Office for National Statistics

Statistical bulletin

UK natural capital: peatlands

Natural capital accounts for peatlands measures the ecosystem services which nature provides from this dramatic landscape, including water, carbon sequestration, food and recreation.

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1 . Executive summary

This is a summary of a Eurostat grant funded report. This will be accessible on the Eurostat website. Alternatively, you can email the Natural Capital team at natural.capital.team@ons.gov.uk.

Peatlands occupy around 12% of the UK land area. This dramatic landscape provides over a quarter of the UK's drinking water and stores a significant amount of carbon making it an important habitat for providing both provisioning and regulating ecosystem services in the UK. Peatlands are also a major tourist destination and provide cultural history contributing significantly to the UK's cultural ecosystem service. They form some of the UK's most extensive wild spaces and are rich in rare and endangered wildlife boosting the UK's biodiversity.

Peatlands include both the highest and lowest value agricultural lands in the country. Agriculture on lowland peats, mainly in the east of England, include areas of high cropping value. However, this activity on peatlands has a negative impact on the peat from drainage and ploughing activities. It is estimated croplands on peat emit a total of 7,600 kilotonnes of carbon dioxide equivalents per year (kt CO2e yr-1) in the UK. Upland peat is used for livestock. When subsidies are excluded from farming income, livestock grazing has a negative contribution to ecosystem services for peatland.

We estimated restoration cost accounts for the UK's peatlands. In the absence of a comprehensive plan to achieve this in the UK we initially used a blunt set of assumptions with the intent of highlighting the trade-offs involved and providing a conservative estimate of cost. The costs of restoring 100% of peatlands could be significant at between £8 billion and £22 billion but these are approximately one-tenth to one-fifth of the carbon emissions benefits that would be gained. More conservative estimates of the benefits of meeting the committee on climate change objective of having 55% of peatland in good status were of the order of £45 billion to £51 billion over the next 100 years.

2 . Main points

- Supply over a quarter of the UK's drinking water, valued at £888 million in 2016.
- Climate regulation through carbon storage has a negative contribution to ecosystem services; only 22% peatlands are in a near natural or rewetted condition, consequently the Centre for Ecology and Hydrology (CEH) estimated peatlands emitting around 23,100 kt CO2e yr-1 greenhouse gas (GHG) in total.
- Estimated time spent for recreation on peatlands in 2016 is 180 million hours valued at £274 million.
- Publicly funded research on Peatlands estimated to be £882,796 in 2018.
- The net benefits, in terms of climate change emissions alone, of restoring 55% of peatlands to near natural condition are estimated to have a present value of approximately £45billion to £51 billion.

3 . Collaboration

Department
for Environment
Food & Rural Affairs

The Office for National Statistics natural capital accounts are produced in partnership with the Department for Environment, Food and Rural Affairs (Defra). Further details about the natural capital accounting project are also available.

We would also like to thank colleagues at Centre for Ecology and Hydrology (CEH), Natural England (NE), Joint Nature Conservation Committee (JNCC), Scottish Natural Heritage (SNH) and Natural Resources Wales (NRW) for their invaluable comments and review of this work.

4 . Introduction to natural capital

Nature provides the basic goods and services that make human life possible: the food we eat, the water we drink and the plant materials we use for fuel, building materials and medicine. The natural world also provides less visible services such as climate regulation, natural flood defences, removal of air pollutants by vegetation, and the pollination of crops by insects. Then there is the inspiration people take from wildlife and the natural environment.

This report includes ecosystem services and the values of those services. This helps us to think logically about what aspects of the natural world we are measuring and how they impact on people.

Natural capital assets are the things that persist long-term such as a peat bog or food and wool from livestock grazing. From those assets people receive a flow of services such as recreational hikes on the peatlands and livestock grazing on upland areas. Finally, we can value the benefit to society of those services by estimating what the hikers spent to enable them to walk over the peatlands or the profit to the farmers of bringing the livestock into the market. Applying this logic consistently across assets and services enables us to start building accounts of the value provided by nature.

The benefits we receive from nature are predominantly hidden, partial or missing from the nation's balance sheet. However, by recognising nature as a form of capital and developing accounts of natural capital's contribution to the economy and our well-being, decision-makers can better include the environment in future policy planning.

The development of natural capital accounts has been flagged by the Natural Capital Committee and the UK National Ecosystem Assessment as a fundamental activity that is necessary if natural capital is to be mainstreamed in decision-making.

There has also been strong international momentum to develop natural capital accounts. The UN System of Environmental-Economic Accounting (SEEA) is the main source of technical guidance and sharing of experiences, the principles of which these accounts are built upon.

In 2011, the Department for Environment, Food and Rural Affairs (Defra) committed to working with the Office for National Statistics (ONS) to measure the value of UK natural capital (see Natural Environment White Paper, June 2011). Since then, the ONS has collaborated with Defra to develop innovative methods to measure this strand of economic statistics, with an objective of including UK natural capital estimates in the UK Environmental Accounts by 2020.

Natural capital accounts include stock accounts of specific habitats and flow accounts of services. Both physical (non-monetary) accounts and monetary valuations are presented as a time series to monitor change over time. Monetary valuations of natural capital begin to reveal the value of benefits provided by nature. Valuations were developed under the principle of comparability with the 1997 to 2015 UK Ecosystem Service Accounts and consistency between individual ecosystem services.

It is recognised that the UK accounts remain experimental and future UK publications will be subject to methodological improvements over time. Ecosystem service valuations offer comparative analysis across services whereas physical flows provide information about the changes over time independent of price changes. The services are presented by type, which include provisioning, regulatory and cultural. Types of service are defined at the beginning of each section.

All estimates are experimental and are subject to adjustment and improvement as the natural capital accounts are developed. A number of ecosystem services are not being measured in this report, so the monetary accounts should therefore be interpreted as a partial or minimum value of Peatlands natural capital.

5 . What are peatlands?

Peatlands are wetland landscapes that are a unique ecosystem formed of partially decomposed plant and animal remains. The wet and acidic conditions slow decomposition enabling organic matter to gradually accumulate over centuries and millennia to form deep peat deposits. Peat in a good condition contains around 90% water, with its key component Sphagnum having an ability to store 20 times its weight in water. Sphagnum's ability to store water in dry conditions both protects the peatland through droughts and enables it to spread the same conditions into drier adjacent land.

These are habitats with a unique biodiversity and are recognised as of national and international significance (Joint Nature Conservation Committee, 2011). These areas provide an archive of change over time. The peatland archive forms a multi-proxy record of its formation as it contains plant macro- and microfossils, archeological remains, volcanic ash, animal remains, charcoal and other natural or anthropogenic materials. A chronology is developed from oldest to youngest, with the deepest deposit being the oldest and the younger ones closer to the surface (Greiser and Joosten, 2018).

Peatlands provide significant water resources to larger parts of the UK and are also areas with a significant proportion of the UK's soil carbon store (Billet and others, 2010). In the UK it is estimated there is over 3 billion tonnes of carbon stored in the peatlands, equivalent to all carbon stored in the forests in the UK, Germany and France together (Moors for the Future, 2019). The amount of carbon stored in Scottish peatland is equivalent to 140 years' worth of Scotland's greenhouse gas emissions (Scottish Natural Heritage, 2017).

Peatlands in the UK can be referred to as either a soil type or habitats such as fens and bogs. In the UK there are three broad peatland habitats.

Blanket bog – these are peatlands which receive all their water from precipitation and typically form across a hilly landscape (SNH, 2014). These are globally rare, although in the UK this is the largest peatland habitat. As a consequence of only being fed by precipitation they are nutrient poor and acidic (International Union for Conservation of Nature, 2018).

Raised bog – these form in the lowlands on wet floodplains or in basins, often on the surface of existing fen peats (SNH, 2014). They form localised domes of peat. They are also nutrient poor and acidic due to being fed by precipitation and they have similar plant species to blanket bog.

Fens – these receive water from precipitation and ground water that has been in contact with the underlying geology. Consequently, they exhibit a wide range of types, including base-poor fens resembling bog-type vegetation of cotton grass, heather and Sphagnum mosses to fens rich with sedges, reeds and brown mosses (IUCN, 2018).

A peatland landscape can display a complex combination of blanket bog, raised bog and fens. Upland blanket bogs can be interspersed with nutrient poor fens, whereas raised bogs can grade into fringing “lagg” fens (SNH, 2014).

An internationally accepted definition is the Ramsar Convention 1971 proposed definition “ecosystems with a peat deposit that may currently support a vegetation that is peat-forming, may not, or may lack vegetation entirely. Peat is dead and partially decomposed plant remains that have accumulated in situ under waterlogged conditions” (Smyth and others , 2015).

Peat vegetation and land use

The different land management uses of peatlands can have a significant impact on the condition. How a peatland functions is influenced by its vegetation. Changing the vegetation can change the hydrology and the geochemical conditions. Peatland in a poor condition can release carbon rather than storing it. This changes the quality of the water in the rivers and increases the amount of greenhouse gases emitted into the atmosphere.

There is currently no available data in the UK for the same year on the extent of the different habitats where peatlands can be found. Most of the data available refers to fens, marshes, swamps and bogs. Peat also exists below forests, farmland and grasslands. The report by Evans and others (2017) does include the latest estimations on peatland condition by categories in Table 1.

Table 1: Summary of habitats for UK peatlands

Habitat	Hectares	Percentage
Cropland	194,125	7
Forest	439,292	15
Grassland	234,761	8
Bog	1,922,016	65
Fen	27,545	1
Extracted	144,887	5
Total UK	2,962,626	100

Source: Centre for Ecology and Hydrology, Evans and others, 2017

6 . Peatland extent

It is a significant challenge to compile a consistent UK base map of peatlands. Several national soils maps exist, however, they all have limitations regarding resolution. The latest estimations on peatland extent from the implementation of an emissions inventory for UK Peatlands project calculated an estimated total area in the UK of around 3.0 million hectares (12.2% of total UK land area), see Table 2 for area by country. Of this around 640,000 hectares (22%) is estimated to be in a near-natural condition. To calculate the total estimated peatland area the project used national peat depth definitions of 40 centimetres in England and Wales and 50 centimetres in Scotland and Northern Ireland. They did not include soils with a peaty organic horizon over mineral soil even though they are extensive in the UK as they do not meet national definitions of peat. This mapping has been more effective at identifying the small peat units. However, there remains some uncertainties over the location and extent of all deep peat across the UK (Evans and others, 2017).

Table 2: Total estimates peat areas for UK administration

Country/ administration	Peat area (hectares)		Source data	Reference
Scotland		1,947,750	James Hutton Institute, British Geological Survey	Evans et al. (2017)
England	Deep	495,828	National Soil Research Institute, British Geological Survey	Natural England (2010)
	Wasted	186,372		
Wales		90,050	British Geological Survey, Natural Resources Wales	Evans et al. (2014)
Northern Ireland		242,622	Deep peat from British Geological Survey, Agri-Food and Biosciences Institute, Peat Survey of Northern Ireland	Cruikshank & Tomlinson (1990); Evans et al. (2017)
Total		2,962,622		

Source: Centre for Ecology and Hydrology and Evans and others, 2017

7 . Peatland condition

The condition of an ecosystem asset, in terms of its characteristics, reflects its overall quality. The relationship between the extent and condition of ecosystem assets is likely to be non-linear and variable over time (UN System of Environmental Economic Accounting, 2014; paragraph 2.34). The condition of an ecosystem asset plays a large part in determining the quantity and quality of services the asset provides and its capacity to provide those services into the future. If the peatland is in a degraded state, over time the ecosystem services provided will be less than if the peatland was in good condition and being used sustainably.

Land use

The condition of peatlands is strongly related to land use. There currently is no data source that has condition of peatlands in the UK for a consistent reference year. The latest estimations on peatland condition categories is included in the Implementation of an Emissions Inventory for UK Peatlands project report, Table 3 (Evans and others, 2017). The approach was to use a map reference year and then estimate changes over time relative to that reference year.

Table 3: Peat areas (hectares) by condition categories for each UK administration for the reference year used

Country	**England**		**Scotland**	**Wales**	**NI**
Peat category	Deep peat	Wasted peat	All	All	All
Data sources	LCM2007 NE257 NFI2013	LCM2007 NE257 NFI2013	LCS88	Phase 1 Habitat Survey	LCM2007 NI Peat Survey
Reference map year	2013	2013	1990	1990	2007
Forest	51,764	13,728	332,746	9,520	31,534
Cropland	50,594	132,107	8,181	102	3,141
Drained Eroded Modified Bog	5,653	0	75,147	19	2,170
Undrained Eroded Modified Bog	43,560	8	198,116	206	3,470
Drained Heather Dominated Modified Bog	19,208	0	155,196	1,588	6,667
Undrained Heather Dominated Modified Bog	87,166	55	409,154	6,237	10,702
Drained Grass Dominated Modified Bog	24,053	0	33,130	1,588	6,667
Undrained Grass Dominated Modified Bog	32,992	1,833	87,344	29,000	15,747
Extensive grassland	1,377	518	31,794	8,993	1,932
Intensive grassland	38,416	35,265	78,641	6,577	31,248
Near Natural Bog	83,930	2,348	490,497	23,548	35,915
Near Natural Fen	0	0	0	2,674	0
Extracted Domestic (fuel peat)	4,254	137	44,923	0	87,539
Extracted Industrial (horticultural)	4,627	1	2,881	0	525
Rewetted Bog	23,784	286	0	0	5,032
Rewetted Fen	24,451	86	0	0	334
Total	495,829	186,372	1,947,750	90,050	242,623

Source: Centre for Ecology and Hydrology, Evans and others, 2017

The International Union for Conservation of Nature (IUCN) estimates 80% of the UKs peatlands are in a damaged and deteriorating condition having been modified as a result of present and past land management activities, including extraction for horticulture and draining for agricultural improvement (IUCN, 2018).

Quick and others (2013) identified that it is important to know the condition of peatlands as it is a major store of carbon. The deep peat can store carbon for hundreds or thousands of years. Peatlands in a good condition are better at storing and long-term sequestering of carbon. Whereas, degraded peatlands will emit greenhouse gases. See Table 4 for the impacts of different peat conditions.

Table 4: Impact of peat condition on Greenhouse Gas emissions

Peatland condition	Type of ecosystem service	Quality of ecosystem service	Flow of ecosystem service	Effect on climate
Healthy peatland	Carbon sequestration and carbon storage	Very good	Improving	Positive
Grazed peatland	Carbon storage	Adequate	Steady or deteriorating	Variable
Burnt peatland	Carbon storage	Adequate	Steady or deteriorating	Variable
Degraded peatland	Carbon storage	Poor	Deteriorating	Negative
Eroding peatland	Carbon storage	Very poor	Deteriorating	Negative

Source: Department for Environment, Food and Rural Affairs and Natural England, Quick and others, 2013

Protected sites

Investigating the condition of sites protected by statutory designations also gives an indication of the UK's peatlands condition. Peatlands can have formal designations, including Special Areas of Conservation (SACs) or a Site of Special Scientific Interest (SSSI) or Areas of Special Scientific Interest (ASSI) in Northern Ireland. It is an area of peatlands of interest to science that has rare fauna or flora present or important geological or physiological features. Wetlands with an international importance are also designated Ramsar sites, usually designated for their water birds.

Special areas of conservation (SACs) are protected sites under the EC Habitats Directive (92/43/EEC). This directive requires the establishment of a European network of important conservation sites which make a significant contribution to conserving 189 habitat types and 788 species identified in the Annexes of the directive (JNCC, 2017). Data in Table 5 is based on data for the period April 1998 to March 2005. The data were provided by the country agencies to the Joint Nature Conservation Committee (JNCC) in July and August 2005. The data was not available for Wales in the blanket bog category and there was not a 100% return rate for the assessments of the SAC site condition (JNCC, 2006).

Table 5: Condition assessment of core peatland habitat features designated SACs in the UK, 2005

Reporting categories	Favourable	Un-favourable recovering	Un-favourable	Destroyed (Whole or part)	No. assessments reported	% returns	Regions
Blanket bog	45%	14%	39%	2%	66	65%	E,S,NI
Lowland raised bogs	19%	52%	29%	0%	79	81%	UK
Fens and marshes - upland	45%	19%	36%	0%	58	74%	UK
Fens and marshes - lowland	18%	39%	43%	0%	80	85%	UK

Source: Joint Natural Conservation Committee (2011)

Sites of special scientific interest (SSSIs) are areas that represent the best areas of natural heritage in terms of their fauna, flora, geology and landforms in Wales, Scotland and England. Northern Ireland has areas of scientific interest (ASSIs) for natural heritage sites.

Between 2011 and 2018 the protected sites areas classified as favourable for blanket bog, lowland fens and lowland raised bog in England has increased, however, upland flushes, fens and swamps has seen a decline in area for favourable, as shown in Table 6.1 and 6.2. There has only been a small rise in peatlands habitats being classed as favourable, from 31,353 hectares in 2011 to 33,656 hectares in 2018. In the same period sites classed as unfavourable have risen from 6,893 hectares to 12,862 hectares of all sites.

Table 6.1: Condition of SSSI, SAC and RAMSAR sites in England, 2011 to 2018

Habitat		**Blanket Bog**			**Upland Flushes Fens and Swamps**		
Condition		Favourable	Recovering	Unfavourable	Favourable	Recovering	Unfavourable
2011	ha	23,685	159,967	3,588	2,128	4,179	203
	%	13	85	2	33	64	3
2012	ha	24,421	159,807	3,011	2,125	4,199	187
	%	13	85	2	33	64	3
2014	ha	24,995	158,622	3,622	1,997	4,239	274
	%	13	85	2	31	65	4
2015	ha	25,121	157,406	4,713	1,998	4,233	278
	%	13	84	3	31	65	4
2016	ha	24,061	156,407	6,771	2,015	4,180	317
	%	13	84	4	31	64	5
2017	ha	25,700	156,092	9,688	2,015	4,055	350
	%	13	82	5	31	63	5
2018	ha	25,325	155,814	9,774	1,986	4,044	390
	%	13	82	5	31	63	6

Source: Natural England

Table 6.2: Condition of SSSI, SAC and RAMSAR sites in England 2011 to 2018

Habitat		**Lowland Fens**			**Lowland Raised Bog**		
Condition		Favourable	Recovering	Unfavourable	Favourable	Recovering	Unfavourable
2011	ha	5,144	6,587	1,545	396	6,313	1,557
	%	39	50	12	5	76	19
2012	ha	5,136	6,571	1,572	385	6,212	1,672
	%	39	49	12	5	75	20
2014	ha	5,696	6,201	1,383	470	6,438	1,362
	%	43	47	10	6	78	16
2015	ha	5,701	6,273	1,303	386	6,025	1,322
	%	43	47	10	5	78	17
2016	ha	5,782	6,176	1,339	579	6,473	1,328
	%	43	46	10	7	77	16
2017	ha	5,834	6,041	1,269	492	6,506	1,393
	%	44	46	10	6	78	17
2018	ha	5,855	5,885	1,326	490	6,519	1,372
	%	45	45	10	6	78	16

Source: Natural England

As shown in Table 7, all peatland habitat categories in Scotland showed an increase in the number of sites in favourable condition from 2007 to 2018. With the total number of favourable protected sites rising from 333 sites in 2007 to 428 sites in 2018, an increase from 58.1% of total sites to 69.8%.

Table 7: Condition of SSSIs, SACs and RAMSAR sites in Scotland, 2007, 2010, 2015 and 2018

Habitat		**2007**		**2010**		**2015**		**2018**	
	Condition	No.	%	No.	%	No.	%	No.	%
Upland bog	Favourable	121	67	116	61	120	63	128	67
	Unfavourable	59	33	55	29	47	25	34	18
	Unfavourable recovering	0	0	18	9	22	12	29	15
	Not assessed	0	0	1	1	2	1	0	0
Wetland bog	Favourable	33	31	64	57	69	60	74	64
	Unfavourable	75	69	27	24	26	23	13	11
	Unfavourable recovering	0	0	20	18	20	17	28	24
	Not assessed	0	0	1	1	0	0	0	0
Upland fen, marsh and swamp	Favourable	34	53	41	58	49	69	55	77
	Unfavourable	30	47	17	24	10	14	9	13
	Unfavourable recovering	0	0	9	13	12	17	7	10
	Not assessed	0	0	4	6	0	0	0	0
Wetland fen, marsh & swamp	Favourable	145	66	155	65	166	71	171	72
	Unfavourable	76	34	42	18	39	17	36	15
	Unfavourable recovering	0	0	22	9	25	11	27	11
	Not assessed	0	0	21	9	3	1	1	0
	To Be Denotified	0	0	0	0	1	0	1	0

Source: Scottish Natural Heritage

Data in Table 8 is based on data for the period April 1998 to March 2005. The data were provided by the country agencies to JNCC in July and August 2005. There was no data for Wales in any of the reporting categories and the return percentage was unknown (JNCC, 2006).

Table 8: Condition assessment of core peatland habitat features on SSSI and ASSI designated sites in the UK, 2005

Reporting categories	Favourable	Un-favourable recovering	Un-favourable	Destroyed	Number assessments reported	% returns	Regions
Blanket bog	58%	15%	27%	0%	156	unknown	E,S,NI
Lowland raised bogs	22%	35%	41%	2%	120	unknown	E,S,NI
Fens and marshes - upland	46%	18%	34%	2%	56	unknown	E,S,NI
Fens and marshes - lowland	41%	21%	37%	1%	709	unknown	E,S,NI

Source: Joint Natural Conservation Committee (2011)

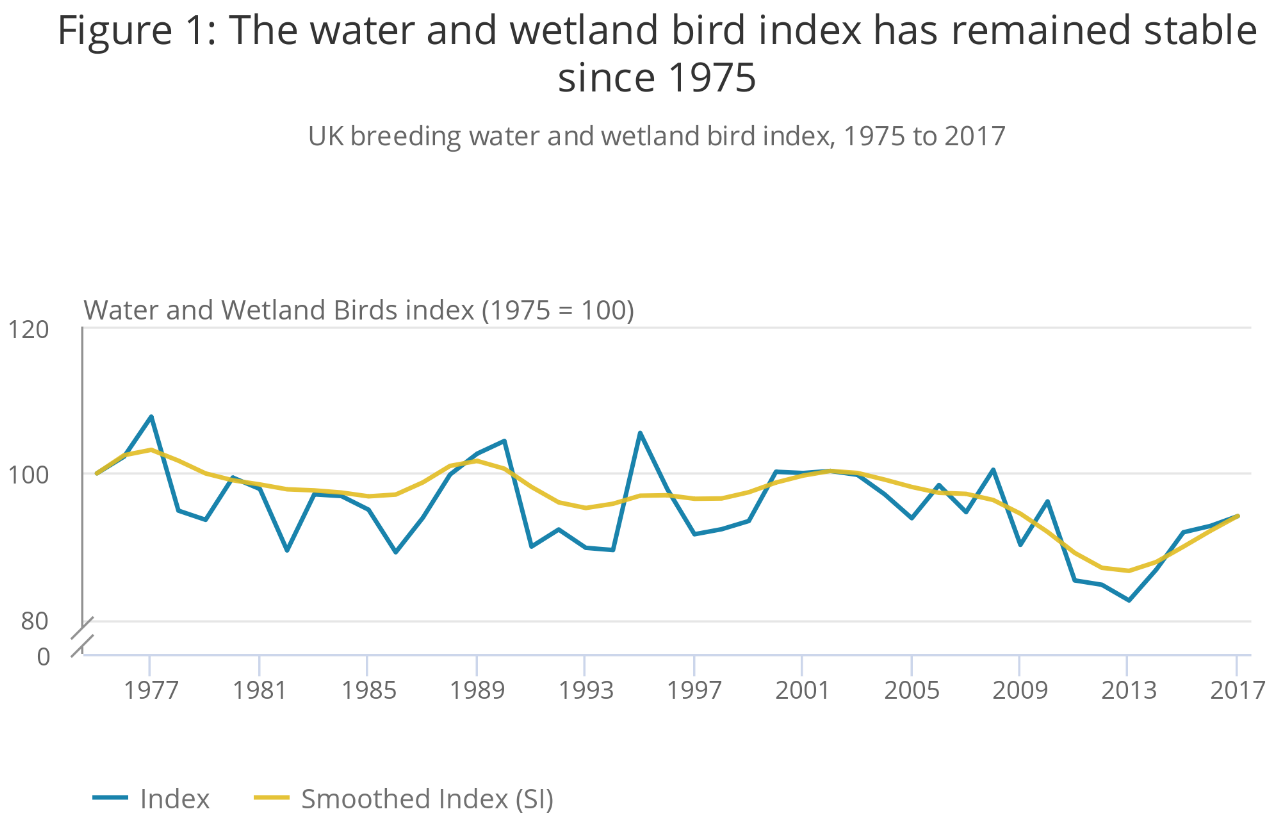
Water and wetlands bird index

A good indication of the broad condition of wildlife in the UK is the bird population. Birds occupy a range of habitats and respond to environmental pressures. There is a wealth of long-term data available on birds making them suitable for long-term trend analysis (Defra, 2018). This can be an additional indicator of peatland condition.

Wetlands includes fens, marshes, swamps and bogs which are generally peat environments. The water and wetlands bird index include rivers, lakes, ponds, reedbeds, coastal marshes and lowland raised bogs. The index measures 26 bird species. The species are selected if they have a population of at least 300 breeding pairs and are a native species. The water and wetland bird index has remained fairly stable since data collection started in 1975, however, it has been lowest in the last decade (Figure 1) (Defra, 2018).

Figure 1: The water and wetland bird index has remained stable since 1975

UK breeding water and wetland bird index, 1975 to 2017



Source: Department for Environment, Food and Rural Affairs (DEFRA), British Trust for Ornithology (BTO), Royal Society for the Protection of Birds (RSPB), Joint Nature Conservation Committee (JNCC) and the Wildfowl and Welands Trust (WWT)

8 . Ecosystem services

Peatlands provide a wide range of services that benefit people. This section summarises the main services that the peatlands provide. It is only a partial picture as it is not currently possible to capture all off the services provided and attribute a monetary value. The ecosystem services presented are split into provisioning, regulating and cultural.

Provisioning

Provisioning ecosystem services create products. Within Peatlands these include fresh water, food, fibre and energy sources. The services provided vary significantly across different peatlands. For instance, fen peatlands have been drained and provide very fertile land for high value agriculture; whereas the upland blanket bogs are used for rough grazing (Bonn and others, 2009).

Water supply

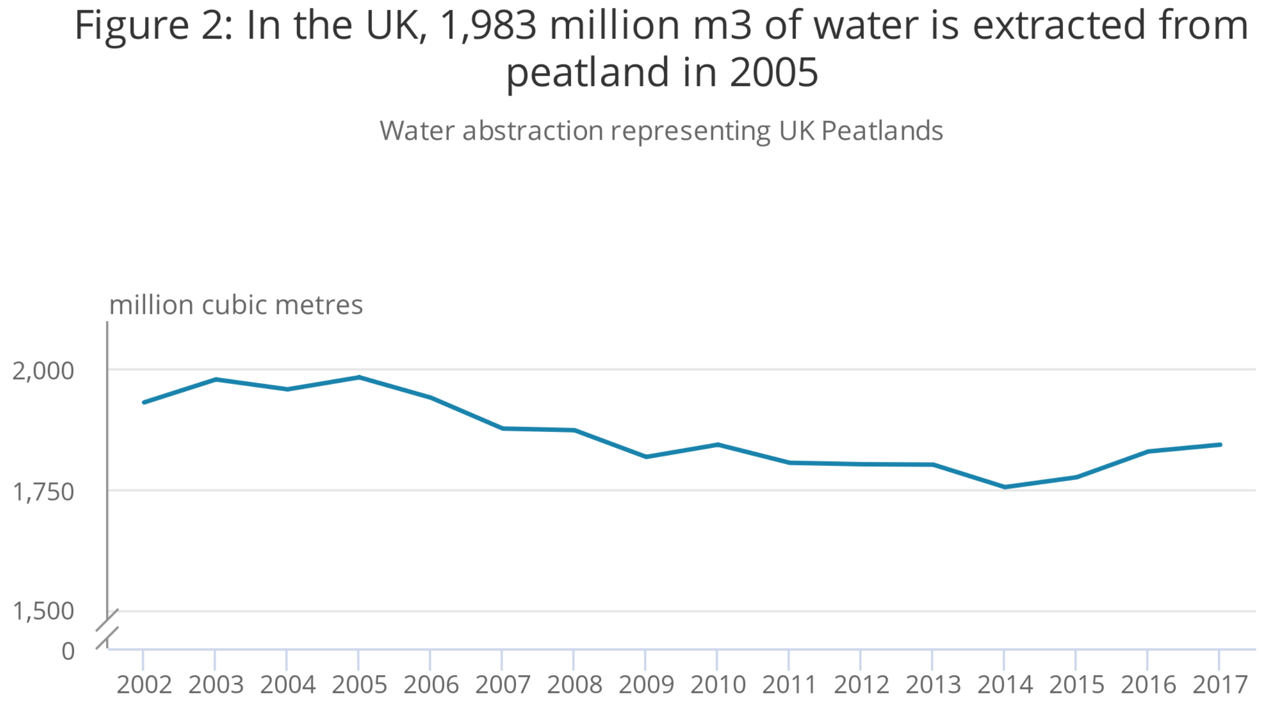
Peat is dominant in the higher grounds and so a significant proportion of the UK’s water supply lands or flows through peatlands. It is estimated 70% of the drinking water as a whole comes from upland areas (Scottish Forum on Natural Capital, 2016; IUCN, 2018b).

In the UK water abstraction for the public water supply peaked in 2005 with the apportioned figure for water from peaty catchments at 1,983 million cubic metre, see Figure 2. A possible reason for the decline from 2005 is more efficient and sustainable use of water, as advocated in the Water Act 2003. As a result, fewer licences have been granted for water abstraction in England and Wales, with fewer being issued annually in the last decade than between 1997 and 2002.

To ascertain values for water supply from UK peatland, these accounts have been apportioned from the ONS UK Ecosystem Service accounts. We can only make rough approximations. The extent of blanket bog in Scottish Water catchments was estimated to be 13.7% by Scottish Natural Heritage (SNH) (Artz and others, 2014). For England and Wales, the area was calculated by working out the percentage the uplands which are peatlands then then taking 70% of this to estimate drinking water from peatlands, with England as 32.1% and Wales as 5.9%. Data was not available for Northern Ireland, so the same percentage was used as Wales since this was the lowest and most conservative figure.

Figure 2: In the UK, 1,983 million m3 of water is extracted from peatland in 2005

Water abstraction representing UK Peatlands



Source: Scottish Government, Natural Resources Wales, Department for Environment, Food and Rural Affairs, Drinking Water Inspectorate (Northern Ireland)

In total, based on the described apportionment, water from peatlands represents 27% of the UK ecosystem service accounts. We can then estimate the volume of supply from peat catchments (Figure 2). It is accepted that water from peatland catchments has a different capital infrastructure and different cost to water supplies in lowland regions. If non-peat dominated water catchments are more or less expensive to run, then our apportioning of economic figures will be inaccurate. We will be considering alternative approaches in the future to provide a more pertinent representation of the cost of water in peat catchments.

Annual monetary estimates are based on resource rents calculated for the Standard Industrial Classification (SIC) subdivision class: Water collection, treatment and supply. The resource rent can be interpreted as the annual return stemming directly from the natural capital asset itself, that is, the surplus value accruing to the extractor or user of a natural capital asset calculated after all costs and normal returns have been considered (see Section 12: Methodology for full details). The annual value fluctuates between 2002 and 2016, with a low value in 2002 of £208 million and a high in 2016 of £888 million (Table 9).

Table 9: Estimated value of UK drinking water from Peatlands, 2002 to 2016

Year	Annual value (£m)	Asset value (£m)
2002	208	4,372
2003	274	4,814
2004	227	5,359
2005	344	6,643
2006	359	8,457
2007	263	8,754
2008	553	10,473
2009	480	12,005
2010	486	12,834
2011	527	13,811
2012	632	16,003
2013	632	16,442
2014	510	16,682
2015	392	16,111
2016	888	18,366

Source: Office for National Statistics

Peat extraction

Extraction of peat continues in Northern Ireland, Scotland and England, mainly for horticultural use (International Union for Conservation of Nature, 2014). Extracted peat has contributed to the economy, however, the extraction of peat results in loss of the peat resource and carbon emissions. It is estimated total greenhouse has (GHG) emissions from sites where extraction has taken place is around 1,200 kt CO2e yr-1 from domestic extraction sites, with higher emissions from industrial sites (Evans and others, 2017). The peat which has been extracted will eventually be oxidized to CO2, creating an additional emission source. As can be seen from Table 10 peat extraction between 1997 and 2015 peaked in 2003 with 2,008,000 cubic metres extracted. The total income generated from the peat extraction has an underlying trend declining from £119 million in 1997 to £36.2 million in 2015 with a peak in 2013 of £74.7 million, based on 2017 prices (Table 10). The quantities extracted and income from peat extraction is expected to continue to decline as the UK Government has stated in the 25-year environment plan (HM Government, 2018) an action to cease using peat in horticultural products by 2030.

Table 10: Peat extracted by volume and income, 1997 to 2015

Year	Peat (m3)	Total Income (£m, 2017 prices)
1997	1,619,000	119.0
1998	1,076,000	72.9
1999	1,653,000	101.2
2000	1,626,000	100.9
2001	1,814,000	114.0
2002	973,000	59.3
2003	2,008,000	108.3
2004	1,262,000	68.2
2005	1,505,000	93.8
2006	1,593,000	76.1
2007	885,000	40.6
2008	760,000	42.2
2009	887,000	47.4
2010	1,004,000	48.2
2011	825,000	42.7
2012	568,000	33.0
2013	1,254,000	74.7
2014	795,000	44.7
2015	800,000	36.2

Source: British Geological Survey - Minerals yearbook (2015 data is an estimate) and Office for National Statistics

Evans and others (2017) estimated changes in peat extraction area over time (Table 11). Data from the Land use, land-use change and forestry (LULUCF) inventory on peat extraction sites and changes in sites registered in the Directory of Mines and Quarries (BGS) were assessed using Google Earth imagery from 2002. Earlier data was obtained from planning consents for 1991. Domestic extraction refers to peat cutting on blanket bog for fuel and industrial extraction on fen and raised bog peat for horticultural use. A small amount is also extracted for the whisky industry. As this data is area and not cubic metres it makes it difficult to compare to the BGS extraction rates. There is no extraction depth data.

Table 11: Area (hectare) of industrial and domestic peat extraction sites by country in 1990 and 2013 (Evans and others, 2017)

Activity	Year	England	Scotland	Wales	N. Ireland	Total
Industrial extraction	1990	7,082	2,881	0	761	10,724
	2013	4,628	2,840	0	503	7,971
Domestic extraction	1990	4,402	44,923	0	92,202	141,527
	2013	4,391	44,649	0	87,539	136,579
Total	1990	11,484	47,804	0	92,963	152,251
	2013	9,019	47,489	0	88,042	144,550

Source: British Geological Survey and Land use, land-use change and forestry (LULUCF)

Food

Livestock grazing is one of the most common land uses for peatlands (Bruneau and Johnson, 2014). Sheep can be farmed in almost every part of Wales due to their hardiness. In the uplands this may be the only feasible option. However, there are relatively low returns to the farmer despite having low maintenance and capital costs. Most livestock holdings in Wales are in less favoured areas (LFA) (Welsh Government, 2018), an area of 1.53 million hectares (RSPB, 2012). In Scotland the land quality for agriculture is quite poor with over 5.73 million hectares classed as LFA. As a result, most of the agriculture is livestock grazing, with 3.6 million hectares classified as rough or common grazing (Scottish Government, 2018).

In England around 240,000 hectares of drained lowland peat is used for farming and food production with the east of England having high value cropping (Morris and others, 2010). The Fenland peatland accounts for approximately 10% (133,000 hectares) of the national areas given to potatoes, sugar beet and vegetables (Graves and Morris, 2013). The National Farmers' Union (2019) estimated the Fens produces more than 7% of the total of England’s agricultural production, which was valued at £1.23 billion.

The area of peatlands that has been drained for use as cropland is currently estimated as 194,124 hectares in the UK (7% of total peat area), with 182,701 hectares being in England (Evans and others, 2017). Using peatlands for drainage-based agriculture (horticulture, arable and intensive grassland) has a negative impact on the peat. There is an estimated peat wastage of 10 to 30 millimetre per year from arable farming on peat from drainage and ploughing (Graves and Morris, 2013). It is estimated 7,600 kt CO2e yr-1 emissions from croplands on peatlands, total of 32% of the GHG emissions from peatlands (Evans and others, 2017).

The estimate for agriculture on peatlands is derived from the different land uses data calculated by the Centre for Ecology and Hydrology (CEH) (Evans and others, 2017), data on area high value crops in the fens (Graves and Morris, 2013) and data from the Farm Business Survey (FBS). The FBS is an annual survey commissioned by Defra and uses a sample of farms that represent the national population, with a sample size around 2,300 farms in England and Wales. This is not sampled by soil types, so includes all soils not just peat. The FBS provides data for England on the outputs from agriculture excluding subsidies, costs for agriculture excluding Agri-environment activities and data on the total farmed area. A rate is then calculated per hectare and applied to the different land use classifications used by CEH. The rate calculated is for England and applied to the whole of the UK. Further work is needed to calculate a £ perhectares rate for the rest of the UK as the data is only currently available by £ per farm. Table 12 shows horticulture has a positive contribution, however, overall there is a negative contribution to ecosystem services for agriculture.

Table 12: Summary peatlands use for agriculture 5-year average, UK, 2013 to 2014 to 2017 to 2018

CEH classification	Agriculture land use	hectares	£ per hectare	Total £
Cropland	Horticulture	133,000	556.3	73,986,366
	Arable/cereal	61,125	-12.8	-783,385
Modified Bog	sheep	560,703	-79.4	-44,507,445
Heather modified bog	sheep	695,973	-79.4	-55,244,897
Grassland	Grazing livestock/hay	234,761	-89.1	-20,915,014
Total		1,685,562		-47,464,375

Source: Centre for Ecology and Hydrology and Office for National Statistics

The Farm Business Income by type of farm in England (Defra, 2018b) reveals LFA Grazing Livestock farms failed to make a positive return in 2017 to 2018 (see Table 13 for selected farm types, full list in Defra report), with a higher average loss than in 2016 to 2017. The value per farm for agriculture was negative £12,500 with Agri-environment payments of £12,000. In addition, they had an average of £25,900 per farm from the Basic Payment Scheme, an EU rural grant payment. The farms, in aggregate, were only profitable as a result of subsidies. In comparison, Horticulture farm agriculture income is £26,700 with Agri-environment subsides of £1,200 and Basic Payment Scheme of £4,600 per farm. The horticulture farms total farm business income being £47,700 per farm (Table 13).

Table 13: Farm business income by type of farm (£ per farm) in England, 2017 to 2018

Farm type	Agriculture	Agri-environment payments	Diversified income	Basic Payment scheme	Farm business income
Cereals	1,600	3,800	18,700	40,200	64,200
General cropping	16,000	8,800	20,600	47,900	93,300
Grazing livestock (lowland)	-6,100	3,400	8,400	16,500	21,900
Grazing livestock (LFA)	-12,500	12,000	2,900	25,900	28,300
Horticulture	26,700	1,200	15,200	4,600	47,700

Source: Department for Environment, Food and Rural Affairs

There is a high degree of variability between income from different crops. According to the John Nix Pocket book for Farm Management 2019 (Redman, 2018) gross margin per hectare at the average price for wheat is £791, potatoes £1,534 and sugar beet £760. With high variability on the income from different crops and lack of data on specific crops on peatlands a more accurate valuation may be feasible with further research.

Timber

In the UK the total area of forestry in 2019 was 3.19 million hectares (Forest Research, 2019a). The total area for forest on peatlands is 439,292 hectares for the UK, 15% of the area of total peatlands and 14 % of the total forestry area. Research by the Centre for Ecology and Hydrology (CEH) assessed the change in areas of afforestation on peat based on data from the Forestry Commission on grant assisted planting and deforestation from area of restored peat which was formerly forest, see Table 14. However, this data does not reflect changes in forestry policy which has encouraged tree removal on peat. It does reflect the general decrease in the rate of afforestation from 1,086 hectares in 1990 to 83 hectares in 2015 for the UK (Evans and others, 2017).

Table 14: Area of afforestation and deforestation on peat between 1990 and 2013, UK countries (Evans and others, 2017)

Activity	England hectares	Scotland hectares	Wales hectares	Northern Ireland hectares	Total hectares
Afforestation	411	24,348	76	3,930	28,766
Deforestation	1,503	2,857	331	0	4,692
Net change	-1,092	21,491	-255	3,930	24,074

Source: Centre for Ecology and Hydrology

Historically the uplands had a significant expansion of woodlands to create a reserve of timber for national security. This started with the formation of the Forestry Commission in 1919. Recently forestry on peatland has been realised as ecologically undesirable or economically unviable (Bonn and others, 2009). Research by Walker and others (2008) revealed in lowland peatlands tree and scrub removal was common. It was usual for the materials removed to be left on site to create onsite features such as boardwalks and unusual for timber to be taken off-site.

Timber grown on peatland tends to be less valuable and less productive than timber grown on different soils. It is difficult to extract timber from peatland as extraction costs can be high due to machinery getting bogged down and large areas can be affected by wind-blown damage (Smyth and others, 2015). Approximately 84,000 hectares of afforested peat is with low productive trees (Committee on Climate Change, 2018). Often the wood goes for pulp, fuel and other low grade uses as the timber from bogs is of poor quality (Sloan and others, 2018). It can cost more to remove trees from peatlands than the value of the timber. A study by Okumah and others (2019) investigated different restoration costs for peat including the felling of trees to waste cost, which has a mean of £1,993 per hectare. Data was only available for one site on normal-age forestry harvesting at £4,306 per hectare. A previous study (Artz and others, 2018) revealed an average cost of £1,480 per hectare for harvesting normal-age forestry. This study showed there is considerable variation of costs between sites due to different site characteristics, such as accessibility.

Decisions need to be taken now as existing forests on peatlands come to harvesting age to either restore bogs or restock. Data is needed on the yields and quality of afforested peatlands in the UK to assess any ecosystem services benefit from timber (Sloan and others, 2018). The future of peatland plantations requires trades offs against biodiversity, value of commercial forestry and ecosystem services provided by the different habitats. There are conflicting issues for government to meet targets for extensive peatland restoration and forest expansion (Payne and others, 2018). Currently there is no data on the volume and value of timber from peatlands, only on total amounts of timber harvested.

Wind power

The main criteria for the location of a wind turbine is there needs to be wind with an average speed of 7metre per second or greater (Bonn and others, 2009). Not the substrate they are built on. For windfarms on peatlands there is an important balance between the carbon savings from the windfarm and the loss of carbon sequestration and storage from the peat due to construction (Lindsay, 2010). Wind farms on peatlands have a potential for a range of negative impacts. This includes changes to hydrology caused by the building of access tracks with this also impacting on biodiversity and slope stability (Bonn and others, 2009). Many of the impacts from windfarms are not fully understood on peatlands.

In 2010 it was estimated most windfarms sites on peatlands had potential to reduce net emissions. However, by 2040 most sites will not reduce carbon emissions even with careful management. This is because of projected changes in the amount of fossil fuel used to generate electricity (Smith, Nayak and Smith, 2014). The Scottish Government (2018) uses a carbon calculator tool to assess the carbon impact from wind farm developments. It looks at the carbon savings from the windfarm and compares against the carbon costs of a wind farm development.

Table 15 shows the number of operational turbines in Scotland for 2014 and the depth of the peat they stand on. Currently there is no data on total number of wind turbines for the UK on peatlands. However, Table 16 shows the number of wind turbines on the Mountains, Moorland and Heath (MMH) habitat for 2018. Details on gigawatt hours (GWh) generated can be found in the MMH Natural capital publication (ONS, 2019). Further work is needed to identify all windfarms on peatlands. This can be achieved when a digital map of the area of peatlands is available to overlay with the windfarm location data from the Department for Business, Energy and Industrial Strategy (BEIS).

Table 15: Number of operational wind turbines in Scotland (2014 data) in relation to peat depth (Artz and Chapman, 2016)

Depth of peat/organic matter (m)	**Number of turbines in wind farm development less than 50MW**	**Number of turbines in wind farm development greater than or equal to 50MW**
0	708	264
greater than 0.0-0.5	396	283
greater than 0.5-1.0	131	192
greater than1.0-1.5	104	295
greater than1.5-2.0	21	1
greater than 2	76	60
Total	1,436	1,095

Source: James Hutton Institute

Table 16: Number of UK wind turbines on Mountain, Moorland and Heath habitat by Land Cover Map 2015 classifications for 2018

LCM2015 habitat	**Number of turbines**
Heather grassland	601
Heather	456
Bog	693
Fen, marsh and swamp	19
Inland rock	3
Total MMH	1,772

Source: Department for Business, Energy and Industrial Strategy

Regulating

These are the benefits provided by the regulation of natural processes. Including air quality regulation, climate regulation, water quality and natural hazard regulation such as flooding and wildfires (Bonn and others, 2009).

Climate regulation through carbon storage

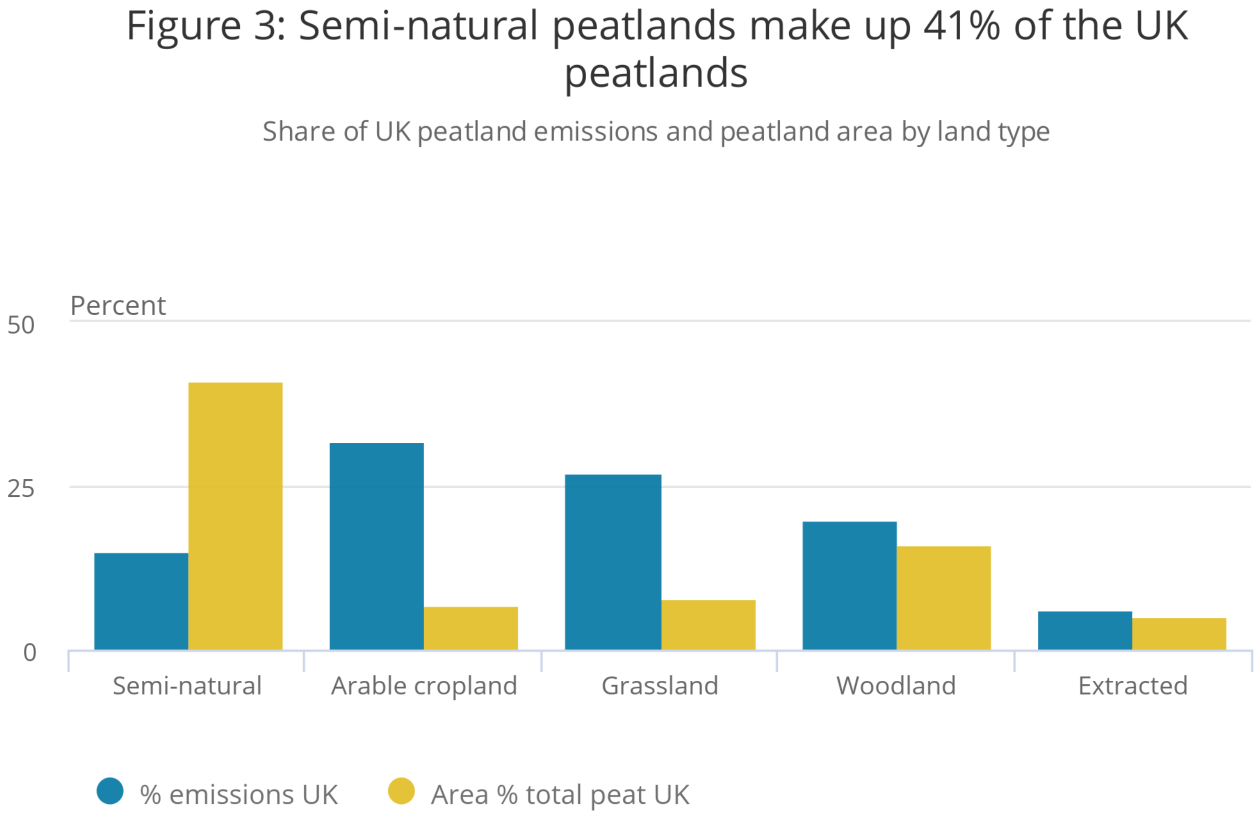
Peatlands can store a significant amount of carbon and is an import “stock” value for the UK. However, this cannot be currently accurately measured or valued (Smyth and others, 2015). Data is available on the amount of carbon being sequestered from near natural fens and bogs. A near natural bog can remove 3.54 tonnes carbon dioxide per hectare per year (tCO2 ha-1yr-1) and a near natural fen 5.44 tCO2 ha-1yr-1 (Evans and others, 2017). Peatlands can also be a source of methane due to their waterlogged nature. Methane has a potential higher effect on global warming as it is a stronger greenhouse gas than CO2, but it also has a shorter lifetime in the atmosphere which limits its impact. Over the long term the climate cooling effects of CO2 sequestration by growing peat outweighs the warming impacts of the methane emitted. When methane and nitrous oxide are included near natural bog has small emissions of 0.01 tCO2e ha-1yr-1 and near natural fen sequesters at 0.61 tCO2e ha-1yr-1 (Evans and others, 2017). A peatland in a good water-logged condition can grow at around a rate of 0.5 to 1 millimetre per year (IUCN, 2014b).

Currently there is only around 640,000 hectares (22%) of peatlands in the UK that are in a near natural or rewetted state. It is estimated this area acts as a carbon sink with approximately 1,800 kt CO2 yr-1. When looking over the longer term near natural peatlands are close to climate neutral as there are emissions of methane which counterbalance the CO2 sink, making them a very small net greenhouse gas (GHG) sink. The remaining 78% of peatlands are in different states of degradation, which either reduces their capacity to sequester carbon, or turns them into (potentially very large) carbon sources. Overall, this has led to peatlands becoming a large net source of emissions. Recent research by CEH for BEIS estimates emissions from peatland sources to be around 23,100 kt CO2e yr-1 (Evans and others, 2017).

The type of disturbance on the peatlands does result in a significant variation in the amount of emissions. Lowland peat that has been drained for crops emits around 32% (7,600 kt CO2e yr-1) of the total of UK peatlands emissions even though it only accounts for 7% of peatland area (see Figure 3). Semi-natural peatlands making up 41% of UK peatlands area emits around 3,400 kt CO2e yr-1, around 15% of total peatland emissions. The majority of woodlands on peatlands are drained conifer plantations (Evans and others, 2017).

Figure 3: Semi-natural peatlands make up 41% of the UK peatlands

Share of UK peatland emissions and peatland area by land type



Source: Centre for Ecology and Hydrology, Evans and others, 2017

As Table 17 shows peatlands only near-natural peatlands are a sink of carbon and those that have been modified in the UK are emitting greenhouse gases and the resulting ecosystem flow would be counted as negative. On the other hand, any measures to reduce these emissions through changes in land-use and management have the potential to contribute significantly to meeting overall GHG emissions targets and thus contributing to climate change mitigation.

Table 17: Peatland CO2 sink and emissions for the UK by land type

Land use	Area % total peat	CO2 sink/emissions
Near-natural	22	1,800 kt CO2 yr-1
Semi-natural	41	3,400 kt CO2e yr-1
Arable cropland	7	7,600 kt CO2e yr-1
Grassland	8	6,300 kt CO2e yr-1
Woodland	16	4,600 kt CO2e yr-1
Extracted	6	1,200 kt CO2e yr-1

Source: Centre for Ecology and Hydrology, Evans and others, 2017.

Smyth and others (2015) suggests one method to include climate regulation from peatlands in the ecosystem services is to look at the reductions in emissions over time from peatland restoration projects. Currently around 80% of peatlands are in a degraded state and contributing to GHG emissions. Any improvements in peatland management would result in fewer emissions and therefore could be shown in the accounts as a reduction in emissions.

Water quality regulation (waste detoxification)

Peatlands in upland areas play a significant role in the supply and the quality of drinking water. The deep peats intercept and retain a range of atmospheric pollutants, including nitrogen, sulphur and heavy metals, providing less contamination in drinking waters. As a result, water from functioning peatlands is naturally of high quality (Committee Climate Change, 2013). The condition of the peatlands has an impact on the downstream catchments for the quality and quantity of water supplied. This impacts the value of the water for uses such as drinking water quality, agricultural uses and recreation uses on streams and rivers.

The Committee on Climate Change (2013) identified in England that there are increasing amounts of carbon being lost into water bodies. Levels of dissolved organic carbon (DOC) in water courses has doubled over the last 30 years. In upland areas this increase, which has been attributed to ecosystem recovery from the effects of acid rain (Monteith and others, 2007) has been responsible for the largest change in water quality in upland drinking water supplies. The erosion of upland peat is also releasing contaminants that were previously locked away in the peat. In addition, the transportation of particulate organic carbon due to peat erosion is reducing water storage capacity in reservoirs. See the Natural Capital Mountains, Moorlands and Heath publication for further details of DOC levels (ONS, 2019).

The removal of peat sediment and dissolved organic carbon represents a large cost in water treatment for water utilities for water draining from degraded peatlands. Northern Ireland, Republic of Ireland and Scotland are working on the Co-operation Across Borders for Biodiversity project (2017 to 2021) to restore peatlands to reduce runoff and improve quality of raw water, resulting in cost savings at the treatment works from the reduction of chemicals to remove the colour from the water (Northern Ireland Water, 2017).

The Natural Environment Research Council (NERC) and Scottish Water are currently funding a large project (FREEDOM) to improve understanding of the relative importance of peatland management. Atmospheric deposition and reservoir processes in determining DOC levels in raw water supplies, and to develop a modelling system to support catchment-management and treatment infrastructure investment decisions.

DOC is problematic for the water treatment process as water companies must ensure they meet the environmental standards and regulations, including the EU Water Framework Directive 98/83/EC on the quality of water for human consumption.

Smyth and others (2015) identified water quality regulation an important ecosystem service, however, measuring the physical flow is challenging. Suggestions for measuring this service included using catchment specific data on the costs of treating water for public supply. Numerous water companies within the UK are now undertaking restoration projects in their water catchments with the aim of improving water quality. Measuring the improvement in water quality would show a reduction in the negative impact from peatland degradation. An example is Scottish Water where they identified approximately 50% of their catchments contains peatland. They are now working on improving water quality upstream to reduce operational costs of treatment downstream (Rezatec, 2019).

Further research is needed to understand the complex water regulating services from peatlands.

Flood hazard regulation

The impact of peatland in a good condition on flood hazard regulation is not fully understood. Peatlands have the ability to store large volumes of water, as much as 90% to 98% water by mass when saturated. The storage capacity of peat led to a mistaken belief that they can diminish the impact of flooding by storing excess rainwater (Holden, 2005). The water storage capacity of upland wetlands and their influence on flooding downstream varies depending on the size of the wetlands relative to the drainage network (Heathwaite, 1995). For a reduction in flooding the water level in the wetland needs to be low enough to leave the capacity to store water rapidly. With most bogs close to saturation they are rarely able to attenuate flow and more likely to contribute to storm runoff as they are already saturated (Holden, 2013).

The condition of the peatland, such as near natural or damaged, impacts on the speed of surface runoff and the size and timings of water flows in a river catchment, thus influencing amount of flooding (Smyth and others, 2015). Natural and restored peatlands provide reduced downstream flood risks compared to damaged peatlands (Committee Climate Change, 2013).

Further work is needed to quantify the regulation of water flow from peatlands during a flooding events for it to be included as an ecosystem service. Forest Research (2019b) has undertaken initial estimation of flood regulating services for Great Britain woodland by investigating the equivalent to effective flood water storage that would need to be provided if the woodland cover absent and replaced by grassland. A similar approach on peatlands could adopt an equivalent storage capacity approach. If the peat was not there, then how much additional storage would be needed?

Cultural

Cultural ecosystem services are the ones which provide non-material benefits like enjoyment of the landscape, recreation on peatlands and cultural heritage (Bonn and others, 2009). It is difficult to quantify cultural services provided by peatlands because of their subjectivity and how different sectors of society perceive them (Suckall, Fraser and Quinn, 2009).

Archaeology

Peatlands are of considerable historical importance as they can preserve records of interactions between people and places, species, environment, climate and land use over time, for 10,000 years or more. Such records provide insights into past environment and culture, including historic climate changes and land management regimes (Climate Change Committee, 2013). Peatlands have revealed some of the UK’s iconic finds. Examples being Lindow Man “bog body” in Cheshire, the Mesolithic headdress of Star Carr and the Llyn Cerrig Bach hoard containing over 150 Iron Age objects. There are an estimated 22,500 archaeological sites that may survive within or beneath the peat deposits. As important as large finds are the small microfossils, for example pollen grains (evidence of past vegetation change), insect and plant remains, as they preserve a record of environmental change over time. A vertical section taken from undisturbed peatland will show changes over time as the peat steadily accumulates. In addition, the character of a landscape may be of value as they show historic land use, such as mining, peat cutting or royal hunting grounds (Payne and Jessop, 2018; Gearey and others, 2010).

Peatlands are exceptional for preservation of organic and inorganic archeological remains due the characteristic waterlogged, acidic and anaerobic (absence of oxygen) conditions of the peat. An archeologist typically finds up to 90% of materials from past communities in peatlands, whereas on dry land up to 10% may be found (Gearey and others, 2010).

Research by Gearey and others (2010) produced estimates on archeological sites on peatlands based on past surveys and studies. Estimated a total of approximately 22,500 with Scotland having 11,000, England 7,000, Northern Ireland 3,500 and Wales 300. However, there is currently no definitive data on the number of sites in the UK. As of May 2019, Historic England have registered 379 sites linked to peat. This includes Bronze Age and Iron Age trackways, Prehistoric field systems, barrows and buildings with links to industrial and household uses of peat.

The benefits of many archaeological finds in peat come at the cost of the peat itself. Trackways and other finds like bog bodies only become visible when peatland is eroding or damaged. They then get exposed to oxygen and decay. Whereas the well protected sites for archeological remains and paleoenvironmental sequences in healthy peat environments are undiscovered. In the absence of a robust estimate of the number of archaeological sites and their location in peatlands it makes it difficult to provide an accurate estimate of this ecosystem service.

Fluck and Holyoak (2017) identified the historic environment is not well represented in ecosystem services and natural capital accounting. By understanding the historic character of a landscape, it can help to identify the supporting services that makes places special for wildlife and people.

Education and research

Peatlands are widely used as outdoor classrooms providing topics which range from their history and archaeology, through to present day interests and uses their role in influencing, and being affected by, future change.

Numerous National Parks now employ educational officers to accompany educational visits to blanket bogs, written resources for schools and provide information for the public. In addition, conservation organisations have also produced education packs for teachers to use in the curriculum (Bonn and others, 2009). One of the resources created for schools is from Scottish Natural Heritage ‘Peatlands: A guide to educational activities for schools’ (SNH, 2014). An example of education activities is in the Flow Country, a remote area in the north of Scotland, where they have a small laboratory and a field centre with accommodation for research and have learning opportunities through a schools programme (Flows for the future, 2019).

There is no data on the total number of educational visits to peatlands in the UK. Data is available on the publicly funded research on peatlands, with the majority being undertaken at universities. Data in Table 18 is from the Gateway to Research website which has a database on publicly funded research in the UK (UK Research and Innovation, 2019). This table shows funding grants for research on UK Peatlands from 2006 to 2019, with research funding having a peak in 2009 with £979,735 worth of funding.

Table 18: Publicly funded research grants on Peatlands in the UK, 2006 to 2019

Year	£
2006	88,609
2007	492,934
2008	802,286
2009	979,735
2010	849,978
2011	556,605
2012	582,005
2013	496,657
2014	236,782
2015	453,680
2016	557,489
2017	713,422
2018	882,796
2019	622,027

Source: Gateway to Research

Recreation

Recreation on peatlands is a valuable ecosystem service in the UK, however, it remains poorly quantified. It can be difficult to analyse for peatlands as visitors may not be aware they are visiting a peatland environment. It is easier to identify visits to lowland sites as they are often nature reserves, such as Wicken Fen (Smyth and others, 2015). Rewetting resulting from restoration activities will affect popular recreational activities such as hill walking, horse riding or deer hunting, as this becomes increasingly difficult as the land becomes saturated for longer periods of time.

One such example of an easily accessible fen is the National Trust nature reserve at Wicken Fen, an area of around 358 hectares. It currently attracts 65,000 visitors to the reserve for a range of activities including walking, boat trips, school visits and the café. Restoration of the area has resulted in 48 kilometres of public access being created or improved (National Trust, 2019).

In Northern Ireland peatland now popular with tourists is the “Stairway to Heaven” at Cuilcagh Mountain in Northern Ireland. A boardwalk was built to protect the environmentally important sensitive peat bog from erosion. However, due to social media it has now become one of the top attractions in Northern Ireland as people want to share selfies from the 665 metre summit. Prior to its opening it 2015 it attracted less than 3,000 visitors a year. In 2016 this rose to 24,000 visitors and 70,000 in 2017 (Gray per comms, 2018). This increased popularity has threatened to damage the peatland the walk way was built to protect.

Estimates for peatlands are based on apportioning the Monitor of the Engagement with the Natural Environment survey (MENE) from Natural England then upscaled for the whole of the UK (see methodology section for full details). It is estimated time spent in peatlands in 2016 was 179.9 million hours with an expenditure of £273.6 million (Table 19).

Table 19: Estimated recreational visits, hours spent and expenditure on UK peatlands, 2009 to 2017

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Visits (million)	79.4	76.2	87.6	74.9	96.6	87.2	100.7	104.9	78
Time spent at habitat (hours)	115.6	91.7	111.9	122.2	155.8	92.9	119.6	179.9	120.6
Expenditure (£ million)	244.3	216.3	191.8	193.9	284.4	136.7	124.1	273.6	169

Source: Office for National Statistics

Peatlands have been used for recreational hunting over a long period of time. During the late 19th and early 20th century hunting changed from walked-up shoots with gun dogs to driven grouse shoots (Natural England, 2010). PACEC (2014) estimated in the UK 700,000 red grouse were shot and 74,000 red deer stalked in 2012 to 2013. It was also estimated a total of 1,700,000 shooting days in the UK in 2012 to 2013, with an estimated spend of £2.5 billion on the goods and services. The majority of the spending was on shoot subscriptions and shooting fees. However, this is for all hunting habitats and peatlands cannot be identified in these figures. Further details on recreational shooting can be found in the Natural Capital Mountains, Moorlands and Heath publication (ONS, 2019). The Scottish Government commissioned research investigating the costs and benefits of large shooting estates to Scotland's economy and biodiversity. The review found there is an estimated £23 million of gross value added to the Scottish economy from grouse shooting and related activities in 2009 (Brooker and others, 2018).

Currently there is no data available for recreational hunting just on peatlands and it will be excluded from ecosystem services for peatlands. Further research is needed to provide time spent and the values of the benefits from peatlands.

Sense of place, aesthetics and image

An important but less tangible benefit provided by peatlands is their important role in shaping the “sense of place” in the landscape. In Scotland the peatlands provide iconic backdrops which are valued by tourism and film industries and play an important role in the brand for food and drinks.

In England peatlands generally form a significant part of its natural heritage with large tracts of semi-natural habitat. These areas provide a sense of “wilderness”, a now rare habitat within the typical heavily modified landscape. Many areas of uplands with blanket bog are designated as Areas of Outstanding Natural Beauty (ANOBs). They also get referred to as “landscape designations” as they provide conservation and enhancement of biodiversity, and help link people with nature (Natural England, 2012).

Peatlands are an area of cultural enrichment and have provided inspiration for literature, such as “The Hound of the Baskervilles” and “Lorna Doone”, and in art, song and poetry over time. Even today their evocative colours are captured in some tweeds and tartans in Scotland.

The European Landscape Convention (ELC 2000) protects and manages landscapes in Europe and which the UK signed in 2006. This convention recognises the relationship between people and place and it states the landscape “contributes to the formation of local cultures and … is a basic component of the European natural and cultural heritage, contributing to human well-being and consolidation of the European identity”. Giving prominence to the landscape being more than a view and it is important how people interact with the landscape and their experiences gained from their interactions (Bonn and others, 2009).

9 . Future development

Smyth and others (2015) identified a comprehensive list to developing future peatlands accounts. The major advancement since 2015 has been the completion of a unified peatlands map for the UK and estimate of the different land use categories for peatlands. To take this further, access is needed to the digital map created for the 'Implementation of an Emissions Inventory for UK Peatlands' report (Evans and others, 2017). This report was compiled from multiple sources and subject to different licencing restrictions and is not currently available to access digitally. This project map made significant advances in mapping the peatlands in the UK and provides the first harmonised peat map of the UK. However, this work highlighted many discrepancies between different maps and defining the boundaries between peat and other soil types. It is recommended to continue to develop the UK peat map and the use of standardised mapping across the four UK administrations.

Further developments are needed to produce repeatable condition mapping of UK peatlands. The condition of the peatlands is continually changing. It is important to know the current condition as peatlands in a good condition provide better ecosystem services.

New data sources for the UK are needed to identify the currently poorly understood contribution timber, wind power, flood hazard regulation, water quality, carbon storage and recreation bestow to peatlands ecosystem services.

10 . Restoration

Introduction – Objective and Approach

In this section we estimate the cost of restoring the UK's peatlands. A restoration cost account requires a clearly defined objective. The ONS Peatland account is "cross cutting" because peaty soils are found across the UK's nations and in a variety of habitats and circumstances. There are a variety of government and legal objectives for some peatlands but there is no single objective with a detailed course of action (for example see Natural England, 2010). The Committee on Climate Change suggest 55% of peatlands should be restored by 2050 in Committee on Climate Change (2019). The detail of the report indicates that this would not include all lowland agriculture but does not provide detail on which 55%.

In addition, we can only gather a relatively coarse description of the condition and extent of peatlands. This presents a challenge to a policy neutral organisation since we must make appropriate assumptions.

Objective

This section therefore begins with the simplest possible assumptions and chooses the simple objective of restoring peatlands to near natural condition. Between the current state of peatlands and "near natural condition" there are a range of compromise solutions which decision makers may find preferable. A coarse objective has the benefit of enabling us to simply estimate the cost of stopping some activities and starting others. An approach which yields simpler calculations and stark outcomes which better illustrate the potential trade-offs than approximations of potential compromises. There are also new activities which might be used but their novelty means that there are few good economic data making a useful analysis even harder.

The most notable implication of our approach has been for us to assume that all crop farming would cease on peatlands. The Office for National Statistics is a not a policy-making agency and in no way advocates any particular policy. By initially assuming that all farming would cease the intention is not to suggest that this will or should occur – it is done because it is possible to cost this option and it would achieve the stated objective for those landcover types. Alternative ways to maintain agriculture on these lands and reduce carbon emissions are being explored.

Evans and others (2016) examine the impact of raising the water table on emissions on agricultural lands and find that raising the water table 10 centimetres can save 4 million tonnes of carbon dioxide equivalent (MTCO2e) per year. The Committee on Climate Change (2019) suggests that seasonal management of the water table in agricultural lands could save 1.5 MtCO2e in 2050. We understand that further work is needed before we fully understand how water table management trades off with agricultural output.

This section presents our current best estimate of the cost of restoring each type of peatland to near natural condition and the net impact of restoring all peatlands to illustrate the issue. We then present alternative methods for prioritisation of the restoration of 55% of all peatlands with and without croplands because of the specific uncertainty surrounding it.

Baseline

The baseline for this work is the current state of the world. As such there are a number of costs which might be incurred under the counterfactual which are not included in the valuation. For instance, if water pumping is required now and if we restore peatlands that cost is not included. The cost may move from private to public hands (or vice versa) but the net impact on the UK will be the same as these are transfer costs not highlighted in this form of analysis.

Method

The account is built from the basic landcover types defined in the 'Implementation of an Emissions Inventory for UK Peatlands' report by the Centre for Ecology and Hydrology (CEH) (Evans and others, 2017) matched against a set range of land management activities. We first considered which of the land management activities would be required for each peatland type to convert it to a near natural state. This work was desk based and checked with our steering group and other experts.

A per hectare cost for each intervention was estimated. Where the cost would be over a number of years the future costs were discounted using the Green Book discount rate to estimate the current value of that intervention per hectare for the period of time over which it is expected to be incurred or 100 years for perpetuity.

If a given landcover type is identified as requiring a given intervention the present value of the cost is multiplied by the total area of that landcover type. Then the total cost of all interventions on that landcover type are added together before the cost of all landcover types are added for a UK cost.

To contrast the costs, we estimate the climate change benefits of restoring peatlands to near natural condition. The first step is to estimate when the work would be complete and the benefits start accruing. We could find no strict basis on which to make this assessment. As a simplification we assume all land is fully restored within 10 years, that there are no benefits before this date and all of the benefits come subsequent to it.

We take the emissions per year by landcover type from CEH (Evans and others, 2017) and use the BEIS non-traded carbon price (GOV.UK, 2019) discounted to current prices to estimate the present value of 100 years' worth of value.

A simple sensitivity analysis was performed in which all of the largest costs identified were used instead of mid-range estimates. In addition, it was assumed that all livestock farmed lands shift to being maintained with "conservation grazing" stocking rates. Finally, we priced domestic peat extraction at the same value per hectare as commercial extraction.

A detailed breakdown of the methods used to estimate the costs is provided in the report published by Eurostat or can be obtained on request from the Natural Capital Team.

Results

Tables 20 summarizes the basic and sensitivity scenario costs. The basic scenario gives a present value cost of £8.4 billion of restoring all peatlands to near natural condition. Noting that we have assumed that all upfront costs are incurred in the first year this value would fall in reality since future costs would be further discounted. The “Sensitivity” shows that the total cost increases by more than double from £8.4 billion to £21.3 billion over the next 100 years if we assume that all costs are shifted to the highest found in the literature.

The total climate change benefits of restoration are estimated at £109 billion (see Table 20). This is over five times the “Sensitivity” scenarios estimate of the costs.

Table 20: The carbon benefits for restoring peatland are estimated to outweigh the cost by 5 to 10 times, UK
Basic and sensitivity test cost estimates alongside estimated climate change emission benefits presented as a present value discounted over 100 years disaggregated by peatland type

Land Cover	Basic: Cost estimate £	Sensitivity: cost estimate £	Present Value of carbon benefits £
Forest	3,030,851,405	5,129,807,534	20,497,497,042
Cropland horticulture	2,672,199,052	3,415,268,425	24,409,976,388
Cropland arable	189,264,111	530,768,738	11,218,494,787
Drained Eroded Modified Bog	70,377,752	757,589,990	1,895,117,551
Undrained Eroded Modified Bog	-216,643,775	466,392,759	4,101,153,264
Drained Heather Dominated Modified Bog	581,011,507	2,668,037,827	2,924,111,147
Undrained Heather Dominated Modified Bog	1,177,980,396	4,410,245,180	5,027,132,451
Drained Grass Dominated Modified Bog	-67,267,836	443,198,492	1,047,569,434
Undrained Grass Dominated Modified Bog	-319,471,030	126,497,429	1,634,689,177
Extensive grassland	-7,809,222	340,849,919	3,822,338,613
Intensive grassland	20,363,234	1,562,033,971	26,760,195,163
Near Natural Bog	475,005,164	475,005,164	
Near Natural Fen	4,674,360	5,267,955	
Extracted Domestic (fuel peat)	480,160,258	1,324,911,854	5,096,883,292
Extracted Industrial (horticultural)	195,100,275	239,102,493	523,530,275
Rewetted Bog	21,727,090	22,166,010	111,126,484
Rewetted Fen	43,476,439	48,997,497	745,944,581
Total	8,350,999,180	21,966,141,237	109,815,759,647

Source: Centre for Ecology and Hydrology, Department for Business, Energy and Industrial Strategy and Office for National Statistics

The Climate Change Committee Objective

Though we have only presented climate change benefits (since these are most readily estimated) restoration cost accounts are built for a broad range of natural capital benefits. The key issue for peatlands is the flux in climate change emissions and we therefore consider the Committee on Climate Change objective of restoring 55% of peatlands.

Since there is no clear description of which 55% should be restored we started by removing cropland from the objective since we are uncertain as to the most likely intervention for climate change purposes or its costs. We then ranked each landcover type. First by benefit cost ratio and then total carbon emissions per year. Starting at the highest benefit cost ratio or total emissions we began adding landcover types to the list until 55% of peatlands were included. Once adding a landcover type pushed the total beyond 55% then only the necessary proportion of the lowest ranked landcover was included. We then repeated this exercise including cropland which was ranked high enough to be included each time. We used the “Sensitivity” scenario costs for comparison.

On a Benefit:Cost ratio basis we exclude the Drained Eroded Modified Bog, all Heather Dominated Modified Bogs, drained modified grass dominated bogs and peat extraction. Only two-thirds of forest is included. On an emissions basis we reach 55% while leaving out: extensive grassland, commercial peatlands and all modified bogs except 6% of Undrained Heather Dominated Bog. It is worth noting that these were simply two ways to rank landcover types and alternatives such as ranking by emissions per hectare would be equally appropriate and would, for instance, rank restoration of domestic peat extraction more highly. Domestic peat extraction receives significant attention but falls out of these prioritizations due to its small area and the significant income we impute for it.

Scenarios in which we included cropland in the set of landcover types prioritised led to approximately 16 to 19 MTCO2e per year as opposed to the 12 MTCO2e per year without it (Table 21). The two ranking approaches lead to similar emissions reductions but oddly an emissions-based ranking led to higher overall net benefits.

Table 21: Net emissions reduction and net benefits of restoring 55% of peatlands to near natural condition, land included by ranking landcover types on a benefit:cost or total emissions basis excluding cropland

Ranking Option	Net Emissions Reduction MTCO2e/year	Net Present Benefit (£ Billions)
Benefit:Cost	12	45
Emissions	12	51

Source: Office for National Statistics

11 . Discussion

In this report we examined ecosystem extent, condition and service accounts and restoration cost accounts for Peatlands. We used the first unified peat map created by the Centre for Ecology and Hydrology (CEH) (Evans and others, 2017) and their land use categories for peat to assess peatland condition to assess extent and condition. We found that additional work is needed to update the peatlands extent map developed by CEH. Detailed mapping is needed on extent and condition of the Peatlands if the Peatland Account is to be repeated regularly.

The condition of the peatland has a significant impact on carbon and the climate. Without knowing the true extent and depth of peat deposits it is not currently possible to estimate the amount of carbon currently stored. However, CEH estimated the amount of greenhouse gas (GHG) emissions from the current land use of peatlands, in total around 23,100 kt CO2e yr-1 from peatland sources (Evans and others, 2017).

One of the main services provided by peatlands is the supply and quality of drinking water. It is estimated to supply over a quarter of the UK's drinking water. The value of this service is significant and varies according to location. Peatland in a good condition requires less treatment as the removal of peat sediment and dissolved organic carbon represents a large cost for water utilities.

The food provided by peatland varies by location on its impact to ecosystem services. Upland blanket bogs have a low value as it is mainly suitable for light grazing. Lowland fens are highly profitable for horticulture and arable farming; however, this is at a detriment to the peat from erosion and the release of GHG from agricultural activities.

Recreation is of high value on peatlands, but it is currently unclear on the true value that this provides. Further research is needed to understand the true benefit provided by peatlands. New data sources are also needed to understand the true contributions made from peatlands from timber, wind power, flood hazard regulation and water quality.

The net benefit of achieving the Committee on Climate Change objective of restoring 55% of peatland by 2050 was estimated to have a net benefit of £45 billion to £51 billion over the next 100 years if croplands are excluded.

12 . Methodology

Water supply

Physical data for water abstraction is sourced from the Scottish Government, Department for Environment, Food and Rural Affairs (Defra) for England, Natural Resources Wales (NRW) and Welsh Water for Wales and the Northern Ireland Drinking Water Inspectorate.

Monetary estimates are based on resource rents calculated for the Standard Industrial Classification (SIC) subdivision class: Water collection, treatment and supply. The definition of this industry subdivision states: "the collection, treatment and distribution of water for domestic and industrial needs. Collection of water from various sources, as well as distribution by various means is included". A limitation of this approach, therefore, is that the calculated resource rent is not purely related to water supply, but also includes the process of treating the water.

The resource rent can be interpreted as the annual return stemming directly from the natural capital asset itself, that is, the surplus value accruing to the extractor or user of a natural capital asset calculated after all costs and normal returns have been considered. The steps involved in calculating the resource rent are given in Table 22.

Table 22: Derivation of resource rent

	Output
Less	Operating costs
	Intermediate consumption
	Compensation of employees
	Other taxes on production PLUS other subsidies on production
Equals	Gross operating surplus
Less	Specific subsidies on extraction
Plus	Specific taxes on extraction
Equals	Gross operating surplus – resource rent derivation
Less	User costs of produced assets (consumption of fixed capital and return to produced assets)
Equals	Resource rent

Source: Office for National Statistics

To calculate the asset valuation of the water supply the net present value (NPV) approach is recommended by the System of Environmental-Economic Accounts (SEEA) and it is applied to ecosystem services to estimate the asset value. The NPV approach estimates the stream of services that are expected to be generated over the life of the asset. These values are then discounted back to the present accounting period. This provides an estimate of the capital value of the asset relating to that service at a given point in time. There are three main aspects of the NPV method:

- pattern of expected future flows of values
- asset life – time period over which the flows of values are expected to be generated
- choice of discount rate

This data was then apportioned to represent the water supply from peatlands. From available information we calculated 27% of water supply is from peat catchments. This was calculated by looking at the total volume of water for the four countries from a peat source and taking this as a percentage of UK total water volume. The percentage of water from peat catchments in Scotland was previously estimated by Scottish Natural Heritage as 13.7% (Artz and others, 2014). For England and Wales the percentage the uplands which are peatlands was calculated and it was assumed that 70% of this provided an estimate of drinking water from peatlands. England was estimated at 32.1% and Wales with less upland peat was much lower at 5.9%. Data for uplands area in England came from Defra and for Wales from NRW. Data was not found and possibly not available for Northern Ireland, so the same percentage was used as Wales since this was the lowest and most conservative figure.

Peat extraction

The data on peat extraction volumes and sales income is from the British Geological Survey Minerals yearbooks. Data is at 2017 prices, deflators were applied from the ONS Quarterly National Accounts.

Food

The estimate for extent of agriculture on peatlands is derived from the different land uses data contained in the CEH report 'Implementation of an Emissions Inventory for UK Peatlands' (Evans and others, 2017). The high value crops area in the fens is estimated in Graves and Morris (2013) as 133,000 hectares. Data on farm income by type of farm is from the Farm Business Survey (FBS). The FBS provides data for England on the outputs from agriculture excluding subsidies, costs for agriculture excluding Agri-environment activities and data on the total farmed area. A £ per hectare is estimated for the different farm types and applied to the different land use classifications used by the Centre for Ecology and Hydrology (CEH). The rate calculated is for England and applied to the whole of the UK.

Recreation

The recreation estimates are adapted from the "simple travel cost" method developed by Ricardo-AEA. The methodological report Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimate is available.

The method looks at the expenditure incurred to travel to the natural environment and expenditure incurred during the visit. This expenditure method considers the market goods consumed as part of making the recreational visit (that is, fuel, public transport costs, admission charges and parking fees). This expenditure is currently assumed as a proxy for a marginal price for accessing the site.

The English recreation estimates were produced using the Monitor of Engagement with the Natural Environment survey (MENE). This survey ran between 2009 and 2017. Over 1,000 face-to-face interviews were undertaken each month, each interview was capped at 30 minutes and was undertaken through a weekly consumer omnibus survey. This is then upscaled to represent the whole of the UK.

The methodological approach followed ensures that the resultant sample for each survey is consistently representative of the adult population in terms of sex, age group, working status and socioeconomic status. To calculate the element of the MENE survey that is peatlands it was apportioned using the broad habitats that make up peatlands, these being forest, farming, MMH and freshwater. To apportion these habitats the land use classifications designated by CEH were taken as a percentage of the LCM2015 classifications to work out percentage of peatlands.

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