8 - Valuation of ecosystem services provided by UK woodlands

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Executive Summary

i. Woodlands provide a wide range of ecosystem services. These include provisioning (e.g. fuel and fibre), supporting (e.g. soil formation), regulating (e.g. climate, flood hazard, noise, and air quality regulation), and cultural (e.g. cultural heritage, amenity, health, recreation and tourism) services. Ecosystem service provision is sensitive to land management objectives.

ii. Two provisioning (wood production and deer) and one regulating (carbon sequestration) are the focus of the NEA woodland habitat valuation exercise. (Several others are covered in other chapters).

iii. The total quantity of wood produced in the UK has risen substantially over the past three decades, more than tripling since the mid 1970s to over 8 million green tonnes currently as coniferous woodlands planted in the 20th century have matured. Mean standing sales prices for softwood fell in real terms by about two-thirds from around £30/m^3 overbark (£35 per green tonne) in 1971/2 to about £10/m^3 ob (£12 per green tonne) in 2009/10 at 2010/11 prices. This appears to follow a longer term downward trend.

iv. UK hardwood production has halved since 1976, reflecting factors including a shift in forest management objectives away from timber production towards provision of multiple ecosystem services. The limited evidence that exists suggests mean prices for UK hardwood probably fell by at least a third in real terms between 1989 and 2007/8. A drop in hardwood prices over the past two decades fits with reports of falling import prices for hardwood logs and a decline in demand by upstream sectors. The past decade was characterised by a collapse in purchases of UK-grown hardwood by UK sawmills and by pulp and paper mills, which together fell from over 400,000 green tonnes in 1999 to under 70,000 green tonnes in 2008.

v. Domestically-produced wood accounts for under a fifth of the total used in Britain. Changes in UK prices are thought to largely reflect changes in import prices.

vi. There has been little overall change in the total gross value of softwood from 1976 to the present. Falling real prices have been largely offset by increasing volumes as coniferous plantations matured.

vii. The apparent decline in hardwood prices combined with the fall in production suggests a decline in real terms of at least three-quarters in hardwood gross values between 1989 and 2007/8.

vii. Estimates show net carbon sequestration by UK woodlands planted after 1921 rising from 2.4Mt CO_2 in 1945 to a peak of 16.3MtCO_2 in 2004, subsequently falling to 12.9MtCO_2 in 2009. Over the period 2001-2009 they imply annual mean net sequestration rates of around 5.2tCO_2/ha across all UK woodlands (with an additional 0.3tCO_2/ha net increase in carbon storage in harvested wood products).

viii. If assumed permanent and valued at the DECC central social value of carbon estimate of £53/tCO_2 in 2009, the estimates suggest that the total value of net carbon sequestered by UK woodlands increased five-fold from £124m in 1945 to £680m in 2009 at 2010 prices. It would also imply a mean value per hectare of the carbon sequestered annually by UK woodlands (£239/ha) of more than double the mean value for softwood production (£66/ha) and of the order of ten times the value of hardwood production (£7-£25/ha) in 2009.

ix. Although by far the highest value of the three ecosystem services considered, carbon sequestration remains a largely non-market value, with little incentive at present for landowners to increase provision of this ecosystem service (or to maintain existing carbon storage). A Woodland Carbon Code is currently being developed to help stimulate emerging markets for carbon sequestration in the UK.

x. Forestry Commission forecasts of availability from existing British woodlands suggest that softwood production will continue to rise over the next decade, and then decline until the mid 2050s.

xi. Forecasts of net carbon sequestration based upon continuation of current rates of woodland creation indicate a drop of more than half in net carbon sequestration by woodlands alone from 2010 to 2028. When combined with changes in carbon storage in harvested wood products, the forecasts show combined net sequestration falling from 14.5MtCO_2 in 2010 to a minimum of 2.5MtCO_2 in 2034, before gradually rising to 3.3MtCO_2 by 2050. Analysis for the Read Report suggests an additional 12MtCO_2-15MtCO_2 per year could be sequestered in 2060 were a programme of enhanced afforestation of an additional 23,200ha a year adopted.

xii. Existing data gaps include the lack of consistent time-series data on hardwood standing sales prices, on woodfuel, on venison and stalking revenues, and on forestry costs. Knowledge gaps include spatial differences in marginal values between regions, woodlands types and forestry management approaches.

8.1 Introduction

Woodlands provide a wide range of ecosystem services (Quine et al, 2011). These include provisioning (e.g. fuel and fibre), supporting (e.g. soil formation), regulating (e.g. climate, flood hazard, noise, and air quality regulation), and cultural (e.g. cultural heritage, amenity, health, recreation and tourism) services. Seven provisioning services, twelve regulating services, four supporting services and ten cultural services were initially considered by the woodland science group as potential candidates for valuation. After excluding supporting services on the grounds that they are not 'final' but intermediate ecosystem services, and services (e.g. recreation and biodiversity) subject to valuation exercises across all habitat types in other chapters, the following three (two provisioning and one regulating) were selected on the grounds that availability of time-series data was expected to be relatively good:

i) Wood production (timber and fuel)

ii) Deer (stalking and venison)

iii) Carbon sequestration

Each of the three ecosystem service categories are considered in turn, with separate subsections covering hindcast and forecast periods – latter drawing upon existing forecasts.[1]

8.2 Provisioning: Wood Production

This section reviews the role that woodlands play in the production of wood for both timber and for woodfuel.

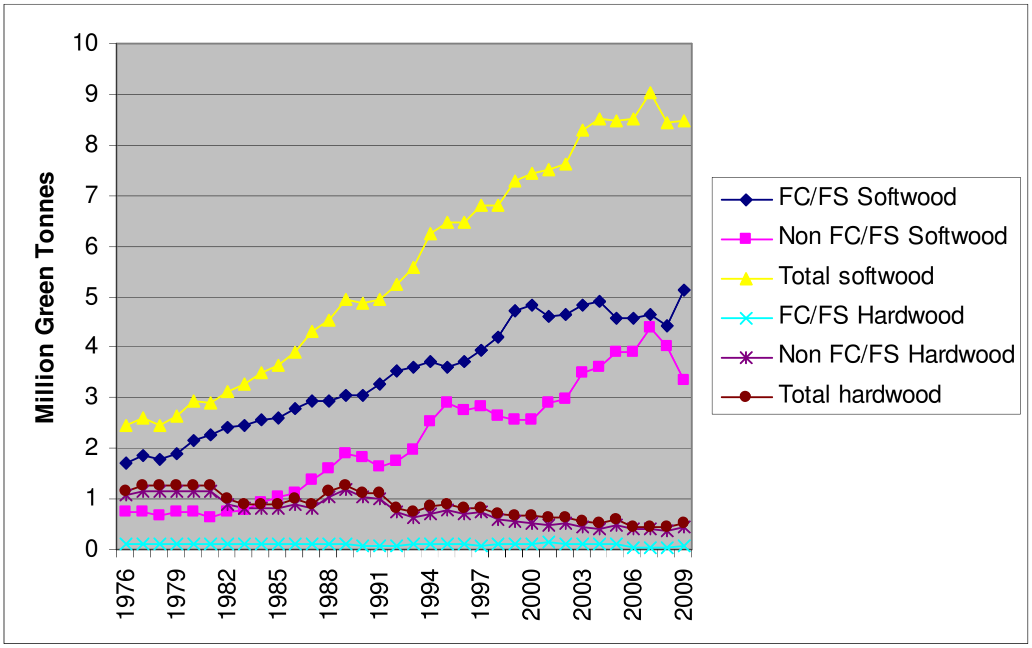
8.2.1 Wood Production, 1945-2010

Overall total UK wood production has risen substantially since the mid-1970s as forests have matured. For softwood, production by the Forestry Commission (FC) is the major element, while for hardwood, most production comes from the private

[1] It has not proved possible to link these with the work of the NEA scenarios group. The existing forecasts also do not take account of expected climate change impacts – although clearly an important area of ongoing research.

sector (see **Figure 1** below). Softwood production appears to have increased substantially since 1945.[2]

Figure 1 – Total wood production from UK woodlands (by source and type).

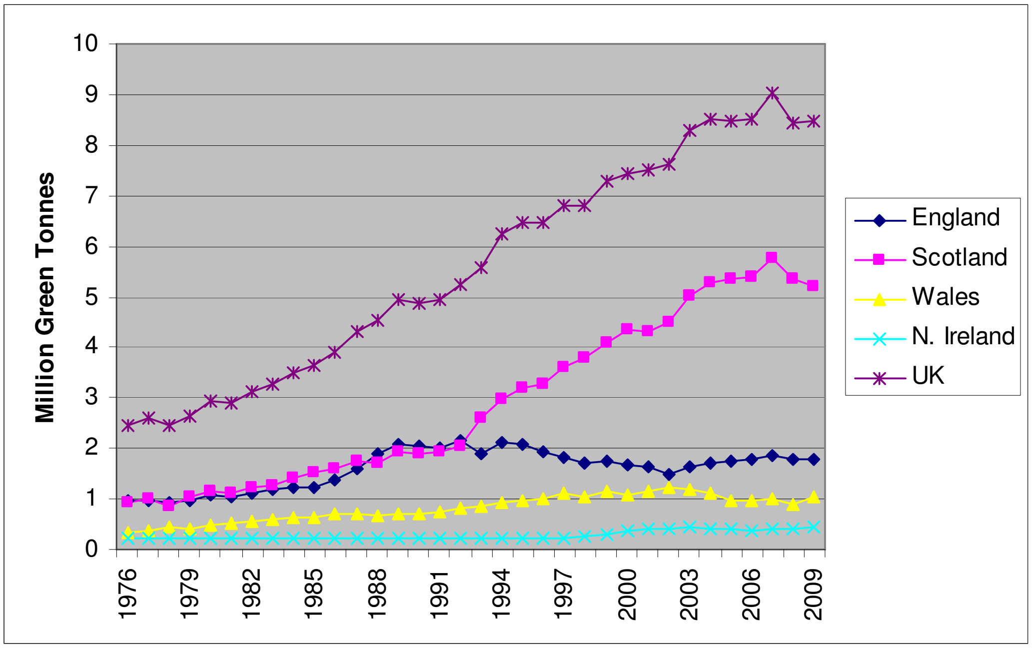


Source - *Forestry Commission.*

As this illustrates, the quantity of wood produced from Forestry Commission land tends to be more stable between years by comparison with wood harvested from private woodlands, as the latter is influenced to a greater extent by prevailing price levels. Since the mid 1990s softwood production has increasingly been concentrated in Scotland (see **Figure 2** below).

[2] Information from the Timber Trade Federation indicates that production of sawn softwood from UK woodlands was at a similar level in 1946 and 1976, having fallen to about one third of this level in several intervening years (1952, 1958, 1962) – see: Bateman and Mellor (1990, Fig 2).

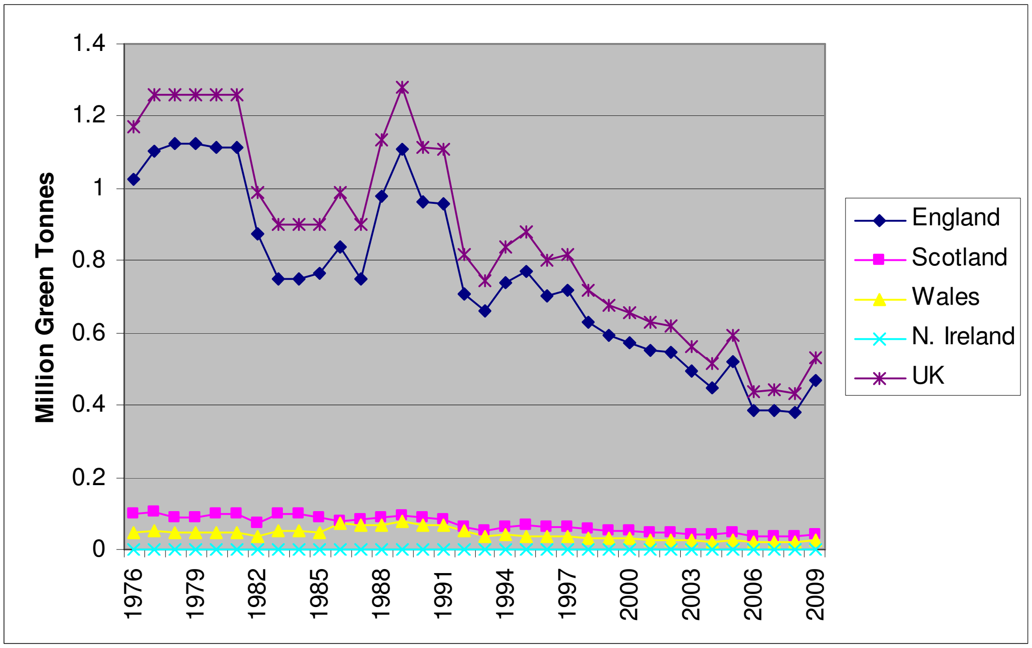
Figure 2 – UK softwood production by country (million green tonnes).



Source - *Forestry Commission.*

By contrast, hardwood production has declined since the mid 1970s, and is largely concentrated in England (see **Figure 3** below). High volumes in the period 1988-1990 were probably partly due to the series of storms from late 1987 to early 1990 (see: Quine, 2001, Table 2.5, p.29), including the storm of 16th October 1987 that damaged 3.9 million m^3 (13%-24% of the growing stock in S.E. England), and the 'Burn's Day' storm of 25^{th} January 1990 that damaged 1.3 million m^3 (1%-3% of the growing stock in south and west Britain).

Figure 3 – UK hardwood production by country (million green tonnes).



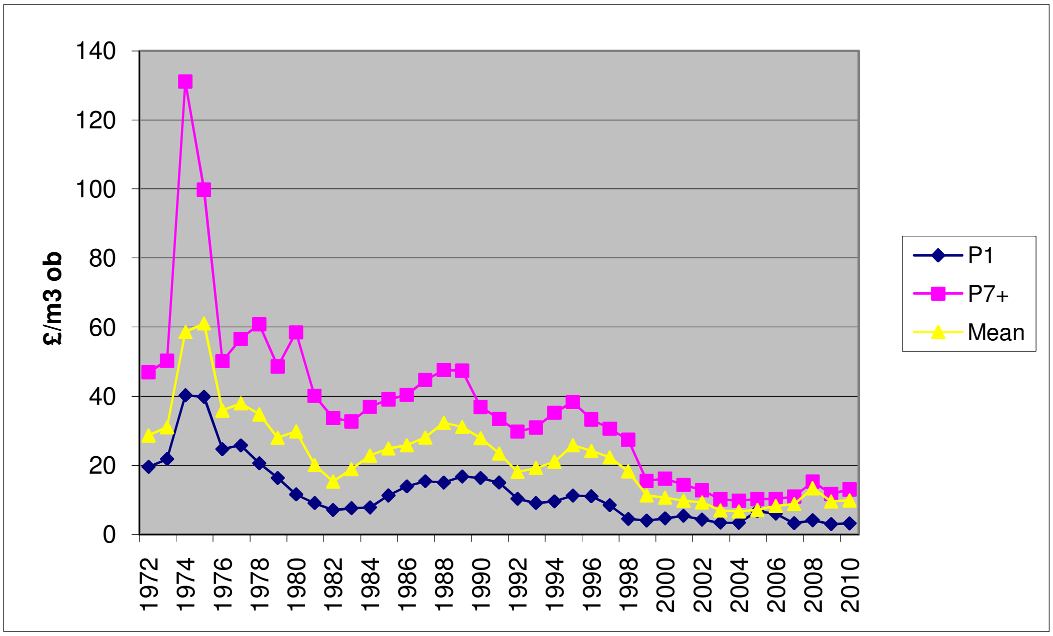
Source - *Forestry Commission.*

All wood currently produced from Forestry Commission land in Britain and Forestry Service (FS) land in Northern Ireland, as well as around 70% of wood from non-FC/FS land, is certified as meeting sustainable forest management criteria (FS, 2009, Table 2.29).

Previous studies mainly suggest that real timber prices (generally for sawn softwood) have not changed significantly over time except for during the commodity price boom during the 1970s (Bateman et al, 2003). However, over the period 1971/72 to 2009/10 mean softwood standing sales prices for the Forestry Commission estate fell in real terms by about two thirds, from around £30/m^3 overbark (£35 per green tonne) to £10/m^3 ob (£12 per green tonne) at 2010/11 prices (see **Figure 4** below).[3] This appears to follow a longer term downward trend, with the British softwood standing sales price index reported in FC (1977, Table 6.1) indicating a previous fall of around one quarter in real terms over the period 1958 to 1970-72. (See also: Mitlin, 1987, Fig 1, p.5, and Insley et al, 1987, section 1.6, Fig 1).

[3] More recent data on coniferous standing sales indicates a rise to £12/m^3 ob (equivalent to about £15 per green tonne) for the year to September 2010 (FC 2010b).

Figure 4 – Softwood standing sales prices in Britain by tree size (at 2010/11 prices).

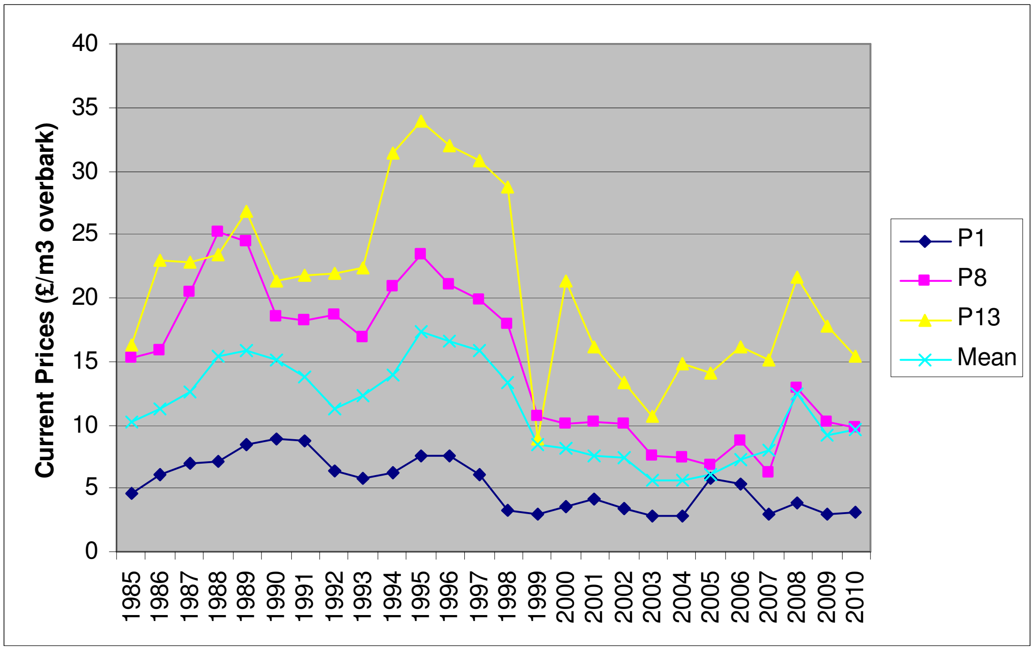


Notes: data for financial years ending in March of year shown;

Tree sizes: P1: ≤ 0.074m^3; P7+: ≥0.425m^3; Mean: all size categories (P1-P7+).

Forest management decisions regarding rotation length can affect the prices for selling wood to the extent that prices tend to be higher for larger (i.e. generally older) trees. Small trees are generally of lower value as they cannot be used for producing sawlogs (which tend to be relatively high value). Relationships between tree size and price are traditionally modelled as price-size curves (Mitlin, 1987, Whiteman, 1990, Whiteman et al, 1991, Sinclair and Whiteman, 1992, Pryor and Jackson, 2002, Bateman, *et al*, 2003). However, as the graph below (**Figure 5** at unadjusted prices) illustrates, the largest trees are not invariably the most valuable, and a range of other factors including species mix, quantity sold, timber quality, site conditions, and strength of local demand also influence prices.

Figure 5 – Softwood standing sales prices in Britain by tree size (current prices).



Notes: data for financial years (ending in March of year shown);

Tree sizes: P1: ≤ 0.074m^3; P8: 0.500-0.599m^3; P13: ≥ 1m^3;

Mean: all sizes (P1-P13).

Source - *Forestry Commission.*

Very little time-series data on hardwood standing sales prices is available at present.[4] The mean price for all hardwood sales in 2007/8 by the Forestry Commission in England (which accounted for over 90% of hardwood sales by the Forestry Commission that year, although less than 10% of total UK hardwood production) was around £15/m^3 (equivalent to about £18 per green tonne at 2010/11 prices). Standing sales prices for the fraction (around 10,000 green tonnes a year) sold through the annual hardwood auction at Westenbirt were around £22 and £19 per green tonne in 2008 and 2009 respectively at 2010/11 prices.[5]

[4] Historical data - including values of a UK-grown hardwood wholesale price index for 1963-1971 (TTF, 1972, Table 31), of a UK-grown sawn hardwood price index for the early 1980s (UNECE & FAO, 1985, Annex Table 3, p.45) and up to the mid 1990s, suggests an upward trend in hardwood prices for parts of the period from the early 1960s to the mid 1990s. While a graph of the index of the real price of home-grown hardwood logs in Whiteman et al (1991, Fig 8, p.16) suggests little overall trend over the period 1958-1989, extending the graph to the mid 1990s suggests a slight upward trend over the extended period (although the series appears to be for sawnwood rather than logs).

[5] See: http://www.forestry.gov.uk/forestry/hcou-4u4jgj. However, for a number of reasons these prices are thought to be above the average for all UK hardwood standing sales.

In the absence of more comparable data, the Forestry Commission price data might be compared to hardwood prices for all British woodlands reported in a 1989 survey. In real terms, the mean hardwood price reported for 1989 (Whiteman et al, 1991, Table 7, p.23) of £47.50/m^3 at 1990/91 prices (equivalent to around £90 per green tonne at 2010/11 prices) is more than double the mean price for Forestry Commission England hardwood sales in 2007/8. A higher mean price in the 1989 survey may not be entirely surprising given that the Forestry Commission estate in England contains few broadleaf stands of comparable size and quality to those in private woodlands. However, it is notable that the mean price in 1989 of the lowest quality grade hardwood (used for fuelwood, pulpwood, boardwood, and stakes) of £14/m^3 at 1990/91 prices (equivalent to around £26 per green tonne at 2010/11 prices) was also higher in real terms than the mean price for Forestry Commission sales in England in 2007/8. As the latter are not confined to the lowest quality category (including higher quality material too), the 2007/8 mean price for Forestry Commission sales in England can be considered to provide an upper bound estimate of the price of the lowest grade hardwood that year (as well as a lower bound estimate of the mean price for all hardwood sales). If the ratio of the price of the lowest grade hardwood to the mean is assumed to be no greater than in 1989,[6] this suggests a higher bound estimate for the mean hardwood price in 2007/8 of around £55/m^3 (equivalent to about £61 per green tonne at 2010/11 prices). Were changes in hardwood prices simply assumed to reflect changes in softwood prices over this period, this would imply an intermediate mean hardwood price in 2007/8 of around £35/m^3 (equivalent to about £39 per green tonne at 2010/11 prices).

Comparison of evidence from the two sources suggests that hardwood prices probably fell by at least a third over this period. However, as the prices include both direct production (wood sold after the trees are harvested and extracted from the woodland) and standing sales (wood sold with trees still standing), difference between years might partly reflect different proportions of standing sales and direct production. Nonetheless, a drop in average hardwood prices in real terms over the

[6] Renewed interest in using woodfuel may imply a recent narrowing of this ratio.

past two decades appears consistent with reports of falling import prices for hardwood logs[7] and apparent decline in demand for UK-grown hardwood by some upstream sectors. The past decade has also been characterised by a collapse in purchases of British hardwood by UK sawmills and by pulp and paper mills, which fell from 227,000 and 191,000 green tonnes respectively in 1999 to 67,000 green tonnes and zero in 2008, with numbers of UK sawmills processing hardwoods roughly halving (FC, 2009, Tables 2.7 and 2.11). Overcapacity and investment in Eastern European mills are also considered important factors in this (Lawson & Hemery, 2007).

With domestically grown wood accounting for less than a fifth of the total wood used in the UK (FC, 2009, Table 3.1), the UK is generally assumed to be a price-taker with respect to global prices (McGregor & McNicoll, 1992, Thomson & Psaltopoulos, 2005, Lawson & Hemery, 2007), and the supply of imported timber perfectly elastic at the world price (Bateman & Mellor, 1990). To the extent that UK standing sales prices simply reflect changes in prices on the world market,[8] the marginal value of wood produced by UK woodlands can be considered independent of the quantity produced.

Wood production can be valued at standing sales prices, at roadside prices, or using an average of these. Having to cover harvesting and extraction costs, roadside prices tend to be higher than standing sales prices, but as differences relate principally to application of capital and labour in harvesting and extraction, standing sales prices

[7] By contrast, data on hardwood import prices for the period 1945-54 inferred from TDA (1955, Table 5), and wholesale import price indices for the period 1954-71 published in TTF (1972, Table 31) and TTF (1966, Table 23), suggest increasing hardwood import prices over the period 1945-1971, as does FAO data on UK imports of industrial roundwood over the period 1989 to 2007-8 (available at http://faostat.fao.org/site/626/default.aspx). However, separating out any changes associated with potential confounding factors, including product mix and quality, is difficult. (Note that the FAO data cannot be compared directly as values are given in $, with different £:$ exchange rates apparently used in different years).

[8] Changes in average prices for home-grown wood do not always match changes in average import price (e.g. see: TTF 1972, Table 31) and vary between European countries (e.g. see: UNECE, 2005, chapter 4), although a variety of factors (e.g. differences in species, quality and product mixes) can hamper direct comparisons.

appear to provide the better basis for estimating the contribution of woodland habitats to ecosystem service values.[9]

Valued at standing sales prices, the gross value of UK softwood production has shown little overall trend in real terms from 1976 to the present.[10] Falling real prices for softwood were offset by increasing volumes as coniferous plantations matured, with production more than trebling from 2.4m green tonnes of softwood in 1976 to 8.5m green tonnes in 2009. However, despite little overall trend, gross values varied considerably in real terms over this period, with peaks in the late 1980s and mid 1990s, including a maximum of over £190 million in 1995 at 2010 prices, and troughs in the early 1980s and early 2000s, including a minimum of under £60 million in 1981 at 2010 prices.

Information to construct trends in hardwood values is sparse. However, the reduction in the total volume of UK hardwood sold (which more than halved from over 1.2m in 1989 to 0.4m green tonnes in 2007-8) combined with an apparent fall in hardwood prices, suggests total gross values of UK hardwood sold fell sharply over this period. Valued at the mean price for 1989 from Whiteman et al (1991, Table 7, p.23) equivalent to around £90 per green tonne at 2010/11 prices, the total value of hardwood produced from UK woodlands that year was over £110m. Valued using the above lower and upper bound mean price estimates (of £18 and £61 per green tonne at 2010/11 prices), the total annual value of UK hardwood production in 2007/8 would have been between £8m-£26m at 2010/11 prices. Were changes in hardwood prices simply assumed to track changes in softwood prices over this period, the total annual value of hardwood produced from UK woodlands in 2007/8

[9] Externalities also affect the social value of wood production. Pearce (1991), for example, suggests a 0.2-0.8% increment in prices to take account of shadow value of economic security due to reduced risks of disruptions should embargoes and other supply interruptions occur (Bateman et al, 2003, p.151). Carbon sequestration benefits are considered separately in a subsequent section.

[10] While values fell from £112m in 1972 to £102m in 2009 at 2010 prices, the more recent increase in softwood standing sales prices suggests that values may currently be slightly higher in real terms than in 1972. (Were the mean price for the 12 months to September 2010 of about £15 per green tonne were instead used to value the 2009 volumes, it would imply a higher value in real terms than 1972 of around £124m in 2009 at 2010 prices).

would have been intermediate at around £16m at 2010/11 prices. (Note that valued at standing sales prices, each estimate would probably be lower).

The total area of predominantly coniferous woodland in the UK has remained at around 1.5m ha over the past two decades, while there has been an expansion in predominantly broadleaved woodland in the UK from 0.9m ha in 1990 to 1.1m ha in 2010 (FC 2010a, Table 1.1b). Indicative per hectare values for softwood production derived by dividing total production by the total area of coniferous woodlands suggest gross production values fell from around £95/ha per year in 1990 to £66/ha per year in 2009 at 2010 prices. By contrast, the decline in hardwood production combined with the apparent fall in prices suggests a much sharper decline in gross values of UK hardwood production per hectare. Gross values for hardwood production were around £120/ha in 1989. Valued using the above lower and upper bound mean price estimates (of £18 and £61 per green tonne at 2010/11 prices), gross values in 2007/8 would have been £7-£25/ha at 2010/11 prices. Were changes in hardwood prices assumed to track changes in softwood prices over this period, the gross value of hardwood produced from UK woodlands in 2007/8 would have been around £15/ha at 2010/11 prices. The decline is consistent with reports that it is often less expensive at present to buy imported hardwood than to process UK-grown wood. This could change in the future.

Land management objectives affect wood production. The decline in hardwood production may partly be due to the reorientation of forestry management objectives on the public estate away from a focus primarily on wood production towards providing a wider range of ecosystem services (amenity, recreation, biodiversity, etc). For Forestry Commission England, Tinch et al (2010, p.77) report values net of wood selling costs of £120/ha for conifers and plantations on ancient woodland sites (PAWS), £15/ha for ancient and semi-natural woodland and restored PAWS, and £30/ha for other broadleaved woodland.

Whether (and how) forestry costs are apportioned between wood production and other ecosystem services such as carbon sequestration, as well as the range of costs covered, and the assumed shadow price of labour,[11] can all affect estimates of marginal values of wood production net of capital and labour costs and of subsidies. More fundamentally, whether expenditures and revenues are simply compared for individual years, or annual equivalents computed over a single or series of rotations also affects estimated values (with annualised estimates sensitive to the discount rate adopted in comparing costs and revenues over time).

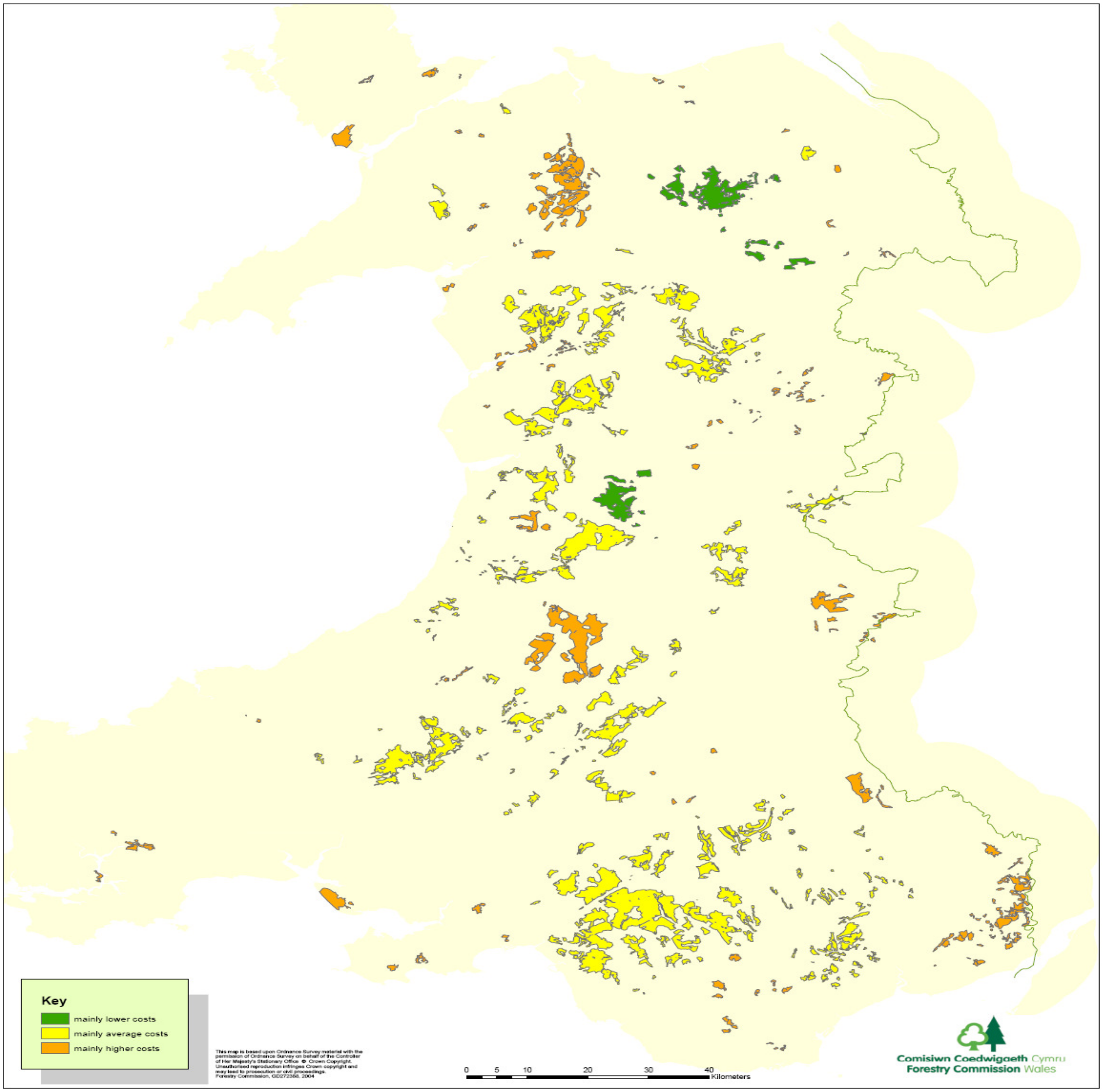
Regular surveys of forestry costs, incomes and expenditures were undertaken from the 1960s until the early 1990s for private woodlands. Averages for Scotland reported in Todd et al (1988, Table 6, p.27) for 1961-1986 based upon surveys covering all forestry costs and incomes show per hectare expenditure exceeding income (excluding grant income) in all but two of the 26 years, with mean expenditure of around £200/ha and income of about £130/ha implying a mean deficit of £70/ha at 2010/11 prices. For England and Wales, Dolan and Russell (1988, Table 7, p.11) report higher expenditure than income in each forest year (ending September) 1961-1986 based upon surveys of private woodlands, with a similar mean deficit of £70/ha, but a higher mean income of around £220/ha and expenditure of about £290/ha (at 2010 prices). Reflecting a market perspective, no account is taken of shadow values for labour, non-market values of wood production (e.g. carbon substitution benefits associated with using wood instead of fossil fuels or more fossil-fuel intensive materials) or (to the extent that these costs are partly associated with provision of these wider benefits) non-market ecosystem services. Therefore they can be considered to significantly under-estimate marginal social values of wood production. However, in the absence of mechanisms that value such wider non-market ecosystem services, profitability has tended to be low, with woodland grants and tax breaks major influences on woodland planting rates.

Forestry costs per hectare of woodland vary between sites, depending upon characteristics such as slope, road access, size of woodland, and species planted.

[11] In its report on forestry in Great Britain, for example, the Treasury adopted a central assumption that 55% of the jobs in forestry would be filled by those who would otherwise be unemployed locally, implying that the true cost to the economy of employing them was zero (Treasury, 1972, p.8).

Establishment costs tend to be higher for broadleaves than conifers. For example, estimates of standard costs for the public estate in Wales show establishment costs for 'quality mixtures' of 90% broadleaves / 10% conifers (of £4,817/ha) to be almost double those for standard planting of 90% conifers / 10% broadleaves (of £2,684/ha). Costs can also vary regionally. Forestry Commission estimates of standard costs of broadleaf woodland establishment in England (£9,738/ha), for instance, are currently more than double standard costs in Wales. An example of indicative spatial variations in forestry establishment and management costs in Wales is shown in **Figure 6** below.

Figure 6 – Indicative variations in establishment and management costs in Wales



Source: Forestry Commission Wales (work in progress).

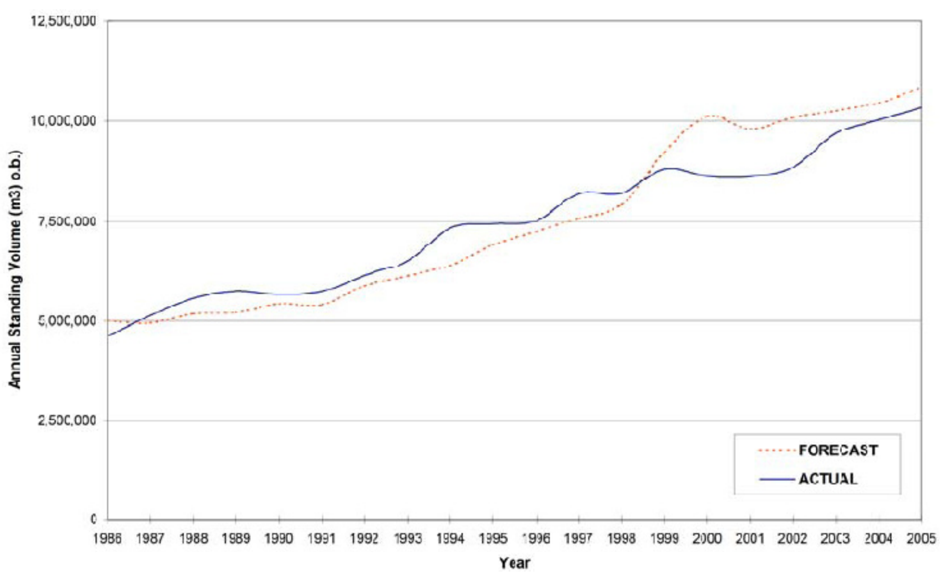
Net values vary considerably between sites, and depend upon species and rotation length choices (see: Pryor and Jackson, 2002). Pryor and Jackson (2002, Table 7, p.25), for example, report mean net annual income estimates (that take no account of changing values over time and discounting) for 11 species/yield class (YC)/rotation length combinations considered typical of plantations on ancient woodland sites. These range from -£2/ha for birch YC6 to £262/ha for ash YC10 (both over a 70-year rotation) for broadleaves and from £77/ha for larch YC12 to £247/ha for Douglas fir YC18 (both over a 45-year rotation) for conifers.

8.2.2 Wood Production, 2010-2050

The Forestry Commission produces regular forecasts of timber production, focusing primarily on softwood. The most recent of those published date from 2005 (Halsall, et al, 2005). These cover timber production over 5-year periods from both the public and private estate for 2007-2011 until 2022-2026, based on parameters such as date and area of planting, species and yield class.

The forecasts are for availability rather than production of softwood, recognising that various wider market factors will also affect production. Forecasts are subsequently compared with actual production records (**Figure 7**) in order to track the reliability of forecasts, with a view to developing more accurate forecasts in the future.

Figure 7: Comparison of annual GB softwood forecasts & actual production



Source: Halsall et al (2005, Fig 2, p.21).

The forecasts for the public estate are generally more reliable than those for private woodlands. The former draw upon production targets under existing forest plans and in-depth knowledge of the species and yield class composition of the public estate. The latter currently rely upon more dated information from surveys in the late 1990s for the national inventory of woodlands and trees, and expert judgement[12] (with yield class characteristics of private woodlands assumed to be similar to those of the public estate and no estimates included for woodlands transferred to private ownership since the late 1990s).

However, even forecasts for the public estate are subject to a range of uncertainties. These include potential changes in species growth and suitability due to future climate change, risks associated with future storms, pests and diseases, and possible changes in government policies that shift the balance of woodland management between wood production, carbon sequestration, recreation, amenity and other objectives, or alter the size of the public forest estate.[13] In addition, neither the public sector nor private sector forecasts take account of new woodland planting.

As previously discussed, market prices for wood in the UK are widely considered to be determined primarily by prices for imported wood. The latter depend upon a range of factors influencing supply and demand for timber internationally. These include the supply of timber from former Soviet-bloc countries (e.g. Russia), and demand for timber from China and other emerging economies such as Brazil and India. In addition, prices are affected by exchange rates, and can be influenced by European and national policies relating to energy production (e.g. incentives for use of woodfuel as a source of renewable energy or heat) and the use of wood as a low-carbon construction material (Lawson & Hemery, 2007).

[12] An expert group advises on rotation length, thinning, and re-stocking assumptions to use for the private sector forecasts.

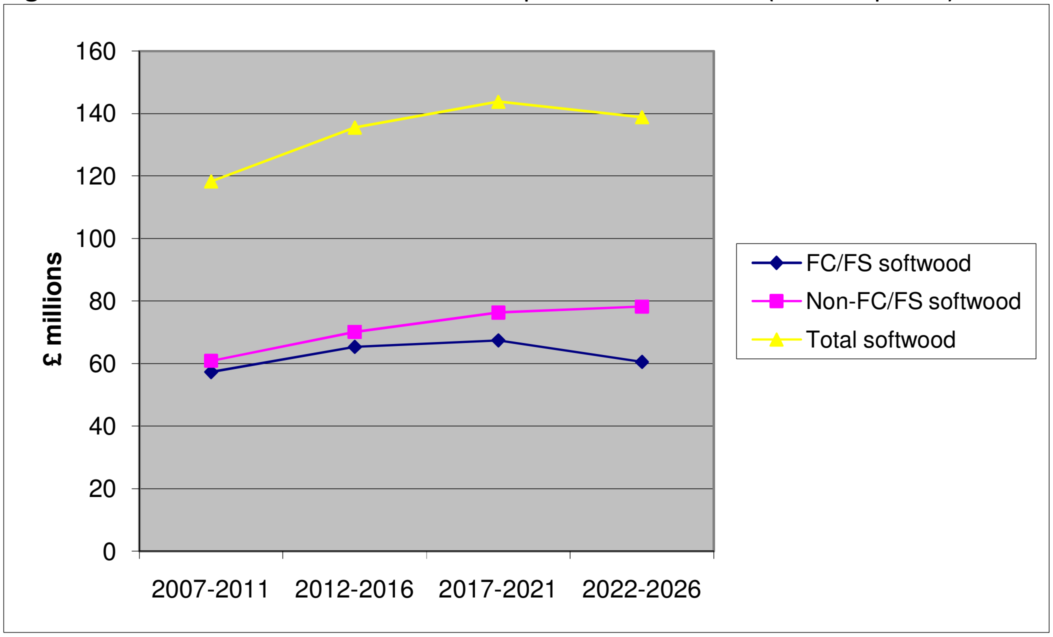
[13] For example, despite increasing interest in the ecosystem service approach, there is no inevitability in the shift in recent years within the public estate away from timber production towards a greater emphasis on wider benefits of forestry continuing.

Lawson & Hemery (2007) argue that there is likely to be increased global and domestic demand for most types of wood product, with Government policies likely to encourage greater domestic consumption of domestically produced timber. All these factors point to future increases in timber prices being likely.

A recent study commissioned by three UK forestry industry organisations also predicts large rises in demand for wood fibre in the UK over the period 2007 to 2025, mainly due to Government policies and incentives to encourage use of woodfuel. Were these policies to lead to a significant number of new wood energy plants being built, they could lead to increased prices for woodfuel and reduce the supply of UK-grown wood for other purposes (JCC, 2010).

The studies reviewed suggest that wood prices are likely to increase over time, and that a continued fall in standing sales prices in real terms is unlikely (although the extent and timing of expected increases over time are unclear). From this perspective, simply assuming softwood standing sales prices remain constant at the 2009/10 price of £10/m^3 over-bark (£12 per green tonne) could be considered a conservative approach. If the forecast availabilities from the Forestry Commission production forecast are assumed to represent forecast production quantities, and valued at the 2009/10 standing sales price, this would imply that the total value of UK softwood production would rise to around £140m in 2021-6, compared to the total value of softwood produced in 2009 of £102m (see **Figure 8**). However, to the extent that real prices are expected to increase over this period, this would be expected to underestimate the rise in the total value of UK softwood production.

Figure 8 – Forecast values of UK softwood production to 2026 (at 2010 prices).

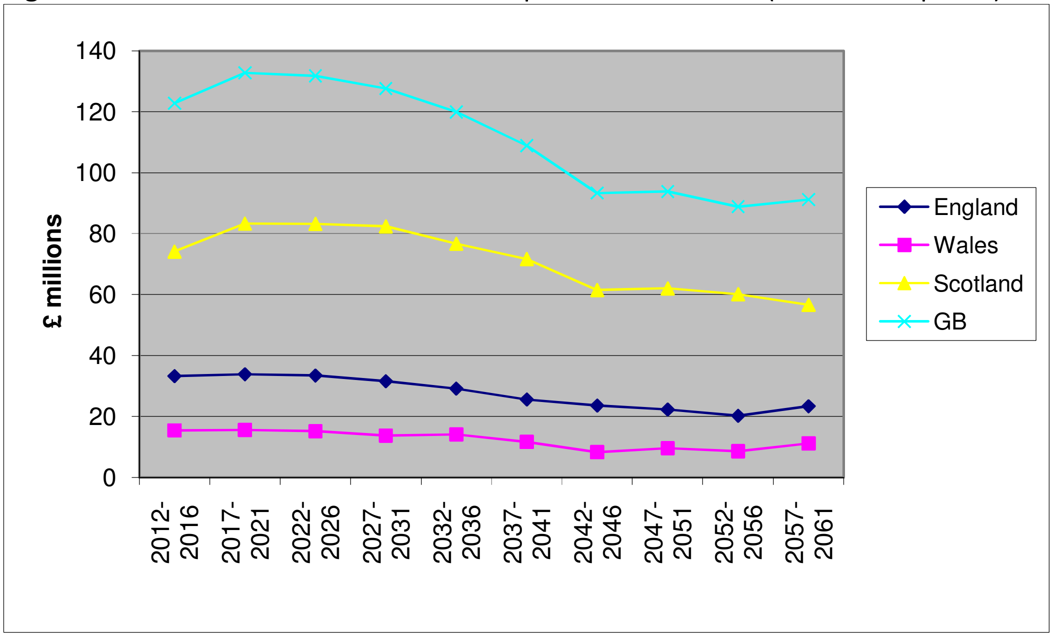


Source: Quantities taken from Halsall, et al (2005, Table 1, p.13).

The latest Forestry Commission timber production forecasts published also contain forecasts of hardwood production, although these are limited to production from the Forestry Commission estate (Halsall, et al, 2005, Table 5, p.20). The forecasts imply a gradual increase in annual hardwood production from around 87,000 green tonnes (97,000m3 ob) in 2007-11 to 100,000 green tonnes in 2022-2026. (If valued at the mean price for Forestry Commission hardwood sales of £18 per green tonne in 2007/8 at 2010/11 prices, this would correspond to a rise in the value of annual Forestry Commission hardwood production from £1.6m to £1.8m over this period, and a corresponding increase in per hectare values to £18/ha in 2022-2026).

In addition to the published forecasts, longer-range wood availability forecasts for Britain are produced within the Forestry Commission for internal planning purposes. (They do not reflect a commitment to the timber market – with any public commitments published as part of Forestry Commission marketing strategies). The latest long-term forecasts imply an increase in GB softwood production to 2017-2021, followed by a decline to 2052-56. If the forecast availabilities are similarly valued at the 2009/10 standing sales price, this would imply that the total value of GB softwood production from existing woodlands would fall from the mid 2020s to around £90m in the mid 2050s. However, to the extent that coniferous woodland is expected to increase and real prices are expected to rise over this period, this would be expected to underestimate the total value of UK softwood production in 2060.

Figure 9 – Forecast values of GB softwood production to 2061 (£m at 2010 prices).



Source: quantities from Forestry Commission long-term production forecasts

8.3 Provisioning: Deer

Six species of deer are currently found in the wild in the UK. While each may be encountered in, and make use of, woodlands, Chinese Water Deer are primarily encountered in wetlands, and are therefore not focused on in the discussion below.

Data on UK deer populations and their change over time is generally sparse and approximate.[14] However, there is general agreement in the literature that wild deer populations have been increasing. For example, Dolman, et al (2010) argue that the deer population in Great Britain is approaching the level reached during the Mesolithic period (despite the large drop in forest cover since then), with an estimated total population of 1.5 million deer. Noting estimates are "approximate

[14] Obtaining precise deer population estimates is extremely difficult (with Roe deer apparently being particularly difficult). The estimates that exist are generally regarded as minimum estimates (see Hunt, 2003, Ward, 2005).

and contentious", Spence & Wentworth (2009, p.1) provide the following estimates (**Table 1**).[15]

Table 1 – Rough estimates of total UK deer populations and population growth rates

Species	Population	Growth Rate
Red deer (*Cervus elaphus*)	>350,000	~0.3%
Roe deer (*Dama dama*)	>800,000	~2.3%
Fallow deer (*Capreolus capreolus*)	150,000-200,000	~1.8%
Sika deer (*Cervus nippon*)	~35.000	~5.3%
Muntjac deer (*Muntiacus reevesi*)	>150,000	~8.2%
Total	>1,485,000	

Source: Spence & Wentworth (2009).

Few estimates of deer populations associated exclusively with woodlands exist, and most population assessments for woodlands are considered 'very approximate' due to the logistical and visual obstacles compared to open-hill assessments (Hunt, 2003). However, according to Hunt (2003) approximately one quarter (100,000) of the Red Deer population in Scotland could be described as a woodland population, with a higher population growth rate and greater body mass than open-land Red Deer, with woodland stags averaging 200kg compared to 95-114kgs for open-land stags (hinds being 30% lighter).[16]

Deer are associated with a range of ecosystem services, including values associated with wildlife viewing by visitors to woodlands. However the latter can be expected to be captured entirely by the recreational value of woodlands, considered in another chapter. In this section we focus primarily on ecosystem services associated with

[15] The basis for these population estimates is unclear, however, although the growth rates fit range expansion rate estimates from Ward (2005) of 0.3% for Red deer, 1.8% for Fallow deer, 2.3% for Roe deer, 5.3% for Sika deer and 8.2% for Muntjac. Assessments of deer population changes are thought more robust for Scotland than for other parts of the UK due to existence of surveys by the Deer Commission for Scotland dating back to 1959. Hunt (2003), for example, reports that for Red Deer there has been an increase in Scotland from a 1964 population of 150,000 to an estimated 2003 population of between 406,000 and 454,000.

[16] A higher cull rate of 25-30% (compared to 15% for open-land) is also argued to be needed to achieve a stable population (Ibid.).

stalking and venison production. However, potential over-laps (and trade-offs) between stalking and the recreational and amenity values of woodlands are worth noting.

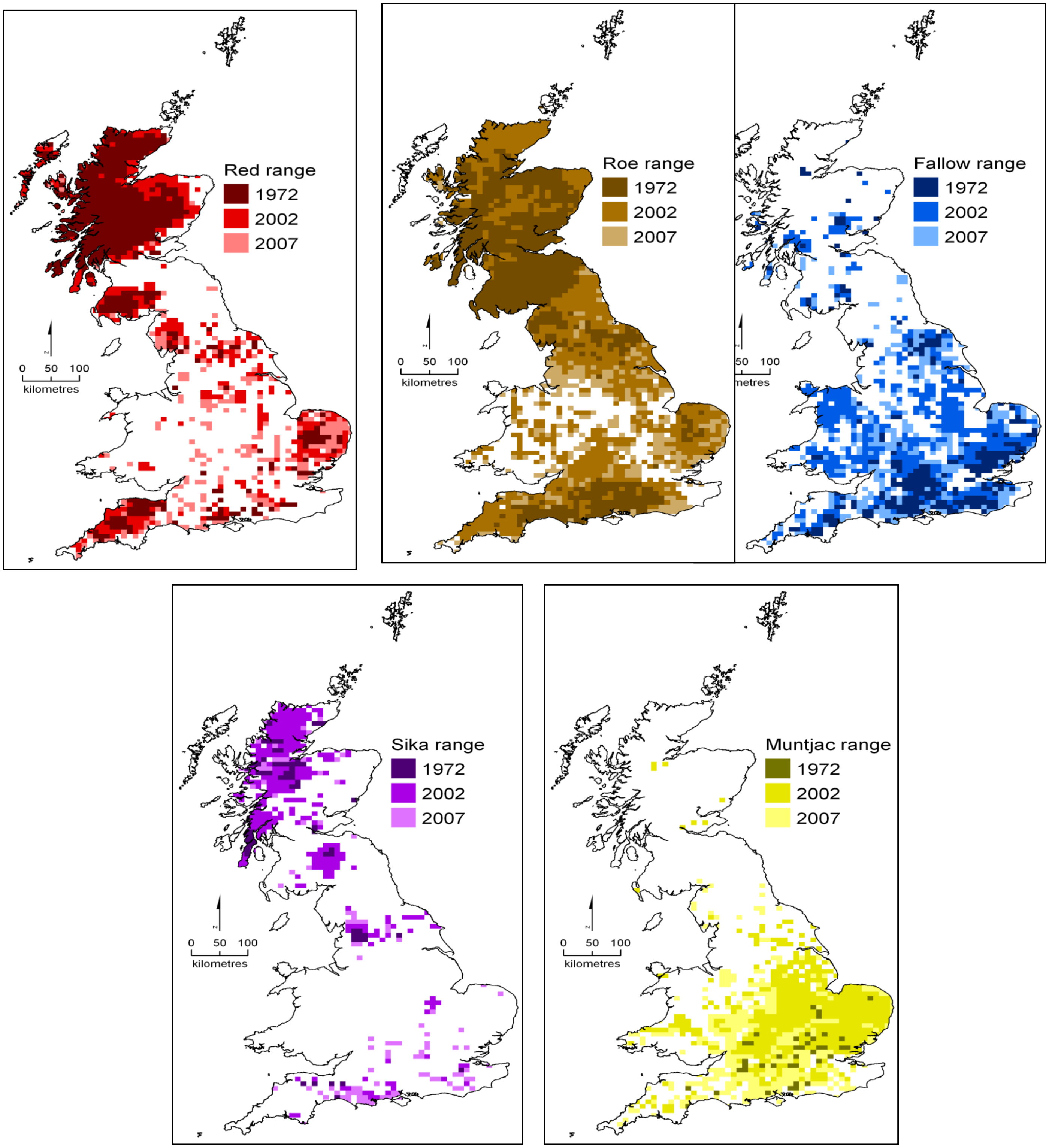
Deer can also be the source of significant ecosystem 'disservices', including negative impacts on wood production (briefly discussed below).

8.3.1 Deer, 1945-2010

Ward, et al (2008) illustrate apparent range expansions of different deer species from 1972 to 2007, shown below for Red, Roe, Fallow, Sika, and Muntjac deer (**Figures 10-14**) based on the reported presence of deer in different locations from British Deer Society surveys. (This data excludes areas where deer are present but not reported, so they represent minimum estimated deer distributions). Distribution expansion may be considered an indicator of deer population increase, with recent factors facilitating deer population increases, including the expansion of forestry and insufficient culling to either maintain a stable population or reduce deer numbers.[17]

[17] Historically, the eradication of natural predators (especially the lynx and grey wolf) have also been important contributors to increasing deer populations in the UK.

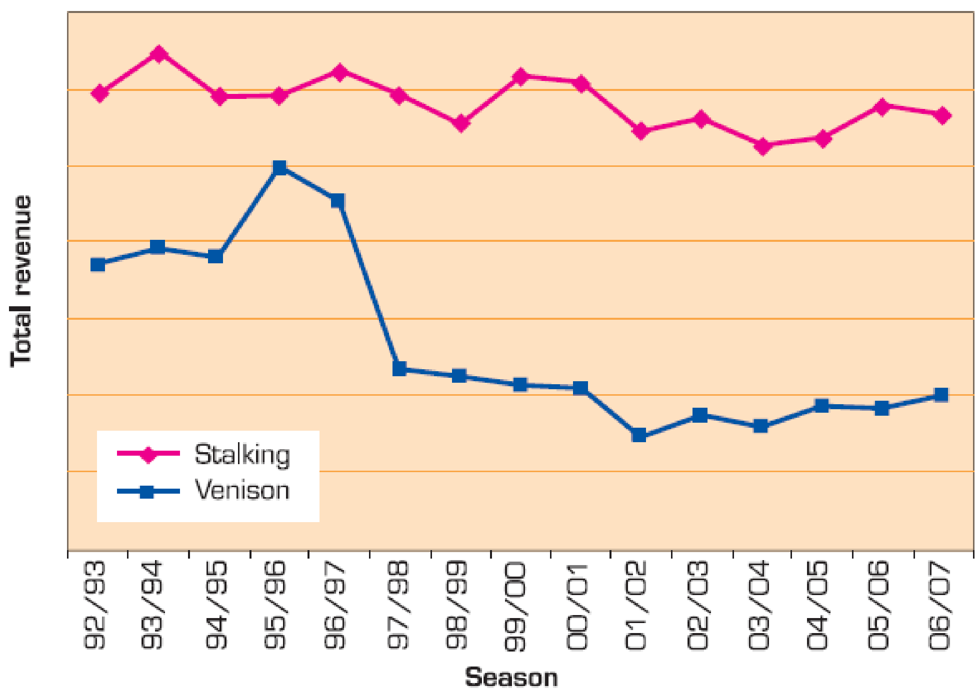
Figures 10-14 – Changing distributions of wild deer in Great Britain by species.



Source: Ward *et al* (2008).

Stalking and venison provide major revenue streams for some private landowners. Although precise data is unavailable, stalking is a significant source of income for Scottish estates and, by extension, for the Scottish rural economy, contributing an estimated £12m direct gross value added (GVA) and £51m indirect GVA to the Scottish economy, and directly or indirectly supporting over 2,000 full-time equivalent jobs (PACEC, 2006). Philip & MacMillan (2007) show that total revenues from stalking exceeded those from venison over the period 1992/3-2006/7, apparently being higher by a factor of 2 to 3 from 1997/8 onwards (see **Figure 15**). However, red deer stalking on private estates is primarily an 'open range' (hill) activity rather than a woodlands one (see Munro, 2003, Table 2), with woodlands contributing principally by providing a habitat for the deer. (Stalking and venison are therefore also considered in the Mountains and Moorlands chapter).

Figure 15 – Relative values of stalking and venison revenues from Scottish estates.



Note – Due to data confidentiality, only the relative value of stalking and venison revenues is shown.

Source – Philip & MacMillan (2007).

For most woodland owners, by contrast, deer stalking and venison revenues are viewed as helping defray the costs of forest management in securing wider wood production, habitat conservation and other benefits, rather than as principal revenue streams. The relationship between controlling deer density and reductions in negative impacts of deer browsing and bark stripping requires further research, and economic estimates of the benefits are sparse, but current deer management activities in woodlands are widely considered cost-effective and necessary in controlling rising deer populations.[18]

White, et al. (2004) is one of the few UK studies to provide economic estimates of deer impacts. Assuming a loss of either one or five year's standing volume, their estimates (based upon Corsican pine over a 55-year rotation and assuming a 3% discount rate) suggest annual impacts of deer browsing on softwood production in the range of £0-£190/ha in 2004 (with estimates of £0-£57/ha most likely). Leading to part of the harvest being downgraded from green logs to pulpwood, indicative estimates for woodlands with red deer populations (the particular species implicated) suggest annual impacts of bark stripping on softwood production of around £60/ha in 2004 (based upon a cumulative bark stripping incidence of 26% in Thetford forest). Assuming a loss of five year's standing volume, annual deer browsing impacts on hardwood production were estimated at around £0-£2/ha (for a mix of oak over a 100-year rotation and ash over a 75-year rotation), reflecting lower reported leader browsing incidence (Moore et al, 1999, 2000) and discounting over longer rotation lengths. By comparison, deer culling and venison production activities on Forestry Commission land in England cost around £7/ha in 2009/2010 (i.e. before accounting for revenues).

8.3.1.1 Stalking

On Forestry Commission land fees vary regionally, and depend on whether stalking rights are leased, or charged per deer shot by private stalkers accompanied by a ranger, although no information is available at present on mean fees charged.

[18] Determining if measures to reduce browsing damage are cost-effective is the subject of a worked example in a Forestry Commission manual (see: Insley et al, 1987, section 2.1).

(Private stalking is not currently permitted on Forest Service land in Northern Ireland).

Fees can also depend upon the species, size and sex of the deer. For eastern England, White et al (2004) assume average stalking fees in 2001/2 for each species of deer (except Sika) that live in woodlands shown in **Table 2** below.

Table 2 – Stalking fees per deer in the East of England in 2001/2 (current prices)

Species	**Sex**	**Average stalking fee (£)**
Red deer	Male	350
	Female	40
Fallow deer	Male	200
	Female	30
Roe deer	Male	120
	Female	40
Muntjac deer	Male	100
	Female	30

Source: *White, et. al. (2004, Table 8.3).*

Note: No comparable data for Sika deer was available.

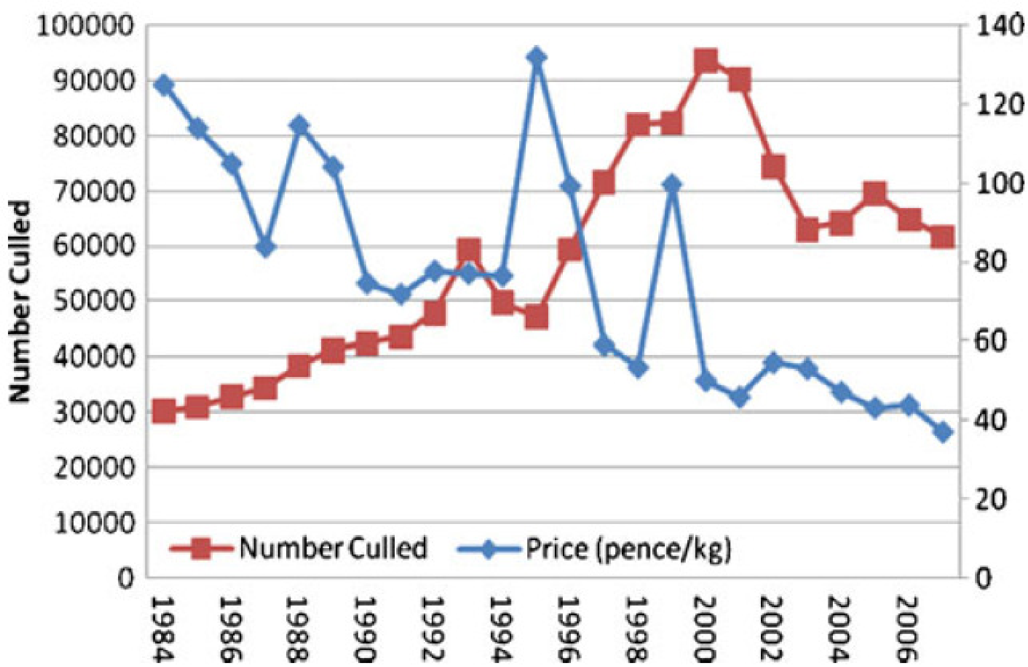
Based on the above fees, White et al (2004) estimate the total annual revenue from day permit stalking and private run stalking on Forestry Commission land in the East of England at £58,000. This suggests a mean per hectare revenue of around £2/ha in 2001/2 (equivalent to about £3/ha at 2010/11 prices). More recent information for Forestry Commission land in England as a whole suggests stalking revenues of under £1/ha in 2008/9 at 2010/11 prices. (Revenues per hectare are likely to be higher in Scotland than elsewhere in the UK due to larger red deer populations).[19]

[19] By contrast Crockford et al (1987, p.6) report that sporting rentals in woodlands commonly range from £2/ha/yr for vermin shooting to approaching £20/ha/yr for woodlands well designed for pheasant shooting.

3.3.1.2 Venison

Venison prices for wild deer are thought to be largely determined by external factors, including competition with farmed venison and Eastern European venison production (Hunt, 2003). Prices for venison have declined steadily in real terms since the 1980s (as shown in **Figure 16** below for Scotland). This is partly due to competition from imported New Zealand farmed venison and other red meat substitutes (Munro, 2003, MacMillan and Phillip, 2010).

Figure 16 – Average venison prices (at 2007 prices) and total number of deer shot.



Source – MacMillan & Phillip (2010, Fig 5).

Notes - prices from private estate stalkers and venison processors in Scotland in 2007; Cull data is from Deer Commission Scotland 2009 and is for deer shot in all habitat types.

Time-series data on venison revenues is not available. However, venison revenue estimates for Forestry Commission land in the East of England of £47,000 in 2001/2 (White, et al., 2004) imply per hectare revenues of around £2/ha a year at 2010/11 prices, and more recent information for Forestry Commission land in England as a whole suggests similar levels per hectare in 2008/9. This value cannot be entirely attributed to woodlands to the extent that some deer culled in woodlands have lived partly in non-woodland habitats. However, part of the value of deer culled in other habitats is similarly attributable to woodlands providing a habitat.

Little information is publically available at present on capital and labour costs associated with stalking and venison production, or on net revenues. Estimates provided by White et al (2004), however, suggest combined stalking and venison revenues net of deer management costs of about £2/ha at 2010/11 prices for Forestry Commission land in the East of England in 2001/2.

8.3.2 Deer, 2010-2050

In view of the limited and contested nature of existing estimates of deer population levels and growth rates (see above; also Ward, 2005; White, et al, 2004; Hunt, 2003), attempting to forecast future changes in deer populations (and associated venison and stalking revenues) appears problematic, especially over a 50-year time horizon.[20] On the basis of past trends (see previous discussion), UK deer populations could be expected to further increase, although the extent to which this continues will depend upon a range of climatic and other factors, including limits to range expansion, displacement effects, extent of culling and, eventually, environmental carrying capacities.

Were it the case that their marginal values remained at current levels (or declined less than the increase in stalking and venison produced as a consequence of the management of larger deer populations), the total value of stalking and venison from UK woodlands could also be expected to increase over time. However, not least as venison prices apparently fell by two-thirds in real terms over the period 1984-2007 (**Figure 16** above), there is no guarantee venison prices will either remain at their current level, or rise in the future. It also seems probable that demand for stalking is inelastic, so increases in provision of stalking opportunities could

[20] White, et al (2004) forecast future social costs and benefits of deer impacts over a five- and ten-year time horizons assuming distribution expansion rates are a proxy for population growth rates, but appear to predict no change in stalking revenues (see: White, et al 2004, Tables 11.1 and 11.2).

potentially be offset by a fall in marginal values (or might simply not be taken up due to market saturation). Furthermore, irrespective of deer population increases, supply-side factors could also affect provision of stalking opportunities (and associated venison production), including evidence, especially in Scotland, of deer stalking being influenced more by cultural factors than by market incentives (see MacMillan, et al, 2010; MacMillan & Phillip, 2010; also Fiorini, et al, 2008).[21]

A modest increase in future aggregate values of venison production from UK woodlands, and little change in associated deer stalking revenues, may appear more likely than significant increases. However, the principal conclusion is that there is scant evidence at present on which to base any predictions.

8.4 Regulating: Carbon

The primary focus of this section is carbon sequestration, with the value of existing carbon storage by woodlands also briefly discussed.

8.4.1 Carbon Sequestration, 1945-2010

Estimates of the net amount of Carbon (in the form of Carbon Dioxide) sequestered by woodland and of changes in carbon stored in harvested wood products (HWP) are available from the Centre for Ecology and Hydrology (CEH) and produced on behalf of the Government as part of the UK's commitments under the Kyoto Protocol. The CEH estimates show net carbon sequestration in UK woodlands rising from 2.4MtCO_2 in 1945 to a peak of 16.3MtCO_2 in 2004, and then falling back to 12.9MtCO_2 in 2009. Over the period 2001-2009 they imply mean net sequestration rates of around 5.2tCO_2/ha across all UK woodlands (and 0.3tCO_2/ha for HWP).

[21] MacMillan & Philip (2010) explore the potential for an increased market price for venison to increase the culling effort for deer on private estates and conclude that this is unlikely. One reason is that there is apparently a strong negative correlation between culling effort and venison price, another that interviews with estate stalkers and owners showed universal agreement that the price of venison was irrelevant to them, with determining factors instead being 'tradition' and 'loyalty' (Ibid.). By contrast, Hunt (2003) argues that the price of venison influences the number of hinds (female deer) culled, with a higher price translating into a higher cull.

Based upon a carbon accounting model (C-Flow) that includes transfers of carbon from living biomass (roots, trunk, branches, foliage) to litter and soils, the estimates rely upon a number of simplifying assumptions. These include using representative species, yield classes (YC) and rotations for conifers (Sitka spruce YC12 59-year rotation in Britain and YC14 57-year rotation in Northern Ireland) and broadleaves (beech YC6 92-year rotation). Only forests planted since 1921 are considered, others being assumed to be in carbon balance (Dyson et al, 2009, MacCarthy et al, 2010), with estimates for HWP similarly based upon wood products from UK forests planted since 1921. The HWP estimates assume multipliers for saleable volumes to estimate dry weights, with carbon subsequently calculated as 50% of this dry weight. Wood derived from thinnings is then assumed to decay within five years (with a half-life of 0.9 years), while wood from harvesting is assumed to have a lifetime equal to one rotation, with a half-life of 14 years for conifers and 21 years for broadleaves. As woodlands are assumed to be replanted after harvesting (generally a requirement of obtaining a felling licence), no account is taken of emissions post-felling (see: Robertson, et al, 2003 and Dyson, et al, 2009).

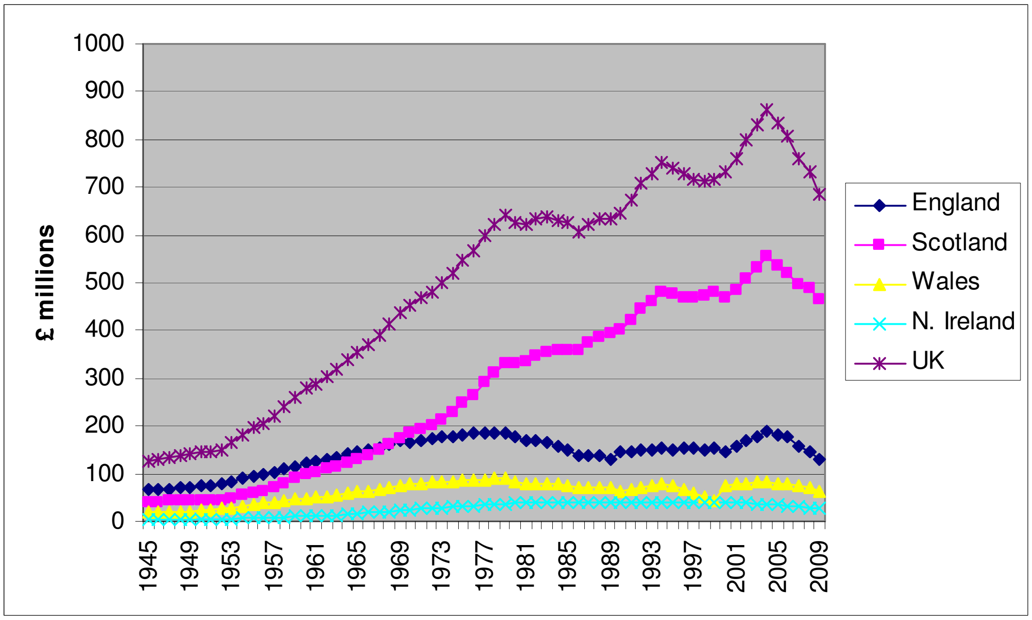
An increase in net carbon sequestration by UK woodlands since 1945 is consistent with increased afforestation rates from the 1950s to 1980s, although exclusion of forests planted before 1921 probably results in lower estimates for the early part of the period than would otherwise have been the case. Carbon accounting methodology is still evolving and it is probable that current estimates from existing models underestimate carbon sequestration rates (Robertson, et al, 2003; Dyson, et al, 2009, pp.156-172; Matthews and Broadmeadow, 2009). Carbon sequestration rates are subject to significant seasonal variations, generally being higher in the summer than in the winter (e.g. see: Jarvis et al, 2009).

Permanence can be a key influence on valuation of carbon benefits, with the present value of the carbon at the point at which it is re-released to the atmosphere generally needing to be subtracted in valuing current gross sequestration. (Where future carbon values are expected to rise, the present value of future emissions can even exceed the value of the original sequestration in some cases – see: Valatin, 2011). For current purposes, however, permanence issues can be ignored providing the total carbon stock in UK woodlands and HWP combined is expected to remain at least at the current level in perpetuity once carbon substitution benefits (associated with using wood instead of fossil fuels or more fossil fuel intensive materials) is also accounted for. This does not seem an unreasonable assumption at present given the current upward trend in carbon stocks in UK woodlands and HWP, and existing government targets to increase woodland cover (at least providing the international community is successful in limiting climate change to a maximum average global temperature rise of a couple of degrees centigrade).

A wide range of values have been used to value carbon. UK Government guidance on valuing carbon (DECC, 2010) is currently based upon a target-consistent approach which, at 2010 prices, includes using a central value of around £53/tCO_2 (equivalent to £193/tC) for 2009 for the 'non-traded' sector (i.e. that not covered by the EU emissions trading scheme). As forestry carbon sequestration is not covered by the ETS at present, values for the 'non-traded' (rather than the 'traded') sector are relevant. In the absence of a consistent time series of values back to 1945, the 2009 value is assumed to apply to sequestration in previous years (an approach suggested by DECC). However, by not accounting for rising social values of carbon over time, the approach underestimates increases (and over-estimates falls) in total and per hectare values of carbon sequestration by UK woodlands over the period.

Valued at the DECC central estimate of £53/tCO_2 in 2009, the CEH estimates suggest that gross value of net carbon sequestration by UK woodlands increased five-fold, from £124m in 1945, to £680m in 2009 at 2010 prices, with Scotland currently accounting for around two thirds of the total (as shown in **Figure 17** below).

Figure 17 – Value of annual carbon sequestration by UK woodlands (at 2010 prices).



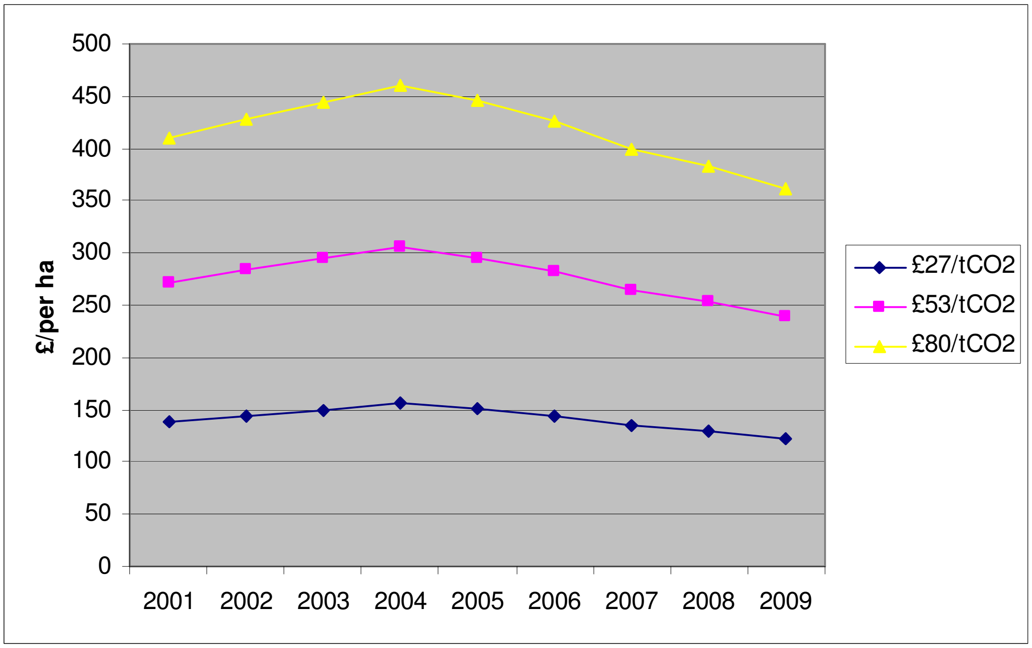
Note: based upon CEH estimates and the DECC (2010) central estimate of £53/tCO_2 in 2009.

Based upon estimates of total UK woodland area (FS, 2001-2009, Table 1.1), values per hectare at the DECC central social value of carbon of £53/tCO_2 rise from £270/ha in 2001 to a peak of £304/ha in 2004, before falling back to a minimum of £239/ha in 2009, with a mean of £276/ha over this period at 2010 prices. Per hectare values are about half of these if the DECC low social value of carbon estimate is used, and about 50% higher if the DECC high social value estimate is used (see **Figure 18** below).

For woodland planted since 1921, per hectare values are significantly higher than the mean. Dividing by CEH estimates for these woodland areas[22] suggests values of net carbon sequestration at 2010 prices of around £590/ha in 1945 falling to about £400/ha in 2009 valued at the DECC central social value of carbon of £53/tCO_2. (A zero value for net carbon sequestration is assumed for woodlands planted prior to 1921).

[22] Based upon projecting forward from 1921, there appear to be significant differences with estimates of woodland areas published by the Forestry Commission (based upon the National Inventory of Woodlands and Trees).

Figure 18 — Value of carbon sequestered by woodlands per hectare (at 2010 prices).



The mean value of net carbon sequestration by woodlands and in HWP combined over the period 2001-2009 was £286/ha at 2010 prices valued at the central estimate of the social value of carbon (and £143/ha and £429/ha at the low and high social value estimates). The combined value remained fairly stable, rising from £279/ha in 2001 to £293/ha in 2004, before falling to £281/ha in 2009.

In addition to net sequestration (i.e. change in carbon stored), existing carbon storage in woodlands might also be valued relative to its release to the atmosphere. Although not currently available from CEH, forest carbon stock estimates are published in FS (2009, Table 4.1) based upon a different model. If assumed to be permanent, valuing the total stored (803MtC) in 1990 at the central DECC estimate of £193/tC (£53/tCO_2) would imply a total value of £155 billion and an average gross value of around £59,000/ha at 2010 prices (increasing slightly over the past decade consistent with a positive per hectare net carbon sequestration rate).[23] However, over four fifths of this total is soil carbon which may vary relatively little in the short run with land use change. Valuing carbon storage in above- and below-ground

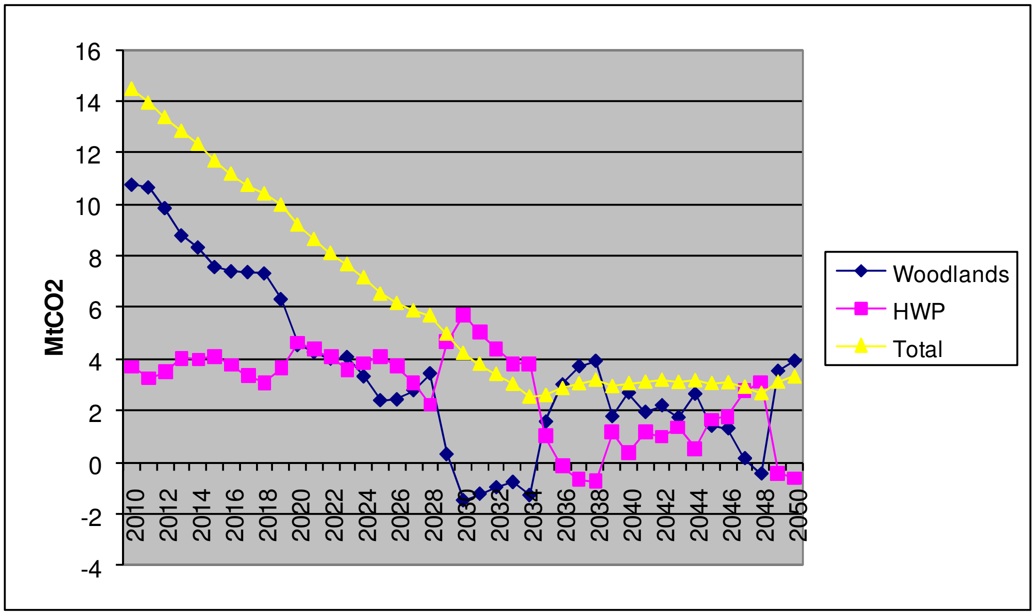
[23] If instead based upon the carbon stock estimate of 790MtC used in the Read Report, these estimates fall to £152 billion and £58,000/ha respectively.

biomass, dead wood and litter alone (which may be more sensitive to land use change) at the central DECC estimate of £193/tC would imply a total value of £28 billion and a per hectare value of around £11,000/ha at 2010 prices (equivalent to an annuity value of £380/ha per year at a 3.5% discount rate). In contrast to the net sequestration values, carbon storage values could be expected to be highest in woodlands planted prior to 1921 other factors being equal.

8.4.2 Carbon Sequestration, 2010-2050

Forecasts of woodland carbon sequestration are available from the CEH C-FLOW model to 2050 for a 'business-as-usual' (BAU) scenario that assumes current woodland creation rates of 8,360ha per year and woodland removals of 1,128ha per year continue throughout this period. With the projected carbon sequestration strongly affected by past planting patterns, including the decline in planting rates from the 30,000 ha per year in the late 1980s, the forecasts show a drop of more than half in net carbon sequestration by UK woodlands from over 10 $MtCO_2$ in 2010 to under 4 $MtCO_2$ in 2028. Forecast net carbon sequestration then falls further and becomes negative in the years 2030-2034 (as well as in 2048) with UK woodlands assumed to become a carbon source rather than a sink. However, once the net carbon sequestered in HWP is added, total net carbon sequestration in both woodlands and in HWP remains a carbon sink over the entire period (see **Figure 19** below). The forecasts show combined net sequestration falling from 14.5$MtCO_2$ in 2010 to a minimum of 2.5$MtCO_2$ in 2034, before gradually rising to 3.3$MtCO_2$ by 2050.

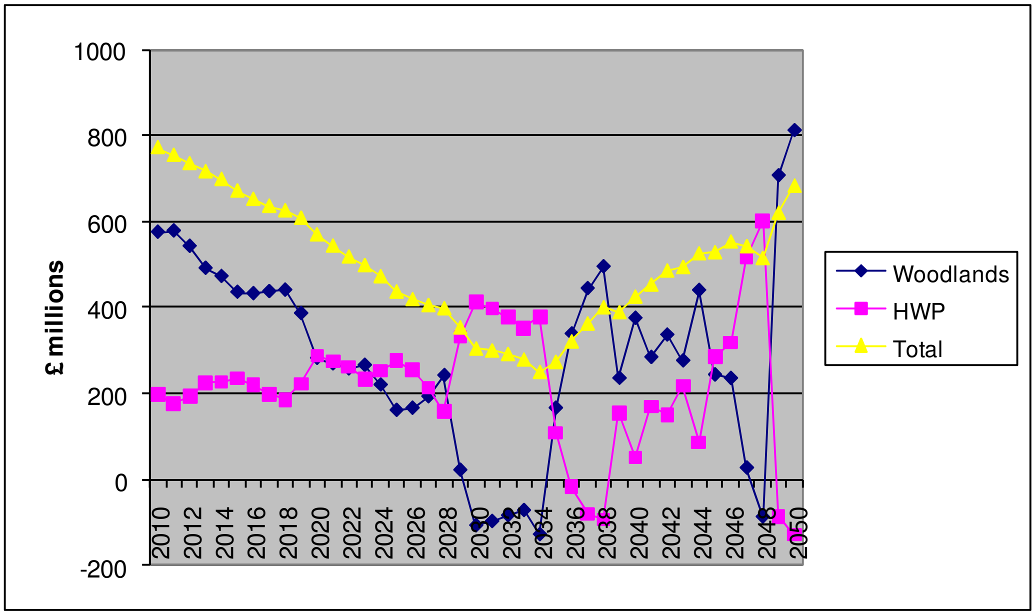
Figure 19 – Net carbon sequestration by UK woodlands and in HWP from 2010-2050.



If the net carbon sequestration is assumed to be permanent (see previous discussion), the CEH forecasts can simply be valued using current UK government guidance on valuing carbon in policy appraisal (DECC, 2009a,b, 2010). The central estimates for the non-traded sector rises from £53/tCO_2e (£196/tC) in 2010 to £207/tCO_2e (£757/tC) in 2050 at 2010 prices for non-ETS sectors.[24] Resultant values per year are shown in **Figure 20** below.

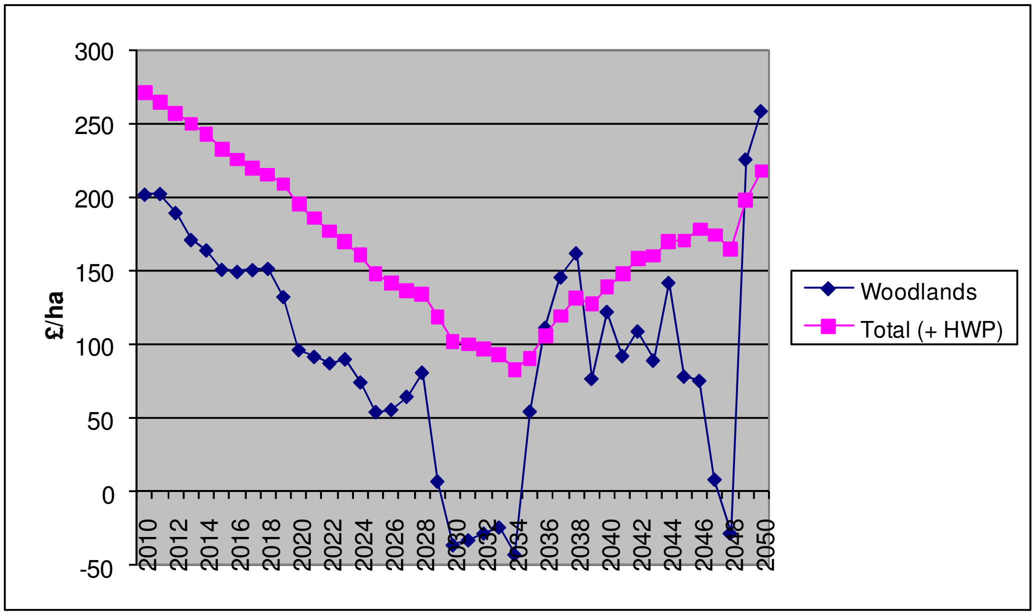
[24] Values for non-ETS sectors are the appropriate ones to use as carbon sequestration by woodlands and in HWP are not covered by the EU Emissions Trading Scheme at present.

Figure 20 – Forecast values of net carbon sequestration 2010-2050 (at 2010 prices).



Forecast values per hectare are obtained by applying the net woodland expansion rate of 7,232 ha per year used in generating the CEH model forecasts to the base year total UK woodland area of 2.8 million in 2010 (FC, 2010) and dividing the total value by the total number of hectares. The resultant forecast values per hectare are shown in **Figure 21** below, and suggest that (in contrast to the fall in the net amount of carbon sequestered) the value of net carbon sequestration by UK woodlands will increase over the period from around £200/ha in 2010 to over £250/ha in 2050. However, the value of total net carbon sequestration in both woodlands and in HWP does not then regain its 2010 level over this period, falling by two-thirds from over £270/ha in 2010 to around £80/ha in 2034, and then climbing to just under £220/ha in 2050).

Figure 21 – Forecast values of net carbon sequestration per hectare (at 2010 prices).



Future net carbon sequestration by UK woodlands can be expected to depend critically both upon planting rates and forest management practices. The Read Report recently considered a range of potential forestry policy and management options that deviate from the CEH 'business as usual' (BAU) scenario. These scenarios (Matthews & Broadmeadow, 2009, p.145-150) include an 'enhanced afforestation scenario' (EAS) with new planting rates of an additional 23,000ha per year (almost three times the BAU assumption of 8,360ha per year), and are summarised below in **Table 3**.

Table 3 – Forestry policy & management scenarios considered in the Read Report.

Scenario: / Country:	Enhanced Afforestation (EAS)	Carbon-stock enhancement (FMS-A)		Enhanced Management (FMS-B)	Improved Productivity plus carbon-stock enhancement (FMS-C(A)), or plus enhanced management (FMS-C(B))	Reinstating management (FMS-D)
	Woodland planting rate (ha/yr)	Proportion of forests managed as carbon reserves (%)	Proportion of forests managed by deferred fell (%)	Proportion of forests managed to optimum rotation length (%)	Species switching at restocking	Proportion of unmanaged woodland brought into production (%)
England	10,000	30%	20%	50%	50% CP to DF 50% SP to JL 50% SS to WRC	50%
Scotland	10,000	20%	30%	50%	50% SS to WRC	50%

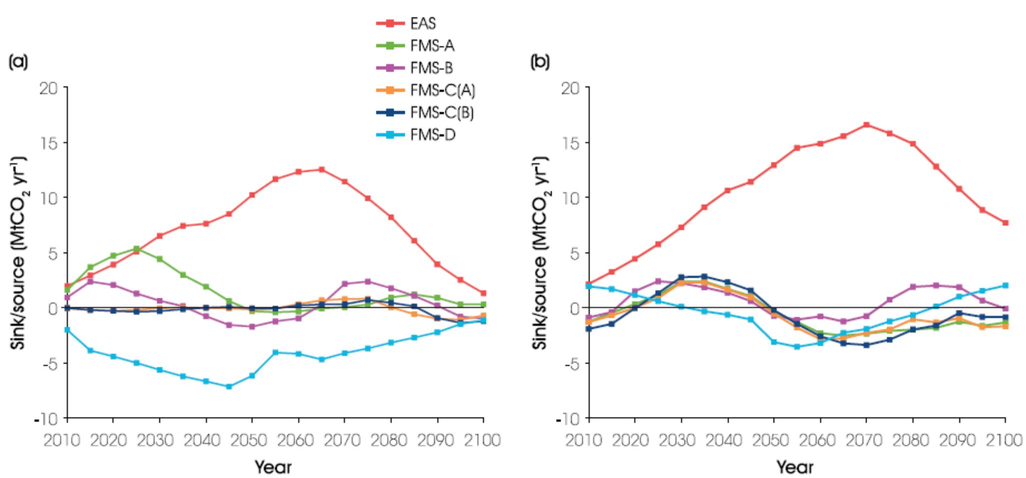
Wales	2,500	10%	40%	50%	50% SS to DF 100% SP to JL	50%
N. Ireland	700	10%	40%	50%	50% SS to WRC	50%

Notes – SRF = Short Rotation Forestry; SAB = Sycamore-Ash-Birch mixture; Native = Native woodland species (as appropriate for country) managed with amenity as main priority; SS = Sitka Spruce; DF = Douglas Fir; CP = Corsican Pine; SP = Scots Pine; JL = Japanese Larch; WRC = Western Red Cedar.

Source: Adapted from Matthews & Broadmeadow (2009, Table 8.1, p.146).

The scenarios modelled show that a policy of increased planting has the potential to greatly increase aggregate future carbon sequestration rates by UK woodlands (**Figure 22**). They suggest that the additional annual value of net carbon sequestered by UK woodlands under the enhanced afforestation scenario could potentially rise by around £3,000m-£4,000m by 2060 at 2010 prices compared with the CEH BAU scenario. (Note this estimate is based upon valuing the additional net 12-15MtCO2 sequestered in 2060 at the DECC central value of £275/tCO2e recommended for that year).

Figure 22 – Impact of scenarios on projected net CO2 uptake compared to BAU scenario: (a) woodlands only; (b) total including HWP and substitution effects.



Source: Adapted from Matthews & Broadmeadow (2009), p.148.

8.5. Summary and Concluding remarks

Paucity of data and different reporting periods precludes identification and comparison of trends in values for each ecosystem service provided by UK woodlands over the same time period. Nonetheless, the review of changes in values of three ecosystem services has highlighted some apparent differences (see also **Table 4** below), notably in the apparently sharp decline in hardwood gross values compared to softwood ones (even if the precise change in these values over time and their representativeness is unclear).[25] However, as previously discussed, a sharp decline in hardwood prices is consistent both with a shift in woodland management objectives away from timber production towards provision of multiple ecosystem services, and with reports of low import prices. (In the case of the per hectare hardwood values, a decline is also consistent with an expansion in the total area covered by broadleaves with an associated transition to a lower average age of stands).

Table 4 – Changes in values of ecosystem services from woodlands (at 2010 prices)

	Annual value (£ millions)				**Annual value per ha** (£/ha)		
Ecosystem service	1945	1976	1990	2009	1990	2001	2009
Softwood production (*)		112	145	102	95	55	66
Hardwood production (†)			110	8-26	120		7-25
Deer (‡) a) venison b) stalking						 2 3	
Net Carbon sequestration							

[25] *Between 1989 and 2007/8 the total gross value of hardwood produced apparently fell by at least three-quarters, while that for softwood production fell by under two-fifths (from £172m in 1989 to £136m in 2007 and £108m in 2008).*

by woodlands (¶)	124	563	642	680	246	270	239
Net Carbon sequestration in harvested wood products (¶)	0	13	77	119	29	8	42

** Estimates based upon prices for standing sales from Forestry Commission land.*
† Dates differ: the first year is 1989 and second 2007/8. Estimates based upon average prices for both standing sales and direct production (data comparability unclear);
‡ Based upon information for 2001/2 for the east of England. (Values for Scottish estates probably significantly higher).
¶ Based upon the central estimate of the social value of carbon for 2009 recommended for non-ETS sectors (DECC, 2010) at 2010 prices; per ha estimate for 1990 derived by dividing by UK forest area from FC (2010a).

The above estimates of gross values take no account of capital and labour costs – which surveys of private woodland owners suggest averaged around £200/ha-£300/ha during 1961-86 at 2010/11 prices (and recent information on total Forestry Commission expenditure in England of £275/ha in 2007/8 may suggest are currently a similar magnitude). To the extent that these costs are common to the provision of each ecosystem service provided by woodlands (including those considered in other chapters),[26] gross estimates provide a useful rough indication of relative social value.

Although sensitive to the social values of carbon assumed (and to assumptions of permanence), at present by far the highest values are for carbon sequestration by woodlands. Remaining largely non-market values, however, there is little incentive at present for landowners to increase provision of this ecosystem service (or to maintain existing carbon storage).[27] A Woodland Carbon Code is currently being

[26] Not all costs will be common, however. For example, wood production may entail timber marketing costs that differ from cases where trees are left standing as a carbon sink. For a 5 ha woodland, Forestry Commission England currently estimates standard costs per hectare of managing a woodland for public access to be almost twice (£236/ha) those of managing a broadleaf woodland for biodiversity (£122/ha), or a coniferous woodland as a red squirrel reserve (£139/ha).
[27] Similarly, except where targeted subsidies exist, there is little incentive at present for woodland owners to provide other non market ecosystem services.

developed by the Forestry Commission (FC 2010c) to help stimulate emerging markets for carbon sequestration in the UK.

The extent both of ecosystem service provision, and to which trade-offs or synergies exist in their provision, is clearly sensitive to land management approaches and objectives (see also the mountains, moors and heaths chapter). For example, stalking and venison production are complementary activities to wood production and habitat conservation in many cases, but where the primary focus of land management, they may largely be substitutes.

Significant data gaps identified above include the lack of consistent time-series data on hardwood standing sales prices, on woodfuel, on venison and stalking revenues, and on forestry costs. Existing knowledge gaps include spatial differences in marginal values between regions, woodlands types and forestry management approaches and may seem unsurprising given this paucity of data. More fundamentally, the marginal value of individual ecosystem services net of capital and labour costs remains indeterminate in the absence of an accepted approach to apportioning forestry establishment and management costs between different ecosystem services. Under these circumstances, analysis of issues of trade-offs and synergies, and of optimal land use has to rely on comparing differences in the total net values (and non-monetised contributions to human wellbeing) of ecosystem services provided. However, in view of existing data and knowledge gaps, including the need still to develop a suitable methodology to quantify some ecosystem services (e.g. spiritual values), robust estimates of total net values to facilitate comparisons of alternative land uses may appear elusive at present.

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