Pennies AONB (to create 'Tyne Gap + NCA 10' reporting area). These are the seven reporting areas that encompass the NUCLNP natural capital account and are shown in Figure 3.1.

The natural capital assets are defined by the extent and condition of habitats and land use types within the account boundary. Biodiversity is reflected in the detailed mapping data, but in the asset register is covered only through data on specific habitats and designated sites. Many benefits are from services that are provided by a combination of assets. Further details of the asset register area in Section 4.

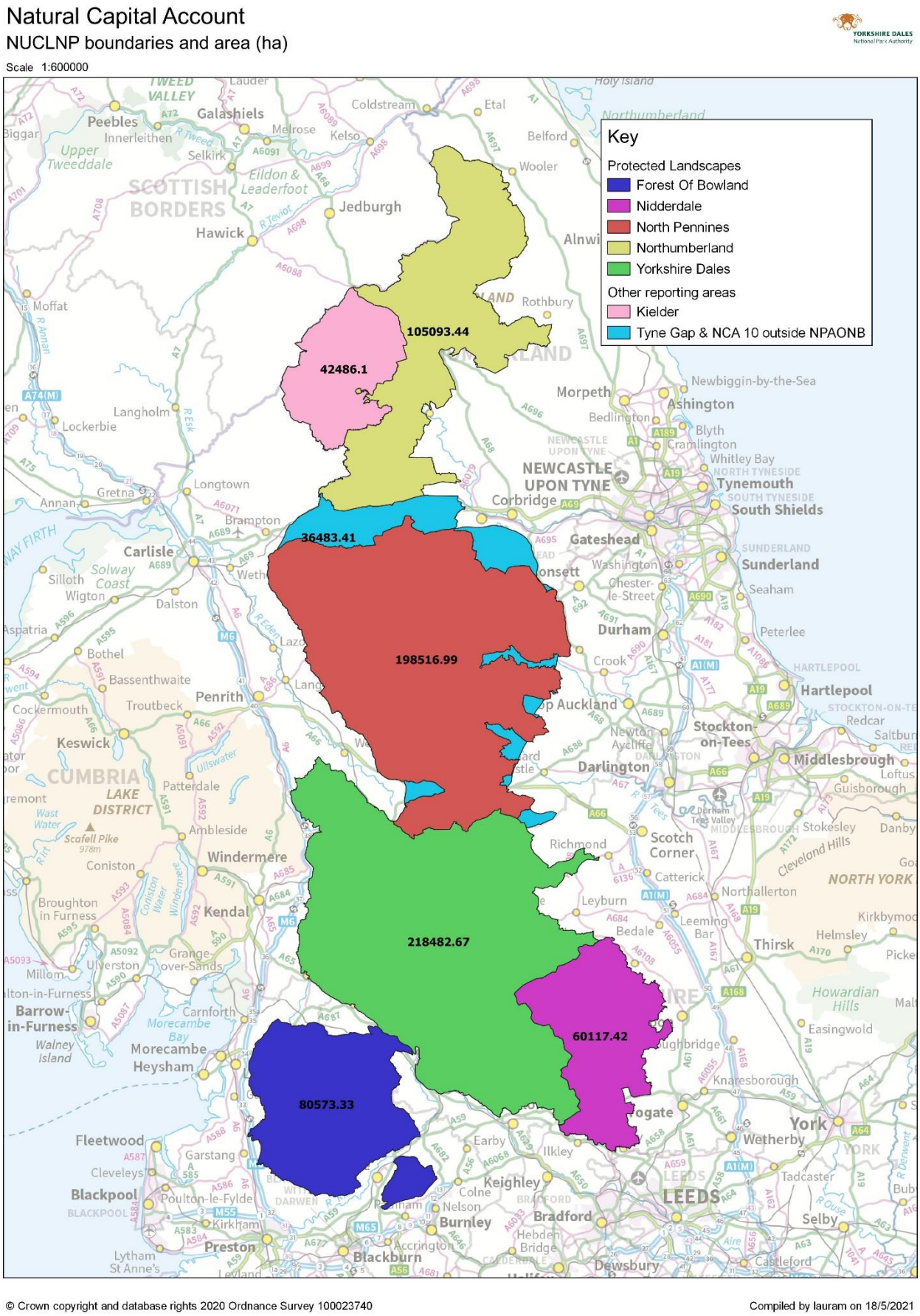

Figure 3.1: NUCLNP accounting boundary and reporting areas

3.2 Benefits

The list of potential benefits to assess reflects the list of individual benefits included in Defra's (2020) 'Enabling a Natural Capital Approach' (ENCA). This includes:

- Food provision
- Fishing (commercial)
- Timber
- Water supply
- Renewable energy
- Carbon sequestration
- Air quality regulation
- Flood risk management
- Noise reduction
- Temperature regulation
- Recreation
- Physical health
- Education
- Volunteering
- Amenity
- Biodiversity
- Soil
- Water quality
- Landscape
- Non-use values

Further to this list, minerals, other fibres and materials as well as mental health benefits are considered.

The methods used to assess these benefits for the NUCLNP are described in Section 4.3.1 and Appendix A. The calculations are linked to the location, extent and condition of natural capital assets, as identified in the asset register, described area in Section 4. Monetary valuations are prioritised in the accounts, but are not possible for all the material benefits. The baseline year for the analysis is 2020. Monetary values published in earlier price years are inflated to 2020 values using the latest HM Treasury (2021) GDP deflators. Asset values are estimated using HM Treasury Greenbook (2020) guidance following a declining discount rate and a 60-year assessment period.

3.3 Presentation of results

Information inputted into and results from the accounting can be presented for different spatial areas and for different beneficiaries. Results can be disaggregated to the five protected landscapes, national character area and Kielder reporting boundaries as per Figure 3.1.

For this account benefits by beneficiaries are shown in two main groups: 'Businesses' (i.e., where the value identified is a financial return to a business) and 'the rest of the society' (i.e., public benefits to wider society). Businesses are represented by sectors (e.g., agriculture, forestry).

This account was developed to provide results for the whole local nature partnership, and to allow comparison of reporting areas within this boundary. Accounts specific to parts of the region can adopt different mapping, list of benefits and analysis approaches specific to local data and issues. The natural capital account(s) that is most applicable to the specific decisions should be used in each case.

4. Summary of the NUCLNP benefits account

This section presents the data for the NUCLNP benefits account, described in Section 2.2. The account uses data for 2020 where possible, otherwise the latest available year is included. It covers the natural capital assets within the NUCLNP accounting boundary. This reflects the land management boundary, including assets that are either owned or managed by the protected landscapes. Where possible, protected landscape partners have provided data which has been combined with other publicly available datasets to fill in any gaps in evidence.

4.1 Asset register

The asset register is a registry of all natural capital assets within the boundary of the account. It forms the foundation of the account and records both the extent and condition of the assets.

4.1.1 Natural capital extent

The extent account records the size and location of the areas of natural capital assets, based on identifiable habitats and land uses. The construction of the asset register aligns to the Natural England Priority Habitat Inventory, utilising data from several sources:

- Protected landscape partner records,
- Land Cover Map 2019 (Morton et al., 2019)
- Priority Habitat Inventory (Natural England, 2020),
- National Forest Inventory (Forestry Commission, 2018), and
- Water Framework Directive Lakes (Environment Agency, 2020).

By combining data from multiple sources, the mapping provides a detailed understanding of land cover area in the asset register.

The natural capital assets within the account are classified by land-use and habitat types and are summarised in Table 4.1. Total area of the Northern Upland Chain LNP is approximately 742,000 hectares, where the predominant habitats are improved grassland (23%), priority wetland (22%), upland grassland (18%) and priority heathland (14%).

Figure 4.1, summarises the asset extent account for the NUCLNP by UK broad habitat. In this account, priority and other wetland are interpreted as the UK broad habitat 'mountain, moorland and heath' rather than 'freshwater' as the majority of this refers to blanket bog and fen marsh.

Table 4.1: Overview of natural capital extent

	Habitat	Area (hectares)	% of total
Woodland	Broadleaved woodland	14,421	2%
	Coniferous woodland[1]	52,480	7%
	Young trees	10,209	1%
	Assumed woodland	3,563	0.5%
Non-woodland	Priority grassland	21,114	3%
	Upland acid grassland	134,854	18%
	Semi-improved grassland	24,796	3%
	Improved grassland	172,657	23%
	Priority wetland	165,355	22%
	Other wetland	9	<0.01%
	Priority heathland	103,038	14%
	Other heathland	2,538	0.3%
	Limestone pavement	1,382	0.2%
	Inland rock outcrops, cliffs and scree	564	0.1%
	Arable and horticulture	4,357	0.6%
	Hedgerows	369	0.05%
	Urban	3,162	0.4%
	Lakes[2]	3,440	0.5%
	Other[3]	24,038	3.2%
	Total	**742,347**	**100%**

Table notes:

[1] For Kielder and Northumberland National Park the National Forest Inventory (NFI) woodland category 'felled, failed, ground prep and windblown woodland' has been added to coniferous woodland in the asset register. This would normally be returned to conifer, and therefore have assumed that part of this has been returned to conifer since 2018.

[2] Represents total area of WFD lakes (Environment Agency, 2020).

[3] Initial mapping results for NNPA, YDNPA and NPAONB resulted in large areas being 'unallocated'. Based on Land Cover Map 2019 data, it was assumed that the majority of this is additional acid grassland (e.g., for YDNPA 90% was reallocated). The remaining unallocated area has been defined as 'other'.

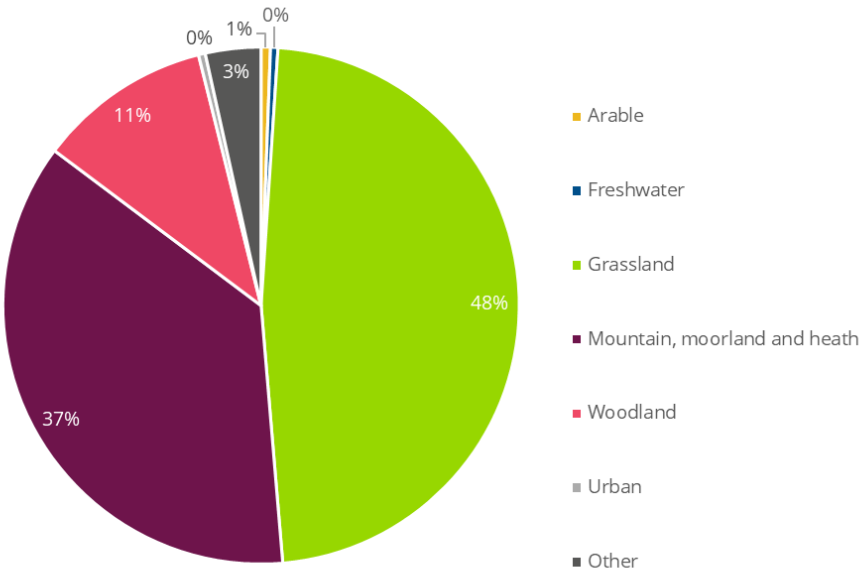

Figure 4.1: NUCLNP area by UK broad habitat

In addition, Table 4.2 summarises the areas of peatland soils and commercial woodland as well as existing mineral resource and renewable energy sites. This is also recorded in the asset register to provide further understanding of land uses within the accounting boundary.

Table 4.2: Other natural capital extents

Indicator		
Peatland	**Area (hectares)**	**% of total**
Deep peaty soils	222,607	48%
Shallow peaty soils	221,270	48%
Soils with peaty pockets	21,226	5%
Total	**465,103**	
Commercial woodland	**Area (hectares)**	**% of total**
Commercial coniferous woodland	30,098	100%
Total	**30,098**	
Mineral sites[1]	**Number**	**% of total**
Carboniferous limestone	3	43%
High PSV gritstone	3	43%
Carboniferous limestone and High PSV gritstone	1	14%
Total	**7**	
Sites of renewable energy – electricity[2]	**Number**	**% of total**
Onshore wind	15	10%
Hydro	12	8%
Solar	124	82%
Total	**151**	

Table notes:

[1] Only represents mineral sites within Yorkshire Dales National Park, and not the total number of mineral sites within the NUCLNP.

[2] Only represents sites of renewable energy within Forest of Bowland AONB, Northumberland National Park and Yorkshire Dales National Park, and not the total number of renewable energy sites within the NUCLNP.

4.1.2 Natural capital condition

The type and size of benefits provided by natural capital assets are determined by the extent (quantity) and condition (quality) of those assets. Therefore, the natural capital asset register also includes data on condition. Such data needs to be collected through establishing indicators of condition such as different land use, existing monitoring data and designations.

These include recreation land (parks), open access land, and specific designations such as Sites of Special Scientific Interest (SSSI), National Parks and Areas of Outstanding Natural Beauty (AONB). These categories are generated separately and will overlap with habitat areas. For example, for a given area of woodland, the specific area of which is designated as SSSI, or Ancient Woodland can also be recorded.

Table 4.3: Terrestrial designations

Indicator		
Designated SSSIs	**Area (hectares)**	**% of total SSSI area**
Favourable condition	47,679	22%
Unfavourable recovering condition	160,660	74%
Unfavourable declining condition	3,290	2%
Unfavourable no change	4,457	2%
Part destroyed	-	-
Destroyed	-	-
Total	**216,086**	**100%**
Other designated areas	**Areas (hectares)**	**% of total NUCLNP area**
Areas of outstanding natural beauty	339,803	46%
National Parks	323,576	44%
Ancient woodland	4,778	1%
Total NUCLNP extent	**742,347**	**100%**
Accessibility		
Area of greenspace	44,699 hectares	
Length of footpaths	6,009 kilometres	
Length of accessible PRoWs[1]	215 kilometres	
Length of all PRoWs[2]	4,908 kilometres	

Table notes:

[1] Only represents accessible PRoWs within Yorkshire Dales National Park, and not the total length within the NUCLNP.

[2] Only represents length of all PRoWs within North Pennines AONB, Forest of Bowland AONB, Yorkshire Dales National Park, and not the total length within the NUCLNP.

In addition, the asset register presents condition data on the water environment including Water Framework Directive status (number, length and area of water bodies by status).

Table 4.4: Water Framework Directive waterbodies

Water Framework Directive status			
Rivers	**Count**	**Length (kilometres)**	**% of total length**
Bad	3	22	1%
Poor	50	283	9%
Moderate	350	2,873	90%
Good	-	-	-
Total	**403**	**3,178**	**100%**
Lakes	**Count**	**Area (hectares)**	**% of total area**
Bad	-	-	-
Poor	-	-	-
Moderate	47	3,440	100%
Good	-	-	-
Total	**47**	**3,440**	**100%**

Data on the extent and condition of assets in the asset register forms the basis of the materiality and benefits assessments methods, which combine it with unit value and other context data, as described in Section 4.3.

4.2 Materiality assessment

A materiality[8] assessment is used to determine which benefits should be included in the account, given the natural capital assets in scope. All the individual benefits in Defra's ENCA guidance (2020) were considered for inclusion in the account[9]. The assessment shows which benefits are considered material, and out of the material benefits which have been possible to include in this account and which have not. The assessment has been undertaken using a service-asset attribute matrix which aims to show:

- Which ecosystem services are material for each asset within the NUCLNP account boundary;
- Of these material ecosystem services, which benefits have been assessed and how; and
- Which have not been possible to measure in biophysical units or value in monetary terms and why.

The materiality assessment for the NUCLNP benefit assessment is shown in Table 4.5. The assessment was conducted in consultation with the protected landscape project partners and represents the consolidated materiality for the NUCLNP accounting boundary. Note individual materiality assessments for each reporting area have not been produced.

Benefits that are considered not to be material for these accounts include:

- Fishing (commercial),
- Noise regulation, and
- Temperature regulation.

The following benefits are considered material but have not been measured in these accounts:

- **Water supply** – Abstraction data has been requested from the Environment Agency. The request has not been fulfilled within the project timeframe. Future iterations of the account can work towards including water abstractions by purpose and its value.
- **Flood risk management by non-woodland habitats** – Difficult to quantify the benefit provision without more detailed modelling (e.g., identifying flood risk areas and natural capital assets providing flood risk benefits)
- **Mental health benefits of engagement with nature** – Following current ENCA guidance (Defra, 2020), only physical health benefits are valued in this report as there is currently insufficient evidence to value mental health benefits in general terms. While the evidence for mental health benefits from green space is strong, it is context dependent and not readily generalisable for the purposes of accounting and policy analysis.

[8] This is defined in the Natural Capital Protocol as "an impact or dependency on natural capital is material if considering it, as part of the set of information used for decision making, has the potential to alter that decision" (p. 43, Capitals Coalition, 2016).

[9] Defra's ENCA (2020) also reflects 'bundled' benefits which include amenity, soil, landscape and non-use values. These are not considered for this account to avoid double-counting with the individual benefits already included (e.g., recreation).

Table 4.5: Materiality assessment

	Natural capital assets						
Public and private benefits	Arable	Freshwater	Grassland	Mountain, moorland and heath	Woodland	Urban	Other
Food provision	●						
Fishing (commercial)							
Timber					●		
Fibre and materials	●						
Water supply							
Renewable energy							●
Minerals							●
Carbon sequestration	●		●	●	●		
Air quality regulation					●		
Flood risk management					○		
Noise reduction							
Temperate regulation							
Recreation	●	●	●	●	●	●	
Physical health	●	●	●	●	●	●	
Mental health							
Education	●	●	●	●	●		
Volunteering	●	●	●	●	●		
Tourism	●	●	●	●	●	●	
Water quality		●					
Biodiversity	○	○	○	○	○		○
Legend							
Material service provision							
No material service provision							
Benefit estimated in quantitative and monetary terms						●	
Benefit estimated in non-monetary terms						○	

4.3 Natural capital asset values

This section provides a summary of the methods used to estimate natural capital asset values for the NUCLNP, with further details in Appendix A.

The NUCLNP account results represents a sum of the seven reporting areas. Where possible, the methods described in Table 4.6 are used for all reporting areas. However, due to lack of quantified information or spatial data on natural capital assets, some of the benefits at the NUCLNP are only representative of a few of the reporting areas. This is for a few benefits, which include:

- Renewable energy – only reflects Northumberland National Park and Forest of Bowland AONB as these are the protected landscapes that provided data on electricity generation.
- Minerals – only reflects Yorkshire Dales National Park as they were able to provide mineral extraction data.
- Education – only reflects Northumberland National Park and Yorkshire Dales National Park as these are the protected landscapes that could readily provide visitor data.
- Volunteering – only reflects Northumberland National Park and Yorkshire Dales National Park as these are the protected landscapes that could readily provide volunteer data.

4.3.1 Methodology

Table 4.6 provides an overview of the benefits included in the accounts and the methods used to evaluate them. The methods used in the two accounts are aligned to ensure the results for each operating area can be compared.

The distribution of benefits between private benefits to business sectors and benefits to wider society, is also noted. The distribution of values across business sectors can be readily extracted from the accounts, for several benefits:

- Agriculture sector – arable and livestock income;
- Forestry sector – softwood removals value;
- Wool sector – value of wool production;
- Hydropower and onshore wind sector - renewable energy resource rent;
- Minerals and aggregates sector – ex-works sales value of sand and gravel; and
- Tourism and outdoor leisure – domestic tourism spending (note this excludes spending in trips of under 3-hour durations, but this spending is known to be very small compared to overall tourism spending (eftec et al, 2019)).

Table 4.6: Summary of natural capital benefit methods

Benefit	Description	Annual physical flow measure	Monetary valuation metric & method	Beneficiary
Food provision	Estimated yields for land in agricultural use (Defra, 2021) is assumed to be represented by wheat, barley and oilseed rape (Redman, 2018; 2019; 2020). The monetary value of arable production is calculated using average gross margin estimate per tonne of representative of crops (Redman, 2018; 2019; 2020).	Total arable production (t/yr)	Gross margins from arable production (£/tonne)	Agriculture sector
	In addition, total livestock production is quantified based on available records from Defra (2021). The monetary value of livestock production is calculated by using gross margin estimates per unit (Redman, 2018; 2019; 2020).	Total livestock production (heads/yr)	Gross margins from livestock production (£/head)	Agriculture sector
Timber	Estimated based on the area of coniferous woodland and the UK average volume of softwood removals (m^3/ha). Estimated volume of removals is valued using the GB average softwood stumpage price (£/m^3).	Volume of softwood removals (m^3/yr)	Value of softwood removals (£/yr)	Timber sector
Other fibres and materials	Estimated for wool production by upland sheep, based on average volume of wool per ewe and valued using the average price of wool (Redman, 2020).	Volume of wool produced (kg/yr)	Value of wool production (£/yr)	Wool sector
Renewable energy	Estimated electricity generation from hydropower and onshore wind (MWh) based on installed sites within protected landscapes. Electricity generated is then valued at the national average resource rent (ONS, 2019).	Electricity generation from onshore wind (MWh/yr)	UK unit resource rent (£/MWh)	Renewable energy sector
	The benefit of energy generated from onshore wind (MWh) (BEIS, 2019) valued at the national average resource rent (ONS, 2019).	Electricity generation from hydropower (MWh/yr)		
Minerals	The volume of sand and gravel extracted based on output estimates provided by the protected landscape partners. The volume is valued at the UK average price of sand and gravel (British Geological Survey, 2021).	Volume of sand and gravel extracted (tonnes/yr)	UK unit ex-works sales value of sand and gravel (£/tonne)	Minerals and aggregates sector
Carbon sequestration	Estimated for woodland habitat using the average UK sequestration rate (tonnes CO_2 equivalent per hectare) and the non-traded price of carbon.	Carbon sequestered in woodland and improved grassland (tCO_2e/yr)	Non-traded central carbon value BEIS (2021)[10] £/t/CO_2e	Global society
	Estimated for peatland habitat using the IUCN Peatland Code (2015) rates (tonnes CO_2 equivalent per hectare) and the non-traded price of carbon.	Carbon emitted by peatland (tCO_2e/yr)		
	Emissions are estimated using livestock emission factors by livestock type (Defra, 2019b; Jones et al., 2019) and the non-traded price of carbon (BEIS, 2021).	Carbon emitted by livestock (tCO_2e/yr)		

[10] BEIS. (2021). Valuation of greenhouse gas emissions: for policy appraisal and evaluation. Available at: https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation

Benefit	Description	Annual physical flow measure	Monetary valuation metric & method	Beneficiary
Air quality regulation	Estimated for woodland using the average rate of PM2.5 removal for the local authorities covered by the account and avoided health risks and medical costs as a result.	PM2.5 removed by woodland (kg/yr)	Avoided cost (medical treatment and productivity) and welfare gain(£/ha) by eftec and CEH (2019)[11]	UK society
Flood risk management	Estimated for woodland using the annual average additional woodland soil water storage capacity (Forest Research, 2018).	Annual average additional woodland soil water storage capacity (m^3/yr)	Not evaluated in monetary terms	-
Recreation	Estimated in terms of number of visits to accessible greenspaces (that are less than 3 hours), and the welfare value associated with these visits.	Recreational visits, less than 3 hours (visits/yr)	Benefit to visitors evaluated as total welfare value from (ORVal) tool[12].	Visitor population
Physical health	Estimated by the proportion of the visits that are active, the health benefits of active recreation (in terms of improvements in Quality Adjusted Life years (QALYs)[13]) and the economic value of health improvement. Avoiding these costs is additional to the welfare from enjoying good health/recreation.	Total active visits	Avoided medical treatment costs per year, based on Claxton et al. (2015)[14].	Visitors
Education	The number of pupils making educational visits to protected landscapes in NUCLNP are valued through a proxy based on the costs of providing the visit.	Educational visits (days/yr)	Resource cost (£/pupil visit) as proxy for value, based on Clark (2017)[15]	Visitors
Volunteering	Estimated through volunteer effort and valued based on labour cost differentiated by the type of work volunteers undertake.	Volunteering effort (days/yr)	Resource cost (£/day) of unskilled and skilled labour, from Heritage Lottery Fund[16]	Volunteers
Tourism	Domestic tourism is measured in terms of the number of day visits (i.e., visits that are more than 3 hours but do not include an overnight stay) and tourism visits to areas	Total overnight stays (visits/yr)	Expenditure by domestic overnight stays attributed to	Local businesses

[11] https://shiny-apps.ceh.ac.uk/pollutionremoval/

[12] Day, B. H., and G. Smith (2018) Outdoor Recreation Valuation (ORVal) User Guide: Version 2.0, Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter. https://www.leep.exeter.ac.uk/orval/

[13] QALY is a health measurement used widely in health and health economics research. QALY of zero denotes death, and 1 denotes full health.

[14] Claxton K, Martin S, Soares M, Rice N, Spackman E, Hinde S, et al. (2015). Methods for the Estimation of the NICE Cost Effectiveness Threshold. Health Technology Assess. [online]. Available at: https://www.york.ac.uk/che/research/teehta/thresholds/

[15] Clark, R. (2017). Is Corporate Natural Capital Accounting appropriate for monitoring nature reserves? An assessment for National Nature Reserves managed by Natural England. Natural England Research Reports, Number 072. [online]. Available at: http://publications.naturalengland.org.uk/publication/5727968978010112

[16] Heritage Lottery Fund (2017). Our heritage - Application guidance. [online]. Available at: https://www.heritagefund.org.uk/sites/default/files/media/attachments/oh_application_guidance.pdf

Benefit	Description	Annual physical flow measure	Monetary valuation metric & method	Beneficiary
	within the NUCLNP and valued using the average expenditure per visit for local authorities within each reporting area (Kantar, 2019a; 2019b). This is then adjusted to reflect the attributable spend to nature (approx. 8% of total spend based on ONS (2021).		nature (£/trip)	
Water quality	Estimated as the welfare gain from maintaining the Water Framework Directive (WFD) quality status of the of waterbodies (Environment Agency, 2020) as reported in the natural capital asset register. The welfare gains from maintaining the WFD status makes use of the NWEBS values for each river basin district in the accounting boundary.	Length (km) and area (km^2) of WFD waterbodies by status	WTP for avoided deterioration from NWEBS (£/km) (Metcalfe, 2012; NERA Economic Consulting, 2007)	UK society
Biodiversity	The valuation of biodiversity is complex and, in many contexts, contentious. A portion of this value is indirectly captured in the biodiversity indicators presented in the account for SSSI condition, as well as through the value of other benefits to which biodiversity contributes.	Area of SSSI (hectares)	Not evaluated in monetary terms	-

4.4 Results for the NUCLNP

The physical and monetary estimates for each benefit are given a confidence rating which is described in Table 4.7. The estimated annual physical and monetary values, and present value of benefits over the 60 years are summarised in Table 4.8.

Table 4.7: Assessing data quality

Level of confidence	Symbol	Description
Low	●	Evidence is partial and significant assumptions are made so that the data provides only order of magnitude estimates of value to inform decisions and spending choices.
Medium	●	Science-based assumptions and published data are used but there is some uncertainty in combining them, resulting in reasonable confidence in using the data to guide decisions and spending choices.
High	●	Evidence is peer reviewed or based on published guidance so there is good confidence in using the data to support specific decisions and spending choices.
No colour	●	Not valued

The accounts identify a wide range of benefits from the natural capital within the NUCLNP management area. Table 4.8 shows significant values for provisioning (e.g., agriculture), regulating (e.g., carbon sequestration) and cultural (e.g., recreation) services, as well as significant health benefits in relation to physical activity. Overall, there is medium to high confidence for most benefits, except for the estimated tourism expenditure attributed to nature which is low.

Total net annual benefit value for the NUCLNP is approximately, £33 million in 2020 prices. This comprises both positive (e.g., carbon sequestration) and negative impacts (e.g., carbon emissions) from monetized benefits. The greenhouse gas impact of livestock and peatland (-£493 million per year) outweigh the benefits of carbon sequestered by woodland and improved grassland (£139 million per year). Other key benefit values include domestic tourism expenditure supported by the NUCLNP environment (£85 million) and livestock income (£79 million).

Table 4.8: Summary of benefits values in the NUCLNP benefits account

At September, 2021	Physical flow (unit/yr)	2020/21	Confidence	Monetary value (£m/yr)	2020/21	Confidence	PV60 (£m)
Key monetised benefits							
Food provision	Arable food production (tonnes)	30,892	●	Arable income	4	●	109
	Livestock production (no. heads)	1,035,586	●	Livestock income	79	●	2,066
Timber	Volume of softwood removals (m^3)	235,571	●	Value of softwood removals	7	●	179
Other fibres and materials	Volume of wool production (kg)	1,636,835	●	Value of wool	0.3	●	7
Renewable energy	Electricity generated by onshore wind (MWh)	13,332	●	Resource rent value of onshore wind	0.1	●	3
	Electricity generated by hydropower (MWh)	46,854	●	Resource rent value of hydropower	0.4	●	9
Minerals	Volume of minerals extracted (tonnes)	3,912,317	●	Ex-works value of mineral production	49	●	1,045
Carbon sequestration	CO_2e sequestered in habitats (tCO_2e)	576,162	●	Value of CO2e sequestered in habitats	139	●	5,089
	CO_2e emitted by habitats (tCO_2e)	(1,757,532)	●	Value of CO2e emitted by habitats	(424)	●	(15,524)
	CO_2e emitted by livestock (tCO_2e)	(289,550)	●	Value of CO2e emitted by livestock	(70)	●	(2,558)
Air quality regulation	PM2.5 removal by woodland (kgPM2.5)	354,009	●	Value of PM2.5 removal by woodland	7	●	183
Recreation	Adult recreation visits (under 3 hours) (visits)	16,365,676	●	Adult recreation welfare value (under 3 hours)	71	●	1,864
Physical health	Active visits (active visits)	8,428,323	●	Avoided medical treatment costs	29	●	1,159
Education	Number of education visits (visits)	8,748	●	Value of educational visits	0.03	●	1
Volunteering	Number of volunteer days (days)	10,848	●	Value of volunteer days	1	●	31
Tourism	Domestic day visits and overnight trips attributed to NC (visits)	3,161,170	●	Domestic tourism expenditure attributed to natural capital	85	●	2,236
Water quality	Length of WFD rivers (km)	3,178	●	Welfare of avoiding deterioration in rivers	55	●	1,433
	Area of WFD lakes (km^2)	34	●	Welfare of avoiding deterioration in lakes	0.2	●	6
				Total value	**33**	●	**(2,662)**
Key non-monetised benefits							
Flood risk management	Annual average additional woodland soil water storage capacity (m^3)	11,058,735	●		Not valued	●	Not valued
Biodiversity	Total SSSI area (ha)	216,086	●		Not valued	●	Not valued

5. Results and next steps

This section shows the NUCLNP baseline benefits account results and interpretation with account results for the Yorkshire Dales National Park shown in Appendix B as an example of accounts results for a reporting area. The accompanying workbook (NUCLNP-NCA-workbook-final.xls) facilitates comparisons across the seven reporting areas through a drop-down function.

The asset values estimated are reported in the natural capital balance sheet. The asset values are separated into benefits to businesses and benefits to the rest of society. Asset values are calculated by summing the expected future annual flow of benefits over 60 years, discounted according to HM Treasury Green Book Guidance (2020) to express in present value terms. Where possible, future values take into account expected trends in the quantity and/or value of the benefit. Where this information is not available, benefits are assumed to be constant over time – this assumption increases the uncertainty of the results, the implications of which are reported in Section 5.3.

Interpretation of the LNP account would also be improved through better understanding of the current spending to manage natural capital in the region (Step IV in Section 2.1), which would allow production of an LNP 'natural capital balance sheet' (V). This spending data is not routinely gathered in the UK, but methods are now available to do so – this is one of a number of potential next steps, discussed in Section 5.3.

5.1 Northern Upland Chain baseline account

Table 5.1 reflects the distribution of benefits to businesses and wider society. Most of these benefits accrue to wider society through air quality regulation, carbon sequestration, water quality, recreation and physical health, equating to around £12 billion in present value terms. These are however offset by the dis-benefits of greenhouse gas emissions from livestock and peatland equal to approximately £18 billion over the assessment period. Therefore, total net asset value to wider society is -£6 billion in present value terms. A further £3 billion accrues to businesses through agriculture, timber, wool production, renewable energy and minerals. Overall, the NUCLNP's natural capital assets have a negative asset value of £2.6 billion in present value terms.

In general, there is high to moderate confidence in both the physical and monetary flow estimates, with present value estimates having greater uncertainty due to assumptions on future trends. Key gaps and uncertainties for the NUCLNP accounting boundary include:

- Partial estimates of renewable energy, minerals, education and volunteering benefits across the NUCLNP, as data for each protected landscape partner was not easy to access.
- The non-monetised and unquantified benefits listed in Table 5.1 are expected to be material. Further work could include undertaking a baseline biodiversity assessment for the region; however, this is expected to require support from other stakeholders.
- The maintenance costs associated with natural capital and their distribution (e.g., tree thinning, greenspace maintenance) should be included in order to understand the relationship over time between spending on assets and the benefits they provide.

Table 5.1: Northern Upland Chain natural capital asset valuation, PV60 £m

	Valuation metric	Value to businesses	Value to the rest of society	Total
Asset values (monetised)				
Food provision	Arable income	109		**109**
	Livestock income	2,066		**2,066**
Timber	Value of softwood removals	179		**179**
Other fibres and materials	Value of wool	7		**7**
Renewable energy	Resource rent value of onshore wind	3		**3**
	Resource rent value of hydropower	9		**9**
Minerals	Ex-works value of mineral production	1,045		**1,045**
Carbon sequestration	Value of CO_2e sequestered in habitats		5,089	**5,089**
	Value of CO_2e emitted by habitats		(15,524)	**(15,524)**
	Value of CO_2e emitted by livestock		(2,558)	**(2,558)**
Air quality regulation	Value of PM2.5 removal by woodland		183	**183**
Recreation	Adult recreation welfare value (under 3 hours)		1,864	**1,864**
Physical health	Avoided medical treatment costs		1,159	**1,159**
Education	Value of educational visits		1	**1**
Volunteer	Value of volunteer days		31	**31**
Tourism	Domestic tourism expenditure attributed to natural capital		2,236	**2,236**
Water quality	Welfare of avoiding deterioration in rivers		1,433	**1,433**
	Welfare of avoiding deterioration in lakes		6	**6**
Total gross asset value		**3,418**	**(6,080)**	**(2,662)**
Asset values (non-monetised)				
Flood risk management	Volume of water held back by woodland: 11 million m^3			
Biodiversity	Total SSSI area: 216,000 hectares			
Other material unquantified benefits				
Water supply				
Mental health				

5.2 High Nature Value farming account

To investigate the natural capital benefits of high nature value upland farming, a scenario representing a typical upland livestock farm was defined – involving a 650 ha upland farm, including 400 ha of moorland. For this farm, a high-nature value farming system is compared to a conventional farming system. The grassland area is grazed more intensively under the conventional system, supported by higher Nitrogen inputs. As a result, the conventional system achieves a higher gross margin per hectare on the grassland area. Further details are in Appendix C.

For the comparison for the farming systems, the following benefits are measured and valued:

- Food provision
- Other fibres and materials (i.e., wool)
- Carbon sequestration in woodland
- Air pollutant removal by woodland

- Recreation
- Tourism

The measured benefits exclude some significant impacts to society from management of farms in the upland landscape, including biodiversity, landscape, water quality and flood risk management.

The differences in the valued benefits between the two scenarios are shown in Table 5.2. These differences mainly arise from the management of the grassland area, with the moorland SSSI is likely to be supported by different funding lines targeted at biodiversity. Therefore, payment rates are calculated per ha for the 250 ha of grassland and woodland.

Compared to the conventional scenario, the HNV farm provides significantly less direct farm income from livestock (- £26,300 per year), this could be used to design payments on an income forgone basis (giving £105 per ha). It also generates far greater public benefits (£91,900 per year), which would justify higher payments (£367 per ha per year). An overall payment rate would add these values, but society would want the value of the public benefits to exceed the payment: this could be £105 plus some fraction of £367 (say half): (i.e., £105 + (£367/2)) = £289/ha per year.

Table 5.2: Difference in annual values between farming scenarios

		Difference in value (HNV – Conventional, £ per year)	
	Valuation metric	**To farm business**	**To the rest of society**
Key monetised benefits			
Food provision	Livestock income	(26,000)	
Other fibres and materials	Value of wool	(326)	
Carbon sequestration	Value of CO_2e sequestered in habitats		(6,312)
	Value of CO_2e emitted by livestock		32,943
Air quality regulation	Value of PM2.5 removal by woodland		1,519
Recreation	Adult recreation welfare value (under 3 hours)		45,882
Tourism	Domestic tourism expenditure attributed to natural capital		17,833
Difference in gross annual value		**(26,326)**	**91,866**

To put the values and potential payment rates in context, they can be compared to the costs of recreating HNV grassland habitats. eftec et al (in prep) assesses the costs of recreating habitats for biodiversity net gain in England. It identifies costs of £27,000-£68,000 per ha of high distinctiveness grassland over 30 years. The present value of paying £289 per ha over 30 years is £5,500, which is significantly lower. Such payments to maintain existing HNV farming, as well as being ecologically preferable, therefore offer better value for money than restoration of such habitats.

5.3 Recommendations

eftec has successfully worked with the NUCLNP, coordinated by YDNPA, to develop a natural capital account for the LNP and the constituent designated landscapes. The account can be used in different ways. Firstly, it provides a consistent evidence base for different groups and decision-makers to refer to. For

example, Biodiversity Net Gain, ELMS design and other policies can work off connected data. Secondly, the account provides useful information to help manage natural capital, but the positive balance sheet values do not mean that the natural capital assets are being managed sustainably.

Lessons learnt from this accounting process:

Data collection and collation can be challenging. The system for collating asset register data for each protected landscape has successfully enabled a large amount of data to be collated, but it is not as smooth as it could be. Internal (e.g., within NUCLNP) and external (e.g., Environment Agency) data systems are not necessarily set up to provide data for this accounting boundary. These systems can be improved through collaboration and digital analysis but doing so has resource implications.

Improvements to the account:

The following suggestions are made to improve future analysis in the accounts.

- **Refine asset and benefit data:** More work could be undertaken to refine certain data, particularly the extent and condition of habitats (e.g., grasslands, peatlands) and the benefits included in the balance sheet that are material but only partially reflect the protected landscapes (e.g., minerals). The extent and condition of peatlands is critical data in relation to biodiversity, current carbon emissions and potential future carbon finance.
- **Assess the cost of maintaining natural capital assets, including in response to future pressures from climate change:** As described in Section 2, a complete natural capital account would include an assessment of current and planned spending on maintaining the extent and condition of the natural capital assets providing the benefits assessed. Maintenance can be understood in the broadest sense of including restoration, maintenance and enhancement. This enables comparison of expected costs and benefits, and consideration of whether enough resources are being put into the right actions to ensure those benefits and the natural capital assets that provide them are sustained over time. However, at the LNP scale this would require buy-in from key public and private stakeholders who manage the majority of relevant spending and their willingness to provide such data.
- **Better understanding is needed of future trends in benefits from natural capital, including those caused by climate change:** The economic value of the benefits provided by natural capital assets is the values aggregated over time based on the assumption that the assets are maintained to provide those benefits over time. Expected future changes in the quantity and/or value of benefits are reflected in the estimates where relevant data is available (such as factoring in population growth and increasing value of mitigating carbon emissions – as reflected in the account workbook). However, there is insufficient data to represent some expected future changes (such as climate change risks) in the account. While management effort is made to maintain natural capital assets (e.g., through soil management on farms and biodiversity targets) it is not certain that current maintenance costs will be sufficient to maintain the natural capital assets in the long term, particularly in the face of climate change.
- **Develop a natural capital risk register:** An assessment of future risks and pressures is suggested to identify what actions NUCLNP, and relevant stakeholders can take to address those and how much these actions will cost. This will help address the points above, going forward, as well as help identify potential sources of finance for different actions. The key risks may be recorded within individual landscape's risk management processes, or in a combined natural capital risk register for the NUCLNP.

In terms of updating the account, there are some technical updates to methods needed over time. An example is the UK Government approach to valuing GHG emissions was revised on 2 September 2021. This has not fed through to this iteration of the NUCLNP and reporting area accounts. To facilitate these updates and enable collaboration across the NUCLNP training to relevant partners should be considered. As well as, developing an NUCLNP network (e.g., for practitioners) but also a larger network with different user groups (e.g., peatland projects) to enable better data collection.

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Appendix A - Benefit methodologies

This appendix describes our approach to quantifying and valuing the benefits provided by natural capital assets in the NUCLNP accounting boundary. The analysis covers the physical and monetary flows of the benefits listed in Section 4.3.1. In future iterations of the account, other benefits can be added.

A.1 Food provision

Food provision comprises both arable and livestock outputs and is a significant sector in the region. The benefit is measured based on the marketed production from the sector at the market prices. The distinction was raised by stakeholders between business and societal benefits of food provision. Business benefits refer to net income to farmers, which can be proxied by gross margin. Defra (2021) agricultural census provides the area of crops and the number of livestock (cattle and sheep) within commercial landholdings by protected landscapes in 2016. Records from 2016 are assumed to be representative of current and future years.

For the five protected landscapes within the NUCLNP, the arable crop area is estimated as the sum of the cereals and other arable crops within the Defra (2021) statistics. To estimate arable production, average yield (tonnes/ha) is estimated based on a selection of representative crops. It is assumed that spring milling wheat, spring barley and spring oilseed rape are representative crops across the NUCLNP and the reporting areas. Yield for these crop types is sourced from Redman (2018; 2019; 2020) and estimated as a three-year average to smooth out any volatility in output. Total arable output, tonnes, is then calculated by multiplying the estimated arable area by the estimated average arable yield. Livestock production within the five protected landscapes is set equal to the number of beef cattle, dairy cattle and breeding ewes recorded in Defra (2021).

The NCA 10 and Tyne gap and Kielder reporting areas arable and livestock production are estimated using Defra (2021) records at the National Character Area scale. The relevant National Character Areas (i.e., those that overlap with the reporting areas) are selected and adjusted using area proportions. An arable area adjustment factor is estimated by dividing total arable area in each reporting area (in asset register) by the area of arable in the relevant National Character Area. This is then multiplied by the total arable area within the representative national character area for that reporting area. The same approach average yield for a set of representative crops is then applied to the estimated area to produce an estimate of total arable production in tonnes. For livestock production, a grassland adjustment factor is estimated by dividing total improved grassland within each reporting area by the area of grassland in the relevant National Character Areas. This is multiplied by the total number of dairy cattle, beef cattle and breeding ewes in the relevant National Character Area to produce an estimate of the number of livestock heads.

For the monetary values of produce, the John Nix gross margins for each crop and livestock output has been collated to produce a three-year average estimate based on 2019, 2020 and 2021 figures (Redman, 2018; Redman, 2019; Redman, 2020). A rolling average figure is used to adjust for any potential volatility in agriculture markets. To estimate the arable and livestock farm income, the average gross margin unit value (£/tonne or £/head) is multiplied by the estimated arable and livestock production figures (e.g., tonnes of potatoes; number of beef cows) in each reporting area. For arable crops, the average gross margin of spring

milling wheat, spring barley and spring oilseed rape is applied to the estimated arable output. For livestock, gross margins for upland spring lamb and spring calving upland sucklers are applied to the number of breeding ewes and beef cattle respectively. Whilst all-year-round calving Holstein gross margin is used for dairy cattle. The average unit gross margin figures are assumed to be constant over time.

A.2 Timber

This benefit has been estimated using the data from the Forestry Commission (2018) and the ONS (2019; 2020) for the volume of timber at the market value. The account uses the average figures and does not differentiate between species.

In 2018, the volume of softwood removals in the UK was estimated as 13.8 million cubic meters based on estimates of removals from the Forestry Commission Timber statistics (Forest Research, 2019a)[17]. Dividing this by the Forestry Commission (2019) estimated area of coniferous woodland in the UK (roughly 1.6 million hectares), gives an estimate for the volume of softwood timber removals per hectare in the UK of 8.5 m^3/ha/year. This is multiplied by the area of commercial woodland within each reporting area. It is assumed that over time timber yields are harvested sustainably, with the volume of removals per hectare remaining constant.

The value of softwood timber production is based on the Forestry Commission coniferous standing sales price index (Forest Research, 2020). The stumpage price used in the account is estimated as the average of prices recorded in March and September 2020, roughly £29/m^3 overbark in 2020 prices. This monetary unit value is then applied to the estimated volume of softwood removals. It is also assumed that the unit value remains constant over time.

A.3 Other fibres and materials

Wool production by upland sheep has been included in the NUCLNP account and is a significant output in the accounting area. The benefit is measured based on the marketed production from the sector at the average market price of wool.

The total volume of wool produced (kilograms/yr) is estimated by multiplying the average volume of wool per ewe by the number of breeding ewes in a reporting area. The number of breeding ewes has been estimated as part of the 'Food Provision' benefit[18]. The volume of wool per ewe is approximately 1.7 kilograms/ewe (Redman, 2020). The volume of wool per year is assumed to remain constant over time.

For the monetary values of wool, the John Nix average price of wool from upland sheep equal to £0.17 per kilogram (or £0.28 per ewe) is used (Redman, 2020). To estimate the market value of wool production, the average price is multiplied by the estimated volume of wool produced). The average market price is assumed to remain constant over time.

[17] Forestry Commission removal statistics provide volume estimates in green tonnes. This has been converted to cubic metres using a conversion factor of 1.222 as recommended by Forest Research (2019b) and is consistent with the approach used in the ONS (2020) woodland natural capital account.

[18] See A.1 – Food provision – livestock calculation.

A.4 Renewable energy

The renewable energy benefit is estimated by the amount of energy generated (in megawatt hours MWh) from hydroelectricity and onshore wind valued using the national average resource rent[19]. Currently, the estimates reflect the protected landscapes that were able to provide data, namely Forest of Bowland AONB, Northumberland NPA and Yorkshire Dales NPA. Therefore, the resulting estimate for the NUCLNP does not capture all electricity generated from renewable energy sources within the accounting boundary.

The protected landscapes provided a count of the number of hydropower and onshore wind sites that are operational. Northumberland NPA also provided installed capacity (KW) for onshore wind. Renewable energy statistics are available from the Department of Business, Energy & Industrial Strategy (BEIS, 2020), and reflect the generation, installed capacity and load factors by renewable energy source in the UK in 2019. Based on this data, for each energy source, the UK average generation by installed capacity is calculated by dividing total installed capacity (MW) by the total electricity generated (MWh)[20]. Similarly, the average generation by site (MWh/site) is estimated by dividing total number of sites by total electricity generated in the UK.

Where installed capacity is available, this is converted to MW and then multiplied by the estimated UK average generation per MW. When only the number of sites is available, this is multiplied by the UK average generation per site (MWh/site). It is assumed that 2019 is representative of the baseline year of 2020, and that electricity generation is constant over time.

The monetary value of electricity produced from renewable energy sources is estimated following the approach used by ONS (2019) that estimates the annual resource rent of renewable energy provisioning equal to £686 million, with associated generation of 98.7 million MWh in 2017. Dividing these figures produces an average unit resource rent value of £7.5/MWh/year, in 2020 prices. This is then applied to the estimates of renewable energy generated by hydro power and onshore wind within each reporting area and is attributed to businesses. It is assumed that the monetary unit value remains constant over time.

A.5 Minerals

The benefits associated with minerals extraction include sand and gravel, and crushed rock. The quantity extracted (tonnes) is valued using the UK average ex-works sales value of sand and gravel, and crushed rock (£/tonne). UK mineral production and value estimates are reported on a national basis (British Geological Society, 2021). Note that data on extractions has been provided by North Pennines AONB, Yorkshire Dales NPA and Northumberland NPA, therefore the estimates produced are partial and do not represent the total across the NUCLNP.

The quantity of extracted minerals within each protected landscape has been provided by the project partners. The volume of mineral outputs in tonnes is set equal to the five-year average output by mineral type. Where five-year average output is not available, the annual limits are used.

[19] Calculated as gross value minus costs of production.

[20] BEIS (2020) reports generation in gigawatt hours (GWh), which has been converted to MWh by multiplying total generation by a factor of 1,000.

Since minerals are a non-renewable resource, and therefore mineral extractions are not assumed to remain constant across the accounting period (i.e., 60-years). As land-bank years[21] are reported at the county level, this is assumed to be representative for all quarry sites within a given county. West Yorkshire Combined Authority (2019) and Durham County Council (2020) report that remaining land-bank years for crushed rock are approximately 37 and 40 years respectively. Land-bank years are adjusted to reflect 2020 estimates by reducing the number of years remaining for extraction by the number of years since the latest report (i.e., 2019). This is then used to represent the remaining asset life of quarries within the reporting area. West Yorkshire Combined Authority land-bank years are assumed representative for Yorkshire Dales NPA, whilst Durham County Council land-bank years are applied to North Pennines AONB and Northumberland AONB.

The monetary value of mineral production is estimated using the UK Minerals Yearbook to produce an average unit production value for sand and gravel and crushed rock respectively (British Geological Survey, 2021). This is then applied to the estimates the volume of sand and gravel produced within each reporting area and is treated as a value to businesses. It is assumed that the monetary unit value remains constant over time.

A.6 Carbon sequestration

Carbon sequestered in habitats

Three different natural capital assets within the accounting boundary, namely, woodland and improved grassland areas sequester carbon. This benefit is estimated using the sequestration rates for each habitat (tonnes CO_2 equivalent per hectare) and the non-traded price of carbon.

Table A. 1: Habiat sequestration rates

Habitat	Sequestration rate	Source
Woodland	5.7 tCO_2e/ha/yr	ONS (2019) and Forestry Commission (2017)
Improved grassland	0.6 tCO_2e/ha/yr	Soussana et al. (2010)

Table A. 1 shows the per hectare carbon sequestration rates for woodland and improved grassland that are used within this assessment. The unit sequestration factor for woodland covers both coniferous and broadleaved woodland. Improved grassland is estimated as 0.18 tonnes of carbon sequestered per hectare (Soussanna et al., 2010). The rate for improved grassland has been converted to tonnes CO_2e using a conversion factor of 3.67 (IPCC, 2018). Sequestration rates are assumed to remain constant over time.

The total amount of CO_2 equivalent sequestered is estimated by multiplying these per hectare rates with the total hectares of the respective habitat type, as recorded in the asset register. The amount of CO_2e sequestered is then valued following the BEIS (2021) for the non-traded central price, £241 per tonne of CO_2e in 2020. This is multiplied the estimated tonnes of CO_2e sequestered. Future flows of carbon are valued using the BEIS (2021) carbon values series until 2050. Following BEIS (2021) advice, a real annual growth rate is then applied starting at the most recently published value for 2050 and into the future.

[21] Land-bank years represent the remaining stock of sand and gravel or crushed rock within a county and is assumed to be representative for all quarries in the county.

Carbon emitted by peatland

Peatland stores significant quantities of carbon. If peat is in pristine or near natural condition the rate of carbon sequestration is significant but is roughly offset by the warming potential of methane emissions (produced under anaerobic conditions by microbes). Consequently, the net greenhouse gas sequestration potential of peatland in good condition is low or close to zero. However, peatland in drained or eroding condition can emit very large quantities of carbon and other greenhouse gases. The IUCN UK Peatland code (2017) provides a useful classification of condition and methodology for assessing condition and establishes a range of greenhouse gas emissions factors for peatland by condition as shown in Table A. 2.

Table A. 2: Peatland emission rates

Peatland condition	Emission rate	Source
Near natural	-1.08 tCO_2e/ha/yr	IUCN (2017)
Modified	-2.54 tCO_2e/ha/yr	
Drained	-4.54 tCO_2e/ha/yr	
Eroding	-23.84 tCO_2e/ha/yr	

The total amount of CO_2 equivalent emitted is estimated by multiplying the near natural and modified[22] rates by the estimated area of peatland that is either near natural or degraded. As peatland condition is largely unrecorded within the NUCLNP, it is assumed that the UK distribution of peatland condition is representative of the NUCLNP reporting areas. ONS (2019) indicate that in the UK, 22% of peatland is near natural or rewetted, with the remaining 78% in different states of degradation. For each reporting, the total area of peatland from the asset register is multiplied by the proportion for each condition category. Total emissions by peatland are then estimated by multiplying the area of peatland that is near natural or degraded by the appropriate emission rate. The amount of tCO_2e emitted is then valued following the same approach as for tCO_2e sequestered in habitats and in accordance with the BEIS (2021) guidance.

Carbon emitted by livestock

The account estimates the volume and value of carbon emissions from livestock. Note that this calculation does not account for emissions from all farm operations (e.g., electricity, fuel from vehicles, fertiliser and pesticide use) and is therefore an underestimate of the carbon emitted from farming activities.

Table A. 3: Livestock emission rates

Livestock type	Emission rate	Source
Cattle (other cattle)	-1.5 tCO_2e/head/yr.	Defra (2019b) and Jones et al. (2019)
Sheep	-0.2 tCO_2e/head/yr.	
Dairy cow	-2.1 tCO_2e/head/yr.	

Table A. 3 shows the per head carbon emission rates for cattle, sheep and dairy cow that are used within this account. The unit sequestration factors used have been estimated using the total carbon dioxide equivalent emitted by each livestock in the UK (Jones et al., 2019) and the total number of heads for each livestock type (Defra, 2019). Emission rates are assumed to remain constant over time.

The total amount of CO_2 equivalent emitted is estimated by multiplying the per head rate for a given

[22] The drained peatland emissions rate is applied to all degraded peat in the accounting boundary. This is done in the absence current peatland condition data, which can be added to future iterations of the account.

livestock type by the corresponding number of heads in a reporting area. The number of dairy cows, cattle and upland sheep has been estimated as part of the 'Food Provision' benefit[23]. The amount of tCO_2e emitted is then valued following the same approach as for tCO_2e sequestered in habitats and in accordance with the BEIS (2021) guidance.

A.7 Air quality regulation

Air quality benefit arises from the ability of different types of vegetation to remove pollutants from the air. This benefit is estimated for the amount of PM2.5 removed by woodland (which makes up more than 70% of this benefit in the UK (Jones et al, 2017) and the human health benefits of this removal.

Jones et al. (2017) modelled this benefit for the UK national accounts reflecting the variety of different levels of PM2.5 concentration, types and extent of vegetation and density of human population across the country. An update to this study has produced estimates of PM2.5 removal per hectare of woodland by local authority. The kilograms PM2.5 removed by hectare of woodland (eftec and CEH, 2019) is multiplied by the total woodland area in a given local authority in each reporting area. The PM2.5 removal per ha of mature (i.e., existing) woodland is falling over 2015-2030 based on the assumption about emissions and concentrations falling over time.

The economic value of this service is estimated through the resulting avoided healthcare cost at local authority level (eftec and CEH, 2019). The account shows the benefits as the result of: £ per ha of woodland (in terms of avoided health care cost due to PM2.5 removed, in 2020 prices) for a given local authority area (eftec and CEH, 2019), which is multiplied by the total woodland area in that area (as produced by further GIS analysis). This produces the annual value of PM2.5 removal by woodland.

Future benefits decline in line with lower emission / concentration assumption mentioned above but are discounted at lower levels using the lower health discount rates (HM Treasury, 2020).

A.8 Flood risk management

The account measures the flood risk management benefit based on an estimate of the additional water storage capacity of woodland following methods from Forest Research (2018). This benefit is not monetised, as the flood water storage replacement cost[24] approach used by Forest Research (2018) is not considered robust to apply across the NUCLNP accounting boundary.

Forest Research (2018) provide Great Britain average cubic metre per hectare (m^3/ha) unit values based on estimated flood water storage due to woodland water use and floodplain woodland hydraulic roughness. In the NW region account, it is assumed that the Great Britain average is representative of the region. The unit value for the annual average additional woodland soil water storage capacity is applied to the total area of woodland in the NUCLNP and each reporting area.

[23] See A.1 – Food provision – livestock calculation.

[24] Reflects the replacement cost of building a reservoir to retain the same volume of water, which is not necessarily the least cost option.

A.9 Recreation

Recreational benefit is measured in terms of number of visits to accessible greenspaces, and the average welfare value associated with these visits.

The ORVal[25] tool is used to estimate the number and welfare value of visits to the accessible open spaces in the account boundary. ORVal also breaks down the estimated number of visits and associated welfare value by socio-economic group. Estimates can be produced for various spatial breakdowns including local authorities. For a given local authority in a reporting area, the estimated number of visits and associated welfare value produced by ORVal is multiplied by the proportion of the local authority area that lies within the reporting area boundary.

It should be noted that the data from ORVal takes into account the location of the recreation asset, surrounding population, habitat type(s) and local alternatives, but makes the assumption that accessible green space is in average condition for its type. Where this is not the case, green space with better/ worse condition than average will likely have higher/lower values for number and welfare value of visits. Similarly, as the model underlying ORVal is based on MENE data[26], it does not take into account visits by children or overseas visitors to the UK.

Therefore, as ORVal captures all domestic visits by adults, there is a risk of double counting with domestic tourism visits, in particular day visits[27]. To adjust the visit numbers to reflect recreation visits under three hours, the MENE cross-tabulation viewer was used to determine the number of visits across England that were over and under 3 hours (Natural England, n.d.)[28]. 78% of visits across England were under three hours, this percentage is applied to the estimated total annual visits in each reporting area. The annual visits under three hours are multiplied by the estimated average welfare value per visit for that reporting area (ranges between £3.6-£5.0 per visit in 2020 prices). The unit monetary value (i.e., £ welfare value per visit) is assumed to remain constant over time.

ORVal does not distinguish on-water recreation. This is estimated through the values for maintaining WFD status from the National Water Environment Benefits Survey (NWEBS)[29]. ORVal is based on the MENE survey which asks respondents about the types of activities they undertake during their recreational visits, including fishing and water sports as broad categories (Natural England, 2018a). Therefore, there is a risk of double-counting if both ORVal and separate on-water recreation valuation are used. Consequently, the estimated value of on-water recreation within the NWEBS data, estimated as part of the method described in Section A.14, is not included in the account to avoid double-counting.

A.10 Physical health

[25] ORVal is a spatial model that shows the recreational sites, number of visits and the benefit to visitors using data from mapping tools, Monitor of Engagement in Natural Environment (MENE) survey and economic valuation literature. University of Exeter (2018) ORVal v2.0 - The Outdoor Recreational. https://www.leep.exeter.ac.uk/orval/

[26] See: https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results

[27] A day visits is any leisure visit that is at least 3-hours (round-trip).

[28] This is based on the Year 7 (2015/16) MENE survey weighted base results for "Question 3: How long did this visit last altogether."

[29] See Section A.14 for water quality methodology.

In addition to improving the general welfare of visitors, if people are active during their visits, recreation can also have measurable physical health benefits. White et al. (2016) estimate that 51.5% of recreation visits[30] are 'active', where an 'active visit' is defined as those who met recommended daily physical activity guidelines either fully, or partially, during visits.

The White et al. (2016) proportion of active visits is applied to the annual visits to greenspaces within the account boundary[31], producing the number of annual active visits which is assumed to remain constant over time.

The benefit is valued as the health benefits of active recreation (in terms of improvements in Quality Adjusted Life years – QALYs[32]) and the economic value of health improvement (in terms of the avoided health cost due to improvement in QALY). Beale et al. (2007) analysed Health Survey for England data, estimating that 30 minutes a week of moderate-intense physical exercise, if undertaken 52 weeks a year, would be associated with 0.0106768 QALYs per individual per year. Beale et al. (2007) assume this relationship between physical activity and QALYs is both cumulative and linear. Claxton et al. (2015) estimate a cost-effectiveness threshold of a QALY to be roughly £12,900/QALY in 2008 prices. This figure is used as a proxy for health costs, reflecting the avoided health costs when QALY is improved by one unit. Based on this information, the avoided health cost is estimated as £3.41 in 2020 prices. The monetary unit value is assumed to remain constant over time.

A.11 Education

The natural environment can be an important resource in education in terms of improving health and wellbeing and learning attainment of students. The number of education visits are valued using the average value per educational visits from Natural England's CNCA for National Nature Reserves (Clark, 2017). Note that data on number of education visits has been provided by Northumberland NPA and Yorkshire Dales NPA, therefore the estimates produced are partial and do not represent the total across the NUCLNP. Where possible, the annual number of education visits is set equal to the five-year average number of visits, where not available the latest year recorded is used. The number of educational visits is assumed to remain constant over time.

The educational visits are valued using evidence from the National Nature Reserve CNCA (Clark, 2017) which used the price charged by other providers (e.g., RSPB, Wildlife Trusts)[33]. The values range between £2.08 and £6.90 per visit and vary based on user type (e.g., public, half school day or higher education) and the level of involvement from Natural England staff and volunteers. However, an average value of £3.31 per visit[34] is used in the NNR account. After accounting for inflation, the average value per educational visit is £3.66, which is applied to the number of education visits reported by the protected landscapes. It is assumed that the monetary unit value remains constant over time.

[30] Refers to recreation visits that are under three hours, as reflected in Section A.9.

[31] As described in Section A.9.

[32] QALY is a health measurement used widely in health and health economics research. QALY of zero denotes death, and 1 denotes full health.

[33] A summary of the values is available in Clark (2017).

[34] It is assumed this average value is in 2017 prices, which is the same price year as the NNR account.

A.12 Volunteering

The benefits to an individual of volunteering are many and varied, including for example physical and mental health benefits, as well as a sense of contribution to wider society. The number of days should relate to nature-based volunteering only. The number of volunteer days are valued based on the value of employing volunteers by various skill levels used by the Heritage Lottery Fund (HLF, 2017). Note that data on volunteer effort (i.e., days) has been provided by Northumberland NPA and Yorkshire Dales NPA, therefore the estimates produced are partial and do not represent the total across the NUCLNP.

Where the number of volunteer hours has been provided this has been converted to days by assuming one day equates to 7.5 hours. A five-year average is used when available, otherwise an estimate from the latest year recorded is used. It is assumed that all volunteer effort is nature related. The number of volunteer days is assumed to remain constant over time.

The value of volunteer effort is calculated using the value of skilled and unskilled labour per day, from the Heritage Lottery Fund (HLF, 2017). The value of the volunteer input ranges between £55 to £166 per day, in 2020 prices. It is assumed that volunteer effort in each reporting area is evenly divided between unskilled and skilled volunteer inputs. Then the number of volunteer days is multiplied by the appropriate input value. The monetary unit value is assumed to remain constant over the accounting period.

A.13 Tourism

Domestic tourism is measured in terms of the number of day visits (i.e., visits that are more than three hours but do not include an overnight stay) and the number of domestic overnight trips and the associated expenditure of these visits and trips that are attributable to natural capital. The Great Britain Day Visitor Survey (Kantar, 2019a) and the Great Britain Tourist Survey (Kantar, 2019b) produce annual figures for Great Britain, but also three-year average visit and trip numbers and associated expenditure by local authority and national parks. The latter has been used in this assessment to allow for subdivision across the reporting areas. The day visits (i.e., over three hours) and overnight trips are treated as additional to the recreation visits (i.e., those under three hours).

The number of day visits per year and the number of overnight trips per year for each reporting area are estimated by multiplying the total visits[35] in a local authority by the proportion of that local authority area that falls within the reporting area boundary. The GBTS does provide three-year average trip numbers for the Yorkshire Dales and Northumberland National Parks, therefore for these protected landscapes overnight tourists are not estimated using the proportional approach described.

Total domestic tourism visits for a reporting area are the sum of the estimated annual day visits and domestic overnight trips. For each visitor group, the average expenditure per visit is estimated at the local authority level. The average expenditure (£/visit) for a given local authority is then multiplied by the estimated number of day-visits and overnight trips to that area within a set reporting area. Except for overnight trips to Yorkshire Dales and Northumberland National Park, as estimated three-year average expenditure is already reported in the GBTS (Kantar, 2019b). The sum of day-visits and overnight trip

[35] A day visit is treated as equal to an overnight trip, therefore visit = trip.

expenditure provides an estimate of the total expenditure that supports the local economy.

The proportion of visits and trips and their associated expenditure that are attributable to natural capital are estimated using ONS (2021) tourism and leisure natural capital account for the UK. Based on this work, it is estimated that nature's average contribution to total expenditure on tourism and outdoor leisure related activities within GB is approximately 8%. This proportion is applied to both the number of total visits (day and overnight) and their associated total expenditure, to produce an estimate of the natural capital attributable visits and expenditure within each reporting area. Both visits and expenditure are assumed to remain constant over time.

A.14 Water quality

Maintaining the quality of water in the environment could have financial benefits for businesses (e.g., avoided water treatment costs) and welfare benefits to the public as proxy for many ecosystem services provided. The approach taken here is the latter and the welfare benefits are linked to maintaining the Water Framework Directive (WFD) quality status of the of waterbodies as reported in the natural capital asset register.

The physical change is estimated by a given status (i.e., change in the WFD status from Good to Moderate). The economic value is based on the National Water Environment Benefits Survey (NWEBS) values (NERA Economic Consulting 2007; Metcalfe, 2012). The NWEBS values provide low, central and high estimates of values for coastal and transitional water bodies, in 2012 prices. NWEBs values have been inflated to 2020 prices using the HM Treasury (2021) GDP deflator.

The NWEBS values represent survey respondents' willingness to pay (WTP) for six equally weighted ecosystem components (Defra, 2015, p.69):

- Fish;
- Other animals such as invertebrates;
- Plant communities;
- The clarity of water;
- The condition of the river channel and flow of water; and
- The safety of water for recreational contact.

Therefore, to avoid potential double-counting with recreation estimates, as discussed in Section A.9 , one sixth of the estimated total value is deducted from the account values. It should be interpreted with caution as it has not been possible to disaggregate the impact of water quality on other benefits valued in the account.

This assessment uses the central value estimates for avoiding the deterioration of lakes, coastal and transitional water bodies and for rivers in the catchments relevant to the account boundary: Humber, Northumbria, North West and Solway Tweed River Basin Districts. Estimates are produced for lakes, coastal and transitional water bodies (i.e., annual £ value per km^2) and for river water bodies (i.e., annual £ value per km). Using the central estimates, the total annual value of avoiding the deterioration of the current water quality across all identified water bodies in the NUCLNP is estimated using the relevant river basin district values for each reporting area.

Appendix B - Example NUCLNP reporting area account

This appendix presents the results for the Yorkshire Dales National Park. It includes the asset register and asset value account that can be extracted from the accompanying workbook. The same outputs are available for the remaining six reporting areas.

B.1 Asset register

Table A. 4 shows the Yorkshire Dales NPA extent account. The majority of YDNPA is made up of upland acid grassland (29% of YDNPA area) and accounts for 46% of this habitat across the NUCLNP. 55% of priority grassland within the NUCLNP boundary lies in YDNPA – where this habitat accounts for 5% of total area. Overall YDNPA covers 29% of the total NUCLNP area.

Table A. 4: Yorkshire Dales NPA extent account

	Habitat	Area (hectares)	% of NUCLNP
Woodland	Broadleaved woodland	3,362	23%
	Coniferous woodland[1]	2,488	5%
	Young trees	327	3%
	Assumed woodland	728	22%
Non-woodland	Priority grassland	11,606	55%
	Upland acid grassland	62,413	46%
	Semi-improved grassland	13,118	53%
	Improved grassland	46,796	27%
	Priority wetland	51,146	31%
	Other wetland	-	-
	Priority heathland	18,970	18%
	Other heathland	1,173	46%
	Limestone pavement	1,054	76%
	Inland rock outcrops, cliffs and scree	237	42%
	Arable and horticulture	21	0.5%
	Hedgerows	-	-
	Urban	797	25%
	Lakes[2]	286	8%
	Other[3]	3,903	16%
	Total	**218,483**	**29%**

Table notes:

[1] For Kielder and Northumberland National Park the National Forest Inventory (NFI) woodland category 'felled, failed, ground prep and windblown woodland' has been added to coniferous woodland in the asset register. This would normally be returned to conifer, and therefore have assumed that part of this has been returned to conifer since 2018.

[2] Represents total area of WFD lakes (Environment Agency, 2020).

[3] Initial mapping results for NNPA, YDNPA and NPAONB resulted in large areas being 'unallocated'. It was assumed that the majority of this is additional acid grassland (e.g., for YDNPA 90% was reallocated). The remaining unallocated area has been defined as 'other'.

Table A. 5 presents the area of SSSIs designated areas by condition category within the YDNPA. Furthermore, it shows that of all SSSIs in unfavourable no change condition, YDNPA accounts for 50% of

this category, but only accounts for 27% of all SSSI across the NUCLNP.

Table A. 5: Yorkshire Dales NPA terrestrial designations

Indicator		
Designated SSSIs	**Area (hectares)**	**% of SSSI area in NUCLNP**
Favourable condition	16,913	35%
Unfavourable recovering condition	38,109	24%
Unfavourable declining condition	94	3%
Unfavourable no change	2,249	50%
Part destroyed	-	-
Destroyed	-	-
Total	**57,365**	**27%**
Other designated areas	**Areas (hectares)**	**% of total indicator area in NUCLNP**
National Parks	218,483	68%
Ancient woodland	4,778	34%
Accessibility		
Area of greenspace	2,827 hectares	
Length of footpaths	2,127 kilometres	
Length of accessible PRoWs	215 kilometres	
Length of all PRoWs	2,623 kilometres	

Table A. 6 illustrates that a third of all WFD rivers in NUCLNP lie within the YDNPA.

Table A. 6: Water Framework Directive waterbodies in Yorkshire Dales NPA

Water Framework Directive status			
Rivers	**Count**	**Length (kilometres)**	**% of total length in NUCLNP**
Bad	-	-	-
Poor	8	65	23%
Moderate	93	992	35%
Good	-	-	-
Total	**101**	**1,056**	**33%**
Lakes	**Count**	**Area (hectares)**	**% of total area**
Bad	-	-	-
Poor	-	-	-
Moderate	6	286	8%
Good	-	-	-
Total	**6**	**286**	**8%**

B.2 Yorkshire Dales National Park baseline account

Following the approach and methods described in Section 4.3 and Appendix A, Table A. 7 reflects the distribution if benefits to businesses and wider society supported by natural assets within the YDNPA boundary. The majority of these benefits accrue to wider society, equating to £2 billion in present value terms. These benefits are offset by greenhouse gas emissions from livestock and peatland equal to approximately £5.1 billion over the assessment period. Therefore, total net asset value to wider society is -£2.7 billion in present value terms. A further £1.5 billion accrues to businesses through agriculture, timber, wool production, renewable energy, and minerals. Overall, the YDNPA's natural capital assets have a negative asset value of £1.3 billion in present value terms.

Table A. 7: Yorkshire Dales NPA natural capital asset valuation, PV60 £m

	Valuation metric	Value to businesses	Value to the rest of society	Total	% of NUCLNP PV60
Asset values (monetised)					
Food provision	Arable income	11		**11**	10%
	Livestock income	585		**585**	28%
Timber	Value of softwood removals	9		**9**	5%
Other fibres and materials	Value of wool	2		**2**	29%
Renewable energy	Resource rent value of onshore wind	-		**-**	-
	Resource rent value of hydropower	9		**9**	100%
Minerals	Ex-works value of mineral production	863		**863**	83%
Carbon sequestration	Value of CO_2e sequestered in habitats		625	**625**	12%
	Value of CO_2e emitted by habitats		(4,404)	**(4,404)**	28%
	Value of CO_2e emitted by livestock		(705)	**(705)**	28%
Air quality regulation	Value of PM2.5 removal by woodland		48	**48**	26%
Recreation	Adult recreation welfare value (under 3 hours)		327	**327**	18%
Physical health	Avoided medical treatment costs		248	**248**	21%
Education	Value of educational visits		0.2	**0.2**	24%
Volunteer	Value of volunteer days		21	**21**	67%
Tourism	Domestic tourism expenditure attributed to natural capital		609	**609**	27%
Water quality	Welfare of avoiding deterioration in rivers		487	**487**	34%
	Welfare of avoiding deterioration in lakes		1	**1**	9%
Total gross asset value		**1,479**	**(2,743)**	**(1,264)**	
Asset values (non-monetised)					
Flood risk management	Volume of water held back by woodland: 1 million m^3				9%
Biodiversity	Total SSSI area: 57,000 hectares				27%
Other material unquantified benefits					
Water supply					
Mental health					

Appendix C - High Nature Value farming NCA

This appendix provides further details on the approach and methods used to develop the HNV scenario account which is presented in Section 5.2.

C.1 Background

This scenario compares an HNV farming system to a more intensive commercial farm using the same land. The data is laid out to inform potential ELMS funding, based on the opportunity costs and public goods value of HNV farming, compared to the commercial alternative. Within the benefits, the key trade-offs are between biodiversity value, carbon emissions and agricultural productivity.

C.2 Scenarios

The total farm area is 650 hectares. Table A. 8 presents the assumed livestock density and gross margin per hectare in each habitat for each scenario. Other assumptions used in the analysis include:

- It is assumed that there is a 50% split of livestock units (LUs) between cattle and sheep in semi-improved grassland. One head of sheep accounts for 0.12 LU whereas one head of cattle has an equivalent of 1 LU. (Natural England, 2013)
- Both the HNV Scenario and the Comparator Farm have 6.5 km of hedgerow. We assume the hedgerow to be 3 metres wide.
- We apply a 3.5% discount rate to calculate the present value over 60 years (HM Treasury, 2020).

Table A. 8: Habitat areas and land use for each scenario

Habitats	Land use	HNV (ha)	Commercial (ha)
Moor	Sheep - 0.05LU/ha. GM £15 per ha	400	400
Rough wet grazing	Sheep 0.15 LU. £40 GM per ha	60 (Moderate distinctiveness)	40
Semi-improved 0 kgN/ha.	Sheep & Cattle 0.4 LU. £150 GM per ha	120 (Species rich - high distinctiveness)	0
Semi-improved 50 kgN/ha	Sheep & Cattle 0.6LU, £180 GM per ha	60 (Species rich - high distinctiveness)	35
Improved 75 kgN/ha	Sheep 1LU. £290 GM per ha	0	170
Native woodland	No timber extraction	10	5
	Total area	**650**	**650**

Table notes:
Ha = Hectares
LU = Livestock Unit
GM = Gross Margin. The GM reflects the different fertiliser input costs for the different land uses.

C.3 Measuring and valuing benefits

The HNV and conventional farming scenario compares four benefits:

- **Food provision:** Based on gross margins from expected farm outputs.
- **Other fibres and materials:** Estimated for wool production by upland sheep, based on average volume of wool per ewe and valued using the average price of wool (Redman, 2020).

- **Carbon sequestration:** Calculations use central non-traded price of carbon (BEIS, 2021) in a given year. This value of carbon is based on the UK Government guidance on valuing non-traded Carbon released 2nd Sept 2021.
- **Air quality regulation:** To estimate PM2.5 removal we employ an average of the removal rates in local authorities within the Northumberland National Park and use the 1.5% health discount rate instead of 3.5% (HM Treasury, 2020).
- **Recreation:** An average visits per ha within Northumberland National Park is applied to the farm area. It is assumed that the HNV Scenario will receive 30% more recreational visits than the Conventional Farm. Visits are valued using the average welfare value per visit within Northumberland National Park.
- **Tourism:** An average visits (day-visits and overnight stay) per ha within Northumberland National Park is applied to the farm area. It is assumed that the HNV Scenario will receive 30% more tourism visits than the Conventional Farm. Tourism visits are valued using the average expenditure value per visit within Northumberland National Park. This is then adjusted to reflect the attributable spend to nature (approx. 8% of total spend) based on ONS (2021).

C.4 Unquantified benefits

Upland grazing systems will use areas of permanent grassland, defined as land that is not part of an arable rotation. However, HNV farmland will often include areas that has never been ploughed, contributing to its higher levels of biodiversity. The diversity of plant species with HNV grasslands means that there is a more complex root system. This has implications for the benefits the land provides, as it can increase pathways for GHG sequestration and storage and give a variety of root depths which are more effective at preventing soil erosion and reducing runoff.

The measured benefits exclude some significant impacts to society from management of farms in this landscape. Benefits from the HNV farming that are considered important but are not quantified in this analysis include:

- **Water Quality:** Teesdale is a catchment used for water abstraction, and nutrient runoff / leaching from livestock systems can have negative impacts on water quality. However, the extent to which lower nutrient inputs/ livestock numbers translates into lower nutrient flows to water bodies is uncertain.
- **Flood risk management:** Less intensive grazed HNV grasslands can potentially absorb heavy rainfall better than conventional grasslands. However, the extent to which HNV farming translates into lower flood risk downstream is uncertain.
- **Biodiversity:** The quantity of biodiversity benefits can be estimated using the Defra biodiversity Metric (3.0). This gives a broad estimate that the HNV farm would support 2,000 additional biodiversity units (32% more). The scenarios do not take account of habitat connectivity.

C.5 High nature value vs conventional comparison

A comparison of the valued benefits between the two scenarios are shown in Table A. 9. These data can inform the case for public payments under ELMS. The farming systems both involve significant areas of moorland. These will have different stocking levels under the HNV and conventional scenarios, but no differences in benefits between the two systems are measured and valued.

The large majority of moorland areas within the LNP are designated as SSSI, so we therefore assume that they will be supported by funding streams targeted towards protected areas and biodiversity outcomes. These payments are made to secure the long-term existence value of biodiversity, and so are distinct from the benefit values calculated in Table A. 9. They are likely to be funded under ELMS Tier 3.

To assess potential payment rates under ELMS Tier 2 for management of the HNV system, the grassland and woodland area, of 250 ha, is used to calculate per ha figures. It is noted that ELMS Tier 1 is a likely source of funding for management measures to support water quality and flood risk reduction benefits, which are not measured and valued in Table A. 9 and so not reflected in the benefit data:

- Compared to the conventional scenario, the HNV farm generates significantly less farm income (-£26,300), but greater public benefits (£91,900).
- The lower farm income would be used to design payments on an income forgone basis (giving £105 per ha), but the latter would justify higher payments (by up to £367 per ha).
- An overall payment rate would add these values, but society would not pay for the full value of the public benefits (as this would not give an increase in society's welfare). So, a payment rate could be £105 plus some fraction of £367 (say half), giving £105 + (£367/2) = £289/ha.
- The public goods benefits are only partially calculated. For example, they omit grassland carbon sequestration, as well as other benefits discussed above (water quality and natural flood management, landscape, biodiversity and other benefits).

Table A. 9: Difference in annual values between farming scenarios

		Difference in value (HNV – Conventional, £)	
	Valuation metric	**To farm business**	**To the rest of society**
Key monetised benefits			
Food provision	Livestock income	(26,000)	
Other fibres and materials	Value of wool	(326)	
Carbon sequestration	Value of CO_2e sequestered in habitats		(6,312)
	Value of CO_2e emitted by livestock		32,943
Air quality regulation	Value of PM2.5 removal by woodland		1,519
Recreation	Adult recreation welfare value (under 3 hours)		45,882
Tourism	Domestic tourism expenditure attributed to natural capital		17,833
Difference in gross annual value		**(26,326)**	**91,866**

To put the values and potential payment rates in context, they can be compared to the costs of recreating HNV grassland habitats. eftec et al (in prep) assesses the costs of recreating habitats for biodiversity net gain in England. It identifies costs of £27,000-£68,000 per ha of high distinctiveness grassland over 30 years. The present value of paying £289 per ha over 30 years is £5,500, which is significantly lower. Such payments to maintain existing HNV farming, as well as being ecologically preferable, therefore offer better value for money than restoration of such habitats.

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