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National Forest in Wales Evidence Review Annex-6

ERAMMP Report-38
Annex-6: Economics and Natural Capital Accounting

Saraev, V.[1], Beauchamp, K.[1], Bursnell, M.[1], Fitch, A.[2], Kuyer, J.[3], Thomas, A.[2], Dickie, I.[3], Jones, L.[2], Valatin, G.[1] & Wong, J.[4]

[1] Forest Research, [2] UK Centre for Ecology & Hydrology, [3] Economics for the Environment Consultancy, [4] Wild Resources Ltd/Bangor University

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UKCEH contact details	Bronwen Williams UK Centre for Ecology & Hydrology (UKCEH) Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, LL57 2UW 01248 374500 erammp@ceh.ac.uk
Corresponding author	Vadim Saraev, Forest Research vadim.saraev@forestresearch.gov.uk
Authors	Saraev, V.[1], Beauchamp, K.[1], Bursnell, M.[1], Fitch, A.[2], Kuyer, J.[3], Thomas, A.[2], Dickie, I.[3], Jones, L.[2], Valatin, G.[1] & Wong, J.[4] [1] Forest Research, [2] UKCEH, [3] eftec, [4] Wild Resources Ltd/Bangor University
Contributing authors & reviewers	Clare Hall[1], Tom Jenkins[1], Jerry Langford et al. [2], Eleanor Warren-Thomas[3] [1] Forest Research, [2] Woodland Trust, [3] UKCEH
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Abbreviations Used in this Annex

ABS	Annual Business Survey
APS	Annual Population Survey
BEIS	Department for Business, Energy & Industrial Strategy
CARBINE	Forest carbon dynamics - CARBINE carbon accounting model [modelling tool]
CEH	Centre for Ecology & Hydrology (now UKCEH)
DEFRA	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
eftec	Economics for the Environment Consultancy
EMEP4UK	European Monitoring and Evaluation Program Unified Model for the UK
ENCA	Enabling a Natural Capital Approach
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
ES	Ecosystem Services
ESC	Ecological Site Classification [ESC-DSS modelling tool]
EWP	Engineered wood products
FRC	Flood Risk Catchment
FT/PT	Full Time/Part Time
FTE	Full-time equivalent
GDP	Gross Domestic Product
GVA	Gross Value Added
GWC	Glastir woodland creation
IPD	Investment Property Databank
IUFRO	International Union of Forest Research Organizations
ktoe	kilotonnes of oil equivalent
LISS	Low Impact Silvicultural Systems
MENE	Monitor of Engagement with the Natural Environment
MFTA	Multilateral Free Trade Agreements
NAEI	UK National Atmospheric Emissions Inventory
NCA	Natural Capital Accounting
NPV	Net Present Value
NRW	Natural Resources Wales
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
ORVal	Outdoor Recreation Valuation [modelling tool]
PAYE	Pay as you Earn
PAYES	Payments for ecosystem services
PPG	Payments for public goods
QALYs	Quality-Adjusted Life Years
SEEA	System of Environmental Accounting
SIC	Standard Industrial Classifications
SNA	System of National Accounts
SRF	Short Rotation Forestry
SSSI	Site of Special Scientific Interest
UKCEH	UK Centre for Ecology & Hydrology
WGWE	Welsh Government Woodland Estate
WORS	Wales Outdoor Recreation Survey
WTA	Willingness to Accept
WTP	Willingness to Pay

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

Contents

1. INTRODUCTION TO ANNEX-6

This Annex reviews the evidence base for the contribution of the forestry sector to the Welsh economy, including human capital; both in Section 2. We also review forest products and markets and how these are influenced by forest management (Section 3).

We describe how woodland expansion and bringing woodlands into active management can benefit the forestry sector and support the local and national economy in Wales. Reciprocally, a strong vibrant forestry industry has the potential to support woodland creation and sustainable forest management in the context of clear environmental and forest policies. We refer to where incentives may be required to deliver these benefits.

In Section 4 we explore the evidence for valuing the ecosystem services provided by forests and woodlands using a National Capital Accounting approach, we review the Office for National Statistics (ONS) methodologies and values. We recognise that all green space has value and note that this Annex focuses on forests and woodlands.

2. The Forest Industry in Wales, Economics and Human Capital

2.1 The Economic Contribution of the Welsh Forestry Sector

Sector economic performance is generally measured in terms of gross value added (GVA) – which is the measure of the value of goods and services produced by a sector and encompasses both profits and wages. The most recent data show that in 2017 the forestry sector contributed a total GVA of £665 million to the Welsh economy (Welsh Government 2019). This figure is compiled from the ONS Annual Business Survey (ABS) using UK Standard Industrial Classifications (SIC) with a breakdown of: £50 million from 'Forestry and logging' (SIC 02), £250 million from the 'Manufacture of wood and products of wood and cork' (SIC 16), and £335 million from the 'Manufacture of paper and paper products' (SIC 17). The GVA associated with wood, cork and paper products may include imported wood, which exceeds domestic supply by 5:1 in the UK (Welsh supply chains are integrated with the UK) (Welsh Government 2018).

The annual Business Survey is widely used to calculate GVA and is considered an accurate source of information, however it is likely to underestimate GVA for the forestry sector as it excludes small companies and sole traders that do not pay VAT (Forestry Statistics 2019), of which there are an estimated 2000 in the Welsh forestry sector (Welsh Government 2019). GVA may be further underestimated as businesses supported by forestry may be classified under another SIC code e.g. engineering (CJC Consulting 2015).

The economic contribution of forestry to the Welsh economy, calculated as described, has increased since 2006 as illustrated in Figure 2-1; partly due to the increasing price of timber (Timber Price Index, Forestry Commission 2019) and an increase in the volume of timber processed (Forestry Commission 2019). Competing land uses can also be taken into account; for example, in Wales, agriculture uses 9 times more land than woodland and generates a GVA of £355 million (Welsh Government 2018), although as the forestry sector estimate of GVA includes some processing and downstream revenue these figures are not directly comparable.

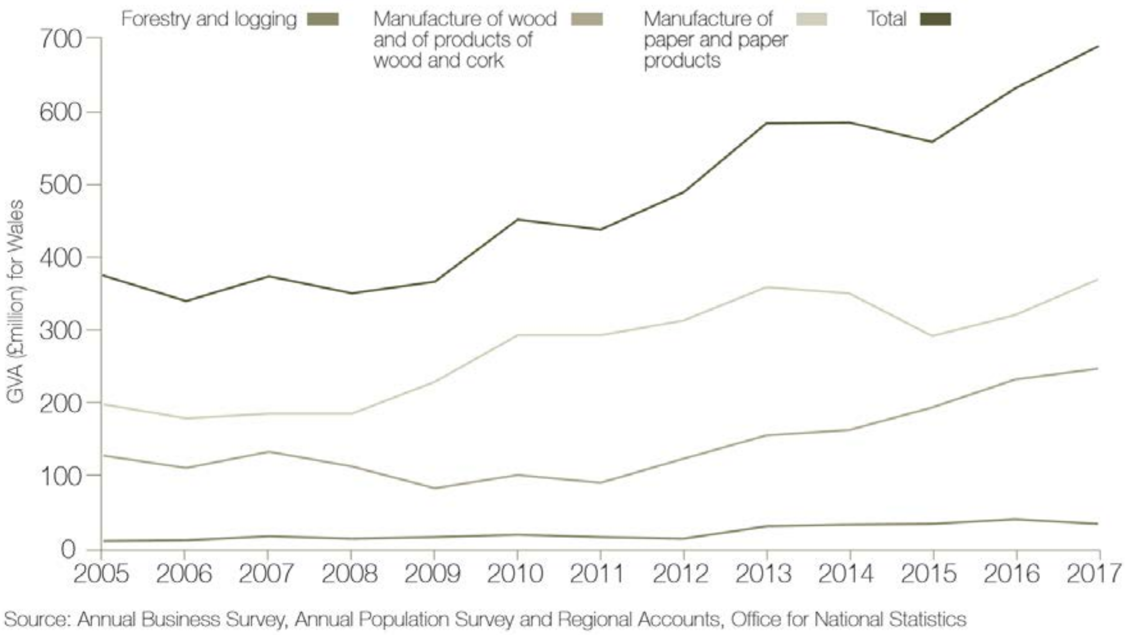
These values do not include the full extent of secondary processing of timber, or income from recreational use of forests and woodland. Analysis by Jaakko Pöyry Consulting (2004) estimated a GVA of £236 million for secondary processing of forestry products in Wales, employing 6000 full-time equivalent (FTE) employees in 1500 businesses. Based on the increasing value of the sector and investment in mills and secondary processing facilities (FIM 2017) GVA is also likely to have increased since 2004 (low confidence).

Analysis of the forestry sector in Scotland valued GVA from forest recreation and tourism at £183 million (CJC Consulting 2015). This includes visitor spending associated with visits to public-, private- and community-owned forests, for a wide range of activities such as walking, mountain biking, and cultural and wildlife tourism. The main expenditure by visitors was on food, drink, travel and accommodation, as well as entry charges, car parking and use of facilities.

As well as supporting recreational visits (the majority of which are undertaken locally and free of charge), woodlands' also play a role in supporting tourism and leisure activity. Eftec et al. (2019) identified £2.75bn of tourism and outdoor leisure spending, and £1.28bn of GVA, in Wales that is attributable to ecosystems. Across Great Britain, the data suggest that spending and GVA attributable to woodland is around 4% of the total (2/3rds is attributed to coastal margins). This would suggest that woodlands may support £110m of tourism and outdoor leisure spending and £51m of GVA, in Wales. However, these attempts to subdivide results between woodlands and other ecosystems are uncertain and constrained by data limitations. This spending will have further beneficial economic impacts through supply chain effects, including spending by employees in the sector, and turnover in the supply-chain to the sector.

Scotland has 46% of UK woodland by area and Wales 10% (Forestry Commission 2019) and, whilst a wide range of variables and investment will affect its value, recreation is an important potential revenue stream from existing and new properly managed woodland in Wales. Evidence on forestry sector GVA is moderate.

Figure 2-1 Change in time of the Gross Value Added of the Forestry Sector in Wales. Reproduced from Woodland for Wales Indicators (Welsh Government 2019).



2.2 Human Capital and Employment in the Welsh Forestry Sector

Human capital is defined by the ONS as a measure of the "knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD 2001, ONS 2019a). The concept of human capital cannot simply be proxied by the number of people employed in a specific sector unless human capital per employee is constant over time and human capital of those not in employment such as the self-employed and those not currently working due to being in full time education is excluded.

Education and earnings are component indicators of human capital, with an evidence review commissioned by the ONS (Samek et al. 2019) identifying a number of factors which impact on these, such as family background, cognitive and non-cognitive skills and health - many of which are themselves affected by education and earnings. As a range of interrelated factors affect human capital, it is quite difficult to measure both precisely and holistically (Fender 2013). The ONS is currently in the process of reviewing how to measure human capital in the UK. The UK's human capital stock has been valued at £21.4 trillion in 2018. This is equivalent to around 10 times the size of UK gross domestic product (GDP) (ONS 2019a); only a UK wide estimate is currently available.

The Woodland for Wales Indicators 2017-18 (Welsh Government 2019) summarise the information on the number of employees and businesses in the forestry sector in Wales from two sources; according to figures from the ONS Business Register and Employment Survey there are between 10,300 and 11,000 employees. This is <1% of the workforce of Wales, but is significant for employment in rural areas (ONS APS, Welsh Government 2020). This is broken down as 500/400 Full Time/Part Time (FT/PT) employees in forestry and logging, 5,500/100 (FT/PT) in the manufacture of wood and products of wood and 3,500/300 (FT/PT) in paper and paper products. As with data for GVA, these figures exclude small businesses and small traders below the VAT and PAYE thresholds and are subject to the same limitations as SIC categories. Woodland for Wales Indicators 2017-18 also present data from The Annual Population Survey (2017) which indicates approximately 11,000 workers in the forestry sector in Wales, comprising 9,000 employees and (a minimum of) 2,000 self-employed workers (data on self-employment is considered low quality, being based upon a survey with a low response rate). Both sets of employment figures also exclude those down the supply chain which depends on wood and non-wood products, nor does it include indirect employment in tourism and recreation,

There is a knowledgeable and passionate work force in the Welsh forestry sector. There is also scope for increasing employment and skills in the sector through training and knowledge exchange events such as those provided by organisations such as Farming and Forestry Connect, Focus on Forestry First, Forest Research and the Institute of Chartered Foresters. There are also opportunities for increasing recreation and tourism opportunities and subsequent revenue and employment. While evidence on employment is 'well accepted', evidence on human capital values associated with the Welsh forestry sector is sparse ('limited evidence').

2.3 Forest Industry in Wales

According to the ONS Inter-Departmental Business Register there are 805 business units in the three SIC categories which refer mainly to forestry as described previously (Welsh Government 2019). The same caveats described in Section 2.1 apply, this classification underestimates the number of enterprises within the forestry sector, as many other businesses depend on forest products. However, there are no inclusive studies of the wider forestry sector in Wales.

Forest Research carries-out an annual sawmill survey, which showed that in 2017 there were 14 sawmills in Wales that consumed in total 691,000 green tonnes of softwood and produced 319,000m^3 of sawn softwood. The latter represent 9% of UK mills, 10% of UK consumption and 9% of production (Forestry Commission 2019). A GVA of £665 million is 9% of the UK-wide GVA (£7,334 million) for the forestry sector (Forestry Statistics 2019) and is consistent with 10% of the UK's forest resource, by area, being in Wales.

The Woodland for Wales Indicators 2014-15 (Welsh Government 2015) reported that in 2010 70% of enterprises were confident in the future of their business and less than 10% were not confident. More than 50% of businesses also expected an increase in turnover in the three years following. These data are not updated in the 2017-18 report and are therefore provided with low confidence. A map of current mills and forest industries can be found in FIM Services Limited (2017), along with details of recent investments.

3. Forest Management, Markets, Profitability & Potential Impacts on Land Use

3.1 Forestry Sector Timber Markets and profitability

Coniferous standing sales and sawlog price indices for Great Britain are published in Forestry Statistics (Forestry Commission 2019, Table 8.1). This shows, for instance, that standing sales prices almost doubled in real terms over the period 2012-2019.

The data on timber volumes and prices for hardwoods are not available on a national scale in the literature, due in part to much smaller volumes traded. Volumes and prices could be estimated by requesting from sector agents if required. During the period 2009-2018 hardwood production in Wales was on average less than 2% of total wood production (Forestry Commission 2019, Wood Production section).

Currently, published information on forestry sector profitability is available only for productive conifer plantations. Information on financial returns to investors for a sample of around 150 private sector coniferous plantations of predominantly Sitka spruce in mainland Britain are published as a UK Forestry Index by the Investment Property Databank (IPD). The returns are based upon sales of timber (standing or felled) and of other goods and services, increases in the value of the woodland (from annual increment or market factors), and net income from subsidies (e.g. planting grants) less taxes, with investors' costs covering employment costs and other purchases. The IPD's UK Forestry Index indicates, for example, that that over the decade 2008-2017, forestry returns to investors in commercial conifer plantations ranged between 7% and 33%, with the annual average percentage over 3 years always above 11% (Forestry Commission 2018).

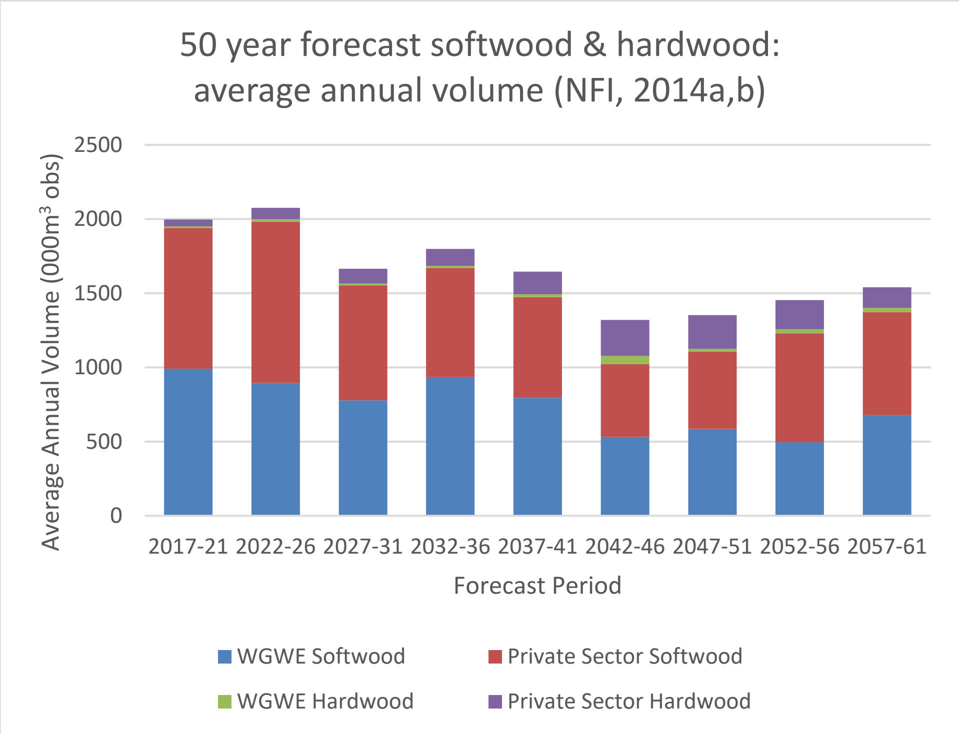
It is unclear to what extent the UK Forestry Index could be viewed as a reliable indicator of returns across the entire forest sector. Average returns for broadleaved woodlands and for small forests in particular may well be far lower. While evidence on coniferous timber markets is 'well accepted', there is 'limited evidence' on profitability (apart from the IPD index) and on prices for broadleaves.

3.2 Welsh Roundwood Availability & Timber Use

The 50-year softwood production forecast for Wales (Forestry Commission 2014a) predicts a reduction in softwood timber availability in the 2040's (Figure 3-1) (a trend that is seen across GB) due to the age-class structure of the existing forest resource and a reduction in new conifer planting and delayed restocking (*e.g.* following the clearance of large areas of woodland, particularly in south- and mid-Wales, to control the spread of *Phytophthora* Ramorum larch disease). This predicted downturn in softwood availability poses a risk to wood supply, and confidence and investment in the sector (Confor 2014, NRW 2016). The planting of new productive woodland, bringing more woodland into active management, and deferred harvesting can help to fill this gap by stabilising softwood production. Plans in the Woodlands for Wales Strategy (Welsh Government 2018) support the forest sector in this area, however Confor (2014) highlight that there are only approximately 200,000 hectares of land available for productive forestry in Wales that will not be contested by other interest groups.

Public sector softwood production in Wales remains similar to that by the private sector for the duration of the production forecast, whereas nationally production by the private sector continues to dominate (Forestry Commission 2014a).

Figure 3-1 50-year forecast of Welsh softwood and hardwood availability.



Welsh-grown softwood is currently used for construction timber, fencing, pallet-making, pulp for paper and as biomass fuel (Coombs 2018). In 2017, 57% of Welsh-grown roundwood was processed in Wales (Forestry Statistics 2019, Welsh Government 2019) with the remainder processed in England. In addition, a large volume of wood is imported annually for processing in Wales. Accurate figures on volume are not available, but Jaakko Pöyry Consulting (2004) estimated that "around 90% of the hardwood and 65% of the softwood raw material flowing into the Welsh industry is imported". The Woodlands for Wales Strategy (Welsh Government 2018) supports the increase of Welsh-grown wood processed in Wales and the development of local supply chains to increase the value of the forestry sector in Wales.

3.3 Adding Value to Welsh Forests & Forestry Supply Chain - Management, Markets and Land use

In addition to supporting the Welsh forestry sector by increasing timber supply, there are opportunities to further increase the value of the sector by using Welsh grown timber in higher value markets, such as construction, engineered wood products (EWP) and veneers. Welsh grown timber is increasingly used in the building of Welsh homes, for example the Home-Grown Homes project with Powys County Council's Housing and

Regeneration Services is using more timber to build social housing in Wales, and Woodknowledge Wales are a Welsh-based organisation working to support the forest wood chain. Bryans (2011) concludes that there are opportunities to add value at each stage of the supply chain, and that, due to the smaller scale of the Welsh forest industry, its competitiveness and value could be increased through greater levels of innovation and integration across the supply chain.

The increase in economic value of supply chains and wood products has the potential to drive the sustainable management of existing and new Welsh forest and woodland. In this Section we explore the role of woodland expansions and management in supporting the Welsh forestry economy. Table 3-2 (on p.17) summarises the information provided here regarding forest type and management, timber and non-timber products and environmental impacts.

3.3.1 Industrial Roundwood

The current supply of Welsh-grown softwood can be structurally graded at C16+ (Coombs 2018) and therefore can be used in some higher value construction markets, but the author highlights that this use must be within the standard sawn sizes and C16 grade (many building specifications require a higher grading to C24, however C16 would be sufficient in some cases). Due to the larger scale and competitiveness of European markets the majority of Welsh-grown timber is not currently strength-graded and 88% of softwood used by the secondary processing sector in Wales is imported (Bryans 2011).

An additional opportunity for Welsh wood and fibre is the expanding engineered wood product market for which both Welsh softwoods and hardwoods are well-suited. Manufacturing methods for engineered products don't require long straight clear sections of timber (Bryans 2011) from traditionally managed conifer plantations under clearfell and restocking regimes but can also use woody material resulting from the use of closer to nature forestry and Low Impact Silvicultural Systems (LISS). Developing a supply chain in Wales could support a more sustainable, resilient and diverse Welsh forest by providing a valuable market for productive broadleaves and less intensively managed conifer stands, however this will need to be traded-off against the slower growth rates and different timber values of these trees. The challenge of market demand driving production for the forestry sector is complex due to the long time periods involved, which creates additional uncertainty and undermines change for forest managers. Further social research into the barriers against management and species diversification, and potential solutions, is required.

3.3.2 Industrial Wood Fuel

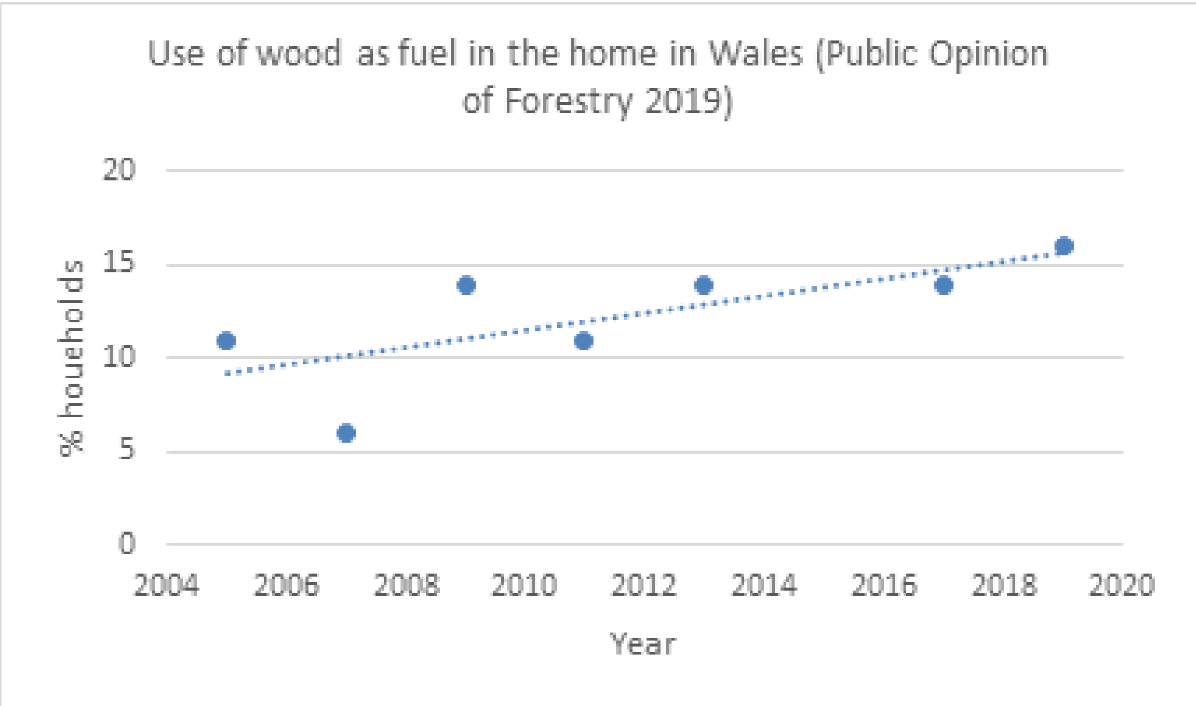
Consumption of industrial woodfuel is around 1.6 million tonnes, making this the second largest market for coniferous timber. Wood is used to produce three different types of energy; electricity, process heat and wood pellets/briquettes. Fuelwood can be made from lower quality parts of the tree, and the sector uses significant volumes of recycled wood and sawmill coproducts. The market has grown 16-fold in under a decade, which has in some cases disrupted traditional timber processing industries by consuming high-quality virgin timber. This also has negative impacts on carbon accounting (see Annex-3/ERAMMP Report-35: *Future-proofing our Woodland*). A high proportion of industrial wood fuel consumed in the UK is imported (Forestry Commission 2019).

3.3.3 Domestic Firewood

At UK level, domestic firewood is considered a renewable fuel and is reported in the Digest of United Kingdom Energy Statistics. In 2014 the Department of Energy and Climate Change commissioned an omnibus survey to update estimates of the contribution of domestic burning of wood to UK energy consumption. UK domestic wood use was estimated at 72 kilotonnes of oil equivalent (ktoe) which represented 57% of total renewable heat and 11.5% of all renewable energy fuel use in 2014 (Department of Energy & Climate Change 2015; calculations based on 2014 omnibus survey by Beaufort Research in support of uncompleted MSc project at Bangor University).

It is very difficult to quantify wood flows into and within the domestic woodfuel market. This is because it is largely informal, unregulated and unmonitored. Attempts have been made to estimate the scale of the sector using questionnaire-based surveys of households which burn wood. The longest standing of these is the biennial Public Opinion Survey of Forestry administered by Forest Research as an omnibus survey of around 1000 households in Wales. The results of the 2019 survey indicate that woodfuel is burnt in 16% of households with a suggestion that this has been increasing over the past fourteen years (see Figure 3-2).

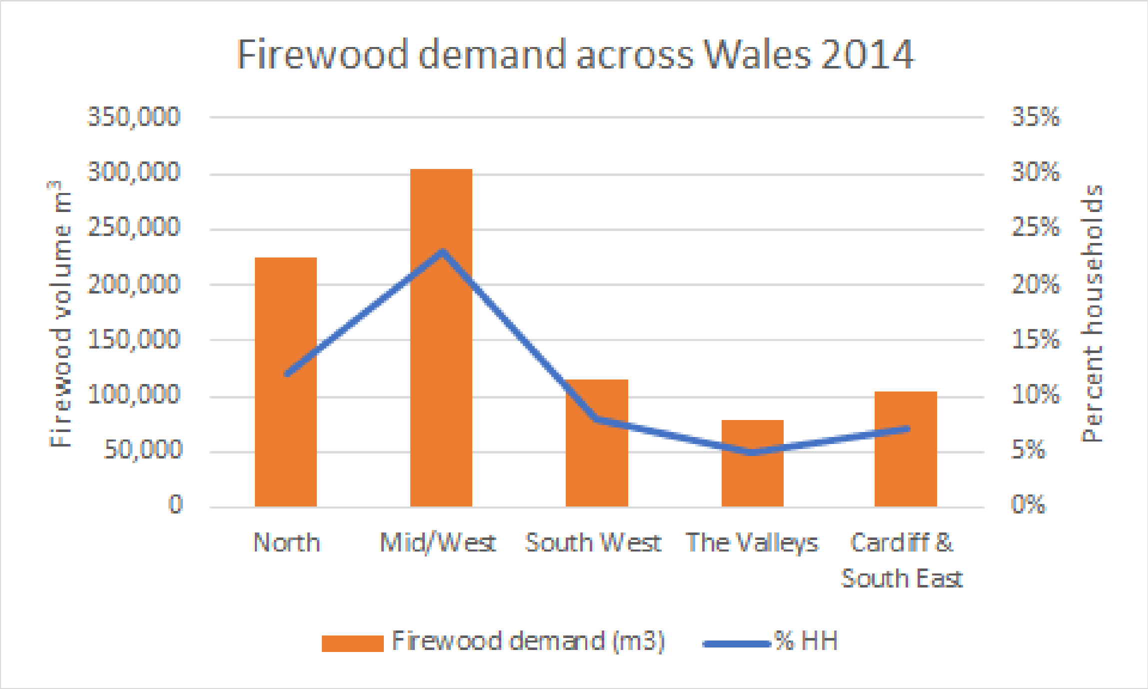
Figure 3-2 Percentage of households in Wales using wood as a fuel



Several approaches to estimating what this means in terms of wood volumes have been tested with estimators based on the length of time a wood-burning appliance is in use over a year being considered the most reliable (Department of Energy & Climate Change 2015, Waters 2016). Estimates of annual firewood volumes entering the domestic firewood market range from 650,000 m^3 (Wong & Walmsley 2013) to 827,000 m^3. Comparison of these figures with Table 4-1 suggests there is possibly a large oversight in both estimates of current wood production and of future demand for wood.

Demand for woodfuel for domestic use is correlated with availability of mains gas and is most prevalent in rural areas (see Figure 3-3).

Figure 3-3 Firewood demand by region in Wales



The surveys to date have focussed on the sources of firewood rather than species but there is a strong preference for ash, oak and other hardwoods with only 3% of users stating a preference for softwood though 53% would take it as a second choice if no hardwood is available. More than 90% of firewood takes the form of logs with pellets representing 2% and briquettes 5.6% of total volumes (Waters 2016). Across the UK 21% of logs are sourced from informal (grey) markets or self-sourced from the users' own trees (Waters 2016). In Wales the indication is that informal and social supply chains are even more prominent with 46% of respondents indicating they purchased firewood with the rest coming from work, in kind transactions and from family, neighbours and friends (Wong & Walmsley 2013). Where wood is self-sourced it appears that only a small proportion comes from conventional 'woodland' with most arising from farms, hedgerows, gardens, and from fallen trees (Wong & Walmsley 2013). In addition, much firewood is arboricultural arisings which explains the continuing availability of hardwood firewood. There is a strong preference for 'local' firewood which in this case is considered by users to be within ten miles of their location (Kinash et al. 2013, Wong & Walmsley 2013).

Creation of a source of firewood is a driver for small woodland planting but there is little guidance available on silviculture for firewood. Wolton (2012) illustrated two different hedgerow systems for producing woodfuel – a lay + log and coppice + chip and concluded that although coppice + chip might yield higher returns that both systems could deliver a sustainable source of woodfuel which would contribute to the retention and management of hedgerows. More work is needed to examine incentives for small scale plantings and management across the landscape for woodfuel. Given recent concerns with emissions of $PM_{2.5}$ by wood burning this needs to be co-ordinated with policy on clean air and development of local landscape planning. It is also activity which will be almost entirely within the private sector, small scale and likely to strongly favour broadleaves. Value added in this area should not be considered in wholly financial terms but in relation to providing a wide range of ecosystem and social benefits.

Bringing undermanaged woodland into active management would provide significant opportunities to create local supply chains, bring revenue to Wales and supporting an increase in biodiversity (Woodland Trust 2017); see Annex-2/ERAMMP Report-34: *Managing Undermanaged Woodland*. Likewise, the establishment of new broadleaved woodlands would further support local domestic wood fuel markets.

3.3.4 Small scale wood-based enterprises

Hand-crafted bespoke wood products create some of the greatest added value in the wood chain and can provide high quality employment, maintain rural populations and generate the local, circular economies promoted by sustainable development policies. In particular carpentry, furniture, and traditional and artisanal wood products, such as those crafted by wood turning, green wood working, basket making, and coppice products.

Most timber from the public estate and commercial private estate is sold in large lots for industrial processing targeted towards standard markets for a narrow range of fast-growing species, especially Sitka spruce. This disadvantages small scale operators, as well as growers, and cuts off supply of timber to local small-scale and artisanal processors. Consideration should be given to increasing access to small lots for standing sales to support local businesses. These businesses can make use of a wide variety of species and support the increase of species diversity at re-stocking. High quality timber from diverse species is needed to underpin resilient landscapes and a vibrant and diverse timber sector.

Developing supply chains for wood products derived from broadleaves species and novel conifer species, such as veneers, furniture, and traditional and artisanal products would also add value to the Welsh forestry sector by supporting smaller growers, processers and manufacturers. The Coed Ceiriog Co-operative, producing ‘forestry to furniture’ woodworking products and sculptures in the Ceiriog valley is an example of this, however more needs to be done to support the sector across Wales.

3.3.5 Non-Timber Forest Products

Non-timber products such as fruits, nuts mushrooms and their derived products, such as alcoholic beverages, can provide additional income and supplement the diet of landowners, recreation users, animals and birds. Fruit trees include those from canopy species such as cherries, plums, and other stone fruits, apples, pears; woody understorey and edge species including elder, juniper and sloe and understorey vegetation such as raspberries, blackberries, bilberries or wild strawberries. Nut tree species include canopy species such as walnut, and woody understory such as hazel. Cherry and walnut are also valuable timber species and can produce high value timber and veneers. Fruit and nut species can provide valuable agroforestry habitats for farm birds such as chickens using the habitat, and 'food forests' are planted which comprise of purely 'edible' species. The incorporation of these in the landscape can add economic, health and biodiversity value.

3.3.6 Tourism and Recreation

Nature based tourism can result in a range of ecosystem service benefits, including cultural and economic. Stein (quoted in IUFRO 2017) states that "Forest managers and policy makers must recognize that quality nature-based tourism planning and management can result in a multitude of benefits. If managers are not even aware of the benefits of recreation and tourism and only see recreation and tourism as a cost – as many managers currently do – then we should not be surprised that managing for tourism and recreation is consistently considered a "new" idea and/or a distraction from "more important" forest management goals such as timber or restoration

Nature-based recreation facilities such as mountain bike centres, high ropes courses and outdoor play parks, arboreta, amongst many others, attract a wide range of visitors each year, with income generated from car parking, onsite cafes, restaurants and retail opportunities, and entry cost to some organised activities. This is illustrated with reference to Coed y Brenin where a 2014 study found that 57% of surveyed visitors used the café, restaurant or other catering, and 25% used the visitor centre or shop (25%) (Beaufort Research Ltd 2014). There is limited evidence about the distance visitors are willing to travel for specialized faculties, with proximity to the forest and access via car parking and footpaths still being a main influence on visitor numbers. However, some recreational activities and organised events can draw a wider range of visitors. Highly valued (in terms of visitor aesthetics and sensory interaction) landscapes and natural environments also attract a wide range of visitors, such as national parks, seasonal colour displays, and many other designated sites.

As well as opportunities for on-site revenue from recreation facilities, highly valued landscapes and designated sites, including those within or incorporating forests and woodlands, there are economic opportunities for surrounding tourism and hospitality facilities such as hotels, camp sites, catering facilities and retail opportunities. It is important to plan facilities carefully and in some cases to engage the local community in conceptualising, planning and development, in order to prevent disbenefits from increased traffic and visitor numbers which can damage local appreciation of nature. There are many examples of successful recreation sites in Wales and beyond.

The *Outdoor Recreation Valuation Tool* (ORVal)[i] models patterns and value of recreational visits across England and Wales. It estimates that 158 million visits per year are made to the natural environment in Wales, and values the welfare from these (based on the Travel Cost Method) at £570m. ORVal estimates that over half of these visits 98 million (value: £321 million) are to sites or paths containing woodland habitat.

While woodlands are a major recreational resource with considerable value, the key question for the business case for the national forest is the additional value that new woodland would provide. To illustrate this, data were taken from the ORVal tool (University of Exeter), for theoretical new sites. The new sites were located near Swansea, one was on the edge of the City, the other 10 miles to the North. At each location two sites sizes were examined (10 ha and 100ha), and two potential habitat types (a woodland of 50% broadleaved and 50% conifer) and a mixed habitat (of (1/6th each of broadleaved/conifer, 1/3rd natural grassland and a1/3rd moor/heath). The data from these sites is shown in the Table 3-1 below. The number of 'new' visits is used, which is ORVal's estimate of the additional visits undertaken as if the site was created. It does not include visits to these sites which displace from other existing sites. The data should only be taken as a rough guide, as other local and cultural factors can determine recreational value. However, the data illustrate:

- Significantly higher values per ha for sites nearer the urban area.
- More values to larger sites, but diminishing marginal returns to scale, with larger sites have lower values per ha.
- More visitors, and slightly higher value per visit, to the site with mixed habitats. However, this result should be treated with caution as this location has significant existing accessible woodland areas. This can result in the additional value of new woodland being lower.

Table 3-1 ORVal estimates of recreation value for two modelled new woodland sites.

	Mixed habitats			Woodland		
Annual £ (2020)	**Total value of new visits**	**Value per visit**	**New visit value/ ha**	**Total value of new visits**	**Value per visit**	**New visit value/ ha**
Urban edge - 100 ha	249,198	3.50	2,492	158,816	2.93	1,588
Urban edge - 10 ha	126,839	3.77	12,684	46,421	2.68	4,642
10 miles - 100 ha	106,956	4.22	1,070	22,282	3.00	223
10 miles - 10 ha	59,815	4.42	5,982	9,349	3.42	935

[i] Outdoor Recreation Valuation, Land, Environment, Economics and Policy (LEEP) Institute Business School, University of Exeter, <https://www.leep.exeter.ac.uk/orval/>.

Physical health benefits arise to individuals who make 'active visits' to the natural environment. Active visits are defined through physical activity guidelines.[ii] Regular physical activity is associated in reductions of in some of the most frequent health risks in the UK population, such as heart disease, stroke, diabetes and several cancers (Public Health England 2016a). In England it is estimated that around a half of all visits to the natural environment meet the definition of physical activity (White et al. 2016), and this is also likely to be the case in Wales. Based on the estimate of recreation visits to woodland from ORVal (98m), this evidence suggests that accessible woodlands in Wales could support around 50m physically active visits.

Applying further assumptions from White et al. (2016, which references Beale et al. (2007)), it is estimated that 30 min a week of moderate-intense physical activity is associated with an increase of 0.010677 Quality-Adjusted Life Years (QALYs) per individual. Therefore, physically active recreational visits to woodlands in Wales could support over 500,000 QALYs per year, making them a major health resource for Wales. DEFRA's[iii] Enabling a Natural Capital Approach (ENCA) guide suggests that the NHS regards spending of £15,000 per QALY as cost-effective, suggesting that the costs of achieving the QALY's supported by woodlands could be £7.5bn per year.

3.3.7 Strategic development for future generations

Welsh wood and wood products are in high demand, with demand likely to increase in future due to the growing use of timber in construction, demand for domestic wood fuel, and increased interest in locally and nationally sourced material. There is both demand and need for a sustainable increase in the timber resource, coniferous and broadleaved, through woodland creation and expansion in Wales. Strategic development and investment in the forestry sector can support active and sustainable forest management and the delivery of a wide range of ecosystem services for current and future generations.

3.4 Disbenefits and Considerations for Woodland Expansion

In order to deliver the full range of economic benefits and minimise disbenefits there are a range of factors that need to be considered. Here we explore economic and industry considerations, with environmental and social factors included in Annex-1/ERAMMP Report-33: *Biodiversity* and Annex-5/ERAMMP Report-37: *Ecosystem Services*.

The location of the woodland is important in relation to both potential processing facilities and markets, in order to minimise timber transport distance and the associated emissions and transport cost. Forest machinery and timber haulage vehicles can be disruptive to communities local to the woodland and those along the transport route, therefore the access point and transport route need to be considered alongside the frequency of management intervention and access. Where the potential revenue is intended to be from tourism and recreation, location and accessibility are important considerations.

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ii *As outlined by the Chief Medical Office (CMO, 2011), at least 150 minutes per week of moderate intensity activity in bouts of 10 minutes or more. For example, one way to do is to exercise 30 minutes at least 5 days a week. Chief Medical Office (CMO) (2011). Physical activity guidelines for adults.*

iii Department for Environment, Food and Rural Affairs

Potential alternative land use can be important, as creating new woodland will be at the loss of land available for other uses such as agriculture, infrastructure and building land.

The size of the forest is important, as smaller woodlands can be less economically viable. There is no defined minimum size, and it will depend on management type, species and growth rate, as well as the quality of the timber and current timber prices, however at least 2 hectares and ideally 10ha is recommended. The volume and value of material harvested during thinning needs to be enough to warrant extraction and to generate income. Where thinning is not profitable the value of the final harvest needs to be sufficient to pay for management, harvesting, and restocking.

The species composition of the forest, its suitability to site conditions, and its resilience to external threats is also significant. Resilience is considered in Annex-5/ERAMMP Report-37: *Ecosystem Services*. Different species are suited to different potential markets, and therefore can have different market value. Sitka spruce is the most widely planted conifer species in the UK and in Wales (Forestry Statistics 2019) and the most in demand for construction and pulp for paper. Whilst there is no pulp mill in Wales the data show this is still a key market for Welsh grown wood. Scots pine is the second most widely planted conifer and is also much in demand. Minor conifer species currently have less developed markets and are less profitable to growers. Support for these markets would

Species diversification is seen as a potential strategy for increasing resilience to pests and pathogens, however this shift comes with higher planting, establishment and management costs, and a potential reduction in yield (Beauchamp et al. 2016) and market value. Overcoming these challenges and supporting diversification would increase the resilience of the forestry Diversification of the forest resource may benefit from strategic planning and the planting of sufficient volume of a select range of species (Mason 2018) over a sustained time period, in order to provide a steady volume of quality material, underpin new markets and justify investment. There are calls from the forestry sector for the public sector to lead this process and to shoulder some of the perceived risk of diversification.

Table 3-2 Woodland types, management options, timber quality: timber products, non-timber products: impacts on land use

Woodland type	Management	Timber Quality	Timber Products/Markets	Non-Timber Products	Economic Value	Impacts on land use
Productive conifer (primary species)	thin/fell	high	sawn timber, construction	recreation	+++	-
		medium	fencing, pallets, EWP	recreation	++	-
		low	pulp, biomass	recreation	+	-
	no-thin/fell	medium	fencing, pallets EWP		++	-
		low	pulp, biomass		+	-
	LISS	mixed	fencing, pallets, EWP, pulp, biomass	recreation	++	+
Productive conifer (minor species)	thin/fell	medium	fencing, pallets, EWP	recreation	++	+/-
		low	biomass/wood fuel	recreation	+	+/-
	no-thin/fell	medium	fencing, pallets, EWP		++	-
		low	Biomass, wood fuel		+	-
	LISS	mixed	EWP, biomass	recreation	++	+
Productive broadleaf or mixed	thin/fell	high	veneers, sawn timber, construction, furniture, EWP	recreation, fruits & nuts*	+++	+
		medium	EWP, furniture	Recreation, fruits & nuts*	++	+
		low	Biomass, wood fuel	recreation, fruits & nuts*	+	+
	LISS	mixed	EWP, biomass, woodfuel, furniture	recreation, fruits & nuts*, protection, shelter	++	+++
	Short Rotation Forestry (SRF)	low	biomass/wood fuel		+	+
	Agroforestry	mixed	EWP, biomass, woodfuel, furniture	recreation, fruits & nuts*, protection, shelter	++	++
Amenity broadleaf (native)	thin/ retention	mixed	EWP, biomass, woodfuel, furniture	recreation, fruits & nuts*	++	+++
	LISS	mixed	EWP, biomass, woodfuel, furniture	recreation, fruits & nuts*	++	+++
	SRF	low	biomass/wood fuel		+	+

Note: the information in this table has been developed with expert knowledge, rather than from published values; it is therefore provided with 'low confidence.

* *Fruits include those from canopy species such as cherries and other stone fruit, apples, pears; and understorey vegetation such as raspberries, blackberries, bilberries or wild strawberries. Nuts include canopy species such as walnut and woody understory such as hazel.*

4. ONS Methodologies for National Capital Accounting.

4.1 Introduction

The UK is one of the world leaders in development and application of Natural Capital Accounting (NCA) principles. The research and applied work in the UK is led by the Office for National Statistics (ONS) and DEFRA. The environmental 'satellite' accounts developed by ONS 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.

The Net Present Value (NPV) approach is recommended for valuing natural capital within SEEA. This approach involves valuing the natural capital stock based on annual ecosystem services (ES) flows.

The value of the annual ES flow is estimated by multiplying a physical measure of the benefit flow by a monetary unit value. The most appropriate monetary value to use varies between ES. (E.g. where a competitive market characterised by absence of significant externalities exists the actual market price net of input costs may be used. In other cases, a non-market value may be needed). Use of a monetary value provides a common metric to facilitate comparisons between the different natural capital values and their aggregation.

To calculate the NPV one needs to estimate the stream of services that are expected to be generated over the life of the asset (forest, woodlands and trees in our case). Five issues related to the NPV calculation are:

1. Annual values of the service flows provided in constant prices.
2. Profile of expected future flows of values.
3. Time period over which the flows of values are expected to be generated.
4. Time horizon over which flows assessed (often, but not always, same as 3)
5. Choice of discount rate.

NCA methodologies adopted by ONS assume that ES flows and prices (and thus, the annual values) remain constant throughout the life of the asset, except where official projections are available, e.g. for carbon sequestration. Expected ES values are assumed to be the mean over the latest 5 years, up to and including the reference year in question.

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

In cases where 5 years of data are not available, the most recent available value is currently used in forward projections.

A 100-year asset life is applied to all renewable natural capital assets.

The discount rate set out in the HM Treasury Green Book (HM Treasury 2018) is applied assuming a 3.5% discount rate for flows projected out to 30 years, declining to 3.0% between 30 and 75 years and 2.5% after 75 years.

For all price adjustments the UK Government GDP deflator for Calendar Year series is used.[4]

ONS methodologies for NCA (ONS 2017, 2019c) provide a balance between complexity and practicality. Methods used to value ES (timber, carbon, air quality, recreation) for which ONS methodologies currently exist are the primary focus of this section, together with approaches to valuing an ES (flood risk attenuation) for which an ONS methodology is known to be currently under development.

For each of these ES the different approaches are used to value annual flow of services are described in relevant Sections below. Sections focusing on valuing timber, carbon, air quality and recreation draw on two recent reports on NCA for Wales. These reports are one by Forest Research (FR; Saraev et al. 2017) and one by the ERAMMP project team led by the UK Centre for Ecology and Hydrology (UKCEH) (Engledew et al. 2019). Both reports adopt ONS and DEFRA methodologies for NCA. However, Engledew et al. (2019) adopt two changes in ONS methodologies that were adopted since Saraev et al. (2017) was completed, namely: i): a 100-year asset life is assumed for renewable natural capital assets (instead of an assumption in earlier ONS methodologies of 50-year asset life); and ii) use of an improved model for quantifying air pollutant removal, developed by UKCEH (Jones et al. 2017).

In this review we focus on evidence for forests and woodlands rather than all green space.

4.2 Ecosystem Services with ONS Valuation Methods

A wide range of ecosystem services (ES) are provided by forests. For some of them, e.g. impacts on mental health, the science is not yet fully developed and there is currently no consensus on how valuation for natural capital accounting is best achieved. In this section we focus on methodologies used for valuing the following ecosystem services for which ONS has developed methods, or work on the development of a method is known to be currently in progress, hence not all ecosystem services considered elsewhere in this review are covered here:

- 8.3.3 Timber production (timber removals) – Provisioning service
- 8.3.4 Carbon sequestration – Regulating service
- 8.3.5 Air quality – Regulating service
- 8.3.6 Flood mitigation – Regulating service
- 8.3.7 Recreation – Cultural service
- 8.3.8 Other forest ES in urban areas

[4] https://www.gov.uk/government/collections/gdp-deflators-at-market-prices-and-money-gdp

Where possible we present an indicative average figure of the ES value per hectare of woodland. Although many ES values are highly location specific, e.g. air filtration, flood mitigation and recreation, and/or vary between forest types and management, e.g. timber production and carbon storage, the average values nonetheless provide a good indication of the magnitude of benefit that could be expected across the large area envisaged of the new National Forest.

4.3 Timber

Although it is important to distinguish the value of the current stock (standing timber in the forest) from that for the annual flow of the wood harvest, in principle, methods to value a given volume of timber are straight-forward. In both cases, the value is generally computed simply by multiplying the volume by the market price – with the standing sales price often applied to estimate the value net of harvesting costs.

For example, the timber standing stock in Wales in 2015/16 was valued at £1,184.5m and annual timber production in 2015 at £28.3m (Saraev et al. 2017). The equivalent mean values are £3,871 per hectare and £92 per hectare (Saraev et al. 2017). The latter may appear relatively low, but this is largely due to the preponderance of years in a forest cycle with little or no timber harvesting. Natural Resources Wales (2019) states that, as of 31 March 2019, "The most significant component [of our non-current assets] is the value of the Welsh Government Woodland Estate (WGWE) which accounts for £903 million of the total." This estimate is only for the value of the WGWE and not privately-owned forest but illustrates the high value and that the value for the whole of Wales has increased.

In valuing the stock, it is generally assumed that all standing timber is available to be harvested, although this is not always the case. However, no estimates have been published of either the proportion of the total stock that can be harvested, or the proportion that cannot – whether due to legal constraints (for example, that limit felling in Sites of Special Scientific Interest (SSSI)), or due to challenging site conditions and small areas where harvesting costs would be expected to exceed revenues.

Although there is generally good information on conifer prices (as noted above under 'markets'), information for specific species is not generally published and information on hardwood prices (for broadleaved species) is sparse. Timber prices for broadleaved species also tend to be highly variable due to the greater influence of timber quality.

The level and timing of timber production associated with a woodland creation project depends not just on the species, but also on environmental factors that affect tree growth and windthrow risks of trees being blown down in the specific location in which planting occurs, and how the stand is managed. For species for which yield models exist, estimating the volume of timber associated with a given tree spacing and forest management regime is generally fairly straight-forward (e.g. drawing upon yield class information from the Ecological Site Classification model (ESC)[5]), although uncertainties are associated with future impacts of climate change and

[5] https://www.forestresearch.gov.uk/tools-and-resources/ecological-site-classification-decision-support-system-esc-dss/about-esc-dss/

biotic risks. In the case of climate, testing for a range of future climate scenarios can help to explore the uncertainty. Values are more uncertain as future timber prices are unknown and difficult to predict - especially for new species for which no market for the timber currently exists in the UK. The ESC model can also be used to help identify which species might have greater suitability and yield class under different climate scenarios, to guide decision making and support creation of climate resilient woodlands[6]. There remains a need for comparative economic analyses of expected returns (and ES benefits more widely) associated with forest planting and climate change adaptation options based upon information on expected species suitability and yields in a changing climate (some work on this is currently [2020] ongoing within Forest Research).

Evidence on timber values for the main conifer species is generally 'well accepted', but there is 'limited evidence' on values for broadleaves and new conifer species.

4.4 Carbon storage and sequestration

As with the stock of standing timber and the annual flow of timber production, it can be important to distinguish carbon storage (stock) from carbon sequestration (annual flow), see Annex-3/ERAMMP Report-35: *Future-proofing our Woodland*. Carbon sequestration is often the focus of natural capital accounting (e.g. ONS 2019).

Methods to value carbon storage and sequestration by forests are closely linked to those for timber as the carbon content of trees is generally derived by applying fixed conversion factors to the biomass related to wood density, with other components (e.g. soil carbon) then added to provide more comprehensive estimates. (As for timber production, some evidence gaps exist for those species and management options for which yield models are currently lacking).

National estimates of the volume of carbon sequestered are generated through modelling for the UK greenhouse gas emissions inventory, taking account of the types and age profiles of forest stands across the UK.[2] To do this, the ESC model is linked with the CARBINE model[7], which combines information on climatic zones, soil type, species and management with yield class data from ESC. Values are then calculated by multiplying the volume of carbon sequestered by forests by the associated social value of carbon recommended by government for policy appraisal. The carbon value to use needs to be taken from the 'non-traded' carbon price series published by the Department for Business, Energy & Industrial Strategy (BEIS) and varies depending upon the year in which the carbon is sequestered. (A review of approaches to valuing carbon can be found in Valatin (2011)).[8]

[6] Sources: Forestry Statistics from Forestry Commission and Forest Research (https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/)
Physical quantities are from the Wood production section of Forestry Statistics.
Prices are from Timber Price Indices, Coniferous Standing Sales Price, from the Finance & Prices section of Forestry Statistics.

[7] https://www.forestresearch.gov.uk/research/forestry-and-climate-change-mitigation/carbon-accounting/forest-carbon-dynamics-the-carbine-carbon-accounting-model/

[8] Physical quantities for carbon sequestration are taken from the UK NAEI (http://naei.beis.gov.uk/reports/reports?report_id=927) inventory which reports current and future projections of

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 woodland carbon stock 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 the wood harvested instead of fossil fuels or more fossil fuel intensive materials are also accounted for). A proportion of harvested wood is used for wood fuel, short-lived products such as paper and pulp, and a proportion of wood products in use are burnt each year, so the carbon storage in wood products produced from any specific harvest declines over time. However, the change in total carbon stock in wood products tends to increase over time due to subsequent harvests leading to a greater increase in the carbon stock due to production of additional wood products than is lost through decay and combustion. Full lifecycle analyses are needed to account for the variables involved, although precise estimates are not currently available due to remaining uncertainties. There are also currently no methods available to quantify impacts of some factors (e.g. potential rebound effects) on carbon substitution benefits – an overview of different types of rebound effects can be found in Valatin (2017).

Social values of carbon recommended by government for policy appraisal are published by BEIS (https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal). To reflect underlying uncertainties, they are ranged, with high estimates 50% greater than central estimates, and low estimates 50% of the central estimates. The estimated carbon values have been published up to 2100, being assumed to remain constant thereafter. The carbon values are based upon a target-consistent approach. The adoption in 2019 of net-zero targets may be expected to lead to the values being revised upwards.

Carbon sequestration by Welsh forests was valued at £109m in 2016 (Saraev et al. 2017). This is equivalent to £356 per ha.

These methodologies can also be applied to predict carbon sequestration potential for new woodland creation. For example, in the ERAMMP project ESC and CARBINE have been applied to predict potential C sequestration for new woodland, in biomass and soils, as well as mitigation in the energy and construction sectors. This modelling has been applied across Wales for a range of woodland species and management type combinations and can be used to identify where new woodland planting might produce the greatest value from carbon sequestration and substitution. As with timber, there is uncertainty associated with climate change and disease and pest risks. There is also ongoing debate over carbon valuation as in some contexts (e.g. impacts of pests and diseases) application of the BEIS carbon values can lead to perverse outcomes (if carbon losses are more than compensated by higher carbon values in subsequent periods for the carbon sequestration by replacement trees). In valuing projected sequestration over time, it is important to account for both how carbon sequestration rates change, and how the carbon values change – even

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UK emissions by sources and removal by sinks due to the Land Use, Land Use Change and Forestry (LULUCF,), which incorporates all air pollutants including greenhouse gases. LULUCF contains a category called 'Forest Land' which is comprised of 'Forest Land remaining Forest Land' and 'Land converted to Forest Land'. Carbon estimates exclude the pool of carbon in timber products though in some cases (e.g. when considering potential impacts of biotic or abiotic risks) using fixed carbon prices may be more useful than applying the BEIS series.

When using data for potential new woodland creation, it is important to consider competition for the land, and restrictions on woodland planting opportunity. For example, the ERAMMP project looked at the potential to plant up to 100,000ha of new woodland (in line with previous targets (Warren-Thomas and Henderson 2017) on land which could come out of agricultural use under three modelled Brexit scenarios (see Table 4-1). The land which was modelled as being potentially available for non-agricultural uses is in general of lower quality (based on Agricultural Land Class), and currently in use by an agricultural sector projected to contract under the given Brexit scenario.

To consider other competition for land, in terms of the current legislative context, land was then filtered based on restrictions used for the Glastir woodland creation (GWC) scheme (Welsh Government 2014), to explore potential impacts of these under each scenario. These planting restrictions are split into two levels: “sensitivities”, where woodland would be detrimental to e.g. SSSI, open habitat for ground dependant birds and historic environment features; and “guidance” where there are potential risks or administrative issues which would need to be addressed before planting could be permitted, e.g. historic landscapes or common land (these are listed in full in Cosby et al. (2019)).

Table 4-1 illustrates the importance of competition with both agriculture and the level of restrictions which must be applied. For example, under the EU deal and no deal scenarios, agriculture is less strongly affected, and there is not sufficient land available for 100,000ha of new woodland even without accounting for sensitivities. Conversely, under the Multilateral Free Trade Agreements (MFTA), the land which could become available for woodland planting would come close to the required target even if sensitivities were considered. The guidance issues identified by the GWC scheme cover a significant proportion of the country, and thus would prevent achieving the planting targets under any of the Brexit scenarios.

The data on projected carbon sequestration can then be extracted to the desired area to calculate potential benefits. For these scenarios, assuming “guidance” restrictions can be circumvented, woodland planting of productive conifers under LISS management could sequester a predicted, tCO_2yr^{-1} of 23,163 under the EU deal; 129,011 for no deal; 389,102 for MFTA.

Table 4-1 Woodland Area of Wales by species, data from Forestry Statistics (2019) and National Forest Inventory (2014a, b)

Potential area (ha and % of total) for planting up to 100,000 ha woodland, subject to constraints, sensitivities and guidance				
	Potential Area (ha) out of Agriculture	**Constraints only**	**Constraints and Sensitivities**	**Constraints, Sensitivities and Guidance**
EU Deal	37,430	21,647 (58%)	7,215 (19%)	6,820 (6%)
No Deal	118,258	83,783 (71%)	31,171 (26%)	6,820 (6%)
MFTA	259,292	99,982 (39%)	98,343 (38%)	44,671 (17%)

Evidence on carbon sequestration for the main tree species is generally 'well accepted' (although for some species and management options for which yield models do not exist currently, estimates are based upon those for similar species for which these do exist). However, the underlying basis used in determining published social values, as well as the pattern of values themselves, remains controversial - especially as applications to tree health issues have been found to lead to perverse results. Currently recommended social values may also be expected to change in future[9]. Uncertainty: Medium

4.5 Air filtration

Trees reduce air pollution through the interception and deposition of pollutants on leaves and needles (see Annex-5/ERAMMP Report-37: *Ecosystem Services*). Social values for the removal of different pollutants are published by DEFRA (DEFRA 2019a, 2019b) based upon the estimated benefits to human health. These include values for particulate matter 10 and 2.5 micrometres (µm) or less in diameter (PM10 and PM2.5), nitrogen dioxide (NO2), ground-level ozone (O3), ammonia (NH3) and sulphur dioxide (SO2).

The latest ONS methodology to quantify the volume of pollutant removal for use in natural capital accounting was developed for the by UK Centre for Ecology and Hydrology (UKCEH) in association with Economics for the Environment Consultancy Ltd (eftec) and EMRC (Jones et al. 2017). The calculations are obtained from scenarios run using the European Monitoring and Evaluation Program Unified Model for the UK (EMEP4UK), an atmospheric chemistry and transport model developed by UKCEH in combination with the health economics model AlphaRISKPOLL. Air pollutant removal estimates are available for 2007, 2011, 2015, and projected values modelled for 2030 based on a future emissions scenario (ONS 2020b). Between these years linear interpolation has been used. The approach taken for linear interpolation is currently under review.

The change to the new method of quantifying pollution absorption benefits has had a dramatic impact in reducing estimated values. Previous estimates (based upon the earlier ONS methodology using different pollution removal model) valued the absorption of PM10 and SO2 by Welsh forests at £385m in 2015 (Saraev et al. 2017), equivalent to a mean value of £1,258 per ha. However, the new approach incorporates revised deposition velocities for a number of pollutants and is calculated dynamically on an hourly time-step through the year, also taking account of interactions among pollutants and meteorology. In the new approach, value is calculated for removal of PM2.5, SO2, O3 and NH3. PM10 removal is not valued since PM2.5 is considered far more damaging and damage costs for PM10 are now outdated. NO2 removal is not valued because differentiating between NO2 and PM2.5 effects in the epidemiological attribution of risk is not considered sufficiently robust and is assumed to incur double-counting at present. PM2.5 removal accounts for ~90% of the health benefit from vegetation removal of pollutants (Jones et al.

[9] Sources: the UK National Atmospheric Emissions Inventory (NAEI) and the department for Business, Energy and Industrial Strategy (BEIS).

2017), with the greatest value attributable to a reduction in Life Years Lost. The quantity and value of pollutants removed by woodland in Wales are shown in Table 4-2 a, b below, separated by broadleaf and conifer woodland. Based on the area of woodland used in the modelling assessment, the value per ha is calculated at £146.74 per ha for broadleaf woodland and £121.52 per ha for conifer woodland.

Table 4-2 Pollution removal by broadleaf and conifer woodland in Wales, 2015, showing (a) Pollution removed and (b) Health benefit (£ 2012 prices).

Habitat	**a) Pollution Removed, 2015 (kg)**					
	NH3	**NO2**	**O3**	**PM10**	**PM25**	**SO2**
Broadleaf Woodland	579,416	157,242	8,881,705	1,186,564	648,402	537,291
Coniferous Woodland	483,508	175,511	11,929,059	2,520,692	1,229,257	454,283

Sub Habitat	**b) Value of Pollution Removed, 2015 (£ prices 2012)**				
	PM25	**SO2**	**NO2**	**O3**	**Total**
Broadleaf Woodland	17,915,695	13,481	85,069	345,726	18,359,971
Coniferous Woodland	17,152,620	7,589	-12,715	287,226	17,434,719

Evidence on air quality improvement values per unit of pollutant is 'well accepted'. However, changes in methodology used to quantify the volume of pollutants removed have led to large changes in estimated values for the air quality improvement benefits of woodlands. Caution is also required in interpreting changes over time as reductions in these natural capital values can reflect improvements in background environmental quality associated with a reduction in ambient air pollution. This was the case over the period 2011-2015, for example (see: Saraev et al. 2017). The changes over time in the latest ONS reporting (ONS 2010a, Jones et al. 2017, Engledew et al. 2019) primarily reflect a decline in concentrations of the most damaging pollutant for human health, PM2.5, rather than changes in woodland cover.

4.6 Flood mitigation - Flood risk attenuation

There are a wide variety of approaches that in principle can be used in valuing the various flood risk attenuation benefits of woodlands. Approaches and aspects that can be covered include:

(i) Surveys of households' and of business' Willingness to Pay (WTP) to prevent or reduce risks of flooding;

(ii) Hedonic price methods to quantify price premiums for properties at lower risk of flooding;

(iii) Insurance premium reductions associated with properties facing lower flood risks;

(iv) Avoided Damage costs to residential and non-residential property;

(v) Avoided Damage costs to agriculture;

(vi) Avoided Damage costs to vehicles;

(vii) Avoided Damage costs to infrastructure (e.g. utilities, rail lines, roads, bridges);

(viii) Avoided evacuation costs;

(ix) Avoided Disruption costs (e.g. costs to emergency services, schools and other public services, impacts of road closures on travel times/costs);

(x) Valuation of impacts on Recreation;

(xi) Avoided loss of life and morbidity (e.g. Quality Adjusted Life Year) valuation;

(xii) Cost savings to the National Health Service;

(xiii) Subjective wellbeing benefits due to lower flood risks;

(xiv) Surveys of household and business Willingness to Accept (WTA) flood risks;

(xv) Local Economic output and employment impacts;

(xvi) Replacement costs of providing an equivalent level of flood storage through alternative measures (e.g. reservoir construction).

While some of these are alternatives (e.g. i and xiv), and others overlap (e.g. xiii and xiv), many are complementary allowing more comprehensive estimates that cover a range of flood risk attenuation benefits. The approach recommended in UK policy appraisal, for example, involves estimating avoided costs of flood damage to property and infrastructure, adverse health impacts and disruption, plus (where material) local economic output and employment impacts net of potential displacement (HM Treasury 2018, pp.66-67). Welsh Government guidance on economic appraisal of flood and coastal erosion risk management focuses primarily on reduced risk to life and residential properties (Welsh Government 2018, p.78).

In practice relatively few studies have valued the flood risk attenuation benefits of woodlands in Wales, or elsewhere in Britain. This is mainly due to complexities in quantifying reductions in flood risk attributable to woodlands, which can depend not only upon the characteristics of the woodlands (e.g. woodland scale, design and management) and flood events (e.g. duration and peak height) and seasonal factors (e.g. evapotranspiration rates and initial ground wetness), but geographical location and types of land use change considered. It may also in part be due to spatial variations in value estimates – which can also depend upon factors such as number and type of properties in the areas susceptible to flooding.

Methods and estimates from three pioneering studies that report values for the flood risk attenuation benefits of woodlands in Britain are shown in the Table 4-3 below. Although the geographical focus and methods adopted were different in the first and third study, estimated ranges for annual values per cubic metre of flood storage by the woodlands are similar. This was the favoured metric for valuing the flood attenuation benefit based on available data and ease of upscaling assessments to region and country levels.

Table 4-3 Existing studies of the flood risk attenuation benefits of Woodlands in Britain

Study	Woodland Focus	Approach(es)	Land use change (from/to)	Values (£ per m3 of flood storage)
(Nisbet et al. 2015)	Woodland Creation (and creation of Large Woody Debris dams)	Avoided damage costs to property	Rough pasture [α]	central estimate £1.20/m3 (range: £0.19/m3 to £1.23/m3) [β]
(Dixon and Pettit 2017)	Conifer or Broadleaved Woodland Creation	Avoided damage costs to property; WTP; Avoided disruption costs;	[γ]	[η]
(Broadmeadow et al. 2018)	Existing Woodlands in ‘Flood Risk Catchments’ (FRC)	Replacement costs	Grassland	central estimate £0.42/m3 (range: £0.10/m3 to £1.19/m3) [δ]

***Notes:** [α]: land use change to riparian woodland. (Improved grassland for farm woodland in neighbouring River Seven Catchment); [β]: avoided damage cost estimates (at 2015 prices) based on costs of previous floods in Pickering. [δ]: annual mean equivalent costs (at 2018 prices) over 100-year expected lifespan of alternative constructed reservoir storage - including procurement, enabling works, capital cost, maintenance, monitoring and inspection costs, based upon total cost estimates ranging from £3.02/m3 to £35.59//m3 (central estimate £12.66/m3). [γ]: areas adjacent to main watercourses and their tributaries assumed planted; [η] values per m3 of flood storage associated with the avoided property damage costs not reported, but annual values include avoided health and wellbeing cost for fluvial flooding of £286/household (based upon WTP to prevent flooding) and avoided damage cost to vehicles of £868/property.*

Nisbet et al. (2015) does not report flood risk attenuation values per hectare of woodland. However, the creation of 19 ha of riparian woodland in the Pickering Beck catchment was expected to create 2,000m^3 of additional flood storage (Tom Nisbet, pers., comm). This implies a central estimate for the annual flood risk benefit in the catchment of £126 per hectare of woodland created (range: £20 to £129 per ha).

Dixon & Pettit (2017, p.35) report estimated flood risk attenuation benefits of around £7,500 per hectare of woodland created over the 100-year appraisal period, equivalent to about £250 per hectare per year.

Broadmeadow et al. (2018, p.22) report flood risk attenuation values per hectare for different woodland types in FRAs in Britain as a whole. These Natural Capital values are shown in the Table 4-4 below.

Table 4-4 Flood risk attenuation Natural Capital values per hectare for FRC woodlands in Britain

Woodland Type	Season	Flood storage due to	Central estimate: Value (£ per ha at 2018 prices)	Range: Value (£ per ha at 2018 prices)
Floodplain	All-year	Hydraulic roughness	£6,600/ha	£1,600/ha-£18,500/ha
All	All-year	Storm-day interception	£133/ha	£32/ha-£375/ha

Woodland Type	Season	Flood storage due to	Central estimate: Value (£ per ha at 2018 prices)	Range: Value (£ per ha at 2018 prices)
All	Growing season	Below-ground soil	£573/ha	£137/ha-£1,610/ha
All	Winter season	Below-ground soil	£3,600/ha	£863/ha-£10,200/ha
All	All-year	All the above	£2,642/ha	-

Source: (Broadmeadow et al. 2018, pp.22-23)

Associated natural capital values for woodlands in Wales are shown in the Table 4-5 below, by catchment category (whether entirely in Wales or not), together with preliminary estimates estimated for Wales as a whole (based upon more recent analysis showing that 55% of all the woodland in the Flood Risk Catchments (FRCs) straddling the border with England are in Wales and 41% of the floodplain woodland).

Table 4-5 Aggregate flood risk attenuation Natural Capital values for woodlands in Wales

Flood storage due to	Values for FRC entirely in Wales (£m at 2018 prices)	Values for border FRCs (£m at 2018 prices)	Values for Welsh area of border FRCs (£m at 2018 prices)	Aggregate Value for Wales (£m at 2018 prices)
Canopy interception	£34m	£18m	£10m	£43m
Soil Storage	£330m	£300m	£165m	£495m
Floodplain storage	£142m	£36m	£15m	£156m
All	£505m	£352m	£190m	£695m

Sources: Broadmeadow et al. (2018), Table 8, subsequent analysis by Forest Research;

Broadmeadow et al. (2018, p.22) report associated annual flood risk attenuation values (central estimates) for different effects and woodland types in FRCs. These are compared in the Table 4-6 below with the estimates from Nisbet et al. (2015) for riparian woodland and from Dixon & Pettit (2017) both reflated to 2018 prices.

The existence of flood risk mitigation benefits of woodlands is well accepted, but there remain a number of areas requiring further development in methods – including in the parameterisation of existing models used to quantify the benefits of woodlands (Broadmeadow et al. 2018, pp.23-25). For the replacement cost approach, there is also a need for evidence that the flood protection benefits provided by woodlands equal or exceed the costs associated with constructing and maintaining a reservoir to provide the equivalent flood storage. Applying most other approaches (e.g. avoided property damage costs, or avoided costs to the NHS) to derive national level estimates, is challenging due to the need for detailed hydrological modelling of each catchment. The current state of knowledge on flood risk attenuation values of woodlands in Wales is characterised by limited evidence and, as many of the benefits remain to be valued, existing estimates are far from comprehensive, so aggregate values in Table 4-5 above could be considered conservative.

Table 4-6 Estimated annual flood risk attenuation benefits of Woodlands in Britain (2018 prices)

Study	Woodland Type	Effects that lead to flood storage	Central estimate: Value (£/ha/year)	Season
(Nisbet et al. 2015)	Riparian	Interception & soil water	£129/ha/yr [α]	All-year
(Dixon and Pettit 2017)	All	Interception, hydraulic roughness & soil water	~£260/ha/yr	All-year
(Broadmeadow et al. 2018)	Floodplain	Hydraulic roughness	£221/ha/yr	All-year
(Broadmeadow et al. 2018)	All	Storm-day interception	£5/ha/yr	All-year
(Broadmeadow et al. 2018)	All	Below-ground soil water	£19/ha/yr	Growing season
(Broadmeadow et al. 2018)	All	Below-ground soil water	£121/ha/yr	Winter season
(Broadmeadow et al. 2018)	Non-floodplain	All	£75/ha/yr [β]	All-year
(Broadmeadow et al. 2018)	Floodplain	All	£296/ha/yr [β]	All-year

Notes: [α]: values reflated to 2018 prices based upon changes in the Treasury GDP deflator; [β]: uses mean value for growing season and winter season below ground soil storage.

4.7 Recreation

Two approaches to valuing recreation benefits are currently used by the ONS for natural capital accounting.

The first of these uses estimates adapted from Ricardo-AEA's 'simple travel-cost' method (Whiteley et al. 2016). The 2014 Wales Outdoor Recreation Survey (WORS) acts as the primary data source for collecting environmental engagement data, visit costs and travel distances within the previous 4 weeks. Visit costs, which encompass fuel, public transport, parking and admission fees, are used as a proxy for the marginal value of accessing a recreational site.

The 'simple travel-cost' method provides a conservative estimate of the recreational value, as it is unable to capture the value of recreational visits where there is no market interaction. As such, visits by foot or bicycle are not included in these estimates. Those who arrived on foot accounted for 52% of all recreational visits according to 2009-2015 data from the Monitor of Engagement with the Natural Environment (MENE), using survey data in England (Day and Smith 2017).

The second approach to valuing recreation benefits – which is the latest ONS methodology for urban natural capital accounts (ONS 2019b), uses the University of Exeter's Outdoor Recreation Valuation Tool (ORVal). This is a map-based tool that explores welfare values based upon predicting visit numbers across greenspaces in England and Wales, utilising a large econometric model based upon MENE and WORS data (Day and Smith 2018). It is important to note that this approach does not assign higher value to woodland than to other publicly accessible green space –

although some recent work is understood to have been exploring how values differ between different types of greenspace.

ORVal can estimate how welfare values and visit numbers change with modifications to existing greenspace such as creation of new woodlands, as well as the benefits that newly created greenspace will deliver. The model incorporates a wide variety of variables, including socioeconomic characteristics, qualities of greenspaces and the availability of alternative greenspaces, as well as the time of year of a particular visit and the weather.

Welfare values are taken from the Department for Transport's (DfT) estimates of the value of travel time (Department for Transport 2015) and the cost of fuel consumption (Department for Transport 2014). The total monetary cost for driving is estimated based upon the time taken to drive to a particular greenspace plus the fuel costs. Values for accessing greenspaces on foot are also estimated using DfT's calculations on walking time costs (Day and Smith 2017). Greenspace values are taken as the monetised welfare loss experienced by individuals if they are no longer able to access that site.

The two methods lead to different estimates. Using 'simple travel-cost', recreation benefits of forests in Wales in 2014 were valued at £85 million (Saraev et al. 2017), equivalent to a mean of around £278 per ha. With inclusion in the estimate of travel time and walking visits, ORVal's approach values Welsh recreation at £570 million (Day and Smith 2018) – although this is for visits to all greenspace, not just forests.

ORVal's ability to model the benefits and demand associated with newly created greenspaces makes it a valuable tool. New greenspaces can be specified by land cover percentage (such as broadleaf woodland, managed grassland, marshland) and water features, and demand can be explored for different socioeconomic groups. ORVal also accounts for greenspace accessibility and the influence of nearby greenspaces in modelling recreational demand [see more details on ORVal estimates in 3.3.6 above]. The recreational benefits of visits to woodlands are well accepted. However, there is continuing debate over the best approach to value recreation with a wide range in values estimated by different approaches.

4.8 Valuing other forest ES in urban areas

There is currently also development in natural capital accounting approaches for woodlands in urban areas. This includes experimental approaches applied to estimating natural capital values for temperature regulation and noise mitigation benefits (ONS 2019b, 2020a), based on work by UKCEH and eftec (eftec et al. 2017, eftec et al. 2018, eftec & CEH 2018).

The value of the cooling benefit provided by woodlands in urban environments has been estimated for 11 city regions in the UK (ONS 2020a) based mainly upon cost savings associated with not using air conditioning and benefits of improved labour productivity. The annual value for the principal city region in Wales (Cardiff) is estimated at about £1.5 million in 2018 (2018 prices) (ONS 2020a, Table 11).

The ONS reports that 12,000 urban buildings in Wales benefited from noise mitigation by woodlands (ONS 2020a). Valuation of these benefits is based on the avoided loss of Quality-Adjusted Life Years (QALYs) associated with avoiding adverse outcomes such as lack of sleep and annoyance. In Wales, 12,000 buildings are estimated to receive some form of noise mitigation from woodland, where noise levels are >60 dBA (decibels; eftec & CEH 2018). The annual value for urban noise reduction benefits of woodlands is estimated at £1.1 million (ONS 2020, Table 14) for buildings exposed to noise levels > 60 dBA, with an associated natural capital asset value of £61 million (2018 prices) (ONS 2020, Table 15).

Due to the exploratory nature of these methods which remain under development, the current state of knowledge on urban cooling and noise reduction benefits of woodlands is best characterised currently as one of ‘limited evidence’.

4.9 Aggregate Natural Capital Values

The aggregate value of the natural capital of woodlands in Wales associated with the provision of four ecosystem services was estimated by Forest Research (2017) in 2015 at £606 million at 2015 prices, of which by far the greatest value was for air pollution absorption (£385 million), followed by carbon sequestration (£108 million), recreation (£85 million) and then timber extraction (£25 million). More recent estimates in Engledew (2019) put the aggregate value in 2014 at £310m at 2017 prices with the highest valued service for recreation (£123.1 million), followed by carbon sequestration (£113.3 million), air pollutant removal (£43.7 million), and timber provision (£29.6 million). The difference in the aggregate value is primarily due to a major revision in the approach to quantifying air quality improvements (described in section 4.5 above). The higher recreation value in the second study mainly reflects the use of data on higher expenditure per recreational trip for Wales than the UK average, information not available for the earlier study from the Welsh Outdoor Recreation Survey indicating that admission and parking fees paid by visitors are higher and distances travelled longer than UK averages. The range of benefits covered by the two studies is quite limited (reflecting those covered at UK level by ONS at the time), with the aggregate natural capital value of woodlands in Wales likely to be far higher were a broader range of ecosystem services accounted for.

5. Summary of Annex-6

The Welsh forestry sector is economically valuable, currently adding more than £665 million GVA to the Welsh economy each year and employing around 11,000 people across more than 800 business enterprises. There is a knowledgeable and passionate work force, and it is a confident, stable business sector.

There is high demand for Welsh roundwood and wood products that is likely to increase in future. There is demand and need for a sustainable increase in both the coniferous and broadleaved timber resource.

Strategic development of the forestry sector, new markets, and local supply chains can support active and sustainable forest management and the delivery of a wide range of environmental, social and cultural benefits. This is true for commercial and small-scale timber processing and wood crafts, domestic and industrial woodfuel, non-timber forest products, as well as indirect supply chains for recreation and tourism.

The effect of location, size, species composition and management on existing and new woodland are important economic considerations, alongside the environmental and cultural factors explored in Annex-1/ERAMMP Report-33: *Biodiversity,* Annex-2/ERAMMP Report-34: *Managing Undermanaged Woodland and Annex-4/ERAMMP Report-36: Climate Change Mitigation*.

The ONS natural capital accounting methodologies considered in this chapter represent a good balance in terms of their practicality-complexity-precision, although scope remains to refine them further. They cover a range of forest ecosystem services including timber production, carbon storage, air filtration, flood mitigation and recreation, and much of the evidence is well accepted. A few aspects remain controversial, such as BEIS carbon values in considering tree health risks and interpreting the reason for changes in natural capital values.

However, for some ecosystem services natural capital accounting methodologies are still at the early stage, e.g. noise and temperature regulation, with only limited evidence in these cases. There also remain some important benefits of forests for which natural capital accounting approaches have yet to be developed, such as benefits to mental health. Nevertheless, the research is ongoing and methodologies that cover some of these may be developed in the near future.

This refinement of methods is illustrated in the shifts in the value of the Wales Woodland Natural Capital Account. For example in Forest Research (2017), the woodland estate in Wales for the year 2015 was valued at £606m with the service of greatest value for air quality whilst in Engledew (2019) for the year 2014 the value was put at £310m with carbon sequestration and recreation as the most valued services see section 4.9 above. This was primarily due to a major revision of the approach relating to the valuation of air quality as described in section 4.5 above. These values are always a partial account due to lack of methods for many services including biodiversity.

An important finding from Natural capital accounting exercises is that non-market values of many forest ecosystem services are significantly larger (by a magnitude) than that for marketable goods like timber. For example, per hectare values cited in Report 37 are higher for carbon sequestration, recreation, air pollution absorption and (in most cases of flood risk catchments) for flood risk attenuation.

Natural capital accounting methods and values can contribute to payments for ecosystem services (PAYES) and payments for public goods (PPG) and support delivery of policy targets.

6. References for Annex-6

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ERAMMP Programme Office
UKCEH Bangor
Environment Centre Wales
Deiniol Road
Bangor, Gwynedd
LL57 2UW
+ 44 (0)1248 374500
erammp@ceh.ac.uk

www.erammp.cymru

www.erammp.wales