**Social & Environmental Benefits of Forestry**
**Phase 2 :**

# THE SOCIAL AND ENVIRONMENTAL BENEFITS OF FORESTS IN GREAT BRITAIN

Report to

## Forestry Commission

Edinburgh

from


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## Executive Summary

Forests in Britain produce social and environmental benefits, in addition to marketable timber outputs. These non-market benefits include open access non-priced recreation, landscape amenity, biodiversity, carbon sequestration, pollution absorption, water supply and quality, and protection of archaeological artefacts.

The aim of this study was to provide empirical estimates of each of these social and environmental benefits in terms of

- marginal values, as an input into forest management, and
- their total value across forests and woodlands in Great Britain, to assess the importance of woodlands to the British economy.

The study used existing data sources and information where relevant, and commissioned new surveys to up-date the recreational values of forests and to estimate the landscape benefits of forests.

The recreational value of woodland is based upon the EU CAMAR data set, which sampled 15,000 recreational visits to 42 forests in Scotland and Ireland. The recreation study also commissioned new recreational visitor surveys in seven English and Welsh forests to assess the transferability of recreational values between forests based upon the characteristics and the forest and visitors.

The landscape study commissioned a new survey of over 400 residents across England, Scotland and Wales to estimate the value of woodland views from properties and on journeys. It explored the value of forests in different landscape contexts (e.g. mountain, hilly/rolling, peri-urban) and in terms of different configurations of forest.

The biodiversity study employed an existing study valuing biodiversity enhancement in remote commercial Sitka spruce forests. This study conducted eight focus groups in England, Scotland, and Wales, to evaluate the relative importance and value of biodiversity in different types of forest (e.g. upland native broadleaved woodland; lowland conifer forest; lowland ancient semi-natural broadleaved woodland).

The carbon sequestration study modelled carbon sequestration throughout Sitka spruce, oak and beech yield class rotations. The model took into account carbon changes in soil, the effect of thinning, and energy use to manage the forest. The study used the Forestry Commission sub-compartment data base and the National Woodland Inventory to map this carbon sequestration across woodland throughout Great Britain. The study also used three different values for the social value of carbon to reflect global uncertainty about the cost of carbon in global warming damage estimates.

The study of pollution absorption measured the impact of tree type (deciduous and conifer) on improved air quality in terms of particulate matter (dust particles) and sulphur dioxide. It estimated the health impact using epidemiology information on the link between air pollution and deaths and hospital admissions for respiratory diseases adopted by the Department of Health; and matched the distribution of woodland with the distribution of population across Great Britain. Values of preventable fatalities and hospital care were also those adopted by the Department of Health.

The impact of forests and woodland on water supply was assessed from hydrological and ecological models of the effect of woodland on rainfall inception and transpiration rates compared to grassland. The cost of woodland on water supply can be estimated from marginal costs faced by different water companies for abstracting potable water supplies. Information from existing literature and discussions with water companies were used to assess the impact of forests on water quality.

Archaeological benefits of forests proved difficult to estimate, because of uncertainty about the quantity of archaeological artefacts on forested land, and the public's value of different quantities and types of archaeological artefacts.

The marginal benefits of woodland were estimated to be:

- £1.66 to £2.75 for each recreational visit
- £269 per annum per household, for those households with a woodland landscape view on the urban fringe
- 35p per household per year for enhanced biodiversity in each 12,000 ha (1%) of commercial Sitka spruce forest; 84p per household/year for a 12,000 ha increase in Lowland New Broadleaved Native forest, and £1.13 per household/year for a similar increase in Ancient Semi Natural Woodland
- £6.67 per tonne of carbon sequestrated
- £124,998 for each death avoided by 1 year due to $PM_{10}$ and $SO_2$ absorbed by trees, and £602 for an 11 day hospital stay avoided due to reduced respiratory illness
- A cost of 13p to £1.24 per $m^3$ where water is lost to abstraction for potable uses, although for most areas the marginal cost is zero. The externality cost of woodland on water quality has been 'internalised' within forestry through the application of guidelines on woodland planting and conditions attached to forest certification.

These are indicative values for particular contexts, e.g. for landscape it is the value of seeing some woodland in the urban fringe rather than this landscape without woodland. Different marginal landscape values exist for non-urban periphery woodland views, i.e. woodland in other landscape contexts, and for different woodland configurations in the landscape in terms of woodland shape and species mix. Similarly there are different values for marginal increases in biodiversity in different types of woodland. Thus, there is no single marginal benefit (MB) or marginal cost (MC) value for any of the SEBs. MBs vary for each SEB depending upon circumstances. The MBs per hectare of carbon sequestration depends upon tree type, yield class and forest management regime. The MBs of recreation depend upon the recreational attributes of the forest. These different MBs are documented briefly in this report, and more fully in the individual research reports for each SEB upon which this summary report is based.

The aggregate total annual and capitalised values of the SEBs of woodland in GB amount to £1.0 billion and £29.2 billion respectively (see Table below). This total aggregate value of woodland is dominated by recreational and biodiversity values, followed by landscape benefits, with carbon sequestration also contributing significantly to the total social and environmental benefit of forests. Air pollution absorption (health effect) of woodland is relatively insignificant because of the absence of significant population numbers in close proximity to areas of woodland.

The total value of the social and environmental benefits of forestry is dependent upon individual values (e.g. WTP per recreational visit; social value of t/C; etc) and the number to which these individual values are applied (e.g. the number of visits to forests; tonnes of carbon sequestrated by forests; etc.)

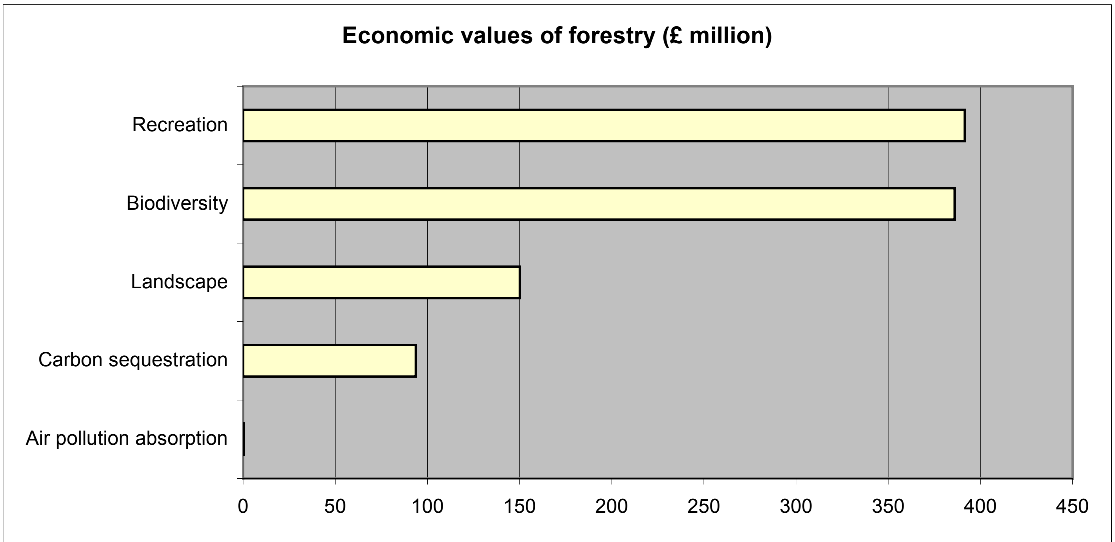
Aggregating individual SEB estimates to derive total aggregate benefits of woodland for recreation, landscape, biodiversity, carbon sequestration, and air pollution absorption, is highly dependent upon accurate estimates of the population of relevance in each case. The area of woodland to calculate tonnage of carbon sequestrated by woodland can also be fairly accurately determined from the National Woodland Inventory Survey. The population of areas containing woodland can be accurately determined from the Population Census. However, there is considerable uncertainty about the number of households with woodland landscape views; and the number of households who enjoy forest views on journeys. Similarly, uncertainty also exists about the number of visitors and visits to the FC estate and private woodlands in GB.

**Annual and capitalised social and environmental benefits of forests in GB**
(£ millions, 2002 prices)

| ***Environmental benefit*** | ***Annual value*** | ***Capitalised value*** |
|---|---|---|
| Recreation | 392.65 | 11,218 |
| Landscape | 150.22 | 4,292 |
| Biodiversity | 386.00 | 11,029 |
| Carbon sequestration | 93.66 * | 2,676 |
| Air pollution absorption | 0.39 * | 11 |
| **Total** | 1,022.92 | 29,226 |

* An approximation, since carbon sequestration, and probability of death and illness due to air pollution, varies over time. More carbon is sequestrated in early rotations than in later rotations, resulting in an annuity stream that is inconsistent over multiple rotations. Similarly for air pollution, that results in an individual's life being shortened by a few days or weeks at the end of the individual's life at some point in the future.

More accurate information on the population of relevance to different categories of social and environmental benefits of woodland is necessary if a more accurate and robust total aggregate SEB of woodland is to be provided. Further research is required to identify the populations over which the different categories of social and environmental benefits and costs are to be aggregated. A more precise assessment of the number of visits and visitors to forests and woodland is essential for a more accurate and robust estimate of the aggregate recreational benefit of woodland. Similarly for landscape: a more reliable estimate of the number of households with varying degrees of forest views is required. There is generally more uncertainty about the aggregate value of woodland than the marginal values of individual social and environmental benefits of forests.



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## 1. INTRODUCTION

Forests in Britain produce social and environmental benefits, in addition to marketable timber outputs. These non-market benefits include open access non-priced recreation, landscape amenity, biodiversity, pollution absorption, and a range of other environmental and social benefits.

An accurate valuation of these social and environmental benefits (SEBs) is necessary to ensure the optimal provision of woodland, with appropriate structural characteristics. Under-valuation of any of these SEBs will impede the efficient allocation of resources to achieve sustainable forest management.

The purpose of this Phase 2 project commissioned by the Forestry Commission (FC) is to examine the different SEBs of woodland in more depth than was possible in the Phase 1 study (see Willis *et* al, 2000).

## 2. AIMS AND OBJECTIVES

Phase 1, which preceded this study,

- reviewed existing valuation methodologies and research to determine the best approach to valuing non-market benefits (NMBs) of U.K. forestry;
- investigated existing data to determine which topics future research might address;
- determined which valuation techniques should be used in such research if accurate and robust values are to be obtained.

The review (see Willis *et al*, 2000) concentrated on the main NMBs of forestry: recreation, landscape amenity, biodiversity, and carbon sequestration. Other benefits briefly reviewed encompassed water quality, pollution absorption, health effects and preservation of archaeological artefacts.

The Phase 1 study noted that research on the NMBs of forestry had derived varying values for each NMB; and that this variability had not been adequately nor consistently addressed. Differences in estimated benefits for forestry arose because studies rarely valued *exactly* the same commodity using *exactly* the same technique; and studies also varied in the types of benefits they sought to measure.

Recommendations of the Phase 1 study were that existing NMB estimates of forests should be updated, with respect to recreation, landscape and amenity, biodiversity, carbon sequestration, and other NMBs.

This Phase 2 study followed the recommendations outlined as Option 2 of the Phase 1 study. It uses both existing data and previously completed studies, along with new survey work to validate model predictions and assess the robustness of the SEB estimates. Although the Phase 1 Study identified the most important SEBs as being recreation, landscape, biodiversity and carbon sequestration, other use and non-use benefits, as far as they can be quantified and valued, are included in this Phase 2 study.

The aim of this Phase 2 Study is to provide empirical estimates of the

- total value of SEBs of Britain's public and private forests, disaggregated to country and regional levels;
- marginal value of SEBs that can be used to inform a selected range of forest management operations.

The methodology to be used in Phase 2 had to accurately estimate the different SEBs of woodland, avoid double-counting of benefits, and correctly identify the population of beneficiaries for aggregation.

The Forestry Commission (FC) made a number of their data-bases available to the Phase 2 study, namely their Sub-Compartment Data-Base, National Inventory of Woodland and Trees, Woodland Grant Scheme data-base, and Yield Class models.

This report summarises the research estimating the value of the SEBs of the existing stock of woodland, and marginal values of changes to that stock, in the five main areas comprising the research programme:

- recreation,
- landscape,
- biodiversity,
- carbon sequestration, and
- other SEBs
  - archaeological preservation,
  - pollution absorption, and
  - water supply and quality.

The report presents an estimate of the aggregate value for most of these SEBs at a national, country (England, Scotland, and Wales), and regional level (by government office areas).

It should be noted that values for some of the social and environmental characteristics of forests produced in this report are *gross* rather than *net* values. This is an inevitable consequence of not knowing what alternative land-use would pertain in the absence of forestry. Thus, for recreation we do no know what type of agriculture or other land-use would occur in the absence of woodland, what recreational access would be available on this land, and hence what recreational value would be attached to this alternative land-use. A similar situation pertains for biodiversity. Indeed, it is likely that a number of alternative agricultural land-uses would have a greater biodiversity value than blanket conifer sitka spruce forest that replaced them (see Hanley and Craig, 1991). The carbon sequestration value approximates a *net* value, in that it takes into account changes in soil carbon content in moving from agriculture to forestry, and assumes that carbon outputs of alternative land uses are insignificant. Pollution absorption and water supply values also attempt to measure *net* values by reference to grassland as the alternative land-use; whilst landscape values are measured with respect to the value of a '*without*' woodland view alternative landscape.

## 3. RECREATION

The objective of this section of the research programme was to provide up-to-date estimates of the benefits of recreational use of woodlands in GB, disaggregated by regions and countries. The value of marginal visits, and the total value of all visits, had to be consistent with the main microeconomic tenets of individual choice; and determine, as far as possible, the extent to which these values were depended upon measurable forest attributes.

The benefit from visits to outdoor recreation sites is frequently estimated as a "compensating variation". This is a money measure of the loss of utility individual visitors would suffer from the closure of the recreation site. This compensating variation procedure was adopted by Scarpa (2003) for the study of the recreational value of woodland. The study used a contingent valuation (CV) approach. Visitors to different woodland recreation sites were asked the maximum they would be willing to pay for access to the woodland for recreational purposes, rather than go without recreation in that woodland. This value depends upon the characteristics of the forest and recreational opportunities within it, as well as the availability of substitute sites in the area, and the income and taste characteristics of the population in the market area surrounding the forest.

The recreational value of woodland in GB was estimated using the European Union CAMAR data set. The EU funded CAMAR data set is the largest benefit valuation study of woodland recreation in the UK. The study was conducted in 1992 by Ni Dhubhain et al. (1994). The socio-economic component of the study involved surveying visitors to 42 woodland sites (14 in Scotland; 14 in Northern Ireland; and 14 in the Republic of Ireland), with an average sample size of over 350 per site (over 15,000 observations). The EU CAMAR data set contains details of the characteristics or woodland and recreational facilities in each forest, as well as socio-economic characteristics of each visitor.

The objective of the study by Scarpa (2003) was to estimate the recreational value of forests in GB through a benefit transfer function from the EU CAMAR data set. Benefit transfer is a process by which either (a) the recreation demand function or (b) the actual willingness-to-pay (WTP) amount, estimated for one recreation site, is applied to other similar recreation sites. The reliability of this benefit transfer procedure was verified through a new survey in 2002 of visitors to 7 forests in England and Wales. These 7 forests were: Brenin (in Wales), Dartmoor, Delamere, Epping, New Forest, and Thetford. Reliability was assessed by comparing mean and median estimates of visitors' WTP to gain access to each of these 7 forests by benefit transfer with estimates from the actual 2002 survey.

Two types of contingent valuation (CV) question were used in the EU CAMAR study, and by Scarpa (2003) in the 2002 survey of visitors to 7 forests in England and Wales: an open-ended question[1] and a discrete choice question[2] .

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[1] What is exactly the maximum amount in pence you would pay as an entry charge <u>for your visit today</u> and <u>for each person in your party</u> (including young people under 18) rather than going without the experience? £ _______ . _____pence)

[2] If it were necessary to raise funds through an entry charge to ensure this forest or woodland remained open to the public, with no additional charge being made for parking (this charge, if it exists, would stay as present), would you:

The benefit transfer function for recreational visits to EU CAMAR forests, on the basis of the characteristics of the forests and recreational facilities provided, was applied to each of the 7 forests in the 2002 survey. Because the site characteristics are not identical between forests the estimated WTP for access to each of the 7 forests will vary. These benefit transfer estimates were compared to the actual WTP amounts derived from the 2002 on-site surveys at each of the 7 forests. The recreation demand BT function from the EU CAMAR data derived conditional mean WTP values per visit based on woodland attributes. These attributes covered total forest area in hectares, percent coverage of broadleaves, larch, presence of nature reserves (SSSI, etc.) [all of which had a positive effect on utility], conifers, and a measure of congestion (yearly visits/car parks capacity [both of which had negative impacts on utility]. Applying this BT function to the attributes of the seven forests produced mean WTP per visit values that ranged from 110 pence per visit to Epping, to 300 pence per visit to Delamere.

The benefit transfer function can be used to compute the recreational value of any combination of forest attributes. For example, an English woodland of 900 hectares, with 60% of the area conifers, 20% broadleaves, 12% larch, 5% of tree planted before 1940, with a nature reserve, and a congestion index of 20, would have a mean WTP value of per visit of 148 pence.

The aggregate benefit of recreation in woodland can be estimated in two ways. Both are benefit transfer methods, and both are based on the benefit or WTP for a single visit. The first method employs a generic (site-independent) value transfer; whilst the second employs site specific estimates, constructed on the basis of woodland attributes shown to be of importance to visitors. One limiting factor in adopting site specific benefit transfer estimates is the availability of adequately measured site-attributes for a large number of woodlands in GB.

The contingent valuation open-ended WTP question in 2002 survey of visitors to English and Welsh forests, indicated a mean maximum WTP of £1.66 (standard deviation £1.4), with a median of £1.5. From the cumulative frequency of responses: 17% of respondents indicated that they would not be willing to pay anything to visit the forest; 27% of respondents would pay 50p or less; 48% of respondents £1.00 or less; and 80% of respondents indicated that they would be willing to pay less than £2.50 per visit.

Open-ended CV responses are known to produce estimates of benefits that are systematically lower than those produced by discrete choice responses. An analysis of discrete choice responses estimated mean WTP values of £2.19 (± £0.10)[3] (using a single-bounded linear-in-the-bid model); £2.78 (using a double bounded linear-in—the-bid model); and to £2.75 (± £0.68) (using a double bounded log-in-the-bid model) which also gives a median WTP value of £1.91 (± £0.24). The double bounded log

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(a) still visit the forest as frequently and pay an entry charge of £ 2 for each person in your party (including young people under 18) rather than go without the experience?

Yes_______ NO_______

(b) still visit this forest and pay the above entry charge, but decrease the number of visits by

□90% □80% □70% □60% □50% □40% □30% □20% □10%

(c ) stop visiting this forest altogether and try to find a substitute site where to go and live the same experience.

[3] Standard error of the sample mean.

model exhibited the greatest goodness-of-fit, and is consistent with the skewed WTP distribution, and it is also a property consistent with the distribution of income.

The 2002 recreation survey of the 7 English and Welsh also revealed that if a price for entry to a forest were charged, 34% of respondents would reduce the number of visits they made to forests (Scarpa, 2003). These people would change their visit behaviour to forests substantially if an entry fee were charged: 54% said their number of visits would halve. While 20% of respondents would reduce their visits by less than half, the other 80% would reduce their visits by one-half or more.

In addition WTP for each visit declined with frequency of visit [frequent visitors(>50 times per year) were only willing to pay 60p for each visit]; whilst visitors who travelled less than 10 miles were also willing to pay less than that for the 'average' visit [90p per visit instead of £1.66].

A generic (site independent) value transfer was undertaken to determine the aggregate value of woodland recreation. This was calculated by multiplying the open-ended CV estimate of consumer surplus per visit by the number of visitors to woodland as reported by the UK Leisure Day Visits Survey (1998). The UK Day Visits Survey estimates that 77% of woodland visits are within a short distance from home (less than 10 miles). Using the mean WTP for these visits (£0.90) and the mean WTP for the remaining 23% of visits (£1.80), the aggregated value of woodland recreation is estimated to be £392.65 million per annum for GB. Over 90% of this recreational value is attributable to woodland located in England. The distribution of recreational values by regions and countries is reported in Table 10.1.

It is difficult to judge the reliability of the aggregate value for recreation. Open-ended CV estimates are conservative lower bound values. The analysis of the discrete choice data relating to visits to the 7 forests suggests the value per visit might be higher than £1.66 (see Scarpa, 2003), perhaps even as high as £2.75 per visit. There are also differing views on the reliability of general household surveys such as the UK Leisure Day Visit Survey (UKDVS). Some people believe it may over-estimate the number of visitors to forests, because of respondents' memory bias, and lack of a rigorous definition of woodland. Reliable information on visit numbers, by counting numbers entering at 'the forest gate', only exists for a few forests. The UKDVS survey should exclude most casual visits to woodland. WTP by people making casual visits to woodland (e.g. by people walking dogs) is much lower than that for 'purposeful' day visits, perhaps between 10p to 30p per visit (see Crabtree *et al*, 2002; Willis and Garrod, 1991). Of course, the value of such visits would be additional to the value of 'day visits' reported by UKDVS. Unfortunately no information exists on the number of such casual visits to woodland.

## 4. LANDSCAPE

The rationale for the landscape element of the project was to investigate public preferences and willingness to pay (WTP) for forested landscapes, seen either from home or during regular journeys to and from home. This work by Garrod (2003) extends the scope of previous investigations, such as those Willis and Garrod (1992) and Entec and Hanley (1997), by investigating a wider range of generic forest landscapes. The study by Garrod (2003) also explicitly attempts to separate WTP for woodland views from WTP for the open-access recreation (which was also measured) or biodiversity that those landscapes also support.

The Forestry Commission (FC) identified six generic forested landscapes within which to explore public preferences. These are defined by two generic forest types (broad-leaved and conifer) each set within three landscape contexts as shown in Table 1 below. To take account of the impact of design on preferences, a number of forest configurations were specified for each of these landscape types. The configurations used were chosen to reflect those commonly found in the UK, thus ensuring that any results could be applied as broadly as possible. Six configurations of conifer forest were defined, based on four factors: shape, scale, structural variety and species variety. For broad-leaved forests five configurations were used based on only the first three factors. The resulting 33 forest landscape configurations were illustrated in a series of 33 computer-generated images generated by consultants Cawdor Forestry. These were supplemented by a further four images depicting the landscape without forestry in order to estimate net values.

**Table 4.1: Landscape contexts**

| GENERIC FOREST TYPE | |
|---|---|
| Coniferous | Broad-leaved |
| LANDSCAPE CONTEXT | |
| Upland Plateau<br>Mountain<br>Rolling/Hilly | Mountain<br>Rolling/Hilly<br>Peri-urban |

The final 37 images were used to form the basis of a choice experiment (CE) designed to investigate public WTP for views containing forests. CEs are used by economists to determine individuals' preferences for the attributes of a good or service. This is achieved within a questionnaire framework when respondents are asked to make choices between various hypothetical alternatives offering different levels of those attributes. If one of these attributes is price, then respondents' WTP for the other attributes can often be inferred. Most CEs involve some form of survey where respondents are asked to study a series of profiles and then make choices based on their preferences for them. The task that respondents were set in this case, was to rank a given set of profiles in order of preference

The CEs were incorporated within a questionnaire that was administered by a professional survey company to over 400 respondents. Six appropriate areas were chosen to act as survey sites (in four sites two of the generic landscapes were investigated, while only one landscape was investigated at the remaining two sites). Two versions of the questionnaire (H and T) were used, respectively looking at preferences of landscapes viewed from home (H) and when travelling (T).

The scenario used in version H is based on a hypothetical choice between three houses differing only in terms of the views that they have, recreational access to that view and the cost to the respondent of living there (depicted respectively using a picture of the view and an associated information card). Version T uses a similar scenario except that in this case it is the view on regular journeys to and from home that is the focus of the choice. In each case one of the three alternatives consisted of the landscape without woodland, with no recreational access available at no additional cost to the respondent. The CE profiles therefore comprised a combination of pictures and text. The images of landscapes provided the visual element, while the text reported the availability, or otherwise, of recreational access and the size of any difference in annual household costs between the associated house and the cheapest alternative. Respondents were given four sets of three alternatives to rank.

Respondents were also asked about their preferences for the types of forest that they would like to see in a view. The results suggest that people have well defined preferences about the characteristics of forests that they would like to see in a view. Preferences across the seven sets shown in Table 4.2, suggest that a 'typical' respondent prefers small woodlands comprising of stands of randomly spaced broad-leaves of varying heights, interspersed with areas of open space. The majority of respondents also prefer to see woodlands on hills and away from towns, though more than half of respondents had at least an equal preference for seeing forests on flatter land or near towns.

**Table 4.2: Respondents preferences for different forest characteristics**

| | | | | |
|---|---|---|---|---|
| **Set 1** | Coniferous trees<br>13.7% | Broad-leaved trees<br>54.6% | Equal preference<br>30.8% | Neither<br>1.0% |
| **Set 2** | Large forests<br>22.4% | Small woodlands<br>57.2% | Equal preference<br>19.2% | Neither<br>1.2% |
| **Set 3** | Trees of various heights<br>74.8% | Trees that are all similar heights<br>9.9% | Equal preference<br>14.7% | Neither<br>0.7% |
| **Set 4** | A mix of trees and open spaces<br>83.4% | Just trees<br>5.3% | Equal preference<br>10.8% | Neither<br>0.5% |
| **Set 5** | Regularly spaced trees<br>10.1% | Randomly spaced trees<br>77.4% | Equal preference<br>11.8% | Neither<br>0.7% |
| **Set 6** | Trees on hills<br>49.0% | Trees on flatter land<br>14.7% | Equal preference<br>35.6% | Neither<br>0.7% |
| **Set 7** | Near to towns<br>32.2% | Away from towns<br>38.5% | Equal preference<br>27.6% | Neither<br>1.7% |

Of all the preferences investigated, the strongest were for plantings that mixed trees and open space and where spacing of trees was random rather than regular. If these preferences were translated to the factors that determined the forest configurations used in the choice experiment, it might be expected that respondents would prefer shape to be 'more organic' rather than 'basic'; scale to be 'small' rather than 'large'; structural variety to be 'high' rather than 'low'; and species variety to be high' rather than 'low'. If preferences for these attributes are separable and additive, then those configurations that offer all of the favoured factors should attract the highest values.

A range of approaches was used to model the choice experiment data. These reflected differences in the data used, with the main variations being the use of the full set of ranks (full ranks or contingent ranking model) or the use of data on only the most preferred alternative (MPA model). Socio-economic characteristics were also used in certain models to help to explain choices, though these were omitted in the models used for aggregation purposes.

It was found that for a number of configurations robust WTP estimates could not be estimated due to a lack of statistically significant coefficient values. In other cases there is evidence that respondents experience a loss in welfare associated with certain forests in particular landscapes (e.g. broad-leaves in a mountain setting). Clear preferences for forested landscapes compared with the non-forested alternatives were only found for broad-leaved woodland in a peri-urban setting. For views from home, WTP ranged from between £200 and £500 per household per year depending on model used and the forest configuration, while for views while travelling WTP was in the range £155 to £330 per household per year (Garrod, 2003). These values excluded recreational benefits estimated separately.

The MPA model provided a much better statistical fit to the data than the ranks model. Hence WTP estimates derived from the MPA model were adopted in the aggregation. The MPA model indicated that households were willing to pay £268.79p per year for woodland views from home, and £226.56p per year for views whilst travelling.

A high proportion of responses reflected preferences for the recreational access attribute of the profiles. Estimated recreational benefits were calculated for the six generic landscape types and were in general lower than the comparable landscape benefits, ranging from about £40 to £370 per household per year. Benefits were generally highest for respondents who would see the forest landscape from home.

The aggregate landscape value of woodland should be based upon the number of households with woodland views of the different types of forested landscapes. However, estimating the number of residential properties in each of these categories through some GIS system such as ARCVIEW, using ‘viewsheds’ to determine which properties have views of woodland and which do not, is clearly an enormous task well beyond the resources available to this project. A less reliable approach, to establishing the number of households over which aggregation should proceed, would have been to estimate the number of households with a certain distance, say 3 kms, of woodland in specific types of landscape. Unfortunately the FC was unable to provide GIS data on the number of households living within a certain distance of woodland landscape types in spatial areas of GB.

The method adopted to aggregate households’ WTP for urban fringe wooded landscapes was therefore to use the 1991 Census classification of wards. This classified wards into (i) wholly rural, (ii) predominantly rural (1-25%), (iii) mixed rural (25-50%), (iv) mixed urban (50-75%), (v) predominantly urban (75+%), and (vi) wholly urban. GIS was used identify mixed urban wards by regions in GB. The number of households in these wards was summed to provide an estimate of the number of urban fringe households. These household totals amounted to 795,912 in England (0.04216 of all households in England); and 52,220 in Wales (0.04663 of all households in Wales). The Scottish census did not classify wards into rural-urban types. Hence, the average proportion of mixed urban wards in England and Wales (0.04241) was used to estimate the number of households in mixed urban wards in Scotland (86,290) from the total number of Scottish households (2,035,134).

The number of urban fringe households was multiplied by the proportion of households in the survey (0.23) who reported that they had a ‘woodland view’ from their house, to estimate the number of households with woodland views, by regions of GB. These regional household totals ‘with woodland views’ were multiplied by the conditional logit model estimate of annual WTP (£268.79p) for this ‘with-without’ woodland scenario, capitalised at a 3.5% discount rate into perpetuity, to estimate the landscape value of forestry. The capitalised value amounted to £7,680 per household (i.e. property). Table 4.3 documents the estimated number of households with a woodland view, and summarises the aggregate value of woodland landscape by country in £ millions.

**Table 4.3: Aggregate capitalised value of woodland landscape.**

| *Area* | *Number of households with woodland view* | *Value of woodland view for houses (£, millions)* | *Number of households seeing woodland on journey* | *Value of woodland view on journeys per household (£, millions)* | *Total value of views of urban fringe woodland (£, millions)* |
|---|---|---|---|---|---|
| England | 183,324 | 1407.88 | 329,444 | 2132.54 | 3540.42 |
| Scotland | 19,875 | 152.63 | 60,506 | 391.66 | 544.29 |
| Wales | 12,028 | 92.37 | 17,733 | 114.79 | 207.16 |
| GB | 215,227 | 1652.88 | 407,683 | 2638.99 | 4291.87 |

Garrod (2003) estimated that an average household was willing to pay £226.56p per year for views of urban fringe broadleaved woodland on journeys. Views of woodland in other landscape settings were either very small or statistically insignificant. The aggregate value of urban fringe broadleaved woodland was estimated by calculating the proportion of population in predominantly rural wards plus mixed rural wards who commuted outside the district, from the 1991 Census. Applying this proportion to households provides an estimate of the number of households who commute outside the district. If we assume these households commute into an urban area, the number of households that commute can be multiplied by the probability that they encounter an urban fringe broadleaved woodland on their journey. The FC estimated that 15.5% of the urban and urban fringe area has tree cover.[4] This figure was used as the probability of encountering a woodland view on a journey. The capitalised value, at 3.5%, of the average household’s willingness to pay for views of urban fringe broadleaved woodland on journeys, is £6473. This capitalised value was multiplied by the number of commuting households who encounter this woodland.[5] The results are reported in column 5 of Table 4.3.

The capitalised value of forest landscape of £7,680 per house in the study by Garrod (2003) is consistent with the results of previous hedonic price models that have estimated the contribution of trees to house prices. Local trees were estimated by Anderson and Cordell (1988) to add 4% to house prices, whilst Morales (1980) estimated they added 6%. Garrod and Willis (1992) estimated that 20% general tree cover added 7.1% to house prices, although higher percentages of tree cover could

4 This figure of 15.5% relates to Scotland. No comparable figures exist for England and Wales. Hence the 15.5% for Scotland was also applied to England and Wales.

5 Equating woodland cover with the probability of seeing woodland is unrealistic, but tends to a conservative estimate.

detract from property values. The Entec-Hanley (1997) study investigated landscape improvements in British forests using expressed preferences: choice experiment and contingent valuation. The CE assessed WTP per household per year for forest shape; felling method; species mix in autumn, and winter, and spring. This produced WTP values for (selective) felling: £12.89; (organic) shape: £13.90; and species: £11.36 (diverse mix of evergreen, broadleaf, and larch). WTP for the ideal forest landscape was inferred by summing these variables, and produced a value of £38.15 per household per year. The separate CV study indicated households would be willing to pay £29.16 per year to see enhancements in the appearance of British forests that resulted in the perception of an "ideal" forest emerging. Thus whilst both the Entec and Hanley (1997) and the Garrod (2003) studies provide estimates of marginal values for changes in forested landscapes, the Entec and Hanley study cannot be used to derive a total value for woodland landscape.

## 5. BIODIVERSITY

The framework adopted to estimate the non-market benefits biodiversity values was based upon biodiversity values for changes to remote coniferous forests derived by Garrod and Willis (1997) for the FC. The values from that study are already used by the FC to value biodiversity in forests. Thus the research for this study was designed so that the results of the Garrod-Willis (1997) study could be generalised to estimate the biodiversity value of the remaining forest area in Britain, which has different biodiversity characteristics from remote coniferous forest.

Hence the objective of the Phase 2 non-market biodiversity benefit study of woodland was to

- ascertain non-use biodiversity values for other types of forest, in addition to that for remote coniferous forest, and to
- estimate the (marginal) biodiversity value of additions to these forests, in terms of extending their area.

Marginal values are an important management tool to assess changes in the structure of woodland areas, and also additions to woodland acreage.

FC ecologists identified biodiversity types that characterised woodland in Britain. Six types were identified:

1. upland conifer forests: medium and large scale conifer forest with clear felling
2. upland native broadleaved woodland: small scale ancient woodland
3. upland new native broadleaved woodland
4. lowland conifer forest: medium and large scale conifer and mixed conifer and broadleaved forest
5. lowland ancient semi-natural broadleaved wood
6. lowland new broadleaved native woodland

The upland conifer forest biodiversity type equated to the remote coniferous forest in the Garrod-Willis (1997) study.

Non-use biodiversity values are particularly difficult to capture. Both CV and stated choice (SC) experiments encounter difficulties in deriving biodiversity values. These problems arise for a number of reasons. First, people have widely different preferences for wildlife, so the variance of the mean WTP value is large. Second, people's WTP for biodiversity in different types of British woodland is a very small fraction of income; whilst WTP variation between individuals is mainly driven by taste for different forms of wildlife, *vis a vis* other goods, rather than by income. Because taste is difficult to measure, the variation in WTP between individuals is difficult to explain. Third, biodiversity is a difficult concept for people to grasp, and people find it difficult to trade-off species importance within fungi, plants, invertebrates, birds, and mammals, and to trade-off species importance between these groups. They also find it difficult to trade-off changes in numbers in a particular species against changes in the number of species represented in a habitat. Thus biodiversity is a complex issue over which many people struggle to form preferences. These preferences, once formed, seem to vary widely.

The valuation was undertaken by the use of in-depth research on people's preferences for biodiversity and wildlife conservation in other types of forest. As previous authors have noted (e.g. Spash and Hanley, 1995), biodiversity is a complex issue that may not be especially suited to valuation using normal questionnaire techniques. Hence a focus group based approach was adopted. In each group, participants had the chance to learn about biodiversity in forests before being asked to express their preferences.

Focus groups allow people more time to consider and discuss the various aspects of biodiversity in forests, compared with individuals' responses in a CV or CE questionnaire survey. More information can also be provided than is typically the case in a CV or SC questionnaire survey. This was one reason for choosing a focus group approach in this part of the study. However, it is difficult to know how respondents interpreted the information on the information cards. Clearly only a limited amount of information could be portrayed on each card, and the information only provided some indication of the species and diversity found in different types of forest. Respondents probably used a combination of their preconceived knowledge and notions of biodiversity in different types of forest, perceptions on biodiversity as a result of any visits to different types of forest, and information on the information sheets.

The focus groups employed tokens and a simple open-ended CV to elicit values and WTP for forest biodiversity. The token results are probably the more accurate and reliable of the two measures, for two reasons. First, respondents spent more time considering the relative merits of different types of forest for biodiversity in the token experiment. Second, many respondents were more reluctant to engage in the CV exercise. Moreover, the CV study did (could) not conform to the rigorous standards recommended by widely accepted authorities on this technique; nor was the CV of sufficient sample size.

Hence the relative values as revealed by the "tokens" exercise, and as summarised in Table 5.1, can be taken to represent the relative preferences for different types of woodland biodiversity; and WTP values for marginal increases in biodiversity associated with different types of woodland.

The values in Table 5.1 were derived through a series of eight focus group meetings in England, Scotland, and Wales. Each focus group had six to eight participants. The participants were aged between 22 and 55, fell within either B/C1 or C2DE socio-economic groups. Thus participants did not come from the full socio-economic spectrum of the population: old age pensioners and white-collar managerial people were not represented. The small number attending the focus groups also meant that the preferences expressed are not necessarily representative of the general population in a statistically significant sense. Nevertheless, the preferences expressed provide some indication of the relative value of biodiversity in different types of forests by a substantial section of the population, and these preferences appear to be rational and generally in line with *a priori* expectations.

**Table 5.1: Relative biodiversity values for different types of forest**

| Biodiversity forest type | Relative preference for existing area | Relative preference for an increase+ of 12,000 ha. | Relative WTP values per household for an increase of 12,000 ha. | Absolute WTP values per household for an increase of 12,000 ha. |
|---|---|---|---|---|
| Upland Conifer Forest (control) | 1.00 | 1.00 | 1.00 | 0.35 |
| Lowland Conifer Forest | 1.21 | 1.15 | 0.94 | 0.33 |
| Lowland Ancient Semi-Natural Broadleaved Forest | 2.11 | 2.31 | 3.23 | 1.13 |
| Lowland New Broadleaved Native Forest | 1.95 | 4.23 | 2.40 | 0.84 |
| Upland Native Broadleaved Woods | 2.32 | 3.31 | 2.57 | 0.90 |
| Upland New Native Broadleaved Woods | 1.95 | 3.15 | 1.74 | 0.61 |

+ Or in the case of ancient lowland and upland native broadleaved woodland to protect and regenerate these woodland types.
In columns 2 and 3, the base value is the individual mean preference for upland conifer standardised to 1.0, and the other figures for individual means are expressed as a ratio of this upland conifer 'preference'.
In column 4 the base value is the group mean (£0.35) for upland conifer, and the other figures are expressed as a ratio of this upland conifer 'value'.
Column 5 documents the actual WTP amounts.

The Garrod and Willis (1997) and the Hanley *et al* (2002) studies both assess WTP for marginal increases in biodiversity from restructuring remote commercial conifer plantations. Thus total biodiversity aggregate values have to relate to structural change in forests or protection and regeneration of ancient semi-natural woodland. Aggregate biodiversity values were derived by multiplying relevant WTP values by the number of households in each country. For example, the value of biodiversity in England represents the marginal value multiplied by the number of households in England. However, this method excludes the non-use values that exist in one country for woodlands in another country; for example, the values ascribed by the English population to woodlands (e.g. Caledonian pine forests) in Scotland. An alternative approach is to multiply marginal values by the number of GB households which produces much higher values, especially in Scotland and Wales (see Tables 10.1 and 10.2). It should be noted that the estimates of biodiversity values reported in Table 5.2 are according to the location of the woodland, not the population that benefits.

The FC supplied data on three types of structural change that had taken place. The first type is the area replanted in the 10 years to March 2001. This totalled 146,000 hectares for GB. This information is based on grant scheme and FE statistics published annually. Most of the area harvested was conifer, and can be assumed mostly to have been in single species plantations. After replanting there should normally be more open space, and a larger proportion of broadleaves. This is the restructuring that was valued at 35p/year/household in Garrod and Willis (1997) study. Some of this replanted area may not have been restructured, either because the original forest was diverse before harvesting, or because the replanted forest did not fully meet the biodiversity standards.

The second type is the area of new broadleaved woodland created, again taken as the 10 years to March 2001. This totalled 96,000 hectares for GB. This new woodland acreage is again based on grant scheme and FE statistics. This is a wider category than the "new native woodland" described to the focus groups; e.g. it includes farm woodlands primarily intended for shelter belts rather than with the primary aim of establishing native woodland with characteristics similar to semi-natural woodland. Hence the average biodiversity value for this wider category is likely to be lower than an average of the 61p and 84p values given to new native broadleaves. We assume that it has an average value of 50p/year/household.

Information on replanting and new broadleaved woodland created is available by country, but not by English region. It was not possible for FC to tabulate replanting and grant scheme information by English regions, for the above categories, in the time scale agreed for the completion of the project. However a reasonable accurate regional breakdown for the total of the two categories, based on the National Woodland Inventory, can be made. This regional breakdown uses the National Woodland Inventory sample areas recorded as being planted in 1991 or later, plus a regional GIS analysis of the areas of new planting from grant scheme and FE sources to 2001, to get an approximate percentage regional breakdown of the England total.

The third category is Ancient Semi-Natural Woodland. The latest estimates of the ASNW area are based on matching National Woodland Inventory (NIWT) and Ancient Woodland Inventory (AWI) digital maps. It totals 285,000 hectares for GB, and can be disaggregated to countries and English regions. This estimate is limited to the intersection of NIWT and AWI digital map layers, while previous estimates used AWI only and give slightly higher acreage estimates. However, limiting the valuation to 285,000 hectares can be viewed as a conservative estimate. Since it is not possible to create new ancient woodland, the WTP value derived in the biodiversity study by Hanley *et al* (2002) can be viewed as a WTP for its continued existence. Valuing this category at 100p/year/household (an average of the lowland and upland ASNW values) suggests an annual value of around £300 million per year.

It should be noted that this aggregation approach only assigns a biodiversity value to just over 0.5 million hectares of woodland in total, leaving almost 2.2 million hectares with no assigned biodiversity value. Hence the estimate should be viewed as a conservative estimate. But it amounts to more than £380 million a year, or around £11 billion capitalised at 3.5%. This indicates that biodiversity values are about as large as recreation values for woodlands. It is worth noting that public opinion surveys have regularly found that supporting forestry for wildlife is actually deemed more important than supporting forests for recreation (with both biodiversity and recreation being regarded as more important than landscape, and with timber production given least importance). If biodiversity values were assigned to the remainder of the forest estate, the total value for biodiversity may exceed that for recreation.

**Table 5.2: Total aggregate annual biodiversity values for woodland types (aggregated at a country rather than GB level)**

| | Area (thousand ha) | | | | Value (£ million) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | ASNW | NPB | RP | NPB+RP | ASNW | NPB | RP | NPB+RP | Total annual biodiversity value |
| Eastern | 18 | - | - | 13 | 28 | - | - | 9 | 37 |
| East Midlands | 11 | - | - | 9 | 17 | - | - | 7 | 24 |
| North East | 6 | - | - | 15 | 9 | - | - | 10 | 19 |
| North West | 14 | - | - | 9 | 22 | - | - | 6 | 28 |
| South East (incl.London) | 82 | - | - | 19 | 128 | - | - | 12 | 140 |
| South West | 35 | - | - | 14 | 54 | - | - | 9 | 63 |
| West Midlands | 19 | - | - | 6 | 30 | - | - | 4 | 34 |
| Yorkshire & Humberside | 9 | - | - | 7 | 14 | - | - | 5 | 19 |
| | | | | | | | | | |
| England | 193 | 43 | 49 | 92 | 302 | 34 | 27 | 61 | 363 |
| Scotland | 65 | 49 | 71 | 120 | 11 | 4 | 4 | 8 | 19 |
| Wales | 27 | 4 | 26 | 30 | 3 | 0* | 1 | 1 | 4 |
| Great Britain | 285 | 96 | 146 | 242 | 316 | 38 | 32 | 70 | 386 |

* less than 0.5

Some figures may not sum due to rounding

ASNW = ancient and semi-natural woodland; RP = replanting; NPB = new planting broadleaves.

## 6. CARBON SEQUESTRATION

Evidence suggests that global warming is underway, and that part of this is at least attributable to the anthropogenic emission of greenhouse gases (GHGs). Governments have agreed to reduce the rate GHG emissions, through a number of policies: taxes (e.g. fuel taxes; emission taxes; road congestion pricing; variable car excise taxes), subsidies (e.g. public transport subsidies to encourage a switch from private to public transport, home insulation) and regulatory controls (e.g. emissions regulations, land-use planning policies to reduce the need to travel especially by car by steering development towards locations accessible by public transport).

The strategy for forestry in Scotland (National Office for Scotland, 2000) suggested that on an annual basis Scotland's forests might absorb approximately 10% of $CO_2$ emissions attributable to Scotland, and that "the greatest sequestrations gains are likely to come from forests growing high quality timber (which will be put to long-lived end uses) on long rotations, in complex forest ecosystems with soils of low organic content" (NOS, 2000, page 26).

A social and environmental benefit of forestry policy is thus the extent to which woodland can contribute to the policy objective of reducing $CO_2$ in the atmosphere by locking up carbon through carbon sequestration. The aim of the study of carbon sequestration study by Brainard, Lovett and Bateman (2003) was to produce a more accurate and robust value for carbon sequestration over GB woodland.

The study estimated *net* carbon sequestration under woodland, and combined this with the value per tonne of carbon sequestrated, to derive a carbon sequestration value for woodland in GB. Since carbon sequestration in GB forms only a small part of $CO_2$ contribution to global warming, the marginal and average values for $CO_2$ sequestration are identical.

Carbon sequestration varies spatially depending upon woodland coverage, structure of the woodland (e.g. broadleaves or conifer), tree growth, and also soil conditions. Carbon storage in livewood is directly linked to timber volume, which can be derived from tree yield class. This data was available for the FC estate, but had to be estimated for private woodland through the National Woodland Inventory, by applying FC predicted yields to private holdings. Sitka spruce, beech and oak were used to represent the general categories of broadleaf and coniferous trees.

A considerable proportion of carbon sequestration associated with woodland is in soils and leaf litter. The carbon sequestration models did not consider leaf litter, but took account of soil sequestration differentiated by soil type (peat and non-peat), thickness of soil, and elevation (upland or lowland). Both the total gains (or losses) and rate of loss are critical to predictions of the social value of carbon sequested. New carbon sequestration in afforested non-peat soils was assumed to occur over a 265 year period, with 95% of the net change in soil carbon occurring within 200 years of planting. In non-peat soils, gains of 50 tC/ha for uplands, and 100 tC/ha for lowlands can typically be expected. More uncertainty attaches to the magnitude and rate of carbon loss on afforested peatlands, and this leads to uncertainty in the analysis by Brainard *et al* (2003). Early studies suggested that losses might range from 0.5 to 3 tC/ha $yr^{-1}$, but recent research suggests peat soils might emit carbon long term at a rate of about 0.3 t/ha per year. This value (0.3tC/ha) was adopted as the upper limit of expected annual losses on afforested peat after 26 years. This loss continues in perpetuity, or until the total expected maximum is reached, eg, 750 tC/ha for deep peat soils. Lacking further information about carbon releases from thin peat soils, Brainard *et al* (2003) assumed that these were approximately 15% of the suggested maximum from thick peat soils, or 112 tC/ha. This potential loss for thin peats may be too low, given that peat soils in Wales are estimated to contain a mean value of 250 tC/ha in their top 15 cm, compared to just 20 tC/ha for Welsh agricultural soils. Sensitivity analysis shows the that final valuation of carbon sequestrated on afforested deep peat soils is extremely sensitive to assumed carbon changes in these soils. Because of the considerable uncertainty around the magnitude of the possible carbon losses on afforested peat, the report by Brainard *et al.* (2003) includes separate calculations for planting on thin or thick peat soils.

Harvesting and management of a timber site creates its own carbon emissions. The model assumes that carbon releases from machinery and log transport for felling operations in the UK are 1.25% of carbon seqestrated, and transpire entirely during the year of felling. In practice releases would be expected to occur steadily throughout the rotation, notably during thinning and planting. The inclusion in the models of carbon releases from harvesting machinery reduced total monetary values for carbon sequestration between 0.5 and 3%.

The models for Sitka spruce, beech and oak were used when these species could be identified in the FC database. Sitka models were employed for other conifers in the FC sub-compartment data base, and the conifer category derived from the National Woodland Inventory. The beech YC models were similarly used as a surrogate for other broadleaves.

Carbon sequestration in live trees is closely related to timber volume, or what foresters term yield class (YC). YC is expressed as an even number integer, and denotes the cubic metres of expected timber production per year, per hectare, over the stand's rotation.[6] Regression models were used to relate YC, where known, with other environmental characteristics.

The models distinguish between three specific species in the FC estate, as well as other broadleaves and conifers on both FC- and privately-managed woods. Coppice and Christmas tree stands are also considered separately, due to their short rotation length and relatively quick carbon release period. Except where the FC SCDB indicated otherwise, it is assumed that coppice trees are cut down every 12 years, with a release period of 22 years, of which 44% is within the first two years. It was assumed that Christmas trees are grown on a ten year rotation, with all carbon in live wood released in the first year after harvest.

A variety of estimates have been produced for the social values for each metric tonne of sequestered carbon. The study used three values: £6.67, £14.67 (Fankhauser, 1994, 1995; lower bound and mean value estimates), and £70 (Clarkson and Deyes, 2002) per tonne to encompass the entire social value of carbon range. These are all used by Brainard, *et al*, (2003) to estimate the parameters of the value of carbon sequestration in Great Britain. However, Pearce (2003) in a review of studies estimating the social value of carbon, argues that many studies of the social cost of carbon over-estimate damages because they are based upon models in which there is no adaptation to climate change. Thus Pearce (2003) argues that the 'base case' estimate of the social marginal cost of carbon is £2.66 to £6 t/C without equity

[6] YC represents the maximum mean annual increment (MAI) during the rotation, but only represents the average of annual timber growth over the rotation if the stand is felled at the optimal point (i.e. where MAI is highest). After that point, MAI will fall.

weighting and using a constant discount rate. Applying the lowest equity weight[7] ($\varepsilon$ = 0.5) to the highest discount rate ($i$ = 6%), and the highest equity weighting ($\varepsilon$ =1.5) to the lowest discount rate ($i$ = 1%) produces a social cost of carbon estimate range of £2.40 to £15 per tonne. This range encapsulates two of the social cost of carbon values used in the study by Brainard *et al* (2003): £6.67 per t/C and £14.67 per t/C, and these values probably represent the limits of carbon sequestration value. This parameter is also supported by the price at which carbon permits trade in the UK Emissions Trading Scheme. Whilst the price has varied since the scheme was launched from £3 to £12.50, probably due to the slow adjustment of market dynamics,[8] permits are currently trading at £3 per t/C equivalent (IPAC, 2003).

Hence a social cost of carbon value of £6.67 t/C is used in the aggregation. This value is discounted over time at 3.5%: the rate proposed by HM Treasury for public sector projects (HM Treasury, 2003). The aggregate capitalized value of carbon sequestration value for woodland by region is reported in Table 6.1, and amounts to some £1.1 billion.

**Table 6.1: NPV of Carbon sequestration for woodland by region (£ millions, 2002 prices)**

| *Region* | *t/C value: £6.67* | *t/C value: £14.67* |
|---|---|---|
| Eastern | 136.07 | 300.48 |
| East Midlands | 85.89 | 189.61 |
| North East | 69.45 | 153.45 |
| North West | 142.72 | 315.38 |
| South East | 330.56 | 729.70 |
| South West | 257.03 | 567.58 |
| West Midlands | 109.06 | 240.74 |
| Yorkshire & Humberside | 100.87 | 222.75 |
| | | |
| England | 1231.65 | 2719.69 |
| Scotland | 1181.91 | 2618.38 |
| Wales | 262.55 | 580.13 |
| Great Britain | 2676.10 | 5918.20 |

The value of carbon sequestration varies between regions depending upon the amount of woodland in the region, the proportion of different types of tree species and yield classes (which affects the rotation and hence carbon accumulation), and soil conditions. This is exemplified in the per hectare value of carbon sequestrated by tree type: Table 6.2.

[7] Where $\varepsilon$ is the elasticity of the marginal utility of income (a measure of 'inequality aversion').

[8] Companies were slow in having their baselines verified, which delayed allocated allowances, causing an initial shortage of supply and price rise. Companies have now gone through their first reconciliation deadline, and this has led to a fall in demand for permits. Companies meeting their targets receive an 80% discount from the Climate Change Levy tax on business use of energy.

**Table 6.2: NPV of carbon sequestrated per hectare in woodland.**
**t/C = £14.37, *i* = 3.5%, 2002 prices**

| | Great Britain |
|---|---|
| *Forestry Commission* | |
| Beech | 2250 |
| Oak | 1629 |
| Sitka Spruce | 2311 |
| Other Broadleaf | 1409 |
| Other Conifer | 1414 |
| | |
| *Woodland Inventory (non-FC)* | |
| Broadleaf | 2353 |
| Conifer | 1996 |
| | |
| *All GB woodland* | 2098 |

## 7. ARCHAEOLOGY

GB forests contain a diverse and rich collection of archaeology including burial mounds, fortifications, earthworks, field systems, and standing stones. The Archaeology Report (Macmillan, 2002) investigated the estimation of a monetary value for the protection service forests provide for these archaeological remains.

A separate WTP survey for archaeology was not included within the remit of the Phase 2 Social & Environmental Benefits of Forests study. Hence a valuation was attempted by means of a benefit transfer exercise involving previous work on archaeological management in Environmentally Sensitive Areas (ESAs). The benefit transfer approach adopted was that of unit value transfer, in which WTP is adjusted to take account of factors such as landscape context, target populations, and payment scenario.

Under the range of assumptions considered in the archaeology report (Macmillan, 2002), this value is estimated to range from £0 to £247 per hectare depending on assumptions. Values at the higher end of the range would be more appropriate if we assume that WTP is unaffected by landscape context and if we are interested in estimating benefits over a relatively small area of forest (less than 250,000 hectares). Lower values are appropriate when we wish to aggregate over the entire forest area and/or we believe that the archaeology is negatively affected by landscape context. All benefit estimates assume that forests are managed according to best practice for protecting archaeology, not the value of current practice.

Considerable uncertainty surrounds a benefit transfer exercise of this kind and it is recommended that further empirical research should be commissioned to investigate WTP for archaeology in forests. This research could examine the influence of forest management on WTP and target different groups of beneficiaries. For example, given the increasing interest in family history it would be interesting to assess WTP for additional expenditures on interpretation and restoration of archaeological sites.

## 8. POLLUTION ABSORPTION

This study investigated the impact of woodland on air quality. The benefit of improvements to air quality can be valued indirectly through improvements to health. The Committee of the Medical Effects of Air Pollution (COMEAP), set up by the UK government found the strongest link between health and pollution was associated with particulates ($PM_{10}$), sulphur dioxide ($SO_2$) and ozone ($O_3$) (Department of Health, 1998). A subsequent study by the Department of Health (1999) investigated the link between deaths brought forward and hospital admissions caused by air pollution, and estimated its economic cost, which was found to be substantial.

Although the main consideration of policy should be the reduction in pollution at source, there has been an increasing recognition that the biosphere is an important sink for many pollutants. Plants facilitate the uptake, transport and assimilation or decomposition of many gaseous and particulate pollutants. The layered canopy structure of trees, which has evolved to maximise photosynthesis and the uptake of carbon dioxide, provides a surface area of between 2 and 12 times greater than the land areas they cover. A review of the literature has shown pollution absorption by trees to be sizeable.

The study by Powe and Willis (2002) endeavoured to investigate the link between pollution absorption and health effects, considering both $PM_{10}$ and $SO_2$. Ozone was also seen to be an important pollutant but was excluded from this analysis due to the complexity of the link between the effects of vegetation and ozone formation and absorption. There is still uncertainty about the net effect of pollutants on health, since health impacts are confounded by the presence of and interaction between different air pollutants.

The research by Powe and Willis (2002) attempted to estimate the net health effects and the reduction in economic costs attributable to the current woodland in Britain. The research was based on a 1 $km^2$ scale, with the distribution of woodland and health impact on the population being confined to that within the 1 $km^2$ grid. The current lack of information on the link between pollution dispersion and tree absorption of pollutants on a wider scale prohibited extending the health impacts beyond those occurring with the local (1 $km^2$) locality.

Net pollution absorption by woodland was found to have reduced the number of deaths brought forward by air pollution by between 59-88 deaths and between 40-62 hospital omissions. The net reduction in costs (or increase in benefits) attributable to pollution absorption by woodland was estimated to range between £199,367 and £11,373,707.

Aggregating the data on a county basis, Hampshire, Strathclyde and Surrey have benefited the most, with the net effect also being important within Greater Manchester, Lothian, Mid-Glamorgan and Outer London.

Given the magnitude of the task to determine the epidemiological impact of woodland on health, and the limitations of resources available to this project, many simplifying assumptions had to be made, with perhaps the most notable being the area benefiting from the pollution absorption: the 1 $km^2$. Most 1$kms^2$ in Britain with woodland have few people, and vice-versa. However, the impact of woodland on pollution levels over longer distances is as yet unclear and there is a need for further research on this particular problem. Many issues are involved, including rainfall, pollution levels, wind speed and direction, tree type, population, as well as regional differences in mortality rates.

The results presented here should be regarded as a lower bound estimate of the net health effects of pollution absorption of trees. The results identify the counties that have the highest levels of pollution, and through the interaction with population, the areas in which increases in woodland cover will have the highest level of net health benefits.

## 9. WATER SUPPLY AND WATER QUALITY

Forestry can potentially affect the quality and amount of water available to other users. The principal uses of water flowing into and from forested catchment areas are:

- abstraction for potable water (for drinking and commercial uses)
- agriculture and irrigation in down-stream areas
- hydro-electric power generation
- wildlife, including recreational and commercial fisheries
- other recreational uses, such as canoeing and sailing.

The lost use benefit most easily and comprehensively quantified is that for potable water. However, even for this use, the value of potable water lost through forestry is still subject to considerable uncertainty. As with all the above uses, the extent of the impact of forestry depends upon the proportion of the river catchment area covered by woodland.

The Calder and Newson model (Calder, 1999), was used to estimate the annual and seasonal differences in runoff from afforested upland catchments in GB compared to an alternative vegetation cover, typically grass cover. The model estimates the annual evaporation attributable to woodland in addition to grassland, taking into account the area of the land under forestry, the fraction of the year that the canopy is wet, and the inception rate (rate at which trees intercept rain preventing it reaching the ground). In uplands, trees result in an approximately 30% inception loss compared to grass and moorland grasses; but where the alternative is bracken then the inception loss from trees is only of the order of 18%-20% (see Willis, 2002).

The Calder-Newson model was used to estimate decreases in water availability through forestry for England and Wales, in relation to rainfall (in mm) and annual evaporation (effective transpiration rates). Woodland cover (forest %) was supplied by the FC, from the national inventory of trees and woodland, covering all woodland (private and public) in Britain. Inception is taken to vary according to rainfall.[9] From this information the loss in mm per hectare can be estimated. This, multiplied by the forested hectares (adjusted to take account of felled, newly planted, and forested area) gave the reduction in the amount of rainfall available under forestry, relative to grassland coverage. This can then be converted into a cubic metre loss per hectare, and expressed on a spatial basis.

[9] Inception rates were taken to be

| *rainfall (mm)* | *inception* | *rainfall (mm)* | *inception* |
|---|---|---|---|
| ≥ 1000 | 0.30 | 700-799 | 0.15 |
| 900-999 | 0.25 | 600-699 | 0.10 |
| 800-899 | 0.20 | ≤ 599 | 0.05 |

The externality cost of forestry in terms of the increased costs per $m^3$ of water abstraction can thus be approximated as the long run marginal cost (LRMC) of increasing water supply, minus the short run marginal cost (SRMC) of increasing water supply. LRMC faced by different water companies are reported by OFWAT (2001)[10]. The SRMC is the cost of treating water (comprising a variety of chemicals and power), which has to be undertaken irrespective of the source; and since treatment costs are included in OFWAT estimates LRMC, the SRMC need to be subtracted from LRMC. The maximum potential externality cost of forestry in terms of the increased costs of water abstraction can thus be approximated as the volume of water ($m^3$) lost through forestry multiplied by the externality cost per $m^3$.

The cost of alternative supplies of water varies by spatial area, and is a function of the annual evaporation above the annual grassland evaporation, climatic conditions, proportion of the year the canopy is wet, the amount of forest coverage, and the LMRC-SRMC of water abstraction.

If it is assumed that there is a direct one-to-one trade-off between forestry and water availability, the external costs of forestry on water supply would create an externality cost of £52.491 million for England and £35.357 million for Wales. [An externality value could not be calculated for Scotland because of lack of data on water supply costs].

These estimates should be regarded as ‘ball-park’ estimates. Lack of spatial information meant that it was not possible to link LRMC with woodland cover and with household numbers other than at the county level. Even at this level of aggregation, more than one water company can cover the same county (e.g. in the case of Kent, Hampshire, Surrey, Sussex, Durham, etc.). Moreover, the LRMC curves relate to water companies as a whole, but LRMC are likely to vary significantly between company areas, especially for major companies such as Dwr Cymru that covers the whole of Wales, United Utilities which covers north-west England, and Severn Trent which covers vast areas of the Midlands.

Moreover, whilst hydrologists point to the theoretically large impact of forestry on water availability; British water companies perceive little impact in general of existing forestry on water supply costs (Willis, 2002). Of course the impact on water company costs may increase if large areas were afforested, especially in southern England with coniferous species. There is no data-base on the opportunity cost of water supply and water quality improvements on a spatial unit basis. Hence the costs and benefits of forestry on water supply and water quality cannot at present be mapped in any accurate, robust and reliable manner.

It can be argued that, to a large extent, many negative externalities from forestry with respect to water quality have already been internalised through adherence to the Forestry Commission’s *Forests and Water Guidelines*.

There is also an unquantified opportunity cost in terms of hydro-electricity production. In addition, there may be a loss of wildlife and recreational benefits from reduced stream flow due to forestry. However, these lost benefits as a result of forestry are likely to be minimal. Trees also produce positive, but unquantified, benefits through reducing flood risks.

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[10] LRMC is defined by OFWAT (2001) as the present value (PV) of the expected costs of the optimal supply strategy, per unit of water.

# 10. AGGREGATE VALUE OF WOODLAND

Table 10.1 and Table 10.2 document the aggregate total value of woodland by regions of England, and by countries, in terms of annual values and capitalised values (at 3.5%) respectively. The aggregate total capitalised value of the social and environmental benefits of woodland is over £29.2 billion. Thus woodland contributes some £1.02 billion annually in terms of non-market benefits. It is immediately apparent that the total value of woodland is dominated by recreational and biodiversity values, followed by landscape benefits, with carbon sequestration also contributing significantly to the social and environmental benefits of forests.

The total value of the social and environmental benefits of forestry is dependent upon individual values (e.g. WTP per recreational visit; social value of t/C; etc) and the number to which these individual values are applied (e.g. the number of visits to forests; tonnes of carbon sequestrated by forests; etc.) Whilst there is some uncertainty about individual values, for most SEBs there is considerably more uncertainty about the number (population of relevance) to which these values should be applied), to derive aggregate values.

The value of a woodland recreational visit is a reliable 'ball-park' estimate. The aggregate value of recreation is dependent both upon the number of visitors to forests, than on the value per visit. There is uncertainty about the number of visits to FC and private woodland.

Similarly, the aggregate total value of landscape might be inaccurate because we do not have a precise estimate of the number of households who have views of trees from their property, not do we have a reliable estimate of the number of households who regularly see trees on their journeys.

The study derived a range of marginal values for increasing biodiversity in woodland, depending upon the habitat characteristics of different woodland. The values for marginal changes in woodland biodiversity should be regarded as "ball-park" estimates. Moreover, the biodiversity values for woodland are gross values and not a value *net* of the alternative land-use. In addition, the aggregate value reported here assumes that the marginal value can be extrapolated across all woodland of that type. There is further uncertainty over the relevant population for aggregating the biodiversity values. Tables 10.1 and 10.2 show biodiversity benefits if the value of each unit area of woodland is multiplied by the number of households in the country in which it is located or, alternatively by the number of households in GB.

In contrast, the aggregate total tonnage of carbon sequestrated by woodland is quite accurate. Unfortunately there is no consensus about the social value of t/C. Mean social value t/C estimates lie within the range £6 to £70, with wide variances around individual means within this range. The aggregate value in Table 10.1 is based upon the lowest value: £6.67 t/C. Adopting a value of £14.67 t/C would effectively double the aggregate value of carbon sequestrated, and proportionately increase the total aggregate SEBs of forestry.

**Table 10.1: Annual aggregate value of the social and environmental benefits of forestry in GB (£ millions)**

| *Region* | Recreation | Landscape | Biodiversity (aggregated at country level) | | Carbon seq. | Air pollution absorption | **Total** | *Biodiversity *** (aggregated at GB level)* |
|---|---|---|---|---|---|---|---|---|
| | | | ASNW | NP+BL | t/C £6.67 | | | *ASNW, NP + BL* |
| Eastern | 60.31 | 19.21 | 28.00 | 9.00 | 4.76 | 0.04 | 121.32 | *(45)* |
| East Midlands | 35.28 | 12.86 | 17.00 | 7.00 | 3.01 | 0.01 | 75.16 | *(28)* |
| North East | 3.54 | 6.14 | 9.00 | 10.00 | 2.43 | 0.02 | 31.13 | *(24)* |
| North West | 34.43 | 11.49 | 22.00 | 6.00 | 5.00 | 0.04 | 78.96 | *(34)* |
| South East* | 91.09 | 34.21 | 128.00 | 12.00 | 11.57 | 0.08 | 276.95 | *(172)* |
| South West | 39.72 | 17.56 | 54.00 | 9.00 | 9.00 | 0.03 | 129.31 | *(78)* |
| West Midlands | 42.40 | 11.75 | 30.00 | 4.00 | 3.82 | 0.03 | 92.00 | *(41)* |
| Yorkshire & Humberside | 47.45 | 10.69 | 14.00 | 5.00 | 3.53 | 0.03 | 80.7 | *(23)* |
| | | | | | | | | |
| England | 354.24 | 123.92 | 302.00 | 61.00 | 43.11 | 0.28 | 884.55 | *(445)* |
| Scotland | 24.58 | 19.05 | 11.00 | 8.00 | 41.37 | 0.07 | 104.07 | *(220)* |
| Wales | 13.84 | 7.25 | 3.00 | 1.00 | 9.19 | 0.04 | 34.32 | *(73)* |
| Great Britain | 392.65 | 150.22 | 316.00 | 70.00 | 93.66 | 0.39 | 1022.92 | *(738)* |

* South East includes London.

** These figures show the biodiversity benefits if the value of each woodland is multiplied by the number of households in GB rather than that of the country in which it is located.

**Table 10a: Numbers of day visits to woodland, and households with landscape and commuting views of woodland**

| | UKDVS: millions of forest visits | Landscape: households with forest views | Landscape: households with commuting views |
|---|---|---|---|
| Eastern | 54.48 | 30273 | 48882 |
| East Midlands | 31.87 | 19248 | 33940 |
| North East | 3.20 | 8109 | 17477 |
| North West | 31.10 | 13073 | 35206 |
| South East* | 82.29 | 40910 | 102430 |
| South West | 35.88 | 31377 | 40310 |
| West Midlands | 38.30 | 15999 | 32897 |
| Yorkshire & Humberside | 42.86 | 24343 | 18320 |
| | | | |
| England | 319.99 | 183332 | 329462 |
| Scotland | 22.20 | 19876 | 60510 |
| Wales | 12.50 | 12028 | 17735 |
| Great Britain | 354.70 | 215236 | 407707 |

* South East includes London.

### Table 10.2: Capitalised aggregate value of the social and environmental benefits of forestry in GB (£ millions)

| *Region* | Recreation | Landscape | Biodiversity (aggregated at country level) | | Carbon seq. | Air pollution absorption | **Total** | *Biodiversity ** (aggregated at GB level)* |
|---|---|---|---|---|---|---|---|---|
| | | | ASNW | NP+BL | t/C £6.67 | | | *ASNW, NP + BL* |
| Eastern | 1723.12 | 548.91 | 800.00 | 257.14 | 136.07 | 1.26 | 3466.50 | *(1285.71)* |
| East Midlands | 1008 | 367.52 | 485.71 | 171.43 | 85.89 | 0.42 | 2118.97 | *(800.00)* |
| North East | 101.21 | 175.4 | 257.14 | 285.71 | 69.45 | 0.54 | 889.45 | *(685.72)* |
| North West | 983.65 | 328.29 | 628.57 | 171.43 | 142.72 | 1.21 | 2255.87 | *(971.43)* |
| South East* | 2602.71 | 977.22 | 3657.14 | 342.86 | 330.56 | 2.21 | 7912.70 | *(4914.28)* |
| South West | 1134.83 | 501.9 | 1542.86 | 257.14 | 257.03 | 0.78 | 3694.54 | *(2228.58)* |
| West Midlands | 1211.37 | 335.82 | 857.14 | 114.29 | 109.06 | 0.87 | 2628.55 | *(1171.43)* |
| Yorkshire & Humberside | 1355.6 | 305.54 | 400.00 | 142.86 | 100.87 | 0.80 | 2305.67 | *(657.14)* |
| | | | | | | | | |
| England | 10120.51 | 3540.59 | 8628.57 | 1742.86 | 1231.65 | 8.09 | 25272.27 | *(12714.28)* |
| Scotland | 702.29 | 544.33 | 314.29 | 228.57 | 1181.91 | 2.10 | 2973.49 | *(6285.72)* |
| Wales | 395.36 | 207.17 | 85.71 | 28.57 | 262.55 | 1.01 | 980.37 | *(2085.71)* |
| Great Britain | 11218.16 | 4292.1 | 9028.57 | 2000.00 | 2676.10 | 11.20 | 29226.13 | *(21085.71)* |

*South East includes London.
** These figures show the biodiversity benefits if the value of each woodland is multiplied by the number of households in GB rather than that of the country in which it is located.

## 11. POLICY IMPLICATIONS

A number of policy implications for the future distribution and structure of woodland to maximise the social and environmental benefits of forestry can be drawn from the research.

Woodland planting in peri-urban fringe areas is likely to maximise landscape benefits of woodland, especially if the woodlands are small and of irregular shape, with broadleaves. Recreational value of woodland is enhanced with broadleaved trees, presence of nature reserves, and provision of car parks. Similarly biodiversity value is enhanced most through the broadleaved woodland in both the uplands and lowlands, particularly ancient semi-natural woodland which has a high biodiversity value. Broadleaved woodland also contributes most to carbon sequestration values. Planting in the peri-urban areas will also have the greatest impact in terms of pollution absorption and improved air quality; and, with greater concentrations of population in these areas, will also contribute to a larger reduction in mortality and illness from air pollution.

However, there may be trade-offs in the social and environmental benefits of forest recreation, landscape, biodiversity, etc. Increasing peri-urban woodland will maximise landscape benefits but may not maximise recreational benefits per visit if the majority of visits to the peri-urban woodland are casual short visits, e.g. dog-walkers who have a lower value per visit than 'purposeful forest day visits'. Trade-offs may also exist between planning for air pollution absorption and biodiversity benefits. Policy will need to ensure that the combined social, environmental, and commercial benefits are optimised to ensure sustainable forestry development.

## 12. CONCLUSIONS

The aims of this study were to provide empirical estimates of the (i) marginal values and (ii) total values for the social and environmental (i.e. non-market) benefits of woodland. These social and environmental benefits (SEBs) encompassed recreation, landscape, biodiversity, carbon sequestration, air pollution absorption, and water.

Strenuous efforts were made to avoid double-counting of benefits (.e.g. between recreation and landscape; recreation and biodiversity; etc.). Further, this study avoided over-estimating the value of the different SEBs of woodland by not using values from individual benefit studies to derive a holistic value for that environmental attribute (see Hoehn and Randall, 1989). However, relatively few resources were available to the project to accurately identify the population of beneficiaries for aggregation of the recreational and landscape benefits; and the forest structure for the aggregation of biodiversity benefits.

There is no single marginal benefit (MB) or marginal cost (MC) value for any of the SEBs. MBs vary for each SEB depending upon circumstances. Thus the landscape benefits of woodland depend upon the context and type of the forest in its landscape setting. The marginal social value carbon is invariant over space, but the amount of carbon sequestration depends upon tree type, yield class and forest management regime. The MBs of recreation depend upon the recreational attributes of the forest. These different MBs are documented in the text of this report and more fully in the individual research reports upon which this summary report is based.

The total SEB of forestry is very large: approximately £29.2 billion. The size of this benefit is largely attributable to biodiversity and recreation, and to a lesser extent by landscape and carbon sequestration values. There is some uncertainty about the individual values for these SEBs, particularly the social value of carbon, and the biodiversity value of increments in woodland area. This is further compounded by lack of accurate estimates of the population of relevance for landscape benefits, and the number of recreational visits to woodland. Thus the total SEB values are more uncertain than the marginal values for each SEB.

Further research should as a matter of priority be devoted to identifying the populations over which MBs and MCs are to be aggregated. A more precise assessment of the number of visits and visitors to forests and woodland by categories of visits (e.g. purposeful, casual, etc) and categories of visitors (e.g. frequent, etc.) is essential if more accurate and robust aggregate recreational benefit estimates are to be derived. Similarly for landscape: a more reliable estimate of the number of households with varying degrees of forest views is required. Thus more accurate information on the populations of relevance to different categories of SEBs are necessary if a more accurate and robust total aggregate SEB of woodland is to be provided.

The annual and capitalised SEBs of woodland are clearly large. They mostly relate to areas of woodland of 2 hectares of more. However, other woodland and trees (e.g. hedgerow trees, garden trees, tree in parks, etc.) also provide some additional recreational, landscape (amenity), biodiversity, and air pollution absorption benefits. Thus there are additional benefits, which have not been estimated in this study, from small areas of wood and trees planted for amenity purposes in urban areas. For example, urban trees along roads, and in parks and gardens, absorb more air pollution per tree than those in rural areas simply because of higher levels of particulate pollution along roads.

There are also social and environmental costs associated with trees that have not been quantified. For example, periodic storms result in deaths of people from falling trees[11] and falling trees also sever and disrupt power supplies. There is also the annual disruption and delay to trains through leaves falling on railway lines. Tree roots near property can damage building foundations and block drains, incurring expensive repair costs. Most of these costs are associated with non-FE and non-commercial woodland.

Nevertheless, it is clear that forestry provides high levels of non-market social and environmental benefits. This has implications for future policy in delivering non-market as well as market benefits, and optimising these combined benefits. Achieving a balance between market and non-market benefits is critical to delivering sustainable forest management.

[11] In a storm on 27-28th October 2002, 6 people in Britain died from falling trees.

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## 14. Glossary

**Benefit transfer:** An approach which makes use of previous valuations of similar goods at a study site and, with any necessary adjustments, applies them to produce estimates for the same or similar good in a different context, known as the policy site. What is transferred may be a mean WTP, with or without some adjustment for changed conditions (e.g. different income levels), or a benefit function.

**Choice experiment:** A form of choice modelling in which respondents are presented with a series of alternatives and asked to choose their most preferred.

**Choice modelling:** encompasses a range of stated preference techniques, including choice experiments, contingent ranking, contingent rating, and paired comparisons. CM approaches describe an asset in terms of its attributes, or characteristics, and the levels that these take, and may be used to determine which attributes are significant determinants of value; their implied ranking; the value of changing them; and the total economic value of a resource or good.

**Choice set:** A set of alternatives presented to respondents, usually in a choice experiment context, where they are asked to choose their most preferred.

**Compensating variation:** The compensating variation of a price fall (rise) is the sum of money that, when taken away from (given to) the consumer, leaves him/her just as well of with the price change as if it had not occurred. Thus, initial utility is held constant.

**Consumer surplus:** is the difference (or the net gain) between the price actually paid when purchasing a good or service and the price the consumer would have been willing to pay for the same good or service.

**Contingent ranking:** A form of choice modelling in which respondents are required to rank a set of alternative options. Each alternative is characterised by a number of attributes, which are offered at different levels across options. Respondents are then asked to rank the options according to their preferences.

**Dichotomous choice:** An elicitation format in which respondents are faced with only two response alternatives, such as yes/no, agree/disagree, or vote for/vote against. Sometimes, a ‘don’t know’ option is also included to avoid forcing respondents into artificially choosing one of the answers.

**Direct use value:** Where individuals make actual use of a resource for either commercial purposes or recreation.

**Discounting:** is the process of expressing future values in present value terms which allows for the comparison of cost and benefit flows regardless of when they occur. The present value of a future flow of benefit or cost will be lower than the future value because of discounting. There is no a priori correct way to discount future gains and losses, although *exponential discounting* is most widely used. Stated preference techniques may be used to derive discount rates.

**Economic value:** The monetary measure of the wellbeing associated with the change in the provision of some good. It is not to be confused with monetary value unless the latter is explicitly designed to measure the change in wellbeing, nor with financial value which may reflect market value or an accounting convention. As

Freeman (1993), notes the terms 'economic value' and 'welfare change' can be used interchangeably.

**Equivalent variation:** The equivalent variation of a price fall (rise) is the sum of money that, when given to (taken from) the consumer leaves him/her just as well off without the price change as if it had occurred. Thus, it preserves the post-change utility level.

**Focus group:** is a structured discussion group on a specific topic, facilitated by a moderator.

**Indirect utility function:** A function that describes household utility (or wellbeing) usually in terms of how much utility it can derive from income, given the prices of goods and, say, the level of provision of a non-market good.

**Logit specification:** The logit models used for choice modelling explain the probability of respondents choosing a particular scenario as a function of the attributes of the scenario, respondent-specific characteristics and ASC (see above). See above for the meaning of the coefficients of attributes in logit models.

**Marginal rates of substitution:** is the rate at which a respondent is willing to trade off one attribute with another. WTP of an attribute estimated through choice experiments is in fact the marginal rate of substitution between that attribute and money (the price or cost attribute). This is why, WTP is estimated by dividing the coefficient of the attribute with the coefficient of the price or cost attribute.

**Non-use value:** The value placed on a resource by people who are not current users of that resource and who do not intend to use the resource themselves. See *altruistic, bequest* and *existence values*.

**Open-ended format:** A straightforward elicitation format which asks respondents to state their maximum willingness to pay (or minimum willingness to accept).

**Protest bid**: A response to a valuation question which does not give the respondent's genuine WTP (or WTA), but either a zero value or an unrealistically high (or low) value.

**Use value:** The value placed on a resource by users of that resource. See *direct use value, indirect use value* and *option values*.

**Utility:** originally thought of as a number measure of a person's happiness, utility is used in economics as a way of describing consumer preferences (through *utility functions*), where a more preferred choice set is said to provide a higher utility.

**Validity:** refers to the degree to which a study measured the intended quantity.

**Welfare:** (or social welfare) is the sum of individual utilities. The maximisation of social welfare is the goal of welfare economics, a branch of economics concerned less with *how* the economy works, but more with how *well* it works.

**Willingness to pay:** The amount of the money people are willing to pay to avoid a loss or for a gain.