Environment and Rural Affairs Monitoring & Modelling Programme

ERAMMP Year 1 Report 24:
Welsh National Natural Capital Accounts - Ecosystem Service Accounts for Woodland, Farmland and Freshwater Habitats

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Client Ref: Welsh Government / Contract C210/2016/2017

Version 1.0

Date 30/09/2019

Funded by:

Llywodraeth Cymru
Welsh Government

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Programme/ Project	Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)
Title	ERAMMP Year 1 Report 24: Welsh National Natural Capital Accounts - Ecosystem Service Accounts for Woodland, Farmland and Freshwater Habitats
Client	Welsh Government
Reference	C210/2016/2017 NEC06297 Task 8.11
Confidentiality, copyright and reproduction	
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How to cite (long)	Engledew, M., Maclean, K., Thomas, T., Fitch, A., Robinson, D.A. & Jones, L. (2019) Environment and Rural Affairs Monitoring & Modelling Programme – **ERAMMP Year 1 Report 24: Welsh National Natural Capital Accounts - Ecosystem Service Accounts for Woodland, Farmland and Freshwater Habitats.** Report to Welsh Government (Contract C210/2016/2017). Centre for Ecology & Hydrology Project NEC06297.
How to cite (short)	Engledew, M. et al. (2019) **ERAMMP Report 24: Welsh National Natural Capital Accounts.** Report to Welsh Government (Contract C210/2016/2017)(CEH NEC06297)
Approved by	James Skates
Signed	

This document is also available in Welsh / Mae’r ddogfen yma hefyd ar gael yn Gymraeg

Version History

Version	Updated By	Date	Changes
0.1	PMO	30/4/19	Initial draft.
0.11	PMO	8/5/19	Mainly formatting edits – draft for SG
0.12	CB/LJ	25/6/19	Additional sections on condition accounts
0.13	CB	11/9/19	New graphic and text for farmland valuation
0.14	PMO	27/9/19	Approved for publication
1.0	PMO	30/9/2019	As published

Contents

Abbreviations and some of the technical terms used in this report are expanded in the project glossary: https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

1 Executive Summary

This report presents 7 service accounts, containing estimates of the quantity and value of services being supplied by Welsh natural capital in woodland, farmland, and freshwater broad habitats. These services include food, water, air filtration and recreation.

Farmland is the largest of these three Welsh habitats, at 1,015,693 hectares, followed by woodland at 268,588 hectares (125,117 broadleaf and 143,471 coniferous), and freshwater at 42,309 hectares.

The value of the stock of Welsh natural capital in woodland, farmland, and freshwater was estimated to be approximately £30.5 billion in 2014. This is a partial value and the true value is expected to be significantly higher than this figure as only 7 of the benefits received from natural capital in Wales are currently measured. Some notable examples of ecosystem services which aren't currently measured are flood protection, hydropower, and tourism. Of the services measured, 76% of this value was attributable to intangible services not traditionally captured in GDP (recreation, pollution removal and carbon sequestration).

This construction of accounts for Welsh habitats is necessary for potential future commissioning of work to exploit the many condition indicators relevant to provisioning and regulating services which come from the ongoing national monitoring programme Welsh Government has funded through the GMEP and ERAMMP programmes. These condition metrics are particularly important for assessing the underpinning resilience of ecosystems to sudden shocks. Examples include change in soil condition - increases in soil pH over time; variable trends in soil carbon - with increases in woodland and losses in Mountain, Moor and Heath habitats; and condition indicators relevant to cultural services (recreation) which show improvement in the condition of footpaths and public rights of way over time. Other condition metrics include indicators of diversity and connectivity.

The accounts reported here reflect a Welsh-data focus for three habitats. A broader set of ecosystem service accounts would benefit from inclusion of other habitats such as mountain moors and heaths, and urban and coastal accounts.

The potential to link to environmental monitoring, such as the new indicators developed under the Environmental and Rural Affairs Monitoring and Modelling Programme (ERAMMP) and National Survey questions should also be explored further. This will particularly benefit measures of habitat condition, which are not typically represented in the reporting of many natural capital accounts.

With resource rent residual value methods in valuing many ecosystem service flows, geographical breakdowns of Natural Capital accounts, such as Welsh ecosystem service accounts, currently rely upon apportioning UK national accounts. Further development work should take place to investigate other possible valuation methodologies outlined in the System of Environmental Economic Accounting (SEEA) Experimental Ecosystem Accounting[1]

[1] https://seea.un.org/ecosystem-accounting

2 Collaboration

This report was produced in partnership with the Centre for Ecology & Hydrology (CEH) as part of the Environmental and Rural Affairs Monitoring and Modelling Programme (ERAMMP).

Office for National Statistics (ONS) Natural Capital accounts are produced in partnership with the Department for Environment, Food and Rural Affairs (Defra). For full details about the natural capital accounting project please refer to the ONS website[2].

[2] https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital

3 Introduction

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, the natural flood defences provided by forests, removal of air pollutants by vegetation, and the pollination of crops by insects. Then there's the inspiration we take from wildlife and the natural environment.

This article includes natural capital assets, including the quality of those assets, the flows of services and the values of those services. These terms help 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 mountain or a fish population. From those assets people receive a flow of services such as recreational hikes on the mountain and fish captured for consumption. The flow of service may be dependent on the quality or other attributes of those assets. This relationship may differ, depending on the type of service. Finally, we can value the benefit to society of those services by estimating what the hikers spent to enable them to walk over the mountain or the profit to the fishermen of bringing the fish 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 our wellbeing, decision makers can better include the environment in their plans to allocate resources to develop and maintain the economy.

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. The World Bank's wealth accounting WAVES project is looking to implement ecosystem accounting in a range of partner countries. In 2010 at Nagoya, 193 countries agreed to a strategic target to incorporate the values of biodiversity into national accounting and reporting systems by 2020 (subsequently referred to in the Sustainable Development Goals).

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[3]). 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

[3] https://www.gov.uk/government/publications/the-natural-choice-securing-the-value-of-nature

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.

Where available, estimates are presented between the period 1997 to 2017 and all monetary valuations are given in 2017 prices deflated using the HM Treasury June 2018 GDP deflators[4]. Valuations were developed under the principle of comparability with the existing UK ecosystem service accounts[5] and consistency between individual ecosystem services. 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, such as regulating water flows (flood protection); the monetary accounts should therefore be interpreted as a partial or minimum value of Welsh natural capital.

[4] https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-june-2018-quarterly-national-accounts

[5] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemserviceaccounts1997to2015

4 Provisioning services

Food, water, and materials produced by nature and consumed by society are known as provisioning services.

Currently included within Welsh habitat based ecosystem provisioning services are: agricultural biomass from farmland, timber from woodland, and water abstraction and fish capture from freshwater habitats. A comparative annual valuation time series of these provisioning services are presented in Figure 1, with agricultural biomass being the most valuable service since 2010.

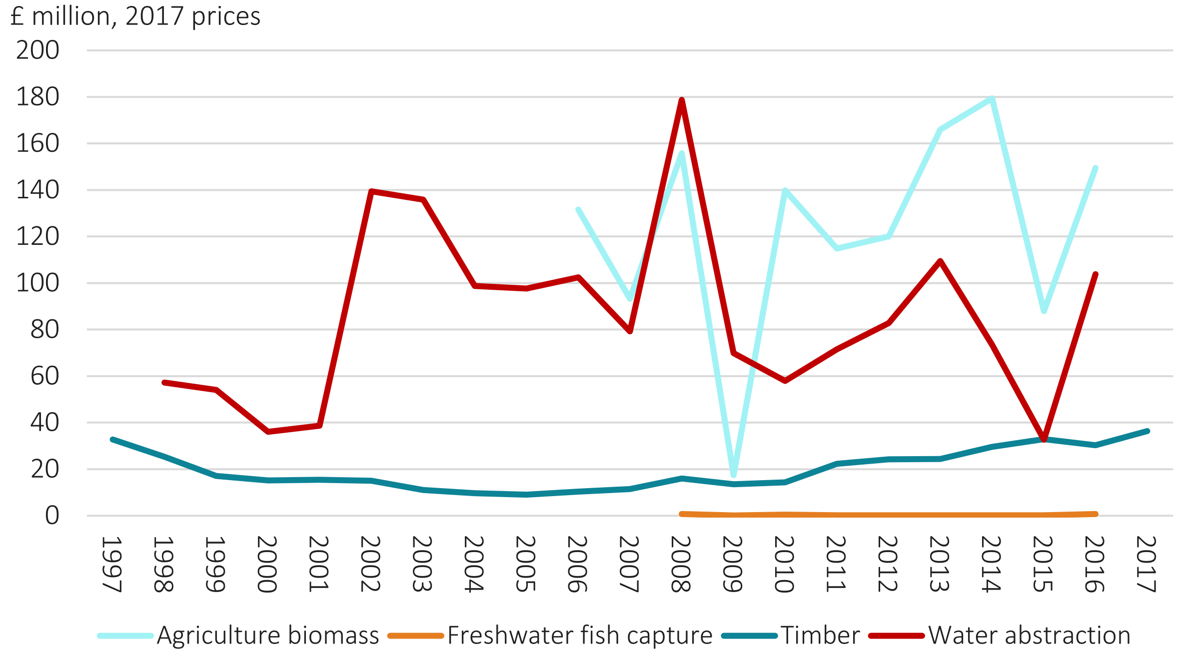


Figure 1: Provisioning services annual value, 1997 to 2017

Sources: Office for National Statistics, Natural Resources Wales, Forestry Commission, Environment Agency, Welsh Government and Defra.

Condition (quality) accounts are provided for a number of indicators relevant to provisioning services for agricultural land and woodland. These include soil pH, soil phosphorus concentrations, soil carbon concentrations and soil biological diversity.

4.1 Agricultural biomass

Farmed animals are not included in these estimates as they are seen as produced rather than natural assets, instead the grass and feed that livestock eat are regarded as ecosystem services and so are included.

Agricultural biomass relates to the value of crops, fodder and grazed biomass provided to support agricultural production in Wales. The overall volume of agricultural biomass produced in Wales (Figure 2) declined from 12.2 to 9.8 million tonnes between 1999 and 2012, a 19.3% overall reduction. Since 2012, volume has increased 7.4% (about 730 thousand tonnes), reaching 10.6 million tonnes in 2017. This 2017 figure is still 13.3% below 1999 levels.

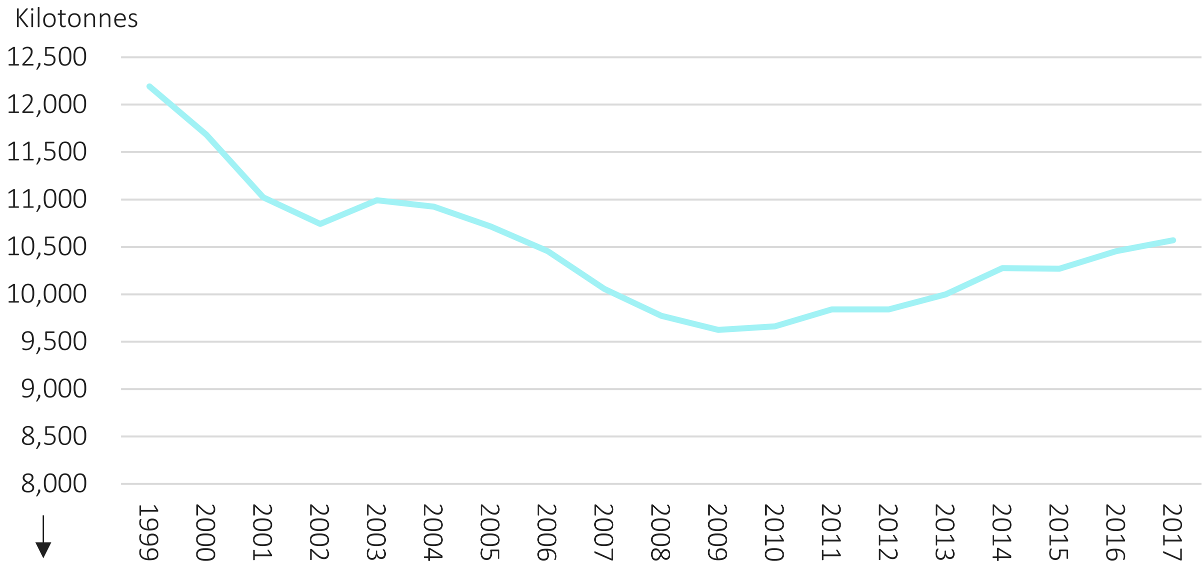


Figure 2: Agricultural biomass physical flow, 1999 to 2017

Sources: Office for National Statistics, Welsh Government and Defra.

The volume of agricultural biomass in Wales is primarily made up of animal feed (an estimate of feedstocks and grazed biomass such as grass and other vegetation consumed by animals) which drove much of the overall trend. Animal feed made up over 95% of agricultural biomass between 1999 and 2017, with arable and horticultural crops representing the rest. The estimated volume of crops produced (arable and horticultural crops) increased by 15.3% from 376 thousand tonnes to 433 thousand tonnes between 1997 and 2017, driven largely by increased wheat production. Animal feed fell by 14.2% in this same period.

The value of the agricultural biomass provisioning service between 2006 and 2016 has fluctuated, with no underlying trend. The significant dip in the 2009 value was due to a fall in gross operating surplus combined with increases in subsidies and consumption of fixed capital. The average annual value of the agricultural biomass provisioning service, excluding 2009, was £134 million.

4.1.1 Comparison with UK Accounts

With a very similar trend to Wales, the UK agricultural biomass was estimated at 119.9 million tonnes in 1997 with a steady decline to 105.9 million tonnes in 2017, an 11.7% overall reduction. From 1999 to 2017, physical flows of Welsh agricultural biomass made up 9.6-10.4% of the overall annual UK agricultural biomass, 0.8-1.2% of UK crop biomass, and 15.1-16.3% of UK animal feed biomass. The comparatively high contribution to animal feed biomass is due to large numbers of livestock in Wales, having 11.4% of UK cattle and 28.8% of UK sheep in 2017.

Wales and the UK do differ in the contribution of broad biomass types to their overall trends, with Welsh agriculture production being more livestock focused. The proportional contribution of crops to overall biomass is significantly larger at the UK aggregate level, representing 36.3-41.0% of annual UK biomass in contrast to under

5% representation in Wales. Inherently, this means that Wales has much larger proportional contributions of animal feed than the UK.

The valuation trends of the agricultural biomass provisioning service in Wales largely reflect aggregate UK valuation trends between 2006 and 2016. Agricultural biomass provisioning service valuation is based upon an apportioning model, detailed in section 9.3.1.

4.2 Freshwater fish

Freshwater fish capture estimates are available within the Salmonid and freshwater fisheries statistics[6] joint publication by Natural Resources Wales (NRW) and the Environment Agency (EA). Country level freshwater fish capture data is also provided to the Food and Agriculture Organisation (FAO) for aggregated UK level input into Fishstat[7], the current source of fish capture in the UK ecosystem service accounts[8]. It has not been possible to acquire underlying freshwater fish capture data for Wales within the timeframe of this report.

The value of the freshwater fish capture provisioning service between 2008 and 2016 has fluctuated significantly with no underlying trend and an average annual value of £0.3 million. For context, this represented less than 5% of the estimate average annual total fish capture provisioning service value in Wales over the same period (£6.8 million).

There is a high degree of uncertainty surrounding these estimates due to the relative size of the Welsh fishing industry in apportioning UK data, detailed in 9.3.2.

4.3 Timber

Timber production (timber removals) increased by 34.3% between 1997 and 2017. It is estimated that 1.42 million cubic metres (m^3) of timber (overbark standing) was removed in woodland in 1997, the volume rising to 1.91 million in 2017. The increase in timber removals has largely occured in the last 10 years (from 2008), before which there was a slow decline in production (since 1997, the start of the reference period) with a low of 1.11 million m^3 of timber being produced in 2008.

[6] https://www.gov.uk/government/publications/salmonid-and-freshwater-fisheries-statistics
[7] http://www.fao.org/figis/servlet/TabSelector
[8] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemserviceaccounts1997to2015

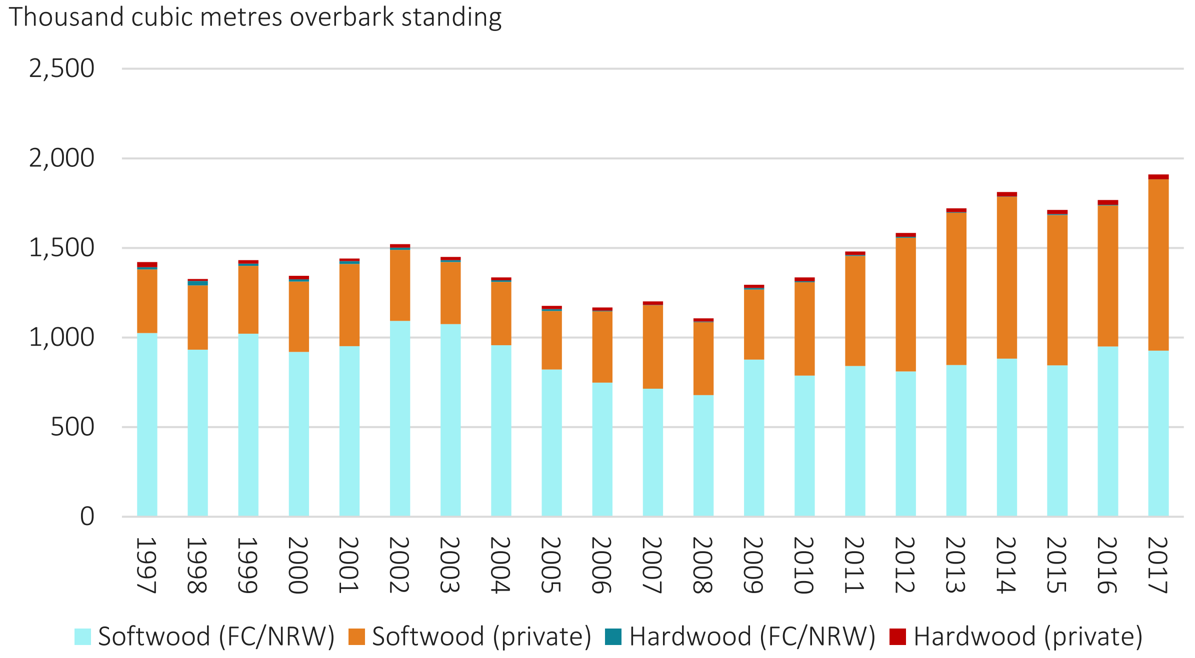


Figure 3: Timber physical flow, 1997 to 2017
Notes: FC stands for Forestry Commission, NRW stands for Natural Resources Wales

Source: Forestry Commission

This rise in production was driven by increased softwood (coniferous trees such as spruce, pine and larch) production, which accounts for the majority (97-98.5% of all timber production. Hardwood (broadleaved trees such as oak, birch and beech) production represents only 1.5-3.0% of all timber production and decreased from 40,000 m^3 of timber in 1997 to 26,700 m^3 in 2017.

Overall production increases are driven largely by the private forest estates. In 2017, private production represented over half (51.4%) of all production, a sigificant increase from 27.0% in 1997. In the same period, Forestry Commission and Natural Resources Wales timber production decreased by 10.6%. This is primarily due to differences in the age structure and timing of timber production between woodlands on the public and private forest estates.

In real terms, the average coniferous sales price[9] fell from £23 in 1997 to £7 in 2004. Since 2004, the price has risen, with some fluctuation, to £19 in 2017. Price trends are reflected in the valuation of the timber provisioning service (Figure 4). The value fell to £9 million in 2005 but reached a high of £36 million in 2017.

[9] Average £ per m^3 overbark standing during the year to March of the following year.

Figure 3: Timber annual value, 1997 to 2017

4.3.1 Comparison with UK Accounts

In 2017, 13.9 million m^3 of timber was estimated to be produced in the UK. Wales represented 13.7% of this production (1.9 million m^3), slightly greater than the 9.8% of UK woodland area[10] Wales makes up. Welsh timber, as a proportion of UK timber, fluctuates; with a high of 15.5% in 2002 and a low of 10.5% in 2008. Since 2008, the proportion has been steadily increasing. As these accounts use the same average price indices as the UK accounts, comparison of timber provisioning service valuation simply reflects these physical flow trends.

4.4 Water abstraction

With fluctuations, the water abstraction provisioning service has neither a clear positive or negative trend between the period 2001 and 2014 (Figure 5). Across the period, water abstraction spiked in 2008 and 2013; where it reached a high of 6.2 billion cubic metres.

[10] https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/woodland-statistics/

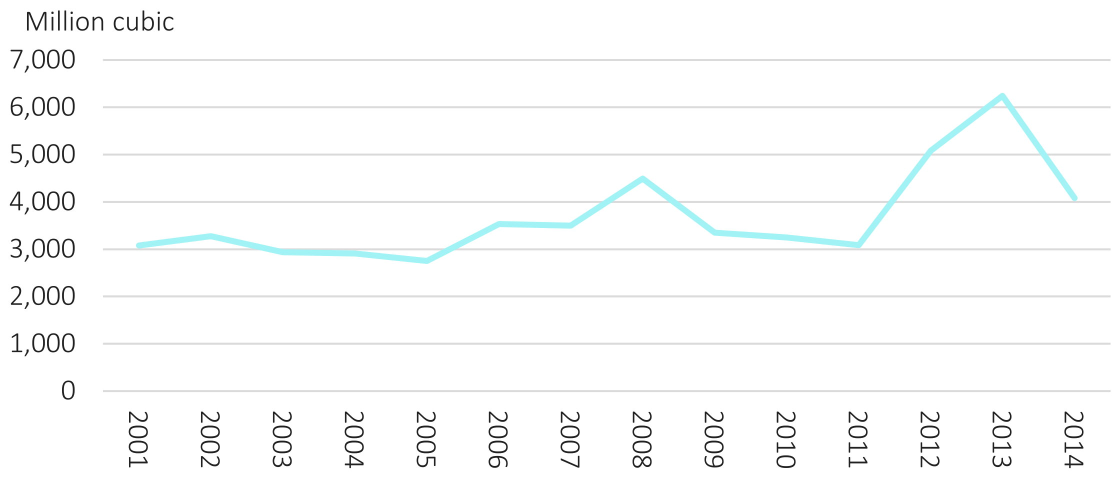


Figure 4: Total water abstraction, 2001 to 2014
Source: Natural Resources Wales

Overall trends in the time series have largely been driven by water abstraction for use in the electricity industry. Within the electricity industry water can be used in hydroelectric generation, thermoelectric generation and for cooling/heat removal. In 2014 the electricity industry represented 83.7% (3.4 billion cubic metres) of overall water abstraction use, increasing from 69.3% (2.1 billion cubic metres) in 2001 (Figure 6). This increase in relative use is also partly due to declining water abstraction for other uses.

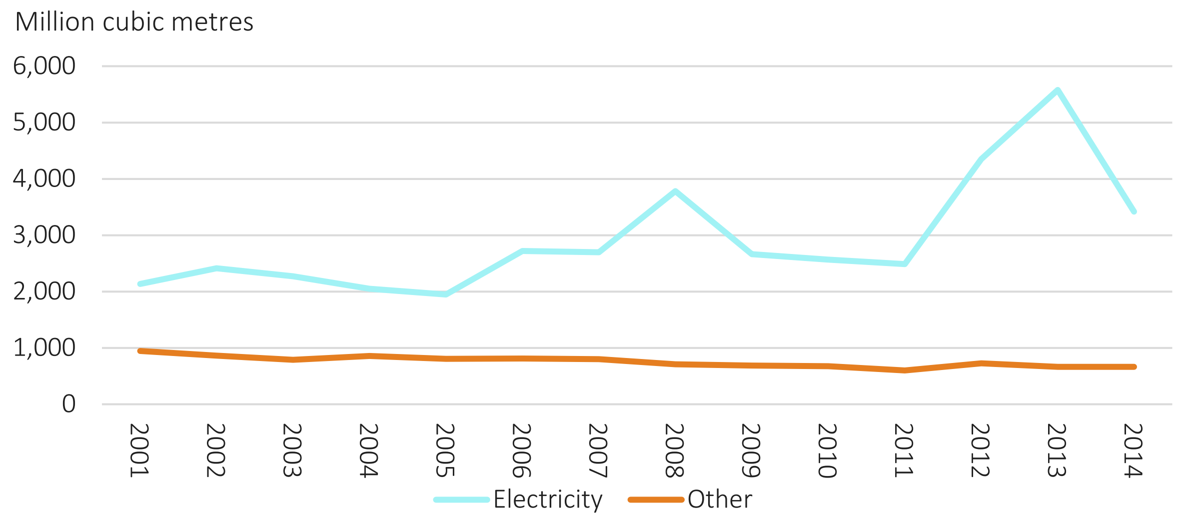
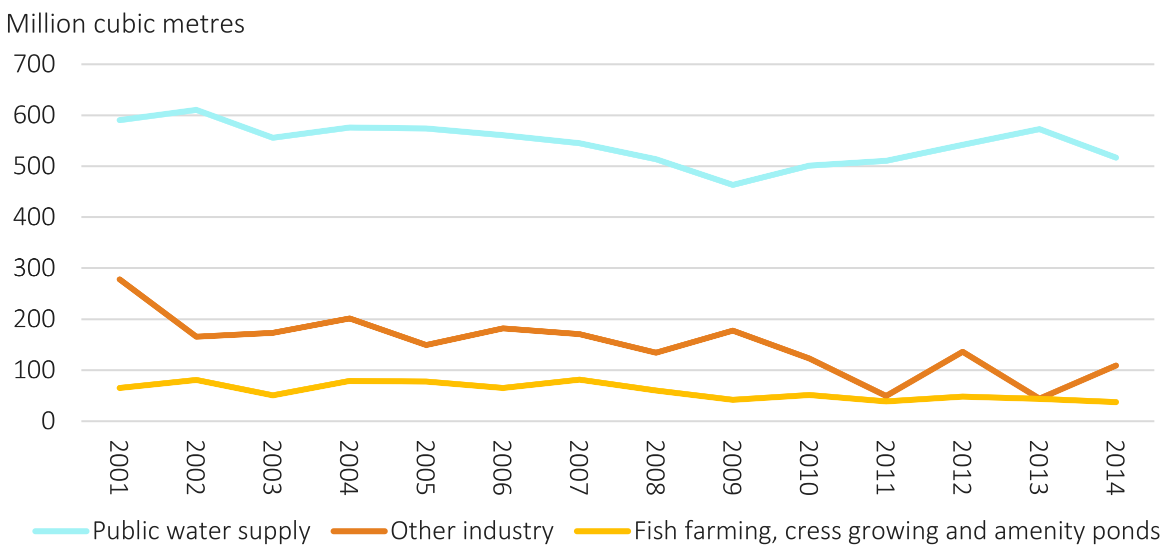


Figure 5: Water abstraction physical flow by use category, 2001 to 2014
Source: Natural Resources Wales

Other main uses of water abstraction are public water supply and other industries (Figure 7). From 2001 to 2014 water abstraction for public water supply has decreased 12.5% from 0.6 to 0.5 billion cubic metres. Since 2001, water abstraction for other industry use declined 60.8% to 0.1 billion cubic metres in 2014. A similar declining trend is also observable in the fish farming, cress growing, and amenity ponds use category. Water abstraction for use in both private water supply and agriculture is minimal, consistently contributing less than 0.4% combined to overall water abstraction.

Figure 6: Non-electricity use water abstraction, 2001 to 2014



Source: Natural Resources Wales

Between 1998 and 2016 the value of the water abstraction provisioning service has fluctuated, with a significant spike in 2008 (£178.8 million), with no underlying trend and an average annual value of £85.2 million (Figure 8). It should be noted that from 1998 to 2001 the average annual value was £46.5 million, after which the average annual value increased 105.5% to £95.6 million, from 2002 to 2017. In 2001 Welsh Water became a not-for-profit organisation without shareholders.

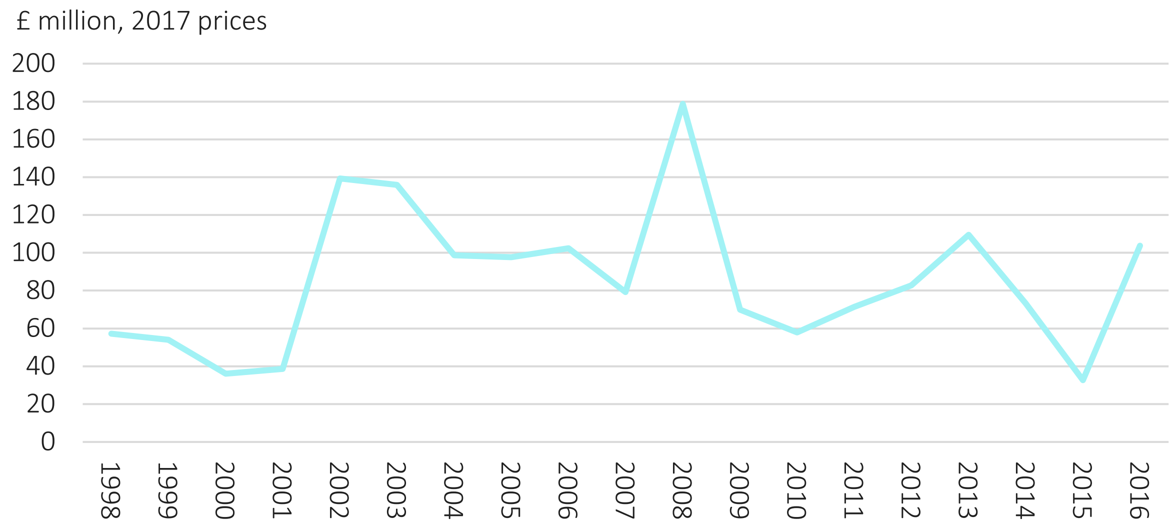


Figure 7: Water abstraction annual value, 1998 to 2016

4.4.1 Comparison with UK Accounts

In order to maintain consistency when aggregating different country-level data for the physical flows of water abstraction in the UK ecosystem service accounts[11] only data on public water supply is provided. This means, despite the availability of non-public water supply data in Wales, comparative analysis of physical flows is limited to public water supply. Wales represents between 6.3%-9.6% of UK public water supply.

The valuation trends of the water abstraction provisioning service in Wales largely reflect aggregate UK valuation trends between 1998 and 2016. Water abstraction provisioning service valuation is based upon an apportioning model, detailed in section 9.3.4. Peaks and troughs in UK trends can be minimised or exaggerated dependent upon annual apportioning. Wales represented between 6.4% (2000) and 20.3% (2002) of UK water abstraction provisioning service valuation, with an average of 10.6% over the time series.

4.5 Peat abstraction

In the initial project plan for the Wales ecosystem service accounts, one of the proposed services to be scoped was the provisioning service of peat abstraction. Upon review, peat extraction no longer takes place in Wales and former peat extraction sites are being restored[12]. Retrospective figures have not been included in the accounts.

4.6 Condition accounts relevant to provisioning services

A number of habitat condition indicators are relevant to the ongoing supply of these provisioning services. In both enclosed farmland and woodland, soil condition and vegetation diversity can illustrate the condition of the habitat and its capacity to continue to produce agricultural products and timber into the future. Condition accounts for these indicators, derived from Welsh monitoring survey data are shown in Figure 9.

[11] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemserviceaccounts1997to2015

[12] Smyth, M.A., Taylor, E.S., Birnie, R.V., Artz, R.R.E., Dickie, I., Evans, C., Gray, A., Moxey, A., Prior, S., Littlewood, N. and Bonaventura, M. 2015. *Developing Peatland Carbon Metrics and Financial Modelling to Inform the Pilot Phase UK Peatland Code*. Report to Defra for Project NR0165, Crichton Carbon Centre, Dumfries.

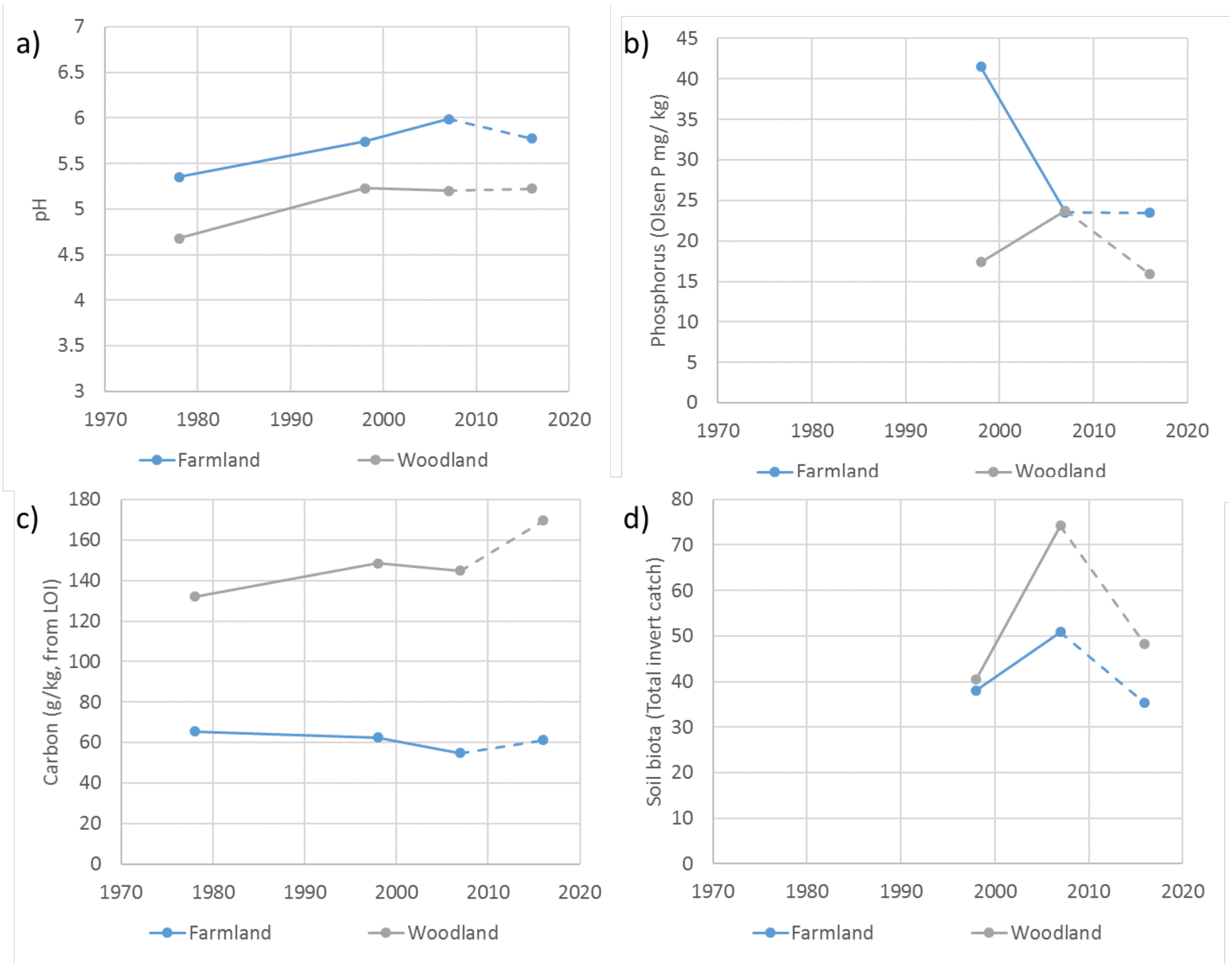


Figure 8: Condition accounts for indicators related to agricultural production and timber production in farmland and woodland. a) Soil pH, b) Soil phosphorus (Olsen P, mg/kg dry soil), c) Soil carbon (g/kg, calculated from Loss On Ignition), d) Soil invertebrates, total invertebrate catch. Solid lines: Data from Countryside Survey[13] dotted lines: data from Wales GMEP project (Emmett et al. 2017)[14].

[13] Scott, W. A. 2008 CS Technical Report No. 4/07: Statistical Report. NERC/Centre for Ecology & Hydrology, (CEH Project Number: C03259).

[14] Emmett B.E. and the GMEP team (2017) Glastir Monitoring & Evaluation Programme. Final Report to Welsh Government - Executive Summary (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Projects: NEC04780/NEC05371/NEC05782)

5 Regulating services

As well as tangible provisioning services, natural assets in Wales provide a number of typically intangible regulating services, such as cleaning the air, sequestering carbon and regulating water flows to prevent flooding.

This section presents two such ecosystem services that are classed as regulating ecosystem services: carbon sequestration and air pollutant removal from vegetation.

The pollutants covered in pollution removal are:

- PM2.5
- PM10
- nitrogen dioxide (NO_2)
- ground-level ozone (O_3)
- ammonia (NH_3)
- sulphur dioxide (SO_2)

PM2.5 is a component of PM10.

Air pollution leads to respiratory diseases in humans and the risk of those diseases for a population can be estimated based on the levels of pollution and the health costs of that disease.

Interrelating biological processes underpin both carbon sequestration and air pollution removal. Underpinning carbon sequestration and air pollution removal trends are the emissions levels that are available to be removed.

Please note the valuation methods used differ; carbon sequestration valuation is a removal cost and air pollution removal valuation is a societal cost. To put it another way the cost of avoiding damage (for carbon) and the cost of treating damage that has already happened (for air pollution) is being valued. Air pollution removal valuation does not consider the cost of abatement and carbon sequestration valuation does not consider the global societal impacts of carbon dioxide.

Whilst the annual ecosystem service value of carbon sequestration across Welsh woodland, farmland, and freshwater habitats is larger than pollution removal it should be noted that much of the value of air pollutant removal occurs outside these habitats; in urban areas. This is because air pollutant removal valuations considers avoided health damage costs to people – the more people that benefit from the removal of pollution the higher the value. As a result, population density is a major determinant of the final valuation.

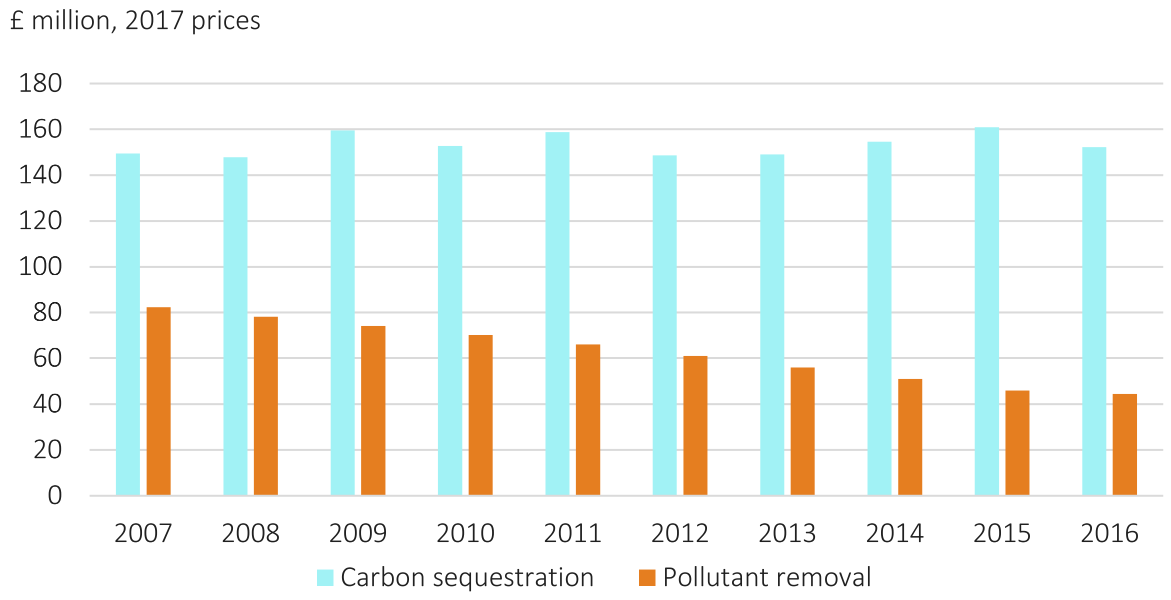


Figure 10: Annual value of carbon sequestration and air pollution removal by vegetation, 2007 to 2016

Sources: Office for National Statistics, Centre for Ecology and Hydrology (CEH) and National Atmospheric Emissions Inventory (NAEI), Department for Business, Energy & Industrial Strategy (BEIS)

Carbon sequestration and air pollution removal are cross cutting ecosystem services which are provided by a range of habitats.

5.1 Carbon sequestration

Overall estimated carbon sequestration in Wales decreased 9.0% from 2.6 million tonnes of carbon dioxide equivalent ($MtCO_2e$) in 1990 to 2.4 $MtCO_2e$ in 2016 (Figure 11). From 1990 to 1998 estimated carbon sequestration increased to a high of 2.9 $MtCO_2e$ and since has had an underlying declining trend, with slight rise in 2014-15 followed by a relatively large decline in 2016 (6.8%).

Carbon sequestration (negative net CO_2 emissions) occurs almost entirely in woodland and Grassland land use categories, around 75.0% and 24.8% respectively between 1998 and 2016. Cropland contributed a maximum of 0.24% annually towards overall carbon sequestration in Wales. Carbon sequestration in woodland fluctuated across the timeseries, peaking at 2.14 $MtCO_2e$ in 2001, but displays a declining trend over the timeseries. Carbon sequestration in grasslands has fluctuated less, decreasing from a high of 0.87 $MtCO_2e$ in 1998 to 0.61 $MtCO_2e$ in 2001 then slowly increasing to 0.67 $MtCO_2e$ in 2016, still 23.5% below 1998 levels.

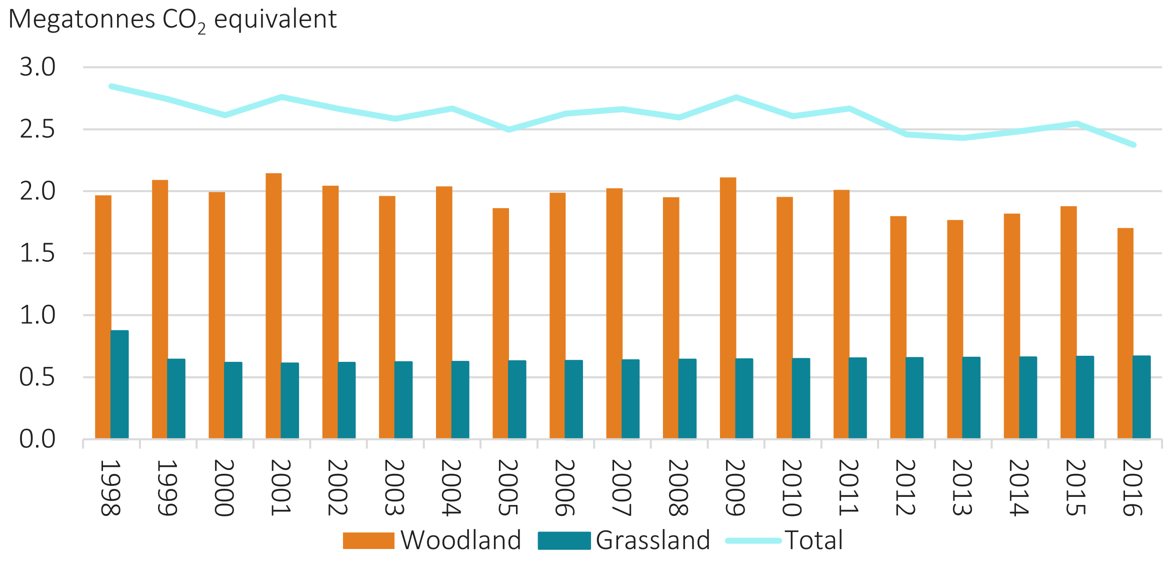


Figure 9: Carbon sequestration physical flow. 1998 to 2015
Sources: National Atmospheric Emissions Inventory (NAEI).

Projected annual carbon sequestration, up to 2050, estimates continued decline in overall carbon sequestration, at an average rate of around 1% annually, to 1.6 $MtCO_2e$ in 2050. Woodlands carbon sequestration is projected to continue decreasing, with fluctuation, at an average rate of 1.8% annually, whereas grasslands carbon sequestration projections show a steady increase, at an average rate of 0.4% annually. In 2050 woodlands and grasslands are projected to sequester 0.9 $MtCO_2e$ and 0.7 $MtCO_2e$ respectively.

Despite carbon sequestration falling overall, estimated annual valuations of the regulating service that carbon sequestration provides show a positive trend, with the overall value increasing from £139.7 to £152.3 million between 1998 and 2016 (Figure 12). This trend has been driven by the steady increase in the abatement cost of carbon (1.5% annual growth over this period) which is estimated to keep increasing until around 2080. As the annual carbon price is applied uniformly, the comparative valuation contribution of woodland and grassland carbon sequestration is proportional to physical trends. In 2016, the carbon sequestration regulating service was valued at £109.3 million for woodlands and £42.8 million for grasslands. Carbon sequestration's estimated annual valuation is projected to be £355 million in 2050, £206 and £149 million for woodlands and grasslands respectively.

Figure 10: Carbon sequestration annual value, 1998 to 2016

The asset valuation of the carbon sequestration regulating service, utilising future annual valuation projections, increased 31.9% between 1998 and 2016 from £6.9 to £9.1 billion. Over the same period, woodland asset valuation increased 25.4% (£4.6 to £5.8 billion) and grassland increased 45.4% (£2.3 to £3.3 billion).

5.1.1 Comparison with UK Accounts

Between 1990 and 2016, whilst overall carbon sequestration in Wales decreased (9.0%), carbon sequestration in the UK increased 35.1%, from 25.50 $MtCO_2e$ in 1990 to 34.4 $MtCO_2e$ in 2016. Woodland's average contribution to overall carbon sequestration is slightly higher in Wales compared to the UK, 75% and 71% respectively, inherently grassland is slightly lower. Wales represented 10.2% of UK carbon sequestration in 1990, declining to 6.9% in 2016. Sharing the same price basis, Wales-UK comparative valuations reflect the physical flow relationship.

5.2 Air pollutant removal by vegetation

Air pollutant removal data modelling is available for 2007, 2011, 2015, and 2030. Between these years linear interpolation has been used as an estimation of pollution removal. This method is under review.

Between 2007 and 2017 pollution removal decreased from 84.4 to 81.1 thousand tonnes, a 3.9% decline (Figure 13). Much of this drop occurred between 2007 and 2011, decreasing 3.8%, after which the decline slowed. Beyond 2017, pollution removal by vegetation is projected to continue decreasing to 78.3 kilotonnes in 2030. This declining trend is largely due to less pollution being emitted into the atmosphere for vegetation to remove, rather than a reflection of changing condition or extent of vegetation.

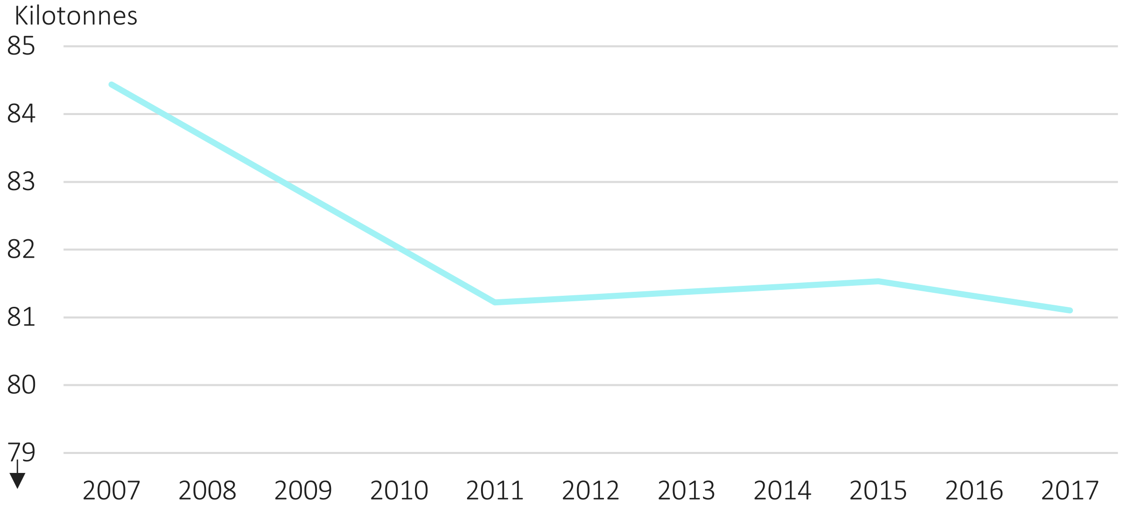


Figure 11: Pollution removal, 2007 to 2017
Source: Centre for Ecology & Hydrology (CEH).

The pollutants covered are PM2.5, PM10, nitrogen dioxide (NO_2), ground-level ozone (O_3), ammonia (NH_3) and sulphur dioxide. PM2.5 is a component of PM10. Ground-level ozone represents approximately 80% of pollution removal from 2007 to 2017. However, the most harmful is PM2.5 (fine particulate matter with a diameter of less than 2.5 micrometres, or 3% of the diameter of a human hair) which can bypass the nose and throat to penetrate deep into the lungs, leading to potentially serious health effects and healthcare costs.

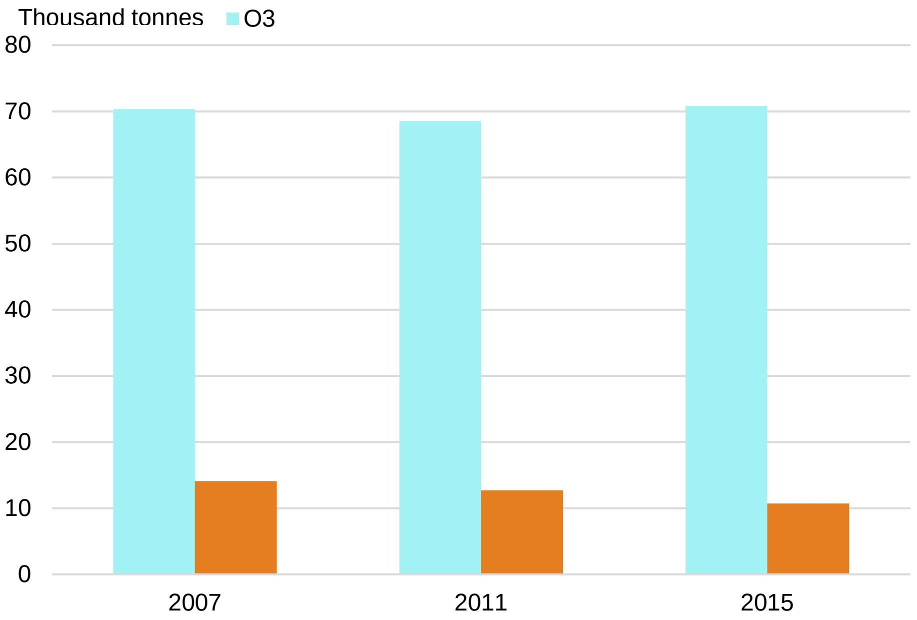


Figure 12: Pollution removal of ground level ozone (O_3) and other[15] pollutants, 2007, 2011, and 2015
Source: Centre for Ecology and Hydrology (CEH)

[15] *"Other" pollutant removal includes PM10, PM2.5 (a component of PM10), NO_2, NH_3, and SO_2.*

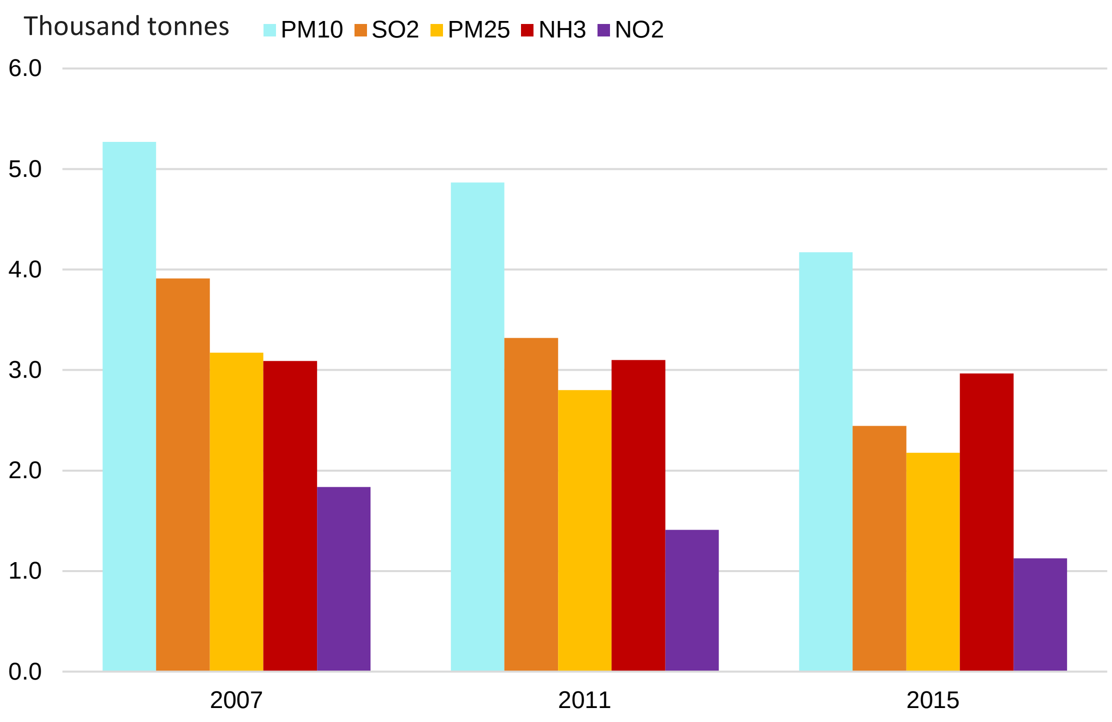


Figure 15: Pollution removal by pollutant (excluding O_3), 2007, 2011, and 2015
Source: Centre for Ecology and Hydrology (CEH)

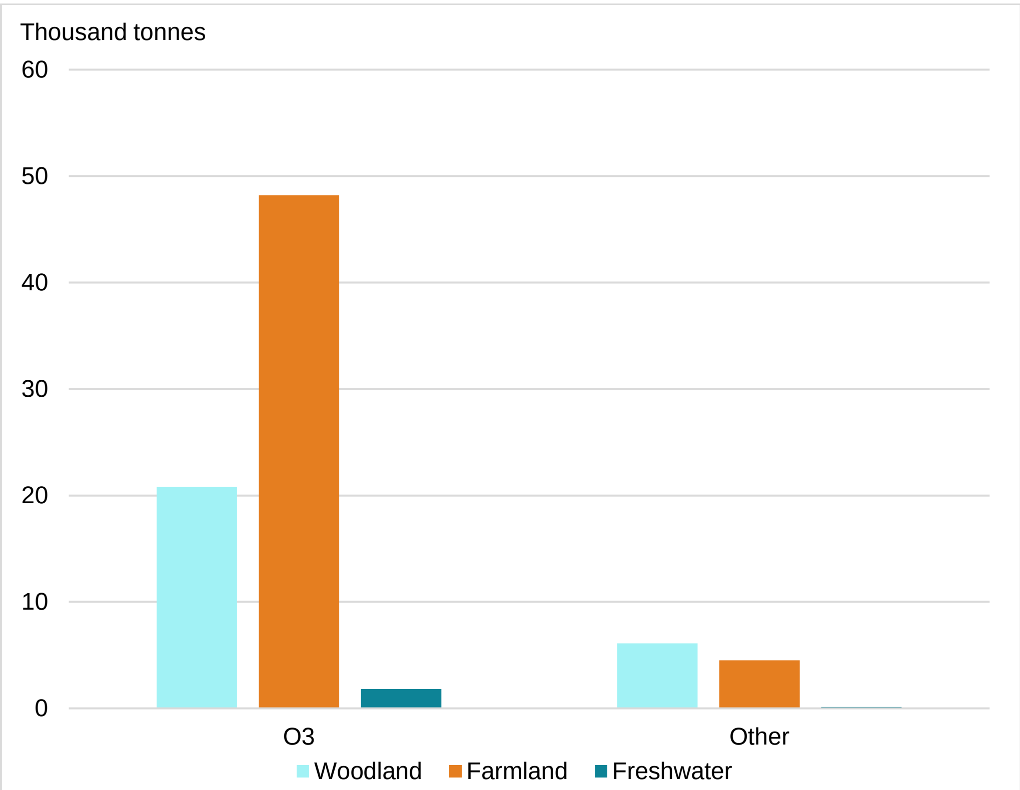


Figure 16: Pollution removal of ground level ozone (O_3) and other[16] pollutants by habitat, 2015
Source: Centre for Ecology and Hydrology (CEH)

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[16] "Other" pollutant removal includes PM10, PM2.5 (a component of PM10), NO_2, NH_3, and SO_2.

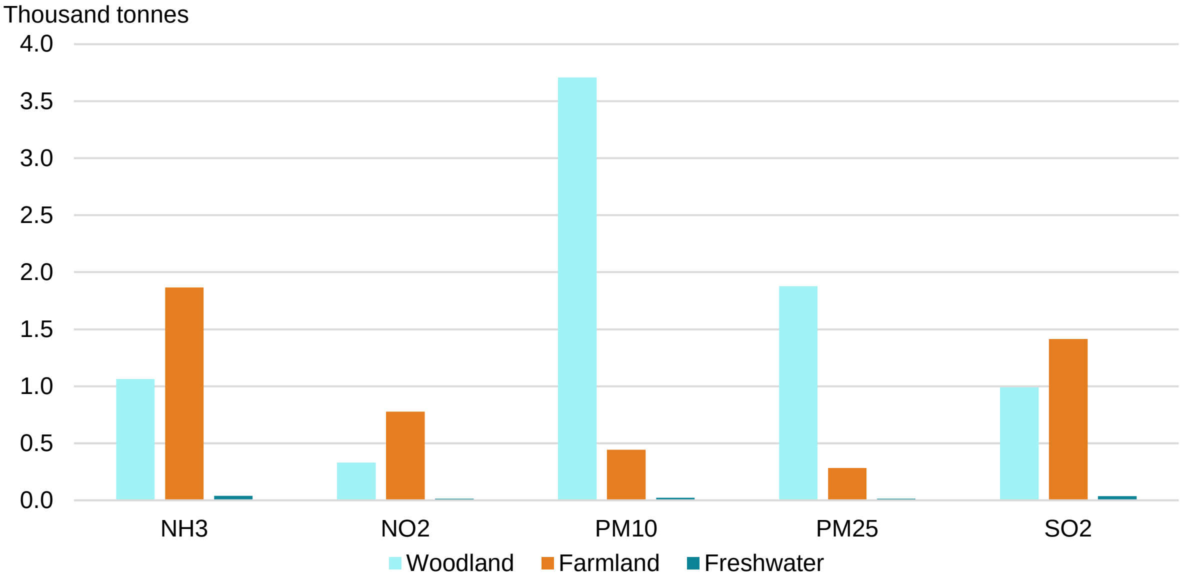

Figure 17 Pollution removal by pollutant (excluding O_3) by habitat, 2015
Source: Centre for Ecology and Hydrology (CEH)

Absolute pollution removal by vegetation is greatest in farmland (1,015,693 ha), representing on average 64.5% of total pollution removal (Figure 15). Pollution removal by vegetation in farmland decreased 3.2% from 54.2 thousand tonnes in 2007 to 52.5 thousand tonnes in 2017. Woodland (268,588 ha) pollution removal, from both Broadleaf (125,117 ha) and Coniferous (143,471 ha) woodland, making up an average 33.2% of overall removal, has also declined (5.4%) from 28.2 to 26.7 over the same period. Pollution removal by vegetation in freshwater (42,309 ha) declined 7.2% over the time series and consistently represented near to 2.4% of total pollution removal.

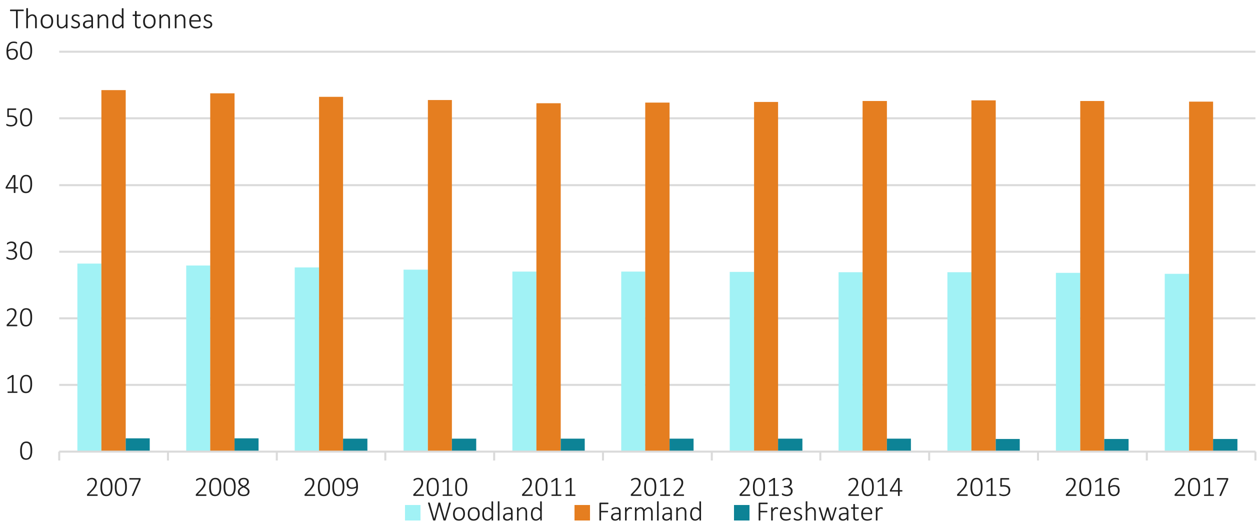

Figure 138: Absolute pollution removal by habitat, 2007 to 2017
Source: Centre for Ecology & Hydrology (CEH).

Absolute pollution removal values reflect the extent of habitats more than the habitat's effectiveness at removing pollution. For instance, despite removing the most pollution, farmland, on average, removed 52.0 kilograms of pollutant per hectare (kg/ha) over the time series, in comparison to 101.3 kg/ha for woodland (Figure 16). Freshwater averaged 45.9 kg/ha.

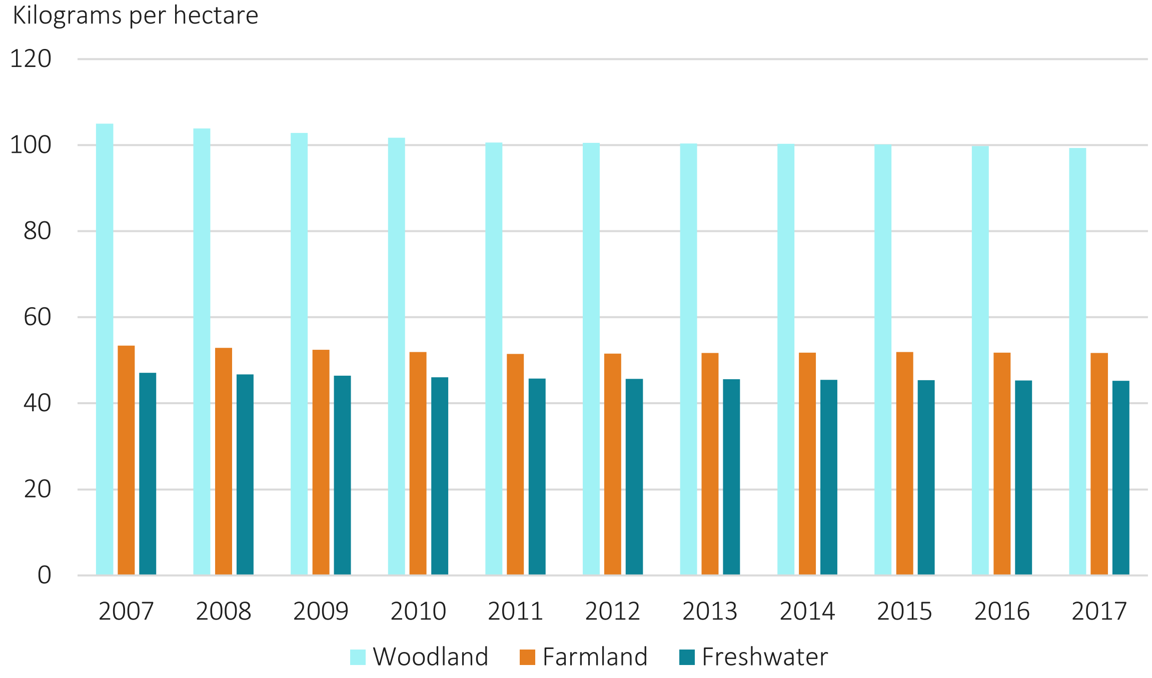

Figure 19: Pollution removal rate by habitat, 2007 to 2017
Source: Centre for Ecology & Hydrology (CEH).

It should also be noted that the type of pollutant removed by vegetation in each habitat can differ significantly. This is particularly the case in woodland habitats which accounts for the vast of majority of average annual PM10 and PM2.5 pollution removal, 88.9% and 86.5% respectively.

The pollution removal regulating service is valued through avoided health cost modelling, detailed in section 9.3.6 of this publication. Pollution removal annual valuation for woodland, farmland, and freshwater declined (46.8%) from £82.3 million in 2007 to £43.8 million (Figure 21). This trend is attributable to declining physical pollution removal, particularly those most harmful such as PM2.5, due to falling emissions. With woodland removing the majority of the PM2.5 it represents an annual average of 84.6% of overall valuation. In 2017 woodland in Wales provided a pollution removal regulating service valuation of £36.9 million, or £137/ha.

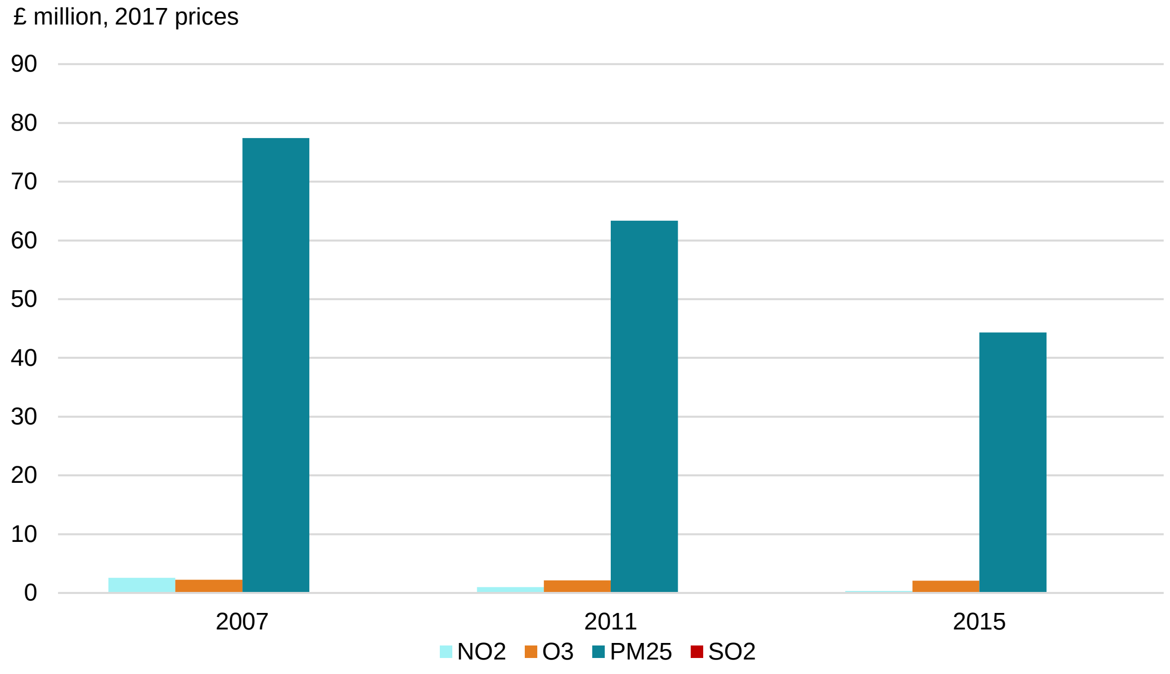

Figure 20: Pollution removal annual value by pollutant, 2007, 2011, and 2015
Source: Centre for Ecology and Hydrology (CEH).

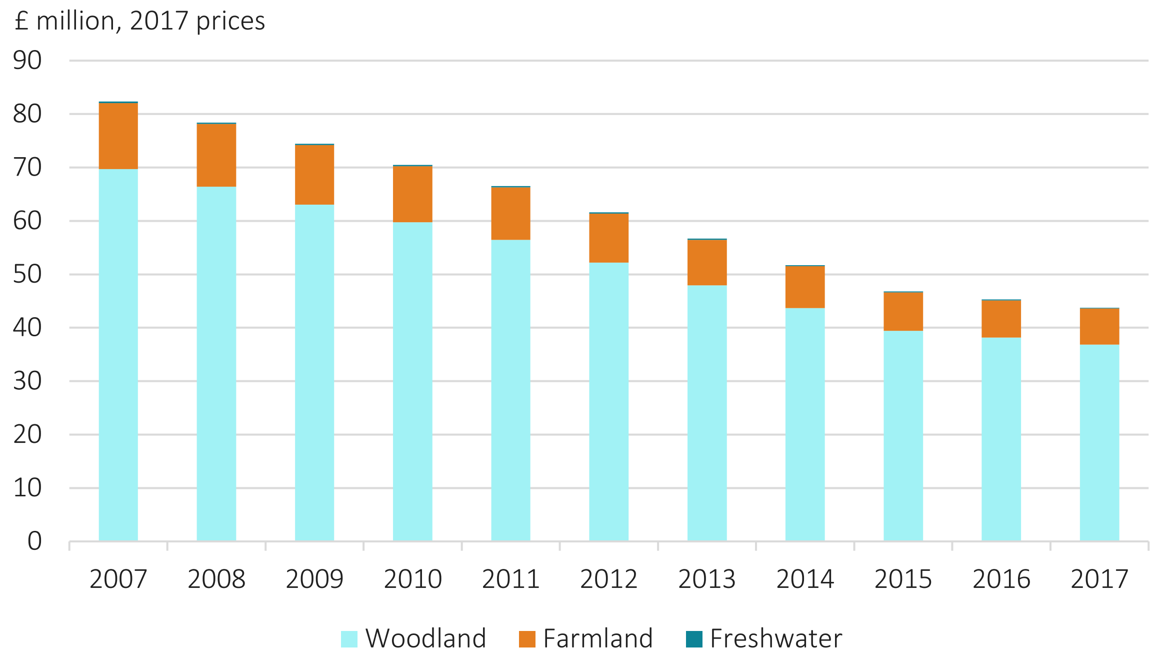

Figure 214: Pollution removal annual value by habitat, 2007 to 2017
Source: Centre for Ecology & Hydrology (CEH) and Office for National Statistics (ONS).

The asset valuation of the pollution removal regulating service for woodland, farmland, and freshwater, utilising future annual valuation projections up to 2030, fell 3.6% between 2007 and 2013 from £1.62 billion to £1.56 billion. Since 2013 the value has increased 1.7% to £1.59 billion in 2017. This trend shift is due to projected income growth and health cost increases beginning to outweigh the, slowing, pollution removal decline over the asset lifetime. Habitat asset valuations follow the proportional habitat breakdowns of annual valuations.

5.3 Condition accounts relevant to regulating services

Habitat condition indicators relevant to the ongoing supply of these regulating services may differ by service. Of the two services presented in this account, the most relevant indicator for which data was readily available was for soil carbon concentration. This is relevant to the condition of woodland and agricultural areas and their capacity to continue to sequester carbon into the future. Condition for this indicator, derived from Welsh monitoring survey data is shown in Figure 9c above.

6 Cultural services

This section presents the cultural service of nature providing recreational opportunities. Many more cultural services are also provided by natural capital in Wales, such as aesthetic appreciation and heritage value. These additional cultural service accounts are not yet developed.

6.1 Outdoor recreation

The recreation estimates were produced predominantly using the 2014 Welsh Outdoor Recreation Survey (WORS). In 2014, there were 124.6 million visits to the outdoors in woodland, farmland, and freshwater habitats in Wales. As shown in Figure 22, visits to woodland make up the largest proportion of this, at 41.5%, followed by farmland (30.5%), then freshwater (27.95%). Through these visits, there was a total of 355.8 million hours spent in the natural environment; this means that 2 hours and 52 minutes were spent on average per visit. The time spent per visit is roughly comparable along all three habitats. Visits to the three before mentioned habitats constitutes 28.5% of all 437.4 million visits to the outdoors in 2014.

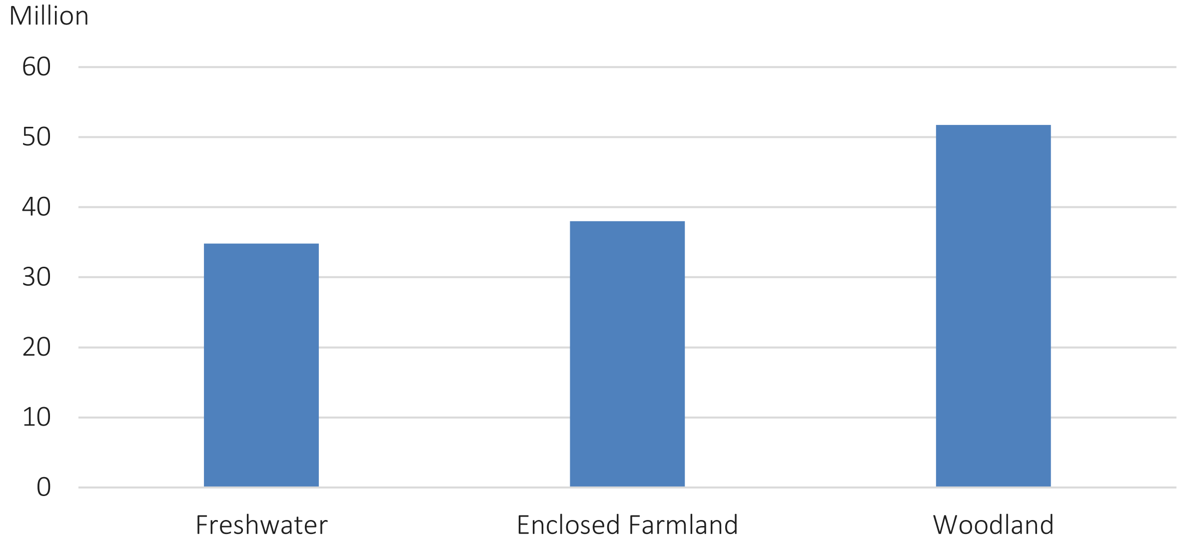

Figure 22: Recreation visits in 2014
Sources: Natural Resources Wales, Office for National Statistics and Natural England.

The annual valuation method for recreation, detailed in section 10.3.7, is based on the willingness of the public to spend money on travelling to visits to the natural environment and admissions. Recreation in woodland, farmland, and freshwater is valued at £311.4 million in 2014. The average visit to the natural environment cost £2.50; visits to freshwater had a slightly higher value (£2.84) than those to farmland or woodland (£2.46 and £2.38 respectively). This gives an average annual expenditure on recreational visits of £122.70 per person of 16 years or over.

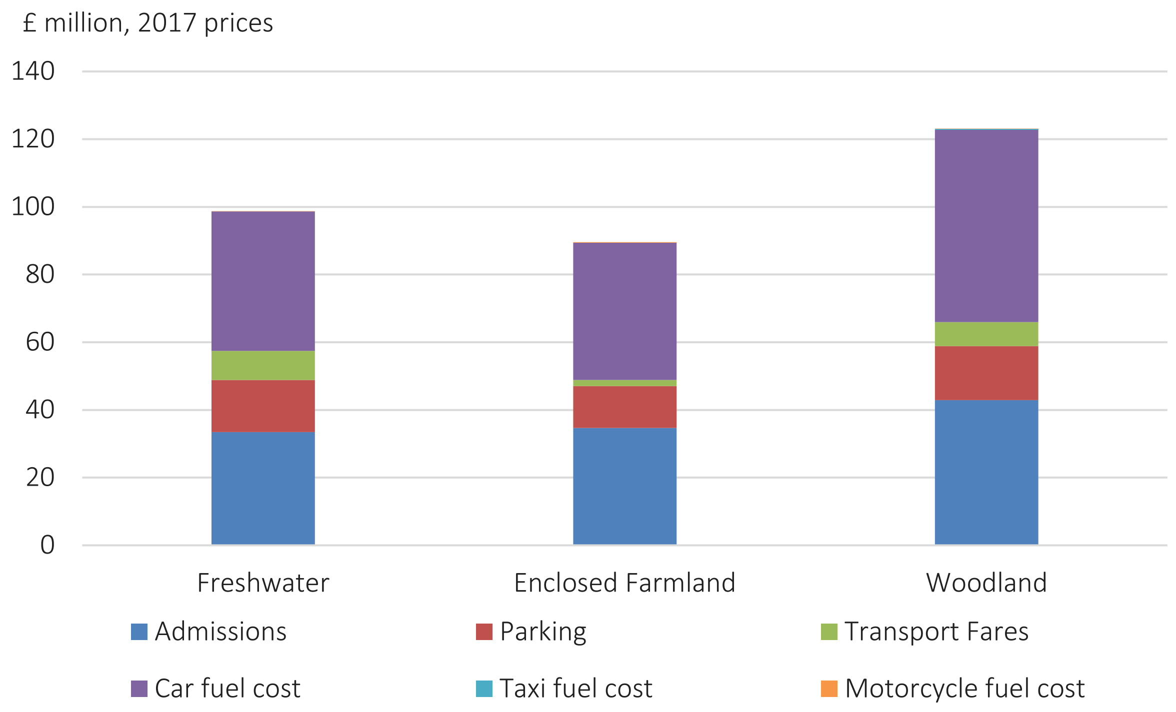

Figure 23: Recreation annual value by expense, 2014

The breakdown of the annual value in Figure 23 shows that the majority (80.16%) of the 2014 recreation annual value is from admissions and car fuel costs.

The 2014 WORS report notes that the total spent on visits to all habitats was £5.6 billion, however this was inclusive of expenditure on items not included in the estimates of this report, such as food and souvenirs, which were not seen as good indications of the contribution of the natural environment to the recreational experience.

6.1.1 Comparison with UK Accounts

UK aggregate figures were calculated using data from the Monitor of Engagement with Natural Environment (MENE) survey covering recreation in England which were scaled up to represent the UK population.

In 2014, there were 1.05 billion visits to woodland, farmland, and freshwater habitats in the UK, while the total time spent on these visits totalled 1.08 billion hours; this gives an average visit time of 1.03 hours per visit. This is significantly lower than the average visit time in Wales which is 2.78 times higher.

UK recreation for 2014 was valued at £1.7 billion; Welsh recreation is 18.9% of this. The annual value per visit to the natural environment in the UK was £1.57, £0.93 per visit lower than the Welsh average visit value. This is predominantly attributable to much larger reported admission and parking fees in the WORS. Participants travelling to visits in Wales also travelled further than those from the English survey.

There is a stark difference between the Welsh and UK accounts in the rate at which the population of over 16s visit the natural environment. In 2014, the average person in Wales visited woodland, farmland, and freshwater 49 times. Comparatively, the corresponding UK visit rate per capita was 20.

6.2 Condition accounts relevant to cultural services

Habitat condition indicators relevant to the ongoing supply of cultural services (recreation) include the following: Percentage of footpaths which are easy to use, the percentage of Historic Features in good condition, and a wider metric of Landscape quality calculated from five component metrics and validated against visitor perceptions. Available data for these indicators are shown in Figure 24 below, data from Emmett et al. (2017).

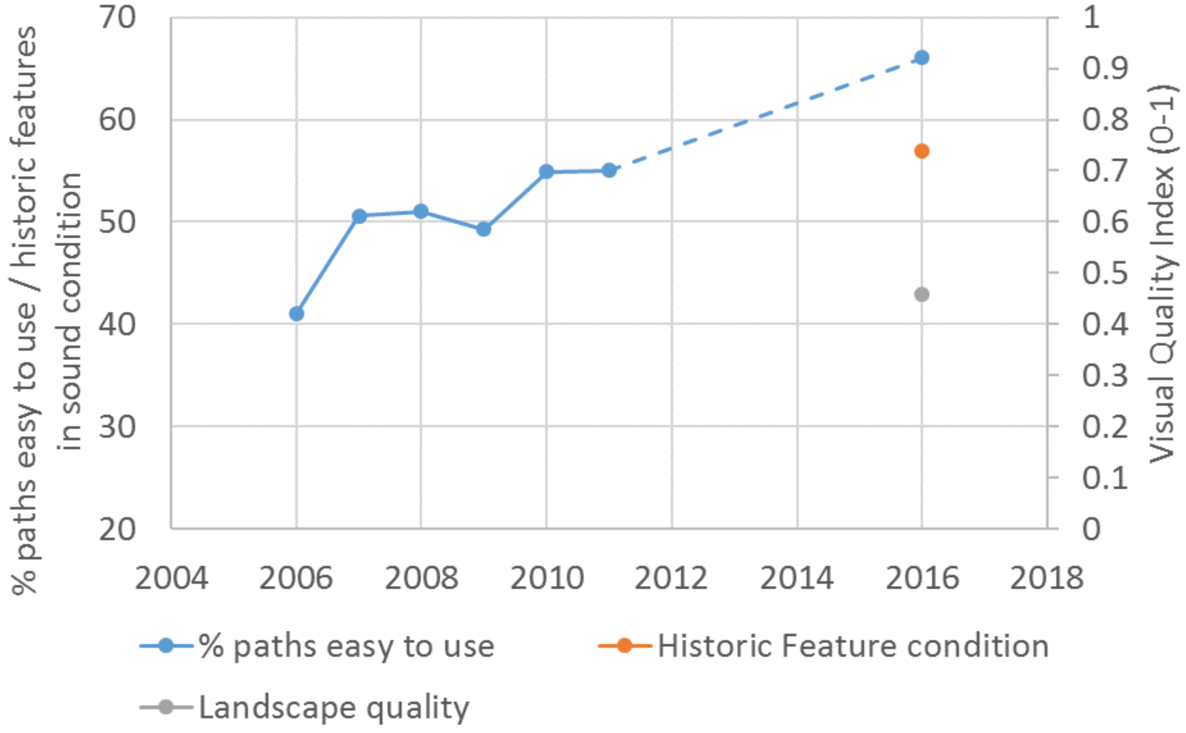

Figure 24. Condition indicators relevant to recreation. % footpaths or rights of way that are easy to use (solid lines show CADW data, dotted lines from GMEP monitoring of Glastir scheme (Emmett et al. 2017); Historic feature condition: Historic Environment Feature Condition (% in 'Sound' or 'Excellent' condition); Landscape quality: Visual Quality Index (VQI) composite measure of landscape positive and negative features across five categories (all data reported in Emmett et al. 2017).

7 Asset valuation

Figure 25 presents partial Wales natural capital asset value estimates for the three types of broad habitat for 2014 by ecosystem service. 2014 is currently the only year for which the cultural service of recreation provision is available.

This is a partial value as many ecosystem services provided by natural assets in Welsh woodland, farmland, and freshwater habitats are not yet estimated. The total value is expected to be higher than estimates provided here.

The asset values are estimated by capitalising the annual flow of services from the natural resource that are expected to take place over a projected period. This period is known as the asset life. The annual environmental service flows reported in the previous section provide the basis for the projected flows. This method, known as Net Present Valuation (NPV), is explained in more detail in the methodology section of this report.

All the environmental services presented in this report are produced from renewable resources whose stock is not exhausted over time, for example Welsh woodland in delivering carbon sequestration. For renewable resources a 100-year asset life has been assumed.

As data on future physical flows and unit prices is limited, a decline in the asset value generally reflects a decline in the average annual flow between periods. Exceptions are carbon sequestration and air pollution removal, where future projections are incorporated.

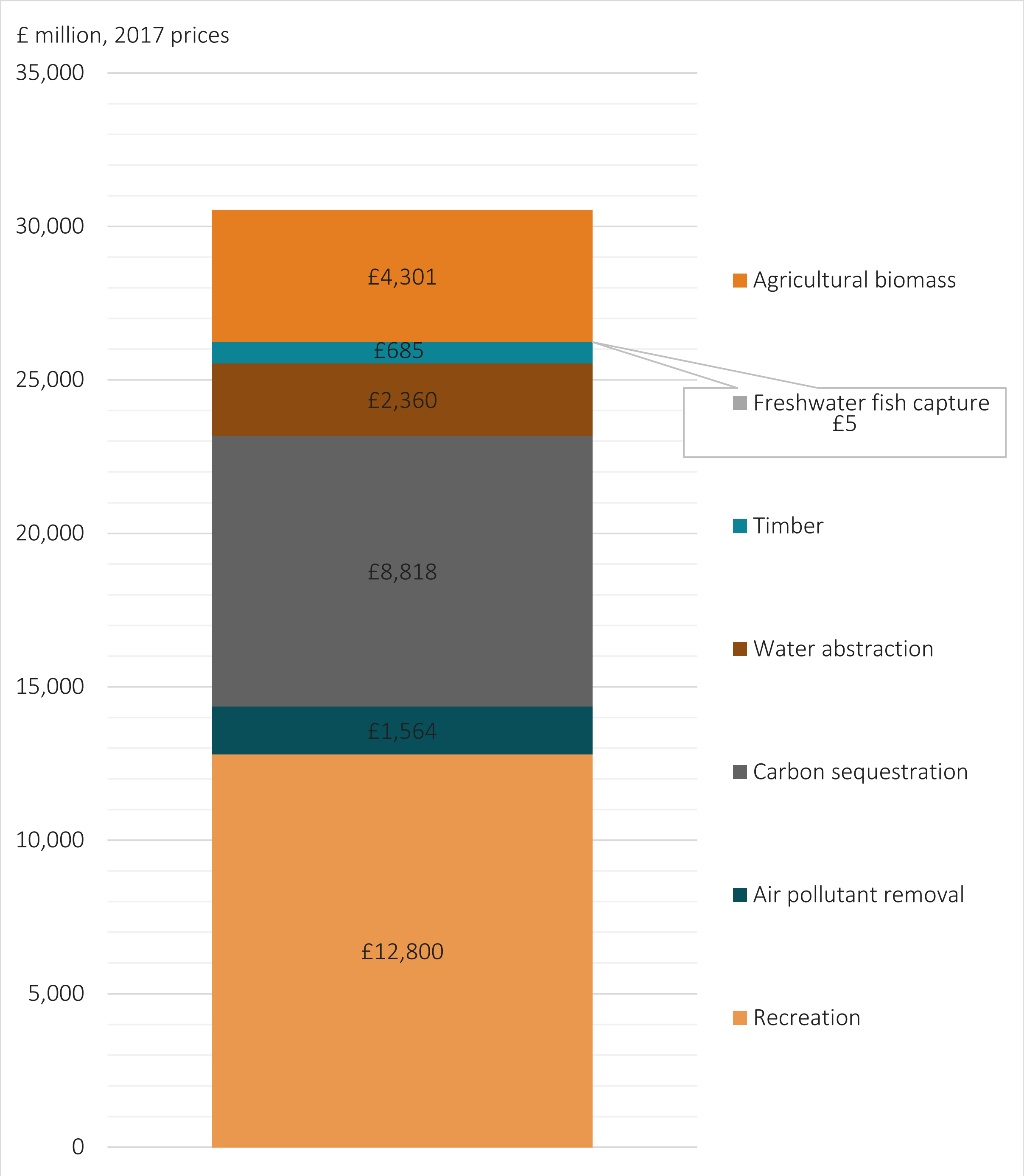

Figure 15: Asset valuation, 2014

8 Habitat accounts

Presented in Figures 26, 27 and 28 are habitat based ecosystem service flows annual valuations for woodland, farmland, and freshwater habitats respectively.

Data availability of different ecosystem services varies across the time series so full comparison of the services provided by habitats is not possible in most years. Currently, 2014 is the only year with data available for all the individual ecosystem services covered in this report so will be the focus of service comparisons.

Welsh habitat based ecosystem service accounts represent just a partial value of benefits received from natural capital in Welsh woodland, farmland, and freshwater. In this report habitats are represented by the sum of ecosystem service valuations they currently include – these are not comprehensive valuations of the habitat and so are not directly comparable.

In 2014 the sum of currently measured ecosystem service annual valuations for woodland is £309.7 million, £318.1 million for farmland, and £172.4 million for freshwater habitats. Incorporating these annual valuations, in 2014 the asset valuation of woodland is £13.0 billion, the valuation of farmland is £11.4 billion, and freshwater is £6.4 billion.

In 2014 the most valuable service provided by Welsh woodland was recreation, valued at £123.1 million, followed by carbon sequestration (£113.3 million), air pollutant removal (£43.7 million), and timber provision (£29.6 million).

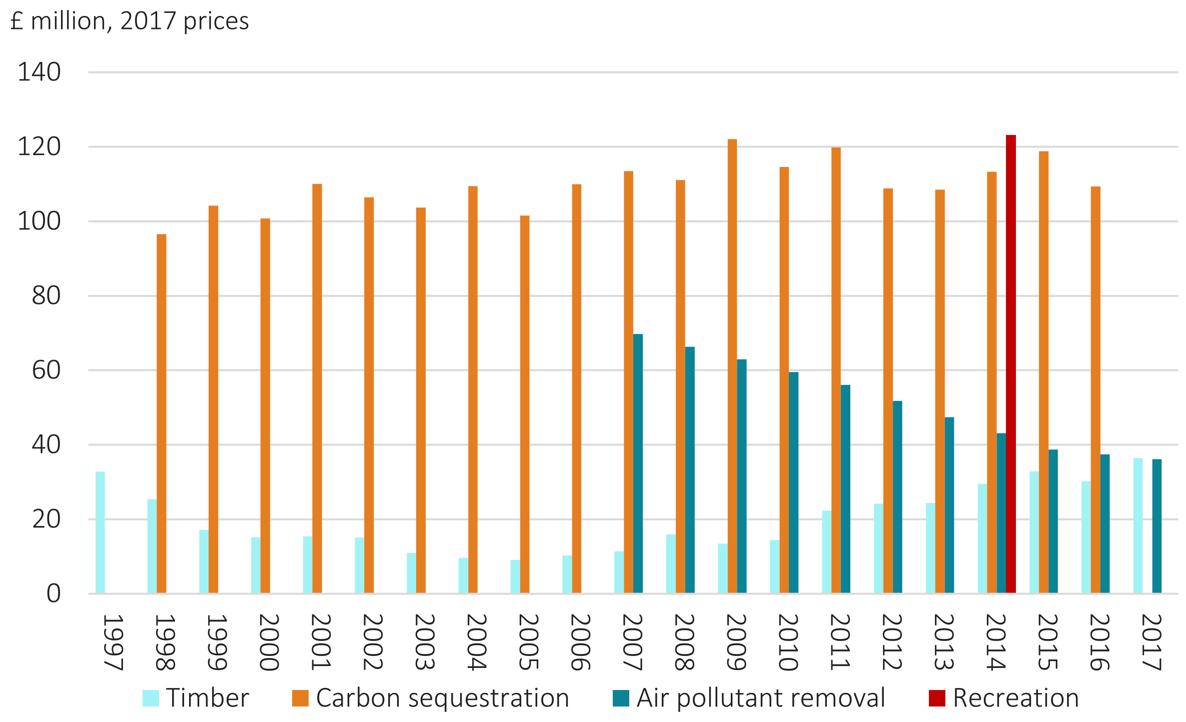

Figure 16: Woodland habitat ecosystem service annual valuation, 1997 to 2017

In Welsh farmland the most valued ecosystem service (2014) was agricultural biomass, valued at £179.4 million, then recreation (£89.5 million), carbon sequestration (£41.3 million) and air pollutant removal (£7.9 million).

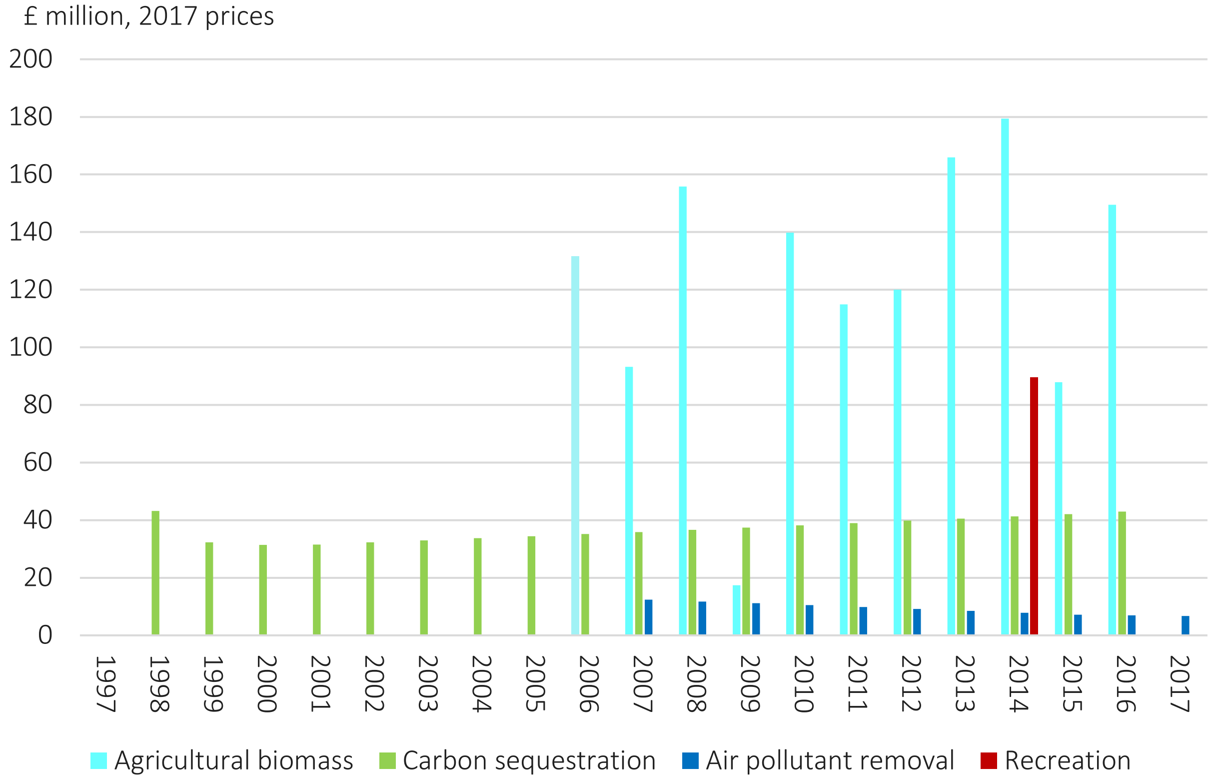

Figure 17: Farmland habitat ecosystem service annual valuation, 1997 to 2017

The highest value single ecosystem service across Welsh freshwater habitats in 2014 was recreation, at £98.7 million, then water abstraction at £73.4 million. Valuations of freshwater fish capture and air pollutant removal were comparatively small, representing less than 0.2% of Welsh freshwater ecosystem service total valuation combined.

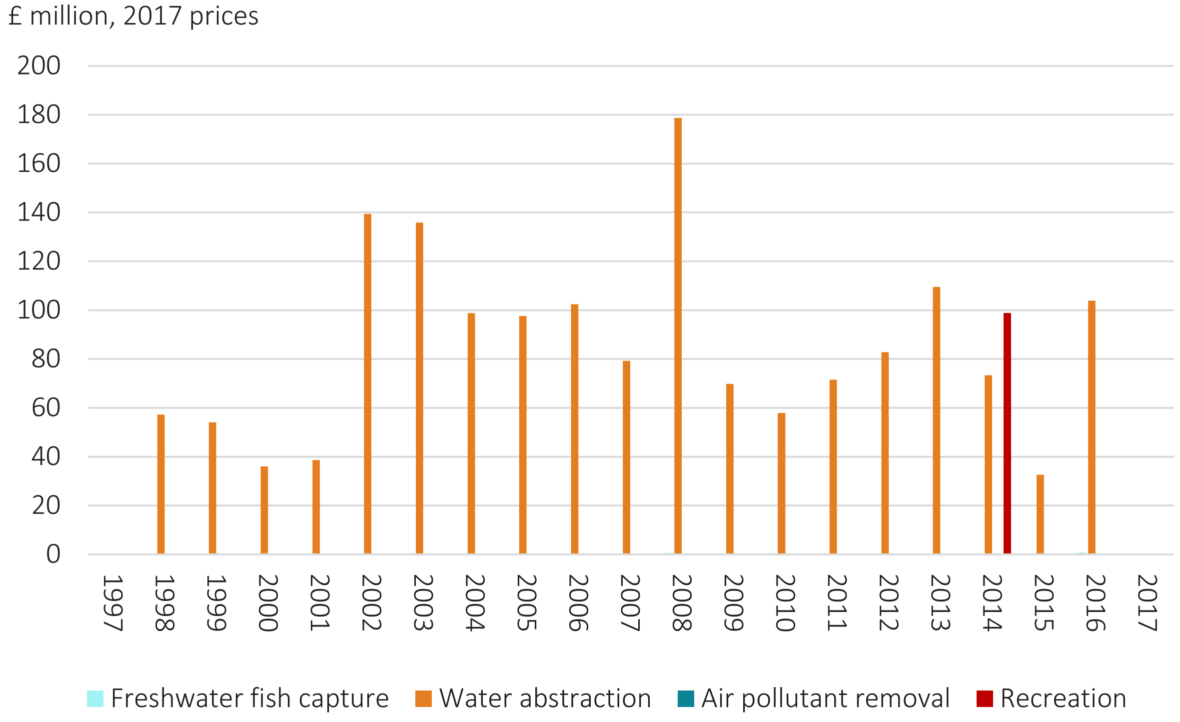

Figure 18: Freshwater habitat ecosystem service annual valuation, 1997 to 2017

9 Quality and methodology

This section describes the methodology used to develop Wales' natural capital accounts. The broad approach to valuation and the overarching assumptions made are explained in this section, followed by a more detailed description of the specific methodologies used to value the individual components of natural capital and physical and monetary data sources.

We welcome discussion regarding any of the approaches presented.

9.1 Annual ecosystem service flow valuation

Two approaches are used to value the annual service flows. For carbon sequestration, pollution removal, recreation and timber an estimate of physical quantity is multiplied by a price.

For water abstraction, agricultural biomass, and freshwater fish capture a "residual value" resource rent approach is used. Before detailed data source and methodology is described, the resource rent approach is defined below.

9.1.1 Resource rent definition and assumptions

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 1 below. Variations of this approach are applied depending on the category of natural capital under assessment, the variations are explained in the individual ecosystem service methodology.

Table 1: Derivation of resource rent

	Output
	Operating costs
	Intermediate consumption
	Compensation of employees
Less	Other taxes on production PLUS other subsidies on production
Equals	Gross operating surplus – SNA basis
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 + return to produced assets)
Equals	Resource rent

Most of the data used in Welsh resource rent calculations are apportioned from the Office for National Statistics Supply and Use tables[17]. Return to produced asset estimates are calculated using the nominal ten-year government bond yield[18] published by the Bank of England, and deflated using the gross domestic product (GDP) deflator to produce the real yield. This rate is relatively conservative compared to those expected in certain markets and could overstate the resulting resource rent estimates.

9.2 Asset valuation

The net present value (NPV) approach is recommended by the System of Environmental-Economic Accounts (SEEA) and it is applied for all 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:

1. Pattern of expected future flows of values.
2. Asset life – time period over which the flows of values are expected to be generated.
3. Choice of discount rate.

9.2.1 Pattern of expected future flows of services

A key factor in the valuation of natural capital is determining the expected pattern of future flows of services. These paths are not observed and hence assumptions concerning the flows must be made, generally as a projection of the latest trends. A more basic way to estimate the expected flows is to assume that the current flow (averaged over recent years) is constant over the asset life, but this might not be the case. In some cases, more information is available on future expected levels of services in non-monetary terms or future unit prices. Where there are readily available official projections these have been considered but otherwise the default assumption in these estimates is that the value of the services is constant over time.

This paper assumes constant service values throughout the asset life, except for the estimates for carbon sequestration and air pollutant removal by vegetation, where further projections are used.

Where the pattern of expected service values is assumed to be constant, it is based on averages over the latest five years, up to and including the reference year in question. This is set out in Figure 29.

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[17] https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables
[18] http://www.bankofengland.co.uk/boeapps/iadb/index.asp?Filter=Y&Travel=NIxIRx&levels=1&XNotes=Y&C=DUS&G0Xtop.x=51&G0Xtop.y=7&XNotes2=Y&Nodes=X41514X41515X41516X41517X55047X76909X4051X4052X4128X33880X4053X4058&SectionRequired=I&HideNums=-1&ExtraInfo=true

$$SV_t = \frac{SV_{t-4} + SV_{t-3} + SV_{t-2} + SV_{t-1} + SV_t}{5}$$

Where SV = service value and t = reference year

Figure 29. Equation to calculate future service values

9.2.2 Asset life

The asset life is the expected time over which the services from a natural resource are expected to be provided. An estimate of the asset life is a key component in the NPV model because it determines the expected term over which the service flows from an asset should be discounted. This publication takes one of three approaches when determining the life of a natural capital asset.

Non-renewable natural capital assets: Where a sufficient level of information on the expected asset lives is available this asset life is applied in the calculations. Where a sufficient level of information on their respective asset lives is not available a 25-year asset life is assumed.

Renewable natural capital assets: A 100-year asset life is applied to all assets that fall within this category of natural capital. The assets covered in Wales ecosystem service accounts are all renewable.

9.2.3 Choice of discount rate

A discount rate is required to convert the expected stream of service flows into a current period estimate of the overall value. A discount rate expresses a time preference – the preference for the owner of an asset to receive income now rather than in the future. It also reflects the owner's attitude to risk. The use of discount rates in NPV calculations can be interpreted as an expected rate of return on the environmental assets.

Based on an extensive review[19] by external consultants, ONS and Defra use the social discount rate set out in the HM Treasury Green Book (2003, page 100). In line with guidance set out in the document, estimates presented in this publication assume a 3.5% discount rate for flows projected out to 30 years, declining to 3.0% thereafter, and 2.5% after 75 years.

9.3 Methodology by service

Table 1 provides a broad overview of the steps involved in calculating a resource rent using a residual value approach. While this method forms the overarching basis to producing many of the estimates presented in this publication, slight adjustments to the method are required for individual service flows. The following section provides an

[19] https://www.ons.gov.uk/file?uri=/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital/discountingforenvironmentalaccounts.pdf

in-depth explanation of the adjustments made for each service, together with more detail where the resource rent approach has not been used.

9.3.1 Agricultural biomass

Agricultural biomass relates to the value of crops, fodder and grazed biomass provided to support agricultural production in Wales. Physical production of wheat, barley, oats and potatoes estimates are published by Welsh Government (Welsh Agricultural Statistics[20]) and are consistent with Department for Environment, Food & Rural Affairs (Defra) UK statistics[21]. These estimates are based upon the Agricultural survey[22], which contains arable land areas but not yield/production, and yield figures in neighbouring English regions. For comparability with the UK accounts[23], this approach has been extended to include estimates for Fruit and Vegetables which are based upon fewer observations and are thus prone to greater potential standard error. However, as highlighted in the analysis, the impact of potential error is limited as crops represent a small portion of agricultural biomass in Wales.

Grazed biomass calculations are based upon Welsh livestock numbers, from the Agricultural survey[17], and livestock annual roughage requirements provided in the Eurostat Economy-wide material flow accounts[24] (EW-MFA) questionnaire. This approach is used in the UK Ecosystem Service Accounts[25] and Material Flows Accounts[26].

For the valuation of agricultural biomass a “residual value” resource rent approach is used. This is based upon data for the SIC subdivision class: Crop and animal production, hunting and related service activities (SIC 01). The approach can produce quite low values for the ecosystem service, but this is not wholly unexpected as anthropogenic inputs into the production are so significant.

In estimating the resource rent for the Welsh agricultural biomass provisioning service, source-level apportioning of ONS UK supply and use tables[27] and UK capital stocks[28] is used. The factor used for apportioning gross operating surplus and taxes less subsidies from the UK supply and use tables is the proportional relationship between

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[20] https://gov.wales/statistics-and-research/welsh-agricultural-statistics/?lang=en
[21] https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june
[22] https://gweddill.gov.wales/statistics-and-research/survey-agricultural-horticulture/?lang=en
[23] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemserviceaccounts1997to2015
[24] https://ec.europa.eu/eurostat/documents/3859598/9117556/KS-GQ-18-006-EN-N.pdf/b621b8ce-2792-47ff-9d10-067d2b8aac4b
[25] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemserviceaccounts1997to2015
[26] https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsmaterialflowsaccountunitedkingdom
[27] https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables
[28] https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/datasets/capitalstocksconsumptionoffixedcapital

Wales[29] and UK[30] aggregate agriculture accounts gross output. To apportion net capital stocks and consumption of fixed capital from the UK capital stocks the factor used is the proportional relationship between Wales and UK aggregate agriculture accounts consumption of fixed capital.

The separation of the services provided by the farmland ecosystem from other economic inputs to agricultural production is challenging because of the degree to which the activity of farming manages and interacts with those services, for example, through sowing, irrigation, fertiliser spreading and livestock management. With very intensive arable farming, natural inputs may be limited to the provision of a medium for growing, with nutrients, light and water provided by the farmer, whilst intensive livestock farming may even take place entirely indoors. At the other extreme, livestock may be allowed to roam freely over semi-natural grassland with very limited human intervention.

As with the principles applied to the UK Natural Capital Accounts, we draw the line between the farmland ecosystem and the economy at the point at which vegetable biomass is extracted (Principle 5.3[31]). This means farmed animals are not included in these estimates as they are considered as produced rather than natural assets, instead the grass and feed that livestock eat are regarded as ecosystem services and so are included. This is also consistent with the boundary between the environment and the economy used in the Material Flows Accounts[32].

9.3.2 Freshwater fish

Monetary estimates are based on the "residual value" resource rent approach calculated for the SIC subdivision class: freshwater fishing (SIC 03.12). This industry class includes: fishing on a commercial basis in inland waters, taking of freshwater crustaceans and molluscs, taking of freshwater aquatic animals, and gathering of freshwater materials.

In estimating the resource rent for the Welsh freshwater fish capture provisioning service apportioning of ONS UK supply and use tables[33] and UK capital stocks[34] is used. The factor used for apportioning all components of the resource rent is the proportional annual relationship between Wales and UK annual business survey local unit[35] total turnover at basic prices for the Fishing and Aquaculture industry (SIC 03) multiplied by the proportional annual relationship between UK *Fishing and Aquaculture*

[29] https://gov.wales/statistics-and-research

[30] https://www.gov.uk/government/statistics/total-income-from-farming-in-the-uk

[31] https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

[32] https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsmaterialflowsaccountunitedkingdom

[33] https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables

[34] https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/datasets/capitalstocksconsumptionoffixedcapital

[35] https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/datasets/uknonfinancialbusinesseconomyannualbusinesssurveyregionalresultssectionsas

(SIC 03) and UK freshwater fishing (SIC 03.12) annual business survey reporting unit (RU)[36] total turnover at basic prices.

9.3.3 Timber

The method used to value the provisioning services related to timber supply requires two inputs: the stumpage price and the physical amount of timber removed. Annual flow values are then generated by multiplying the two factors together.

Removals estimates are taken from Forestry Commission Timber Statistics[37] and converted from green tonnes to metres cubed (m^3) overbark standing, using a conversion factor of 1.222 for softwood and 1.111 for hardwood.

The stumpage price is the price paid per standing tree, including the bark, for the right to harvest timber from a given land area. Stumpage prices may include some management overheads and return to capital but these amounts are not expected to be significant. Stumpage prices are sourced from the Forestry Commission Coniferous Standing Sales Price Index in the Timber Price Indices[38] publication (2018). The Coniferous Standing Sales Price Index monitors changes in the average price received per cubic metre (overbark) for timber that the Forestry Commission/ Natural Resources Wales sold standing, where the purchaser is responsible for harvesting.

9.3.4 Water abstraction

Monetary estimates are based on the “residual value” resource rent approach calculated for the SIC subdivision class: Water collection, treatment and supply (SIC 36). 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.

In estimating the resource rent for the Welsh water abstraction provisioning service apportioning of ONS UK supply and use tables[39] and UK capital stocks[40] is used. The factor used for apportioning all components of the resource rent, using the “residual value” approach, is the proportional relationship between Wales and UK annual business survey local unit total turnover at basic prices.

Future work is required to better value the range of services relating to water provided by the natural environment. The residual value method has in our experience to date generated a relatively high resource rent for public water supply which could be considered inconsistent with the concept of a price regulator and normal returns. In

36 https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/datasets/uknonfinancialbusinesseconomyannualbusinesssurveysectionsas

37 https://www.forestresearch.gov.uk/tools-and-resources/statistics/data-downloads/

38 https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/timber-statistics/timber-price-indices/

39 https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables

40 https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/datasets/capitalstocksconsumptionoffixedcapital

future, water may be traded between water companies although the prices charged may depend more upon covering the overheads of delivery than on the value of the resource in situ. It is also possible that abstraction licence charges may provide an estimate of the amount of resource rent captured by the Government. This requires further research.

9.3.5 Carbon sequestration

Estimates relate to the removal of carbon gas from the atmosphere by UK terrestrial ecosystems. The approach used combines data on the physical changes in subdivisions of the Land use, land-use change, and forestry (LULUCF) sector (published in the Greenhouse gas inventory[41] and LULUCF emission projections[42], with information on the central non-traded price of carbon[43].

Due to data constraints values related to carbon sequestration by marine ecosystems, including those intertidal areas such as coastal margins, are not included in current estimates. As a result, annual flow values related to carbon sequestration services are likely to be an underestimate.

The LULUCF sector breakdown identifies carbon sequestration activities in the following subcategories:

- Forest Land remaining Forest Land
- Land converted to Forest Land
- Grassland remaining Grassland
- Land converted to Grassland

For the years 2010 to 2016, actual physical estimates of carbon sequestration by land use class are sourced from the Greenhouse gas inventory[36]. In the asset valuation, projections of carbon sequestration rates are provided for the years 2017 to 2050 by the National Atmospheric Emission Inventory (NAEI) in the LULUCF emission projections[37]. Central projections are used. For years used in the projections beyond 2050, the carbon sequestration rate is assumed to be constant as at 2050 levels.

The carbon price used in calculations is based on the projected non-traded price of carbon schedule. This is contained within the data table 3 of the Green Book supplementary guidance[44]. Carbon prices are available from 2010 to 2100. Prices prior to 2010 are backdated in line with recent trends. Prices beyond 2100 are assumed to be constant at 2100 levels.

The non-traded carbon prices are used in appraising policies[45] influencing emissions in sectors not covered by the EU ETS (the non-traded sector). This is based on estimates of the marginal abatement cost (MAC) required to meet a specific emission reduction target. Beyond 2030, with the development of a more comprehensive global carbon market, the traded and non-traded prices of carbon converge into a single traded price of carbon.

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[41] http://naei.beis.gov.uk/reports/reports?report_id=958
[42] http://naei.beis.gov.uk/reports/reports?report_id=927
[43] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
[44] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
[45] https://www.gov.uk/government/publications/carbon-valuation-in-uk-policy-appraisal-a-revised-approach

9.3.6 Air pollutant removal by vegetation

Air quality regulation estimates have been supplied in consultation the Centre for Ecology and Hydrology (CEH). A full methodology report published in July 2017 is available[46].

Calculation of the physical flow account uses the EMEP4UK atmospheric chemistry and transport model which generates pollutant concentrations directly from emissions, and dynamically calculates pollutant transport and deposition, considering meteorology and pollutant interactions.

The health benefits were calculated from the change in pollutant exposure from the EMEP4UK scenario comparisons which is the change in pollutant concentration to which people are exposed. Damage costs per unit exposure were then applied to the benefitting population at the local authority level for a range of avoided health outcomes:

- respiratory hospital admissions
- cardiovascular hospital admissions
- loss of life years (long-term exposure effects from $PM_{2.5}$ and NO_2)
- deaths (short-term exposure effects from O_3)

Some years generated negative values for the economic value of NO_2 removal. In cases where a net disservice is presented the economic value is adjusted to zero.

Future flow projections used for asset valuation incorporate population projections and an assumed 2% increase in income per year (declining to 1.5% after 30 years and 1% after 75 years). Income elasticity is assumed to be 1. More work is being conducted in this area.

Habitat breakdowns provided employed aggregations of CEH Landcover Map 2007 classes:

- Values reported for freshwater only includes vegetated wetlands: CEH Landcover Map 2007 classes of *fen, marsh, and swamp* and *bog*. Open freshwater is not included.
- Values reported for farmland consists of CEH Landcover Map 2007 classes of *arable and horticulture* and *improved grassland*.
- Values reported for woodland consist of CEH Landcover Map 2007 classes of *Broadleaved Woodland* and *Coniferous Woodland.*

9.3.7 Outdoor recreation

The recreation estimates are adapted from the 'simple travel cost' method developed by Ricardo-AEA. This method was originally created for use on the Monitor of Engagement with the Natural Environment (MENE) survey which covers recreational visits by respondents in England.

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

46 http://nora.nerc.ac.uk/id/eprint/524081/7/N524081RE.pdf

costs, admission charges and parking fees). This expenditure is currently assumed as a proxy for a marginal price for accessing the site.

The 2014 Wales Outdoor Recreation Survey (WORS) is the primary data source. The WORS is a large-scale survey of people across Wales that is carried through telephone interviews of 5,995 people aged 16 and over. This was the third iteration of the survey with previous surveys in 2008 and 2011. Following the 2014 survey, it was absorbed into the National Survey for Wales which covered a broad range of topics; the latest including recreation questions is the 2016/17 survey.

WORS collects information about the way people engage with the environment, such as visiting the countryside, enjoying green spaces in towns and cities, watching wildlife and volunteering to help protect the natural environment. Included in the survey are questions related to the most recent visit to the natural environment within the last 4 weeks; the distance travelled to the visit, costs associated with the visit and the habitats visited are asked.

The visits numbers are taken directly from the habitats that each respondent reported. The visit weighting is split equally across all habitats reported by each participant. The time spent in the habitat is calculated by taking the total time (including travel time) which is asked in the survey and subtracting an estimated travel time. Travel time is calculated using the reported distance travelled to get to the visit which is multiplied by the average speed relating to the form of transport used, taken from the Ricardo report.

The ‘simple travel-cost’ method used on the WORS data forms a monetary estimate for the amount a person is willing to spend visiting the natural environment. This is done by adding the reported costs on admissions, car parking and bus/train/ferry fares; for participants who travelled by car, motorcycle or taxi were then the cost was calculated and added. The reported fuel costs were deemed to be an unreliable for the purposes of this estimation. The fuel costs for these vehicles is estimated using the mileage and multiply it by a cost per mile value which is taken from the Ricardo report.

The recreation estimates were only created for 2014 because there were differences with the other iterations of the survey. Unlike the 2014 survey, the WORS 2008 and 2011 surveys did not include the equivalent of Q15b which asks respondents to report on their expenditure on various categories. This question is replicated from the MENE survey and without it, it’s not possible to create comparable estimates from these years.

Similarly, in the 2016/17 National Survey for Wales does not include a question about what type of transport was used to travel to the visit location, so estimates for this year could not be made with the same method.

The UK estimates are created using the same method on the MENE survey which is then scaled to represent the UK population. The WORS questions used in the method were largely replicated from the MENE survey. In the WORS there is a question for the main habitat that was visited; it was considered that this could be used as opposed to splitting the visit data across all habitats visited, however, it was decided that the same method should be used to ensure the Welsh estimates would be as comparable as possible with the UK estimates.

For the asset valuation of recreation, projected population growth calculated from ONS population statistics[47] and income uplift matching the method, used in the most recent UK ecosystem services accounts[48], were implemented into the estimation; 1% declining to 0.75% after 30 years and 0.5% after a further 45 years. It is assumed that these factors impact the willingness of the public to spend money on recreational visits to the outdoors.

It is acknowledged that the ‘simple travel-cost method’ provides an underestimation of the monetary worth of the natural environment. Primarily, this is because there are several benefits which are not accounted for including scientific and educational interactions, health benefits and aesthetic interactions. Currently, there is no method in use which incorporates these considerations. Additionally, the value of the time spent by people in the natural environment is not incorporated because no method is thought to be reliable enough to accurately capture this.

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47 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea11principalprojectionuksummary

48 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemserviceaccounts1997to2015

10 Recommendations

The accounts reported here reflect a Welsh-data focus for three habitats. A broader set of ecosystem service accounts would benefit from inclusion of other habitats such as mountain moors and heaths, and urban and coastal accounts.

The potential to link to environmental monitoring, such as the new indicators developed under the Environmental and Rural Affairs Monitoring and Modelling Programme (ERAMMP) and National Survey questions should also be explored further. This will particularly benefit measures of habitat condition (diversity, connectivity and a suite of other functional condition indicators), which are not yet widely represented in many natural capital accounts but are particularly important as the characteristics which can confer resilience of ecosystems to sudden shocks.

With resource rent residual value methods in valuing many ecosystem service flows, geographical breakdowns of Natural Capital accounts, such as Welsh ecosystem service accounts, currently rely upon apportioning UK national accounts. Further development work should take place to investigate other possible valuation methodologies outlined in the System of Environmental Economic Accounting (SEEA) Experimental Ecosystem Accounting[49].

[49] https://seea.un.org/ecosystem-accounting

11 Acknowledgements

The Office for National Statistics (ONS) Natural Capital Accounts team and the Centre for Ecology & Hydrology (CEH) would like to thank Colin Smith (Defra) and Rocky Harris (Defra) for the time and effort they have contributed to developing this report.

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