Office for National Statistics

Article

UK natural capital: developing UK mountain, moorland and heathland ecosystem accounts

A discussion of mountain, moorland and heathland ecosystem accounting techniques, data sources and the recommended approach to developing an initial account.

Contact:
Stephen O'Connell
environment.accounts@ons.gsi.gov.uk
+44 (0)1633 456881

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1 . Collaboration

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2 . Summary

This article scopes the development of ecosystem accounts for mountains, moorlands and heathlands and discusses several methodological challenges arising from the unique characteristics of these habitats. To help the development of initial accounts, recommendations are given where possible.

Feedback from experts from all disciplines will be essential for the successful development of ecosystem accounts. All feedback is welcome and can be sent via email to environment.accounts@ons.gsi.gov.uk

3 . Introduction

This work is part of the Office for National Statistics and Department for Environment, Food and Rural Affairs (ONS-Defra) Natural Capital Project. In 2015 a Natural Capital Accounting 2020 Roadmap was created, which discusses progress, challenges and objectives of the project. Among the objectives is the development of eight habitat-based ecosystem accounts, one of which being mountains, moorlands and heathlands (MMH).

Natural capital accounts offer a consistent way of monitoring our natural assets and can help identify drivers of ecosystem change. Development of monetary valuation in particular, aids this integration with other economic statistics, as economic and environmental data are presented in a consistent unit. The valuation estimates aim to raise awareness of the economic significance of natural capital and provide a basis on which changes in value of components of the UK's natural capital can be recorded. In time, this information will help develop an aggregate indicator of sustainability.

The UK National Ecosystem Assessment (UK NEA) highlights the important role that mountains, moorlands and heathlands play as a highly "multi-functional" habitat, providing opportunities for carbon storage, biodiversity and water quality. MMH are home to some of the UK's rarest species of flora and fauna and are recognised as "nationally treasured landscapes"; providing sources of inspiration and recreation. These features of MMH justify a stand-alone account.

4 . Structure of an ecosystem account

The UK is defined as an ecosystem accounting area that is made up of eight ecosystem types. These ecosystem types are based on the broad habitats given in the UK National Ecosystem Assessment (UK NEA), which include mountains, moorlands and heathlands (MMH), but also woodland, farmland, freshwater, coastal margins, marine, urban and semi-natural grassland.

The term “ecosystem asset” will be used throughout this article and refers to the natural asset of mountains, moorlands and heathlands. Ecosystem services will also be discussed in detail and are the benefits we receive from the asset, such as food or clean air.

An ecosystem account is comprised of five main components:

- an extent account (size of the asset, for example, hectares of land covered)
- a condition account (containing indicators, for example, quality of soil)
- physical ecosystem service flow accounts (annual change in physical benefits we receive, for example, tonnes of pollution removed)
- monetary ecosystem service flow accounts (annual change in monetary value of benefits)
- monetary ecosystem service stock accounts (value of ecosystem services for the life of the asset)

After defining the nature of the asset, this article will work through each component separately, providing recommendations where possible for developing a mountains, moorlands and heathlands ecosystem account.

5 . Defining mountains, moorlands and heathlands

Mountains, moorlands and heathlands (MMH) can be defined by the characteristics of the habitat, land cover or land use as displayed in Table 1.

Table 1: Habitat, land cover and land use definitions, UK National Ecosystem Assessment

Habitat	An ecological or environmental area that is inhabited by a particular animal or plant species.
Land cover	The physical coverage of land, usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, land use.
Land use	The human use of a piece of land for a certain purpose (such as irrigated agriculture or recreation). Influenced by, but not synonymous with, land cover.

Source: UK National Ecosystem Assessment

Simplistic habitat definitions for MMH can be found in a 1998 Department for Environment, Food and Rural Affairs (Defra) paper, which provided a plan to enact a new statutory right of access for English and Welsh countryside. In this paper, the definitions were:

- mountain areas – an area of land 600 metres above sea level
- moorland – includes upland heathland, bogs and grass, and soils usually have a peaty top characterised by semi-natural vegetation; although usually associated with uplands over 200 metres, moorland vegetation can be found down to sea level, especially in the North West
- heathland – characterised by the presence of dwarf shrubs such as heather, gorse, cross-leaved heath, bilberry and crowberry, and may include scattered trees, scrub, bare ground, grassland, bogs and open water; lowland heathland is usually found below 300 metres while upland heathland is found on higher ground

These definitions are problematic for these accounts as moorlands and heathlands could overlap with the definitions of mountains if they are more than 600 metres above sea level.

The UK National Ecosystem Assessment (UK NEA) classifies MMH into six sub-habitats: bracken, dwarf shrub heath, inland rock, montane, upland bog and upland fen, marsh and swamp. These MMH classifications can overlap with a number of other habitats, as shown in Table 2, and to prevent double-counting, overlaps should not occur.

Table 2: Linkages between mountains, moorlands and heathlands (as defined by the UK NEA six broad habitats) and other habitat accounts

	Habitats	Potential overlap
Bracken	Freshwater	
	Farmland	Sheep-grazed acid grassland
	Woodland	Conifers, broadleaved and yew, below canopy cover
	Urban	
	Costal Margins	Bracken in coastal areas
	Marine	
	Semi-natural grassland	Acid grassland
Dwarf shrub heath	Freshwater	Wet heath, bog
	Farmland	Rough grazing
	Woodland	Lowland heathland
	Urban	Lowland heathland
	Costal Margins	Dune heath and coastal heath
	Marine	
	Semi-natural grassland	Heather, calcareous, acid and molinia grasslands
Inland rock	Freshwater	
	Farmland	
	Woodland	
	Urban	Quarries
	Costal Margins	
	Marine	
	Semi-natural grassland	Calaminarian grassland
Montane	Freshwater	Fens, springs, blanket bog
	Farmland	
	Woodland	Alpine woodland, such as Scots pine
	Urban	
	Costal Margins	
	Marine	
	Semi-natural grassland	Alpine calcareous grassland
Upland bog	Freshwater	Bog
	Farmland	
	Woodland	
	Urban	
	Costal Margins	
	Marine	

	Semi-natural grassland	Molinia grasslands
Upland fen, marsh and swamp	Freshwater	Fen, marsh and swamp
	Farmland	
	Woodland	
	Urban	
	Costal Margins	
	Marine	
	Semi-natural grassland	Molinia grasslands

Source: Office for National Statistics

A significant overlap is bracken, which can be found amongst heath. It is most extensive on deep well-drained fertile soil and therefore can be found across a variety of habitats, including coastal margins, woodlands and most commonly within semi-natural grassland.

Lowland heathland, through natural succession, can revert to secondary woodland meaning the land cover will change to woodland. However, amidst this process the land cover may display characteristics of both lowland heathland and woodland leading to confusion in terms of land cover categorisation.

An area of notable overlap is grazing, which occurs within the MMH habitat but is not exclusive to it. The Centre for Ecology and Hydrology Land Cover Map (LCM) defines rough grazing within its sub-habitat target classes, but as it occurs predominately within farmland and semi-natural grassland habitats, it will not be included within the MMH accounts.

Once initial ecosystem accounts have been developed for the full range of broad habitats, it will be necessary to review the coverage of each account to ensure that they are comprehensive and that there is no double-counting.

6 . Devloping the extent account

The extent account records the estimated size of the asset, in this case the size of the mountain, moorland and heathland (MMH) area, and changes in the extent, or size, over time.

In other Office for National Statistics and Department for Environment, Food and Rural Affairs (ONS-Defra) habitat ecosystem accounts, a land cover approach has been taken using a variety of sources. Suitability of the Centre for Ecology and Hydrology Land Cover Map (LCM), Countryside Survey (CS) and CORINE European satellite data were reviewed for the UK natural capital land cover accounts 2015. The Countryside Survey was recommended due to accuracy and the length of the time series.

The Countryside Survey was also recommended in a Coastal margins scoping study because the LCM had two weaknesses; “a lack of comparability between the LCM2000 and LCM2007, and an error of around 20%”. It was recommended that if future versions had greater consistency in terms of classification, they could be used.

A new LCM has been released recently (LCM2015), which has improved consistency, although it is still not completely consistent with the LCM2007. It is now recommended as the source for the extent account as the CS is not expected to be updated in the future.

A notable issue for MMH is the removal of the “montane” class from LCM2015. The class was removed as it was based purely on variable altitude, rather than spectral data, and therefore its distribution would be constant across LCMs. In the LCM2015, “montane” is split between “inland rock” and other upland classes as it is now mapped based on spectral data. A full discussion of the differences between LCM2007 and LCM2015 can be found in the Centre for Ecology and Hydrology Land Cover Map 2015 dataset documentation.

The LCM contains sub-habitat target classes, which are broader than the six sub-habitats suggested by the UK National Ecosystem Assessment (UK NEA). For example, the LCM contains bog, but does not define between upland and lowland.

Table 3 provides the LCM target classes, which can be mapped to suggested UK NEA sub-habitats and definitions for each.

Table 3: Land Cover Map target class definitions to be included in the UK mountains, moorlands and heathlands habitat accounts

Land Cover Map 2015 target class number	Land Cover Map 2015 target class & Broad habitat	Definition
9	Heather - Dwarf Shrub Heath	Vegetation that has greater than 25% cover of plant species from the heath family (ericoid) or dwarf gorse. It generally occurs on well-drained, nutrient-poor, acid soils. Heaths do also occur on more basic soils but these are more limited in extent and contain herbs characteristic of calcareous grassland. Dwarf shrub heath includes both dry and wet heath types and occurs in the lowlands and the uplands.
10	Heather Grassland - Dwarf Shrub Heath	
12	Inland Rock	This broad habitat includes areas such as inland cliffs, caves, and screes and limestone pavements, as well as various forms of excavations and waste tips such as quarries and quarry waste. The habitat covers a wide range of rock types, varying from acidic to highly calcareous. It occurs throughout the uplands, and is particularly characteristic of high altitudes, but is also found at low altitudes.

Source: Centre of Ecology and Hydrology, Joint Nature Conservation Committee and Office for National Statistics

Bracken is not included as it is defined as acid grassland within the LCM classification and therefore bracken will be included in the semi-natural grassland accounts.

According to the UK NEA, upland bog (blanket bog) is a relatively dominant broad habitat in MMH, encompassing roughly one-third of all uplands in the UK. However, the LCM does not distinguish between upland and lowland bog (lowland raised bog), which are associated with wetlands. Therefore, the freshwater accounts incorporate all bog. As upland bog is so prominent in MMH, further work is needed to separate the two.

Finally, fen, marsh and swamp are also currently included within the freshwater habitat for the same reason, that upland and lowland cannot be separated.

The choice of data source can have a notable impact on the extent account. Table 4 compares the extent of MMH in the UK when using different data sources.

Table 4: Extent of mountains, moorlands and heathlands in the UK when comparing sub-habitat classes [1]

Land Cover Map (LCM) 2007	2007 extent	Countryside Survey (CS) 2007	2007 extent	CORINE Land Cover (CLC) 2006	2006 extent
Dwarf shrub heath	2,112	Dwarf shrub heath (heather and heather grassland)	1,351	Shrubland, bushland, heathland	2,578
Montane habitats and inland rock	622	Montane habitats and inland Rock	111	Sparsely vegetated areas and barren land	569
Total	2,734	Total	1,462	Total	3,147

Source: Office for National Satistics

Notes:

1. Figures expressed in thousands of hectares.

The extent of MMH in the UK was estimated at 2,734,000 hectares in 2007 when using the LCM and at nearly half that when using the CS. Despite these variances, Table 4 also shows that the LCM2007 and CS 2007 both estimated that the MMH habitat covered between 11% and 6% of UK total land cover (excluding sea). CORINE Land Cover (CLC) 2006 estimated this figure to be nearly 13%.

The UK Land Cover Accounts (using CS 2007 data) show roughly 75% of all UK MMH were found in Scotland, Wales and Northern Ireland, as seen in Table 5.

Table 5: UK mountains, moorlands and heathlands extent comparison, 2007 [1,2]

	England	Scotland	Wales	Northern Ireland
Dwarf shrub heath (heather and heather grassland)	354	870	119	17
as % of UK	26%	64%	9%	1%
Montane habitats and inland rock	11	93	3	5
as % of UK	10%	83%	3%	4%
Total MMH	365	964	122	22
Total MMH as % of UK	25%	65%	8%	1%

Sources: Countryside Survey (1998;2007), Northern Ireland Countryside Survey (1998, 2007), OS Meridian, UK Hydrographic Office, Office for National Statistics calculations

Notes:

1. Figures expressed in thousands of hectares.

2. Using Countryside Survey data.

7 . Developing the condition account

The condition of the ecosystem asset sheds light on changes to the state of the ecosystem and its capacity to provide ecosystem services into the future. The Principles of Natural Capital Accounting proposes seven dimensions of quality for which condition can be indicated (principle 4.1). The dimensions are as follows:

- relevant volume estimates
- biodiversity indicators
- soil indicators
- ecological condition indicators
- spatial configuration
- access
- management practises

Potential mountains, moorlands and heathlands (MMH) indicators are summarised in Table 6, with suggested sources.

Table 6: Suggested UK mountains, moorlands and heathlands condition indicators

Indicator and discussion	Recommended source(s)
Soil indicators	
Carbon content: Soil and vegetation can sequester or emit carbon depending on the management of the ecosystem.	Carbon storage by habitat (Alonso et al, 2012) and Carbon Stock Account (ONS).
Soil ammonia and nitrogen levels: High levels of either can lead to acidification and eutrophication of the soil, leading to losses in biodiversity. Uplands and lowland heathlands are particularly acid-sensitive. Acidification is where the soil or a river, lake or stream acidifies, unbalancing the ecosystem. Eutrophication occurs when the environment is excessively enriched with nutrients, such as nitrogen, causing dramatic alterations and affecting the ecosystem's function.	Centre for Ecology and Hydrology –Review of Transboundary Air Pollution (RoTAP, 2012).
Biodiversity indicators	
Specialist bird populations: Golden eagles are almost exclusive to Scottish MMH. The RSPB estimates the UK golden eagle population as 440 breeding pairs. Other birds such as the peregrine falcon, merlin, hen harrier and short-eared owl are typical of English MMH. Common lowland heathland bird species include nightjar, woodlark and Dartford warbler. The presence or absence of these species could inform on the condition of the habitat.	Breeding Bird Survey (BBS), The Royal Society for the Protection of Birds (RSPB), Golden Eagle Review (Scottish Natural Heritage 2000).
Mammal populations: Red deer and mountain hare are both common to Scottish MMH and can be used as a biological indicator of condition. Although it must be noted that red deer are not exclusive to MMH.	BBS, Mountain Hares James Hutton Institute, SNH Deer Census, British Deer Society.
Species richness scores: The average count of plant species per 10 metres by 1 metre plot surveyed. Use with caution as many upland habitats and lowland heathlands are intrinsically species poor. An increase in species will likely be due to an increase of generalist rather than specialist species, indicating habitat degradation rather than improving condition.	CS (not preferable as data is not current enough). Reports and Data – CEH Environmental Information Platform – natural capital maps of England produced with CS data.
Invertebrates: Spiders, honey bees, bumblebees (for example, bilberry bumblebee), heather beetles, emperor moths, northern eggar moths, large heath butterflies and Scotch argus butterflies are all native to MMH. Their numbers could act as an indicator of condition; however, increasing numbers doesn't always correlate with increasing condition. For example, increasing numbers of heather beetles is likely to cause worsening condition of heather, as the beetle's larvae feed on heather, stripping it bare.	UK Butterflies and UK Biodiversity Action Plan (BAP) and butterfly larvae data is also provided in the Countryside Survey (CS).
Management practices	
Sites of Special Scientific Interest (SSSI) and Areas of Special Scientific Interest (ASSI) condition status: SSSI and ASSI designation and percentage in favourable condition will correlate with favourable condition of MMH.	Joint Nature Conservation Committee Protected Areas Designations Directory.
Wildfire: Wildfire is identified by Sutherland et al (2008) as one of the top 25 priority risks to UK biodiversity. Albertson et al (2009) notes that there is a greater ignition risk following increased visitor pressure in hot dry summers (UK NEA, 2011).Wildfire risk could be used to indicate threat to habitat condition.	National Aeronautics and Space Administration (NASA) MODIS active fire data, Department for Communities and Local Government (DCLG).
Managed burning: Managed burning in sensitive areas or when carried out too frequently, can lead to the habitat degradation. There may be a threat to habitat condition where sensitive areas are being burned or an agreed prescribed burning frequency is being exceeded.	If the NASA MODIS active fire data shows both wildfires and managed fires, this can be used.
Ecological condition indicators	

Water quality: The Upland Water Monitoring Network (UWMN) provides data on acidity, macro invertebrates, acid neutralising capacity, dissolved organic carbon and non-marine sulphate. These values and changes year-on-year in values can indicate the current water quality and its trend.	UWMN annual summary of data – need to ensure sites are MMH. Does not account for lowland heathland water quality.
Access	
Proximity of human habitation to MMH habitat: Can also be used to indicate urban development pressure on MMH habitat, which is one of the main pressures.	Census data for England and Wales, together with the AECOM (2015) method for Scotland
Length of National Trails (kilometres): Extent of paths and trails can act as a proxy indicator for cultural ecosystem services associated with access and interaction with nature (AECOM, 2015).	Scotland's Great Trails and The National Trails for England and Wales. WalkNI could be used for Northern Ireland.
Relevant Volume Estimates	
Volume of sheep grazing: An increased number of grazing sheep can lead to loss of heather moor. Therefore, higher volumes of sheep within MMH could relate to worsening condition. The metric of number of sheep per hectare could be used.	Defra livestock numbers in England and UK – not spatially disaggregated. Scottish Natural Heritage sheep per hectare map.
Volume of air pollutants: A higher volume of air pollutants would indicate a poor condition of the habitat. The metric of average background pollution concentration (g/m3) can be used for pollutants such as SO_2, PM_{10}, NH_3, NO_2 and O_3.	New pollutant removal estimates to be published with the ONS-Defra habitat account in July.

Source: Office for National Statistics

8 . Trends in extent and condition of mountains, moorlands and heathlands

Moorlands and heathlands are very fragile ecosystems; if not managed at all, or inappropriately managed, they can revert to secondary woodland, or be converted to poor-quality grassland. The overall condition on the mountains, moorlands and heathlands (MMH) habitat has substantially deteriorated over the last 60 years, which can be attributed to several land use activities and pressures (according to the UK National Ecosystem Assessment (UK NEA)). This section discusses the main pressures contributing to the declining trend of MMH.

Inappropriate grazing

A destructive pressure to MMH, particularly post war, with notable sheep number increases up to the mid 1990s. Pakeman and Nolan (2009) identify a clear correlation between the increase in stocking density of sheep and the deterioration of heather dominated habitats. The Joint Nature Conservation Committee (JNCC) state there is over-grazing in the uplands and under-grazing in lowlands and this agricultural activity is causing substantial fragmentation to the MMH habitat.

According to the Biodiversity Reporting and Information Group (BRIG), 57% of inland rock is in unfavourable condition due to grazing. A study of increased sheep numbers and loss of heather moor in the northern Peak District found that the former had trebled between 1930 and 1976, leading to a 36% decrease in moorland (Anderson & Yalden 1981).

Afforestation

The UK NEA notes that since World War 2 commercial forestry has caused a great loss to MMH. In the 1950s, development of powered cableway extraction methods allowed access to previously unmanageable areas and access roads across areas of MMH were opened up in many parts of the UK. Most of this destruction occurred prior to 1990 and was most abundant in Scottish and Welsh MMH. Since 1990, due to removal of tax incentives, there has been a steep decline in afforestation on organic soils. Today, neglect and excessive encroachment of secondary woodland is a greater risk in lowlands.

Urban development

Urban development is a major pressure to MMH, especially for lowland heath. As settlements develop and expand, and populations grow and strive to become more connected, new and improved infrastructure is constructed and each one of these processes can affect MMH. For instance, roads constructed to access or bypass areas of MMH can fragment the habitat.

Urban encroachment impacts on the quality of our remaining heathlands through disturbance of wildlife (by people or their pets) (Liley and Clarke 2003), arson, dumping of rubbish, trampling (Gallet and Roze 2001), the increased vulnerability of populations of rare species through habitat fragmentation (Haskins 2000, UK NEA 2011), and increased difficulty to implement the most appropriate management, for example, grazing by cattle.

Urban development also offers the threat of greater air pollution and the risk of acidification and eutrophication. Towns and cities such as London and Bournemouth have expanded ten-fold in 100 years, often on previous heathland (Webb 1986).

Inappropriate burning

Burning is a principal tool in the creation and maintenance of habitats suitable for grouse (UK NEA 2011). Inappropriate burning or lack of it can alter the MMH habitat. Encroachment of trees and the “simplification” of vegetation structure can be caused by the lack of controlled burning. Many moorlands are threatened by too frequent burning (UK Biodiversity Action Plan (BAP), 1995); this could lead to the alteration of the moor to grassland. The level of burning within moorlands and upland heathlands is too high according to the UK BAP.

Mineral extraction and quarry landfill

Inland rock has been affected by mineral extraction and quarry landfill. For limestone pavements, the mechanised removal of stone meant that by 1975, only 75% of the area was intact and 3% remained undamaged (Braithwaite et al. 2006). The UK NEA comments on how some areas of MMH are granted permission to become quarries and opencast mines to extract minerals, stone and coal; this often causes destruction to the habitat (so could potentially be used as an indicator of condition). The NEA also notes that requests to open more quarries and coal mines are still being made and some of which are still being granted.

Climate change

When discussing pressures to extent and condition, the impacts of climate change must not be ignored. The UK NEA highlights climate change as one of the major pressures to MMH. However, it is difficult to understand this threat as there is limited historical data and little consensus over what metric could be used to evaluate it. Research would need to be undertaken to gather annual data to then, for example, understand if hotter, drier summers are increasing the risk of wildfires within the MMH habitat.

9 . Physical and monetary accounts for ecosystem services

The System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA EEA) guidance recommends to “initially select a limited rather than a comprehensive set of ecosystem services for inclusion in ecosystem accounting”. The selection should take into account environmental policy priorities, economic importance and the availability of data, as well as the assessments of state and significance set out in the UK National Ecosystem Assessment (UK NEA). This section gives an overview of the different ecosystem services and their importance for mountain, moorland and heathland (MMH) habitats. The services covered in this section do not represent every ecosystem service provided by the MMH habitat. The assessment of services is summarised using the following structure:

- “service” identifies the individual, specific ecosystem good or service; for example, the provision of heather honey
- “discussion” identifies the annual flow of the service we want to measure and assesses whether monetary valuation is possible and if so, whether it can be consistent with accounting principles
- “potential source” identifies available data sources and any limitations

Ecosystem service accounts can be in both physical and monetary terms. Physical accounts will have a range of physical metrics and are not readily aggregated. Monetary ecosystem accounts will be formed of two parts:

- annual flow accounts: value of the service provided annually
- asset accounts: value of service provided for the life of the asset (up to 100 years)

These accounts are explained in more detail in the Office for National Statistics and Department for Environment, Food and Rural Affairs (ONS-Defra) Principles of Natural Capital Accounting. These principles stress using the Common International Classification of Ecosystem Services (CICES) as a checklist for classifying ecosystem services, helping to distinguish between provisioning, regulating and cultural. The principles establish that within basic accounts, supporting services should be excluded as to avoid double counting of benefits.

For accounting purposes, it is useful to identify the beneficiaries of these services and the extent to which changes in the number of beneficiaries affects the value of the service.

10 . Provisioning services

According to the Common International Classification of Ecosystem Services (CICES), provisioning services are defined as nutrition (for example, crops), materials (for example, timber) and energy (for example, bio-fuels).

Table 7: Provisioning services summary

Service and Discussion	Potential Source
Nutrition	
Reared animals and their outputs: Mainly used for sheep grazing, as MMH have naturally low agricultural soil properties due to soil qualities (UK NEA). This would fall under the farmland habitat. The UK produces 2,000 tonnes of honey each year (British Bee Keepers' Association (BBKA)) of which heather honey is twice the value of other British honey (Sanderson and Prendergast 2002).	Defra annual livestock estimates (England and UK) – not spatially disaggregated. BBKA annual honey survey – not spatially disaggregated. Scotland and Northern Ireland aren't always included due to small sample sizes.
Wild animals: This provisioning service should not be included unless game shooting can be divided between hunting for recreation and hunting for provision.	The Game Shooting and Fishing Census –annual but only nine estates fit MMH classifications.
Freshwater provision: Roughly 70% of UK drinking water is sourced from surface water, predominantly from upland catchments (IUCN, 2011).Three main components relate to this service provision; upland landscape position, steep slopes, thin soils or peat cover, and provision of clean (dilute) waters (UK NEA 2011). Freshwater provision is valued in the freshwater habitat account, so to avoid double counting it should not be included in MMH.	Defra annual water abstraction estimates – not spatially disaggregated.
Materials	
Traditional lifestyle products: Heather cuttings have been used as mulch for the restoration of bare peat, air bio-filters and sediment traps.	
Peat extraction: Used for fuel and horticultural use. Peat extraction is recorded in the freshwater habitat accounts and therefore should not be included in the MMH accounts, as to avoid double counting.	ONS mineral extraction in Great Britain – annual estimates for England and Scotland only and do not identify lowland from upland.
Energy	
Wind power provision: MMH offers considerable scope for the implementation of wind farms. Being remote, there are little or no negative externalities (such as, visual and noise pollution) to humans. Being at high altitudes there is often higher average wind speeds giving greater potential wind power generation. Wind farm maps (such as those produced by RenewableUK) could be layered with the Land Cover Map (LCM) to estimate by habitat. It should be noted that wind power is an abiotic service flow related to the location of the ecosystem but not dependent upon its functioning as an ecosystem.	RenewableUK and Department for Business, Energy and Industrial Strategy (BEIS) annual Digest of UK Energy Statistics (DUKES) publication – wind stations are named so potentially could be mapped by habitat.
Biomass-based energy sources: In some areas of the UK bracken is used as a bio-fuel, however, harvesting the bracken on steep slopes can be demanding, so this value is likely to be minuscule. Other heathland materials such as heather cuttings, wood and gorse are also used for bio-fuel.	BEIS annual DUKES publication – biomass estimates do not specify source, for example, if from bracken.

Source: Office for National Statistics

Mountains, moorlands and heathlands (MMH) are generally regarded as being of poor quality for agricultural use due to the topography and soil acidity, according to the UK National Ecosystem Assessment (UK NEA). Despite this, MMH are still used for agricultural production, mainly livestock grazing, particularly of sheep. However, MMH has been subject to some “land improvements” (for example, addition of fertilisers) to allow arable production productivity to increase.

Peat extraction is one of the main provisioning services of the MMH habitat (UK NEA). Peat has multiple uses but is most predominately extracted for horticultural use, with 3 million cubic metres of peat extracted every year for this purpose (Bonn et al 2010). This service has high policy relevance as the UK government aims to phase out peat use by 2030 (Natural Environment White Paper, Department for Environment, Food and Rural Affairs (Defra), October 2014).

Although most UK peatland is located within upland bog, over 99% of peat extracted from England in 2010 (excluding fens) was extracted from lowland raised bog (Natural England 2010b). Peat is accounted for in the freshwater habitat account and should be excluded in this account to avoid double counting.

The MMH habitat is also important in the provision of fresh water, with 68% of the UK's drinking water originating from surface water sources predominately within this habitat. High rainfall due to mountainous topography, widespread distribution from good surface run-off and the dilution of polluted downstream waters by the inflow of clean upland waters are all important components of this service provision.

Game provision is not the main motivation for sporting estates, but some game is still provided through the "hunting experience" (UK NEA). For provisioning services, the market price of the extracted good (for example, meat price) is often used as the price of the ecosystem service. Costs of extraction must be deducted (for example, cost of hunting equipment) to leave a residual that reflects the ecosystem contribution. For recreational hunting, the residual value is likely to be very small or negative as the costs are often higher than the sale price. This reflects the recreational nature of hunting, which will instead be reflected in the cultural service accounts.

11 . Regulating services

Regulating services relevant for mountains, moorlands and heathlands (MMH) include climate regulation (for example, temperature control), hazard regulation (for example, protection from soil erosion or flooding) and water quality regulation.

Table 8: Regulating services summary

Service and Discussion	Potential Source
Climate regulation	
Carbon sequestered by MMH soil and vegetation regulates the climate. Carbon sequestration estimates are published in the partial UK Natural Capital Accounts. Data is drawn from Department for Business, Energy and Industrial Strategy (BEIS) publication: UK Greenhouse Gas Emissions. However, carbon sequestered by MMH is not distinguished and is likely captured in the "grassland" and "wetlands" land use categories.	BEIS annual UK Greenhouse Gas Emissions – MMH not distinguished.
Natural hazard regulation - flood risk mitigation	
Catchments with high proportion of steep areas with thin soils are likely to be sources of runoff. Re-vegetation of bare peat of slopes can reduce flow velocities (UK National Ecosystem Assessment (UK NEA) 2011).	Natural England Ecosystem Services Transfer Toolkit.
Water quality regulation - waste detoxification	
Plant-soil systems of MMH habitats intercept and retain various atmospheric pollutants, including anthropogenic sulphur, nitrogen and heavy metals that would otherwise contaminate drainage waters. MMH soils also buffer the effects of acid deposition on upland stream and lake ecosystems. The Uplands Water Monitoring Network (UWMN) collects data about upland water sources that may be able to be used to quantify how much waste is mediated by MMH. Values could be applied based on how much water companies pay to treat water.	UWMN annual summary of data on each site – caution must be taken as sites may not fit MMH classification.

Source: Office for National Statistics

Water quality regulation is an extremely important regulating service of the MMH habitat. The UK National Ecosystem Assessment (UK NEA) states “water quality is more strongly linked to ecosystem processes in the uplands than in the lowlands”. Water quality is regulated by MMH as less polluted run-off from uplands dilute polluted freshwater in the lowlands. However, the UK NEA does remark on the sensitivity of MMH habitats to anthropogenic pollution, which can reduce the ability of the habitat to regulate downstream water quality.

The UK NEA notes there is limited evidence supporting the idea that MMH regulate natural hazards such as floods and wildfires. Potentially, MMH can exacerbate natural hazards and if so, this would be classed as a disservice. Disservices should not be included in the accounts as “the natural capital accounts should not take into account the disservices or negative externalities arising from ecosystem functioning” (see Principle 5.5 of the Principles of Natural Capital Accounting).

12 . Cultural services

Cultural services are defined by the Common International Classification of Ecosystem Services (CICES) as:

- physical and intellectual interactions with biota, ecosystems, and landscapes; for example, recreational activities, scientific and educational interactions, and cultural heritage and aesthetics
- spiritual, symbolic and other interactions with biota, ecosystems and landscapes; for example, symbolic use, plants, animals, or ecosystem types, sacred or religious interactions, or other existence or bequest cultural benefits

Table 9: Cultural services summary

Service	Discussion	Potential Source
Physical and intellectual interactions		
Cultural heritage and aesthetics	23% of dominant MMH are classified as Areas of Outstanding Natural Beauty (UK NEA, 2011); indicating MMH areas have nationally treasured landscapes with high cultural heritage values. Geo-tagged images online could be utilised to estimate appreciation of aesthetic landscapes (Casalegno et al, 2013) and compared across habitats. Currently, no methods exist to create monetary estimates from this. Annex A discusses aesthetic valuation methods further.	Series of studies (some discussed in Annex A) but no regular data source.
Recreation	Visits to MMH for recreational purposes were valued at £276 million in England in 2014 (see UK Natural Capital Accounts, 2016). The majority of MMH is within Scotland, Wales and Northern Ireland; any estimates scaled up to the UK based on population (as done with the UK accounts) will likely be an underestimation. Alternative methods for scaling up to include the rest of the UK are being looked into, for instance, scaling up by land cover.	Natural England Monitoring Engagement with the Natural Environment (MENE) Survey – England only. Limited survey sample by habitat.
Field sports: game	Game shooting is seen mainly as a recreational activity, rather than for provision of food. The MENE Survey records type of activity and location of activity so could provide physical and monetary estimates.	MENE Survey (see limitations in “Recreation”). Game Shooting and Fishing Census, only covers nine MMH estates.
Scientific and educational interactions	Active promotion of learning opportunities, such as those organised by non-governmental organisations (NGOs) and National Parks occurs through guided walks, visitor centres and school education programmes outside the classroom. Materials, such as on site interpretation panels, audio-trails, publications and websites, offer opportunities for individual learning (UK NEA 2011).	
Spiritual, symbolic and other interactions		
Sacred and religious interactions	MMH is a setting for religious and spiritual reflection. MMH play host to ancient burial mounds and some pilgrimages pass through MMH (for example, St. Cuthbert's Way in Northumbria). The MENE Survey does not currently distinguish the number of visits with religious or spiritual motivation, however, it does ask for the respondent to specify the reason for the visit if not listed as one of the main reasons. This could present an opportunity for further analysis.	MENE Survey.
Bequest	Bequest value represents the importance people place on preserving or maintaining ecosystems for future generations (Oleson et al, 2015). The amount paid by UK citizens for bequest gains from managing areas of MMH could be used for valuation. This requires further research for UK-wide valuation.	
Existence	Existence value is the utility or benefit to an individual by simply knowing that a resource (for example, a mountain) exists, even if the individual never expects to see or use the resource (Haefele et al, 2012). Charity contributions towards conservation of MMH could be used to estimate the value of this service. This requires further research for UK-wide valuation.	

Source: Office for National Statistics

Physical and spiritual recreation are some of the most important services in mountains, moorlands and heathlands (MMH), in particular activities such as walking, skiing, climbing and shooting. Climbing, skiing and shooting are largely confined to MMH areas and can generate substantial revenue for the local economy. According to the UK National Ecosystem Assessment (UK NEA) 2011, in the winter of 2008 to 2009, the Ski Club of Great Britain reported there were 159,888 Scottish (downhill) skier days. These activities within MMH promote mental and physical well-being, although can also provide a disservice through mountain incidents requiring Mountain Rescue help. The Mountain Rescue Committee of Scotland indicated that there were 387 mountain incidents during 2008, of which, 20 were fatal and another 60 resulted in serious injury (UK NEA 2011).

To develop physical and monetary accounts the Monitoring Engagement with the Natural Environment (MENE) Survey can be used. MENE collects information about the ways people engage with the natural environment and is currently used to measure and value recreational visits in the UK Natural Capital Accounts. An important limitation of the source is that it collects for England only and we scale up by population to provide an estimate for the UK in the natural capital accounts. This is problematic for MMH in particular, as the majority exists outside of England. Recreational surveys exist for Scotland and Wales but are not directly comparable with MENE. Further work is needed to utilise these data sources.

Grouse shooting takes place on 450 moors around the UK, covering 16,763 square kilometres (Richards 2004), or 7% of the UK and 36% of MMH. According to the Game and Wildlife Conservation Trust (2010), in 2009 it was estimated that grouse shooting contributed £23 million to Scotland's gross domestic product (GDP) and direct and indirect job creation.

To value this service a resource rent approach should be used, which involves removing the costs of the shoot to calculate the value of the ecosystem service only (discussed further in Annex A). The MENE Survey is a potential data source, but as mentioned previously, it will lead to under estimation as the MENE survey covers England only and 296 of these moors are in Scotland and 10 are in Wales (UK NEA). The Game Shooting and Fishing Census (GSFC) surveys over 3,000 game shooters and could be used as another source, however, only nine estates covered by the survey relate to MMH. If the future GSFC covers more MMH shooting estates then this could become an appropriate data source.

Many of the Scottish shooting estates also conduct salmon fishing and deer shooting, as well as grouse shooting. Further research is needed to find data sources and valuation methods to capture wild deer from MMH estates and salmon fishing would be captured in the freshwater accounts.

13 . Monetary stock account

The asset accounts value the ecosystem services provided by the asset, in this case the mountains, moorlands and heathlands (MMH) habitat, for the life of the asset. Services such as recreation and water filtration are seen as renewable, so the asset life is set at 100 years. Services such as peat extraction are non-renewable, as they are limited by the amount of peat available to extract, so the asset life, or amount of peat left to extract, will need to be established. Often lack of data prevents the estimation of an accurate asset life, so 25 years is assumed for these cases.

The value of the asset is obtained by estimating the net present value (NPV) of the asset. The annual value of all ecosystem services provided by the MMH habitat are projected for the life of the asset and discounted. For more information on monetary flow and asset accounts, please refer to the Principles of Natural Capital Accounting publication.

14 . Suggested recommendations and further research

When developing the extent account, it is recommended the Centre for Ecology and Hydrology Land Cover Map 2015 target classes of heather, heather grassland and inland rock are used.

Further research is needed to disaggregate land cover for upland and lowland bog, and fen, marsh and swamp for the extent accounts. If regular extent data can be produced separating blanket bog and lowland raised bog, then upland and lowland bog can be separated into the mountains, moorlands and heathlands (MMH), and freshwater accounts. Given the prominence of bog in both habitats, this is a priority area.

When developing the initial condition account, the seven broad indicators listed in Table 6 should be included and the suggested indicators should be explored further from the initial account. It is expected other indicators will be added and some of those suggested replaced as the account develops further and new data sources become available.

Table 10 shows the services that should be included when developing the physical and monetary service flow accounts.

Table 10: Summary of services to be included in physical and monetary service flow accounts, UK

Provisioning Services	Wild animals
	Wind power provision
	Biomass-based energy sources
Regulating Services	Carbon sequestration
	Waste detoxification
Cultural Services	Recreation
	Game shooting
	Cultural heritage and aesthetics
	Scientific and educational interactions
	Sacred or religious interactions
	Bequest
	Existence

Source: Office for National Statistics

A much needed area of future research is to establish methods to measure the value MMH provides by regulating water quality. This is an important area for policy and water companies but will be a very difficult service to estimate at a UK-wide scale.

Additionally, it is recommended that natural hazard regulation, more specifically flood regulation, is excluded from the MMH account unless research can be conducted to provide sufficient evidence that MMH mitigate flood risk.

Cultural services in general are also of high importance to the value of MMH. The recreation methodology needs refining to decipher which visits are for recreational game shooting and needs developing to include spiritual and religious value, overseas visits and overnight stays.

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16 . Annex A: Valuation approaches

"Values are derived, if available, from information of individual behaviour provided by market transactions relating directly to the ecosystem service. In the absence of such information, price information must be derived from parallel market transactions that are associated indirectly with the good to be valued. If both direct and indirect price information on ecosystem services are absent, hypothetical markets may be created in order to elicit values." (Brander et al, 2010). The Office for National Statistics and Department for Environment, Food and Rural Affairs (ONS-Defra) publication, Principles of Natural Capital Accounting (Version 2.0), indicates four potential suitable categories of valuation:

- market-based approaches
- revealed preference approaches
- cost-based approaches
- stated preference approaches

All these ecosystem valuation approaches have various valuation methods and techniques and each their own advantages and limitations. Some of these methods will be discussed in this section.

Hedonic price method (revealed preference approach)

The hedonic price method (HPM) is based on observations of individual choices within existing markets, relating to the ecosystem service that is subject of valuation (Brander et al, 2010). The HPM can be defined as a method that uses a surrogate market, for example, the housing market, taking into account a number of variables (for example, number of rooms and house size) to approximate the difference in value caused by a specific variable. For instance, the difference in value of a house caused by mountain, moorland and heathland (MMH) views.

Kaplan (2004) discovered in a survey in Michigan that 66% of respondents said the most important aspect when choosing where to live was the “nature view from home”. Multiple research papers have analysed using hedonics to determine the value of mountain views, such as: Behrer 2010; Gibbons et al 2014; Benson et al 1998; Boxall et al 2005; Jim and Chen 2009; and Franklin, Waddell and Evans 2002.

Behrer 2010 uses hedonic regression of the housing market in Buncombe County, North Carolina to show that the effect of mountain views on property price is positive and statistically significant. This paper also identifies that the effect on property prices due to mountain views is higher for people aged 65 years and over Research for England by Gibbons et al (2014) concluded that for a 1 percentage point increase in the environmental amenity of MMH there was a 0.08% increase in house price. Hedonic regressions such as Behrer’s and that of Gibbons et al can be replicated for the UK to approximate an estimate for the aesthetic value of MMH.

There are four main drawbacks of this method, which may hinder its use to estimate the aesthetic value of MMH. The first is that HPM puts a value on more than one service; it is difficult to differentiate between the recreational and health benefit from improved access to the natural resource and the value of the views. The second is that it generates a capital value, which may not be readily integrated into the flow accounts. The third is that it is difficult to update any estimate on an annual basis. The fourth is that it requires large datasets for accurate and robust valuations.

Within the UK research and data for MMH view amenity values is exceptionally limited and therefore, it is likely that a substantial amount of research may be needed for this approach to be viable.

Resource rent (market-based approach)

The resource rent or residual value (RR or RV) approach is an example of a market-based valuation method, as this approach uses data directly from existing markets that are within the System of National Accounts 2008 (SNA 2008). The UN System of Environmental-Economic Accounting: 2012 Central Framework (SEEA CF, 2014a) describes resource rents in paragraph 5.113 as “the surplus value accruing to the extractor or user of an asset calculated after all costs and normal returns have been taken into account.” For example, Remme et al (2015) use a resource rent approach to value hunting (game shooting) as a recreational ecosystem service.

Replacement cost approach

The replacement cost approach is a cost-based method of valuation as it imputes benefits from any costs avoided by the presence of an ecosystem service. The Principles of Natural Capital Accounting defines replacement costs as “costs of man-made alternatives that would be incurred if the ecosystem asset was lost”. With respect to MMH, the replacement cost method could be used to estimate the costs water companies may incur treating water if the water regulating ecosystem service of MMH was lost.