

Natural Environment Framework: Woodland Creation case study

Gregory Valatin
Vadim Saraev

Centre for Human and Ecological Sciences

Forest Research

Contract number: 480.RH.00008

Description: NEA New Woodland Creation Case Study

Contract Manager: Bill MacDonald / Sue Ginley
Forestry Commission Wales
Welsh Government
Rhodfa Padarn
Llanbadarn Fawr
Aberystwyth
SY23 3UR
Tel: 0300 068 0300
Email: bill.macdonald@forestry.gsi.gov.uk

Project manager: Gregory Valatin
Forest Research
Northern Research Station
Roslin
Midlothian, EH25 9SY
Tel: 0131 445 6995
Fax: 0131 445 5124
gregory.valatin@forestry.gsi.gov.uk

Contents

1	Introduction	4
1.1	Background	4
1.2	Aims	4
1.3	Report Structure	4
2	Methodology and Datasets	5
2.1	Time horizon	5
2.2	Woodland creation time profile	5
2.3	Baseline woodland creation	5
2.4	Spatial distribution of new woodlands	6
2.5	Species mix of new woodlands	6
2.6	Carbon	7
2.7	Wood production	8
2.8	Amenity	9
2.9	Health	13
2.10	Aggregate Amenity and Health benefits	14
2.11	Agriculture	15
2.12	Forestry Costs	17
2.13	Future costs, prices, and values	17
2.14	Climate change cost-effectiveness	18
3	Results	18
3.1	Carbon	18
3.2	Wood	21
3.3	Agriculture	21
3.4	Forestry costs	21
3.5	Amenity	21
3.6	Health	23
4	Discussion	23
	References	25

1 Introduction

1.1 Background

The total woodland area in Wales is 303,500 hectares according to the 2011 National Forest Inventory. This is about 14% of the total land area of Wales (<http://www.forestry.gov.uk/forestry/INFD-8LGCK9>).

In 2010 the Government of Wales announced a target of creating 100,000 ha of new woodland over a 20 year period. It was anticipated that this will be achieved by a mixture of grant funding by the government and other sources, with the latter including carbon finance and corporate social responsibility programmes undertaken by the private sector.

The main instrument for public grant funding of woodland creation at present is the Glastir scheme. This superseded the earlier 'Better Woodlands for Wales' scheme during 2011.

1.2 Aims

A study was commissioned by Forestry Commission Wales (FCW) with the aim of providing a case study of woodland creation for the Natural Environment Framework. Drawing upon analysis undertaken for the National Ecosystem Assessment (NEA), the aim of the study is to provide indicative economic estimates of the expected net benefits of meeting the target of creating 100,000 ha of new woodland over a 20 year period. In discussion with FCW, it was decided to focus upon impacts on the following five ecosystem services: carbon sequestration, wood production, amenity, health, and agricultural production.

1.3 Report Structure

The next section outlines the methodology adopted in this study. A results section then follows. The final section summarises the results and reports cost-effectiveness estimates for the woodland creation as a climate change mitigation measure. It also highlights how the analysis is influenced by existing underlying uncertainties and knowledge gaps.

2 Methodology and Datasets

2.1 Time horizon

After discussion with FCW, it was decided to focus upon a 100-year time frame to fit with that used in a recent study for the Welsh Assembly Government (WAG) that included carbon estimates of woodland creation (WAG, 2010). In contrast to the latter report, however, in this study the first year is assumed to be 2012 rather than 2010.

2.2 Woodland creation time profile

The time profile of woodland creation influences the benefit estimates derived. It was agreed with FCW that the 20-year period over which the 100,000 ha of new woodland target is to be met would be assumed to run from 2012 to 2031 inclusive.

Following consultation with FCW, the following time profile for woodland created under the Glastir scheme was assumed: 1,000 ha planted in the first year (2012), increasing to 2,000 ha in year 2, 3,000 ha in years 3-5, 4,000 ha in years 6-10, 4,500 in years 11-15, and 5,100 ha in years 16-20. Although far higher than the level of planting during 2012, planting 1000 ha in 2012 is considered by FCW to be consistent with existing plans in the system at the end of Feb 2012 under Glastir for creating about 800 ha of new woodland (Bill MacDonald, pers. com.). This pattern of woodland creation implies a total of 80,000 ha will be planted under the Glastir scheme.

In addition, FCW suggested that 10,000 ha would be planted in partnership with other organisations. For the purposes of this study, the same time profile as for the woodland created under Glastir is assumed for this. Thus, this component is assumed to be one eighth of the level of the planting under Glastir in each year.

Instead of involving new woodland planting, on advice from FCW, the remaining 10,000 hectares of the 100,000 ha target is assumed to be notional (Bill MacDonald, pers. com.), arising purely due to reclassification of woodland areas under the 2011 National Forest Inventory (NFI). Adopting this approach implies that the 100,000 ha target is met by the creation of 90,000 ha of new woodland.

2.3 Baseline woodland creation

Forestry Commission estimates suggest that in total there were around 200 hectares of new woodland created in each of financial years 2007/8 to 2009/10, rising to about 300 hectares in 2010/11 (see estimates at: <http://www.forestry.gov.uk/forestry/infd-7aqkx>), with the increase in woodland planting in 2011 coinciding with introduction of the new Glastir grants scheme. For the purposes of this study, the pre-Glastir rate of 200 hectares per year was chosen to represent the baseline level of woodland creation.

Reaching the 100,000 ha target was therefore assumed to involve planting an additional 86,000 ha of new woodland in total over the 20 year period 2012-2031 above the baseline level anticipated in the absence of new public initiatives. This is the overall level of new woodland creation that has been assumed in estimating the impacts on ecosystem service provision of meeting the woodland creation target for Wales.

2.4 Spatial distribution of new woodlands

The spatial distribution of the new woodland created influences those benefit estimates (e.g. amenity and health values) that depend upon factors such as proximity to urban population centres and the extent of existing woodlands in the area. Attempting to model the expected spatial distribution of new woodlands was not feasible within the time-frame for this study. Instead, it is assumed that projected benefits per hectare of new woodland created under the Glastir scheme in 2011 apply to the woodland created subsequently.

A shape file provided by FCW included areas where new woodland was created in 2011. However, the total area covered by the file (2,200 ha) was approaching ten times the area of new woodland created under the scheme (241 ha) during 2011. An initial task was to exclude from this file areas classified as woodland under the 2011 NFI (completed in March that year),¹ for which grants were presumably paid for re-planting woodlands with different species (e.g. 'native' broadleaves). This left around 1,380 ha in total. This area was then assumed to be representative of the areas where the new woodlands are expected to be created over the period 2012-2031.

2.5 Species mix of new woodlands

Similarly, for the purposes of this study the mix of new woodlands created is assumed to reflect the mix of those created during 2011 under the Glastir scheme. These woodlands consisted entirely of native or mixed stands, with indicative estimates provided by FCW suggesting that broadleaved species accounted for around 96-97% of the total area planted.

Excluding the 10 ha of native broadleaves planted, the 15 ha woody shrubs (also thought likely to be broadleaves), as well as the 2 ha of open ground from the total of 241 ha of woodlands created under the scheme during 2011, seven species account for about 92% of the remainder of the area planted. These are ash (33%), oak (24%), birch (13%), alder (8%), wild cherry (5%), rowan (5%), hazel (4%).

¹ Version from: <http://www.forestry.gov.uk/inventory>, accessed on 15/03/12.

In view of this overwhelming preponderance of broadleaves, the simplifying assumption that all 86,000 ha of additional new woodland consist of broadleaves is adopted in this study for the purpose of estimating impacts.

2.6 Carbon

Carbon estimates were derived from the Forest Research C-SORT model. These include estimates of carbon sequestration net of in-year emissions from any forestry operations or wood processing undertaken and accounting for changes in litter, woody debris, soil carbon. They also include estimates of carbon savings associated with carbon substitution of wood for other materials, and of fossil fuels in heat and electricity generation.

Yield models do not currently exist for all tree species, so in those cases where a separate yield model does not exist at present, each species is mapped to that considered the closest (Tim Randle, pers. com.). For the purposes of providing indicative carbon sequestration estimates, alder and hazel are assumed to map to a mixture of sycamore, ash, and birch (SAB), with rowan and wild cherry mapped to oak. This implies a split between SAB and oak of 63%:37% for the broadleaves planted. The carbon estimates for the new woodland created during 2012-2031 were generated assuming the additional 86,000 ha consists of 63% SAB (54,180 ha) and 37% oak (31,820 ha).

Drawing upon estimates for forestry options used in a recent WAG report (WAG, 2010), two sets of species/spacing/yield class/type of management/soil options/previous land use were assumed to typify new woodlands created. These are:

- i) option D1: SAB mix YC4, 1.5m spacing, no thinning, no final felling (indefinite rotation), gley, rough pasture;
- ii) option F1: oak YC6, 1.2m spacing, ATC selection, no final felling, loam, rough pasture;

To allow for wider non-permanence risks (e.g. associated with fires) a buffer of 30% (low estimate), 20% (central estimate), or 15% (high estimate) is then applied, reducing the carbon benefits assumed. These buffers are assumed to apply to the positive sequestration estimates (but not to the net carbon losses in the first years due to forestry operations and soil disturbance). This approach is broadly in line with the 15%-30% buffer to allow for non-permanence risks recommended under the Woodland Carbon Code (West and Matthews, 2011). In addition, carbon estimates are ranged by +/-20% for sensitivity analysis to allow for uncertainties in model estimates.

The new woodland is assumed to be established in perpetuity. In the case of the SAB option, no account is taken of any emissions after the end of the 100-year time horizon as the carbon stock is expected to continue to increase. For the oak option, although felling based upon ATC selection is assumed that periodically reduces the carbon standing stock remaining in the woodland, this is assumed to result in further increases

in the mean carbon standing stock over the long-run, with carbon sequestration over the 100-year time horizon similarly assumed to be permanent. (Although this is subject to potential impacts of wider non-permanence risks already accounted for).

By contrast, instead of estimating the time profile of subsequent releases of carbon stored in harvested wood products, for the purposes of this study it is simply assumed that the carbon is released entirely immediately after the end of the time-horizon considered (i.e. in year 101).

To value carbon impacts, Department of Energy and Climate Change (DECC) and HM Treasury estimates of the social value of carbon (<http://www.decc.gov.uk/en/content/cms/emissions/valuation/valuation.aspx>) are applied. These values have been published up to 2100, and in line with previous advice from DECC, it is assumed that beyond 2100 the social value of carbon remains constant in real terms. This approach is also adopted in economic analysis of woodlands for the NEA (Valatin and Starling, 2010). With the exception of the wood used in electricity generation, carbon benefits are valued at the non-traded sector social values of carbon (which applies to carbon savings in sectors not covered by the EU emissions trading scheme). The carbon benefits of using wood in electricity generation are valued at the traded sector social values of carbon.

2.7 Wood production

Assumptions for wood production consistent with those underpinning the carbon estimates used were adopted. These included assuming no wood production for SAB woodland creation and minimal wood production associated with management by ATC selection for the oak. Similar buffers to allow for non-permanence risks were adopted, and wood production ranged by +/-20% for sensitivity analysis to account for potential variation in yields associated with the mapping used for those species where yields models do not currently exist and for climate change impacts.² Estimates of the volumes of wood produced were also derived from the C-SORT model.

Information on standing timber prices for broadleaves is sparse (Valatin and Starling, 2010). Furthermore, hardwood prices are highly sensitive to species, size and quality grade (Alan Corson, pers. com.). For the purposes of providing indicative estimates of wood production values, a standing sales price of £17/m³ at 2012 prices (roughly equivalent to £15/m³ at 2007/8 prices) is assumed for the low estimate. This level

² Yield models taking climate change impacts into account were not available for this study. However, preliminary estimates based upon applying UKCIP02 scenarios in conjunction with the Ecological Site Classification model suggest that under the high climate impact scenario yields of oak and birch could more than halve in the eastern part of Wales by 2080 due to a dryer and warmer climate. (Thanks are due to Stephen Bathgate for this preliminary investigation).

reflects the mean price for hardwood sold by Forestry Commission England (FCE) in 2007/8. (FCE accounted for over 90% of hardwood sales by the Forestry Commission that year, although less than 10% of total sales of UK hardwood). For the high estimate, a standing sales price of £34/m³ at 2012 prices is assumed (equivalent to the mean of £32/m³ at 2010 prices reached at the Rennies auction at Westonbirt in November 2010 – see: <http://www.forestry.gov.uk/forestry/hcou-4u4jgj>). An intermediate figure of £25/m³ is adopted for the central estimate. While UK wood prices fluctuate over time in part in response to global supply and demand conditions (market prices in the UK are widely considered to be determined primarily by prices for imported wood), for the purposes of this study prices have been assumed to remain constant in real terms (an assumption also adopted in analysis for the NEA).

2.8 Amenity

A benefits transfer approach is taken to estimating amenity impacts of new woodland creation based upon a large-scale hedonic prices study (Mourato *et al.*, 2010) of amenity values undertaken as part of the NEA (NEA, 2011, Chapter 22). The Mourato *et al.* (2010) study uses a sample of around one million housing transactions across England, Wales and Scotland for 1996-2008 from the Nationwide building society, linked information on location at full postcode level, and a rich set of house and local characteristics, including local labour market variables, accessibility and other controls. Using Land Cover Map (LCM) classifications, house prices are related to the share of nine broad habitat categories including the main two woodland ones,³ and six land use types in the locality.⁴ Among the results for the GB level-model (no estimates are reported separately for Wales), a 1% increase in broadleaf or mixed woodland is estimated to increase house prices by 0.25% (or around £340 based upon a mean house price of £135,750 in 2010).

The approach adopted in this study draws upon the 'all GB' model estimate of a 0.25% increase in house prices for each percent increase in broadleaf woodland in a locality (Mourato *et al.*, 2010), in combination with recent information on house prices in Wales. However, as the estimates in the original study are based upon land cover shares relative to the share of the urban area in the total, the coefficient needed to be adjusted

³ Defined as the proportional share (0 to 1) of land cover of a particular habitat within the 1 km square in which a house is located, the habitat variables are: (1) Marine and coastal margins; (2) Freshwater, wetlands and flood plains; (3) Mountains, moors and heathland; (4) Semi-natural grasslands; (5) Enclosed farmland; (6) Coniferous woodland; (7) Broadleaved / mixed woodland; (8) Urban; and (9) Inland Bare Ground.

⁴ Defined as the proportional share (0 to 1) in the Census ward in which a house is located, the land type variables are: (1) Domestic gardens; (2) Green space; (3) Water; (4) Domestic buildings; (5) Non-domestic buildings and (6) 'Other'.

to take account of planting on other types of land (e.g. agricultural).⁵ This was done by adopting an impact coefficient calculated as a weighted average of coefficients for the 'Enclosed farmland', 'Semi-natural grasslands' and 'Mountains' land cover shares. Coefficients for 'Semi-natural grasslands' and 'Mountains' are excluded because regression estimates for these are not statistically significant from zero (Mourato *et al.*, 2010, p. 16). This yielded an impact coefficient of 0.19, which translates into a 0.215 % increase in property price (Mourato *et al.*, 2010, p. 18) for each 1% increase in broadleaf or mixed woodland. Although a house price increase is not a benefit per se, it is considered to represent the capitalised value of an annual stream of additional amenity benefits. The equivalent annual amenity benefits were estimated based upon Treasury green book discount rates in line with the approach used in other parts of this study (see subsection 2.12 below).

Spatial analysis was used to explore the pre-existing and subsequent land cover shares, and to replicate the conditions of the original study (Mourato *et al.*, 2010). This was based upon one kilometre grid squares, focusing upon the 84 in which analysis indicated both the new Glastir woodland and urban settlements were present. The same broad habitat classification used in the original study was also adopted.

The latest LCM (LCM 2007 released in 2011)⁶ was used to estimate previous land cover shares in each of the grid squares. Although the best currently available, its accuracy is 83% on average, with a minimum mappable area of 0.5 ha (CEH, 2011, pp.: 3-4). These limitations together with the tentative nature of other estimates (Mourato *et al.*, 2010) need to be acknowledged when interpreting the results. For example, according to the LCM, small areas of the new woodland were created on previous marine (1.8 ha) or on freshwater (0.6 ha) habitats (see Table 1), while some of the remaining woodland area under LCM is not identified as woodland under the NFI. (As the latter is based upon aerial imagery taken in 2006, while LCM is based on satellite imagery taken between September 2005 and July 2008, differences in areas shown as woodland may be partly attributable to different time frames and methods used, as well as woodland created in intervening periods).

⁵ Thanks are due to Steve Gibbons at LSE for providing advice on the approach to use.

⁶ See: <http://data.gov.uk/dataset/land-cover-map-2007>, accessed on 15/03/12

Table 1. Areas where woodland was created in 2011 by previous land cover

Habitat	Area (ha)	%
Marine	1.83	0.13
Freshwater	0.64	0.05
Mountain	59.15	4.28
Semi-natural grassland	446.65	32.35
Encl. Farmland	795.38	57.61
Coniferous woodland	8.34	0.60
Broadleaved or mixed woodland	51.42	3.72
Urban	13.31	0.96
Inland Rock	3.88	0.28
Total	1380.59	100

As can be seen from the table above, 94% of the area covering new woodland created under Glastir was previously classified in three broad habitat categories. In order of magnitude these are: "Enclosed farmlands" (58%), "Semi-natural grasslands" (32%) and "Mountain" (4%).⁷

As the distribution of the total area by altitude in Table 2 below shows, the land cover share of "Mountain" habitat (4.3%) is closely correlated to the land cover share that is over 400m (4.8%). Table 2 also shows that 83% of area where new woodland was created is below 300 metres and 47% below 200 metres.

Table 2. Areas where woodland was created in 2011 by altitude

Altitude (m)	Area (ha)	%	Cumulative (%)
0-100	297.69	21.56	21.56
100-200	345.11	25.00	46.56
200-300	508.27	36.82	83.38
300-400	163.67	11.85	95.23
400-1079	65.85	4.77	100.00
Total	1380.58	100.00	

In order to estimate the aggregate impact on property prices of creating new woodland in the area covered by the Glastir scheme in 2011, it was necessary to determine the number of properties affected. A population dataset identifying all populated settlements

⁷ These broad habitats are adopted from (Mourato *et al.*, 2010) and differ only slightly due to the fact that LCM 2000 used in (Mourato *et al.*, 2010) had 26 habitat classes while LCM 2007 used in this research has only 23 habitat classes.

in Wales derived from the 2001 Census and updated with mid-2005 population estimates was obtained from the Office for National Statistics (<http://www.statistics.gov.uk/hub/index.html>, accessed on 15/03/12). In total, Wales currently has 316 populated settlements with total population of 2,551,327. Equated to 'Urban' habitat category used in the original study (Mourato *et al.*, 2010), each of the settlements was located using LCM. In order to estimate the number of properties affected by the new woodlands, housing and population statistics for Wales were used. Based upon the total population of Wales in mid-2010 of 3,006,400,⁸ and a total number of dwellings of 1,349,636 in 2010-11,⁹ an average population of 2.23 persons per dwelling was used to estimate the number of houses in each urban area.

Estimates of the number of urban houses affected by the new woodland creation were then obtained by intersection of urban polygons with the grid squares containing new woodland area, and then assuming proportionality coefficients equal to a ratio of the area of the urban polygon selected to the total urban area for a particular settlement. The latter is based upon adopting the simplifying assumption that population density is uniform across the urban areas considered.

The amenity benefit per hectare of new woodland was then derived as the product of three terms. These are the amenity benefit per property associated with a 1% increase in the woodland land cover share, the mean number of properties affected per hectare of woodland created, and the percentage increase in the land cover share associated with planting one hectare:

Amenity benefit (£/ha/yr) = Amenity benefit for 1% increase in LCS (£/yr/%) x Mean number of properties affected x Change in the LCS per hectare (%/ha)

The first term, the amenity benefit (£/yr), is the annual flow measure estimated as outlined above. The second term, the number of properties affected by one hectare of new woodland is estimated by dividing the total number of properties within 1 km of the new woodland (estimated from the spatial analysis for the 84 one kilometre grid squares which contain both the new Glastir woodland and urban settlements), by the total area covering new woodland (ie. 1,381 ha). This allows for areas of woodland planted near urban areas and those planted more than one kilometre away. Finally, the last term, the change in LCS per ha of new woodland effectively drops out of the equation as one hectare in a 1 km grid square (i.e. 100 ha) equals 1% by definition.

In the absence of estimates of how landscape amenity benefits change over time, a similar approach to that used in estimating biodiversity benefits in a recent study for

⁸ (<http://wales.gov.uk/topics/statistics/headlines/population2011/110630/?lang=en>, accessed on 15/03/12).

⁹ (<http://wales.gov.uk/topics/statistics/headlines/housing2012/120222/?lang=en> and <http://wales.gov.uk/docs/statistics/2012/120222sdr252012en.pdf>, accessed on 15/03/12).

Defra (Nisbet *et al.*, 2011) is adopted in this study. The benefits are assumed to have zero value at the year of planting and to increase linearly until the benefits are fully realised and their maximum values are reached once the trees are a certain age, continuing at the maximum thereafter. For sensitivity analysis, the age at which maximum benefits are reached is ranged (55, 20, or 10 years old).

For each of these three scenarios, the aggregate amenity benefits for each year of planting are computed by multiplying the per hectare amenity benefit associated with a woodland of a particular age by the number of hectares created. The total aggregate amenity benefits are then derived as the sum of the amenity benefits for the woodland planted in each year.

2.9 Health

A benefits transfer approach is also taken to estimating health benefits associated with new woodland creation under the Glastir scheme based upon estimates from Mourato *et al.* (2010). The later study used recent geo-referenced survey data (with 1,851 respondents) to estimate the physical and mental health effects associated with UK greenspace, finding that physical exercise has a positive relationship with all health measures used in the study. Significant relationships with environmental variables were identified, including the finding that higher land cover of non-coniferous woodland within 1km of the home is positively associated with health utility scores (Mourato *et al.*, 2010, p. 74). Linking changes in health utility score due to changes in the environment to Quality Adjusted Life Years (QALYs), tentative monetary estimates ranging from £8 to £27 per person per annum are estimated for a 1% increase in the land cover share of broadleaved or mixed woodland within 1 km of the home (Mourato *et al.*, 2010, p. 78, Table 18). Based upon one QALY being valued at £6,414 - £21,519 in 2009 (Mason *et al.*, 2009), the estimates suggest £17.50 as a central estimate.

These estimates, reflatd to 2012 prices, are applied in the current study, by combining them with population estimates derived using the following methodology. Firstly, a 1km buffer was applied to the 1,381 ha where new woodlands were created under Glastir in 2011 in order to identify urban polygons within 1 km of these. Secondly, a number of points were placed randomly in the urban polygons and, for every point, a 1 km circle was drawn. The number of random points chosen was increased for larger urban polygons, and ranged from only two points for polygons less than a hectare in size, to 185 points for the largest urban polygon (543 ha) identified, with 1,634 points used in total. Thirdly, the area of intersection between the point buffers and areas with new woodland were identified and an average change in broadleaved / mixed woodland land cover share for points within each urban polygon estimated. Fourthly, to estimate the population affected, proportionality coefficients were applied to the population of each of the urban areas equal to the ratio of the area of the urban polygon to the total urban area for the particular settlement. (Note the latter step similarly assumes population

density to be uniform across urban areas). Fifthly, and the mean percentage increase in woodland land cover share within a 1 km radius for each urban polygon was estimated as the mean number of hectares of new woodland within a 1 km radius by dividing by π .¹⁰ Sixthly, for each urban polygon, the health benefit associated with new woodland planting was estimated as the product of the population affected, the health benefit per person associated with a 1% increase in woodland land cover share, and the mean increase in land cover share due to new woodland planted. Finally, the health benefit per hectare of new woodland was estimated as the sum of the health benefits for each urban polygon divided by the total new woodland area (i.e. 1,381 ha). The per hectare health benefit calculations are summarised in the following formula:

$$B^k = \frac{H^k}{F} \cdot \sum (P_i \cdot S_i).$$

where: i is an index of the urban polygons affected (132 in total); B^k is health benefit value per ha of new woodland and H^k the health benefit per person for a 1% increase in woodland land cover share, where k denotes low, central or high health estimates from Mourato *et al.* (2010); F is total area of new woodland planted (1,381 ha); P_i is the population affected; S_i is the mean percentage increase in woodland land cover share within a circle of 1 km radius.

As with the amenity benefits, assumptions about the temporal distribution of the health benefits were needed. In the absence of estimates of how health benefits of proximity to woodland vary with the age of the woodland, a similar approach was adopted, assuming the benefits are zero in the year of planting and increase linearly until maximum values are reached once the trees are a certain age (either 55, 20, or 10 years old), and continuing at this level thereafter.

2.10 Aggregate Amenity and Health benefits

Mourato *et al.* (2010) note that their amenity estimates cover a range of benefits associated with living in or within close proximity to desirable natural environments that potentially include physical and mental health benefits. They note that new research is needed in to separately estimate different benefits.

In this study a simple approach to aggregation is adopted. For the low estimate it is assumed that there is complete overlap of health and amenity benefits, with the higher of the two selected and the other not taken into account. For the central estimate, it is assumed that half of the lower benefit is covered by the higher one, with half the lower benefit then added to the higher benefit in estimating the aggregate benefit. For the

¹⁰ Note there are about 314 ha in a circle of radius 1km, with 1 ha equivalent to around 0.32% of the total area.

high estimate no overlap is assumed between the amenity and health benefit estimates, and they are simply summed.

2.11 Agriculture

The impact on the value of agricultural production (and the opportunity cost of land in general) is a key cost of woodland creation (Valatin, 2012) that can encompass three elements. Firstly, there is the direct loss in the net value of annual agricultural (or other) production flows due to the change of land use. Secondly, there can be a reduction in land value due to a loss of option value resulting from felling licence requirements for replanting after felling precluding subsequent land use changes. Thirdly, there may be wider (e.g. hydrological) impacts of land use change. In this study we focus on the first of these.

A range of agricultural opportunity cost assumptions have been adopted in previous studies of woodland creation. In analysis for the Read Report (ADAS, forthcoming), for example, agricultural opportunity costs ranging from £50/ha/yr to £350/ha/yr are assumed, based upon net farm income adjusted for rent (and reduced by 25% to allow for environmental and sporting benefits, and the use of more marginal land).

For the purposes of generating indicative estimates for this study, for the low estimate a similar approach is adopted to ADAS (forthcoming), but based upon the gross margin (income less variable costs excluding labour) to allow for potential inflexibility in farmers reducing fixed costs and on-farm labour,¹¹ rather than the net margin. As the data provided by FCW suggests that almost half the area where new woodland was created under the Glastir scheme in 2011 was at altitudes below 200m (Table 2 above), it was decided to focus upon lowland agricultural opportunity costs for the low estimate.

Drawing upon the Welsh Farm Income Booklet 2011/12 results

(<http://www.aber.ac.uk/en/ibers/enterprise-kt/fbs/fbs-database/booklets/b1011/>), an opportunity cost of -£400/ha/yr at 2012 prices was adopted for the low estimate based upon the average gross margin of £592 per effective hectare of farmland for lowland sheep and cattle farms in Wales that year, reduced by 25% following similar reasoning to ADAS (forthcoming). This level is a third greater than the payments of £300/ha/yr currently available for 15 years to cover agricultural opportunity costs under the Glastir scheme and could be considered a premium to reflect existing uncertainty about the average level of grant payments required to induce the level of woodland creation envisaged.

For the central estimate, it is assumed that the agricultural opportunity cost of land conversion is relatively low at -£50/ha/yr at 2012 prices, a similar level to the low

¹¹ Thanks to Alistair McVittie (Scottish Agricultural College) for suggesting a focus on gross margins.

estimate used by (ADAS, forthcoming). This could be consistent with cases where the least productive agricultural land is converted to woodland (e.g. areas of bracken),¹² or where there is little net impact upon the total value of agricultural production of the farm (e.g. due shelter or other benefits for agricultural productivity largely off-setting the reduction in the area available for agriculture).

For the high estimate, it is assumed that land use change has a beneficial effect. This could be due to woodland displacing existing loss-making agricultural activities. According to the latest survey of UK agriculture (Defra, 2010, Table 2.5, p.9), for example, more than a tenth of farms in Wales (11%) had a net farm income below zero in 2009/10. Alternatively, a beneficial effect could arise where there are environmental disbenefits of existing activities. Spencer et al (2008), for example, provide tentative estimates of positive and negative environmental impacts of UK agriculture,¹³ implying that total negative impacts in 2007 (£2,600m),¹⁴ were more than double total positive impacts (£1,200m),¹⁵ suggesting an average net negative environmental impact of the order of -£75/ha/yr.¹⁶ While the estimate for the largest negative environmental impact, that for greenhouse gas (GHG) emissions, would increase substantially were current social values of carbon applied, per hectare impacts of land use change from agriculture on total GHG emissions could be far lower if agricultural activities are simply intensified elsewhere (i.e. if 'leakage' occurs). A tentative estimate of £50/ha/yr for the potential benefits of land use change from existing agricultural activities is adopted in this study for the high estimate.

¹² FCW suggested that the existing land cover of the agricultural land converted to woodland would be most likely to be bracken (Bill MacDonald, pers. com.). Note that the Welsh Farm Income gross margin estimates are based upon effective hectares, excluding wasteland, as well as some other categories such as rough grazing.

¹³ Separate estimates are not provided in Spencer et al (2008) for Wales in each case.

¹⁴ Estimated negative impacts are associated with green house gas emissions (-£1,413m), air quality (-£634m), flooding (-£234m), drinking water (-£130m), water abstraction (-£62m), rivers (-£62m), lakes (-£27m), bathing waters (-£11m), soil (-£9m), waste treated off-site (-£8m), estuaries (-£3m), and pollution incidents (-£1m).

¹⁵ Estimated impacts include landscape & habitats (£853m), biodiversity associated with farmland birds (£307m), waste sinks avoiding sewerage waste incineration (£35m), and linear features (£2m).

¹⁶ While not accounting for food security issues, it is notable that the estimated average net environmental impact appears larger in magnitude than the mean social value of agricultural production. For example, subtracting total subsidies of £3,013m in 2007 (£3,196m in 2010) from total income from farming of £2,886m in 2007 (£4,337m in 2010) would imply an agricultural profit net of subsidies of -£7/ha in 2007 (£62/ha in 2010). Separate estimates are not available in Spencer et al (2008) for Wales in each case.

2.12 Forestry Costs

Estimates of average forestry establishment costs for different types of woodland were provided by FCW. These indicate average costs in 2010 of £2,684/ha for standard planting, £2,835/ha for simple mixtures, £4,817/ha for quality mixtures, and £4,137/ha for native woodlands. Referred to 2012 prices using estimates for the Treasury GDP deflator, the assumed spread over the first four years based upon the types of operation involved¹⁷ is shown in Table 3 below. The mean forestry establishment costs will depend upon the proportion of the different types of woodland created. For the purposes of this study, it is assumed that the proportions of new woodland planted under the Glastir scheme in 2011 (0% standard, 1% simple mixtures, 5% quality mixtures, and 94% native woodland) also hold for the 86,000 ha of new woodland planted. This implies the mean costs per hectare in the first four years shown in Table 3.

Table 3. Average forestry establishment costs in Wales in 2010 (at 2012 prices)

	Standard planting (£/ha)	Simple mixtures (£/ha)	Quality mixtures (£/ha)	Native woodlands (£/ha)	Mean assumed (£/ha)
Year 1	2,053	2,024	4,092	3,466	3,485
Year 2	454	482	478	441	443
Year 3	234	393	418	364	367
Year 4	88	88	88	88	88

For sensitivity analysis, the cost estimates are ranged. For the low estimate, forestry costs are assumed to be 10% higher, equivalent to a present value of about £4,700/ha (a level that exceeds the top rate for woodland establishment grants currently paid under the Glastir scheme of £4,500/ha). For the high estimate, forestry costs are assumed to be 35% lower than the central estimate, equivalent to a present value of about £2,800/ha, a similar level to establishment costs for standard planting.

2.13 Future costs, prices, and values

For the purposes of this study, future costs and prices are assumed to remain at their 2012 level in real terms. (Note, however, that the social value of carbon is assumed to change). Costs and benefits are then compared in present value terms by applying Treasury Green Book discount rates (Treasury, n.d., Table 6.1, p.99).

¹⁷ First upkeep, weeding, and beat-up, for example, are assumed to occur in year 2, second in year 3, etc, with annual inspection costs assumed to be 20% of other costs each year.

Prices, costs and values are expressed in 2012 prices, with estimates from earlier years reflatd using the Treasury GDP deflator.¹⁸ An exception to this is the December 2011 house price for Wales which, in view of the current state of the housing market, is assumed to remain the same in 2012.

2.14 Climate change cost-effectiveness

Current government guidance on estimating cost-effectiveness in appraisal and evaluation (DECC and HM Treasury, 2010, p.25) recommends deriving the cost-effectiveness of a measure by dividing its net present value (NPV) excluding the present value of the carbon benefits by (the negative of) the total tonnes of carbon dioxide equivalent saved. Whether a measure is cost-effective is then determined by comparing the cost per tonne of carbon dioxide equivalent abated with the relevant cost comparator based upon estimates of the social value of carbon. The relevant cost comparator is computed as the weighted average discounted social cost of carbon, where the weights are the proportion of carbon savings in each year, the social cost of carbon is taken from DECC social value of carbon central estimates, and discounting is based upon the approach in the Treasury Green Book. In the current study this approach for the central estimates is followed in estimating the climate change mitigation cost-effectiveness of the woodland creation envisaged in Wales. However, for sensitivity analysis, the low and high social values of carbon are used in computing cost comparators for the low and high cost-effectiveness estimates.¹⁹

3 Results

3.1 Carbon

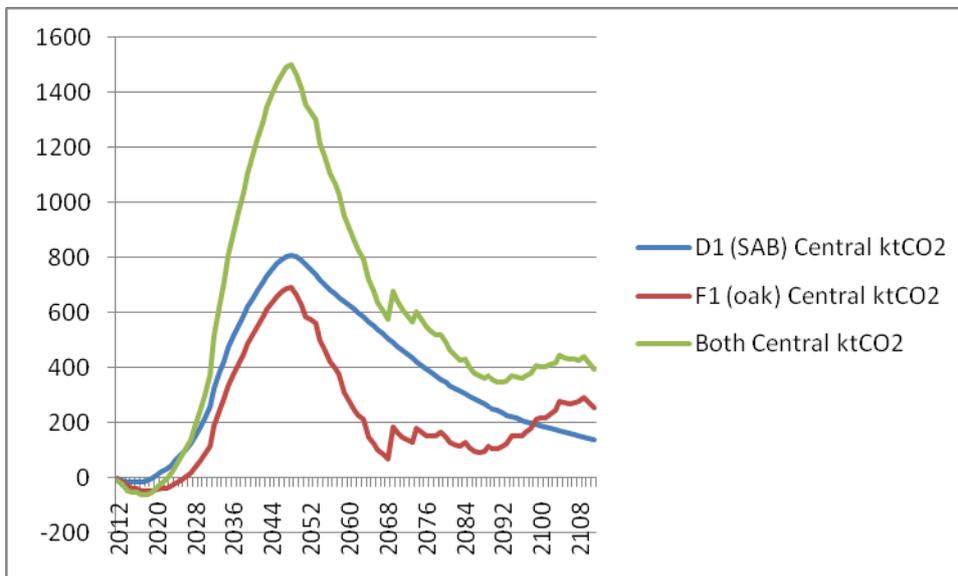
As both carbon sequestration rates and carbon values vary over time, the estimated values of carbon sequestered vary annually. As a consequence of factors including soil

¹⁸ Available at: http://www.hm-treasury.gov.uk/data_gdp_fig.htm (accessed 14th Feb 2012).

¹⁹ Methods used to estimate the various benefits and costs are different, but are considered broadly consistent for the purposes of calculating the NPV. For example, in contrast to most other benefits, wood production and agricultural opportunity cost estimates relate to impacts on producer surplus rather than consumer surplus. However, if (as is often assumed), land owners are essentially price-takers, with wood prices in the UK determined by prices of timber imports, and agricultural prices and aggregate output levels set through the Common Agricultural Policy or prices just reflecting international markets, no significant changes in consumer surplus would be expected. Similarly, for amenity and health benefits, in the absence of landowners being able to capture any of the higher values for nearby properties associated with woodland creation on their land, further changes in producer surplus would not be expected.

disturbance and use of machinery for planting, the estimates show net carbon emissions in the first three years from planting for SAB and in the first four years for oak. Under the central estimates, carbon sequestration remains negative for the first eleven years from 2012 to 2022 as a consequence of the increasing rate of woodland creation. This is followed by increasing abatement rising to a maximum around 1.9 MtCO₂/yr (central estimate) in 2048, thereafter declining for the next twenty years, and then becoming more variable as a consequence of the ATC selection regime for oak (see Fig 1 below). The mean carbon sequestration rate over the 100 year period is about 0.59 MtCO₂/yr (central estimate).

Figure 1: Carbon sequestration estimates (thousand tonnes of CO₂ sequestered a year)



Estimates of the aggregate impacts are summarised in Table 4 below. These suggest total net sequestration over 100 years due to planting an additional 86,000 ha of new woodland ranging from 41 MtCO₂ (low estimate) to 76 MtCO₂, (high estimate), with a central estimate of 59 MtCO₂.

Table 4. Estimated net carbon sequestration over 2012-2111 (MtCO₂)

	Sycamore/Ash/Birch (MtCO ₂)	Oak (MtCO ₂)	Total (MtCO ₂)
Low estimate	25.5	15.5	41.0
Central estimate	36.6	22.6	59.3
High estimate	46.8	29.2	76.0

Valuing the net carbon sequestration at the low, central and high social values of carbon recommended by DECC for sectors not covered by the EU emissions trading scheme implies that the present value of the carbon sequestered ranges from around £820m to £5,200m with a central estimate of £2,600m at 2012 prices. (This is based upon reflating DECC social values of carbon at 2011 prices by 2.8% based upon the Treasury's forecast for the GDP deflator).

Taking account of carbon substitution of wood for fossil fuel in heat generation and of wood for more energy-intensive materials in construction as well (and assuming complete revolatisation of carbon stored in harvested wood products at the end of the 100-year time-horizon), increases the level of the total carbon savings by around one tenth (see Table 5), with associated present values ranging from over £870m to £5,500m, with a central estimate of £2,800m at 2012 prices.

Table 5. Total carbon sequestration and substitution 2012-2111 (MtCO₂)

	Sycamore/Ash/Birch (MtCO ₂)	Oak (MtCO ₂)	Total (MtCO ₂)
Low estimate	25.5	18.2	43.7
Central estimate	36.6	27.4	64.0
High estimate	46.8	34.9	81.8

In addition, estimated carbon benefits of using wood in electricity generation range from 1.5 MtCO₂ (low estimate) to 2.8 MtCO₂ (high estimate), with a central estimate of 2.2 MtCO₂. As these occur in a sector covered by an emissions cap under the EU ETS, these are not considered to provide additional carbon savings above those expected to occur anyway, resulting instead in displacement of other fuel (e.g. renewable) types. However, reducing the need for other abatement measures, they can be valued at social values of carbon applying to the traded sector, implying associated present values ranging from around £26m to £190m at 2012 prices, with a central estimate of £92m.

3.2 Wood

C-Sort model estimates for the oak option focused upon imply an average wood production of 1.6 cubic metres per hectare in total over a 100-year time horizon due to the ATC-selection. The first wood is assumed to be extracted in year 48, with subsequent extraction at five-yearly intervals.

For the 31,820 ha of the oak option assumed, total wood production over the period 2012-2111 is estimated at between 23,000 m³ (low estimate) and 42,000 m³ (high estimate), with a central estimate of 33,000 m³. The associated estimated present value ranges from £35,000 (low estimate) to around £130,000 (high estimate) at 2012 prices, with a central estimate of £73,000.

3.3 Agriculture

Based upon assumed impacts of land use change from agricultural activities ranging from -£400/ha/yr (low estimate) to £50/ha/yr (high estimate), associated present values over the 100-year time horizon range from around -£12,000/ha (low estimate) to £1,500/ha (high estimate), with a central estimate of -£1,500/ha. Present values for impacts on existing agricultural activities of land use change on the total of 86,000 ha over 2012-2111 range from around -£720m (low estimate) to £90m (high estimate), with a central estimate of -£90m.

3.4 Forestry costs

Assuming per hectare present values of forestry establishment costs ranging from around -£4,800/ha (low estimate) to -£2,800/ha (high estimate), estimated present values of the total cost of establishing the 86,000 ha of new woodlands range from -£290m (low estimate) to -£170m (high estimate), with a central estimate of -£260m at 2012 prices.

3.5 Amenity

The spatial analysis of the 84 one kilometre grid squares where both new woodland and nearby urban settlements were present estimated that in total around 30,000 properties were within one kilometre of the new woodland. Dividing by the total area (including woodland planted in other grid squares) implied on average each hectare of new woodland affected about 21 properties.

A 0.215% change in property price in response to a 1% increase in broadleaved and mixed woodland land cover share (estimated using method outlined in section 2.8)

equates to about £314 for an average house in Wales. This is based upon average value of £145,926 in December 2011.²⁰

The estimated maximum annual amenity benefit per property for a 1% increase in broadleaved and mixed woodland land cover share depends upon the time it takes for the annual amenity benefit to reach its maximum, as shown in Table 6 below:

Table 6. Maximum annual amenity benefits per property (£/yr)

Number of years taken to reach maximum benefit	Maximum annual benefit (£/yr)
10-year	11.47
20-year	13.20
55-year	19.93

Despite being associated with lower maximum amenity values than the 55-year scenario, due to the shorter time to reach the maximum value, the present value of the flow of annual amenity benefits within a time-frame of 100 years or less is always highest for the 10-year scenario, followed by the 20-year one. The figures for the 10-year, 20-year, and 55-year scenarios were therefore adopted for the high, central, and low estimates, respectively. These were then multiplied by the average number of properties affected per hectare of woodland created. This gives the estimates of the maximum annual amenity values per ha of woodland created shown in Table 7.

Table 7. Maximum amenity benefits per ha of woodland created (£/ha/yr)

Scenario	(£/ha/yr)
10-year (High)	246
20-year (Central)	284
55-year (Low)	428

Based upon the level of woodland planting assumed in each year to create 86,000 ha of new woodland, the present value of total amenity benefits over the 100 year time horizon were estimated to range from about £340m (low estimate) to £370m (high estimate), with a central estimate around £360m at 2012 prices.

²⁰ Table A2: Mix-adjusted average house prices by region from: <http://www.communities.gov.uk/housepriceindex> (accessed on 15/03/12).

3.6 Health

The analysis identified 66 urban settlements located within 1km of the area (1,381 ha) covering where new woodland was created under the Glastir scheme in 2011. As some settlements were intersected by the 1 km woodland buffers in several places, a total of 132 urban polygons were identified within 1km of areas of new woodland. Covering a total of 3,645 ha, the urban polygons varied considerably in size, from under a tenth of a hectare to a maximum of 543 ha, with a mean size of 27.6 ha and a median size of 5.8 ha. Based upon placing a total of 1,634 random points in the polygons, summary statistics showed that there were on average 0.77 ha of the area of new woodlands per polygon within a 1 km radius (ranging from nearly zero to a maximum of 9 ha), and 102 ha in total (i.e. under a tenth of the total area covering where new woodland was planted was within 1 km of an urban area). The estimated average population affected was 944 per urban polygon (ranging from nearly zero to a maximum of 19,244) and totalling 124,558.

The maximum annual health benefits per hectare of woodland created are estimated (see section 2.9) to range from about £500/ha/yr (low estimate) to £1,700/ha/yr (high estimate), with a central estimate of around £1,100/ha/yr at 2012 prices. Assuming these to also be typical of the health benefits of the 86,000 ha of new woodland to be created from 2012, implies present values over a 100 year time horizon ranging from about £400m (low estimate) to £2,600m (high estimate), with a central estimate of around £1,400m at 2012 prices.

4 Discussion

As noted above, the value of most of the ecosystem service impacts focused upon above can be expected to vary over time and to be sensitive to a range of underlying assumptions. Indicative estimates of the present value for each of the impacts and costs are summarised in Table 8 below, together with the NPV. Reflecting underlying sources of uncertainty (e.g. concerning the level of agricultural opportunity costs) and knowledge gaps, the Table indicates a wide range in the estimated NPV, from around £300m to £8,600m, with a central estimate of about £4,200m.

Table 8: Indicative present values of net ecosystem service impacts (£m at 2012 prices)

	Low (£m)	Central (£m)	High (£m)
Climate regulation	901	2,899	5,736
Wood production	0.03	0.07	0.13
Amenity	339	363	369
Health	402	1,421	2,559
Amenity and Health ¶	402	1,603	2,928
Agricultural production	-718	-90	90
Forestry costs	-286	-260	-169
Net Present Value	299	4,152	8,585

¶ see subsection 2.10 on aggregation of amenity and health benefits.

Each NPV (excluding carbon benefits) was divided by the (negative of) the estimated total carbon dioxide saved (which, as Table 5 above shows, ranges from about 44 MtCO₂ to 82 MtCO₂, with a central estimate of 64 MtCO₂). This gives climate change mitigation cost-effectiveness estimates ranging from -£37/tCO₂ (for the high estimate) to £13/tCO₂ (for the low estimate), with a central estimate of -£21/tCO₂ at 2012 prices.²¹ As in each case these are below the associated cost-effectiveness comparator (estimated to range from £22/tCO₂ for the low estimate, to £76/tCO₂ for the high estimate, with a central estimate of £49/tCO₂ at 2012 prices), the woodland creation is judged cost-effective as a climate change mitigation measure.²²

²¹ Negative values imply that woodland creation is cost-effective even without considering the carbon saved in the non-traded sector.

²² Note that were the comparator based upon the central social value of carbon estimates, the low estimate would appear far more cost-effective.

References

- ADAS (forthcoming). Analysis of Policy Instruments for Reducing Greenhouse Gas Emissions from Agriculture, Forestry and Land Management – Forestry Options, Report to Forestry Commission England, ADAS, Abingdon, Oxfordshire. (Final draft versions dated June 2009 & July 2011).
- CEH (2011). Land Cover Map 2007 Dataset documentation. Centre for Ecology & Hydrology, Wallingford, <http://www.countrysidesurvey.org.uk/sites/default/files/LCM2007%20Dataset%20Documentation%20-%20Version%201.pdf>.
- DEFRA (2010). Agriculture in the United Kingdom. DEFRA, Department for Agriculture and Rural Development (Northern Ireland), Scottish Government Rural and Environmental Research and Analysis Directorate, and Welsh Assembly Government Department for Rural Affairs and Heritage, <http://www.defra.gov.uk/statistics/foodfarm/cross-cutting/auk/>.
- Mason, H., Jones-Lee, M. AND Donaldson, C. (2009). Modelling the monetary value of a QALY: A new approach based on UK data. *Health Economics* 18, 933-950.
- Mourato, S., Atkinson, G., Collins, M., Gibbons, S., Mackerron, G. and Resende, G. (2010). Economic assessment of ecosystem related UK cultural services. UK NEA Economic Analysis Report. The Economics Team of the UK National Ecosystem Assessment, London School of Economics. London. Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx>
- NEA (2011). UK National Ecosystem Assessment. UNEP-WCMC. Cambridge, <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx>.
- Nisbet, T., Marrington, S., Thomas, H., Broadmeadow, S. and Valatin, G. (2011). Slowing the Flow at Pickering, Final Report to Defra of FCERM Multi-objective Flood Management Demonstration Project RMP5455, <http://www.forestresearch.gov.uk/fr/INFD-7ZUCQY#final1>.
- Spencer, I., Bann, C., Moran, D., McVittie, A., Lawrence, K. and Caldwell, V. (2008). A Framework for Environmental Accounts for Agriculture. Report SFS0601 by Jacobs with Scottish Agricultural College and Cranfield University to DEFRA, Welsh Assembly Government, Scottish Government, and DARD (N. Ireland), <http://webarchive.nationalarchives.gov.uk/20060213205517/http://statistics.defra.gov.uk/esg/reports/envacc/report.asp>.
- Treasury (n.d.). *The Green Book: Appraisal and Evaluation in Central Government*. http://www.hm-treasury.gov.uk/data_greenbook_index.htm.
- Valatin, G. (2012). Marginal Abatement Cost Curves for UK Forestry, Research Report, Forest Research, Edinburgh, <http://www.forestry.gov.uk/forestry/HCOU-4VXJ5B>.

Valatin, G. and Starling, J. (2010). Valuation of ecosystem services provided by UK Woodlands, appendix to chapter 22 of UK National Ecosystem Assessment, UNEP-WCMC/Defra, London. <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx>.

WAG (2010). Land Use Climate Change Report to Welsh Assembly Government. Carbon estimates included derived from Forest Research models, March.

West, V. and Matthews, R. (2011). Estimating woodland carbon sequestration from the Carbon Lookup Tables, Version 1.3, Forestry Commission, Edinburgh, <http://www.forestry.gov.uk/forestry/INFD-8jue9t>.



Forest Research
