Forest Research

Valuation of Welsh Forest Resources

Commissioned and funded by Welsh Government

Vadim Saraev
Stuart MacCallum
Darren Moseley
Gregory Valatin

Llywodraeth Cymru
Welsh Government

The Research Agency of the Forestry Commission

Forest Research is the Research Agency of the Forestry Commission and is the leading UK organisation engaged in forestry and tree related research. The Agency aims to support and enhance forestry and its role in sustainable development by providing innovative, high quality scientific research, technical support and consultancy services.

Contract number:		FRB1701
Description:		Valuation of Welsh Forest Resources

Contract Manager:		Richard Morgan Forest Resources Policy Branch Department for Natural Resources Welsh Government Cathays Park Cardiff CF10 3NQ
	Tel:	0290 823 384
	Email:	Richard.Morgan4@wales.gsi.gov.uk
Project manager:		Gregory Valatin Forest Research Alice Holt Lodge Farnham Surrey GU10 4LH
	Tel:	0300 067 5699
	Fax:	01420 23653
	Email:	gregory.valatin@forestry.gsi.gov.uk

Contents

Executive Summary **5**

Introduction **9**

Timber **13**

Standing timber 13
Timber production 14

Carbon Sequestration **16**

Recreation **18**

Air Quality **19**

Discussion **24**

References **26**

Annex: Methodologies **28**

Specific methodology issues and sources of data: 29
Value of standing timber 29
Value of timber extraction 29
Carbon sequestration 31
Recreation 32
Air quality 34

List of Figures

Figure 1 Composite total annual values for Timber, Carbon and Air filtration ecosystem services in the years 2012 to 2015 (£ million, 2015 prices) 7
Figure 2 Annual value of ecosystem service flow related to timber removal from forests in Wales 2012-2015 (£ million, 2015 prices) 15
Figure 3 Annual value of ecosystem service flow related to carbon sequestration 17
Figure 4 Composite of values for PM_{10} absorbed by forests in Wales (£ million, at 2015 prices) 21
Figure 5 Composite of values for SO_2 absorbed by forests in Wales (£ thousand, at 2015 prices) 22
Figure 6 Annual value of ecosystem service flow related to pollution absorption by forests in Wales for PM_{10} and SO_2 in 2011-2015 (£ million, 2015 prices) 23

List of Tables

Table 1 Annual value of service flows from forests in Wales in 2015 6

Table 2 Annual values of service flows from forests in Wales in 2011-2015 (£ million, 2015 prices) 6
Table 3 Asset values of ecosystem services in Wales in 2015, the NPV over the next 50 years 8
Table 4 Area of woodland by ownership & forest type at 31 March 2015 (thousand hectares) 10
Table 5 Non-monetary timber asset account, 2015-2016 13
Table 6 Monetary timber asset account, 2015-2016 (£ million, 2015 prices) 14
Table 7 Volume of standing timber (millions of cubic meters overbark) 14
Table 8 Volume (physical flow of timber removed, thousand cubic metres overbark) and value (£ million, 2015 prices) of timber removed 15
Table 9 Prices, Amounts and Annual values of ecosystem service flow related to carbon sequestration 16
Table 10 Expenditures on recreation in forests in Wales (2015, prices) 18
Table 11 Quantity of PM_{10} (tonnes) absorbed by forests in Wales in 2011-2015 19
Table 12 Quantity of SO_2 (tonnes) absorbed by forests in Wales in 2011-2015 19
Table 13 Annual value of PM_{10} absorbed by forests in Wales in 2011-2015 (£ million, at 2015 prices) 20
Table 14 Annual value of SO_2 absorbed by forests natural capital in Wales in 2011-2015 (£ thousand, at 2015 prices) 21
Table 15 Carbon prices and sensitivities 2010-2016 for appraisal, 2015 £/tCO2e 32
Table 16 Correspondence between MENE and WORS questions, relevant to recreation valuation 32
Table 17 Costs of pollution for PM by location 35

Executive Summary

This study estimated the value of woodlands in Wales in the context of five specific ecosystem goods and services: standing timber, timber extraction, carbon sequestration, recreation and air quality improvement. To help relate the estimates for Wales to those for the UK as a whole, it is useful to note that woodlands in Wales represent about 10% of the total area of UK woodlands. The full ONS UK timber asset accounts and woodland ecosystems valuations can be accessed via this web link (version dated 5 July 2016 used for this report). The headline figures for the UK are presented here for comparison. (For ease of comparison with those derived in this study, the values from ONS for the UK were reflated from 2013 to 2015 prices):

1. In 2015, the total stock of standing timber resource in the UK was estimated at 618.1 million cubic metres overbark. The monetary value of all UK timber resources was estimated to be £8 billion in 2015 (2015 prices).

2. In 2014, the total timber removals in the UK were estimated at 12.4 million cubic metres overbark. The annual value of timber removals was £233 million in 2014 (2015 prices). The asset value for this ecosystem service was estimated at £5.3 billion in 2014 (2015 prices).

3. In 2014, the total carbon sequestration in the UK was estimated at 15.6 million tonnes CO_2e. The annual value of carbon sequestration was £975 million in 2014 (2015 prices). The asset value for this ecosystem service was estimated at £39 billion in 2014 (2015 prices).

4. In 2014, the total number of visits for recreation in woodlands in the UK was estimated at 634 million. The annual value of recreation was £2.3 billion in 2014 (2015 prices). The asset value for this ecosystem service was estimated at £56.2 billion in 2014 (2015 prices).

5. In 2014, the total air filtration in the UK was estimated at 141.4 thousand tonnes of particles removed. The annual value of air filtration was £3 billion in 2014 (2015 prices). The asset value for this ecosystem service was estimated at £70.9 billion in 2014 (2015 prices).

The total annual value of four woodland ecosystem services (excluding standing timber) in 2014 for the UK was estimated at £6.5 billion (2015 prices). The corresponding asset value in 2014 was £171.4 billion (2015 prices).

We estimated the value of annual service flows provided by woodlands in Wales for four ecosystem services: timber extraction, carbon sequestration, recreation and air quality improvement. These annual values are presented in Table 1 below, together with an indicative aggregate value.

Table 1 Annual value of service flows from forests in Wales in 2015

Service	Timber extraction	Carbon sequestration	Recreation*	Air quality	Total
Value, £ million, 2015 prices	28.3	108	85	385	**606.3**

* Recreation value is derived from the 2014 survey. Following new recommendations from the ONS, the value is estimated from the expenditure data and is not based on mean value per visit as the figures for the UK reported above. The new approach yields lower estimates than that based on mean value per visit (see Annex).

As can be seen from the table, the indicative total annual value of the 4 woodland ecosystem services amounts to just over £600 million. Of the 4 services, air quality improvements due to pollution removal is the largest, followed by carbon sequestration, recreation and then timber production (Figure 1).

Table 1 can be expanded to cover a longer time period for the years in which data are available (Table 2).

Table 2 Annual values of service flows from forests in Wales in 2011-2015 (£ million, 2015 prices)

Year	Timber extraction	Air filtration	Carbon sequestration	Recreation
2011	n.a.	535	107	n.a.
2012	21.1	416	105	n.a.
2013	21.1	512	107	n.a.
2014	25.7	447	102	85
2015	28.3	385	108	n.a.

n.a. means data not available

Focusing on ecosystem services for which we have full data series (2012 – 2015) enables comparison of the composite total annual values for each year (Figure 1).

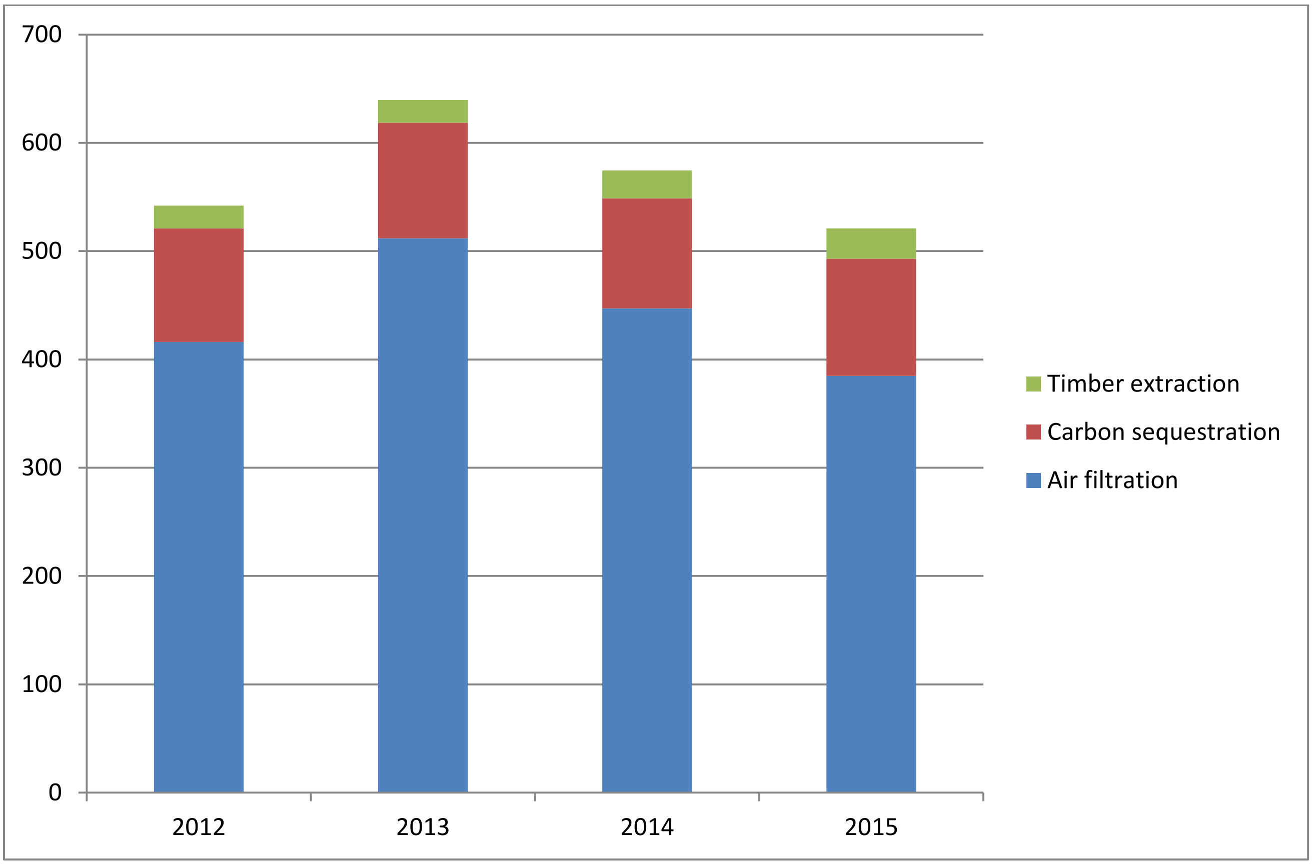


Figure 1 Composite total annual values for Timber, Carbon and Air filtration ecosystem services in the years 2012 to 2015 (£ million, 2015 prices)

As can be seen from the Figure 1 and Table 2 air quality improvements due to pollution removal is the largest component of the total annual value, followed by carbon sequestration and timber production.

An associated asset value for each ecosystem service is estimated as a net present value over 50 years. Following the method used by the Office for National Statistics (ONS) in each case, apart from that for carbon sequestration, this asset value is based upon the assumption that the annual service flow remains the same over this period. In the case of carbon sequestration the annual service value pattern was based upon carbon sequestration projections and the schedule of carbon prices developed by the Department for Energy and Climate Change (DECC), now part of the department for Business, Energy and Industrial Strategy (BEIS).

Asset values together with a tentative total value are presented in Table 3.

Table 3 Asset values of ecosystem services in Wales in 2015, the NPV over the next 50 years

Service	Timber extraction	Carbon sequestration	Recreation	Air quality	Total
Value, £ billion, 2015 prices	0.7	3.9	2.1	11.2	**17.9**

As can be seen from the Table 3, the total asset value of the 4 woodland ecosystem services amounts to about £18 billion. As with the annual flows, that associated with air quality improvements due to pollution removals is the largest, followed by carbon sequestration, recreation and then timber production.

A value for the total standing timber is also derived. In 2015, the total stock of standing timber resource in Wales was estimated at 64.4 million cubic metres overbark. Following the approach undertaken by the ONS, the valuation is based on the assumption that all trees could potentially be sold at the current standing price and felled. In theory this could happen in a particular year, but would be a one-off activity, and would not represent a repeated annual flow. Therefore, this asset value is reported separately. It is estimated to be just under £1.2 billion (at 2015 prices).

As ONS emphasises, development of UK environmental accounts and Natural capital monetary estimates is still at a very early stage, with the methodology and datasets used still under review and subject to change. We applied the latest methodology available (as of February 2017) to derive the estimates in this report.

Given evidence gaps on ecosystem service dynamics and interactions, the estimates are subject to various degrees of uncertainty. Major sources of uncertainty in some of the estimates include: 1) incomplete scientific knowledge about the extent to which woodlands provide a service; 2) imprecise measurement and data collection; and 3) assumptions about future developments (over the next 50 years) in the provision of each ecosystem service and the associated prices to use in deriving an asset value.

Bearing different sources of uncertainty in mind, we rated the ecosystem service value estimates by level of uncertainty from ‘low’ (timber) to ‘medium’ (carbon sequestration, air quality, recreation). None are subject to ‘high’ uncertainty due to the selection of ecosystem services for valuation in this report having initially been based upon those for which relatively good evidence is available.

Introduction

Natural capital is defined as '*the elements of nature that produce value or benefits to people (directly and indirectly), such as the stock of forests, rivers, land, minerals and oceans, as well as the natural processes and functions that underpin their operation*' (Natural Capital Committee, 2014).

In 2015, the Office for National Statistics (ONS) prepared experimental environmental accounts at a UK level to illustrate values of the benefits that the environment contributes to the economy, the impact the economy has on the environment and how society responds to environmental issues. These 'satellite' accounts feed into main UK national accounts and are compiled in accordance with the System of Environmental Accounting (SEEA). The SEEA closely follows the UN System of National Accounts (SNA) which means they are comparable with economic indicators such as GDP. In late 2016 ONS updated their figures based on the most recent data, accompanied by an analysis of change over time.

The State of Natural Resources Report (SoNaRR) published by Natural Resources Wales (NRW) in September 2016 (NRW, 2016) highlighted the opportunities to deliver multiple benefits through increased woodland creation and by bringing more existing woodland into appropriate management. The report also highlighted gaps in evidence in relation to woodlands and forestry particularly in relation to goods and services these provide, for example in terms of recreational use of woodlands and the contribution made towards improved health and wellbeing.

In response, the Welsh Government Forest Resources Policy Branch developed a proposal to appraise the value of woodlands in the context of five specific ecosystem goods and services: standing timber, timber extraction, carbon sequestration, recreation and air quality improvement. It is intended that each of these values will inform policy development to support the Sustainable Management of Natural Resources as described in the Environment (Wales) Act 2016 and delivery against the Wellbeing of Future Generations goals.

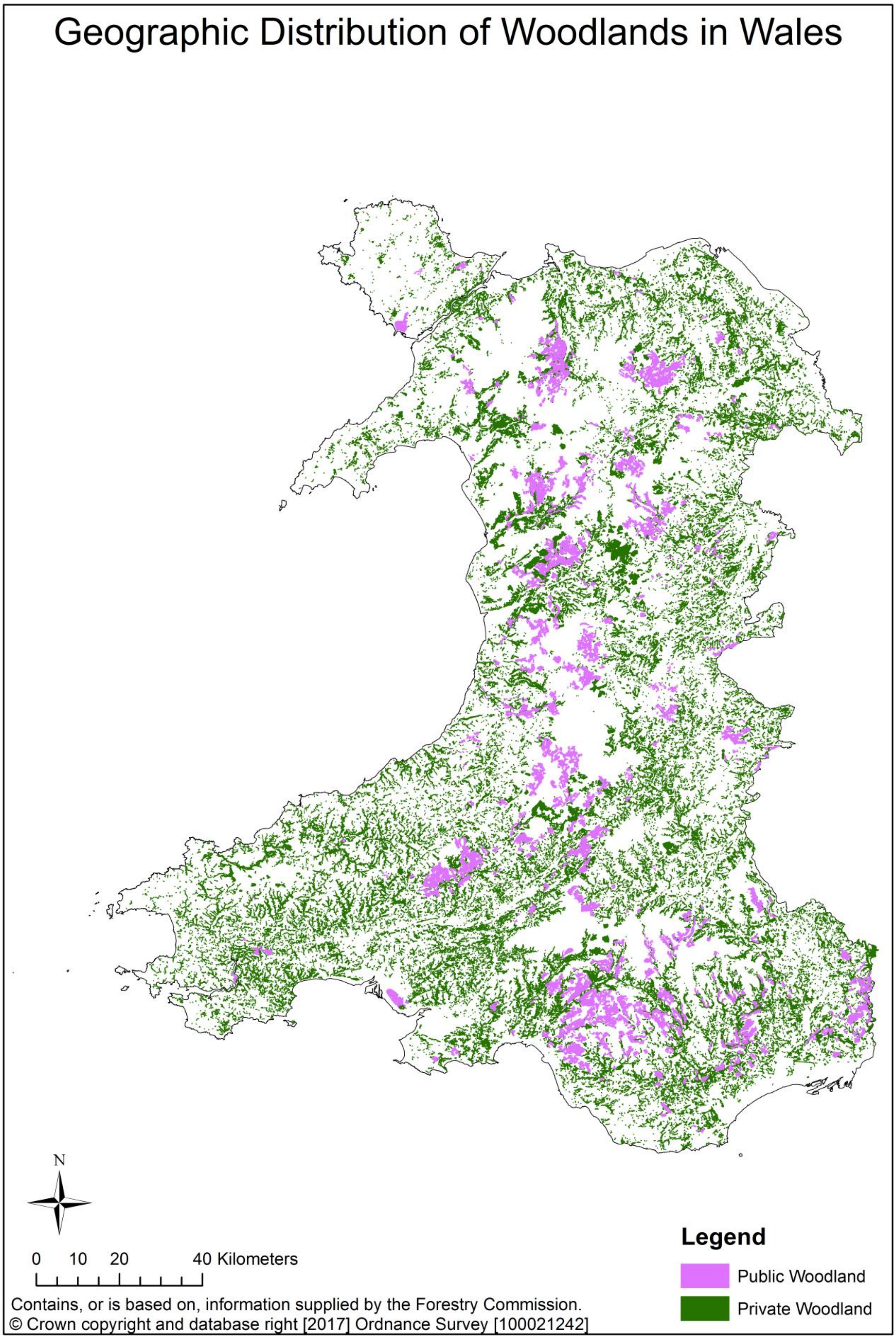
The aim of this work was to provide experimental environmental accounts, at an all-Wales level, using methodologies employed for the UK by the ONS and utilising the best available data for the Welsh context. The findings in this report will allow comparison with the UK Environmental Accounts and help to inform both policy and delivery, as well as future research in relation to woodland resource valuation in Wales.

To help put this study and its estimates in context, Table 4 reproduces information on UK woodland area, by country, taken directly from Forestry Statistics 2015 (Forestry Commission, 2015).

Table 4 Area of woodland by ownership & forest type at 31 March 2015 (thousand hectares)

Forest type and ownership	England	Wales	Scotland	Northern Ireland	UK
Conifers					
FC/NRW/FS	151	98	438	56	743
Private sector	188	53	619	11	871
Total	339	150	1,057	67	1,614
Broadleaves					
FC/NRW/FS	64	19	40	6	129
Private sector	901	136	335	39	1,412
Total	965	156	375	45	1,540
Total					
FC/NRW/FS	215	117	478	62	871
Private sector	1,090	189	954	50	2,283
Total	1,304	306	1,432	112	3,154

Table 4 indicates that woodlands in Wales account for about 10% of the total area of UK woodlands, with a marginally higher proportion of broadleaved woodlands (and correspondingly slightly lower proportion of coniferous woodlands) than the UK as a whole. By area, it also indicates that Wales has a higher proportion of publicly-owned woodlands (38%) than the UK as a whole (28%). A map of the location of private and of public forests in Wales is shown below.


Geographic Distribution of Woodlands in Wales
N
0 10 20 40 Kilometers
Contains, or is based on, information supplied by the Forestry Commission.
© Crown copyright and database right [2017] Ordnance Survey [100021242]
Legend
Public Woodland
Private Woodland

This study sets out to estimate the value of woodlands in Wales in the context of five specific ecosystem goods and services. The report focuses on:

1. Value of standing timber. This is the value of all timber as if it were all currently available for harvest. This is derived from an estimate of the volume of standing timber in Wales, multiplied by the current market price.

2. Economic value of selected ecosystem services resulting from woodlands in Wales. This covers four areas:

   a) Value of timber extraction. Timber quantities estimated through surveys of removals by the forestry industry, measured in terms of the felled volume of timber including bark in cubic metres. The value is calculated by multiplying the volume of timber extracted in Wales by the current market price.

   b) Carbon sequestration. Estimates of carbon sequestered are generated through modelling for the greenhouse gas emissions inventory, taking account of the type and age profile of the trees in forests across the UK. The value is calculated by multiplying the volume of carbon sequestered by forests in Wales by the associated social value of carbon recommended by government for policy appraisal.

   c) Recreation. This value is based on reported expenditures on visits to woodlands in Wales, derived from data contained in the Wales Outdoor Recreation Survey (WORS).

   d) Air quality. Air quality improvement is estimated by reference to recent research on the level of particulate matter absorption per hectare of woodland and estimates of the change in the extent of wooded land.

The sections that follow provide results for each of these. In each case estimates are derived following similar approaches to those adopted by ONS for the UK as a whole. For further details, including on sources and assumptions, see the Annex.

The report in most cases uses 2015 as a base year, while also reporting 2016 data where available. In addition to figures based on the most recent dataset, analysis of data for at least one previous year (where available) for the metrics listed under 1 and 2 above is undertaken. To mirror the approach generally used by the ONS, where data allow, the report reflects changes between 2014 and 2015.

Timber

The method used to value the provisioning services related to timber supply requires two inputs: the stumpage price and the volume. In the absence of data on average hardwood prices, the stumpage price for coniferous wood is assumed to apply to all the timber that is harvested.

Standing timber

The total stock of standing timber resource in Wales was estimated at 64.4 million cubic metres overbark in financial year 2015-2016 (Table 5), with the opening and closing stock on 31 March reported in 2015 and 2016 respectively. Of the total standing stock, 35.1 million cubic metres overbark (54.5%) were coniferous timber (also known as softwood) and 29.3 million cubic metres overbark (45.5%) broadleaf timber (or hardwood).

Table 5 Non-monetary timber asset account, 2015-2016

					Thousand cubic metres overbark
	Type of timber resources				Total
Species types	Conifers		Broadleaves		
Ownership types	Public	Private	Public	Private	
Opening stock	18,531	16,965	1,974	26,751	64,221
Additions to stock					
Natural growth	900	380	49	516	1,845
New planting and restocking reclassification	-	-	-	-	-
Total additions to stock	900	380	49	516	1,845
Reductions in stock					
Removals	759	755	5	18	1,537
Fellings residues	84	84	1	2	171
Natural losses	-	-	-	-	-
Reclassifications	-	-	-	-	-
Total reduction in stock	843	838	6	20	1,707
Closing stock	18,587	16,507	2,017	27,247	64,358

The monetary value of standing timber is derived on the assumptions that the stumpage price is the same for all timber resources and that all timber is available for wood supply (Table 6). In theory harvesting of all the standing timber could happen in a single year, but would clearly be one-off and not represent a repeated annual flow. The total value is estimated at just under £1.2 billion (at 2015 prices).

Table 6 Monetary timber asset account, 2015-2016 (£ million, 2015 prices)

	Type of timber resources				Total
Species types	Conifers		Broadleaves		
Ownership types	Public	Private	Public	Private	
Opening stock	341.1	312.2	36.3	492.4	1,182.0
Additions to stock					
Natural growth	16.6	7.0	0.9	9.5	33.9
New planting and restocking reclassification	-	-	-	-	-
Total additions to stock	16.6	7.0	0.9	9.5	33.9
Reductions in stock					
Removals	14.0	13.9	0.1	0.3	28.3
Fellings residues	1.6	1.5	0.0	0.0	3.1
Natural losses	-	-	-	-	-
Reclassifications	-	-	-	-	-
Total reduction in stock	15.5	15.4	0.1	0.4	31.4
Closing stock	342.1	303.8	37.1	501.5	1,184.5

The volume of standing timber has changed only marginally since 2012. While it fell by 1.8% from 2012-2013, it rose slightly from 2013-2015, and was 1.1% below its 2012 level in 2015 (Table 7).

Table 7 Volume of standing timber (millions of cubic meters overbark)

	2012	2013	2014	2015
Standing timber (million m^3 ob)	65.1	63.9	64.2	64.4

Timber production

Valued at the softwood stumpage price that applied in the particular year, the value of timber production at constant prices by reflating prices for earlier years to make comparisons in real terms (allowing for inflation) has increased from £21m in 2012 to £28m in 2015 (Table 8).

Table 8 Volume (physical flow of timber removed, thousand cubic metres overbark) and value (£ million, 2015 prices) of timber removed

	2012	2013	2014	2015
Removals (000 m^3 overbark)	1,423	1,545	1,630	1,537
Removals (£ million)	21.1	21.1	25.7	28.3

The increase in the annual value of timber produced (also shown in Figure 2) is attributable in large part to the increase in the stumpage price, which rose 24% from just under £15/m^3 overbark in 2012 to just over £18/m^3 overbark in 2015.

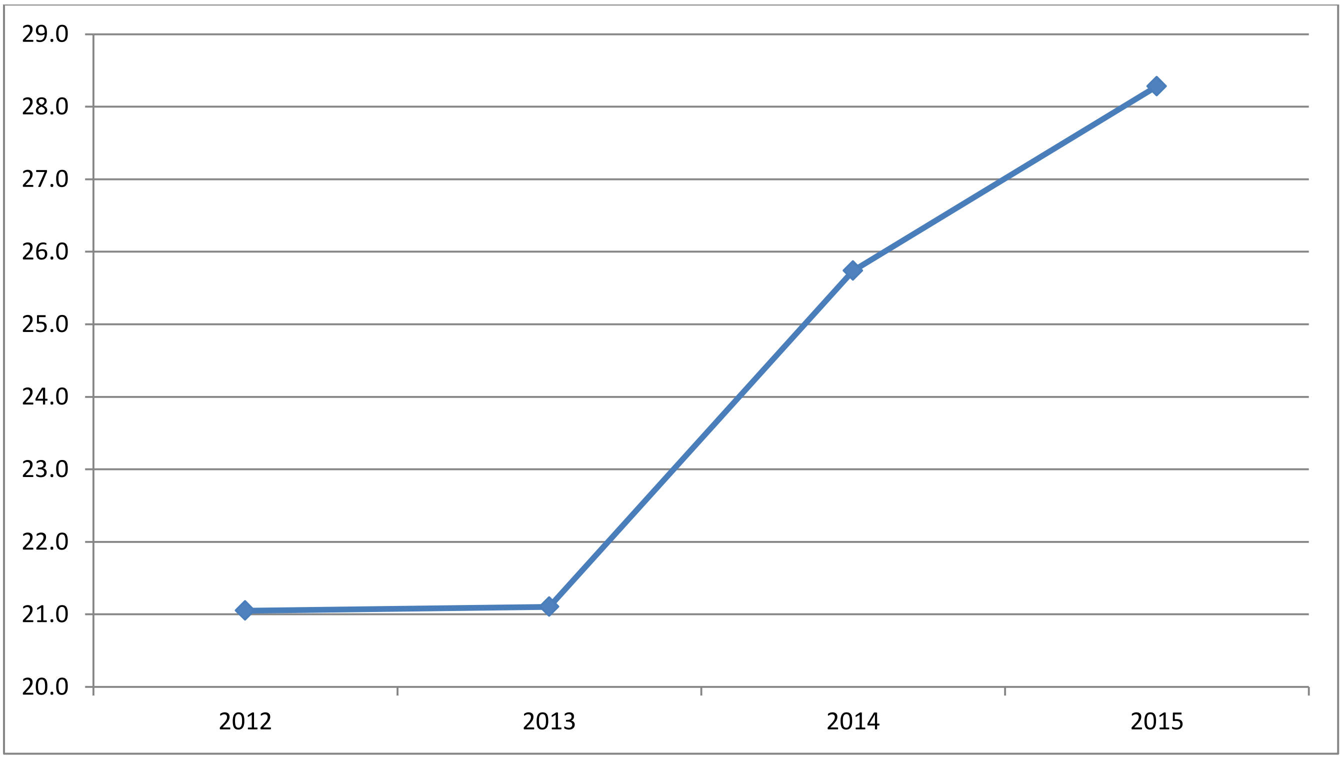


Figure 2 Annual value of ecosystem service flow related to timber removal from forests in Wales 2012-2015 (£ million, 2015 prices)

The net present value (NPV) of this ecosystem service in 2015 was £693 million (at 2015 prices) if one assumes the annual timber revenue for 2015 to be constant into the future. The NPV is the estimated asset value for the ecosystem service of timber extraction over 50 years.

Carbon Sequestration

For carbon sequestration, the physical volume of carbon removed is combined with the non-traded carbon price estimated by the Department of Energy and Climate Change (DECC), now the department for Business, Energy and Industrial Strategy (BEIS). Data on actual and projected physical carbon sequestration are applied for 50-years when calculating asset value estimates. For the years 2010 to 2014, the estimates of carbon sequestration are sourced from the UK greenhouse gas inventory.

For years 2015 to 2050 carbon sequestration rates are modelled using business as usual (BAU) projections to 2050 for the relevant LULUCF (Land use, land use change and forestry) sectors: category A – Forest Land. These data are sourced directly from BIES. Thereafter, estimates are based on the projected carbon sequestration level in 2050, and held constant for the remainder of the 50-year period.

While the price for carbon sequestered has increased steadily by 7.7% between 2010 and 2015 the amount of carbon sequestered fluctuated and fell by 4.5% in the same period (Table 9).

Table 9 Prices, Amounts and Annual values of ecosystem service flow related to carbon sequestration

	2010	2011	2012	2013	2014	2015	2016
Price (£/tCO2e, 2015 prices)	58	59	60	61	61	62	63
Carbon sequestration (thousand tonnes of CO2e)	1,811.5	1,815.2	1,757.6	1,762.2	1,651.8	1,729.2	1,728.1
Carbon sequestration (£, million, 2015 prices)	105	107	105	107	102	108	109

The net effect of a reduction in carbon sequestered and an increase in the social value of carbon was that the annual value of the service increased by 2.8% from £105m in 2010 to £109m in 2015 (see also Figure 3).

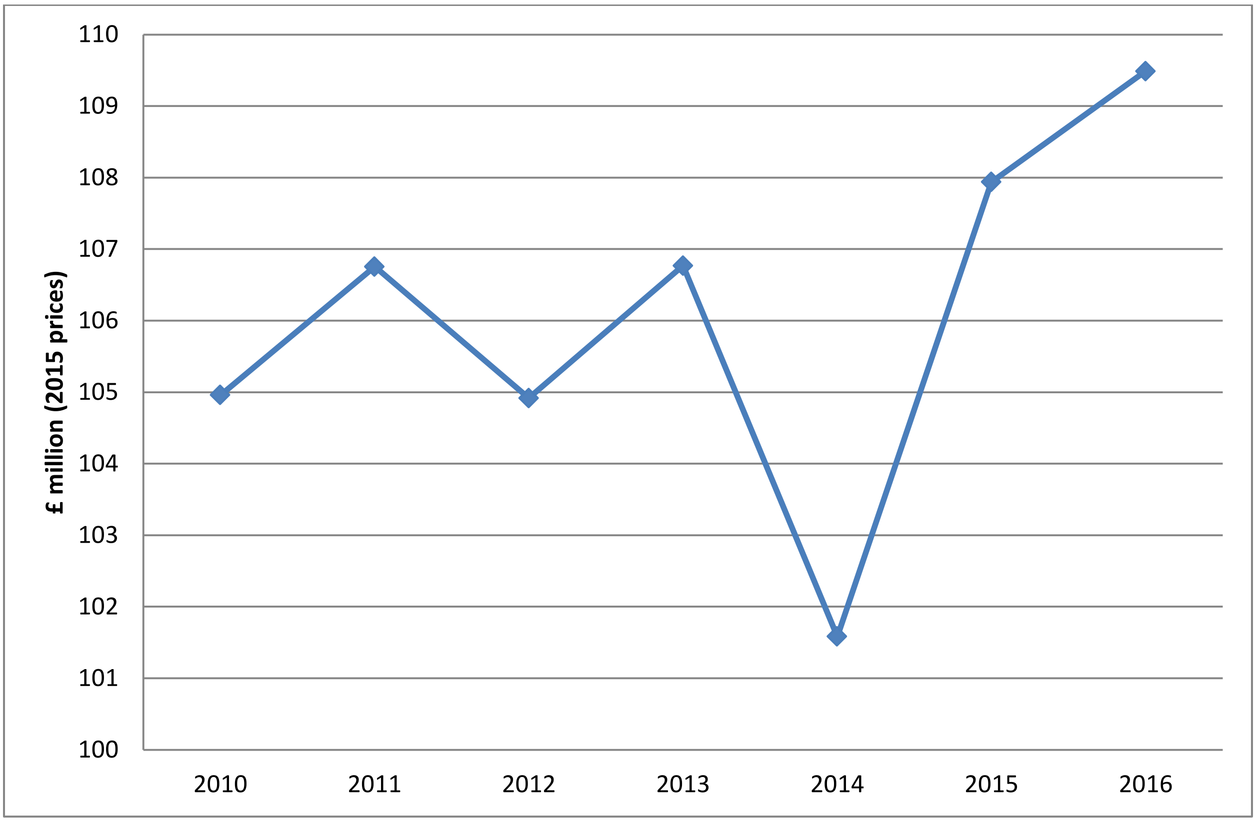


Figure 3 Annual value of ecosystem service flow related to carbon sequestration

The asset value of this ecosystem service in 2015 was £3.9 billion at 2015 prices estimated as a NPV over 50 years.

It was not possible to provide Public/Private and Broadleaves/Conifers breakdowns for the carbon sequestration figures because no breakdown is provided of the estimates in the UK greenhouse gas inventory. Moreover, given potentially large differences in the age structure and species composition of public forests compared to private forests (with potentially different rates and time profiles of carbon sequestration) it is not advisable to apply a simple proportion of current land area under Public/Private forests to infer such a breakdown for carbon sequestered over the next 50 years. This is a research gap that could be addressed by future developments in data collection and methodology.

Recreation

Based on a new recommendation from ONS, recreation values were estimated using expenditure data reported by respondents in the Welsh Outdoor Recreation Survey (WORS). The latest available data are from the survey conducted in 2014.

There were 67.7 million visits to forests in Wales in 2014 where forest/woodland was the main place visited. The associated annual value of recreation services provided by forests in Wales in 2014 (excluding visits where forest/woodland was not the main place visited) is estimated (at 2015 prices) as £85 million (Table 10).

Table 10 Expenditures on recreation in forests in Wales (2015, prices)

Type	Expenditure (£ thousands)	Expenditure (%)
Bus Private	0.0	0.0
Bus Public	346.1	0.4
Car	57,575.8	67.7
Motorcycle	63.8	0.1
Taxi	0.0	0.0
Train	487.1	0.6
Parking	10,084.9	11.9
Admission	16,482.5	19.4
Total	**85,040.2**	**100.0**

Assuming the same level of expenditure to continue into the future yields an asset value of £2.1 billion (at 2015 prices) over the next 50 years.

It is important to note that the WORS is a survey of residents and does not capture data from tourists that are non-residents visiting Wales. Incorporating visits by non-residents would increase the recreational value of woodland visits to forests in Wales. The recreational value also does not take account of any impacts on health which may have resulted from visits to the woodlands.

Unfortunately data from the 2011 Welsh Outdoor Recreation Survey were not available in the time-scale of this study to permit comparisons between years, or to allow a breakdown of the values between public and private forests.

For comparisons the recreation value based on a number of visits and a mean value per visit is estimated and presented in the Annex.

Air Quality

Woodlands are an important ecosystem service in removing pollution from the atmosphere.

Estimates for this ecosystem service were based on the amount of particulate matter 10 micrometres (10 μm) or less in diameter(PM_{10}) and sulphur dioxide (SO_2) absorbed by woodlands and Defra air quality damage cost guidance.

There are other harmful pollutants, including fine particulate matter ($PM_{2.5}$), which trees absorb but for which we do not currently have estimates or associated values. Note that in each case the pollution absorption estimates are based upon the area of forests in Wales in 2012 and do not take account of subsequent land use changes (e.g. net afforestation) or management (e.g. sanitation felling).

In 2015 an estimated 16,211 tonnes of PM_{10} (Table 11) and 145 tonnes of SO_2 (Table 12) were absorbed by forests in Wales.

Table 11 Quantity of PM_{10} (tonnes) absorbed by forests in Wales in 2011-2015

	Conifer		Broadleaf		All
Year	Rural	Urban	Rural	Urban	
2011	18,675	1,358	3,108	435	23,575
2012	14,397	1,044	2,445	337	18,222
2013	17,447	1,326	2,961	424	22,158
2014	15,119	1,157	2,595	375	19,246
2015	12,723	1,004	2,160	324	16,211

Table 12 Quantity of SO_2 (tonnes) absorbed by forests in Wales in 2011-2015

	Conifer		Broadleaf		All
Year	Rural	Urban	Rural	Urban	
2011	177	20	31	6	235
2012	172	17	31	6	226
2013	174	20	30	7	230
2014	160	15	27	5	207
2015	108	13	20	4	145

The annual value of removing PM_{10} in Wales in 2015 was estimated (at 2015 prices) to be £385 million (Table 13 and Figure 4).

Table 13 Annual value of PM_{10} absorbed by forests in Wales in 2011-2015 (£ million, at 2015 prices)

	Conifer		Broadleaf		All
Year	Rural	Urban	Rural	Urban	
2011	327	116	54	37	535
2012	254	90	43	29	416
2013	308	114	52	36	511
2014	268	100	46	32	447
2015	229	88	39	28	385

As illustrated in Figure 4 below, the largest values for PM_{10} absorption are attributed to coniferous woodlands, with higher values in rural areas than in urban areas. The contribution from broadleaves in Wales is smaller and has a similar rural – urban pattern.

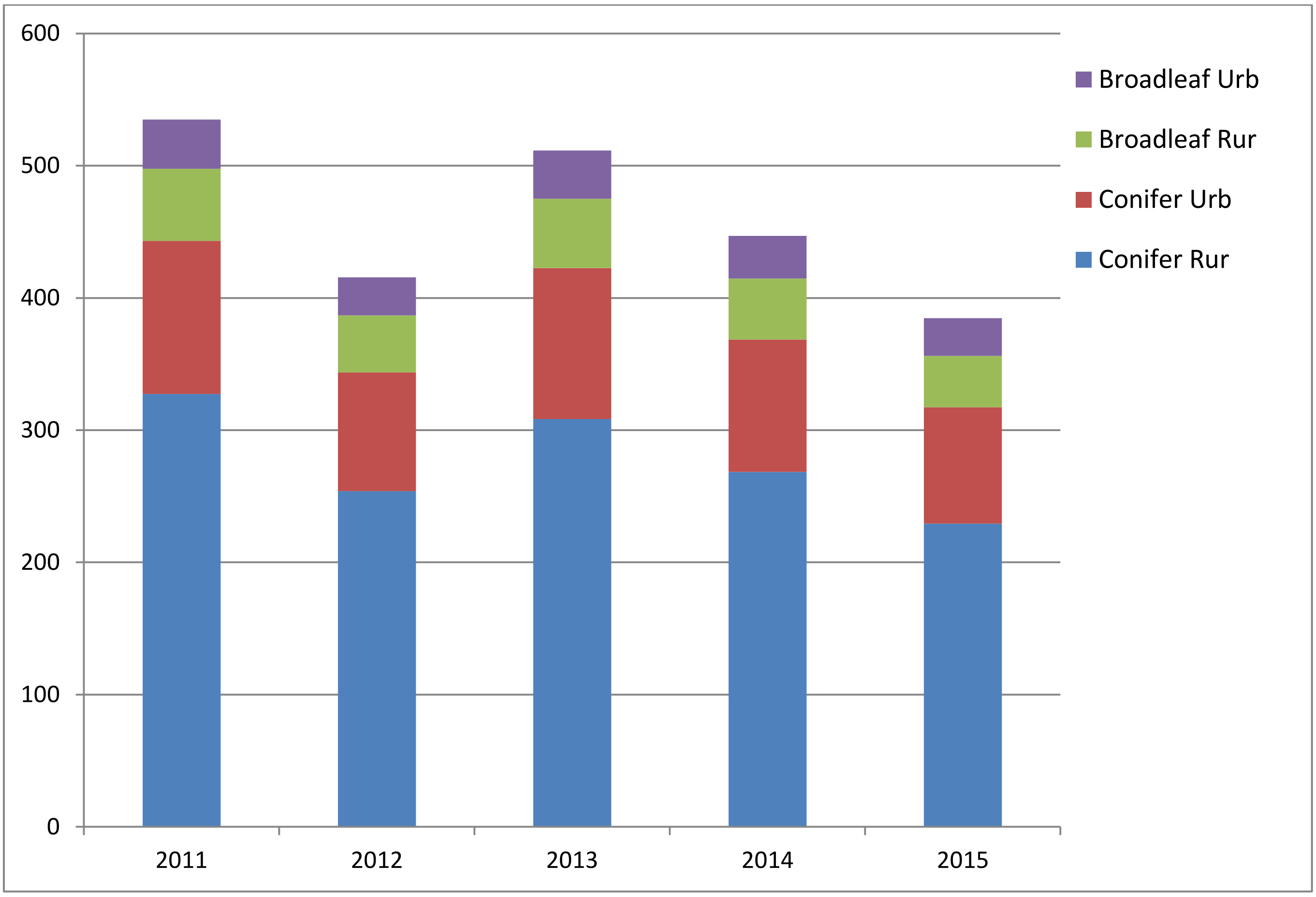


Figure 4 Composite of values for PM_{10} absorbed by forests in Wales (£ million, at 2015 prices)

The annual value of removing SO_2 in Wales in 2015 was estimated (at 2015 prices) to be £0.3 million (Table 14 and Figure 5).

Table 14 Annual value of SO_2 absorbed by forests natural capital in Wales in 2011-2015 (£ thousand, at 2015 prices)

	Conifer		Broadleaf		All
Year	Rural	Urban	Rural	Urban	
2011	337	39	60	12	447
2012	329	33	60	11	433
2013	333	38	58	13	442
2014	308	30	52	9	398
2015	210	26	39	8	284

As illustrated in Figure 5 below, similar to particulates, the largest values of SO_2 absorption are attributed to coniferous rural woodlands, followed by coniferous urban woodlands and broadleaved urban woodlands.

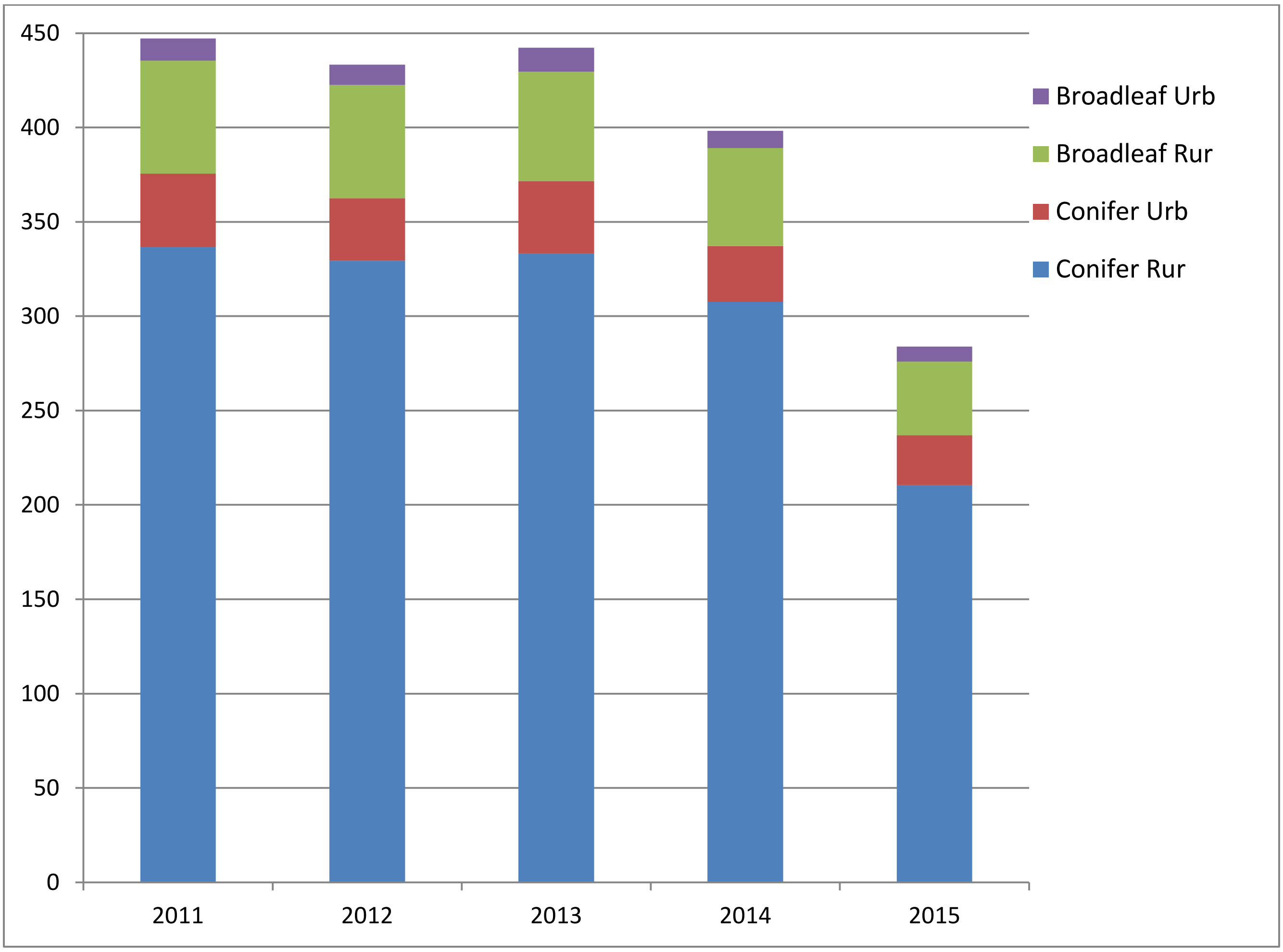


Figure 5 Composite of values for SO_2 absorbed by forests in Wales (£ thousand, at 2015 prices)

In each year both the amount and value of PM_{10} absorption far exceeds that for SO_2 absorption. Being dependent in part on the weather and forest composition, levels of absorption for PM_{10} and SO_2 fluctuate between years. However, overall between 2011 and 2015 the amount of PM_{10} absorbed is estimated to have fallen by 31%, with the annual value of the service falling by 28%. Similarly, for SO_2 the amount and annual value of the service fell by 38% and 37% respectively between 2011 and 2015. The drop in pollution absorption seems to be due to the combination of a number of factors: lower background pollution levels, fewer dry days, and fewer on-leaf days. All of these are lower (by between 5 to 9 percent) for 2015 than the average for the previous 4 years. However, the main contributor appears to be the background pollutant levels which were 14% and 29% lower for PM_{10} and SO_2 respectively in 2015 as compared to the average for the previous 4 years.

The total annual value of removing PM_{10} and SO_2 by forests in Wales for the period 2011 - 2015 is presented in the figure below, which also reflects yearly fluctuations with an overall fall in value:

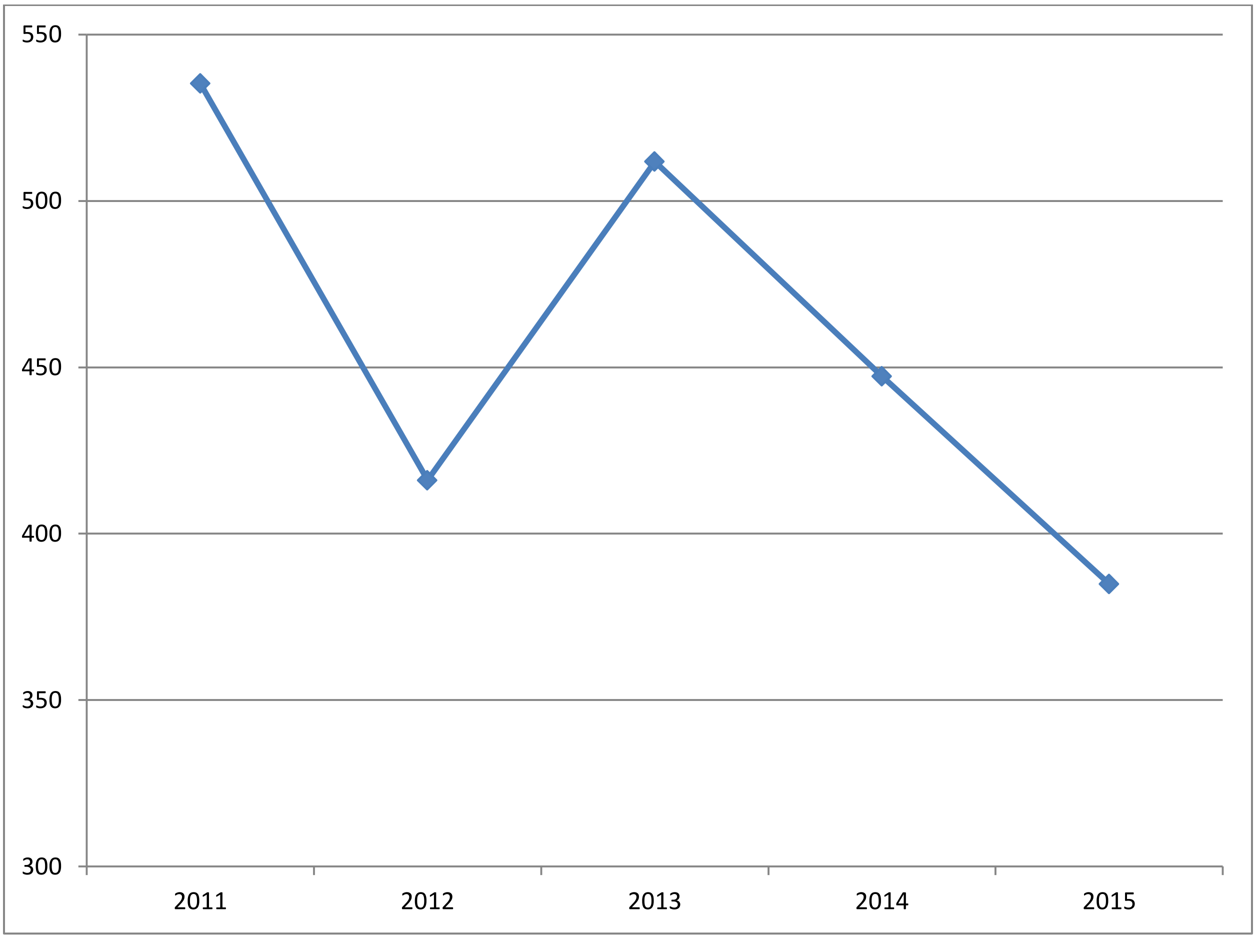


Figure 6 Annual value of ecosystem service flow related to pollution absorption by forests in Wales for PM_{10} and SO_2 in 2011-2015 (£ million, 2015 prices)

The NPV asset value of pollution absorption, estimated in terms of the ability of forests to provide air quality regulation services into the future (50 years), was estimated to be around £11.2 billion for PM_{10} and £9.8 million for SO_2 (at 2015 prices) based on average pollution levels over the period 2011-5.

Discussion

This study provides initial estimates for the value of several woodland ecosystem goods and services in Wales. In particular, it has provided estimates for the value of standing timber, timber extraction, carbon sequestration, recreation and air quality improvements due to pollution removal by forests. Where data allowed we sought to provide breakdowns by woodland ownership (Public/Private) and type (Broadleaves/Conifers).

Some of the major caveats and sources of uncertainty relating to the estimates are noted below, with more details presented in the Annex.

Timber:

The timber extraction asset value in 2015 was estimated above at £693 million assuming the volume of timber produced in 2015 to be constant into the future. However, if in order to smooth out year-on-year fluctuations one instead assumes an average volume for the last four available years (2012-2015) as the constant level into the future, then the NPV is smaller at about £589 million (at 2015 prices). As with carbon sequestration, future estimates could make use of production forecasts rather than assuming a constant level of future harvests.

Potentially the availability of hardwood prices would make for more precise estimates. As in 2015 hardwood timber removals were only 1.5% of total timber produced, the potential correction to the estimates for timber extraction would be small, although that for the asset value of total standing timber could be higher.

Carbon sequestration:

Projections for future carbon sequestration do not currently account for anticipated impacts of climate change on growth rates of woodlands in Wales. As noted above, it was not possible to provide breakdowns for Public/Private ownership or for Broadleaves/Conifers because no such breakdown is provided in the UK greenhouse gas inventory - a research gap that could be addressed by future developments in data collection and methodology.

Recreation:

Although as noted above it was not possible to provide Public/Private breakdown for the figures because geo-coded data were unavailable within the time-scale of this study, this is a research gap that is thought relatively easy to address in future.

Air quality:

Currently air pollution removal services (air quality improvements) are undervalued at present as values are limited to the removal of PM_{10} and SO_2 only. Absorption of fine particles less than 2.5 μm in size ($PM_{2.5}$) are also of importance in considering health impacts of trees and woodlands. However, there is a need to extend the current methodology to estimating volumes of $PM_{2.5}$ absorbed by woodlands and trees and potentially also to refine costs estimates, which do not currently differentiate between particulates of different sizes.

There is also potential to provide alternative estimates of the absorption of pollutants by forests, with more up-to-date land cover estimates enabling a public/private breakdown (see details in the Annex).

As emphasised by ONS, development of the UK environmental accounts and Natural Capital monetary estimates is still at a very early stage and the methodology and datasets for these estimates are changing fast and are constantly under review. We applied the latest methodology available (as of February 2017) to derive the estimates in this report. As the result all estimates in the report should be considered as indicative and subject to potential changes in the future.

Given evidence gaps on ecosystem service dynamics and interactions, the estimates are subject to various degrees of uncertainty. Major sources of uncertainty in some of the estimates include: 1) incomplete scientific knowledge about the extent to which woodlands provide a service; 2) imprecise measurement and data collection; and 3) assumptions about future developments (over the next 50 years) in both the physical state of the forest ecosystem and in prices used to derive each asset value – a natural uncertainty.

Bearing this in mind and the complexity of an ecosystem service valued we rated our estimates by level of uncertainty from ‘low’ (for timber) to ‘medium’ (for recreation, carbon sequestration and air quality improvement). Further details can be found in the Annex. None of the estimates covered in this report are judged subject to ‘high’ uncertainty. This is not because estimated values of ecosystem services provided by woodlands are never subject to high uncertainty, but is related to the initial selection of ecosystem services for valuation in this study. This was based upon those for which relatively good evidence was thought to be available.

Aggregating various ecosystem service values or components of natural capital can sometimes lead to double-counting issues. We think that with the current selection of ecosystem services for this report the potential for double-counting is low and that concerns over the potential for double-counting need not preclude presenting tentative aggregate values. Another issue with aggregation of the different ecosystem services values is their disparate nature. Timber extraction value is based on market prices, recreation value on reported consumer expenditure, while carbon sequestration and air quality improvements are based on non-market benefits. Therefore, the totals for all ecosystem services presented in the report are not straightforward sums, but must be taken as notional indicative values for society as a whole.

References

AECOM (2016) *Annex 1: Background and methods for experimental pollution removal estimates*. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/annex1backgroundandmethodsforexperimentalpollutionremovalestimates.

Cole, B., King, S., Ogutu, B., Palmer, D., Smith, G. and Balzter, H. (2015) 'Corine land cover 2012 for the UK, Jersey and Guernsey'. NERC Environmental Information Data Centre. Available at: https://doi.org/10.5285/32533dd6-7c1b-43e1-b892-e80d61a5ea1d.

DEFRA (2011) *Air Quality Damage Cost Guidance*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182390/air-quality-damage-cost-guidance.pdf.

DEFRA (2015a) *Air quality: economic analysis*. Available at: https://www.gov.uk/guidance/air-quality-economic-analysis#damage-costs-approach (Accessed: 9 March 2017).

DEFRA (2015b) *Air quality economic analysis: Damage costs by location and source*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/460398/air-quality-econanalysis-damagecost.pdf.

DEFRA and HM Treasury (2013) *Valuing impacts on air quality: Supplementary Green Book guidance*. Available at: https://www.gov.uk/government/publications/green-book-supplementary-guidance-air-quality.

Forestry Commission (2015) *Forestry Statistics 2015*. Report. Edinburgh, UK: Forestry Commission (FC). Available at: http://www.forestry.gov.uk/website/forstats2015.nsf/LUContentsTop?openview&RestrictToCategory=1.

HM Treasury (2003) 'The Green Book: Appraisal and Evaluation in Central Government'. Edited by HM Treasury. London: TSO. Available at: http://www.hm-treasury.gov.uk/data_greenbook_index.htm.

Natural Capital Committee (2014) *The State of Natural Capital: Second report*.

NRW (2016) *The State of Natural Resources Report (SoNaRR) 2016*. Available at: https://naturalresources.wales/our-evidence-and-reports/the-state-of-natural-resources-report-assessment-of-the-sustainable-management-of-natural-resources/?lang=en.

ONS (2016a) *UK environmental accounts: 2016*. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/ukenvironmentalaccounts/2016.

ONS (2016b) *UK natural capital: monetary estimates*. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/monetaryestimates2016.

ONS (2017) *Principles of Natural Capital Accounting*. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting.

Powe, N. A. and Willis, K. G. (2004) 'Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain.', *Journal of environmental management*. England, 70(2), pp. 119–128.

Ricardo (2016) *Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimates. Report for Office National Statistics*. Available at: https://www.ons.gov.uk/file?uri=/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital/reviewingculturalservices.pdf.

Sen, A., Harwood, A., Bateman, I., Munday, P., Crowe, A., Brander, L., Raychaudhuri, J., Lovett, A., Foden, J. and Provins, A. (2014) 'Economic Assessment of the Recreational Value of Ecosystems: Methodological Development and National and Local Application', *Environmental and Resource Economics*. Springer Netherlands, 57(2), pp. 233–249. doi: 10.1007/s10640-013-9666-7.

Valatin, G. and Starling, J. (2011) *UK National Ecosystem Assessment: Valuation of ecosystem services provided by UK Woodlands, (Appendix to chapter 22) UNEP-WCMC/Defra*. Report. London. Available at: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx.

WORS (2015) *Wales Outdoor Recreation Survey 2014 Technical Report*. Available at: https://naturalresources.wales/media/4753/wales-outdoor-recreation-survey-2014-technical-report.pdf.

Annex: Methodologies

Our overarching methodology closely follows that detailed in the ONS approach (ONS, 2016a, 2016b, 2017). The net present value (NPV) approach is recommended by the System of Environmental-Economic Accounts (SEEA) and it is used here to value categories of natural capital. To calculate the NPV one needs to estimate the stream of services that are expected to be generated over the life of the asset. Four issues related to the NPV calculation are:

1. Annual values of the service flows provided in constant prices.
2. Pattern of expected future flows of values.
3. Time period over which the flows of values are expected to be generated.
4. Choice of discount rate.

For timber, carbon sequestration, air pollution removal and recreation services different approaches are used to value annual flow of services and are described in relevant sections.

ONS assumes constant service values throughout the asset life, except for the estimates for carbon sequestration, where official projections are used.

The pattern of expected service values is assumed to be constant based on averages over the latest 5 years, up to and including the reference year in question, see equation below:

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

Equation 1: Service value 5-year average

When there are no 5 years of data available to calculate the average we just use the last available value and project it forward (as was the case with timber extraction and recreation).

A 50-year asset life is applied to all assets in this report.

The discount rate set out in the HM Treasury Green Book (HM Treasury, 2003) is applied assuming a 3.5% discount rate for flows projected out to 30 years, declining to 3.0% thereafter.

The NPV is calculated as:

$$NPV = \sum_{t=0}^{50} \frac{Annual\ service\ value\ in\ year\ t}{(1+r)^t}$$

Equation 2: Net Present Value over 50 years

For all price adjustments the GDP deflator for Calendar Year series from the ONS was used: https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-december-2016-quarterly-national-accounts (December 2016 update, accessed 1 March 2017).

Specific methodology issues and sources of data:

Value of standing timber

Sources: Forestry Commission

Forestry Statistics 2016: http://www.forestry.gov.uk/forestry/infd-7aqdgc

Data from the 2012 FC production forecast were used (PF2012_Info.xlsx, obtained directly from Lesley Halsall of the FC's Inventory, Forecasting and Operational Support unit).

Uncertainty: Low.

Value of timber extraction

Sources: Forestry Commission

Forestry Statistics: Wood production: Wales, 1976-2015 (Woodproduction1976-2015final.xls, from https://www.forestry.gov.uk/forestry/infd-8w3lv3).

Timber Price Indices (http://www.forestry.gov.uk/forestry/infd-7m2djr): Table 2: Coniferous Standing Sales Price.

Note that Forestry Statistics provides two prices; one for March and one for September each year. The March price was chosen to follow the ONS methodology more closely.

During 2012 – 2015 differences between the March and September prices were small: less than 4%, except for 2014 when September price was 13% higher than in March.

Using September 2015 price of £18.14 (per cubic metre overbark) instead of the March 2015 price of £18.41 yields £27.8 million of timber extraction value, which is 1.4% lower than the value calculated with March prices.

The standing price potentially may be adjusted by the price *in situ* ratio. This ratio relates to the value of the resource as it is in its natural state, and excludes any additional value that is added through the process of making it more accessible to harvest and extract. The ratio recognises that the unadjusted price includes an element of management overheads insofar as some forests have been actively managed by the owner in the past to make them more accessible for timber harvesting. However, there was no published ONS methodology on how to construct this ratio. Hence the price *in situ* ratio was not applied.

Uncertainty: Low.

Caveats relating to timber removals from Table W1 Wood production: Wales, 1976-2015 (Woodproduction1976-2015final.xls, from https://www.forestry.gov.uk/forestry/infd-8w3lv3).

1. FC = Forestry Commission; Non-FC = All other woodland, including other publicly owned woodland.
2. One green tonne is equivalent to approximately 1.1 m3 overbark softwood or 1.0 m3 overbark hardwood, and to approximately 1.22 m3 overbark standing softwood or 1.11 m3 overbark standing hardwood (see conversion factors at: https://www.forestry.gov.uk/website/forstats2016.nsf/LUContents/00CEB7C418F56FC880257FE0004B2D05). Residues are estimated as the difference between the standing volume and the felled volume.
3. The figures for softwood (conifers) production are based on FC administrative records and on trends reported by the largest harvesting companies.
4. The figures shown for hardwood (broadleaved) production are estimates, based on reported deliveries to wood processing industries and FC administrative records.
5. Country breakdowns for non-FC are estimated from UK/GB totals using available data.
6. All figures have been independently rounded, so may not add to the totals shown.
7. Timber is defined as stemwood with a minimum overbark top diameter of 7 cm. Therefore new planting and restocking are not captured in this account because the trees are too small to contain usable timber.

8. The data for removals and fellings relate to calendar years. For simplicity, it is assumed that felling activity is similar throughout the year and that the figures for financial years are similar to those for calendar years.
9. No data are currently available on catastrophic losses, although such losses are expected to be very small.
10. Following ONS, the timber extraction values are based purely upon volumes felled rather than total standing timber. As the standing sales price applies to the standing volume, the ONS approach could be considered to under-estimate the timber extraction value. A focus instead on the volume of standing timber may be considered a better basis for valuation of timber extraction in future work.

Carbon sequestration

Sources: the department for Business, Energy and Industrial Strategy (BEIS), former DECC.

Carbon sequestration (in Forestry Statistics) is taken from inventory and projections of UK emissions by sources and removal by sinks due to land use, land use change and forestry, produced by CEH for input to 2013 UK Greenhouse Gas emissions final figures (DECC, February 2015, updated in 2017) and the National Atmospheric Emissions Inventory (NAEI, http://naei.defra.gov.uk) which incorporates all air pollutants including greenhouse gases. They exclude the pool of carbon in timber products. As in the National Ecosystem Assessment (Valatin and Starling, 2011), a key assumption is that the carbon is permanently sequestered. This is justified if the total carbon stock in Welsh woodlands is expected to remain at least at the current level in perpetuity once afforestation targets are accounted for (or once carbon substitution benefits associated with using wood harvested from Welsh woodlands instead of fossil fuels or more fossil fuel intensive materials are also accounted for).

As in the ONS approach, the central estimates for the Social values of carbon for the non-traded sector (i.e. sectors not covered by the EU Emissions trading Scheme) are used over a 50-year period. Using the high estimates for the Social values of carbon would increase the estimated value of carbon sequestration by woodlands in Wales by 50%, while using the low estimates for the Social values of carbon would decrease the estimated value by 50%. The range reflects underlying uncertainties. Prices are from Table 3 (part reproduced below) from a set of 20 tables: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal (accessed 7 February 2017). This set of tables supports the September 2015 version of the DECC/HM Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions.

Table 15 Carbon prices and sensitivities 2010-2016 for appraisal, 2015 £/tCO2e

	Non-traded		
Year	**Low**	**Central**	**High**
2010	29	58	87
2011	29	59	88
2012	30	60	90
2013	30	61	91
2014	31	61	92
2015	31	62	94
2016	32	63	95

Uncertainty: Medium.

Recreation

Sources:

Primarily the Wales Outdoor Recreation Survey (WORS), but also Forestry Statistics: Table 6.1 Number of visits to woodland (million, WORS 2014).

Uncertainty: Medium.
Contact Sue Williams: Susan.A.Williams@cyfoethnaturiolcymru.gov.uk

The 'simple travel cost' method recommended in the review of cultural services valuation methodology (Ricardo, 2016) undertaken for ONS in relation to application to the Monitor of Engagement with Natural Environment (MENE) dataset, was adopted and applied to the WORS dataset. The method relies on expenditure data reported and inferred from survey questionnaires. Correspondence between the MENE and WORS questions is detailed in Table 16.

Table 16 Correspondence between MENE and WORS questions, relevant to recreation valuation

Question	Time	Place Type	Distance	Transport	No. Adults	Expenditure
MENE	3	5	8	11	13a	16
WORS	10	7	8	9	11-13	15a-15b

Recreation value is based on expenditure on travel, parking, and admission fees. For non-fare based travel, expenditure is calculated as:

$$Expenditure = \left(\frac{total\ distance\ travelled}{number\ of\ adults}\right) \times cost\ per\ mile$$

Cost per mile estimates were taken from Appendix 2 of Ricardo (2016). In the absence of detailed information about how the stated range of cost per mile estimates for cars were applied to the MENE dataset, the mid-point of this range (26 pence per mile) was applied to the WORS dataset.

All expenditure estimates were based on survey responses from those who stated woodland or forest as the main type of place they had visited on their most recent visit to the outdoors (within the previous 4 weeks). A visit-level weighting was applied to individual respondent expenditures, to provide an estimate representative of the visits taken by the adult population of Wales during the survey period (WORS, 2015).

Caveats

1. A value of 22.07 pence per mile was used in the calculation of travel expenditure for cars and motorcycles as suggested by Ricardo (2016).
2. Responses stating there were more people under 16 years old than all trip participants were excluded from distance-based expenditure estimates.
3. The response from individual case number 5654 was excluded from admission expenditure estimates as an outlier (the stated expenditure of £425 from this single response results in a 36-fold increase in the total expenditure on admissions).

Potential Improvements

The responses to Q7f, "Now please provide the name of the actual place you visited", could be used in conjunction with the NRW sub-compartment database and/or geographic information system to provide a public/private breakdown of recreation value.

Prior to the new recommended methodology (Ricardo, 2016) the ONS used a different methodology for valuing recreation (ONS, 2016a), with the annual value of the recreation service flow from forests estimated as number of visits (taken from recreation surveys) multiplied by an estimated average value per visit per person (Sen *et al.*, 2014). To estimate the asset value over a 50 year period an adjustment based on population projections by ONS was also applied. The value reported in Sen et al., (2014) for visits to woodlands and forests was £3.34 (in 2010 prices), which equates to £3.60 at 2015 prices. Using this value one could estimate the annual value of the recreation service based on visits to forests in Wales in 2014 at £244 million (2015 prices), which is more than double of the value based directly on expenditure data. Adjusting for principal population projections for Wales over a next 50 years (https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea15principalprojectionwalessummary) the asset value estimated as the NPV for this ecosystem service is £5.98 billion (2015 prices), which is similarly more than double of the value based on the expenditure data. From an economic perspective, however, it is not entirely clear why expenditure should be used directly to indicate value, and debate may be expected to continue for some time on the most appropriate approach to estimating an economic value for the recreation services of woodlands.

Uncertainty: Medium.

Air quality

The methods used, followed those described in the Annex to the ONS UK Environmental Accounts 2016 (AECOM, 2016). Estimates of absorption of PM_{10} and SO_2 use a model for quantifying pollution removal rates (Powe and Willis, 2004), with land cover classification data from the Corine 2012 dataset for the UK (Cole *et al.*, 2015). This model estimates the rate of pollution absorption by different habitat types using the following formula:

$$Absorption\ (kg) = Flux\ (kg/m^2 day\ s) \times Surface(m^2) \times Period\ (days)$$

Where:

$$Flux = deposition\ velocity\ (m/s) \times pollutant\ concentration(\mu g/m^3)$$

$$Surface = surface\ area\ index\ (m^2\ per\ m^2\ of\ ground\ area)\ \times\ area\ of\ land\ considered\ (m^2)$$

$$Period = period\ of\ analysis\ (days)\ \times proportion\ of\ dry\ days\ (fraction)\ \times proportion\ of\ on - leaf\ days\ (fraction)$$

Note that *Flux* estimates must be converted from ($\mu g/m^2 s$) to ($kg/m^2 days$) prior to calculation of *Absorption* (initial units represent those of the source data).

Absorption estimates are made for each 1x1 km^2 British National Grid square covering Wales, for both conifers and broadleaves. Each grid square is assigned a rural/urban classification based on population, enabling Wales-wide aggregation of absorption, broken down by conifer/broadleaf and rural/urban. A public/private breakdown is not possible, using the Corine land cover dataset alone (see potential improvements).

Caveats

1. Absorption estimates for all years are based on the same estimates of forest land cover (Corine 2012 dataset) but use year-specific estimates of background pollutant concentrations, proportion of dry days and proportion of on-leaf days.
2. UK-wide annual estimates of the proportion of on-leaf days were used.
3. Wales-wide annual estimates of the proportion of dry days were used.
4. Only forested areas are considered (i.e. unplanted or felled areas of NRW-owned land are not included)
5. The cost of pollution for PM_{10} and SO_2 used in the report corresponds to a central estimate (DEFRA, 2015b). Ranges, which include low and high estimates, indicate the level of uncertainty in the data. For example, for SO_2 the range is: £1,581 (low), £1,956 (central) and £2,224 (high) - see table below for PM_{10}. The ranges are presented in current government guidance on valuing air quality improvements (DEFRA, 2015b).

Table 17 Costs of pollution for PM by location

Location	PM10 damage cost (£ per tonne)		
	Central	Low	High
Urban average	£87,674	£68,645	£99,629
Rural average	£18,020	£14,108	£20,476

Potential improvements

There is potential to provide alternative estimates of the absorption of pollutants by forests, with more up-to-date land cover estimates, by using land cover data from the FC/NRW National Forest Inventory and Sub-compartment datasets. This would also enable estimates with a public/private breakdown to be provided. The Corine 2012 dataset was used in this report for consistency with the ONS UK Environmental Accounts 2016.

The methods described in the Annex to the ONS UK Environmental Accounts 2016, assign a rural/urban classification to each 1x1 km British National Grid square from the population-based classification of *Output Areas*: ONS Rural Urban Classification (2011) of Output Areas in England and Wales. Alternatively, the analysis could be carried out at a more granular level, by applying the rural/urban classification directly to the forest areas rather than the grid square within which they lie.

Consideration could usefully be given to incorporating the historic downward trend in atmospheric particulate and sulphur concentrations, instead of assuming that these remain at the average levels that occurred during the previous 5 years.

Cost estimates are from (AECOM, 2016) and references there (DEFRA, 2011, 2015a, 2015b; DEFRA and HM Treasury, 2013). Access date: 9 March 2017.

Uncertainty: Medium.