



Scoping Study on Valuing Ecosystem Services of Forests Across Great Britain

Final Report

for the Forestry Commission

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EXECUTIVE SUMMARY

ES.1 Introduction

The forestry sector plays a key role in the management of the natural environment and the provision of ecosystem service values, for example through timber production, carbon sequestration, and recreation and tourism benefits. The objective of this study is to review the existing evidence base on the value of ecosystem services to address four specific aims:

- i). Review estimated values for the economic, social and environmental benefits produced by Britain's forests from existing literature and categorise these values according to the ecosystem services framework;
- ii). Identify gaps in the existing evidence base and recommend future research priorities to demonstrate the ecosystem service value of woodlands across the UK;
- iii). Highlight key challenges and uncertainties that could arise in the valuation of ecosystem services and suggest how these could be addressed; and,
- iv). Consider practical market opportunities for forest ecosystem services and their potential scale, using case studies, where possible.

The study covers both the public forest estate managed by the Forestry Commission and all private woodland across Great Britain.

ES.2 Ecosystem services approach

The development of the 'ecosystem services approach' (ESA) (MEA 2003; 2005) has sought to establish and refine an overall framework in which the multiple contributions of ecosystems and the biological diversity contained within them can be consistently assessed for the purposes of environmental policy-making. In the UK, the landmark National Ecosystem Assessment (UK NEA, 2011) provides the first detailed analysis of the benefits that the natural environment provides to society. The increasing interest in the ecosystem services approach reflects the wider-scale recognition of multiple objectives, trade-offs and synergies that exist in realm of 'natural environment' policy.

The four main categories of ecosystem services are provisioning services, regulating services, cultural services and supporting services¹. **Table ES.1** provides a summary of ecosystem services associated with woodlands and forests in Great Britain along with the principal final goods that are derived. This includes a mix of 'market goods' or 'non-market goods'. The former are formally traded in markets (e.g. timber), whereas non-markets goods are un-priced (e.g. recreation and amenity benefits). Final goods benefit human populations through either direct (e.g. burning of woodfuel) or indirect (e.g. carbon sequestration) use values, and/or non-use values, which arise due to altruistic motives, bequest motives, or for the sake of the resource itself (e.g. conservation of species). The summary highlights that the production of final goods is typically dependent on multiple ecosystem services. For example recreation benefits are attributed to provisioning and regulating services as well as cultural services. Similarly the ecosystem services that are listed are dependent on multiple supporting services, although these are not shown.

¹ See the main report (Section 2.2) for further detail on this classification of ecosystem services.

Table ES.1: Classification of final ecosystem services and goods	
<i>Final ecosystem service</i>	<i>Principal final goods</i>
Production of trees, standing vegetation and peat [P]	Timber and wood fuel Non-wood forest products (ornamental, craft/hobby resources)
Food - production of crops, plants, livestock, fish, etc. [P]	Non-wood forest products (wild food products), recreation (field sports)
Production of wild species diversity including microbes [P,R]	Genetic resources and bioprospecting Recreation and tourism, landscape and aesthetic amenity, ecological knowledge Non-use values
Regulation of climate [R]	Reduction of climate stress
Soil, air and water regulation [R] (Clean soil, clean air, clean water from purification processes, breakdown and detoxification of waste and production of water quantity)	Potable water and industrial use of water Pollution control, waste removal, waste degradation Physical and mental health Recreation
Regulation of hazards [R]	Avoidance of damage from natural hazards (e.g. flood protection, coastal protection, erosion protection)
Pest and disease regulation [R]	Avoidance of damage cost (e.g. to crop production)
Noise regulation [R]	Amenity value and avoidance of damage/mitigation costs
Pollination and seed dispersal, herbivory [P, C, S] (Production of wild species diversity including microbes)	Agricultural and horticultural products Recreation and tourism, landscape and aesthetic amenity, ecological knowledge Non-use values
Generation and maintenance of meaningful places; socially valued landscapes and waterscapes [C]	Recreation and tourism, landscape and aesthetic amenity, physical and mental health, ecological knowledge Non-use values

Notes: P = Provisioning services; R = Regulating services; C = Cultural services

ES.3 Valuing ecosystem services

Policy analysis tools such as Impact Assessments and cost-benefit analysis compare financial costs and benefits with environmental impacts; for example, comparing the costs of a habitat restoration programme to its benefits in terms of enhanced ecosystem service provision, to determine if it represents ‘value for money’. Estimating the benefit of ecosystem service provision (or the costs of ecosystem damage) is the final part of a ‘three step’ qualitative - quantitative - monetary valuation assessment process that combines scientific and understanding and analysis of how the provision of ecosystem services changes, as a result of physical impacts on ecological functions, with economic valuation methods (Defra, 2010).

The scope for using information on the value of ecosystem services in relation to forestry policy is broad. Furthermore, this information can also be relevant to other public policy areas that forestry has close links to such as agriculture, flood risk management and health. Comprehensive and reliable valuation evidence enables:

- (i) Better management decisions both at the level of the individual forest and across the nation as a whole. This concerns not only choices for maintaining or enhancing the provision of all

ecosystem services, but also the trade-offs that can be entailed in relation to the provision of individual ecosystem services (e.g. the types of recreation facilities that can be provided for visitors); and

- (ii) Enhances the possibility of capturing more of the value of forest ecosystems, by helping to understand the key factors that influence the provision of services which are not traded at present. For example, new goods and services in terms of provisioning services and payments for ecosystem services (PES) for regulating and supporting services.

The main report (Section 3.2) documents the review of evidence. This categorises estimated values for the economic, social and environmental benefits of woodlands according to the ESA classification presented in Table ES.1, and identifies gaps in the existing evidence base to help develop recommendations for future research priorities. The review builds on previous studies including outputs from the UK NEA and research commissioned by the Forestry Commission. The latter includes studies examining health (CJC Consulting, 2005) and recreation (Christie et al., 2005) benefits, and a major assessment completed almost a decade ago entitled the 'Social and Environmental Benefits of Forests' (SEBF) (Willis et al., 2003). The SEBF comprised of a series of research studies that sought to estimate values for changes in the provision of recreation, landscape amenity, biodiversity, carbon sequestration, pollution absorption, water supply and quality, and protection of archaeological artefacts benefits by forests. The assessments were then used to estimate the aggregate value of benefits provided across Great Britain.

Key findings from the review of evidence include:

- **Timber and woodfuel:** the valuation of timber (softwood production) is straightforward using readily available market price and volume data from the Forestry Commission. In contrast hardwood price data are limited, but at present this represents only a small proportion of timber production in Great Britain. In the short term, timber prices can be subject to volatility but values averaged over time will smooth out these fluctuations and reflect longer term trends. Valuation of timber and wood fuel can be more complex in life cycle type assessments related to climate change impacts of materials, and requires that particular attention is paid to the materials/fuel sources that are displaced by its use so that the net climate change impact is established (e.g. whether burning of wood fuel replaces more carbon intensive heating fuels).
- **Non-wood forest products:** there is currently no coherent evidence base for the value of non-wood forest products that are harvested in Great Britain. This is because they are generally not traded (and hence no price data) and there has not been sufficient research about them. In some cases, prices associated with similar products sold in formal markets may provide a proxy value. However, market values for these products will reflect different opportunity costs (i.e. from non-wood forest products that are obtained from foraging). While this is a gap in the evidence base, at a national level the scale of provision of non-wood forest products is likely to be too small to warrant significant attention. At the local level, the benefits can be significant for certain user groups, particularly if commercially exploited by local businesses. Products that are not commercially exploited (i.e. for craft/hobby purposes) may be better associated with cultural services.
- **Genetic resources and bio-prospecting:** in common with the UK NEA, the review here finds that there is no valuation evidence concerning the provision of genetic resources from forests and woodlands in Great Britain. The significance of this gap in evidence is dependent upon future evidence needs. For example, if opportunities for bio-prospecting entail significant

trade-offs with the provision of other ecosystem services, this could create a greater need for value evidence.

- **Reduction of climate stress (climate regulation):** UK Government guidance for valuing changes in greenhouse gas (GHG) emissions is comprehensively provided by DECC (2009; 2010) and overall there is a substantial evidence base with respect to carbon sequestration rates in woodlands (Read et al., 2009). Average sequestration rates across cycles of planting and rotation are generally taken as appropriate for national scale assessments across all woodlands and forests (as the differences are likely to even out at this scale). The key factor here is to differentiate woodland ecology (coniferous or broadleaved). Site specific assessments, however, would require more detailed analysis of local environmental factors that influence rates of sequestration and emissions. Thus, in some cases more evidence may be needed on different planting and management regimes. The evidence base is weaker for other GHGs, which depend on site-specific factors. For example recent research has shown that afforestation can lower the water table and contribute to reduced methane emissions (Morison et al., 2010).
- **Soil quality:** the review suggests that while the soil quality benefits of forests (e.g. water retention, plant productivity and waste remediation) are widely recognised across various studies in qualitative terms, quantitative assessments of the links between supporting and final ecosystem services, the scale of provision and beneficiaries, and the type of economic goods and benefits provided (e.g. potential human health benefits through stabilisation of contaminated land, avoidance of damage costs, etc.) are currently lacking.
- **Air quality:** also while well-identified and referenced in qualitative terms, value evidence is limited as to the air quality benefits provided by woodlands and forests. In particular, benefits in terms of reduced human health impacts are largely location-specific and dependent on the scale and proximity of the beneficiary population. This suggests that there is scope to understand better the importance of urban woodland and trees in improving air quality. Supporting analysis for the Defra Air Quality Strategy (IGCB, 2007) and the Clean Air for Europe programme (CAFE, 2005) utilise the ‘impact pathway approach’, linking changes in pollutant emissions and concentrations to human wellbeing impacts, via dose-response functions, however this evidence has not been linked to the air quality regulation benefits of forests.
- **Water regulation:** available evidence suggests that forestry impacts on water supply and quality can be very uncertain and highly site and catchment specific. The scale of effects can be influenced by management practices and changes in woodland cover as well as practices in other sectors, such agriculture. Overall there is not a strong base of evidence, particularly given limited quantification of the link between forests and water provision (e.g. in terms of avoided treatment costs). Nevertheless, a number of practical initiatives are being implemented and will, over time, improve understanding of such effects (e.g. the Sustainable Catchment Management Programme (SCAMP) in North West England).
- **Flood protection:** as with water regulation, flood protection is highly location dependent and assessments need to be site or catchment specific to determine the impacts of particular woodland management options on downstream flood risks. A handful of practical assessments are available, based on projects that have been recently implemented (e.g. the ‘Slowing the Flow’ project, North Yorkshire), and guidance provided by the Environment Agency (2010) for appraising flood risk management schemes provides the basis for valuing flood protection benefits, implying that there is scope to develop supporting assessments of the role of woodlands in reducing flood risks.

- **Recreation:** recreation values represent the most researched non-market benefit of forests and woodlands. The evidence base provides values both for informal and specific recreation activities, which is generally consistent and considered to be robust.
- **Landscape and aesthetic amenity:** a number of studies have examined non-market benefits associated with landscape and aesthetic amenity of forests and woodlands. However, in general, this evidence is more dated than that for recreation. Some broad conclusions can be drawn from this evidence; for example a general preference for ‘natural’ looking landscapes. However caution is required in relation to the transferability of this evidence, which in some cases is based on specific woodland management options that may not be reflective of practice across the sector.
- **Physical and mental health:** human health and wellbeing benefits associated with the natural environment are widely recognised in qualitative terms. There is also a significant body of value evidence for physical health end points (e.g. due to air pollution). The impact-pathways to link these end points to forests are lacking. Evidence for wider health benefits, e.g. mental health, is more qualitative at present.
- **Education and ecological knowledge:** this benefit is increasingly recognised but at present empirical evidence is lacking.

ES.4 Mechanisms to capture the value of ecosystem services

There are a variety of mechanisms through which ecosystem service values can be captured. These include formal markets which exist for the products of the provisioning services, although these are not the focus of the discussion here. Traditionally, other mechanisms have involved regulating to reduce environmental damage or subsidising land/forest owners through state budget to incentivise the maintenance of land for ecosystem services (e.g. Woodland Grant Scheme). Increasingly more attention is being paid to a wider range of mechanisms to incentivise private markets and voluntary business and public initiatives. **Table ES.2** provides a categorisation of such mechanisms with illustrative examples. The main report (Section 3.3) provides a more detailed summary each type.

Table ES.2: Mechanisms for capturing ecosystem service values

<i>Mechanism</i>	<i>Description</i>	<i>Illustrative example</i>
Payments for ecosystem services (PES)	The provider (often a landowner) of a service is paid to maintain or enhance that service.	Agri-environment including forestry payments such as the English Woodland Grant Scheme (WGS)
Competitive ecosystem service contracts	Private sector providers compete to offer ecosystem service supply contracts.	Australian 'BushTender' contracts
Green infrastructure investments	Concept based around planning over large areas, usually urban, and based on building interconnected ecosystem services to maximise social benefit.	Plymouth Green Infrastructure - Saltram Masterplan
Carbon finance	Selling the carbon sequestered in the wood and soil into carbon markets.	Voluntary carbon footprint reductions (e.g. Woodland Carbon Code)
Biodiversity offsetting/habitat banking	Protecting or developing new forest in exchange for development losses elsewhere	In the UK to date this has been largely restricted to coastal rather than woodland habitats
Access payments	Charging visitors to access a forest	There are a broad range of possibilities; e.g. forest concerts, Go Ape, etc.
	Extracting animal products	Woodland game shooting

An indication of potential opportunities for capturing ecosystem service values from UK woodlands is provided in the following:

- **Carbon finance:** currently the main forest carbon finance initiatives (REDD and REDD+²) are restricted to developing countries. Within the EU Emissions Trading Scheme there is currently no provision for trading in carbon from soil or plant sequestration. The only available mechanism to UK forestry at present is through voluntary (carbon) schemes. There are existing markets through which businesses and households with no obligation to reduce carbon footprints can voluntarily do so. The Forestry Commission has launched a Woodland Carbon Code to provide quality assurance for woodland creation projects in the UK seeking to demonstrate carbon sequestration benefits³.
- **Payments for access and facilities:** while open access to woodlands and forests in Great Britain is not normally subject to an access fee, charging for more complex or group activities is commonplace. Examples include concerts, visitor attractions (e.g. Go Ape) and parking charges at sites with visitor facilities.
- **Payments for ecosystem services (beyond carbon):** Payments for ecosystem services could potentially provide significant scope for the expansion of funding for forestry, although possibilities for practical application will be dependent on the development of a regulatory framework. The Natural Environment White Paper (HM Government, 2011) signals that in England pilot schemes will be tested to assess both technical challenges and the formation of

² Reducing Emissions from Deforestation and Forest Degradation (REDD) programme. REDD+ includes provision for the protection of biodiversity as well.

³ See: <http://www.forestry.gov.uk/carboncode>

a regulatory framework and commits to a new research fund targeted at these schemes and to publish a best practice guide for their design.

While to date PES has been mostly provided through public budgets, other options are possible in future. The Natural Environment White Paper commits to producing an Action Plan in 2012 “to expand schemes in which the provider of nature’s services is paid by the beneficiaries, after undertaking a full assessment of the challenges and barriers”. With better links between specific services and payments, expanding and improving the Woodland Grant Scheme could be a good example of PES (Rowcroft et al., 2011).

- **Competitive ecosystem service contracts:** there is limited practical experience of competitive ecosystem service contracts in the UK. These are an auction based approach where land owners are then asked to bid for contracts to deliver ecosystem services. The aim is to switch from ‘input’ to ‘output’ orientated measures of ecosystem service provision by relying upon the local land owners knowledge. Contracts are typically awarded to land owners who offer the most cost-effective outcome (e.g. the largest gain in some agreed measure of ecosystem service provision per unit cost).
- **Biodiversity offsets / habitat banking:** Because of the typically long gestation period, forest offsets are likely to be amongst the more expensive offsets. However they also provide opportunities where high quality forest offsets could be used to compensate for losses of lower quality habitats. There are still uncertainties about the way in which offsetting will be implemented in the UK. It is also likely that simpler and quicker restoration projects such as grassland or wetlands may dominate the market, at least initially. However there is certainly scope for woodland to be involved in biodiversity offsetting markets.

ES.5 Recommendations for future ecosystem service research priorities

The main report (Section 4.4) concludes by setting out suggestions for future research priorities to expand the value evidence base. These are summarised in the following.

*Recommendation 1: the forestry sector should **use the ecosystem services approach** - at both national policy and local woodland management levels - to assess the range of ecosystem service values forests and woodlands provide.*

The continuing development of a more common language and understanding of concepts related to the natural environment by scientists, economists and other social scientists is encouraging. The recent emphasis on the ESA in policy development across Great Britain suggests that it will be viewed as a useful and influential tool for the foreseeable future. It represents a framework within which multi-disciplinary research can be undertaken and establishes the range of ecosystem impacts that need to be accounted for in decision-making, alongside more traditional economic and employment impacts of forestry. It also helps to reveal the key gaps and uncertainties in understanding and valuing the provision of ecosystem services.

*Recommendation 2: future ecosystem services research conducted by the forestry sector should incorporate a coordinated **multi-disciplinary assessment of ecosystem service values**.*

Following Recommendation 1, development of an evidence base of ecosystem service values requires multi-disciplinary research input from ecologists and other natural science disciplines, forest management experts, and economists as part of the ‘three step’ qualitative - quantitative

- monetary valuation assessment process. Future research should combine these areas of expertise and avoid studies that are solely focussed on ‘scientific’ or ‘economic’ evidence.

Recommendation 3: *the forestry sector should engage and coordinate future ecosystem services research with other environmental and public policy areas to enable a comprehensive understanding of the benefits associated with ecosystem service provision.*

A more strategic view of economic valuation evidence needs that matches the requirements of several sectors is required. For example, the potential for value capture mechanisms should be jointly assessed across forestry, agriculture, flood risk management, planning, and other policy areas as relevant. This is a fundamental requirement for improving the evidence base pertaining to regulating services. It is also recognised that forestry can contribute to other public policy areas, such as health and wellbeing, and opportunities for ‘feeding in’ evidence to wider objectives should also be considered.

Recommendation 4: *the forestry sector should develop an ecosystem services research strategy that establishes the key calls on the evidence base in the future. Forestry Commission GB should provide the lead on the strategy.*

Within the forestry sector, any future research strategy needs to take account of priorities across England, Scotland and Wales that may be different. The first step would be to assess the key policy issues (particularly in terms of the types of land use management and/or land use change decisions) to be faced, at both national policy and local management levels. While individual research needs can be commissioned separately, a strategic approach should ensure that consistency is maintained across the sector.

Recommendation 5: *a phased research programme of coordinated research including both public and private sector organisations should be considered.*

Taking Recommendations 1-4, a phased approach to future research will ensure that a consistent evidence base is developed. Given that economic analysis can only build on the scientific evidence, priority for new research may initially be focussed on scientific understanding. For updating existing evidence where the science is well understood, economic research should be prioritised.

In terms of individual services, there is already have a significant amount of evidence on provisioning services and hence these are unlikely to a priority for future research. For regulating services however, beyond carbon sequestration benefits, there is a strong need for further evidence, both in terms of science and economics. Final ecosystem services of particular interest include regulation of non-carbon GHGs, air quality, water regulation and flood protection, both in terms of understanding and estimating values, and the potential for implementing value capture mechanisms. The most obvious evidence needs with respect to cultural services relate to non-recreation benefits. Across landscape and aesthetic amenity, physical and mental health, and ecological knowledge there is need to update evidence that is dated (e.g. landscape) or generate value evidence for benefits currently presented in typically qualitative and anecdotal terms (e.g. health and wellbeing benefits).

Recommendation 6: *the forestry sector should conduct research on the benefits of urban trees to demonstrate the range of public policy objectives forestry policy can contribute to.*

The case of urban trees provides a microcosm of the wide range of forestry policy objectives in terms of contributing to wellbeing and health, climate change adaptation, biodiversity and conservation. At present, evidence concerning the ecosystem service values of urban trees in Great Britain is limited. Further research is needed and can be coordinated with other regulatory stakeholders such as the Local Authorities.

Recommendation 7: *the forestry sector should identify policy and research opportunities to contribute to improved valuation of biodiversity.*

Studies such as the UK NEA have highlighted the challenges faced in estimating economic values associated with conservation of biodiversity and understanding the value of stocks of ecological assets in light of issues as thresholds and ecosystem resilience. The forestry sector should actively engage with research opportunities that arise (e.g. research councils, EU and national policy development) to ensure that woodland and forest biodiversity is appropriately examined.

Recommendation 8: *valuation of ecosystem service provision in the forestry sector should consider the appropriateness of all valuation methods.*

In designing research studies to address evidence needs on the value ecosystem services, a thorough assessment of the appropriateness of different valuation methods is required. In general the choice of method depends on the decision-making context, ecosystem service(s) of interest, nature of the affected population(s), availability data, and time and resources available. Valuation methods using market price data, production function approaches (e.g. for regulating services) and revealed and stated preference methods should all be considered, along with the potential for integrating geographical information systems (GIS) to better account for the spatial and context specific nature of economic values.

Recommendation 9: *the forestry sector should commission research on implementing value capture mechanisms that provide the greatest opportunity for engaging the private sector within multi-purpose woodland provision.*

This report highlights a number of approaches towards improving the engagement of the private sector within the provision of ecosystem services. Some of these mechanisms are already in use within other sectors (notably agriculture) and the scope for extending these to the private provision of multi-purpose forestry (including open-access woodland) requires further attention. This could provide a more detailed assessment of the practical application of mechanisms; for example assessing the specific factors that determine the provision of ecosystem services from forests and woodlands. The aim would be to identify the options that are best suited to the circumstances of the forestry sector.

1. INTRODUCTION

1.1 Background

In the past decade the development of the ‘ecosystem services approach’ (ESA) (MEA, 2003; 2005) has sought to establish and refine an overall framework in which the multiple contributions of ecosystems and the biological diversity contained within them can be consistently assessed for the purposes of environmental policy-making.

The landmark UK National Ecosystem Assessment (UK NEA, 2011) provides the first detailed analysis of the benefits that the natural environment provides to society. It stresses that the need to manage the natural environment in the UK in the coming decades to realise the full range of benefits from ecosystem services is becoming more pressing. This is crucial in light of projected population growth and associated demand for food, water and energy, and the predicted impacts of climate change with more severe weather events and changes to rainfall patterns.

Coupled with this, both the UK NEA and the recent United Nations Environment Programme (UNEP) led initiative ‘The Economics of Ecosystems and Biodiversity’ (TEEB, 2010) demonstrate that a healthy natural environment is fundamental to economic growth and prosperity. In particular these studies highlight that environmental degradation can have significant opportunity costs for the productive economy, by requiring the costly maintenance of man-made capital to substitute for the loss of services provided by the natural environment (e.g. flood and coastal protection).

Shifting to a more sustainable management basis for ecosystems is reliant on legal, policy and institutional frameworks that establish appropriate incentives, technology and practices, and voluntary actions for attaining a better balance between the productive and non-productive uses of ecosystems. An integrated approach across all sectors is required such that the natural environment is fundamental to decision-making rather than simply being viewed as a necessary trade-off for economic development and growth. Underpinning these frameworks is the need for a combined scientific and economic evidence base that supports understanding of the linkages between biodiversity, the structure and function of ecosystems and the consequent contributions to social wellbeing. In this regard the UK NEA emphasises that a consistent failure in conventional economic analyses and decision-making has been the under-valuing of many of the benefits provided by ecosystems. It recommends that improved understanding of the full range of values that are derived from the provision of ecosystem services is a vital component of the evidence base that should inform national and local decision-making.

In England this message has been reinforced by the Natural Environment White Paper ‘The natural choice: securing the value of nature’ (HM Government, 2011). It states that the economic and social value of a healthy environment should be at the centre of decision-making across Government, businesses and local communities. Similarly, this theme is evident in policy development in the UK devolved administrations. For example the Scottish Land Use Strategy (Scottish Executive, 2011) sets out the principles that land use decisions should be informed by understanding of the ecosystem functions they provide and ecosystem service benefits that arise, particularly so that flood risk management, water catchment management and carbon storage values are explicitly recognised. In Wales the development of the Natural Environment Framework is also based on the principles of recognising the full value of ecosystem services (Welsh Assembly Government, 2010).

Accounting for approximately 13% of total land cover (ONS, 2011), the forestry sector in Great Britain plays a key role in the management of the natural environment and the provision of ecosystem service values. Woodlands are situated in diverse locations across the country, from rural and often remote areas, through urban fringes of towns and cities, to the heart of urban areas in parks and streets. The functions and services that these woodlands provide vary considerably depending on their environmental characteristics, growing conditions, management objectives and proximity to populations. The benefits from conservation and sustainable management of these woodlands extend beyond their in-situ location, across local, regional, national and global scales.

Overall there are many opportunities and challenges faced in the management of woodlands, particularly in terms of achieving a sustainable balance between the provision of different types of ecosystem service value; for example timber production, carbon sequestration, water catchment management, and recreation and tourism benefits. The continued development of the ESA, as promoted by the UK NEA and TEEB, and the growing recognition of the full range of ecosystem service values, puts a particular focus on the evidence base that underpins the management of the natural environment. Therefore it is timely to re-assess this evidence base to determine whether the current extent of the available evidence is sufficient to inform future management decisions.

1.2 Objective and scope

The objective of this study is to review the existing evidence base on the value of ecosystem services provided by forests in England, Scotland and Wales, and to identify future economic research needs. The Terms of Reference⁴ for the study set out four specific aims:

- v). Review estimated values for the economic, social and environmental benefits produced by Britain's forests from existing literature and categorise these values according to the ecosystem services framework;
- vi). Identify gaps in the existing evidence base and recommend future research priorities to demonstrate the ecosystem service value of woodlands across the UK;
- vii). Highlight key challenges and uncertainties that could arise in the valuation of ecosystem services and suggest how these could be addressed; and,
- viii). Consider practical market opportunities for forest ecosystem services and their potential scale, using case studies where possible.

The study scope covers both the public forest estate managed by the Forestry Commission and all private woodland across Great Britain. A broad definition of forest/woodland is applied throughout this report⁵, such that areas of heathland could potentially be included for example, along with features such as trees in urban areas (e.g. 'street trees').

⁴ Invitation to Tender for Scoping Study on Valuing Ecosystem Services of Forests Across Great Britain, Forestry Commission, Contract No: 1/11.

⁵ Throughout the report the terms 'woodland' and 'forest' are used interchangeably. Strictly the definition of woodland in UK Forestry Statistics (Forestry Commission, 2011) is "land under stands of trees with a canopy cover of at least 20% (or having the potential to achieve this), including integral open space, and including felled areas that are awaiting restocking". The term 'forest' typically describes extensive wooded areas, but in an historical context has also been applied to areas that are not wooded (e.g. heath, grassland and wetland) that support deer and other game, particularly in the case of Royal Forests (the earliest of which date from the 11th century).

Overall the report is intended to provide a ‘reference document’ for valuing ecosystem services of forests and is aimed at a wide and non-technical audience. The review of evidence focuses on previous studies that have estimated values of ecosystem services for forests including economic appraisals and research conducted for the Forestry Commission, other Government departments, and other organisations both in the UK and internationally. It also considers the extent of the scientific evidence that is available on the provision of ecosystem services from woodlands, since this provides the basis for the valuation of ecosystem services.

1.3 Structure of the report

The report is structured as follows:

- **Section 2:** provides a conceptual overview for the study, briefly outlining the forestry policy context and describing the ESA and economic valuation of ecosystem services.
- **Section 3:** provides the review of evidence which is structured around a classification of ecosystem services and a typology of woodlands. Given the scope of work the review is necessarily ‘broad and shallow’, covering studies valuing ecosystem services and identifying gaps. A series of practical examples are provided to illustrate the use of the evidence in practice, along with an overview of mechanisms for capturing ecosystem service values (i.e. ‘payments for ecosystem services’).
- **Section 4:** provides conclusions and sets out recommendations for future ecosystem services research, based on the review of evidence and gaps.

In addition, supporting information is provided in:

- **Annex 1:** an overview of the evolution of forestry policy since the establishment of the Forestry Commission to ‘set the scene’ in terms of how the appreciation of ecosystem service provision from woodlands has developed over the past century.
- **Annex 2:** for reference, a long-list of forest characteristics (based on environmental, geographic and management factors) that influence the provision of ecosystem services from woodlands.
- **Annex 3:** a case study testing the spatial analysis framework developed in the UK NEA for estimating the benefits of recreational visits to woodlands.

2. CONCEPTUAL OVERVIEW

2.1 Forestry policy in Great Britain

Forestry policy in Great Britain (GB) is split between the UK Government and the devolved administrations. Defra is responsible for forestry policy in England and international issues. The Scottish Government has responsibility for forestry in Scotland and the Welsh Assembly Government responsibility for forestry in Wales. The role of the Forestry Commission (FC) - a non-ministerial government department - is the protection and expansion of forests and woodlands in GB. Reflecting devolution, the FC is structured so that the separate policy initiatives of each country are delivered through Forestry Commission England, Forestry Commission Scotland, and Forestry Commission Wales.

Across the UK, the sector encompasses almost 3.1 million hectares of woodland and forest (Forestry Commission, 2011). As detailed in Table 2.1, the majority of this - approximately 2.2 million hectares - is privately owned and managed by various bodies and individuals including commercial timber enterprises, individual estates and charitable organisations. The remainder - around 1 million hectares - comprise the public forest estate and is directly managed by the FC. Approximately 1.4 million hectares of forest are in Scotland, two thirds of which is coniferous woodland. In England two thirds of the 1.3 million hectares of woodland is broadleaved. Over half the 0.3 million hectares of forest in Wales is coniferous woodland.

Table 2.1: Area of woodland by country (thousands of hectares)

<i>Management</i>	<i>Type</i>	<i>England</i>	<i>Wales</i>	<i>Scotland</i>	<i>Northern Ireland</i>	<i>UK</i>
Public (FC/FS)	Conifers	155	98	447	55	755
	Broadleaves	59	16	33	6	114
	Total	214	114	481	61	870
Private (Non FC/FS)	Conifers	256	69	633	10	969
	Broadleaves	827	121	276	17	1,241
	Total	1,083	190	909	27	2,209
Total	Conifers	411	167	1,081	66	1,724
	Broadleaves	886	138	309	22	1,355
	Total	1,294	304	1,385	88	3,079

Source: Forestry Commission (2011)

Notes: FC = Forestry Commission; FS = Forest Service (Northern Ireland)

The evolution of forestry policy in GB in itself reveals how the appreciation of ecosystem service provision has developed over (almost) the past century. **Annex 1** provides an overview and reflects a shifting emphasis from a need to ensure a strategic resource of timber, through to providing a mechanism for rural economic development and employment, to a wider appreciation of the recreation, landscape and biodiversity value of woodland. In the present day much emphasis - particularly in an international context - has focused on the carbon sequestration and storage roles of forests, and most recently the development of mechanisms to 'capture' ecosystem service values via appropriate market-based incentives and price signals.

While there are some differences in priorities between England, Scotland and Wales, the range of objectives for forestry policy to date have been broadly consistent:

1. Rural development: forestry's contribution in the wider countryside including the contribution of both new and existing woodlands to the rural economy, timber and marketing opportunities and its contribution to upstream and downstream job creation.

2. Economic regeneration: forestry's role in strategic land use planning including the restoration of former industrial land and creating a green setting for future urban and urban fringe development.
3. Recreation, access and tourism: providing more and better public access to woodlands, ensuring that woodland and forests continue to be used for a wide range of recreational pursuits as well as complementing and supporting the tourist industry.
4. Environment and conservation: the role that woodlands play in conserving and enhancing the character of our environment and in delivering the government's objectives for nature conservation, biodiversity and climate change.

It is also important to note that forestry contributes to wider Government and public policy objectives. This is evident from the rural development and employment focus in the above objectives, but also includes aspects such as public health and wellbeing. For example, in England the 'Healthy Lives, Health People' White Paper (HM Government, 2010), references the role that access to green space has in encouraging physical activity and healthier lifestyles. The contribution of forestry in these terms has also been previously examined by CJC Consulting (2005) in the report 'Economic Benefits of Accessible Green Spaces for Physical and Mental Health'.

In Scotland and Wales long term strategies for forestry are set out respectively in the Scottish Forestry Strategy (Scottish Executive, 2006) and Woodlands for Wales (Welsh Assembly Government, 2009). In England the future direction of forestry policy, and the role of the FC in implementing this, is at present subject to a fundamental review. The Secretary of State for the Environment has established an Independent Panel on Forestry to consider (Defra, 2011):

- How woodland cover can be increased in light of competing pressures on land use for food production, energy and development;
- Options for enhancing public benefits from all woodland and forests, including: access for recreation and leisure; biodiversity, wildlife protection and ecological resilience, including restoration of open habitats and plantations on ancient woodland sites; climate change mitigation and adaptation; economic development, including a sustainable timber industry; and engagement and participation of civil society.
- Constraints and competing demands on public expenditure for the Spending Review period and beyond;
- The role of Forest Enterprise England as the manager of productive forestry resources; and
- The value for money and cost-effectiveness of the public forest estate in England and options for its future ownership and management.

The panel is expected to report its progress in Autumn 2011 and present its recommendations in Spring 2012.

2.2 Ecosystem service approach

2.2.1 Outline of the ecosystem services approach framework

The ‘ecosystem services approach’ draws particular attention to the crucial role that natural systems play in underpinning economic activity and human wellbeing. It also recognises that the feedback pressures which economic activity places upon natural systems increasingly threatens the sustainability of those systems, and with them, the underpinnings of human wellbeing. This feedback mechanism and the dependence of human society upon the integrity of natural systems is at the centre of the ecosystem services approach to decision-making. It also forms an institutional challenge which recognises that sustainable development requires a new form of decision making which explicitly fuses together natural science, economics and social science (UK NEA, 2011).

The increasing interest in the ecosystem service approach reflects the wider-scale recognition of multiple objectives, trade-offs and synergies that exist in the realm of ‘natural environmental’ policy (e.g. environmental protection, land-use management, sustainable development, etc.). Its development has been the focus of a concerted research effort and policy analyses that highlight and attempt to measure the contribution of ecosystems and the biological diversity contained within them to individual and social wellbeing. In this sense, the term ‘ecosystem services approach’ has come to describe a basis for analysing how individuals and human systems are dependent upon the condition of the natural environment⁶.

In practice there is no single ESA or framework. While numerous research initiatives have been undertaken it is widely recognised that the key contribution in developing a high profile systematic account of ecosystem services was provided by the UN Millennium Ecosystem Assessment (MEA, 2003; 2005). This established the four main categories of ecosystem services:

- **Provisioning services:** these refer to ‘products’ that are obtained from ecosystems, with examples including timber from forests, crops from agricultural production, commercial fish catch and renewable energy (e.g. hydro power or tidal power). This includes most of the market priced final goods embodying ecosystem services. However, there are also numerous goods that are not marketed (non-market goods - e.g. wild foods) which also feature in this category.
- **Regulating services:** these refer to the benefits obtained from the regulation of ecosystem processes, such as flood prevention in river catchment, groundwater recharge, and climate regulation through sequestration of carbon. As is evident from these examples, many regulating services contribute to the provision of non-market goods.
- **Cultural services:** probably the most inaccurately named of all ‘ecosystem services’ (given that all nature dependent goods contribute to wellbeing and society), the MEA defines this category as referring to the non-material benefits that individuals obtain from ecosystems, such as recreation and leisure activities, aesthetic and amenity values, and education and knowledge. Again many of these are non-market goods.

⁶ In practice the term ‘ecosystem service’ may be regarded as being too narrow. Often it can be interpreted as referring to a fusion of ecology with social sciences when in fact all aspects of the natural environment are of relevance; given this it would actually be more accurate to talk of environmental rather than ecosystem services; however it is the latter term which has gained credence across both research and institutional communities.

- **Supporting services:** these refer to services that are necessary for the production of all other ecosystem services. They differ from the other services in that their impacts on people are either indirect (via provisioning, regulating or cultural services) and/or occur over a very long time. Examples of these services include soil formation, nutrient cycling, habitat provision and primary production⁷.

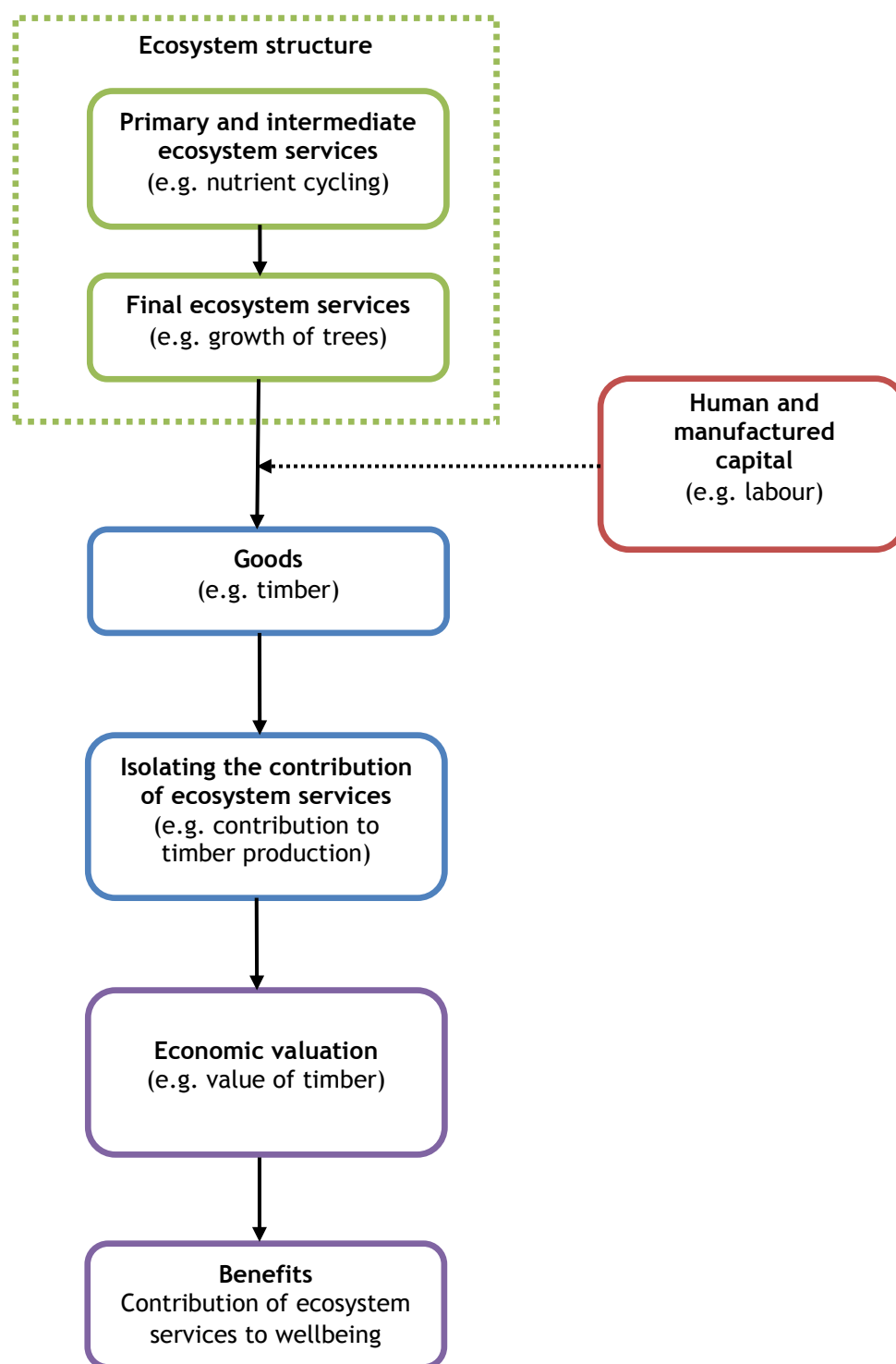
Section 3.1 provides a fuller outline of specific ecosystem services under the provisioning, regulating and cultural services categories.

Studies subsequent to the MEA have sought to improve understanding, refine concepts and develop practical applications of the ESA. These include TEEB (2010) and the UK NEA (2011) as well as a substantial academic literature that has also developed particularly with respect to the role of economic analysis within the ESA⁸. While these studies tend to differ in the terminology used, or the particular emphasis of the analysis, in general the ESA concept can be characterised as depicted in **Figure 2.1**.

⁷ Primary production is the production of chemical energy in organic compounds by living organisms (e.g. through the process of photosynthesis).

⁸ For example: Balmford et al., 2002; de Groot et al., 2002; Heal et al., 2005; Fisher et al., 2008; Mäler et al., 2008; Turner et al., 2010.

Figure 2.1: Outline of key ecosystem services approach concepts



Source: Adapted from Bateman et al. (2011)

From the perspective of economic analysis (see **Box 2.1**), ecosystem services represent flows of economic value that are generated by stocks of ecological assets, which can also be termed ‘natural capital’ (Bateman et al., 2011). This is analogous to familiar manufacturing processes for market goods where physical capital (i.e. machines in factories) and human capital (i.e. labour) are employed in the production of physical goods, such as cars, computers and smart phones. In fact, a key point highlighted in the NEA approach is that flows of ecosystem services often require the use of other capital inputs to convert them to goods and services that are useful to humans; for example, logging machinery that is required to harvest timber from forests. This recognises the important role of human inputs in converting latent services to actual values (see Nicholson et al., 2009; Bateman et al., 2011).

Following Bateman et al. (2011), the ESA concept illustrated in Figure 2.1 comprises:

- **Ecological assets (trees and woodlands in the context of this report):** these are essentially the wealth of ecosystems, being the (physical) natural capital stocks from which flows of ecosystem services are derived. The types of services that may be provided are dependent on the spatial and temporal context⁹ of ecosystems that determine its structure (e.g. the plant and animal species that are found in a certain place at a given time and their interactions) and processes (e.g. soil formation).
- **Ecosystem services (provisioning, regulating, cultural and supporting services):** as noted above these are flows of services that result from the structure and processes associated with ecological assets. Flows of services are also dependent on human interventions such as land use management actions that influence the type, scale and timing of ecosystem service provision.
- **Final ecosystem services:** represent the culmination of a chain of ecosystem functions (and physical and human capital inputs) that are the elements of the natural environment which directly affect the wellbeing of human populations. Crucially this distinction separates final services from ‘intermediate’ and supporting services that indirectly benefit populations by sustaining final services. For example pollination can be considered to be an intermediate service that supports agricultural crop production (a final service). Economic analysis of ecosystem services ordinarily focuses on final services to avoid double-counting by not including supporting and intermediate services in assessments¹⁰.
- **Good:** this is an economic term for an object that increases human wellbeing. Goods derived from the provision of ecosystem services associated with forests and woodlands include physical commodities, such as timber and food products, as well as non-physical experiential outcomes, such as the visual amenity of the natural landscape. These represent both ‘market goods’ or ‘non-market goods’, the distinction being that market goods (e.g. timber) are formally traded in markets and are priced, whereas non-markets goods are un-priced (Box 2.1).

⁹ This includes what Bateman et al. (2011) refer to as ‘boundary conditions’ which are environmental factors such as elevation, slope and climate.

¹⁰ For example, separately valuing soil formation and tree growth and then aggregating them would lead to double counting since the outcome of soil formation (in this context) is the tree growth. However, in some instances it can be informative to value intermediate services. This can highlight the importance of aspects such as shelterbelts (rows of trees or shrubs that act as a windbreak) for livestock production, or pollination services for agricultural crop production. These services represent inputs to market good production processes, the economic contribution of which can be examined via a ‘production function approach’. See for example Barbier (2007). Note also that within the classification of ecosystem services applied in this study, pollination is actually included as a final ecosystem service (Section 3.1).

As noted above, the production of some goods requires both natural and other physical or human capital inputs. This means that it would be incorrect to attribute the entire value of a good to its underlying ecosystem services unless there are no other productive inputs, which is rarely the case.

A further point to also note is that the human and physical capital inputs represent the employment and skills input to forestry which are often the key focus of economic development and regeneration initiatives. Given the (consumption) use and non-use benefits focus of the ESA and economic valuation, however, economic returns to labour and physical capital represent production/management costs of woodlands. In alternative analyses - i.e. those focused on productive outcomes - investment in capital and returns to it would represent part of the value added of forestry enterprise; i.e. it is essentially a matter of the accounting perspective adopted.

- **Benefit:** an important distinction that Bateman et al. draw is between the uses of the terms 'benefit' and 'good'. They note that a benefit is the actual change (i.e. gain or loss) in human wellbeing that results from the consumption of a good. The actual value of a benefit - the change in wellbeing - however is context dependent and determined by factors such as spatial location and timing. For example, the scale of flood protection benefits that may be provided by woodland in a river catchment will depend on the downstream affected population and types of assets at risk (e.g. residential and commercial properties, physical infrastructure, etc.). Changes in wellbeing that arise from the provision of ecosystem services are attributed to use and non-use values. In particular the typology of total economic value (TEV) distinguishes between use value, which arises from either a direct or indirect interaction with a resource, and non-use value, which arises due to altruistic motives (for others' wellbeing), bequest motives (for the wellbeing of future generations) and/or for the sake of the resource itself (existence).

In the ESA concept, the notion of a *flow* of ecosystem services is a key point, differentiating it from the *stock* of ecological assets. A 'stock' is a (physical) quantity that is measured at a specific point in time; for example the stock of woodland in Scotland is approximately 1.3 million hectares and comprises of approximately 2.2 billion trees (Forestry Commission, 2011). A 'flow' is a quantity that is measured over an interval of time; for example the availability of softwood in Scotland which is forecast to be around 6.7 million tonnes of timber *per year* for the period 2012-16 (Forestry Commission, 2011).

The stock of ecological assets (natural capital) can be depleted or augmented over time by out-flows (e.g. harvesting timber) or in-flows (e.g. afforestation and planting). This brings into consideration the sustainability of ecological assets and has important implications for the valuation of ecosystem service provision. However, it may not be straightforward to relate flow values to corresponding stock values. One issue is that the total size of many stocks is either not known or imprecisely estimated. A further issue is that the marginal value is likely to be linked to the stock size, and typically, as a stock shrinks so the marginal value of remaining units extracted begins to increase. This can imply that a reduction in the physical size of flows can be offset to some degree by increases in value. In the context of forestry, such a phenomenon can lead to increased timber harvesting rates; for example, as the stock of mahogany trees reduces in tropical forests, the value of remaining examples increases, raising the profits of such felling¹¹.

¹¹ Note that this exemplifies some of the issues highlighted in the UK NEA (2011) conventional economic analyses focus only on market returns from ecosystems and under-value (or do not value at all) the non-market benefits provided (e.g. carbon sequestration, protection of biodiversity, watershed regulation, etc.).

Problems such as incomplete information can mean that observed marginal values of flows can be unreliable indicators of stock values; i.e. it is not sufficient to simply multiply the per unit (marginal) value of a flow by the size of the stock to obtain the value of the latter. The information problem becomes much worse if there are unforeseen or inexact quantified ‘threshold’ levels beyond which stocks begin to deplete at an accelerated rate¹² (e.g. where populations lose the genetic variation to be viable). This is even more complex for stocks which exhibit ‘irreversibility’. For example, if stock losses can only be reversed at very considerable cost (e.g. exceeding the benefits which their initial depletion generated) there is ‘economic irreversibility’. A similar issue arises if stock replenishment can only occur by very considerably reducing rates of extraction (the so-called ‘hysteresis’ problem). Most extreme is where replenishment is physically impossible, irrespective of the cost (‘perfect irreversibility’) as can happen in the case of species extinctions. A final complexity relates to the substitutability of resources in terms of the ability of alternatives to provide a continuance of some ecosystem service¹³. Again problems of incomplete markets and imperfect information tend to further complicate relationships and hence decision-making in this respect¹⁴.

¹² Threshold levels typically apply to a single resource or ecosystem service. By contrast, ‘tipping points’ usually refer to more general changes affecting multiple resources.

¹³ Note that there is a comprehensive literature concerning sustainability and the implications of depletion of ecological assets. An adequate account of this is beyond the scope of this report, but a useful introduction is provided by Bateman et al. (2011).

¹⁴ As detailed in Box 2.1, economic analysis is ordinarily focused on ‘marginal’ changes in flows of ecosystem services, but this is not to say that economic analysis cannot be applied to non-marginal changes. Indeed a substantial literature exists around ‘resilience values’ and ‘safe minimum standards’. Again, a useful introduction is provided by Bateman et al. (2011). In such cases it is important that assessments also consider the status of the natural capital stocks from which these values flow, and, if necessary, reflect the impact of increasing scarcity on valuations. However the prospect of non-marginal changes can challenge the limits of economic analysis, particularly when coupled with data gaps, lack of a sufficient scientific knowledge, uncertainty regarding the path of natural capital depletions, non-linear and thresholds effects, and problems of partial or complete irreversibility of depletion paths. This represents an area where much progress can be made in moving from academic and theoretical exercises to developing a practical evidence base that can better inform policy development, particularly in understanding the resilience of ecosystems and the implications of exceeding environmental limits.

Box 2.1: The concept of economic value

To support the discussion in Section 2.2 it is useful to outline some key concepts associated with the value of ecosystem services:

- Economic analysis is concerned with measuring the **wellbeing** of individuals and overall society. Trade-offs made between different goods reveals the value that is placed on those goods and their contribution to wellbeing. The existence of a trade-off is the key point; economic value is concerned with what is 'given up' (or 'foregone' or 'exchanged') in order to obtain a good or service, rather than seeking to estimate the absolute value for a resource.
- Economic analysis is ordinarily concerned with a **marginal change** in the provision of a good. This can be defined as a change which is too small to influence the demand and supply conditions for the good and hence the unit value. It goes without saying that ecosystem functions and services are essential for supporting all life. However, it is the marginal value of ecosystem services that is of relevance when considering trade-offs relating to their provision. The marginal value of a good is the additional economic value that is generated by the last unit of consumption and is determined by its relative scarcity in terms of quantity, quality, location and timing (including seasonality).
- When considering trade-offs between different goods, if the resource that is given up is measured in monetary terms then it is possible to express economic value in monetary terms. Money therefore is a 'unit of measure' that enables a common comparison of outcomes in economic analysis; for example, comparing the financial cost of measures to restore woodland habitats with the benefits of nature conservation.
- The trade-off between money and changes in the provision (quantity or quality) of goods - i.e. their economic value - is defined through individuals' **willingness to pay (WTP)** for securing a gain or avoiding a loss, or their **willingness to accept compensation (WTA)** for foregoing a gain or tolerating a loss. Economic valuation methods estimate WTP and WTA using different types of data depending on whether the good or service is traded in actual markets or not.
- A number of goods that arise from the provision of ecosystem services are **market goods** (e.g. timber, crops, livestock, fish, etc.). The **market price** at which a good is exchanged - i.e. the monetary amount - reveals some information about its economic value. In particular, for the buyer of a good, the price reveals the amount of money the buyer is at least willing to give up to obtain the good. For the seller, the price reveals the amount of money the seller is at least willing to accept as compensation for giving up the good. Market price information, however, can be an imprecise measure of the economic value of a particular good if it fails to fully reflect WTP or WTA. For example, many buyers may be willing to pay more than the market price to obtain the good.
- The difference between the maximum amount a buyer is willing to pay and the actual price paid is termed **consumer surplus**, reflecting the element of benefit from obtaining the good that is 'gained for free'. Similarly, the seller of the good may be willing to accept a lower amount than the market price to give up the good. The difference between the minimum amount a seller is willing to accept and the actual price received is termed **producer surplus**, reflecting the additional benefit in exchange gained (in effect 'economic profit'). Overall, in the case of market goods and services, economic value (WTP or WTA) is reflected by the market price paid or received¹⁵ plus any consumer or producer surplus.

¹⁵ Note that the effect of taxes and subsidies on market prices should be factored into the analysis since these distort price signals and can lead to over- or under-estimates of the value of a resource.

- Where resource inputs are required to produce a market good or service, a further concept of economic analysis, termed **opportunity cost**, is of relevance. The opportunity cost of a resource is the value of the next best alternative use of the resource (e.g. the opportunity cost of conserving tropical forests is value of lost agricultural output from forest clearing and land use conversion). This concept is central to the notion of **economic efficiency**, where scarce resources are employed in uses that generate the highest (social) wellbeing.
- Many of the goods associated with regulating and cultural services of ecosystems are not traded in markets and are consequently 'un-priced'. However, for **non-market goods** the metrics of WTP and WTA are still those of interest. For example, the economic value of an improvement in environmental quality should be measured by the resources individuals are willing to give up to obtain the improvement - i.e. willingness to pay - or the compensation they would accept for foregoing that improvement - i.e. willingness to accept. The contrast with market goods is that since there is no price paid for the non-market resource, WTP and WTA are composed wholly of consumer surplus.
- Various **economic valuation methods** have been developed to measure the monetary value of non-market goods or of those goods for which market prices do not accurately (or fully) reflect opportunity costs. Further detail with respect to applying these methods to value ecosystem services is provided in Defra (2007) and eftec (2006).

2.2.2 Valuing ecosystem services

The development of ESA has played a useful role in clarifying the purpose of economic valuation - namely measuring the (human) wellbeing derived from environmental resources. Commonly an understanding of the value of ecosystem services is required as an input to policy analyses such as Impact Assessments and cost-benefit analysis which seek to weigh-up all outcomes associated with a proposed action (see Section 2.3); for example comparing the costs of a habitat restoration programme to its benefits in terms of maintaining or enhancing the provision of ecosystem services.

In practical terms valuation of ecosystem services represents the final step in the "qualitative - quantitative - valuation" assessment process of policy analysis (Defra, 2010). Before any economic analysis is undertaken, qualitative and/or quantitative scientific analysis is required to understand how service provision changes as the ecosystem changes. It is also vital to understand how these changes affect human populations. Only then can economic values be associated with these changes, such as the 'benefit' in terms of an improvement or increase in provision, or the 'cost' in relation to a reduction or deterioration in provision. In the absence of a sound understanding and measurement of physical impacts, the scope for valuation of ecosystem services is limited.

eftec (2010a) describes the information that is needed to estimate the value of change in provision of a market or non-market good as follows:

- An estimate of the change in the provision of the good under consideration:* This can be presented in qualitative and/or quantitative terms and requires scientific understanding of ecological functions and how physical impacts on ecosystem services feed through to changes in the provision of goods consumed by user and/or non-user populations. The changes should be defined in terms of quantity, quality, timing and spatial availability. For example understanding how air pollution, such as the deposition of nitrogen, affects the growth of trees and consequently carbon sequestration and timber production.

- ii). *A reliable estimate of the economic value*: The basic principles of economic valuation assert that economic value is measured by the resource individuals are willing to trade-off to either secure or forego the change in provision of a good. Ordinarily the 'resource' is defined in terms of money and its economic value can be estimated via the metrics of 'willingness to pay' (WTP) or 'willingness to accept' (WTA) (Bateman, 2007). Economic valuation methods have been developed to estimate WTP or WTA using different types of data depending on whether the good is traded in actual markets or not; e.g. market prices, revealed preference methods and stated preference methods (Hanley and Barbier, 2009). For market goods, the direct use value associated with their provision can be reflected by market price information where this represents opportunity cost (i.e. net of distortions such as taxes and subsidies). Valuation of non-market goods relies on revealed and stated preference methods in terms of primary studies, and more commonly in project and policy analyses, adapting previous value estimates through value transfer (Defra, 2010). Different methods are able to capture, to differing extents, the components of total economic value; i.e. direct use values, indirect use values, and non-use values (see for example: Defra, 2007; eftec, 2006).

- iii). *Knowledge of how the economic value (ii) changes due to the change in provision of the good (i)*: In many instances, it is not sufficient to simply assume that there is a constant relationship between economic value and changes in the provision of market and/or non-market goods. For example the value of improvements in environmental quality can be subject to diminishing marginal utility, implying that benefits from initial improvements are valued greater than subsequent improvements. This highlights the context-specific nature of economic values (as noted above) and particularly how they are dependent on the baseline provision of the good and the scale of the change in provision to be valued.

- iv). *Knowledge of which factors influence the economic value*: In addition to the scale of the change in the provision of a good, economic values are also dependent on two important groups of factors: the characteristics of the good and the characteristics of the population that benefit from provision of the good. For example the abundance and quality of substitute goods is a fundamental determinant of demand for both market and non-market goods. Willingness to pay of individuals - the most commonly applied metric for valuing non-market goods - is also dependent upon the socio-economic characteristics (e.g. income) and patterns of use of goods by user populations (or, for example, familiarity with the good for non-user populations). Significantly both these groups of factors are 'spatially sensitive' - i.e. they vary over populations and their spatial distribution - implying that economic values and consequently benefits derived from the provision of ecosystem services are also spatially sensitive. This gives rise to empirically observed relationships such as 'distance decay', which refers to a decline in use value, and the user proportion within the population, as distance from a resource (e.g. a recreation site) increases (Bateman et al., 2006).

Overall, the integration of economic valuation within the framework of the ecosystem services approach provides a basis for establishing and assessing the range of impacts associated with policy proposals. It provides a transparent process for establishing the value of changes in provision of goods that are generated in-part or wholly by ecosystem services. As noted, the economic perspective places much emphasis on the need to avoid double counting in valuation. This is reliant on the necessary scientific understanding and assessments that contribute to multi-disciplinary analysis, requiring them to work towards identifying the 'final' ecosystem services that provide the market and non-market goods which confer economic value to affected populations.

2.3 Uses of economic valuation

The concepts outlined in Sections 2.2.1 and 2.2.2 can be seen as abstract and theoretical. Therefore it is useful to review the circumstances in which the value of ecosystem services may be applied for practical decision-making purposes. In the context of this study, this is particularly relevant since the scope is not confined to a particular aspect of forestry policy, but rather is required to consider all possible needs for valuation evidence that may arise. This includes the four main multi-function objectives of forestry policy: rural development, economic regeneration, recreation and environment and conservation.

On this basis, **Table 2.2** reviews the types of policy and decision-making context in which evidence on forest and woodland ecosystem service values may be required. Largely the breakdown of potential decision-making contexts and the forestry management issues they entail fits within the analytical structure that is promoted by TEEB for the valuation of ecosystem services. This sets out a ‘tiered’ approach of: (a) recognising values; (b) demonstrating values, which is the basis of priority setting, project and policy analyses, damage assessments and green accounting; and (c) capturing values, through mechanisms that incorporate the value of ecosystem services in market-based choices of individuals and businesses (TEEB, 2010).

Table 2.2: Uses of ecosystem service values

<i>Decision-making context</i>	<i>Role of valuation</i>	<i>Forestry context example</i>
Demonstrating the importance of an issue Usually the need is to estimate the economic value (benefit or cost) from some activity, or the value of a policy change	Estimating the value of benefits associated with conservation actions, or the value of costs associated with degradation	e.g. understanding the impact of air pollution on the forest provisioning (timber) and regulating services (carbon sequestration) e.g. understanding the physical and mental wellbeing benefits of access to urban forests
Setting priorities Typically the requirement is to establish a ranking of project or policy proposals for the allocation of expenditure from a limited budget	Estimating the value of outcomes associated with the proposals for the purpose of providing a consistent comparison between competing projects (cost benefit analysis and cost effectiveness analysis)	e.g. establishing locations for new urban fringe woodlands
Project analysis Either appraisal or evaluation of investment projects (e.g. via cost-benefit analysis)	Estimating the value of changes in the provision of market and non-market goods affected by a proposed project (cost benefit analysis and cost effectiveness analysis)	e.g. comparing costs and benefits of improvements to visitor facilities and recreation e.g. benefits of flood risk reduction from tree planting in a river catchment
Policy analysis Either the appraisal or evaluation of local or national policies, or assessing the impact of regulations, standards and best practice requirements (e.g. Impact Assessment)	Estimating the value of changes in the provision of market and non-market goods affected by proposed policy (cost benefit analysis and cost effectiveness analysis)	e.g. comparing the costs and benefits of regulations controlling planting stock

Table 2.2: Uses of ecosystem service values

<i>Decision-making context</i>	<i>Role of valuation</i>	<i>Forestry context example</i>
Establishing the price signals, incentives and markets The design of market-based instruments to capture the value of environmental benefits or costs (damages) (e.g. access/entry fees; user charges; taxes; payments for ecosystem services (PES))	Estimating the value of non-market impacts (i.e. social and environmental) arising from a resource under full-cost recovery or polluter pay principles	e.g. determining entry fees for forest sites e.g. setting payment level of PES
Legal damage assessments Assess compensation required for damages to environmental resources	Estimate the value of environmental impact or damage	e.g. assessing compensation for loss of woodland habitat from land development
Green accounting Modification of national (income) accounts (or corporate accounts) to include environmental capital within the measure of wealth (along with man-made, human and potentially social capital)	Estimate the value of <i>changes</i> in the stock of natural capital (by valuing flows over a snapshot period of time)	e.g. national green accounts estimating the flow of carbon sequestration, recreation, landscape amenity, etc. benefits of woodlands

As Table 2.2 highlights, the scope for using information on the value of ecosystem services in relation to forestry policy is broad, and be relevant to other sectors such as agriculture, flood risk management and health. Comprehensive and reliable valuation evidence on both market and non-market outcomes enables: (i) better management decisions both at the level of the individual forest and across the nation as a whole; and (ii) enhances the possibilities of capturing more of the value of forest ecosystems, by helping to understand key factors that influence the provision of services that are not traded at present (e.g. new goods and services (provisioning) markets and payments for ecosystem services (PES) for regulating and supporting services).

Moreover, forestry management issues concern not only a choice between maintaining or enhancing the provision of all ecosystem services, but also the trade-offs that these entail in relation to the provision of individual ecosystem services (e.g. the types of facilities that can be provided for visitors). Explicit recognition of values generated by different services therefore enables a more transparent comparison of alternative outcomes in order to identify net benefits of particular actions or policies.

3. REVIEW OF EVIDENCE - VALUING ECOSYSTEM SERVICES

The review of evidence addresses each of the four study aims detailed in Section 1.2. It is presented in terms of the ‘tiered approach’ set out by TEEB (2010):

- **Recognising values - framework for assessment** (Section 3.1): the review is structured according to the ESA framework so that the value evidence is categorised in terms of different types of ecosystem service.
- **Demonstrating values - review of evidence** (Section 3.2): the coverage of the existing literature itself is necessarily ‘broad and shallow’ but this is sufficient given the aim of identifying gaps in the evidence base.
- **Capturing values - payments for ecosystem services** (Section 3.3): this combines both descriptions of potential mechanisms and some practical examples and considerations.

A summary of gaps in evidence and key challenges and uncertainties for the valuation of ecosystem services is provided in Section 4, along with recommendations for future economic research needs.

3.1 Recognising values - framework for assessment

The review of evidence is based on a classification of ecosystem services and a typology of forest characteristics. The purpose of the assessment framework is to aid the categorisation of available evidence in terms of ‘ecosystem service values’ and to ensure also that the key factors which influence the provision of ecosystem services from forests and woodlands are assessed, particularly with respect to the context-specific nature of economic values. While the purpose is to review economic evidence, scientific understanding of the ecological processes and functions of woodlands and forests is required to establish the context in which the evidence is presented.

3.1.1 *Classification of ecosystem services*

Table 3.1 presents the classification of ecosystem services adopted for the review of evidence. It is informed by the MEA (2005) and the UK NEA (see Watson and Albon, 2010; Bateman et al., 2011) and is adapted to forest ecological processes. This utilises the familiar provisioning, regulating and cultural services categorisation proposed by the MEA, which are underpinned by supporting services and biodiversity (Watson and Albon, 2010).

Table 3.1: Classification of final ecosystem services and goods	
<i>Final ecosystem service</i>	<i>Principal final goods</i>
Production of trees, standing vegetation and peat [P]	Timber and wood fuel Non-wood forest products (ornamental, craft/hobby resources)
Food - production of crops, plants, livestock, fish, etc. [P]	Non-wood forest products (wild food products), recreation (field sports)
Production of wild species diversity including microbes [P,R]	Genetic resources and bioprospecting Recreation and tourism, landscape and aesthetic amenity, ecological knowledge Non-use values
Regulation of climate [R]	Reduction of climate stress
Soil, air and water regulation [R] (Clean soil, clean air, clean water from purification processes, breakdown and detoxification of waste and production of water quantity)	Potable water and industrial use of water Pollution control, waste removal, waste degradation Physical and mental health Recreation
Regulation of hazards [R]	Avoidance of damage from natural hazards (e.g. flood protection, coastal protection, erosion protection)
Pest and disease regulation [R]	Avoidance of damage cost (e.g. to crop production)
Noise regulation [R]	Amenity value and avoidance of damage/mitigation costs
Pollination and seed dispersal, herbivory [P, C, S] (Production of wild species diversity including microbes)	Agricultural and horticultural products Recreation and tourism, landscape and aesthetic amenity, ecological knowledge Non-use values
Generation and maintenance of meaningful places; socially valued landscapes and waterscapes [C]	Recreation and tourism, landscape and aesthetic amenity, physical and mental health, ecological knowledge Non-use values

Notes: P = Provisioning services; R = Regulating services; C = Cultural services

Table 3.1 highlights that the production of final goods can be dependent on multiple final ecosystem services; for example recreation benefits are attributed to provisioning and regulating services as well as cultural services. Similarly, the final ecosystem services that are presented are dependent on multiple intermediate and primary services, although these are not shown. A further point to note is that woodland management decisions can be influenced by wider ecosystem service values than associated with forests. For example, the economic returns to the alternative uses of forest land (e.g. agriculture, palm oil plantations in tropics etc.) are the opportunity cost of retaining forests in many parts of the world, although less so in the UK. In the UK, trade-offs are likely to exist between types of forestry such as plantations, restoring plantations on ancient woodland sites or even open habitats.

3.1.2 Typology of forest characteristics

An explicit consideration of forest characteristics provides a means to consider how the scale and significance of various ecosystem services associated with woodlands can vary with their specific characteristics and location. In effect such a characterisation gives a practical way in which the

importance of ecosystem structure and processes in determining flows of ecosystem services can be accounted for (see Section 2.2.1). This is of significance both for the purposes of estimating the value of ecosystem services ('demonstrating value' in the terminology of TEEB), and also capturing the value of ecosystem services (e.g. through payments for ecosystem services).

Inevitably any typology will be broad-brush and lacking the greater precision and level of detail that locally specific assessments of ecosystem service provision would yield¹⁶. A requirement for a typology is therefore that it is 'multi-dimensional' drawing out the main influences on the type of ecosystem service provided and their scale and significance. The approach here builds on the analysis presented in eftec (2010b). This suggests that for woodlands the key indicators that differentiate the importance of different types of ecosystem service are:

- **Woodland ecology:** (i) broadleaved, mixed and yew woodland; (ii) predominantly coniferous woodland; and (iii) open habitat. This follows the approach used in the existing literature (see Hanley et al. 2002; Willis et al, 2003), matching with the UK BAP broad habitats classification, and to account for the increasing importance given to open habitats within woodland areas and more generally. Primarily ecosystem service values associated with provisioning services (e.g. timber) will differ across this categorisation.
- **Management practices:** (i) low intensity management; (ii) managed primarily for timber; and (iii) managed for multiple objectives. 'Low intensity management' applies to those woods and forests that are under little or no active forest management (predominately broadleaved and small woodlands). Other forests are managed primarily for timber production with less effort to enhance or protect other ecosystem values compared to (iii)¹⁷. Hence despite restricting this dimension to three categories, and lumping together a diverse range of objectives in the third category (where all FC managed land would appear), this split manages to capture the fundamental distinctions among forest types in Great Britain and the potential for a mix of provisioning, regulating and cultural services to be provided.
- **Proximity to users (residents and visitors):** (i) urban community woodland (within 500m of population centres); (ii) peri-urban woods and forests (up to 10km from population centres); and (iii) rural woods and forests. Overall 'proximity' is the indicator for the provision of certain cultural services, particularly recreation, but also potential regulating services (e.g. potential flood protection benefits).
- **Public access (specific to recreation):** (i) no public access; (ii) access encouraged with low level of facilities; and (iii) access encouraged with high level of facilities. 'Low' facilities are restricted to paths and minor interventions to facilitate access; 'high' facilities means at least provision of toilets and car parking (for which there may be a charge), and also covers more intensive provision at visitors centres and so on.
- **Biodiversity:** (i) 'higher' biodiversity importance; or (ii) 'lower' biodiversity importance¹⁸. 'Higher' importance includes woods and forests that represent at least one of the following

¹⁶ For example, a typology could go into substantial detail on specific kinds of recreation, access, infrastructure and use. Undoubtedly these nuances will influence the value of benefits associated with recreation, since these are highly context-specific. However in broader scope of understanding the provision of ecosystem services across all forests, woodland and individual or groups of trees, it is more useful to identify the key indicators that can differentiate the importance of different types of ecosystem service.

¹⁷ Recognising that these operations are subject to the criteria and standards for sustainable management of all woodlands and forests, as set out in the UK Forestry Standard.

¹⁸ It is also important to note that the classification is in no way intended to suggest that areas identified as 'lower' biodiversity value have little or no value. In particular, conifer plantations are important for certain

categories: UK BAP priority categories (including wet woodland, lowland wood-pasture and parks, upland oakwood, upland mixed ashwoods, native pine woodlands, lowland beech and yew woodland); ASNW (Ancient Semi-Natural Woodlands); restored PAWS (Plantations on Ancient Woodland Sites: ancient, but not semi-natural until restored); OSNW (Other Semi-Natural Woodlands: semi-natural, but not ancient); Areas designated as SPA/SAC or SSSI. The emphasis on *restored* PAWS reflects that intensive/non-native plantations on these ancient sites do not represent ‘high’ biodiversity values. Restored is taken to mean semi-natural or reasserting semi-natural; the ‘plantation’ categories can include beech woodland outside its natural range, and these would be considered as ‘lower’ biodiversity value unless one of the other categories applied.

For reference, the long list from which these characteristics are drawn from eftec (2010b) is presented in **Annex 2**.

3.1.3 Assessment of ecosystem service provision

Along with detailing the characteristics of forests that influence ecosystem service provision, it is useful also to attempt to draw assessments together on individual services and provide an illustration of how their provision may vary across broad woodland types (e.g. habitat classifications). Necessarily this is an indicative exercise which does not account for location and site specific factors, but it does provide further context for the valuation of ecosystem services by suggesting how the scale of their provision can differ across the range of woodland habitats found in Great Britain.

Using the classification of ecosystem services (set out in Table 3.1) **Table 3.3** identifies the potential level of ecosystem service provision by different types of woodland, using the JNCC Phase I Habitat Classification system. The *potential* level of provision is rated on the scale ‘low’, ‘medium’ or ‘high’. The colour coding of each cell characterises the *current* provision of service of each woodland type (dark green = highest level of potential provision already achieved; mid green = current level of provision is at a medium level; light green = current level of provision is at a low level). The distinction between ‘potential’ and ‘current’ provision is important to consider where woodland types, such as plantation forestry, which is currently aimed primarily at timber production, would likely require a change in management to deliver more fully the ecosystem service under assessment.

species of bird, fungi, invertebrates, and red squirrels, and that modern plantation management is more benign for biodiversity than older styles of management.

Table 3.3: Summary of ecosystem service provision by woodland habitats

Final Ecosystem service	Important factors in provision	Broadleaved		Coniferous		Mixed		Parkland/scattered trees		
		Semi-natural	Plant-ation	Semi-natural	Plant-ation	Semi-natural	Plant-ation	Broad-leaved	Conifer-ous	Mixed
Timber and fuel (Production of trees, standing vegetation and peat)	Width and height of tree, forest size and quality of the timber, species, soil and water quality, disease, management and provenance	Medium	Medium	Medium	High	Medium	Medium	Low	Low	Low
Food, ornamental, medicinal and craft/hobby resources (Food - production of crops, plants, livestock, fish, etc. & production of wild species diversity including microbes)	Soils, specific species requirement, management, ecological connectivity, species richness, pollution levels, climate, location, shading and disturbance	High	Medium	High	Medium	High	Medium	Medium	Medium	Medium
Genetic resources and bioprospecting (Production of wild species diversity including microbes)	Ecological connectivity, species richness etc (similar to food provisioning)	High	Medium	High	Medium	High	Medium	Medium	Medium	Medium
Regulation of climate	All of the factors that apply to the 'Timber and Fuel' provisioning services, previous habitat type, forest management and potential habitat type	High	Medium	High	High -	High	Medium	Medium	Medium	Medium
Regulation of hazards	Soil quality, neighbouring habitats, geology, geography, location, water flow regime, climate, weather patterns, forest size and shape, tree species and management	High	Medium	High	Medium	High	Medium	Low	Low	Low

Table 3.3: Summary of ecosystem service provision by woodland habitats

Final Ecosystem service	Important factors in provision	Broadleaved		Coniferous		Mixed		Parkland/scattered trees		
		Semi-natural	Plant-ation	Semi-natural	Plant-ation	Semi-natural	Plant-ation	Broad-leaved	Conifer-ous	Mixed
Soil, air and water regulation (purification processes, breakdown and detoxification of waste & production of water quantity)	Location and geography, forest management, climate, soil quality, biodiversity, health of trees and vegetation, geology, pollution levels, size of catchment and forest, leaf area, forest structure	High	Medium	High	Medium	High	Medium	Medium	medium	Medium
Pest and disease regulation (Production of wild species diversity including microbes)	Species richness and biodiversity, representation of functional types, presence of regulating species, disturbance, proximity to diseased/invaded habitats, climate	High	Medium	High	Medium	High	Medium	Low	Low	Low
Noise regulation (mentioned as an output of 'Production of trees, standing vegetation and peat')	Forest size and shape, canopy height, density of trees and foliage type	High	High	High	High	High	High	High	High	High
Pollination, seed dispersal and herbivory (Production of wild species diversity including microbes)	Biodiversity, habitat connectivity, climate, forest type, forest management, forest structure and disturbance	High	Medium	High	Medium	High	Medium	Medium	Medium	Medium
Cultural Services (Generation and maintenance of meaningful places; socially valued landscapes and waterscapes)	Forest age, forest structure, forest type, location, public access, forest management, availability of alternatives	High	High	High	High	High	High	High	High	High

Notes: The *potential* level of ecosystem service provision is indicated as 'low', 'medium' or 'high'. The current level of ecosystem service provision is indicated by green shading: dark green = high level of potential provision is already achieved; mid green = current level of provision is at a medium level; light green = current level of provision is at a low level.

The assessment of the potential and current level of ecosystem service provision provided by each woodland type is based on the review evidence (Section 3.2):

- Timber and fuel (production of trees, standing vegetation and peat): the provision of timber and fuel wood is in main dependent on species type and management. High potential provision is evident for actively managed plantations.
- Food, ornamental, medicinal and craft/hobby resources (food - production of crops, plants, livestock, fish, etc.) and genetic resources and bioprospecting (production of wild species diversity including microbes): the collection of foods such as berries and fungi are dependent on the diversity and abundance of such species within the woodland. Species associated with this ecosystem service include flowering plants, lichens, fungi and mosses. All of these species groups have strong associations with woodland types with a longer history of ecological connectivity. Plantations will have a decreased level of provision in most cases, but may also derive additional species of value from the land's former habitat type. Such gains would still not equate to the value of a woodland that has seen little interference since the 15th century. Conifer plantations are generally associated with fewer woodland species, and where such species are present, they are usually associated with a previous woodland type. Appropriate management and restoration of such habitat types hold the potential to increase the provision of this service.
- Regulation of climate: although managed and planted forests hold high potential for carbon sequestration, they are not currently managed for this purpose and the current level of provision is considered to be at a relatively low level, due to the regular removal of timber and subsequent damage to the soil. An increase in woodlands managed for carbon sequestration will significantly increase the provision of this service.
- Regulation of hazards: unmodified soil plays an important role in the regulation of hazards, thus making semi-natural woodland types of higher value for this service.
- Soil, air and water regulation (purification processes, breakdown and detoxification of waste and production of water quantity): the processes that govern these regulatory services are complex and reach beyond the woodland habitat. Healthy trees and soil are key to the regulation of such services, thus it has been highlighted that semi-natural woodland types provide a higher level of service. Although it is likely that research will demonstrate methods of increasing the provision of these services, it is unlikely that modified systems will be able to operate at the level of unmodified systems.
- Pest and disease regulation (production of wild species diversity including microbes): such regulation is strongly based around species diversity (see above for 'Food, ornamental, medicinal and craft/hobby resources'). Current provision of plantation based woodlands is identified as low to indicate that there is potential for an increase in provision.
- Noise regulation (mentioned as an output of 'production of trees, standing vegetation and peat'): an increase in the provision of this service is based around an increase in the number and size of woodlands/individual trees, rather than different types of woodland.
- Pollination, seed dispersal and herbivory (production of wild species diversity including microbes): such regulation is strongly based around species diversity (see above for 'Food, ornamental, medicinal and craft/hobby resources'). Current provision of plantation based woodlands is identified as low to indicate that there is potential for an increase in provision.

- Cultural Services (generation and maintenance of meaningful places; socially valued landscapes and waterscapes): different types of woodland can hold differing values for different people, but woodland in general has a high potential to provide a range of cultural services. There is potential to increase the cultural services provided by all woodland types, through management and a greater awareness of wooded areas.

In some cases - particularly cultural services - it is difficult to draw out significant differences between each of the habitat types at an aggregated level. This essentially serves to illustrate where woodland habitat and ecology are not the primary drivers of potential ecosystem service provision benefits, but rather the specifics of location, proximity to populations and the finer details of management are the key determinants (as discussed in Section 3.1.2)¹⁹. Beyond cultural services, however, it is possible to suggest some distinctions between habitat types. For example coniferous plantations are rated highly for the provision of timber, reflecting the productive management focus of these woodlands. In general semi-natural habitats are rated highly for non-timber wood products and the range of regulating services (climate, hazards, soil, air and water, noise, disease, and pollination). Again the realisation of the potential benefits associated with these services is crucially dependent on management practices. Also included within Table 3.3 are parkland and scattered trees. This highlights the potential benefits of urban trees, particularly in terms of climate and noise regulation.

3.2 Demonstrating values - review of evidence

Covering all forest types and all potential ecosystem services, the review of evidence is 'broad and shallow'. The review aims to: (i) categorise estimated values for the economic, social and environmental benefits produced by Great Britain's forests according to the ecosystem services framework; and (ii) identify gaps in the existing evidence base to help develop recommendations for future research priorities to demonstrate the ecosystem service value of woodlands across the UK.

The review builds on a previous survey of existing evidence by eftec (2010b)²⁰. It also draws on the synthesis of valuation evidence presented in CJC Consulting (2009), which reviewed the value of benefits associated with woodlands in the UK for the Woodland Trust, as well as outputs from the UK NEA including the chapters on 'Woodlands' (Quine et al., 2011), 'Economic Values from Ecosystems' (Abson et al., 2011) and 'Valuation of Ecosystem Services Provided by UK Woodlands' (Valatin and Starling, 2010). Research commissioned by the FC includes the major assessment of non-market benefits entitled the 'Social and Environmental Benefits of Forests' (SEBF) (Willis et al., 2003), as well as subsequent studies examining health (CJC Consulting, 2005) and recreation (Christie et al., 2005) benefits. A summary of the Willis et al. (2003) assessment is provided in **Box 3.1**.

¹⁹ In general semi-natural woodland (either broadleaved or coniferous) might be expected to have higher levels of cultural service provision than plantations; likewise scattered broadleaved trees that form a distinctive element of parkland landscapes. However plantation woodlands do provide access for many recreation activities, such as mountain biking and walking, and these can be preferred in comparison to scrubby and thorny native woodland types.

²⁰ In this earlier study the objective was to assess the social, economic and environmental contribution to social welfare of the public forest estate managed by Forestry Commission England. It presents an overall framework for appraising alternative future management scenarios for the public forest estate at the national level along with a set of case studies that apply the framework to different forest types (e.g. urban fringe, recreation-focussed, remote location and biodiversity objectives).

Box 3.1: The Social and Environmental Benefits of Forests (Willis et al., 2003)

The study 'Social and Environmental Benefits of Forests' (SEBF) was commissioned by the Forestry Commission to estimate the value of non-market benefits associated with open access (non-priced) landscape amenity, biodiversity, carbon sequestration, pollution absorption, water supply and quality, and protection of archaeological artefacts. The value of each of these benefits was examined by separate pieces of research which sought to estimate: (i) marginal values for changes in provision of benefits; and (ii) their total value across forests and woodlands in Great Britain.

Recreation (Scarpa, 2003)

The value of recreational visits was estimated via a combined approach, using the available recreation visit datasets (Scotland and Ireland), a value transfer function and visitor surveys (England and Wales). The visitor surveys included a contingent valuation (CV) question that sought WTP of visitors for access to the woodland for recreational purposes, rather than going without recreation in that woodland. Benefit estimates were in the region of £3 per visit (£1.66 in 2002 prices; based on the CV and value transfer function).

Landscape (Garrod, 2003)

The landscape element of the study estimated individuals' WTP for forested landscapes, seen either from home or during regular journeys to and from home. It explicitly sought to separate WTP for woodland views from open-access recreation and biodiversity that forests support. Values associated with six generic forest landscapes were examined, defined by two forest types (broadleaved and conifer) and each set within three landscape contexts (upland plateau, mountain, and rolling/hilly for coniferous forests; and mountain, rolling/hilly, and peri-urban for broadleaved forests). A choice experiment approach produced WTP estimates in the range of £200 - £500 per year for forest views from home, and £155 - £330 per household per year for forest views whilst travelling, depending on forest configurations and estimated models.

Biodiversity (Hanley et al., 2002)

The examination of biodiversity utilised previous analysis by Garrod and Willis (1997) on remote coniferous forests to generalise 'biodiversity values' across the rest of Great Britain. The research sought to: (i) estimate non-use biodiversity values for forest types; and (ii) estimate the (marginal) biodiversity value of additions to these forests, in terms of extending their area. WTP estimates for marginal increases in biodiversity were derived relative to values estimated for remote coniferous forests and were in the range £1-3 per household per year for a 12,000 hectare increase in forest, for upland conifer forests, upland native broadleaved woodland, upland new native broadleaved woodland, lowland conifer forest, lowland ancient semi-natural broadleaved wood, and lowland new broadleaved native woodland.

Carbon sequestration (Brainard et al., 2003)

The benefits of carbon sequestration were modelled through Sitka spruce, oak and beech yield class rotations, accounting for carbon changes in soil, the effect of thinning, and energy use to manage the forest. The analysis applied three different values for the social value of carbon to reflect global uncertainty about the cost of carbon in global warming damage estimates in the range £6 - £70 per tonne of carbon, based on Fankhauser (1994; 1995) and Clarkson and Deyes (2002).

Air pollution absorption (Powe et al., 2002)

The role of forests in improving air quality was assessed in terms of pollution absorption by two general tree types (deciduous and conifer). The pollutants considered were particulate matter (dust particles) and sulphur dioxide. The associated human health benefits of improvements in air quality were estimated by applying epidemiology information on the link between air pollution and deaths and hospital admissions for respiratory diseases. Values of preventable fatalities and hospital care were those adopted by the Department of Health; approximately £125,000 for each death avoided by 1 year due to PM₁₀ and SO₂ absorbed by trees, and £602 for an 11 day hospital stay avoided due to reduced

respiratory illness. However, the study only assessed the effects of air pollution absorption within 1 kilometre squares, and did not allow for absorption that could occur between them. The results therefore represented an under-estimate of the total impact that forests play in improving air quality through the absorption of airborne pollutants.

Water supply and quality (Willis, 2002)

The impact of forests and woodland on public water supply (i.e. water extracted for treatment; i.e. not the regulatory effect on water flows and quality) was assessed using hydrological models of the effect of woodland on rainfall interception and transpiration rates compared to grassland. The cost of this impact was estimated in terms of the marginal costs faced by water companies in abstracting potable water supplies. Based on available data, a cost of approximately £0.10 - £1.25 per m³ was applied where water was not available for abstraction for potable uses. However it was recognised that for most areas of Great Britain the marginal cost is zero, with the effect of woodland mitigated through the application of guidelines on woodland planting and conditions attached to forest certification.

Protection of archaeological artefacts (Macmillan, 2002)

The benefit of the protection service forests provide for archaeological remains was assessed via value transfer. Calculated values ranged from £0 to £247 per hectare depending on assumptions, but it is recognised that these estimates are subject to considerable uncertainty concerning the quantity of archaeological artefacts on forested land and the public's value of different quantities and types of archaeological artefacts.

The aggregate value of woodland

Willis et al. (2003) estimated the aggregate value of the non-market benefits provided by woodland in Great Britain to amount to approximately £1 billion in annual terms and £29 billion as a capitalised value, dominated by recreation and biodiversity values (totally almost 75% of benefits, with an equal split). These estimates were updated by the UK NEA to account for inflation:

- Recreation: £392 million per year (Willis et al.); £484 million per year (UK NEA, 2011)
- Biodiversity £386 million per year (Willis et al.); £476 million per year (UK NEA, 2011)
- Landscape: £150 million per year (Willis et al.); £185 million per year (UK NEA, 2011)
- Carbon sequestration: £94 million per year (Willis et al.); £115 million per year (UK NEA, 2011)
- Air pollution absorption: £0.4 million per year (Willis et al.); £0.5 million per year (UK NEA, 2011)

In Willis et al. air pollution absorption (health benefits) of woodland was found to be relatively insignificant (£0.4 million per year) because of the absence of significant population numbers in close proximity to areas of woodland. However, as previously stated, these values did not account for the full effects of air pollution absorption, as they analysed only very localised effects.

The summary of evidence is structured in terms of the classification of final services and goods presented in Table 3.1, under the heading of provisioning, regulating and cultural services. In practice the classification of final goods does not necessarily fit neatly under each of these headings (as indicated by Table 3.1), although it is relatively straightforward to attribute each good to the main final service type (e.g. recreation is covered under cultural services). Section 3.2.4 explicitly considers the valuation of biodiversity.

3.2.1 Provisioning services

Provisioning services are primarily associated with direct use values, and for goods that are traded in formal markets, market prices can be observed. Goods that are not directly sold in markets (e.g. wild foods products) will ordinarily have market equivalents although these will not

include the informal recreation and cultural aspects of wild food collection and hunting. These elements however can be treated under cultural services. The following are covered here:

- Timber;
- Wood fuel;
- Non-wood forest products; and
- Genetic resources and bioprospecting.

Timber

The provision of wood-based material for construction, other wood products and energy uses have historically been the most important provisioning services derived from forests in the UK. Much of the UK's current provision is satisfied by imports (FC, 2009). The wood processing sector provides an indication of the scale of the domestic market for unprocessed timber. Between 2003 and 2006 this was worth around £1.7 billion per year, rising to £2.1 billion in 2007 (Quine et al., 2011).

Coniferous forest is the main focus of timber production in the UK, but broadleaved woodland is also managed for timber. Oak woodland managed for timber is a significant long-term investment for a forester and will hold a much higher value per tree than many conifer species. However, the number of trees and the speed of growth of a conifer plantation allow more timber to be produced over time than in oak woodland.

The key factors determining the provision of timber include²¹:

- The choice of tree species - it is important that tree species which provide high timber/fuel yields are chosen. This is often based on the width and height of the tree trunk;
- The rate of growth;
- Slope, soil and water quality;
- Susceptibility to disease;
- Forest management;
- Location and access; and
- The ability of a species to grow adequately in the UK (as influenced by the climate) - this is important in relation to non-native crops.

As the primary market good harvested from woodlands, the main distinction is typically between softwoods and hardwoods. Softwood is harvested from coniferous trees, such as spruce, fir, pine and cedar. Hardwood is harvested from deciduous broadleaved trees. In Great Britain, examples include beech, oak and maple.

Timber generates direct consumptive use value, either in terms of an intermediate product (as an input to sawmill, wood-based panel and paper production processes) or as a fuel source (see below). As a market good, the ecosystem service value associated with timber can be inferred from market prices. In general domestic timber production accounts for less than 20% of annual consumption in the UK (Forestry Commission, 2010) hence observed prices can be reasonably assumed to reflect trends in global supply and demand for timber²².

²¹ Note that these are the environmental factors that determine the provision of timber. A host of market factors influence the supply and demand for timber (e.g. quality of domestic timber versus imports).

²² In general the market share of domestic softwood production is increasing. The product is of comparable quality to imports and competitively priced (Pers. comm., S. Goodall (CONFOR), August 2011).

Readily available Forestry Commission data²³ provide price indices for coniferous standing sales and softwood sawlogs²⁴. These prices represent supply and demand in two distinct intermediate product markets. In general the *standing sales* price can be assumed to provide a closer estimate of the ecosystem service value of timber production. In particular for standing sales the buyer is responsible for harvesting and hence the index does not reflect the physical capital and labour cost of harvesting. Sawlogs prices in contrast include the cost of harvesting.

Both indices are subject to short term fluctuations in prices - for example standing sales price index for Great Britain fell 30% in real terms in the year to March 2009, having risen 52% in the year to March 2008 - and it can be difficult to predict the future values of timber. In addition standing sales of timber from a specific site at a given point in time will be lumpy (i.e. a variable index) because of the lengthy harvesting cycle associated with timber.

Price data for hardwood are sparse and weaker compared to softwood data and the hardwood production in Great Britain is much lower (less than 0.1 million tonnes per year for the period 2006-10) than softwood (approximately 5 million tonnes per year for the same period) (Forestry Commission, 2010). The UK NEA (2011) compares intermittent Forestry Commission hardwood price data with a report conducted by Whiteman et al. (1991) and conclude that average prices for UK hardwood fell by at least a third in real terms in the two decades between 1989 and 2008.

A further indicator of the annual flow of 'ecosystem service value' for timber is identified in eftec (2010b) in terms of the value of the *standing stock*. Although these flows may be converted to financial returns infrequently, over a large enough area (e.g. a national level assessment) and a wide distribution of age and yield classes, revenue fluctuations will smooth out over time. However, data on standing stock values are not usually readily available even though values are reported in eftec (2010b) based on Forestry Commission public forest estate land use financial models. These are presented as annual values that could be realised from harvesting (e.g. the flow value).

Wood fuel

In Great Britain, wood fuel mainly represents an intermediate product that is processed from harvested timber. It is a renewable energy source that is primarily available in the form of wood chips, wood pellets and logs for local heat generation (i.e. in small scale businesses), small to medium combined heat and power, biomass electricity generation, and potentially large-scale generation and co-firing plants (Forestry Commission England, undated). Domestic wood burning stoves have become increasingly popular in recent years with 186,000 stoves sold in 2008 alone (Quine et al, 2011).

Current market price information is available from various sources²⁵ and timber price indices (i.e. standing sales) will reflect the variety of uses that it may be put to by processing industries (e.g. wood-panels, paper production, wood fuel). Standing sales or standing stock values for softwood timber will also encompass its use in terms of wood fuel²⁶. It is also possible that wood fuel will become a more important resource derived from broadleaved woodland in the future.

²³ See: <http://www.forestry.gov.uk/forestry/INFD-8ASDZ9>

²⁴ The term 'sawlogs' refers to the part of the tree stem that is processed at a sawmill. Other parts of the tree may be used as wood pulp or 'pulpwood' in paper production.

²⁵ See for example: <http://www.forestfuels.co.uk/fuel-prices.php>;
<http://www.englishwoodfuels.co.uk/fuel-price-comparisons/>

²⁶ Note that it will not encompass all production of biomass energy crops such as willow and poplar; i.e. short rotation coppice produced by agricultural enterprises.

Low carbon energy and construction material

In addition to its direct consumptive value, timber can also be viewed in terms of comparative low carbon benefits as a fuel or construction material. For example ECCM (2006) estimates that in Scotland there could be up to an 86% reduction in the GHG emissions associated with the embodied energy of building materials if timber internal and external structural elements and fittings are specified wherever possible, rather than current building materials.

Wood fuel is also expected to be an important factor in meeting the EU renewable energy target, which requires that 15% of all energy produced in the UK should come from renewable sources. The Renewable Energy Strategy anticipated that 30% of these renewable sources will be bio-energy. On this basis the value of wood fuel can also be considered in terms of the regulation of climate change impacts through displacement of conventional fossil fuel energy sources. The carbon intensity of the 'average grid mix' is 0.49 kgCO₂/kWh (Carbon Trust, 2005²⁷), whereas for wood fuel it can range from 0.354 to 0.349 kgCO₂/kWh for wood chips and pellets, respectively (Forestry Commission England, 2007).

DECC (2009) however stipulates that new renewable investments should be considered as displacing not conventional but rather other renewable sources, with changes in the level of renewable energy delivered valued using the marginal cost of delivering it from other renewable sources (approximately £118/MWh). This is consistent with the target-based approach that underlies the UK Government guidance for valuing GHG emissions (see Section 3.2.2). Specifically the UK has a commitment to meet certain levels of renewables, and the impact of producing renewable energy from woodland sources, is to reduce the need for renewables investments elsewhere. This implies that the value of wood fuel should not take account of the external costs of conventional energy use²⁸. As defined by the guidance, woodfuel in domestic use (as logs for heating) does not contribute to the UK renewable targets. However, in reality it is likely that it is replacing more carbon intensive energy sources, either by reducing demand for grid electricity or through reducing domestic use of coal or oil heating sources.

Non-wood forest products

Non-wood forest products (or non-timber forest products) encompass a variety of resources that can be obtained from woodlands. Food resources are provided to humans by the picking of 'wild foods' which include fungi and berries. Plants, forest debris, mosses and lichens can also be collected for various medicinal and craft/hobby purposes. All of these can be collected on both a commercial and non-commercial basis in the UK (FAO, 2010).

Trees and forest also provide cover for species including pheasants and partridge which are hunted in field sports. These also require more open habitat types to be associated with the woodland (for driving game out of cover).

The key factors determining the provision of non-wood forest products include:

- The requirements of the species being prospected - for example bramble is a common and widespread woodland species, making the picking of berries relatively simple where

²⁷ Note that this differs from 0.43 kg CO₂ per delivered kWh often quoted: "figure quoted here uses different data sources and covers a more recent time-period" (Carbon Trust, 2005)

²⁸ Where the use of wood fuel does not contribute towards the UK renewable targets - i.e. logs for domestic use - it would be appropriate to account for the impacts of displaced conventional energy here, although some of the possible impact will be absorbed by increase in service demand (i.e. heating a house/room more than would be the case without the log fire) so a simple energy-content calculation would not be strictly accurate.

woodland (of any type) is present; conversely, forests abundant and diverse in fungi, mosses and lichens are often associated with a long history of ecological connectivity, thus collection of such materials will likely focus around sites of higher conservation value;

- Soils;
- Tree species;
- Pollution levels;
- Climate;
- Location;
- Shading;
- Forest management; and
- Disturbance.

It should also be noted that activities associated with non-wood forest products can also have effects on other forest ecosystem services, particularly those which are the objective of conservation. For example field sports, and in particular game shooting, may induce a decline in invertebrate numbers due to predation by game species and a decline in herb-layer vegetation. Sympathetic management of game areas has also been shown to improve the conservation value of woodland for bird species (Draycott et al., 2008). Research into the effects of game releases on the biodiversity of woodlands is incomplete. However the UK NEA estimates that forest-reliant game shooting is estimated to contribute £640 million per annum to the UK economy, supporting 28,000 jobs (Quine et al., 2011).

Where non-wood forest products are commercially harvested and sold, market prices in principle can be observed. Without primary data collection from providers, distinguishing these products from mass-marketed agriculturally produced counterparts will likely be difficult in practice. However actual volumes of sales will be low in most cases and more generally observed market prices will likely provide reasonable proxies (notwithstanding some caveats about production, distribution and transportation costs, which should not be reflected in 'ecosystem service values' - see Section 2.2). In addition, products that are collected for non-commercial purposes could also be calculated via market proxies. However these may be better reflected in recreational and cultural values²⁹. Similarly foods arising from field sports are also valuable, but again, this may be better accounted for via the payments made for participation in these activities. An exception is game traded via game dealers, in which case market values could be considered.

Overall there is not a coherent base of evidence related to the non-wood forest products. However research for Scotland (Edwards et al., 2009) showed that the value of non-timber forest products (including mushrooms) was relatively minor (in the order of £1 million in terms of gross value added), and hence the lack of evidence likely reflects the relative insignificance of aggregate values associated with non-wood forest products. Moreover non-commercial use values are likely to be captured by values associated with recreation and cultural services.

Genetic resources and bioprospecting

As the MEA (2005) highlights it is difficult to assess which genes, species or ecosystems will become valuable for bioprospecting in the future. Essentially this reflects a key part of the option value associated with maintaining healthy woodland and forest ecosystems.

²⁹ As an illustration, recent reporting indicates that 18% - 24% of people in Scotland regularly access woodlands for products such as fruit, fungi or foliage for dyes or floristry (Edwards et al., 2009).

Genetic variation within native UK tree species is currently being studied by Forest Research³⁰, but in general the genetic resource of UK woodland is poor in comparison to tropical rainforests. However UK forests are important in a European context due to the UK's isolated geographical location and climate. The wet and humid climate provides conditions for 70% of all European moss and liverwort species, with Atlantic woodland in Scotland being a very important habitat for these species (Church et al., 2001).

The key factors determining the level of the provision of genetic resources include the following:

- The maintenance of natural woodland processes over a considerable period of time - woodlands that have maintained these processes since 1600 are classified as Ancient Woodland. It is important to consider that a key factor in the classification of Ancient Woodland is a lack of modification to the woodland soil bank (Rackham, 2006). For instance, trees may have been cleared from an Ancient Woodland a number of times, but the natural woodland has always been allowed to re-grow and the soil bank has never been converted to another land use.
- The amount of time that woodland has been isolated from surrounding pools of genetic resources - woodlands of islands, for example, may have established sub-species or novel genetics due to the amount of time that the species has been separated from the genetic pool of the archetype. Habitat fragmentation and isolation can be thought of as a human induced version of this process and should also be considered.

The UK NEA reports that there is very limited value evidence with respect to maintaining genetic diversity in UK, citing Defra analysis concerning the Millennium Seedbank (Abson et al., 2011). The aim of the seedbank is to collect the seeds from 24,000 species of plants, representing 10% of the world's dryland flora, and including seeds from the UK's entire native flora (therefore including all native woodland species). Similarly the UK NEA found only limited evidence with respect to bio-prospecting, reporting the potentially significant health treatment costs that can arise from plant based treatments for diseases. The example provided is in relation to Alzheimer's Disease (JNCC, 2011).

Valuation of genetic resources can also be considered from the perspective of conservation of biodiversity, as addressed in Section 3.2.4.

3.2.2 Regulating services

Regulating services are primarily associated with indirect use values. Typically these are non-market in nature. In contrast to provisioning services, the assessment and measurement of regulating services can be difficult, with implications for both estimating associated ecosystem service values and potentially capturing them. The following are covered in this Section:

- Reduction of climate stress (climate regulation);
- Soil, air and water regulation;
- Regulation of hazards (primarily flood protection);
- Pest and disease regulation;
- Noise regulation, and
- Pollination, seed dispersal and herbivory.

³⁰ See: <http://www.forestresearch.gov.uk/fr/INFD-65PBMH>

Forests and trees have also been shown to regulate surface temperatures in urban areas (Gill et al., 2007). A particular focus of the literature has been the benefits of urban trees and the range of regulating services (and indeed other ecosystem services) they can provide (**Box 3.2**).

Box 3.2: The benefits of urban trees

Sarajevs (2011) reviews a number of initiatives aimed at estimating the amenity value of street trees and urban woodlands. Popular trees found in urban areas include birch, horse chestnut, London plane and sycamore. The provision of trees within the urban environment, in parks and municipal forests, gardens, traffic islands and along pavements, can give rise to various benefits including aesthetic and recreational amenities, provision of shade and minimising of temperature fluctuations, carbon sequestration, improvements in local air quality, potential physical and mental health gains, habitats for wildlife and also the provision of non-wood forest products (for both human and animal populations). It is important to note, however, that trees may also have negative impacts on urban infrastructure (for example tree root damage to properties and utility networks). Hence, from an economic analysis perspective, it is the net benefits that are of interest.

In terms of valuing the benefits associated with urban trees, the existing literature contains a number of applications of the hedonic property pricing method. This method utilises the relationship between the demand for housing and the characteristics of properties, including the specific attributes of the local neighbourhood including the presence of trees and proximity to green spaces. Studies that examine the influence of urban trees on residential property prices include Anderson and Cordell (1988) (Athens, Georgia, USA), Thériault et al. (2002) (Quebec City), Mansfield et al. (2005), and Dimke (2008) (Cincinnati). Laverne and Winson-Geideman (2003) examine the effect of urban trees on rents for commercial property (specifically office buildings).

Other valuation methods have also been used. Zhang et al. (2007) estimate household willingness to pay for urban forestry programmes via a contingent valuation survey. Nowak (1993) and McPherson (2007) use the replacement cost method that is the basis of the ‘trunk formula method’ from the Council of Tree and Landscape Appraisers (CTLA). This assumes that benefits provided by a tree can be equated to the costs of replacing it. McPherson (2007) and McPherson and Simpson (2002) apply an approach that seeks to quantify the individual benefits of trees. This includes calculating and valuing energy savings from temperature mediation (via electricity bill savings), carbon sequestration (through emissions factors), air quality benefits (also emissions factors), reductions in storm water runoff (cost of retention/detention basins within the area), and aesthetics (hedonic pricing for residential properties).

For the purposes of planning, insurance, litigation and compensation there also exist a number of commonly used methods in the UK: (i) The ‘Helliwell Method for Amenity Valuation of Trees and Woodlands’ estimates the amenity value of trees; (ii) the CTLA ‘Guide for Plant Appraisals’ values tree stock as financial assets using replacement cost; and (iii) the ‘Capital Asset Value for Amenity Trees’ (CAVAT) also estimates the amenity value of trees, but it differs from the Helliwell Method in that it takes into account the size of the beneficiary population. While in general these represent useful tools for focused applications, the methods applied do not necessarily match well with the principles for valuing ecosystem service benefits as described in Section 3.2.

Reduction of climate stress (climate regulation)

Forests have a well established and important role in the regulation of (global) climate, through carbon sequestration and regulation of greenhouse gases (GHGs). Trees are able to sink a considerable amount of carbon, but it is estimated that some forest soils are capable of storing higher volumes of carbon (Moffat et al., 2010). The climate regulating role of forests is also

significant on a local and regional scale, particularly in terms of climate adaptation (see **Box 3.3**).

Carbon sequestration associated with woodlands can be broken down into four main areas (Brainard et al., 2006): (i) live wood, including all biomass in plantation trees; (ii) wood products (including harvest, storage, displacement factors, fossil fuels used in manufacturing and end-of-life impacts); (iii) leaf litter and debris; and (iv) soils which generally increase carbon storage when first afforested, eventually reaching new equilibrium, although peat soils are an exception and can release large volumes of carbon when afforested. With respect to soils there are also impacts on other GHGs (methane and nitrous oxide fluxes). For example recent research has shown that afforestation in such areas can reduce the water table and thus substantially reduce methane emissions (Morison et al., 2010).

There are a variety of factors that require consideration in the assessment of carbon sequestration including:

- All of the factors that apply to the timber provisioning service.
- Previous habitat type - this is important to consider where upland areas were converted into non-native conifer plantations in the 1950s. Many of these plantations were established on peat bogs, which store carbon far in excess of forests (Heijmans et al., 2008).
- Potential habitat type - it is possible that some forests will act as better carbon sinks if converted to a different habitat type (e.g. peat bog). This is dependent on the situation of individual forests and the carbon sinking properties of their associated habitat. While high productivity forests introduced to shallow peat soils will likely provide a net GHG sequestration over the forest cycle, deeper peat soils require much greater levels of modification and can increase GHG emissions (Forest Research, 2010). However, previous work has highlighted the problems surrounding characterising the depth of peat soils (Smith et al., 2009)
- Forest management - it is important that a forest identified for its value as a carbon sink is managed as such. A forest that is managed for biofuel can be a poor carbon sink if a regular yield is removed from the site to be converted to energy. In practice an assessment is needed that establishes the net effect, balancing potential carbon sequestration/emissions to fuel sources that are substituted by biofuel.

Trade-offs with other ecosystem services may also occur. For instance the planting of conifer species to maximise carbon sequestration will likely not provide the additional ecosystems services that a mixed or broadleaved woodland can provide (e.g. with respect to biodiversity). Again though, much depends on local management actions.

The total carbon in UK woods and forests increased from 1990 to 2005 and the total stock is projected to continue to increase to 893 million tonnes of carbon by 2010. The carbon in forest soils accounts for most (around 80%) of total forest carbon, and most of the increase in the total figures for UK woods and forests is due to change in land-use: existing soil carbon stocks being counted as wood/forest carbon when the land is converted to wood/forest. In climate change reporting, removals to forestland, also called the 'forest sink', measures the net annual accumulation of carbon in woods and forests by woody biomass, soils and litter. The annual rate is reported to have peaked in 2004 at 16 million tonnes CO₂ in total, of which 12 million tonnes of CO₂ was in living biomass, and is expected to fall steadily to 2020. Under the Kyoto protocol, additional woodland planted since 1990 contributes to the UK's carbon dioxide emissions target. This will increase as woodland continues to be planted (Forestry Commission, 2009).

Box 3.3: Woodlands and climate adaptation

Read et al. (2009) provide an overview of the role that woodlands play in helping society adapt to a changing climate. Over the coming century, average global temperatures are expected to continue to rise, increasing the frequency and severity of heat waves. This impact is exacerbated in urban areas by the urban heat island effect. These higher temperatures are also expected to result in changes to the hydrological cycle: water shortages in drier summers will likely be accompanied by higher flood risks in wetter winters.

Woodlands can provide areas of shelter during heat waves. During the 2003 heat wave in Southern and Central Europe, which is estimated to have caused around 35,000 excess deaths, maximum mean temperatures in Switzerland were found to be significantly lower under woodland canopies than their open-site counterparts. This impact was most pronounced in broadleaved and mixed forests, in which the difference was as great as 5.2°C. In order to be most effective, woodland cover is best targeted where people (especially those most vulnerable to high temperatures) live and gather (such as town centres), and where there is currently a lack of woodland cover.

Woodlands also contribute to alleviating flood risks. As described in greater detail in Section 3.2.2, woodlands can help to reduce surface run-off in small scale developments in urban areas by intercepting rainfall, and in larger scale developments in rural areas as part of a wider project remit.

Source of information:

Read et al. (2009) An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change.

Forest carbon accounting faces some uncertainties with regards to both current and future scenarios. Relationships between carbon sequestration and tree species, growth rate, thinning, and rotation length are known reasonably well, but there is uncertainty about changes in the carbon content of soils between agriculture and forestry, and about the fate over time of carbon locked-up in timber products. Other greenhouse gas fluxes may offset the carbon benefits, and should in principle be considered, however these may be site specific (depending for example on underlying soils). Wood and timber products harvested from woodlands also make a contribution to climate change mitigation through substituting for fossil fuels both directly (in the form of wood fuel as discussed above) and indirectly by replacing energy intensive materials such as concrete and steel.

Carbon storage in vegetation or soils is however reversible, although it can be argued that this does not detract from the value at present (future emissions from the land would need to be accounted for separately). Practically, though, the lack of definitive permanence of carbon sequestration in vegetation or soils influences its value as the risk of its release in the future is insured against. This acts as an impediment to including the sequestration of carbon in forests in the EU emissions trading scheme (ETS), and temporary credits have been adopted instead (Valatin, 2011).

Previous research for the FC has examined the value of carbon sequestration benefits provided by woodlands, as part of the Social and Environmental Benefits of Forest research study (Box 3.1). Brainard et al. (2003) calculated net carbon sequestration under woodland and combined estimates of value per tonne of carbon sequestered, to derive a carbon sequestration value for woodland in GB. The analysis sought to control for spatial variation in carbon sequestration due to woodland coverage, structure (e.g. broadleaves or conifer), tree growth, and soil conditions. Sitka spruce, beech and oak were used to represent the general categories of broadleaved and coniferous trees for carbon stored in live wood. Soil sequestration was differentiated by soil type

(peat and non-peat), thickness of soil, and elevation (upland or lowland). Values per tonne of carbon sequestration were sourced from available literature - Fankhauser (1994; 1995) and Clarkson and Deyes (2002).

More recently Read et al. (2009) provide estimates of carbon sequestration rates highlighting that the total flow of carbon from the atmosphere to forests is dependent on both the size of the woodland cover and the type of woodland. In England total sequestration is approximately 0.89 MtC per year, while in Scotland it is 2.66 MtC per year. The significantly higher flow rate in Scotland stems from the greater proportion of fast-growing conifers in comparison to England. Despite similar total levels of woodland cover (1.3 million hectares in England; 1.4 million ha in Scotland), 78% of Scotland's woodland are conifers, while this is just 32% in England (see Table 2.1).

UK Government guidance for valuing GHG emissions (DECC, 2010) establishes that they are a commodity that can be distinguished by whether they originate from the traded or non-traded sector. Traded emissions refer to those from sectors covered by the EU Emissions Trading System (ETS) (electricity, coal and gas energy generation). Non-traded emissions refer to all other sectors currently outside the EU ETS (e.g. transport, biomass and land-use change) and include forestry. Values for traded and non-traded emissions are based on estimates of the abatement costs that need to be incurred to meet specific emissions reduction targets (DECC, 2009) (see also Section 3.2.5). In the short term relevant targets from emissions reductions are specified by the Kyoto Protocol (GHG emissions 12.5% below 1990 levels in the period 2008-12) and EU Climate and Energy Package (the EU ETS cap for the traded sector and 16% reduction from 2005 levels by 2020 in the non-traded sector; in total these amount to a 34% reduction on 1990 levels for UK GHG emissions).

The traded and non-traded values differ until 2030, from when it is assumed that a global carbon market is in place with a single price. The relevant prices for the forestry sector are non-traded and rise from £50/tCO₂e (range £25-£70) in 2008 to £70/tCO₂e (range £35-£105) in 2030, then to £200/tCO₂e (range £100-£300) by 2050.

Soil, air and water regulation

Forests are an integral part of the cycling processes that govern the soil, air and water regulation services.

Soil regulation

Soil quality is defined by the soil's capacity for water retention, carbon sequestration, plant productivity and waste remediation (Schoenholtz, 2000). The key factors determining the level of this service include:

- Pollution levels;
- Compaction;
- Soil/land modification;
- Soil organic matter content (including living bacteria and fungi) - the relationship between soil biodiversity and ecosystem function is incomplete (SEPA, 2001);
- Soil structure; and
- Soil type.

It is possible for certain soil attributes to be artificially increased at the expense of other attributes. For example, tree survival, growth and stability can be increased through soil

cultivation; however this process may cause erosion and nutrient loss (Vangelova et al., 2006). High soil quality is often associated with limited modification.

The UK NEA (Quine et al., 2011) suggest a number of benefits associated with woodlands and soil quality, including a role in stabilising contaminated brownfield land and preventing exposure to pollutants, particularly in terms of human health. Similarly soil protection functions of woodlands can prevent soil erosion and slope failure - **Box 3.4** provides a particular example of how afforestation has been undertaken to achieve local soil stabilisation - and also reduce exposure to chemicals and pesticides and the likelihood of soil compaction compared to agriculture. On this basis a variety of economic values can be generated in terms of avoided damage costs, avoided health impacts, and so on (depending on the nature of beneficiary populations). Empirical evidence however is lacking.

Box 3.4: Regulating functions of woodlands - soil stabilisation

Culbin, Scotland provides an example of the longstanding recognition of the role of woodlands and trees in regulating local environmental conditions and the beneficial effect this has on adjacent land uses. At one time the largest area of open sand dune in Great Britain, it was stabilised by a process of conifer afforestation beginning when the Forestry Commission acquired the land in 1922, and continuing until 1963. Initially, this afforestation was problematic, with sand burying the seedling trees or the wind blowing them away. Progress was only made after branches from neighbouring forests were used to thatch the dunes; this protection released small quantities of nutrients and beneficial fungi into the soil, and allowed the trees to develop. The original impetus to stabilise the sands was driven by a belief that the mobile dunes had engulfed fertile and residential land; however, given that the prevailing wind is from the east, this belief may not have been true.

As well as the stabilisation of the mobile sands, Culbin provides multiple ecosystem services including carbon sequestration, biodiversity, timber production, recreation and historical/cultural services. The planted trees and other flora sequester carbon from the atmosphere at a rate of 3 tonnes of carbon per hectare per year (averaged over a full commercial rotation). With an area of around 3,600 hectares, this is equivalent to a sequestration rate of about 10,800 tonnes of carbon per year. Timber production is around 12,000 cubic metres annually. The site also provides a habitat for a diverse number of species and is listed as a SSSI. In addition, the sands provide habitat for a multitude of bird species which visit or stay at Culbin over different seasons of the year. A waymarked route and several other paths for walking are also provided, along with birdwatching and horse riding. Culbin's relatively recent history with the encroachment of the sands and the subsequent planting of trees to keep back the sands also provide historical and cultural significance, and this is supported by Culbin's longer human history which spans back to nomadic hunter gatherers over 10,000 years ago.

Sources of information

Forestry Commission (2003), 'Forests, Carbon and Climate Change: the UK Contribution Information Note'.
Forestry Commission (2005), 'Stern Review on Economics of Climate Change', response from the Forestry Commission.

Box 3.5 provides an example of how forestry and woodland planting can contribute to wider objectives, including waste management, land remediation and soil improvement.

Box 3.5: Woodlands from waste

The Woodlands from Waste project is a partnership between Global Renewables (a waste treatment company), Lancashire County Council and Blackpool Council, which aims to remediate brownfield land by employing composted material to improve soils and create new woodland areas. The project has five specific objectives:

1. To increase woodland cover by approximately 10% (1,200ha) in Lancashire by 2032. This corresponds to planting approximately 2.5m new trees.
2. To reduce CO₂ emissions from Lancashire's waste network by an average saving of 16,000 tonnes each year at 2020. This is worth approximately £1m per year using current DECC guidance for valuing carbon emissions.
3. To recover the maximum resource (100% of the residual organic component, 'OGM') from municipal waste after 2015.
4. To minimise the disposal of municipal waste to landfill, resulting in diversion of 100,000 tonnes of OGM away from landfill after 2015, and the overall diversion of 88% of municipal waste away from landfill by 2020.
5. To regenerate and remediate marginal land by establishing a minimum of 10 hectares per year of new woodland on marginal land.

What differentiates this project is the integration between the woodland and waste sectors, and the complementary nature of the objectives. Specifically, by diverting OGM from landfill there is a landfill tax saving which is used to fund the woodland planting. Furthermore, reducing the amount of waste to landfill reduces methane emissions, which is additional to the carbon sequestration benefits of creating new woodland. There are also benefits that arise from the creation of new woodland, to include visual amenity, particularly through urban tree planting in Blackpool, the provision of educational and potential recreation opportunities to the public, and helping to contribute to biodiversity conservation.

The objectives are also particularly well targeted to the needs of the Lancashire area. At present, woodland cover in the county is approximately 5%, in comparison to the UK average of 13%. The industrial past of the county has left a legacy of derelict, degraded and underused land, which this project aims to address.

Source of information:

Woodlands from Waste Briefing Note (Pers. Comm. P.Snowdon (Forestry Commission), July 2011).

Air quality

A wide range of chemical and particulate pollutants in the air have negative impacts on ecosystems and human health. Woodlands play a role in regulating air pollution, both via the direct absorption of pollutants and their role in producing oxygen, which reduces the concentration of pollutants in the air. The key factors determining the level of air quality regulation include:

- Leaf area in relation to ground cover (Givoni, 1991);
- Soil quality and compaction;
- Pollution levels;
- Disease and other stress related factors;
- Type of forest (broadleaved or conifer) - evidence shows that broadleaf forests are capable of absorbing more pollution, but conifers are able to absorb pollutants over longer periods of the day (Broadmeadow and Freer-Smith 1996);

- Tree species;
- Biodiversity;
- Location and structure of the woodland; and
- Proximity to high concentrations of pollutants - it should be noted that although close proximity to high concentrations of pollutants can maximise pollutant uptake by trees, it can also cause considerable harm to the health of the trees.

The Social and Environmental Benefits of Forest research study (Box 3.1) provides the main reference with respect to valuing the air quality regulation role of forests. Willis et al. (2003) focus on the human health benefits that can be attributed to improvements in air quality. A number of methods can be used to estimate the value of avoided illness or death from air pollution, and most rely on a dose-response relationship. This expresses a relationship between pollution levels and statistical health outcomes in a population; i.e. estimation of the impact of woodlands on pollution levels, which can then be related to a change in health outcomes. This can then be valued in monetary terms. Willis et al. (2003) used a value of approximately £125,000 for each death delayed by 1 year due to particulates (PM₁₀) and (SO₂) absorbed by trees, and approximately £600 for an 11 day hospital stay avoided due to reduced respiratory illness. More recent valuation evidence for mortality and morbidity impacts from air pollution is provided in the supporting analysis for the Defra Air Quality Strategy (IGCB, 2007) and the Clean Air for Europe programme (CAFE, 2005).

The total value of air pollution regulation by woods and forests reported in Willis et al. is very low compared to other services (Box 3.1) but this may be largely because the research focused on the effects of tree absorption within 1km² areas, and also focused on woodland areas of 2 hectares or more (therefore omitting the impact of smaller woods often in urban areas). A lack of information on trees' absorption of pollution on a wider scale meant that assessment of the impacts of pollution absorption beyond this very local scale was not possible.

Other evidence suggests that trees can also have negative impacts upon air quality by releasing biogenic volatile organic compounds (BVOC) (Donovan et al., 2005). These compounds are, once released into the air, converted into tropospheric ozone and peroxyacetyl nitrate (PAN). Efforts have been made to rank tree species in order to identify those with a net air quality benefit and those which can under some circumstances reduce air quality³¹.

Water regulation

Although water supply can be regarded as a provisioning service, the role of woodlands and forests is more indirect (in terms of purification and retention) such that they contribute to regulating services that support water supply downstream in catchments. In particular hydrological processes are directly impacted by forests as water flows through the landscape, principally by interception, evapotranspiration, and infiltration. Overall forests can have positive and negative influences on water provision; for example forests can intercept pollutants and remove silt from flowing water, but they can also reduce the quantity of water available, or acidify water supplies (Brauman et al., 2007). The key factors determining water regulation service include:

- Location and geography;
- Forest management;

³¹ For example Donovan et al., (2005) report that the species with the greatest potential to improve air quality are pine, larch and silver birch. Species (in large numbers) that may decrease air quality are oaks, willows and poplars.

- Climate;
- Soil quality;
- Biodiversity;
- Health of trees and vegetation;
- Geology;
- Pollution levels, and
- The relative size of the forest in comparison to the size of the water catchment.

A thorough understanding of a forest's role in water cycling and purification can be hindered by the multiple processes that occur across whole catchments. Overall much ecological and hydrological literature exists on the effects of forest conversion on local water supplies (MEA, 2005), where removal of forest cover from a watershed can result in important hydrological changes, resulting in decreased interception of rainfall by the forest canopy, decreased evapotranspiration, decreased rainfall interception by surface litter, and increased runoff volumes (Stednick, 1996).

In terms of the provision of final goods, forests influence particle load and timing of runoff, impacting on downstream catchments in terms of water quality and quantity, which can in turn impact on drinking water and on water for irrigation and industry as well as recreational use of water courses. Nisbet et al. (2011) highlight the role that woodland areas, particularly riparian and floodplain, can play in reducing diffuse pollution by trapping and retaining nutrients and sediment in polluted run-off from adjacent agricultural land. They can also act to moderate stream temperatures, which can protect fish populations from thermal stress. During periods of low precipitation, however, forests can reduce runoff to the point where a negative value due to low flow has been suggested for some areas of South West England (Willis, 2002) and Ireland (Brander et al., 2009), but Willis (2002) also notes that water companies perceive little impact of existing forestry on water supply costs.

The principle assessment of the value of water regulation effects of forest is provided by the Social and Environmental Benefits of Forest research study. This focuses on the decrease in water availability for public supply due to forests. Willis et al. (2003) use a cost of up to £1.24 per m³ where water is lost to abstraction for potable uses, depending on the region, but for most areas the marginal cost is zero. In practice 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. However there may be scenarios under which these costs could be significant. For example Willis (2002) argues that forestry and land-management decisions are long-term and that the value/cost of the water supply service impact can be estimated via the long run marginal costs (LRMC) of water supply in the area. These are estimates for the total cost of abstracting the next cubic metre (m³) of water, including any capital investment costs. Estimates of LRMC are available from water companies via Ofwat (Willis, 2002).

When assessing water regulation effects, local factors are clearly important. For example if the area under assessment drains into a hydro-electric dam, then there may be a need to assess the opportunity cost of reduced flows (renewable electricity generation foregone, and associated increase in conventional energy and emissions) and any impacts on the running costs or expected lifetime of the dam (for example, associated with reduced sediment loads). In principle this can apply also to hydro-power potential: some management options may facilitate hydro-power and others preclude it. This would need to be taken into account in the definition of the environmental baseline and the options.

In principle, reduced water availability for irrigation could reduce agricultural values. However, Willis (2002) notes that, because of subsidies, the marginal social cost of agricultural production exceeds its marginal value to society, so the cost of reduced irrigation water is likely to be low at the margin.

Regulation of hazards (primarily flood protection)

Forests play an important role in the control of soil erosion and water flow that supports flood and storm protection, primarily through water storage capacity and risks of excessive runoff in a river catchment which influences the frequency, severity and/or control costs for flooding downstream. The key factors determining the provision of hazard protection include:

- Soil quality - land conversion and unsympathetic forest management can diminish the condition and quality of forest soils. Some unmodified soils have a large capacity to store water, facilitate the transfer of groundwater and to prevent or reduce flooding (MEA, 2005). The capacity of soil to hold water is dependent on soil texture and structure;
- Neighbouring habitats, such as wetlands and meadows are also important to consider as part of a hazard regulation network;
- Geology;
- Geography;
- Location (altitude);
- Water flow regime;
- Climate;
- Weather patterns;
- Forest size and shape;
- Tree species; and
- Forest management.

Largely there is little empirical evidence that links the potential flood protection role of forests to economic valuation evidence, although Broadmeadow and Nisbet (2010) examine the role of afforestation in reducing the risk of flooding in Cockermouth and Keswick from the River Darent, and also in Yorkshire, where there are planting trials at locations such as Pickering (see **Box 3.6**) and Ripon to mitigate flood risks.

In practice valuation can be carried out through estimating the expected damage costs avoided plus any change in flood defence expenditures. This approach is consistent with current guidance for appraising flood and coastal erosion risk management schemes (Environment Agency, 2010). Values could also be estimated through willingness to pay to reduce flood risks. Care is needed to avoid double counting if mixing these approaches.

Overall, in order to assess values for changes in the provision of flood protection, a clear link between forestry and land management actions and downstream flood risks is needed. Data availability is a significant issue, but conceptually the economic value of flood risk reduction can be split into two main components: (i) the impact on flood risk management expenditures arising from changes in flow and risks; and (ii) the residual risk of flooding and changes in associated damage costs. Both primarily represent resource costs and a well-established valuation methodology is set out in the Flood Hazard Research Centre Multi-coloured Manual (Penning-Rowsell et al., 2005) based on market values, which is consistent with overall Environment Agency (2010) appraisal guidance. The key issue is that flood protection benefits are highly location-specific and dependent on the level of risk and scale of the potential beneficiary population.

Forests can also play an important part in regulating fires. The MEA (2005) identifies the role of forests in fire regulation as ‘reducing accumulations of wood fuel’. Forest fires are a natural process but are considered as a hazard in their own right. Tree species, the water holding capacity of soil, climate and management are important factors in the regulation of fire hazards.

Box 3.6: Regulation of hazards - flood risk management

The potential for woodlands to regulate flood risk has been examined in the ‘Slowing the Flow’ project, Pickering, North Yorkshire. The town has been subject to four floods since 1999, with the most recent in 2007 causing a total of £7m of damage to residential and commercial properties. Woodland creation can reduce downstream flood risk primarily through slowing down flood flows and enhancing flood storage, and also by reducing sediment delivery, riverbank erosion and siltation.

The assessment considered the effects of creation of 85 hectares of woodland (50 hectares riparian, 30 hectares floodplain and 5 hectares on farmland) and the construction of 150 large woody debris (LWD) dams (which raise upstream water levels, increasing potential flood storage) as an alternative to physical capital investments (i.e. flood walls). Wider benefits would also be provided, including habitat creation, climate regulation and erosion regulation.

Scheme benefits were estimated to be in region of £1.6m to £4.5m for habitat creation and £0.9m to £5.5m for climate regulation (present value over 100 years). This compares to flood protection benefits estimated to be between £0.09m and £0.3m. The net benefit of the scheme (including costs of woodland establishment and opportunity costs in terms of agricultural production) was estimated to be between £0.8m and £9.6m in present value terms, with an estimated annual benefit of £0.2m.

While the scheme is assessed to have a marginally positive net present value, it is noted that the scale of woodland creation required (85 hectares) may not be feasible in practice. Despite approximately 400 hectares of land being potentially available land for planting riparian woodland, only 49 to 144 ha was predicted to have a beneficial impact on flood flows in Pickering. Further to this, many of the beneficial sites were to be found within designated areas (SSSI, Scheduled Monuments) and were not considered available for public interest reasons. As a result new planting was deemed acceptable at only 4.1 ha of riparian woodland (in comparison to the 50 ha target). Overall, the Slowing the Flow project has succeeded in raising awareness of the role of woodland in providing flood risk management, although its full scale implementation has not been possible. More generally it is suggested that stronger financial incentives are required to encourage landowners to switch land use to that of woodland.

Sources of information:

Defra (2011), Project RMP5455: Slowing the Flow at Pickering

Forest Research (2011), Woodland for Water: Woodland measures for meeting Water Framework Directive objectives.

Pest and disease regulation

The regulation of pests and diseases in forests depends on a number of biotic (e.g. predators, hosts and competitors), abiotic (e.g. climate) and also socio-economic factors (e.g. policy and management). A prevalent theory is that ecosystems with higher levels of biodiversity are less susceptible to disease and invasion. It is likely that certain attributes belonging to the resident species in an ecosystem determine the system’s resistance to invasion and disease (MEA, 2005). Forests with higher species richness are more likely to include species with such traits. The maintenance of native species communities in forests is theorised to diminish the likelihood of invasion and disease. It is also theorised that the efficient use of resources within ecosystems

with high levels of biodiversity can limit the availability of resources for utilisation by invasive species.

The key factors determining the level of this service include:

- Species richness and biodiversity;
- Representation of functional types (an alternative classification system of vegetation that categorises form and function of plants, useful when considering available substitute species);
- The presence of species with key attributes that limit invasion and disease;
- Disturbance - a forest's previous history of invasion and disease is also important in this regard;
- Proximity to diseased and invaded habitats; and
- Climate.

It is also important to consider the role of forests as vectors of disease and invasion. An example is the positive correlation between the occurrences of European badgers carrying Bovine tuberculosis in agricultural areas and the presence of forest based habitat (Woodroffe et al., 2006).

Conceptually the pest and disease regulation role of forests and woodlands can give rise to economic values in terms of avoided damage costs (e.g. to agricultural and horticultural enterprises). However empirical evidence to this effect is lacking.

Noise Regulation

Forests are able to absorb and reflect sound and are often utilised in mitigating the effects of noise pollution. The key factors determining the level of this service include:

- Forest area and shape;
- Tree/canopy height;
- Density of trees; and
- Foliage type.

Woodland can have mitigating effects on the impacts on noise in two ways. First, trees can be planted to attenuate ambient noise. For example Coder (1996) suggests that 7dB of noise reduction can be achieved for every 33m of forest, through its role in reflecting and absorbing sound energy, while Dwyer et al. (1992) demonstrate apparent loudness reduced by 50% by wide belts of trees and soft ground. Cook and van Haverbeke (1974) illustrated that landform combined with tree cover is more effective at attenuating ambient noise than either by themselves. Woodland planting has been found to be most effective at reducing high frequency noises; for instance a belt of planting 7.5m to 15m wide can reduce high frequency noises by 10-20dB. However planting has been found to have little to no benefit in reducing noises in the mid frequency band, which for example traffic noise can be a dominant component of Kotzen and English (1999).

The second way in which trees can mitigate the impact of noise is through a psychological effect. Coder (1996) discuss how screen plantings in excess of 2m in height, which act to eliminate visual contact with the source of the noise, psychologically reduce the irritating effect of the noise. This is despite the measured decibel level not experiencing as large a reduction. Trees also produce 'white noise', or background noise, such as the noise of the leaves and branches in the

wind, and other associated natural sounds, which act to mask other man-made noise sources, (that may be considered to be more irritating). Abson et al. (2011) also note that noise mitigation can lead to human health benefits, as demonstrated in IGCB(N) (2010).

Overall it is apparent that notable benefits in terms of noise regulation could be associated with urban trees and substantial resident beneficiary populations. However the valuation of the amenity value of nature undertaken for the UK NEA (using the hedonic property pricing method) does not explicitly specify noise within the model. Nevertheless, general relationships are estimated with respect to greenspace and land cover share within 1km square (including coniferous and broadleaved woodlands) and it would be reasonable to assume that noise may have an effect on property prices as measured through these (Gibbons et al., 2011).

Pollination, seed dispersal and herbivory

It is possible to include herbivory³² as a supporting ecosystem service or in amalgamation with other final services. However, herbivory can stimulate plant biomass production, nutrient cycling and also the ecological stability of forests (e.g. regulating forest fires) (MEA, 2005) and can be considered as a regulating service in its own right.

Herbivory is also associated with negative impacts on plant performance (including yield, reproduction and survival). Such impacts are very important in the UK context due to the increase in deer herbivory impacts on forest structure, diversity and regeneration (Rackham 2006). Many types of woodland are unable to generate new growth because of heavy grazing by deer. Damage to existing trees and significant damage to herb-layer flowering plant communities is also reported where deer populations have increased in recent years, which can have significant impacts on the provision of ecosystem services.

Forests act as reservoirs of species that perform pollination and seed dispersal processes, both within the forest (Devoto et al., 2011) and the wider environment; which support various ecological services (including food provision). Such processes are also strongly linked to a forest's ability to produce various ecosystem services (such as resistance to disease and invasion).

The key factors determining the level of this service include:

- Biodiversity - the biodiversity of a forest is important to its ability to provide a range of pollinators and seed dispersers for the local and wider environment. Consequently the factors that influence levels of biodiversity apply to these services, such as climate change and habitat modification;
- Habitat connectivity;
- Climate;
- Forest type;
- Forest management;
- Forest structure; and
- Disturbance.

Valuation evidence with respect to pollination and seed dispersal is considered in Section 3.2.4 in relation to biodiversity. With respect to the economic value of herbivory could potentially be evidenced in terms of damage cost to provisioning services (e.g. non-wood forest products,

³² Herbivory is an animal-plant interaction where an animal feeds on a plant. Plants are primary producers of energy and produce organic material. Herbivores (animals that eat plants) transfer and convert the energy locked within plants and make it accessible to a variety of other plants and animals in the ecosystem (e.g. animals that predate herbivores or insects and fungi that utilise dung etc.).

agriculture, horticulture, etc.), however no UK evidence has been identified. Benefits are also relevant with respect to hunting, but these are captured under recreational benefits.

3.2.3 Cultural services

Cultural services are associated with a mix of value types, including both consumptive (recreational hunting) and non-consumptive (informal recreation, landscape amenity) direct use values, as well as potential non-use values associated with preservation of biodiversity and cultural and historical associations. The following are covered in this Section:

- Recreation;
- Landscape and aesthetic amenity;
- Physical and mental health;
- Ecological knowledge; and
- Non-use values.

Many of these benefits are non-market and generally care is required to avoid double-counting particularly in terms of non-material benefits (e.g. separating a general preference for aesthetic enjoyment of the natural environment and landscape from historic and cultural values, and motivations for their preservation). The following factors are important determinants of cultural services (Willis et al., 2003):

- Forest and individual tree age;
- Forest structure (e.g. open and closed/diverse or uniform);
- Forest type (broadleaved or conifer);
- Location;
- Public access and facilities;
- Forest management; and
- Availability of alternatives (substitutes).

Recreation

Overall outdoor recreation covers a very wide range of human use and enjoyment of the natural environment, including general outdoor activities such as walking, bike rides, observing nature, picnicking, using viewpoints and otherwise simply spending time outdoors, and also more specific and focused activities such as rock-climbing, angling, canoeing, mountain-biking and so on. There are estimated to be 250-300 million day visits per year to UK forests (Quine et al., 2011). Visits need not involve long journeys or lengthy periods of activity, and can occur near the home on a regular basis, as well as less frequent day trips or holiday time spent outdoors. Around 55% of the population has access to woods over 20 ha within 4km of their homes (Quine et al., 2011). Forest recreation has long been recognised as important and valuable, and the Forestry Commission has been at the forefront of using recreation values in the UK. As eftec (2010c) notes recreation values have been applied widely in FC decision-making and management, being used for impact assessment and economic appraisal, and also aggregated for strategic appraisal and advocacy.

The initial focus of valuation research for recreation was on revealed preference methods with a suite of evidence dating back to the early 1990s (see for example Willis and Garrod, 1991; Garrod and Willis, 1992) and resulting in a standard value per visit being adopted in FC economic appraisals, established in 1992 at £1 per visit (since indexed). Scarpa (2003) estimated values of £1.84 to £3.06 (at 2008 prices) per recreational visit. Bateman and Jones (2003) provide a meta-analysis of forest recreation values for the FC. They include 13 different studies published before

1997, covering 21 different woods and forests that provide a total of 77 different estimates of per person per visit recreational benefits from both travel cost and contingent valuation methods. The majority of these estimates relate to use value, although 16 are classified as relating to use plus option values. Of the 61 value observations related to current use values, estimates range from £0.11 to £4.78 (2008 prices).

More recently, the FC has commissioned studies combining revealed and stated preference methods (Christie et al., 2005). This research used travel cost, contingent behaviour and choice experiment methods. The aim was to explore how attributes of sites affect total value and values for different types of users/ segments of the market. Christie et al. estimate the value of recreational improvements to forest sites for different user types (walkers, cyclists, horse riders, nature watchers) ranging from between £8.53 - £16.18 per visit (2008 prices) via travel cost studies. Contingent behaviour and choice experiment analyses were used to estimate changes in visitor welfare associated with improvements to specific recreational facilities (e.g. value of paved cycle track to cyclists). Spending and employment data were also considered, but these were found to be relatively trivial in comparison to the very large values of some non-market benefits.

There has been no primary valuation work since the studies cited above although the UK NEA does include an application of spatial modelling to valuing benefits associated with recreation (Sen et al., 2011). An application of the UK NEA approach is provided in **Annex 3**.

There have also been recent developments with respect to visitor surveys. A comprehensive overview is provided by eftec (2010c) for Defra, which reviewed how recreational survey data in England, including from the new Monitor of Engagement with the Natural Environment (MENE), could be used for generating economic values for policy appraisal purposes, in the short, medium and long term. A summary of MENE survey is provided in **Box 3.7**.

Box 3.7: Monitor of Engagement with the Natural Environment survey (MENE)

MENE survey is a continuous and ongoing survey which commenced in March 2009 and is administered to provide baseline and trend data on how people use the natural environment in England. It is managed by Natural England, with input from Defra and the Forestry Commission. The survey replaces the England Leisure Visits Survey (ELVS) and its predecessors. MENE also has a different sample size and methodology from ELVS and previous surveys. In particular it is part of an omnibus survey conducted in respondents' own homes.

MENE produces useful information for understanding recreation at national and regional levels. It is deliberately focused upon capturing all visits to the natural environment including those that are shorter, more informal and closer to home, such as dog-walking trips. Evidence suggests that these types of visits were underestimated by previous surveys, but are important features of people's lives. MENE will be useful in providing good estimates of overall recreation activity levels, and this will be important for certain purposes, including grossing up value estimates to regional and national levels, and focusing attention on all aspects of outdoor recreation.

eftec (2010c) advises that the main use for MENE data in terms of valuation and visit number estimation is likely to be in providing a clear national level assessment of total visit numbers, which will provide a useful top-down check for estimates derived from bottom-up visit prediction models, and will enable grossing up to total values per region based on estimated values per trip from travel cost work. A secondary use for the MENE data in this context will be for improving / informing value transfer functions.

Landscape and aesthetic amenity

Landscape and amenity values of woodlands have been examined by a number of studies. For example Crabtree et al. (2001) found that woodland close to resident populations is often valued not for physical access but for visual amenity and a number of studies have used the hedonic property pricing method to measure the effect of landscape and aesthetic amenity from woodlands on house prices. For instance Garrod (2003) found that woodland views have a positive effect on house prices while an early study from Willis and Garrod (1992) found both a positive (broadleaved woodland) and negative effect (Sitka spruce) from surrounding forest cover on house prices in the UK, depending on the composition of the forest. More recently, as part of the UK NEA, Gibbons et al. (2011) found that a 1% increase in broadleaved woodland cover led to an average 0.19% increase in house prices (£377 when compared to the average 2008 house price), while coniferous woodland led to an average 0.12% increase (£227 compared to the average 2008 house price).

Stated preference methods have also been applied, including Garrod (2003) as part of the Social and Environmental Benefits of Forests study (Box 3.1). Such studies have been used to assess preferences of the public for different forest management options, including effects on visual amenity and biodiversity (**Box 3.8**). The value of landscape improvements to forests was also examined by Entec and Hanley (1997), focusing on the mix of trees, selective felling and shape (e.g. organic versus straight edges). Overall results indicate that more 'natural-looking' forests are preferred. A point to raise here though is the relatively dated nature of studies that have considered preferences for forest landscapes. As well as specific valuation methods and practice moving on over time, individuals' preferences may also change, particularly as the landscape also changes over time (as a result of land use management actions, more general development and other dynamic changes). This point is considered further in Section 3.2.5.

Box 3.8: Assessing preferences for forest management options

Dalby Forest consists of 3,440 hectares of broadleaved and pine woodlands situated within the North York Moors National Park. The site is managed by Forestry Commission Yorkshire and The Humber. It produces timber from five types of stand, four of which are conservation managed to provide varying benefits to different types of wildlife. In contrast the Sitka spruce timber production stands are closely spaced for maximum stocking and clear felled at optimum economic rotation, with no deadwood retention. However despite not being managed for conservation purposes, the stands produce varied habitats for wildlife depending on the age of the stands.

A study by van Rensburg et al. (2002) examined the preferences for four different forest conservation management programmes within the Dalby Forest. Using an on-site contingent valuation survey, respondents were presented with a hypothetical scenario concerning the replanting of 100 hectares, and asked whether they would prefer Sitka spruce timber production stand or a specific conservation managed stand. The conservation managed stand that they were asked about was one which they could clearly see from the location of the survey. Respondents that preferred the conservation managed stand were told that this would represent a loss compared to a pure timber production stand and asked how much they would be willing to pay in increased taxes to compensate this. Valuation results were:

- £7.86 per household per year for shelterwood. Mixed age stands of Scots pine with 70% of trees felled at commercial optimum, with the remainder left for natural regeneration and 10% felled at 60 years and 20% at 80 years. This represented the best management for ground flora, deer, small mammals, moths, butterflies, many insect species and reptiles.
- £8.61 per household per year for mixed forest. Larch and Scots pine with a rotation age of 45 years with very open canopy. This benefits deer, small mammals and insects, particularly moths and butterflies, and also marginal improvement to bats, songbirds, reptiles, amphibians and fungi.
- £10.12 per household per year for windblown stand. Sitka Spruce with high proportion of deadwood left to encourage wildlife, benefitting woodpeckers, redstarts and spotted flycatchers, small mammals and bats, reptiles, amphibians and fungi.
- £11.66 per household per year for Douglas Fir. Felling delayed by 30 years, resulting in open canopy, tall trees up to 30m. This benefits deer, small mammals, various bird species (goshawks, robins, wrens, dunnock, crossbills and siskin), and insects.

van Rensburg et al. (2002) conclude that this illustrates a significant value for the biodiversity management, set against the 'base' level of biodiversity served by Sitka Spruce stands.

Physical and mental health

Mourato et al. (2010) detail three ways in which environmental quality and proximity to natural amenities can have beneficial direct and indirect effects on physical and mental health. First deteriorated environmental quality can directly impact upon human health; for example with regards to the potential benefits from absorption of air pollutants discussed previously.

Second the natural environment can act as a catalyst for healthy lifestyle choices, for example physical exercise, which affects both physical and mental health. The Department of Health advises that people should have at least 30 minutes of moderately intensive activity (brisk walking) at least 5 days in a week (POST, 2011), but it is estimated that only 39% of men and 29% of women actually do (Craig and Hirani, 2009). Keeping active contributes to delaying or

preventing many chronic diseases and conditions including heart disease, hypertension, diabetes, strokes, cancers, disability, osteoarthritis, osteoporosis, obesity, depression, anxiety and sleep problems (Bird, 2004). Mitchell and Popham (2008) found that circulatory diseases and mortality rates from all causes were decreased in populations exposed to greener environments (including woodlands). It is estimated that the cost of physical inactivity to the economy is approximately £9 billion, including costs of treatment from the NHS, work absence and early mortality (Bird, 2004). From the UK NEA, a reduction in sedentary behaviour of one percentage point is estimated to save the UK economy £1.6 billion from a reduction in coronary heart disease, cancer and stroke (Mourato et al., 2010)³³. However available evidence typically does not make the link between woodland and economic values.

Third, exposure to the natural environment, such as having a view of a tree from a window can be beneficial to health status. For example Hartig et al. (2003) found that tree views promoted a more rapid decline in blood pressure than a viewless room and walking in a natural setting lowered stress better than an urban setting. Maller et al. (2008) report similar findings with respect to exposure to natural environments and a reduction in stress and tension. However Milligan and Bingley (2007) show that whether people experience benefits or losses to welfare from woodlands depends on the individual - woodlands can create anxiety and uncertainty in some.

Education and ecological knowledge

A recent focus of research has been the role in the natural environment in enhancing education and ecological knowledge. Within the UK NEA this is examined by Mourato et al. (2010) in terms of the enhancement in human capital (which can be proxied through examining wage differentials in groups such as school leavers). Woodland specific research has concentrated on forest-based learning, where there has been increasing recognition that trees, woods and forest can play a positive role in education and learning. According to Knight (2009) there are currently 150 forest schools in the UK set up for outdoor play and learning, but as Lovell et al. (2010) report there is no substantive empirical base of evidence as to educational value of forests.

3.2.4 Biodiversity, use values and non-use values

One of the most important services provided by woodland areas in the UK is the conservation of biodiversity. Quine et al. (2011) note that while there is no primary woodland in the UK - and that all remaining woodland has been influenced by human activities - the woodland that remains contains significant biodiversity. For example a quarter of all UK Biodiversity Action Plan priority species are associated with trees and woods. Particularly important biodiversity categorisations are highlighted in the typology of forest characteristics set out in Section 3.1.2 (UKBAP priority habitats, ASNW, PAWS and OSNW). Ancient semi-natural woodland (ASNW) tends to be richer in plants and animals than other woodland areas (Forestry Commission, 2009).

Given the highly interactive and co-dependent role that biodiversity has across different habitat types and consequently on the provision of ecosystem services, the 'value' of biodiversity per se can be challenging to coherently assess. Abson et al. (2011) take the approach of considering the value of biodiversity (conservation) in terms of use and non-use values. The use value component is further split into: (i) the role of biodiversity in the direct delivery of ecosystem services; and (ii) the role of biodiversity in underpinning ecosystem service delivery.

³³ Similarly Stone (2009) estimates the potential value of the universal provision of green space access (including woodland), based on savings to the NHS, to be £2.1 billion per annum. This figure is based on an estimate that 24% of people who have good perceived and/or actual access to green space are more likely to be physically active.

The role of biodiversity in the delivery of ecosystem services incorporates a number of the final ecosystem services and goods set out in Table 3.1, including: pollination, fertilisation and pest reduction effects (e.g. on food production); maintaining genetic diversity and bioprospecting; and (biodiversity-related) recreation. Supporting empirical and valuation evidence is however limited, both for woodlands and wider habitats. From a practical perspective, eftec (2010b) takes the approach that such *use values* of biodiversity and wildlife are (in principle) captured under other categories (e.g. recreation and aesthetic values for uses involving watching wildlife, and provisioning or regulating services for other direct or indirect uses of biodiversity).

Abson et al. (2011) highlight that with respect to the role of biodiversity in underpinning ecosystem service delivery a precursor for valuation is the need to understand how biodiversity is related to the primary structure of ecosystems and the composition that is required to ensure its healthy functioning, the resilience of ecosystems to respond to external shocks (i.e. how does species richness allow systems to recover), and the insurance function that biodiversity provides within systems (i.e. a greater range of species insures that some ecological functions will continue if other fail).

Coupled with the above considerations it can also be argued that separately valuing the supporting and intermediate functions of biodiversity entails a significant risk of double-counting, since - conceptually at least - this is already accounted for in the final services supported by biodiversity. However some caution is required since it must be recognised that value estimates for the supported goods and services will only be accurate if in fact the biodiversity necessary to their provision is maintained in the future. In other words, if a decline in biodiversity is expected - i.e. a depletion in stock in the terminology of Section 2.2 - it will be necessary to account for the implications for the value of final services supported by biodiversity. This then raises issues as to critical levels of natural capital and whether the scientific basis for understanding the implications of biodiversity losses in this regard is presently available.

With respect to non-use values (i.e. existence and bequest motivations), Abson et al. (2011) note that there is substantial anecdotal evidence associated with biodiversity conservation. This includes aspects such as legacy donations to environmental charities engaged in wildlife related conservation. Pharoah (2010) reports that total legacy income by environmental charities in 2008/09 was approximately £100 million. However, as Mourato et al. (2010) note this represents only one element of non-use value.

Non-use values for biodiversity have been examined by various stated preference studies. Specific to woodlands, as part of Social and Environmental Benefits of Woodlands (Box 3.1), Willis et al. (2003) present estimates of £0.35 per household per year for enhanced biodiversity in each 12,000 ha (1%) of commercial Sitka spruce forest; £0.84 per household per year for a 12,000 ha increase in Lowland New Broadleaved Native forest, and £1.13 per household per year for a similar increase in Ancient Semi Natural Woodland.

Outside of the UK, Juutinen (2008) presents a meta-analysis of contingent valuation studies for biodiversity value of old-growth boreal forests in Finland; calculating values for management actions from delaying harvesting (£84/ha/yr) and permanent conservation (£398/ha/yr). Lindhjem (2007) presents a meta-analysis of willingness to pay for forest protection in multiple use forestry; however the value is scale insensitive, and so it is difficult to derive per ha measures³⁴. Nunes et al. (2009) present a meta-analysis of forest biodiversity values, covering 65

³⁴ The issue of scale insensitivity fundamental for stated preference valuations and is a key theme in the literature concerning the challenge of estimating biodiversity values.

separate studies with 248 value estimates. However the definition of 'biodiversity' values is broad in terms of the supporting service underpinning all other values, and their data points are for the total values of forest ecosystem services.

More generally, a series of research studies for Defra have directly sought or included aspects of biodiversity value in stated preference studies. Christie et al. (2011) estimate values of changes in biodiversity and associated ecosystem services that are expected to result from delivery of the UK BAP. Based on choice experiment, values are estimated for wild food, non-food products, climate regulation, water regulation, sense of place, charismatic species and non-charismatic species. The likely provision of service across UK BAP habitats - including native woodland - was then assessed via an expert-weighting exercise. As an illustrative example of results, the willingness to pay for the full implementation of BAP in native woodlands is estimated to be approximately £145 per household per year³⁵. Boatman et al. (2010) provide estimates of the benefits of the Environmental Stewardship scheme, although the biodiversity element is bundled within wildlife and landscape benefits.

Overall the evidence relating to non-use values associated with biodiversity is limited. Beyond forests there are numerous studies that consider the preservation of specific species and habitats but the transferability of results will be limited. Abson et al. (2010) also highlight the particular challenges that are faced by the application of stated preference methods particularly with respect to the framing of hypothetical markets and respondents understanding biodiversity³⁶.

3.2.5 Assessing the relevance of the evidence base

A key motivation for the commissioning of this study by the Forestry Commission is that the main base of evidence on the value of non-market benefits (Social and Environmental Benefits of Forests, Willis et al., 2003) is almost a decade old. Moreover some of the analysis that supported the research in 2003 was produced in the mid-1990s. It is therefore useful to consider the continued relevance of the outputs from this research, plus also the relevance of the wider evidence base reviewed in Sections 3.2.1 - 3.2.4.

In general an assessment of the relevance of the evidence base can include a number of considerations. For example the SEBF work is not presented explicitly in terms of 'ecosystem services', so there could be a question as to whether the evidence fits within an ecosystem services type approach. Clearly though the breakdown of the research in terms of the non-market benefits of woodlands in terms of recreation, landscape, biodiversity, carbon sequestration, archaeological protection, air pollution absorption, and water supply and quality matches well with the ESA categorisation set out in Table 3.1.

Beyond this however there is the issue of longevity and whether the results of the SEBF are still valid. Foremost the UK economy has changed over the last decade in terms of the general level of prices; an increase in the number of UK holidays relative to overseas trips (reflecting a change in demand patterns); and changes in regulation and policy with respect to international commitments. All of these factors impact on the social and environmental benefits of forests. This implies that as an initial assessment, the results of the SEBF should be:

- Updated by the GDP deflator (or a price inflator; e.g. consumer index of prices);

³⁵ This is the estimated aggregate value 'sum of within own region and rest of UK' reported by Christie et al.

³⁶ Note that in relation to this issue, Christie et al (2011) use a workshop based approach for eliciting preferences so that respondents are given time to improve their knowledge as to the valuations that are sought. In contrast, Bateman et al. (2011) suggest that a reliance on workshops results in valuations that are not representative of the wider population who have not been subject to the exercise.

- Amended to account for new research; e.g. on the value of specialist recreation in forests (Christie et al., 2006); and new estimates of visitor numbers to forests (e.g. MENE); and
- Updated to account for revised values for some environmental benefits; e.g. in relation to carbon sequestration benefits (e.g. DECC guidance).

In considering the relevance of the available evidence base there is also a question as to how well it fits within the context of current decision-making issues in the forestry sector, both at the national policy level and local management level. An assessment in these terms is more challenging since much depends on the specifics of the decision in-hand (see also Section 4.1). Some steer however is provided by the recent Defra value transfer guidelines (eftec, 2010d), which describes the typical ‘policy development cycle’ as comprising of five stages: (i) define the issue; (ii) understand the situation; (iii) develop and appraise options; (iv) delivery; and (v) monitor and evaluate. In particular the stage of the cycle determines the precise requirements for the evidence that informs policy development. For example:

- *‘Improving knowledge’*: an understanding of the significance and magnitude of environmental impacts can be aided by ecosystem services value evidence. Here a broad survey of scientific and economic studies on the provision of particular ecosystem services is likely to be well suited to assisting the steps of ‘define the issue’ and ‘understand the situation’. In these terms much of the SEBF evidence and other studies summarised in Sections 3.2.1 - 3.2.4 are likely to be sufficient to improving understanding, since - as demonstrated here - such a broad survey also establishes gaps in knowledge and helps identifies where further research should be targeted.
- *‘Informing policy decisions’*: Impact assessments for policy proposals (or cost-benefit analyses for local management decisions) require robust assessments of the value of environmental costs and benefits to ‘develop and appraise options’ and inform ‘delivery’. In many cases value transfer (the use of economic value evidence from available studies rather than commissioning new research) is an appropriate approach for generating this evidence. However use of value transfer is dependent on a number of criteria that compare the requirements for the evidence to inform decision-making to the evidence that is available from previous study. These include the specific ecosystem services, goods, benefits and location(s) that are considered, the scale of the change in provision, the extent of the affected population, and the influence substitute goods. Study robustness, in terms of how methods used conform to good practice principles and how results conform to theoretical and empirical expectations is also a key consideration.

Recalling Section 2.2.2, judging the relevance of the SEBF and wider evidence base in these terms emphasises the context-specific nature of economic values and the careful application that is required for value transfer. Such an assessment, however, is beyond the scope of this study. That said, it is likely that evidence in some areas, such as recreation values and carbon values (given the DECC guidance), are more readily applicable than others. In particular Bateman et al. (2011) note that in general there is insufficient base of good quality valuation base across the environmental policy field, and there are few studies that are well-suited to value transfer applications. Where primary valuation studies are commissioned it would be helpful if they are designed and implemented with subsequent value transfer applications in mind.

- *‘Reviewing outcomes’*: assessing the effects of policies and projects in retrospect may also require ecosystem service value evidence to judge effectiveness. Here much depends on the scale of accuracy required, which can differ according to considerations such as the scale of investment expenditure, the scale of outcomes, the scope of the policy and so on. In some

case only a broad understanding may be needed (e.g. similar to ‘improving knowledge’). In other cases more stringent demands may be placed on the accuracy evidence inputs (e.g. similar to ‘policy decisions’).

In addition to the above considerations, the Defra value transfer guidelines also stress that ecosystem service value evidence provides one input to the decision-making process; its need and the level of accuracy required should be determined in conjunction with the overall policy context and other types of evidence (e.g. scientific and technical and/or deliberative and participatory, etc.) that are also available. Fundamentally these judgements can only be made on case-by-case basis.

In light of the above discussion, the remainder of this section provides an overview of how SEBF evidence base can be updated based on findings from review of evidence documented in Section 3.2.1 - 3.2.4.

Recreation

The SEBF research estimated the general recreation benefits of woodland per ‘day visit’ at £1.66 to £2.78 (2002 prices) depending on the model used. These values, if updated by the GDP deflator, are still relevant to general forest recreation. However, there are three areas where new evidence is available and additional information required:

- Subsequent research by Christie et al. (2006; 2007) estimated the value of forests to mountain bikers, horse riders, and nature watchers. The value of the forests and woodland should therefore be revised to take account of the higher WTP of these specialist recreationalists. This will necessitate estimating the number of these users relative to general day visitors to forests.
- Estimates for the number of day visitors to forest should be updated by new information, such as the Monitor of Engagement with the Natural Environment (MENE) survey.
- The SEBF report did not provide much information on the value of casual visits to forests and woodland. Drawing on previous studies by Crabtree et al. (2002) and Willis and Garrod (1991) a range of £0.10p to £0.30 per visit by people walking dogs was given. Further research on both the number and the value of woodland to these users should be undertaken, potentially utilising the information from the MENE survey.

In addition Annex 3 presents a case study testing the spatial analysis framework developed in the UK NEA for estimating the benefits of recreational visits to woodlands. This uses geographical information systems (GIS) to explicitly control for the context-specific nature of recreation values and may in certain situations represents a ‘preferred’ approach to valuation.

Landscape

The impact of various woodland landscapes on house prices, derived from a choice experiment in the SEBF study, was consistent at the time with other evidence from hedonic price models on the effect of trees on property prices. New research, undertaken for the UK NEA (Gibbons et al., 2011) provides the latest examination of the amenity value of woodland on property prices. This reinforces earlier findings but in terms of a more general ‘amenity’ value (in contrast to landscape value).

In the SEBF study, households also indicated that they would be willing to pay to see woodland in the landscape on journeys. The greatest uncertainty in this aspect of landscape value was the number of households whose journeys encountered woodland landscape views. Some guidance for appraising 'journey ambience' is provided by DfT transport appraisal guidance³⁷. While this recognises the impact that landscape views can have on quality of travellers' journeys, it does not provide a basis for monetary valuation. Valuation of this benefit therefore remains a gap.

Biodiversity

In the SEBF study, resources did not permit an original study to value biodiversity in forests. Instead the value of biodiversity across different types of forest was derived by scaling the value estimated by Garrod and Willis (1997), for re-structuring remote commercial conifer plantations to enhance biodiversity, across other types of forest. Subsequent research has sought to develop approaches to non-use values associated with biodiversity, particularly through the application of choice experiments. For example the procedures adopted by Meyerhoff et al. (2007), Czajkowski et al. (2009), and Christie et al. (2011). Overall there is merit in trying to derive improved estimates for the biodiversity value of different types of forest and woodland through future research.

Carbon sequestration

The SEBF study estimated *net* carbon sequestration, accounting for changes in carbon content of the soil in moving from agriculture to forestry. It did this through a spatial model of woodland coverage, woodland structure (broadleaves and conifer, by yield class, and rotation), soil conditions (i.e. carbon changes in soil by soil type), and carbon emitted through harvesting and management of timber. This carbon sequestration estimate has been update by Read et al. (2009). In terms of the value of carbon sequestered, however, there has been a significant change in the price attributed to carbon since 2003. Based on available academic evidence and the price at which carbon permits traded at the time (2003) in the UK Emissions Trading Scheme, the SEBF study used a value of approximately £6 - 14 per tonne carbon. DECC (2009) changed the UK government approach to valuing carbon, from damage caused by carbon emissions to the cost of mitigation (abatement) to meet carbon reduction targets in the UK. Values to apply for traded and non-traded carbon are detailed in DECC (2010). In 2011 the non-traded price for carbon dioxide is £52 per tonne CO₂e (equivalent to £190 per tonne of carbon) at 2009 prices. Consistency in appraisal across the non-traded sector requires that the DECC guidance is adopted, and the value of the FC estate and other woodland is re-valued accordingly. However a conceptual point to note is that in cost-benefit analysis the value of carbon should be based on the damage that carbon emissions produce; or the amount people are willing to pay to avoid carbon emissions³⁸.

Other ecosystem services

Non-market benefits associated with other ecosystem services valued in the SEBF report were archaeological protection, air pollution absorption, and water supply:

³⁷ See: <http://www.dft.gov.uk/webtag/documents/expert/unit3.3.13.php>

³⁸ Since they are based on the cost of mitigation, the DECC carbon values could be expected over-estimate the value of carbon reductions resulting from forestry, where the cost of mitigation exceeds damage costs or WTP to avoid carbon emissions. More generally though the use of mitigation costs in environmental valuation is expected to give lower bounds estimates, since opportunity costs of mitigating options are largely considered to be poor proxies for WTP and consumer surplus measures of benefits. In practice though the DECC values are subject to large upper and lower bands such that sensitivity analysis should account for concerns as to over-and under-estimation of benefits.

- The estimated value of archaeological protection in the SEBF report was subject to considerable uncertainty. This represents a potential area for further research since there has been no new evidence on this since the SEBF.
- Air pollution absorption impact of woodlands was measured in the SEBF report in terms of improvements to human health. Unit values for mortality and morbidity impacts should be updated to account for more recent estimates (e.g. IGCB, 2007). The SEBF research used the National Inventory of Woodland and Trees at a 1 km² scale and hence the research did not cover air pollution absorption benefits of trees in urban areas, where air pollution is at a maximum, where the impact of trees on reducing PM₁₀ and SO₂ is likely to be greatest, and where most population benefitting from improvement in air quality is concentrated. The SEBF estimate could be revised - or new research commissioned - to account for the pollution absorption effects of urban trees and other pollutants (e.g. NO_x).
- The SEBF report estimated the opportunity cost of trees in terms of their interception effect in reducing water available for public supply (drinking water abstraction). These opportunity costs might have increased now due increased population, greater potable water use, and climate change.
- The SEBF report discussed the effect of forests on water quality (both negative and positive), but the report did not quantify the value of the impact of woodland on water quality. Given the introduction of the Water Framework Directive (WFD), and the considerable amount of research that has been undertaken on the value of attaining 'good ecological and chemical status' in rivers, lakes and other water bodies in the UK, there is scope to consider further this ecosystem service of woodlands.

Another further ecosystem service that was not estimated in the SEBF study was the impact of forests in reducing flood risks. As detailed in Box 3.6 there has been subsequent research by Broadmeadow and Nisbet (2010) in relation afforestation and reduced flood risk. However, whilst hydrological modelling can estimate the reduction in flood velocity and mean depth, there has been little research to appraise schemes in economic terms (e.g. in relation to loss of existing land use and marginal savings in cost of flood defence along rivers in urban areas). There is a need to undertake some rigorous economic research on the impact of forests on reducing the cost of flooding, which could be developed around available guidance for appraising flood risk management options (provided by the Environment Agency, 2010).

Afforestation can also protect other ecosystem services such as agricultural land and food production, by preventing encroachment from wind-blown sand from coastal dunes. Culbin forest is an example (see Box 3.4). However, such cases are likely to be small in number, and the economic benefits of protecting ecosystem services such as agriculture are likely to be small relative to other ecosystem services (such as biodiversity, carbon sequestration, etc.) provided by forests.

3.3 Capturing values - payments for ecosystem services and other mechanisms

3.3.1 Background

The Economics of Ecosystems and Biodiversity (TEEB) describes ‘capturing’ ecosystem service values as the final element of a tiered ESA. Here the objective is to introduce mechanisms that incorporate ecosystem service values in decision-making, via appropriate incentives and price signals (TEEB, 2010). Essentially this addresses the multifaceted issue of market failure. Examples of such failure include externalities, non-market and public goods, missing information or information asymmetries, and price distortions (e.g. taxes and subsidies). Successfully addressing such problems results in more socially ‘optimal’ outcomes such as the removal of pollution externalities or sustainable use of resources.

Capturing ecosystem service values via market-based mechanisms does not imply the privatisation of natural capital³⁹. Rather it is a case of ensuring that the full economic value of goods and services is accurately reflected in decision-making by all. In some instances, it is sufficient to simply demonstrate the value of ecosystem services. This is particularly the case where strong regulatory frameworks exist for ensuring nature conservation (e.g. EU Habitats and Birds Directives). Outside of public policy, however, market based incentives can provide strong signals to private individuals and organisations to deliver enhanced ecosystem service provision, particularly in the case of non-market values. Traditionally the emphasis has been on state-subsidies to land owners; for example environmental stewardship payments to farmers, or the Woodland Grant Scheme (WGS). However, increasingly more attention is being paid to a wider range of mechanisms that stretch beyond Government fiscal instruments to incentivise voluntary business and public initiatives. Payments for ecosystem services and biodiversity offsetting are the two most prominent such mechanisms and are also discussed in the Natural Environment White Paper (HM Government, 2011).

In some cases it is straightforward to create new markets for ecosystem service values. Timber already has a market. Sequestrated carbon could have a market through carbon finance. This includes the development of the Woodland Carbon Code⁴⁰ in the UK which is a voluntary standard for woodland creation projects (**Box 3.9**). Payments for ecosystem services (through whichever mechanism) can be used for both the direct provision of a service (e.g. carbon storage) and as compensation for other forgone services (e.g. timber)⁴¹. This is particularly the case where there are trade-offs between different ecosystem services. Such direct compensation provides an incentive to the land owner to act responsibly and actively work towards the improvement of the forest as a multi-purpose resource.

³⁹ Note though that some mechanisms may create new or change existing property rights such that values may be captured by private individuals or organisations.

⁴⁰ See: <http://www.forestry.gov.uk/carboncode>

⁴¹ An interesting example is the process of thinning which significantly improves timber values by removing thinner stems but reduces the overall carbon storage potential of a woodland. For an example including valuation see Bateman, I.J., Lovett, A.A. and Brainard, J.S. (2003) *Applied Environmental Economics: a GIS Approach to Cost-Benefit Analysis*, Cambridge University Press, Cambridge

Box 3.9: The Woodland Carbon Code

The aim of the **Woodland Carbon Code** is to encourage investment in the establishment of woodlands in the UK for climate change mitigation. It focuses on voluntary carbon sequestration projects that meet the principles of sustainable forest management. Net emission reductions resulting from projects contribute to the UK's national targets for reducing emissions of greenhouse gases.

Overall the initiative is intended to establish a uniform standard for UK forestry-based carbon projects, so that there is consistency and transparency across issues such as permanence and additionality of carbon reductions and avoidance of 'double selling'. This involves independent certification, a standard measurement approach (covering the baseline carbon stock, predicted future sequestration and actual measurement), and management requirements to ensure the carbon savings are maintained over the long term.

Warcop Training Area, Cumbria, provides an example of where corporate funding to purchase carbon 'rights' has ensured the viability of a woodland creation scheme. It is a partnership between Defence Estates (part of the Ministry of Defence) and the Woodland Trust to plant 176,000 trees on 160 hectares within the Defence Training Estate at Warcop, situated in the North Pennines Area of Natural Beauty (AONB). The scheme is funded by a variety of sources including the North Pennines AONB Partnership's Living North Pennines project, Eurocamp through the Woodland Trust's Woodland Carbon Scheme, and Waitrose.

While the primary objective of the scheme is to improve training facilities for British soldiers and aid them in preparing for operations, meeting the requirements of the Woodland Carbon Code will result in an estimated 145,000 tonnes of carbon dioxide sequestered over the next 100 years. Of this, around 90,000 tonnes of sequestered carbon dioxide is available for sale from the project (due to adjustments for potential error in calculations and risk of not achieving targets). Conservation objectives will also be met by the project, with the planting of mixed density woodland preserving the natural aesthetic of the landscape and providing habitat for BAP species including the black grouse. Several SSSI and a Special Area of Conservation (SAC) are also within the area.

Sources of information:

Woodland Trust

<http://www.woodlandtrust.org.uk/en/planttrees/partnerships/Documents/defence.pdf>

<http://www.woodlandtrust.presscentre.com/content/Detail.aspx?ReleaseID=1834&NewsAreaID=2>

Forestry Commission

<http://www.forestry.gov.uk/forestry/INFD-8GKDMJ>

Ministry of Defence

<http://www.mod.uk/DefenceInternet/AboutDefence/WhatWeDo/DefenceEstateandEnvironment/AccessRecreation/North/Warcop.htm>

3.3.2 Value Capture Mechanisms

There are a variety of mechanisms through which demonstrable ecosystem service values can be captured. The principles for value capture are similar and hence there are several ways to categorise the mechanisms. **Table 3.4** provides one such categorisation with illustrative examples.

Table 3.4: Mechanisms for capturing ecosystem service values

<i>Mechanism</i>	<i>Description</i>	<i>Illustrative example</i>
Payments for ecosystem services (PES)	The provider (often a landowner) of a service is paid to maintain or enhance that service.	Agri-environment including forestry payments such as the English Woodland Grant Scheme (WGS)
Competitive ecosystem service contracts	Private sector providers compete to offer ecosystem service supply contracts.	Australian 'BushTender' contracts
Green infrastructure investments	Concept based around planning over large areas, usually urban, and based on building interconnected ecosystem services to maximise social benefit.	Plymouth Green Infrastructure - Saltram Masterplan
Carbon finance	Selling the carbon sequestered in the wood and soil into carbon markets.	Voluntary carbon footprint reductions (e.g. Woodland Carbon Code)
Biodiversity offsetting/habitat banking	Protecting or developing new forest in exchange for development losses elsewhere	In the UK to date this has been largely restricted to coastal rather than woodland habitats
Access payments	Charging visitors to access a forest	There are a broad range of possibilities; e.g. forest concerts, Go Ape, etc.
	Extracting animal products	Woodland game shooting
Payments for ecosystem services (PES)	The provider (often a landowner) of a service is paid to maintain or enhance that service.	Agri-environment including forestry payments such as the English Woodland Grant Scheme (WGS)
Competitive ecosystem service contracts	Private sector providers compete to offer ecosystem service supply contracts.	Australian 'BushTender' contracts
Education and research	Carrying out education or research in forests	Forest schools

Payments for ecosystem services (PES)

PES provides a good example of the potential overlap between mechanisms. In its broadest interpretation it could be used as an umbrella term for all market mechanisms. For instance, whilst game shooting uses a product - the individual birds shot - the forest itself provides a service which is the rearing of sufficiently large populations that individual birds may be shot sustainably. When the hunter pays the forest owner for a shoot they are in essence paying for an ecosystem service. However more common usage of the term PES is ordinarily restricted to the provision of non-extractive services. These include air and water purification, flood protection, pollination and carbon sequestration. Carbon sequestration is discussed separately (see below) since this topic area is more developed at present.

Costa Rica provides the most famous example of the use of PES for forests. In 1996 a law was put into place to allow the Costa Rican government to enact a fuel levy which would fund payments to forest and farm owners for the ecosystem services their land provides (Pagiola, 2008). Further efforts have also been made to seek payments directly from water consumers. The law does not oblige payments but a range of agreements have been made such that hydro-power plants and water suppliers will pay into the PES fund (Pagiola, 2008). However in the Costa Rican example it

has been more difficult to gather payments for biodiversity and carbon. This is at least in part due to the global nature of the benefits from biodiversity and carbon sequestration and the domestic nature of the Costa Rican markets.

In the UK, payments to landowners such as Environmental Stewardship or via the WGS can be considered a form of payment for ecosystem services. As an example the English WGS comprises of six forms of grant for specific activities⁴²:

- Woodland planning grant: to produce a woodland management plan.
- Woodland assessment grant: to collect information that assists management decision.
- Woodland improvement grant: to undertake projects in woodlands such as access tracks, uneconomic thinning, coppicing, rhododendron clearance and public access facilities.
- Woodland regeneration grant: to re-establish trees after felling.
- Woodland management grant: to carry out regular work such as ride management and pest control.
- Woodland creation grant: to create new woodland.

In the past there has been criticism that forestry payments have been lower than those for agriculture (Forestry and Timber Association, 2004). In recent years, however, payments for replanting native woodlands however can be a significant incentive for investment in woodland creation. In particular upfront payments for planting native pines have the benefit of removing all risk from a transaction; for this reason investors are currently interested in buying land for this purpose⁴³.

Competitive ecosystem service contracts

Ecosystem service contracts are an auction based approach for incentivising land owners to reveal both their true costs of ecosystem service provision and an accurate estimate of the potential ecosystem service output potential of their lands. The aim of such schemes is to switch from 'input' to 'output' orientated measures of ecosystem service provision by relying upon the local land owners knowledge. Under this system the administrative body announces a fund for ecosystem service provision. Land owners are then asked to bid for contracts to deliver ecosystem services. Contracts are awarded to those land owners who offer the most cost-effective outcome (e.g. the largest gain in some agreed measure of ecosystem service provision per unit cost). The approach has a number of appealing properties. For example it is efficient in terms of cost as land owners are aware that all competitors will be considering placing bids for such contracts and therefore they have little incentive to inflate costs. It is also efficient in terms of ecosystem service outcomes as those land owners who realise that the characteristics of their land are unsuitable for delivery of such outcomes will not risk failing to fulfil their contracts and lose payments.

Green infrastructure investments

The term 'green infrastructure' (GI) is often (and incorrectly) understood to mean the 'greening of grey infrastructure', i.e. reducing the impact of physical infrastructure projects. However in the context of EU and UK environmental policy, the concept relates to the interconnectedness of habitats and ecosystems that underpins ecosystem service provision. It has an important role in providing adaptation capacity to climate change, and includes habitats inside and outside protected areas (i.e. the broader landscape matrix).

⁴² See: <http://www.forestry.gov.uk/ewgs>

⁴³ Pers. comm., Jason Sindon (UPM Tilhill), July 2011.

Strictly, GI is not a market mechanism in its own right but it is an increasingly important concept for environmental management. It potentially provides the (*natural capital*) *assets* which private finance can invest in to maintain *flows* of ecosystem services paid for by public bodies or in private PES markets if these develop. The distinction between GI and PES is then one of scale and nature: GI provides the resources (natural capital assets) that underpin ecosystem services from a large area (or network of natural capital). PES takes the form of payments for the flows of benefits resulting from natural capital.

In addition GI may be best differentiated in circumstances where management is entirely governed by the public sector. In these circumstances no transactions for provision necessarily take place. However, within the public sector there is a tacit recognition of the non-market benefits arising from natural capital - which is on a par with physical and human capital - and the need to manage this based on the concept of GI in order to maximise benefits.

Carbon finance (and REDD)

Carbon finance is a special case of PES. It is technically less complex than, for instance, water regulation, since carbon sequestration benefits are unaffected by spatial variation and can be linked to a single area of habitat rather than the linked system within a catchment. It also uses a single commodity unit, a tonne of carbon (or equivalent greenhouse gas emissions), while PES for other ecosystem services may need to use different units.

Carbon finance requires that a baseline activity for an area of forest is established. In the tropics it is typically the case that a given area would be deforested for farmland. Therefore the task is to measure the amount of carbon which a site takes out of the atmosphere in the baseline scenario compared to the amount sequestered in a protection or afforestation scenario. Currently the most well known system for carbon finance from forests is the Reducing Emissions from Deforestation and Forest Degradation (REDD) programme. To date US \$4 billion have been put forward for REDD. REDD and REDD+ (see below) will work through global emissions trading schemes and provide carbon credits which other nations can purchase to offset their emissions. Currently REDD is in the development stage and is restricted to developing nations. Major investment is required for developing nations to set up the technical monitoring and enforcement necessary to trade in forest carbon sequestration. Nine nations are currently developing and demonstrating the systems they might use to implement REDD+ (UN REDD).

Under REDD, carbon sequestration can be achieved using logging monocultures and so biodiversity is not necessarily protected⁴⁴. For this reason REDD+ has been established. REDD+ schemes will provide carbon credits linked directly to biodiversity conservation efforts. Norway recently pledged \$1 billion to the Indonesian government to prevent logging for the next two years as part of a REDD+ scheme.

Biodiversity offsetting / habitat banking

Biodiversity offsetting involves the creation of new habitats or enhancement of existing ones to replace a habitat which is to be lost to land development. There already exists legislation in the UK which allows for the use of biodiversity offsetting (POST, 2011). However there is no legal

⁴⁴ Other criticisms of REDD include that it may simply lead farmers to convert other habitats in order to provide food. Models do indicate that forest protection will come at the expense of increased use of other habitats. However these effects might be mitigated through more efficient agricultural practices on currently farmed land.

obligation to offset and in the majority of cases no other incentive such as the obligatory requirement would be eased if the developer offsets and for these reasons offsetting is rare (eftec, 2011). However offsetting is common in the USA where it has been shown to be a useful tool for conservation (ten Kate et al., 2004). There is also an effort currently in Government to encourage offsetting in the UK. Pilot areas are likely to be created to try out new rules which oblige developers to offset their impacts.

Offsets can either be created directly for a specific development or they can be created in advance and banked for later sale. As it takes time for a newly restored habitat to develop, a hectare of 'promised' heathland, for example, is not worth as many offset credits as a hectare of established heathland. There is therefore an incentive to bank credits. Given the long lead in time that woodland requires to develop woodlands are likely to be banked in advance. In order to fund this it might be necessary to seek private finance.

Access payments

Access payments can cover a range of activities from those requiring little infrastructure such as walking trails to those requiring significant additions to the woodland such as Go Ape or forest based concerts. For example Go Ape have expanded over their 10 years in existence to 27 sites across the UK; their Aberfoyle site had 26,970 visitors in 2008⁴⁵.

Paying to access a forest for a specific organised activity is already current practice but requires specific investment (**Box 3.10**). Paying for individual access to woodlands for walking or cycling is less common in the UK than elsewhere (e.g. Public Right of Way, for which no access payment is required). However where car parks are busy, a charge is often levied. This charge could be thought of as an access payment. The public might also pay for guides or maps or asked for donations. Such access payments are an indication of minimum value received by forest access (and the activities participated).

⁴⁵ See:

<http://www.stirling.gov.uk/index/business/businesslatestnews/stirlingeye/contentsspring09/secfeattourism/ape.htm>

Box 3.10: Forest recreation and access - mountain biking

Mountain bike trails and facilities at forest sites provide a good example of arrangements that can arise between forest managers and users to maintain access and capture recreational values.

For example mountain biking in the **Tamar Valley, Cornwall**, was causing significant damage both to the woodland environment and cultural heritage of the area by using old mining tracks. The trails were eroding mining heritage from the forest and in so doing toxic chemicals from the stone they rode over were dissolved and leached into local water bodies. Controlling access to forests to the forest was not a viable solution and so compromise was sought. Over seven years of planning an alternative site was developed and infrastructure to support recreational activities was put in place. The plantation forest that mountain bikers were moved to is more able to cope with their impact than the previous site. The management arrangement provides for a better balance of environmental, cultural and recreational values in the local area. A local group called (www.woodlandriders.com) took out a five year lease for the trails from the private owners of the woodland.

In **Coed Llandegla, Wales**, the private forestry owners built and maintain trails in collaboration with the local mountain biking users. By doing so they ensure that the trails provided satisfy the needs of users (and ensure sufficient demand for the facilities). Revenues are captured through a bike shop, training and cafes built on site. Their business model also seeks to share risk associated with the provision of facilities. Rather than charging rent - which places all the investment risk on the forest owner - they instead operate a profit share with the private business (www.oneplanetadventure.com) which operates the facilities. The site receives around 100,000 visitors per year.

Flora Extraction

Developed markets exist for timber and some non timber products, primarily as a result of well-defined property rights for land owners. Traditionally a perception has been that timber production does not necessarily encourage land managers to provide a full range of ecosystem services in the most efficient manner. The challenge rather has been to balance production with the other benefits their forests may provide. For the public forest estate, multiple objective management is common practice, based on public good rationales. The private sector however faces the converse; timber production requires capital investment alongside woodland management, resulting in excludable returns to forestry. Returns from informal recreation access generally are not excludable (as noted above), resulting in mainly costs to private landowners which require offsetting through schemes such as the WGS.

Non timber products are traded less and it is likely that where it is economically viable, markets are already in place.

Fauna Extraction

Forest based deer hunts are more common abroad than in the UK. In the UK deer hunting is more famously provided by large highland estates⁴⁶. Highland game estates are often run as loss making ventures owned by high net worth individuals and access to these hunts is for most prohibitively expensive (Wightman et al., 2002). UK hunters have also been found to a significant preference for deer hunting in the open rather than in woodland (Bullock et al., 1998). Typically the desire to maintain high numbers of deer conflicts with forestry needs as deer damage new growth in forests. As such hunting incomes can actually be negatively correlated with woodland.

⁴⁶ As part of the UK NEA, Valatin and Starling (2010) cite from available evidence that deer hunting contributes around £12m gross value added (GVA) and £51m indirect GVA to the Scottish economy, and directly or indirectly supports over 2,000 full-time equivalent jobs.

Pheasant shooting conversely is dependent upon woodlands. Woodlands also provide refuge and breeding habitat for game birds. Currently woodland based hunting is estimated to be worth £640 million per year in the UK supporting 28,000 jobs (Quine et al., 2011).

Education and research

Provision of education and research facilities offers a further way in which land owners can be paid for specific uses of woodlands or particular management practices (in essence a type of access payment but with a different emphasis than recreation). There are currently more than 150 forest schools in the UK (Knight, 2009). Forest based education has been shown to be particularly beneficial to students with difficulties concentrating in traditional classroom settings.

There also exist woodlands owned by research institutions and managed for research. Education and research is included in this list as when woodlands owned by training or research organisations are managed using education and research funding streams. For example, Wytham Woods in Oxfordshire are owned by the University of Oxford. They are managed by the university and have been used to collect a range of long term data-sets for species such as badgers and great tits.

4. SUMMARY AND CONCLUSIONS

The report concludes by returning to the aims of the study presented in Section 1.2, providing a summary of the coverage of the economic evidence base and gaps, an assessment of key challenges faced in the valuation of ecosystem services, consideration of practical market opportunities for forest ecosystem services, and recommendations for future economic research priorities.

4.1 Coverage of existing evidence base and gaps

The survey of literature in Section 3.2 demonstrates that there is a very varied base of evidence across the range of ecosystem services and goods derived from forests and woodlands. Largely, a greater depth of evidence is available for provisioning services (mainly timber) and some cultural services (e.g. recreation, landscape and aesthetic amenity). The latter have particularly been subject to notable research effort over the past 10-15 years with a focus on non-market valuation efforts.

In assessing the coverage of evidence and gaps, a number of considerations are apparent:

- *The context for valuation:* Section 2.3 establishes the range of decision-making contexts within which ecosystem service values may be applied. Whether there are any gaps in the value base and how these should be filled depends on the specific requirements of each context. In other words, different forest policy objectives (e.g. rural development, economic regeneration, recreation, or environment and conservation), and wider public policy objectives (e.g. agriculture, flood risk management, health) will require different types, scales and accuracy of evidence.
- *The policy 'level':* a further distinction is the level at which a decision is made; i.e. a strategic policy level (i.e. national or even international issues) or a local woodland management level (i.e. concerning activities at a specific site). In both cases the basic issues relate either to: (i) land use management; i.e. forest management options; or (ii) land use change, either in terms of maintaining the current stock of woodlands or creating of new woodlands. Evidence needed for (i) will be mostly marginal values and potential trade-offs and synergies between different ecosystem services. Evidence needed for (ii) will also be for marginal changes but could also include non-marginal changes in ecosystem service provision on local and regional scales. Overall in the context of this study, it is difficult to assess the exact sufficiency of available evidence. While there is evidence spanning the breadth of ecosystem services framework, there may still be gaps with regards to the specific needs of specific policy or local management objectives.
- *The requirement for scientific understanding and evidence to support valuation of ecosystem services:* economic value evidence is only 'half of the story'. As described in Section 2.2.2 the application of valuation evidence is dependent on qualitative and/or quantitative scientific analysis that describes how ecosystem service provision changes as a result of policy actions, project impacts, or natural drivers of change (e.g. climate change, invasive species, etc.). Challenges faced in linking scientific and economic assessments are addressed in Section 4.2.
- *The longevity and quality of the available valuation evidence:* this depends on the robustness of the available evidence. The robustness, in turn, is both an absolute concept (e.g. whether

good practice guidance is followed in valuing ecosystem services and statistical results are robust) and a relative concept (depending on the accuracy required by the decision-context). This is especially relevant in the context of value transfer (Defra, 2010). Consideration of value transfer also raises the issue of how well the available evidence matches the context, types, scale and magnitude of changes in ecosystem service provision that may be the focus of future forestry decision-making; a judgement that is informed by scientific evidence and expert judgement for forest management practitioners. Again in an assessment such as this, it is difficult to determine at anything more than a very general level the coverage of evidence; e.g. the longevity of the Social and Economic Benefits of Forest evidence as considered in Section 3.2.4.

Given these considerations, an assessment of the coverage of evidence and gaps is provided in **Table 4.1**. Key findings are discussed according to the classification of ecosystem services (from Table 3.1):

- **Timber:** the valuation of timber is straightforward using readily available market price and volume data from the Forestry Commission. This permits a distinction in terms of ‘woodland ecology’, between coniferous softwood timber and others. Hardwood price data are limited. At present hardwoods represent only a small proportion of timber production, but it does represent a gap in the evidence base particularly in relation to private forestry production. In addition as Section 3.2.1 notes the ‘ecosystem service value’ of timber is better reflected by price measures that do not incorporate man made capital and labour costs associated with harvesting timber. This information is typically not readily available, although is held by the Forestry Commission for the public forest estate. It is also worth noting that in the short term, prices for softwood and sawlogs sales can be subject to volatility and hence use of spot prices could have a bearing on any analysis attempting to estimate the value of timber. Values averaged over time will smooth out these fluctuations and reflect longer term trends.
- **Wood fuel:** valuation of wood fuel can be more complex depending on the purpose of the analysis. The value of timber will reflect demand for a variety of uses, including wood fuel, along with paper, pulp and panel board uses. However assessments of wood fuel from a renewable energy perspective need to consider wider factors (see next point).
- **Wood as a low carbon energy source and construction material:** in specific assessments (e.g. life cycle assessments related to climate change impacts of materials use) the carbon displacement benefits of timber, as a construction material or wood fuel, may be relevant. In the case of wood fuel, trees absorb carbon (accounted for as part of climate regulation below) which is released when wood is burnt for energy. However as noted in Section 3.2.1 this displaces energy and carbon emissions from other sources. Consideration is required as to whether renewable or non-renewable sources of energy are replaced and hence the net effect on carbon emissions. Necessary emissions factors and prices/marginal costs for undertaking this analysis are provided in current UK Government guidance for valuing GHG emissions (DECC, 2009).

Table 4.1: Summary of coverage and gaps in ecosystem service economic value evidence

Final ecosystem service	Principal final goods	Coverage of valuation evidence	Importance of forest characteristics in provision
Production of trees, standing vegetation and peat [P]	<p>Timber and wood fuel</p> <p>Non-wood forest products (ornamental, craft/hobby resources)</p>	<p>Market price information readily available (limited for hardwood)</p> <p>Significant gaps - prices for market equivalents likely to be inappropriate, and some products may be better associated with cultural services</p>	<p>Main distinction in market values is in relation to woodland ecology (coniferous vs. broadleaved).</p> <p>Most significant timber values are likely to be associated with coniferous plantations.</p> <p>The provision of specific products is determined by woodland ecology, management practices, and proximity to populations and at a local level</p>
Food - production of crops, plants, livestock, fish, etc. [P]	Non-wood forest products (wild food products)	Significant gaps - prices for market equivalents likely to provide only limited proxy values.	<p>Specific products determined by woodland ecology, management practices, and proximity to populations and at a local level.</p> <p>Semi-natural habitats are likely to be more important for non-wood forest products.</p>
Production of wild species diversity including microbes [P,R]	Genetic resources and bioprospecting	Limited/no economic value evidence available	<p>Provision is principally determined woodland ecology and management practices.</p> <p>Semi-natural habitats are likely to be more important for significant levels of provision.</p>
Regulation of climate [R]	Reduction in climate stress through carbon sequestration	Value evidence readily available through guidance for valuing GHG emissions (DECC, 2010)	<p>Main distinction in values is in relation to woodland ecology (coniferous vs. broadleaved) which is suitable for national and regional scale assessments. Local level assessments potentially need to consider specific environmental factors (e.g. tree species, growth rates, soil and water quality) and management practices and effect on other GHGs (e.g. methane).</p> <p>Typically semi-natural habitats associated with more significant levels of provision.</p>

Table 4.1: Summary of coverage and gaps in ecosystem service economic value evidence

Final ecosystem service	Principal final goods	Coverage of valuation evidence	Importance of forest characteristics in provision
<p>Soil, air and water regulation [R]</p> <p>(Clean soil, clean air, clean water from purification processes, breakdown and detoxification of waste and production of water quantity)</p>	<p>Potable water and industrial use of water</p> <p>Pollution control, waste removal, waste degradation</p>	<p>Limited evidence base with scope to develop further links between scientific understanding and economic values and whether general relationships can be assumed (i.e. from site specific assessments)</p> <p>With respect to air pollution absorption some evidence but scope for more targeted assessments (e.g. benefits of urban trees) - but would be captured under health benefits (cultural services)</p>	<p>Provision is principally determined by management practices and proximity to populations.</p> <p>In general semi-natural habitats are likely to be associated with higher levels of provision; but local factors particularly important (see Table 3.3)</p>
<p>Regulation of hazards [R]</p>	<p>Avoidance of damage from natural hazards (flood protection, coastal protection, erosion protection)</p>	<p>Limited evidence base with scope to develop further links between scientific understanding and economic values and whether general relationships can be assumed (i.e. from site specific assessments). Some economic value evidence is available (e.g. flood damage costs)</p>	<p>Provision is principally determined by management practices and proximity to populations</p>
<p>Noise regulation [R]</p>	<p>Amenity value and avoidance of damage/mitigation costs</p>	<p>Limited/no economic value evidence available</p>	<p>Provision is principally determined by proximity to populations</p> <p>In general semi-natural habitats are likely to be associated with higher levels of provision; but local factors particularly important (see Table 3.3).</p>

Table 4.1: Summary of coverage and gaps in ecosystem service economic value evidence

Final ecosystem service	Principal final goods	Coverage of valuation evidence	Importance of forest characteristics in provision
Pollination, seed dispersal and herbivory [R] (production of wild species diversity including microbes)	Agricultural and horticultural products Recreation and tourism, landscape and aesthetic amenity, ecological knowledge Non-use values	Limited/no economic value evidence available	Provision is principally determined by woodland ecology, management practices and biodiversity. In general semi-natural habitats are likely to be associated with higher levels of provision
Generation and maintenance of meaningful places; socially valued landscapes and waterscapes [C]	Recreation Landscape and visual amenity Physical and mental health Education and ecological knowledge	Estimates of non-market benefits of forest recreation widely available, and suitable for many assessments. A particular gap is evident in relation to spatial modelling and accounting for site and context-specific factors (e.g. substitutes), plus also frequency and value of 'causal visits' to peri-urban woodlands Evidence for non-recreation benefits is more dated (landscape and visual amenity) or limited, in terms of scientific links (health) or lack of empirical assessment (education)	Principally public access, proximity to users and management practices

- **Non-wood forest products:** the review of evidence indicates that there is no coherent evidence base as to the value of non-wood forest products that are harvested in Great Britain. In some cases, prices associated with similar products sold in formal markets may provide a proxy value. However, market values for these products will reflect different opportunity costs (e.g. from non-wood forest products that are obtained from foraging). While this is a gap in the evidence base, at a national level the scale of provision of non-wood forest products is likely to be too small to warrant significant attention. At the local level, the benefits can be significant for certain user groups, particularly if commercially exploited by local businesses. Specific products (foods, field sport activities) will primarily differ by woodland ecology and potentially management practices and proximity to populations. Products that are not commercially exploited (i.e. for craft/hobby purposes) may be better associated with cultural services than provisioning services.
- **Genetic resources and bio-prospecting:** in common with the reporting in the UK NEA (Abson et al., 2011), this review finds that there is no economic value evidence concerning the provision of genetic resources from forests and woodlands in Great Britain. The significance of this gap in evidence is dependent upon future evidence needs. For example, if opportunities for bio-prospecting entail significant trade-offs with the provision of other ecosystem services, or if changes in management practices threaten option values associated with genetic resources, then this could create a greater need for value evidence.
- **Reduction of climate stress (climate regulation):** UK Government guidance for valuing changes in GHG emissions is comprehensively provided by DECC (2009; 2010). Overall there is a substantial base of evidence with respect to carbon sequestration rates in woodlands. Average sequestration rates across cycles of planting and rotation are generally taken as appropriate for national scale assessments across all woodlands and forests (as the differences are likely to even out at this scale). The key factor here is to differentiate woodland ecology (coniferous or broadleaved). Site specific assessments, however, would require more considered analysis of wider environmental factors that influence rates of sequestration and emissions, such as where the carbon is stored (biomass, timber products, leaf litter and debris, and soils), differences between tree species, lifecycles of forest products, thinnings, and so on. This implies that in some cases more evidence may be needed on different planting and management strategies. The evidence base is weaker for other GHGs, which depend on site-specific factors. For example recent research has shown that afforestation can lower the water table and contribute to reduced methane emissions (Morison et al., 2010).
- **Soil quality:** the review of evidence suggests that while the soil quality benefits of forests (e.g. water retention, plant productivity and waste remediation) are widely recognised across various studies in qualitative terms, quantitative assessments of the links between supporting and final ecosystem services, the scale of provision and beneficiaries, and the type of economic goods and benefits provided (e.g. potential human health benefits through stabilisation of contaminated land, avoidance of damage costs, etc.) are currently lacking.
- **Air quality:** while well-identified and referenced in qualitative terms, value evidence is limited as to the air quality benefits provided by woodlands and forests. In particular, benefits in terms of reduced human health impacts are largely location-specific and dependent on the scale and proximity of the beneficiary population. This suggests that there is scope to understand better the importance of urban woodland and trees in improving air quality. Supporting analysis for the Defra Air Quality Strategy (IGCB, 2007) and the Clean Air for Europe programme (CAFE, 2005) utilise the ‘impact pathway approach’, linking changes in pollutant emissions and concentrations to human wellbeing impacts, via dose-response

functions, however this evidence has not been linked to the air quality regulation benefits of forests.

- **Water regulation:** available evidence suggests that forestry impacts on water supply and quality can be very uncertain and highly site and catchment specific. The scale of effects can be influenced by management practices and changes in woodland cover as well as practices in other sectors, such as agriculture. Overall there is not a strong base of evidence, particularly given limited quantification of the link between forests and water provision (e.g. in terms of avoided treatment costs). Nevertheless, a number of practical initiatives are being implemented and will, over time, improve understanding of such effects (e.g. the Sustainable Catchment Management Programme (SCAMP) in North West England).
- **Flood protection:** as with water regulation, flood protection is highly location dependent and assessments need to be site or catchment specific to determine the impacts of particular woodland management options on downstream flood risks. A handful of practical assessments are available, based on projects that have been recently implemented (e.g. the 'Slowing the Flow' project, North Yorkshire), and guidance provided by the Environment Agency (2010) for appraising flood risk management schemes provides the basis for valuing flood protection benefits, implying that there is scope to develop supporting assessments of the role of woodlands in reducing flood risks.
- **Recreation:** recreation values represent the most researched non-market benefit of forests and woodlands. The evidence base provides values both for informal and specific recreation activities, which all in all is generally consistent and considered to be robust. Some scope exists for improving understanding of key site specific factors using spatial modelling techniques, such as proximity to populations and availability and quality of substitutes as demonstrated in the case study example developed for this study (Annex 3). Distinctions may also be made between the available valuation evidence, which is characteristic of 'day trips', and casual visits to forests and woodland (e.g. walking dogs, etc. for 30 minutes or so in peri-urban woodland) which are not covered as well in the existing literature. The evidence base that will develop with the MENE survey should enable an improved account of the second type of visits.
- **Landscape and aesthetic amenity:** a number of studies have examined non-market benefits associated with landscape and aesthetic amenity of forests and woodlands. However this evidence is more dated than that for recreation. In general, some broad conclusions can be drawn from this evidence; for example a general preference for 'natural' looking landscapes. However caution is required in relation to the transferability of this evidence, which in some cases is based on specific woodland management options that may not be reflective of practice across the sector.
- **Physical and mental health:** human health and wellbeing benefits associated with the natural environment are widely recognised in qualitative terms. There is also a significant body of value evidence for physical health end points (e.g. from air pollution). The impact-pathways to link these end points to forests are lacking. Evidence for wider health benefits, e.g. mental health, is more qualitative at present.
- **Education and ecological knowledge:** the review notes that education and knowledge benefits associated with woodlands are increasingly recognised but at present empirical evidence is lacking.

4.2 Key challenges in the valuation of ecosystem services

While the ESA approach is continuing to develop, the role for economic valuation of ecosystem services is well-established within it. There are though notable challenges in ensuring its practical application:

- *Scientific understanding*: economic valuation is underpinned by qualitative and quantitative assessments of the change in provision of ecosystem services. While not the focus of this review, it is evident that there are significant gaps in scientific understanding with regards to the processes and interactions that govern the provision of ecosystem service values. As part of the UK NEA, Quine et al. (2011) identify a series of gaps in data, knowledge and understanding with respect to woodlands. These include understanding the impacts of climate change and adaption actions on the provision of some services, and comprehensive data on the extent and condition of broad habitats, particularly semi-natural woodlands, including components of supporting services. More generally though there is the need for mapping of linkages between primary processes, intermediate and final ecosystem services, and the economic goods from which social welfare benefits are derived. Bateman et al. (2011) point out that typically there is limited experience in natural science disciplines as to the information requirements of economic analysis. Uncertainties can particularly arise where natural science is required to predict outside of the range of prior data.
- *Scale over which ecosystem service values are provided*: An aspect of the above problem concerns the challenges of capturing processes which only occur or are only significant at certain scales. Examples here include regulating services, such as the water regulation and purification functions of forestry which are relevant over catchment scales or visual amenity goods which are most relevantly assessed at landscape scales. A significant complication is that derived values might differ substantially at such scales from those obtained at more reduced scales. This makes it problematic to aggregate up (or disaggregate down) from one scale to another. Improved understanding here has a particular relevance to the implementation of PES mechanisms and also the use of ecosystem service value evidence (for example its appropriate application in green accounting exercises).
- *Role of woodland management*: the provision of ecosystem services from woodlands is highly dependent upon management actions. While broad relationships and indicative assessments can be provided within a high level assessment, considerable caution can be required in determining if such generalisations are applicable in individual cases. For example semi-natural broadleaved habitats may offer potential for significant biodiversity benefits, however without appropriate management such opportunities may not be fully realised; indeed greater conservation benefits may arise from actively managed plantations than from unmanaged sites. Overall this emphasises the range of factors that need to be controlled for in attempting to assess and value ecosystem service provision. As pointed out in eftec (2010b) there is a risk from attempting to generalise ecosystem service 'knowledge' of ending up with results that are not reflective of real world management of woodlands.
- *Practical application of economic value evidence*: it is generally recognised that widespread use of value evidence will rely on value transfer, rather than primary studies. However this is dependent upon the adequacy of existing evidence base. Bateman et al. (2011) contend that there is a general absence of high quality valuation studies, particularly with regards to issues such as the impact on ecosystem flow values from the depletion of stocks of natural capital and accompanying threshold effects. It is apparent that the current evidence base is amenable to value transfer in some areas (e.g. recreation), but that in other respects the applicability of valuations is likely to be limited.

- *Non-marginal effects:* as highlighted Section 2.2 non-marginal changes in ecosystem service provision, resulting from threshold effects, can represent a significant challenge for economic analysis, particularly in ensuring that the full implications of such impacts on social wellbeing are captured (e.g. irreversible effects). Such effects are relevant across the range of ecosystem services provided by woodlands and the main issues of concern arise where marginal values are applied to policy decisions that involve non-marginal changes (for example the impact of widespread tree disease, or substantial changes in land use and public access to forests). Here it is important that limitations of the available evidence are recognised and where necessary appropriate evidence is developed.
- *Practical application of the ecosystem services approach:* with any form of analytical framework, data limitations, gaps and uncertainties necessitate the use of simplifying assumptions in assessments that inform decision-making (e.g. in terms of the scale of ecosystem service provision, the extent of the affected population, in the use of value transfer, etc.). When subject to appropriate sensitivity testing such assumptions should not be a significant concern and can signal where improved evidence should be sought. There is, however, a risk that assessments which provide monetary valuations of changes in the provision of ecosystem services convey a false confidence in the results of ESA-based analyses, particularly if reporting and interpretation of results fails to convey the uncertainties associated with impacts on underlying ecological functions. It is vital therefore that practical applications provide a transparent ‘audit trail’ of the qualitative and quantitative evidence that support monetary valuations, along with explicit acknowledgement of the limitations and uncertainties associated with results provided.

4.3. Opportunities for capturing ecosystem service values from UK woodlands

Value capture mechanisms - as reviewed in Section 3.3 - can potentially provide the necessary incentives for woodlands to be managed to provide a wider range of ecosystem services, beyond those that currently provide financial returns (e.g. provisioning services and some cultural services, notably recreation). Indeed the extractive forest industries are already marketed goods which have significant history in the UK, and the main challenge exists in developing mechanisms to maximise benefits from the range of regulating services that woodlands and forest provide.

In a review of PES opportunities and barriers for Defra, Rowcroft et al. (2011) suggest that any afforestation effort will have to compete with agricultural demands at a time when food prices are rising. While this is a valid point in some contexts, it is important to also point out that woodland planting is not necessarily always in conflict with agriculture. For example there can be areas of land that are degraded or of poor quality that are more suitable for planting than other types of farm enterprises. Moreover there are potential synergies between tree cover and agriculture; for instance in terms of shelter for livestock and reducing run-off to rivers.

An indication of potential opportunities for capturing ecosystem service values from UK woodlands is provided in the following:

- *Carbon finance:* currently REDD and REDD+ are restricted to developing countries. Within the EU Emissions Trading Scheme there is currently no provision for trading in carbon from soil or plant sequestration. Thus, the only available mechanism to UK forests at present is through voluntary markets. There are significant markets through which businesses and households with no obligation to reduce carbon footprints can voluntarily do so. The Forestry

Commission's Woodland Carbon Code is intended to provide quality assurance for woodland creation projects in the UK seeking to demonstrate carbon sequestration benefits.

There are no mechanisms which would prevent afforestation in the UK from being traded in voluntary markets. However if market remains voluntary then its potential could be limited. In addition it is important to note that such trading should attempt to abide by the Gold Standard methods set out for REDD schemes since in the future it may become possible to trade these emissions in the larger regulated markets either within Europe or globally. As such it is important that carbon trading forests apply the same standards in order to enable them to move into these markets when circumstances change⁴⁷.

- **Payments for access and facilities:** in terms of more complex or group activities, payments for forest access are already well advanced in the UK; i.e. it is not considered unusual to have to pay for access to a concert in a public forest or for activities such as Go Ape. However resistance can be encountered for charging for more informal access provisions particularly based on cultural motivations; e.g. public rights of way. Larger woodlands and forests with high levels of access however could support infrastructure for paid access. In these circumstances payment need not be linked directly to access the wood itself. Instead the visitors could be charged for facilities provided such as parking. These payments are common and may seem obvious but they are mentioned here to highlight that they are alternatives to payments for direct access.
- **Payments for ecosystem services (beyond carbon):** Payments for ecosystem services could potentially provide significant scope for expansion of funding for forestry. However there are likely to be technical challenges and possibilities for practical application will also be dependent on the development of a regulatory framework. The Natural Environment White Paper (HM Government, 2011) signals that in England pilot schemes will be tested to assess both technical challenges and the formation of a regulatory framework. Technical challenges can be illustrated by considering the case of water provision from woodlands. Crucially the UK is not dominated by a single habitat type but made up of a patchwork of arable and livestock farming, semi-natural grasslands, wetlands and woodlands. Complex hydrological processes moving through all of these structures would need to be mapped and continuously measured. Hence location specific payments for units of water provision or filtering - for example from water companies to land managers - are likely to be challenging⁴⁸. Rather it is more likely that an average value could be calculated for various land cover types and a single payment for a range of services made. Simple models are likely to be possible, for instance providing higher air quality payments for woodlands close to urban centres or major roads.

Currently in the UK payments for land owners are largely linked to biodiversity or access benefits. Environmental Stewardship schemes are funded from direct taxation and through the European Common Agricultural Policy (CAP) and so not directly linked with consumption of any particular service. It is likely that such payments would continue and new ones will be publicly funded (or at least coordinated in the public sector; e.g. via Local Authorities). A

⁴⁷ The Gold Standard requirements are that such projects must be additional, contribute to sustainable development and result in real, measurable and verifiable permanent emission reductions (The Gold Standard, 2009). In comparison, the Woodland Carbon Code requires additionality and refers to its role in sustainable forest management, but does not explicitly set out to promote sustainable development (Forestry Commission, 2011b).

⁴⁸ Note that the landmark catchment management scheme in the UK, United Utilities' SCAMP scheme, takes place on land that is owned by the company, and the payment is linked to land use management practices by tenants (e.g. fencing livestock away from areas close to rivers and streams), not the delivery of some quantified ecosystem service good (e.g. improved water quality).

new ecosystem payment for land owners would require new legislation and could not be restricted to forests but would need to cover all land cover types. The Natural Environment White Paper commits to producing an Action Plan in 2012 “to expand schemes in which the provider of nature’s services is paid by the beneficiaries, after undertaking a full assessment of the challenges and barriers”. Defra is also committed to introduce a new research fund targeted at these schemes and to publishing a best practice guide for designing them (HM Government, 2011).

The future of payments is therefore driven by individual government policy and the future of existing policies such as the CAP. Rowcroft et al. (2011) suggest that expanding and improving the Woodland Grant Scheme presents a potentially viable option for expansion of PES for woodlands. They point out that it would first be necessary to better link payments to specific services. Eligible woodlands could then be targeted to maximise the efficiency of the impact of payments.

- **Competitive ecosystem service contracts:** there is limited practical experience of competitive ecosystem service contracts in the UK⁴⁹, and the Natural Environment White Paper does not explicitly signal that they will be considered within the remit of the 2012 Action Plan. Yet, from the perspective of standard economic efficiency analysis, an important element in the design of a successful mechanism for capturing ecosystem service values is to ensure that any payment is targeted upon the desired final outcome. However in most instances payments for access (and facilities) and biodiversity provision are based on the level of input (e.g. the amount of land) rather than the outcome (e.g. the number of breeding birds). Largely this is the result of the difficulties of measuring ecosystem service outcomes compared to the relative ease of measuring inputs. As noted in Section 3.3, competitive ecosystem service contracts switch the emphasis from input to output measures to overcome information gaps that administrators of PES schemes may face. On this basis this mechanism merits further examination as to its comparative advantages and disadvantages compared to other PES options.
- **Education and Research:** The potential to capture this value largely depends upon education and research budgets. However attempts by forest owners to engage with research and education providers could help to encourage more funding from these sources. Again in the Natural Environment White Paper, the importance of learning outside the classroom is mentioned and Defra is committed to work with the Health and Safety Executive to remove unnecessary rules and other barriers to learning in the natural environment. This may provide a further opportunity for forests too (also see a report to Natural England on this issue by eftec, 2011).
- **Biodiversity offsets / habitat banking:** Because of the typically long gestation period, forest offsets are likely to be amongst the more expensive offsets. However they also provide opportunities where high quality forest offsets could be used to compensate for losses of lower quality habitats. There are still uncertainties about the way in which offsetting will be implemented in the UK. It is also likely that simpler and quicker restoration projects such as grassland or wetlands may dominate the market - at least initially. However there is certainly scope for woodland to be involved in biodiversity offsetting markets.

Potential research needs with respect to PES mechanisms for forests and woodlands are considered in Section 4.4.

⁴⁹ Note that the Forestry Challenge Funds, administered by Forestry Commission Scotland, is allocated on a competitive basis to groups applying for funds to improve existing areas of woodland.

4.4 Recommendations for future ecosystem services priorities

The report concludes by setting out suggestions for future ecosystem services research needs with respect to the evidence base on the value of ecosystem services provided by forests in England, Scotland and Wales.

1. Application of the ecosystem services approach

As an initial conclusion, the significance of the development of the ESA should not be overlooked. The continuing development of a more common language and understanding of concepts related to the natural environment by scientists, economists and other social scientists - which is ably demonstrated by the UK NEA - is encouraging. While there is no definitive ESA 'method', the approach represents a framework within which multi-disciplinary inputs to a developing evidence base can be organised. This establishes the range of impacts that need to be accounted for in decision-making, along with an understanding of key gaps and uncertainties. The approach provides for a transparent process for establishing estimates of economic values, including accounting for potential risks of double-counting by requiring that qualitative and quantitative assessments work towards identifying 'final' services that provide the market and non-market goods that confer economic value to affected populations. This point emphasises that economic valuation is the final step of a multi-disciplinary process. The recent emphasis on the ESA in policy development across Great Britain suggests that ESA will be viewed as a useful and influential tool for the foreseeable future. While it has mainly been utilised at a strategic and national policy level, it can also be of practical use at the local management level in helping forest managers determine the level of provision of different ecosystem services.

*Recommendation 1: the forestry sector should **use the ecosystem services approach** - at both national policy and local woodland management levels - to assess the range of ecosystem service values forests and woodlands provide.*

2. Multi-disciplinary research

Following from Recommendation 1, development of an evidence base of ecosystem service values requires multi-disciplinary research input, from ecologists and other natural science disciplines (e.g. hydrologists), forest management experts, and economists. Future research should combine these areas of expertise and avoid studies that are solely focussed on 'scientific' or 'economic' evidence. Coordinated effort is needed so that the challenges highlighted in Section 4.2 can be adequately addressed.

*Recommendation 2: future ecosystem services research conducted by the forestry sector should incorporate a coordinated **multi-disciplinary assessment of ecosystem service values**.*

3. Building on the UK NEA

The UK NEA represents a starting point for an improved assessment of the contribution of natural environment to social wellbeing across Great Britain. At its heart is the tacit recognition that a holistic assessment is required across multiple systems to fully understand functioning, interactions between, and the importance of ecosystem service provision. From a policy perspective this implies that greater coordination is required in establishing the needs of the

economic valuation evidence base; for example developing a strategic view across forestry, agriculture, flood risk management, planning, etc. as to potential for PES mechanisms. This would appear to be a fundamental requirement for improving the evidence base pertaining to regulating services. This report also recognises that forestry can contribute to wider policy areas, such as health and wellbeing, and opportunities for ‘feeding in’ evidence to wider public policy objectives should also be considered.

Recommendation 3: the forestry sector should engage and coordinate future ecosystem services research with other environmental and public policy areas to enable a comprehensive understanding of the benefits associated with ecosystem service provision.

4. Strategic approach to ecosystem services research

Determining research priorities to fill the gaps identified in Section 4.1 requires an assessment of the likely evidence needs for different decision-making contexts in the coming years. As noted forestry policy objectives can also differ across England, Scotland and Wales requiring different types of value evidence. In general, research could be commissioned in: (i) an ad-hoc policy-orientated approach; (ii) a scientific ‘curiosity’ approach; or (iii) a strategic approach. There are pros and cons stemming from each of these possible approaches and issues concerning coordination and research priorities among funding organisations. However a strong case can be made for the strategic approach (iii) across the forestry sector. An initial step would be to refine expectations as to the key policy issues to be faced, particularly in term of the types of land use management and/or land use change decisions to be faced, at both a national policy and local management level. From this basis it will then be possible to further assess the usability of the current evidence base. While individual research needs can be commissioned separately, a strategic approach should ensure that consistency is maintained across the sector.

Recommendation 4: the forestry sector should develop an ecosystem services research strategy that establishes the key calls on the evidence base in the future. Forestry Commission GB should provide the lead on the strategy.

5. Gaps in the evidence base - provisioning, regulating and cultural services

Taking Recommendations 1-4, a phased approach to future research will ensure that a consistent evidence base is developed. Given that economic analysis can only build on the scientific evidence, priority for new research may initially be focussed on scientific understanding. For updating existing evidence where the science is well understood, economic research should be prioritised. In terms of individual services, there is already have a significant amount of evidence on provisioning services and at present gaps relate to goods (e.g. hardwood and non-wood forest products) for which the scale of provision is relatively minor compared to softwood timber. Provisioning services are therefore are unlikely to a priority for future research.

For regulating services, beyond carbon sequestration benefits it is evident that there is a strong case for developing the evidence base. Research may be best targeted where there is potential for significant aggregate benefits accruing to the forestry sector or to other environmental and public policy areas (e.g. populations benefitting from reduced air pollution impacts, reduced flood risk, improved health status, etc.) and/or potential for capturing ecosystem service values (e.g. via PES mechanisms). Final ecosystem services of particular interest include regulation of other GHGs, air quality, water regulation and flood protection. The most obvious evidence needs

with respect to cultural services relate to non-recreation benefits. Across landscape and aesthetic amenity, physical and mental health, and ecological knowledge there is need to renew evidence that is dated (e.g. landscape) or generate value evidence for benefits currently presented in typically qualitative and anecdotal terms (e.g. health and wellbeing benefits).

Recommendation 5: a *phased research programme* of coordinated research including both public and private sector organisations should be considered.

6. Demonstrating the importance of urban trees

The case of urban trees provides a microcosm of the wide range of forestry policy objectives in terms of contributing to wellbeing and health, climate change adaptation, biodiversity and conservation. At present, evidence concerning the ecosystem service values of urban trees in Great Britain is limited. Further research is needed and can be coordinated with other regulatory stakeholders such as the Local Authorities.

Recommendation 6: the forestry sector should *conduct research on the benefits of urban trees* to demonstrate the range of public policy objectives forestry policy can contribute to.

7. Valuation of biodiversity and stocks of ecosystem assets

Contemporary analyses (e.g. UK NEA, TEEB) highlight the challenges that can be faced in estimating economic values associated with conservation of biodiversity and understanding the value of stocks of ecological assets in light of issues as thresholds and ecosystem resilience. Nevertheless these issues represent a critical element of the understanding of ecosystem service values and at present the available evidence is limited. Further research is needed to examine more coherently the scientific basis for the valuation of biodiversity (i.e. the roles in direct ecosystem service delivery and in underpinning ecosystem service delivery, as well resilience and insurance functions) and the specific challenges in valuation, including accounting for both use and non-use values and methodological issues in the application of valuation methods (e.g. framing effects in stated preference approaches).

Recommendation 7: the forestry sector should *identify policy and research opportunities to contribute to improved valuation of biodiversity.*

8. Application of valuation methods

In designing research studies to address evidence needs on the value ecosystem services, a thorough assessment of the appropriateness of different valuation methods is required. In general the choice of method depends on the decision-making context, ecosystem service(s) of interest, nature of the affected population(s), availability data, and time and resources available. Valuation methods using market price data, production function approaches (e.g. for regulating services) and revealed and stated preference methods should all be considered, along with the potential for integrating geographical information systems (GIS) to better account for the spatial and context specific nature of economic values.

Recommendation 8: valuation of ecosystem service provision in the forestry sector should *consider the appropriateness of all valuation methods.*

9. Further development and application of PES mechanisms

This report highlights a number of approaches towards improving the engagement of the private sector within the provision of ecosystem services. Some of these mechanisms are already in use within other sectors (notably agriculture) and the scope for extending these to the private provision of multi-purpose forestry (including open-access woodland) requires further attention. This could provide a more detailed assessment of the practical application of mechanisms such as the specific factors that determine the provision of ecosystem services from forests and woodlands are appropriately assessed. The aim would be to identify the options that are best suited to the circumstances of the forestry sector.

Recommendation 9: *the forestry sector should commission research on implementing value capture mechanisms that provide the greatest opportunity for engaging the private sector within multi-purpose woodland provision.*

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ANNEX 1: THE EVOLUTION OF FORESTRY POLICY

Origins of the Forestry Commission (1919 - post war years)

The Forestry Commission was established in 1919 to create a strategic timber resource, in response to the limited area of forest in the UK in 1914, the heavy dependence on timber imports, and the huge demand for timber during the First World War. The following 60 years were characterised by an emphasis on land acquisition and afforestation by the FC; whilst private owners were also encouraged to plant trees.

Until 1957 the main aim of forestry policy remained a strategic one: the creation of a national timber reserve. In 1957 the Zuckerman Report stated the strategic need for 'a three-year self-sufficiency of timber' had disappeared with the advent of nuclear warfare, and that users of forestry products should now be actively sought. In 1958 an inter-departmental working party was set up by the Treasury to review the objectives of the forestry programme in Britain. The report of the working party advocated emphasis on economic objectives in forestry, with the rate of return on capital investment in forestry forming the basis of future forest policy. The FC applied commercial criteria: short rotation species, mechanisation of operations, and the marketing of forest products to end-users.

Forestry policy was also linked to land settlement and the economy in rural areas from the inception of the FC. Lord Lovat, the first chairman of the FC, was especially keen on using forestry to develop a stable rural population and prevent undue migration to towns, especially in the Scottish Highlands. A number of forest villages for workers in forests were established by the FC in Britain. In 1950 the FC employed 13,220 people.

During the 1950s planting averaged 24,500 acres per year; and the 1950s, 60s and 70s saw a dramatic surge in forestry output and income, with the FC estate nearly doubling to 1.6 million hectares as mechanisation increased and investment in forestry soared. The private forestry sector was also buoyant: by 1969 it accounted for 40 per cent of total planting, and close to 1 million acres had been dedicated. Timber found a ready market in Britain's new and established wood using industries.

The rural employment argument continued to be strongly advocated by the FC in the 1960s and 1970s, in terms of economic multiplier effects with the rapid expansion of British wood processing industries including the establishment of timber and paper mills in rural areas, even though employment in forestry was declining as a result of mechanisation. Thus by the 1970s, under pressure of the Treasury and a growing domestic wood processing industry, British forestry was highly mechanised and dominated by monocultures.

The early years of forestry policy placed little emphasis on the non-market benefits of forests, other than social aspects of rural employment, and also recreation. There was little concern with respect to biodiversity, perhaps because low intensive traditional agricultural practices during the 1920s and 1930s provided habitats for birds and wild animals in hedge rows, meadowland, farm woodland, and wetlands.

However, the FC was responsible for ancient woodlands, notably the Forest of Dean, and the New Forest; and other forested areas also attracted visitors. In recognition of visitors to these areas, and the importance of these areas in terms of heritage and landscape beauty, the FC created greater access and established National Forest Parks. The Royal Forest of Dean National Forest Park was established in 1938; and others quickly followed [Snowdonia, 1940; Glentworth

(Galloway), 1948; Glenmore (Cairngorms), 1948; Queen Elizabeth NFP, 1951; Border (Kielder), 1955]. The FC worked with amenity groups to provide better access, roads, viewpoints, camping grounds, and accommodation in these NFPs.

The post war years saw an explosion in recreation as increasing numbers of people took holidays and visited the countryside in Britain; and an objective of the forest policy was to increase recreational access to forests. FC forests were increasingly opened up for recreation. For example, in the 1950s the FC allowed camping in the New Forest, and by 1969 300,000 camping permits per year were being issued for the New Forest.

Monoculture and recognition of landscape amenity and conservation of wildlife (1960s - 1980s)

The establishment of monoculture forest plantations had a dramatic impact on the landscape which led to increasing public concern about environmental impacts of this policy in some areas. The Forestry Act 1967 consolidated Forestry Acts between 1919 and 1963. But whilst the main objective of the 1967 Act was still afforestation and the production of timber, in that it charged the Commissioners with “the general duty of promoting the interests of forestry, the development of afforestation and the production and supply of timber and other forest products” [Part 1, Section 1(2)]; the Commissioners were required to endeavour “to achieve a reasonable balance between (a) the development of afforestation, the management of forests and the production and supply of timber, and (b) the conservation and enhancement of natural beauty and the conservation of flora, fauna and geological or physiographical features of special interest” [Part 1, Section 1 (3A)].

Even before the 1967 Act there were voices in the FC expressing some concern about the effect of monoculture forest planting on the landscape and wildlife. There was particular concern in the Lake District about the impact of forest plantations on landscape. In the 1970s the public’s awareness of access and recreation needs also grew, along with landscape and conservation considerations. In response, the public were given a ‘right to roam’ in FC forests; and more emphasis was placed on the design of forests in relation to the landscape.

From the 1970s, conservation and amenity issues became more central in FC planning and forestry policy. In 1972/73 there was a major review of policy, which concluded that, as a purely financial investment, forestry had a low yield of about 3% on capital at the margin. The review concluded that the case for new planting, whether in state forests, or with financial aid in private forests, rested mainly on social benefits: improved employment, landscape, and recreation (HM Treasury, 1972).

Landscaping began to be considered on a far wider scale, resulting in woods which were aesthetically pleasing as well as productive; and greater recognition was given to maintaining woodland character, and recognising the importance of broadleaves. Forests were identified as important wildlife reserves, and conservation became a special responsibility in forestry management. Facilities for recreation also steadily developed.

The 1980s were years of change and challenge. In the early 80s recession hit timber users, pulp mills at Fort William, Ellesmere Port and Bristol closed. The FC policy response was to develop export markets, and for a period some 500,000 tonnes of timber a year were being shipped abroad - much to Scandinavia.

During the 70s and 80s the focus for afforestation switched to the private sector with tax incentives playing a major part in encouraging the creation of new commercial forests,

particularly in the uplands. However, the damage to upland ecosystems, such as peat and heather moors, as well as public's dislike of the use of private forestry as a tax avoidance measure by the rich, led to a change in policy. The 1988 Budget removed the tax incentives for forestry, with private planting being encouraged instead through Woodland Grant Scheme (WGS). In the same period a role for forestry in agricultural adjustment was identified and additional incentives for farm woodland planting were introduced. The environmental and social roles of forests thus became an increasingly important element of policy.

Multi-purpose forestry objectives and devolution (1990s to present day)

In seeking to achieve a reasonable balance between the needs of forestry and environment, the concept of multi-purpose forestry had become firmly embedded in forestry policy by the beginning of the 1990s. Recreational and biodiversity benefits of woodlands became more prominent in policy objectives. In the early 1990s HM Treasury allowed the FC to include non-priced recreational benefits of forests in its calculation of the IRR on forest investment.

Forests have long attracted visitors to see charismatic wildlife, ever since the Loch Garten RSPB Osprey Centre was opened in 1959 in Abernethy Forest Reserve, Strathspey. The 1980s and 1990s saw a much greater policy emphasis on wildlife, not only in relation to birds (e.g. peregrine falcons at Symonds Yat (Forest of Dean) 1984; Red Kite centre at Rockingham Forest, Northamptonshire, 2001) but also red squirrels, and other woodland creatures.

The major policy shift in the 1990s was the recognition of the contribution of forests to mitigating against climate change. Under the Kyoto Protocol (1997) on climate change mitigation, the contribution of forests to reducing climate change through carbon sequestration can be included in achieving UK target emission levels⁵⁰. Thus carbon sequestration became a forestry policy objective.

More recently, in the 2000s, there has been a progressive differentiation of forestry policy within the UK reflecting the devolution of government; with England, Scotland and Wales each taking responsibility for their own forest policy from 2003. This has led to some differences in priorities for forestry between the three countries, although the range of objectives remains consistent. Forestry policy has four main multi-functional objectives:

- Forestry for rural development: forestry's contribution in the wider countryside including the contribution of both new and existing woodlands to the rural economy, timber and marketing opportunities and its contribution to upstream and downstream job creation.
- Forestry for economic regeneration: forestry's role in strategic land use planning including the restoration of former industrial land and creating a green setting for future urban and urban fringe development.
- Forestry for recreation, access and tourism which focuses on providing more and better public access to woodlands, ensuring that woodland and forests continue to be used for a wide range of recreational pursuits as well as complementing and supporting the tourist industry.
- Forestry for the environment and conservation: embracing the role that woodlands play in conserving and enhancing the character of our environment and in delivering the government's objectives for nature conservation, biodiversity and climate change.

⁵⁰ The Kyoto Protocol allows verifiable changes in carbon stocks through afforestation, re-afforestation, and de-afforestation since 1990 to meet commitments under the Protocol through the Clean Development Mechanism (CDM).

ANNEX 2: TYPOLOGY OF FOREST CHARACTERISTICS

The table below presents an adapted ‘long-list’ of factors that encompass a wide range of forest characteristics, sourced from eftec (2010b), which include a mix of environmental, geographic and management factors.

Table A2.1: Long-list of forest characteristics

Forest characteristic	Notes
Woodland ecology (vegetation type): broadleaved/coniferous/mixed/open habitat/other	<p>The UK BAP broad classification distinguishes between ‘Broadleaved, mixed and yew woodland’ and ‘Coniferous Woodland’. ‘Open habitat’ is increasingly seen as important for biodiversity/conservation reasons.</p> <p>The FC reports and data typically distinguish between broadleaf and conifer and several valuation studies have adopted this split (see Hanley et al. 2002 and Willis et al. 2003).</p>
ASNW, PAWS, OSNW	These characteristics reflect whether or not woodland is ancient and/or semi-natural, both being important for biodiversity and cultural services.
Ancient/secondary	A forest is ‘ancient’ if it is 400 years or older, otherwise it is a ‘secondary’ forest. A number of studies have utilised an ancient/secondary split (see Hanley et al. 2002 and Willis et al. 2003). Watson and Albon (2010) however note that 80% of woodland in the UK is less than 100 years old.
BAP priority habitats	Presented in eftec (2010b) as a binary indicator: high biodiversity priority or not biodiversity priority.
Tree species	In a broad-scale assessment the most important distinctions between species can be captured via the broadleaf/conifer distinction and the biodiversity priority category. Categorising species individually would lead to an excessively large typology.
Age/class	Age/class of trees is particularly relevant for timber production and greenhouse gas storage functions. In a broad-scale assessment age and class are likely to average across forest types. This would likely need to be considered in individual site-specific assessments.
Upland/lowland	A number of studies have utilised an upland/lowland split (see Hanley et al. 2002 and Willis et al. 2003). This split could be somewhat arbitrary but could still be useful primarily as a combined proxy for environmental characteristics such as soil type, temperature and wind.
Alternative habitats; soil type	<p>Practically accounting for soil type in a basic typology is difficult; however woodland vegetation (ecology) is correlated with soil, while biodiversity considerations will also in part reflect this.</p> <p>Soil type is also an important consideration for afforested bogs.</p>
Slope and aspect	At a very local scale slope and aspect will influence the provision of ecosystem services, although they can vary greatly within a forest unit. In a broad-scale typology these factors cannot be taken into account, but would likely need to be considered in individual site-specific assessments.
Location and size	<p>A key aspect of some ecosystem services is that they may be regarded (in general) as size and location independent; i.e. if their provision and value can be expressed in ‘per hectare’ terms (e.g. carbon sequestration).</p> <p>Other ecosystem services however are size and location specific, accruing ‘per forest’ or in a non-linear relationship with size. There can also be threshold effects (e.g. a minimum size to support a viable population of some bird species).</p>
Setting (urban/peri-urban/rural)	Proximity to population is an important indicator for different types of use values (e.g. beneficiaries from catchment level regulating services, cultural services in terms of visitor population).

Table A2.1: Long-list of forest characteristics

Forest characteristic	Notes
Availability of alternatives	The presence of alternatives does not influence the physical provision of ecosystem services from a particular forest. However the availability of alternatives (substitutes) is a significant influence on the <i>value</i> associated with some ecosystem services (e.g. recreation). This would also be correlated with scale and location.
Management practices	Long-term forest strategies provide an indication of the provision of ecosystem services. However actual management practices may differ from objectives and can be highly site specific (for example in terms of rotation and harvesting) and dependent aspects such as proximity to populations and access and facilities (if any).
Certification	Approximately 1.3 million hectares of woodland in the UK were certified under the Forest Stewardship Council (FSC) in 2009 (around 45% of the total UK woodland area). These woodlands are managed in particular ways that enhance the provision of certain ecosystem services that are related to biodiversity.
Ownership	Ownership type and funding form a central part of the typology used in Cogentsi and PACEC 2004. However a particular issue is that many estate woods under leasehold may act like private woods due to a legal restriction on access (however this captured under the 'public access' indicator).
Public access	The availability of public access is a key indicator for the provision of recreation and other cultural services.
Facilities and accommodation	The presence of facilities and accommodation is an indicator for recreation and other cultural services. Major recreation centres with accommodation (cabins and campsites) may need to be considered as special cases.

Notes: ASNW (Ancient Semi-Natural Woodlands); restored PAWS (Plantations on Ancient Woodland Sites: ancient, but not semi-natural unless restored) OSNW (Other Semi-Natural Woodlands: semi-natural, but not ancient).

Source: adapted from eftec (2010b).

ANNEX 3: CASE STUDY - RECREATION VALUE OF ESTABLISHING NEW URBAN FRINGE WOODLAND

Introduction

This case study considers a scenario in which 100 hectares (ha) of farmland is converted into a recreation-focussed, urban fringe, woodland site. The aim is to test the approach for valuing recreation developed and demonstrated in the UK NEA by Sen et al. (2011). The analysis provides a useful counterpoint to the approach applied in eftec (2010b) which derived per hectare recreation values based on available evidence for recreation benefits and visitor numbers (**Box A3.1**).

Box A3.1: The economic contribution of the public forest estate in England

eftec (2010b) sets out a methodology for a broad assessment of the social, economic, and environmental contribution to public benefit of the public forest estate (PFE) managed by the Forestry Commission (FC) in England. Included within this is the use of value transfer to estimate the benefits of the provision of recreation facilities. Based on available literature the following values per visit are assumed:

- 'High facilities' woods and forests: £12.50 per visit; and
- 'Low facilities' woods and forests: £2.50 per visit.

Using data provided by FC England, the analysis assumes visits range from 74 visits per hectare per year for rural woodland with low facilities, to 400 visits per hectare per year for peri-urban woodland with high facilities, and 1,145 per hectare per year for urban community woodlands. Combining this with the area covered by each woodland type, the following value per hectare estimates are calculated:

- Urban community woodland: £2,850 per ha per year;
- Peri-urban, high facilities: £4,000 per ha per year;
- Peri-urban, low facilities: £400 per ha per year;
- Rural, high facilities: £2,400 per ha per year; and
- Rural, low facilities: £180 per ha per year.

In aggregate these figures result in a total estimate of around £160m per year for recreation in the PFE, or about £740 per hectare per year. Notably this is higher on a per hectare basis than implied by previous estimates (e.g. Willis et al., 2003 as part of the SEBF), although this is expected since eftec (2010b) applied higher values per visit, which in part is based on higher values reported in Christie et al. (2005) (see Section 3.2.3).

eftec (2010b) notes that there are significant reservations about using values per hectare for recreation benefits. In particular neither visit numbers nor per visit values are linearly related to forest size, but rather both diminish rapidly once a forest reaches a certain size. Moreover the number of visitors also diminishes rapidly as distance from population increases (the 'distance decay' effect - see the Jones et al. (2010), Bateman et al. (2006)). It suggests that a spatial analysis in a GIS framework, taking explicit account of location and substitute sites, would be the preferred approach.

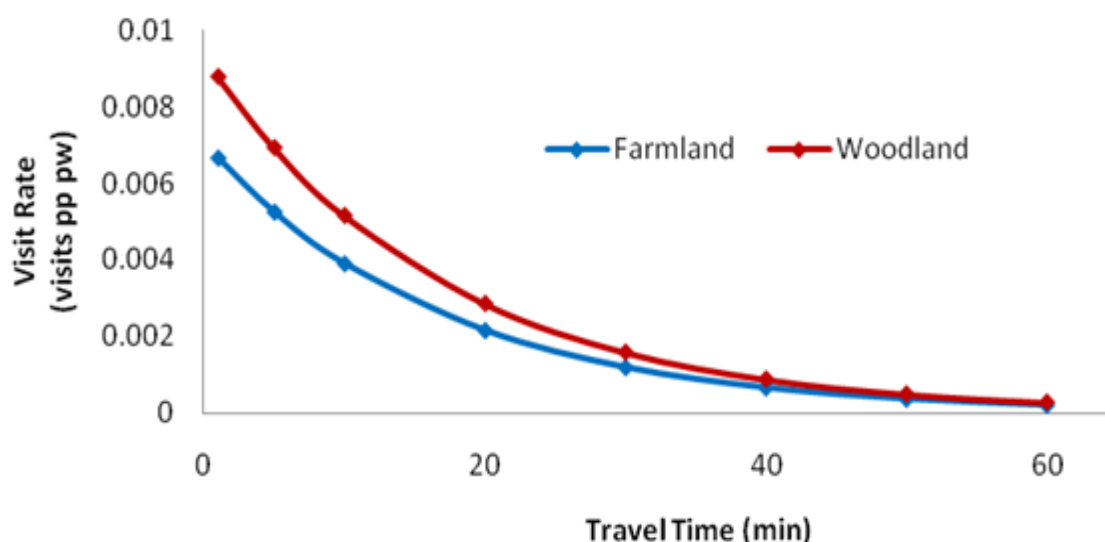
The approach presented in the UK NEA features a trip generation function (TGF) that is used to predict recreation visits to various habitat types, including coastal and marine, urban, freshwater, grassland, enclosed farmland, and mountain (see **Appendix A**). It enables the

estimation of visit numbers to a given site from a specified outset area; i.e. where visitors start their journey from, typically defined in terms of a Census lower super output area⁵¹.

The UK NEA methodology considers all feasible outset areas (including up to, if desired, all of the UK). This approach has certain advantages, since it means that along with characteristics of the destination site (e.g. woodland, farmland, etc.), the characteristics of each separate outset area can be controlled for in the analysis. These include: (i) the travel time and cost from each potential outset area to the destination site; (ii) the availability of substitute recreational resources; and (iii) a selection of household socio-economic characteristics (including income).

To provide an illustration of the TGF results, **Figure A3.1** shows that, at almost any travel time, woodland is significantly more attractive to recreational visitors than enclosed farmland. However, the strong influence of travel time shows that both land uses become relatively less attractive for visits the further away a site is from an outset location, demonstrated by the decline in visit rate (per week) as travel time increases.

Figure A3.1: TGF predictions - travel time impacts on visit rate for woodland and farmland sites (Sen et al., 2011)



Source: Sen et al. (2011) and the SEER project.

Figure A3.1 therefore shows the classic ‘distance decay’ effect. This means that the site location is a significant determinant of the number of visitors that are attracted to the area. An implication of this is that urban fringe woodland sites close to large populations are likely to attract more visitors than similar sites with similar facilities located in more remote areas.

Identifying a case study site

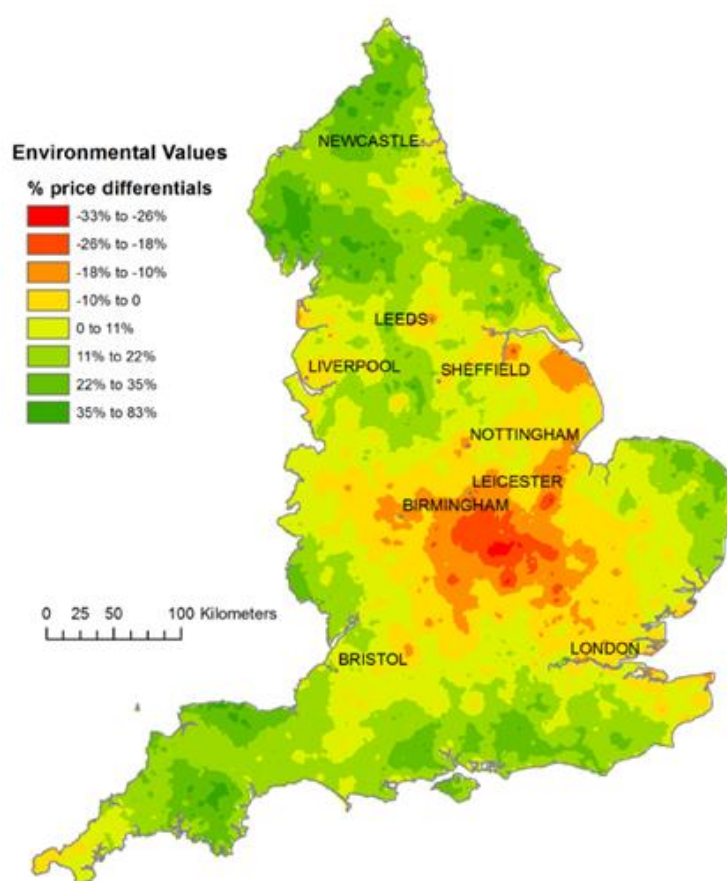
Prior work (e.g. Jones et al., 2010) shows that locating recreational resources in areas which already have large number of substitute sites is unlikely to provide a clear demonstration of the potential impact for gains from such policies. Therefore this case study focuses on an area with demonstrably relatively poor environmental resource availability. Such a site is provided by the analysis of environmental amenity values undertaken by Mourato et al. (2010) as part of the UK

⁵¹ Lower super output area (LSOA) is a geographical area designed for the collection and publication of small area statistics. They have a minimum population of 1,000 (mean average population across all is 1,500). In England and Wales there are 34,378 LSOAs.

NEA. Mourato et al. undertake a hedonic property pricing analysis to predict house price differentials that can be attributed to variations in the level of environmental amenities across England. This is achieved by holding constant the difference in house types and non-environmental characteristics across areas and only looking at the impact on house prices arising from variations in environmental quality.

The resulting predictions show the variation in prices (around the mean house price value) in England that arise due to variations in environmental quality. The results are mapped in **Figure A3.2**. Areas in which environmental quality has the strongest positive impact on house prices are shaded in green, while negative impacts are shown in red. Given that the mean house price in 2008 was just under £200,000, this implies that in areas of the highest environmental amenity values, implicit prices were up to £68,000 higher than the average. Annualised over a long time horizon, this is equivalent to nearly £2,000 per year using the Green Book (HM Treasury, 2003) discount rates. The highest values are seen in areas such as the Lake District, Northumberland, North York Moors, Pennines, Dartmoor and Exmoor.

Figure A3.2: Geographical distribution of environmental value (predicted price differentials from property value regressions)

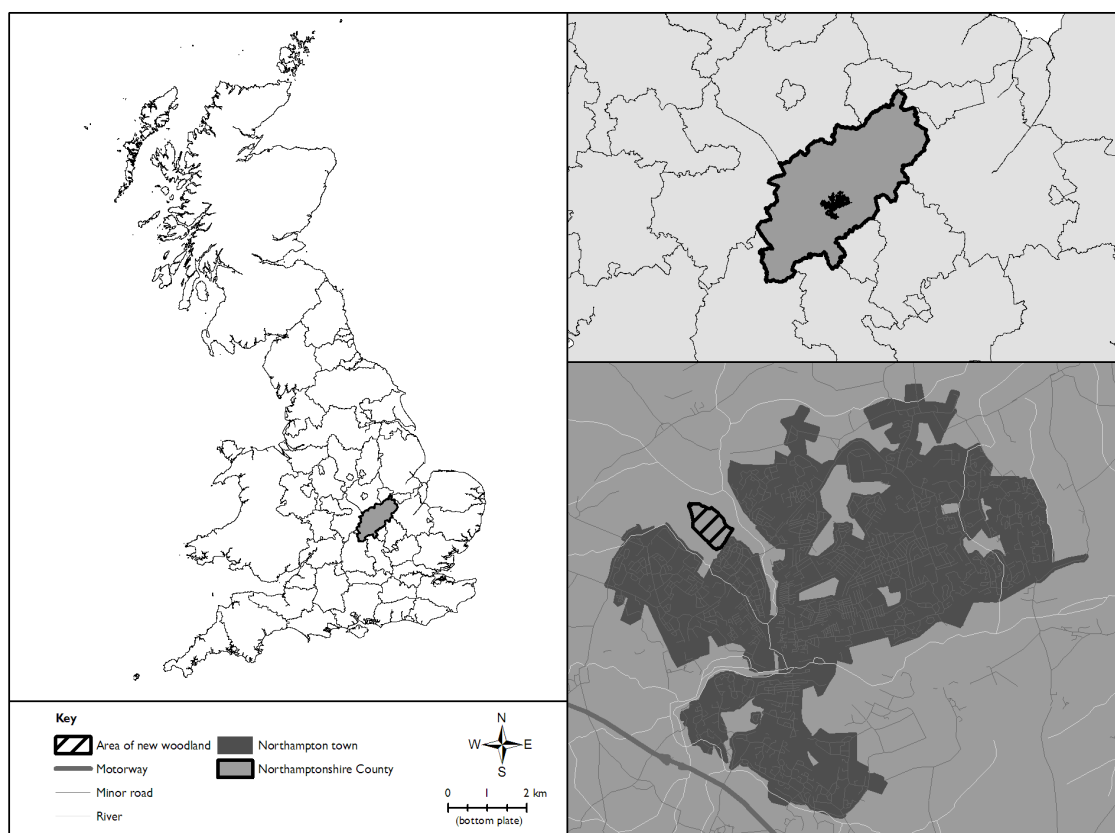


Note: % price differentials are based on log price differentials, and correspond to maximum % differentials relative to the national mean price level. Source: Mourato et al. (2010).

Based on Figure A3.2, the town of Northampton (the centre of the red area in the figure) can be suggested as an appropriate case study site. Examining this area in detail, it is possible to identify a potentially suitable site, which would be an area currently under agricultural use, very close to the city centre and surrounded by developed land on three sides (housing and industrial

use). Such an area is shown in **Figure A3.3** which features some woodland and a golf course to the north. The site ('area of new woodland') is 100 ha (1 km²).

Figure A3.3: Location of case study site, urban fringe of Northampton



Notes: Centre-point located at Easting: 473117, Northing: 263422.

Predicting visitor numbers

Based on the characteristics of the case study site, the TGF can be applied to predict the annual number of visitors that would arrive at the new woodland⁵². The TGF is applied to predict visitor numbers for the baseline situation (without the woodland site) and for the scenario with the woodland. The estimated change in the number of predicted annual visits to the case study site is presented in **Figure A3.4**.

⁵² The total number of visits per annum is calculated by calibrating the predicted weekly visits obtained from the TGF to data for total estimated visits for outdoor recreation in England reported in the MENE survey (Sen et al., 2011). Estimated visit numbers are generated for the 5km × 5km cell in which the 100 hectare woodland site is located.

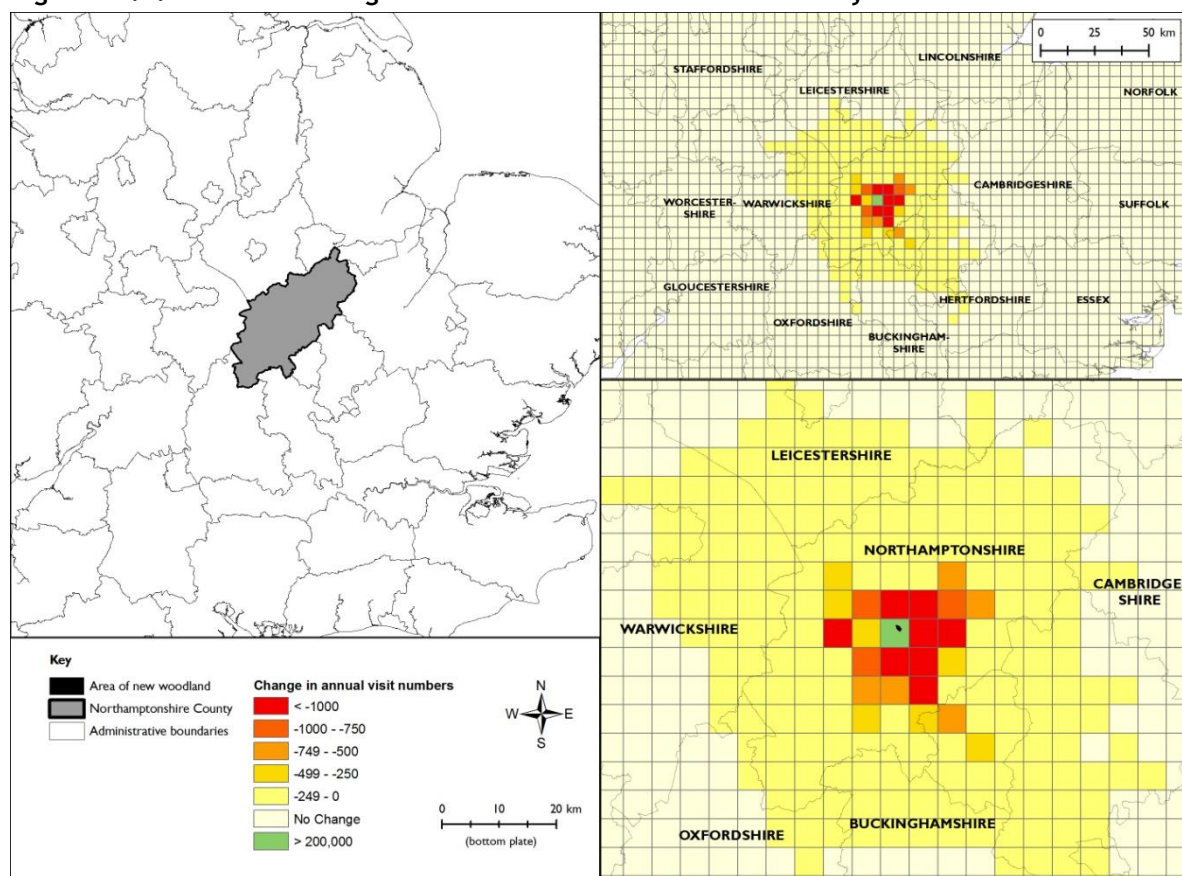
Figure A3.4: Estimated change in annual visit numbers to case study site

Figure A3.4 shows that visits to the 5 km × 5 km cell that contains the new 100 hectare woodland site increase by approximately 215,000 per year. The analysis also predicts a small decline in visit numbers to surrounding 5 km × 5 km cells due to substitution effects; i.e. visits that are transferred to the new woodland site from other sites in the local area.

Valuing the change in recreation visits

Sen et al. (2011) undertake a meta-analysis of over 100 valuation studies encompassing methods ranging from travel cost analyses (that examine visit behaviour relative to the costs of trips) to stated preference methods (which use surveys to directly elicit visitors' valuations) (see **Appendix B**). The meta-analysis model estimated by Sen et al. explains recreational values obtained from the various studies as a function of: (i) the characteristics of the recreational site being valued (i.e. whether the site is a mountain, freshwater lake, grassland etc. and whether the site is designated or not); (ii) the characteristics of the studies used in the meta-analysis (e.g. the sample size, whether substitute sites were considered, the valuation methods used, etc.); and (iii) the characteristics of the country in which the study sites are located (e.g. population density). To enable comparability across studies, the value estimates from non-UK studies are adjusted using a purchasing power parity index and all estimates are converted to consistent UK £ (2010) prices.

The results indicate that a recreational trip to woodland generates a higher value than a trip to a farmland site. Applying the model to estimate the value of visits to the new woodland site gives

an estimated mean WTP of £3.20 per visitor per trip. Over 215,000 visits per year this equates to an annual recreation benefit value of approximately £0.69 million per year⁵³.

For the purpose of sensitivity testing, the Sen et al. estimate can be compared to values reported in previous studies and also the ‘per hectare’ approach applied in eftec (2010b)(Box A3.1). For example, Bateman and Jones (2003) in their meta-analysis of the informal recreational value of woodlands estimate WTP values between £0.12 - £5.04 per visitor per trip (in 2010 prices). Similarly Scarpa (2003) reports values in the range £2.00 - £3.20 per visit (in 2010 prices). Table A3.1 provides a comparison of estimated annual benefits.

Table A3.1: Comparing estimated benefit values

<i>Source</i>	<i>Unit value (2010 prices)</i>	<i>Estimated annual benefit</i>
Sen et al. (2011)	£3.20 per visit	£0.69m
Bateman and Jones (2003)	£0.12 - £5.04 per visit	£0.03m - £1.09m
Scarpa (2003)	£2.00 - £3.20 per visit	£0.42m - £0.70m
eftec (2010b)	£400 - £4,000 per hectare	£0.04m - £0.40m

Based on Table A3.1, the annual benefit value estimate using the Sen et al. meta-analysis model is comparable to high end estimate using Scarpa (2003) results, and a ‘mid-point’ estimate based on Bateman and Jones (2003). Comparison to the eftec (2010b) estimate provides an interesting result; while the unit value is much higher in eftec (2010b), the predicted number of visits is much lower. That is, explicitly controlling for site characteristics, travel distance, substitute availability and socio economic factors yields a higher total benefit estimate. Depending on woodland type the assumed number of visits ranges from 75 - 1,145 per hectare in eftec (2010b); the implied figure for the new woodland site using the TGF is 2,150 visit per hectare.

The key caveat to the comparison of the eftec (2010b) approach and that of the UK NEA is that - using the empirical findings of Mourato et al. (2010) - the case study selects a site location that has relatively poor environmental resource availability. It represents an ‘extreme’ case where the benefit of establishing a new woodland site is likely to be significant. Therefore it is reasonable to expect that the eftec (2010b) approach will under-estimate potential benefits in these circumstances given that is based on ‘average’ visit rates across the entire public forest estate. Overall this comparison ably demonstrates the point highlighted in Section 2.2.1 of the main report that ecosystem service values are context-specific and determined by a range of spatially dependent factors.

Comparing costs and benefits of establishing a new woodland site

In practice comparing the various annual benefit estimates presented in Table A3.1 is only informative to a certain point; i.e. emphasising that estimating visit numbers is as equally

⁵³ This is likely to represent a slight over-estimate of *net* benefits since it does not account for visits that are transferred from other sites in the local area (see Figure A3.4). However the substitution effect is relatively small compared to the additional visits that are generated. Furthermore as the meta-analysis model results demonstrate, woodland trips are valued relatively highly compared to most other habitats, so even the individual ‘transferred’ visits will receive higher benefit from woodlands than the previous location.

important as the actual unit values that are applied when estimating benefits. The practical significance of this issue, and the importance of assumptions made in light of limited information availability, should be assessed by considering the wider decision-making context. For instance sensitivity in benefit estimates can be compared to indicative costs of woodland establishment to determine the accuracy and ‘weight of evidence’ required to support decision-making.

The costs of woodland establishment range between £7,000 - £10,000 per hectare in England, depending on woodland type and various other factors such as the stocking density of trees⁵⁴. Note that this is based on Forestry Commission woodland establishment costs (but it is assumed to be indicative of private woodland establishment costs) and covers various activities required over the first 5 years of operation. It does not include the cost of land purchase.

The RICS Rural Land Market Survey reports that the current national average price for farmland transactions is approximately £7,500 per acre (about £18,500 per hectare), while the assessed ‘bare’ land value is approximately £6,100 per acre (about £15,000 per hectare)⁵⁵. Using the lower of the two values, this gives an indicative total land purchase cost of approximately £1.53 million for 100 ha. Adding in the cost of woodland establishment gives an estimated total (undiscounted) cost for the site of between £2.5 million and £3 million.

Comparing the indicative cost to the results in Table A3.1 suggests that the recreation benefits *alone* from the new woodland site would ‘pay back’ the land purchase and establishment costs within a maximum of 15 years (assuming that visits commence in year 5 following initial woodland establishment actions). Specifically the ‘pay back’ period is 10 years if the Sen et al. estimate is used (approximately £3.3 million present value over 10 years); 8 years if Bateman and Jones (2003) estimate is used (£3.6 million present value over 8 years) and 14 years if the eftec (2010b) estimate is used (£3.0 million present value over 14 years). Overall the comparison of estimated benefits (based on the range of sources) to indicative costs suggests, on cost-benefit grounds at least, there is a strong case for woodland establishment, particularly given that wider benefits (e.g. potential carbon sequestration gains) are not considered.

More generally, the case study provides further and explicit recognition of the substantial non-market values that can be derived by local populations from woodlands. This emphasises the need for decision-making at both the local and national to take account of all ecosystem services (market and non-market) that arise from land use management options.

⁵⁴ Pers. Comm. J. McVey (Forestry Commission), July 2010.

⁵⁵ See RICS Rural Land Market Survey (2011):

http://www.rics.org/site/download_feed.aspx?fileID=10220&fileExtension=PDF

Note that these values may over-estimate the unit cost of land purchase, since forest planting tends not to happen on high quality agricultural land. The bare land value excludes the residential element of farmland.

ANNEX 3 - APPENDIX A

Trip generation function: Predicting visit numbers from an outset location to a site destination

Variable	Variable definition	Coefficient	z
Travel time from a LSOA/DZ to a site	Time from population weighted centroid of LSOA or DZ to destination cell geometric centroid	-0.1753***	(-163.03)
Coast substitute availability		-0.0210***	(-5.98)
Urban substitute availability		-0.0226***	(-28.46)
Freshwater substitute availability		-0.1085***	(-7.00)
Grassland substitute availability	Percentage of habitat (NEA definitions) within 10 km radius of outset point. Outset taken as pop w centroid of LSOA or DZ.	-0.0204***	(-7.64)
Woodland substitute availability		-0.0212***	(-8.60)
Other marine substitute availability		-0.0057***	(-4.81)
Mountain substitute availability		0.0088	(1.80)
% of coast in site		0.0050*	(2.84)
% urban in site		-0.0064***	(-11.28)
% of freshwater in site		0.0196***	(7.11)
% of grasslands in site	Percentage of habitat (NEA definitions) within each 1 km cell (estimation) and 5 km cell (prediction).	0.0023	(1.72)
% of woodlands in site		0.0082***	(7.45)
% of estuary and ocean in site		-0.0282***	(-17.70)
% of mountain & heath in site		0.0251***	(9.00)
% non-white ethnicity		-0.0051***	(-5.20)
% Retired		0.0068***	(3.63)
Median Household Income		0.0000117***	(11.55)
Total Population of outset area		0.000277***	(6.92)
Constant		-1.122***	(-12.33)
Insig2u			
Constant		-0.705***	(-19.31)
Observations		4139440	

Notes: The dependent variable is the number of visits from a specified small area Census unit (LSOA in England and Wales; DZ in Scotland) to a specified site.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The substitute availability variables are calculated as the percentage of a specified land use type within a 10km radius of the outset point.

Enclosed farmland is taken as the base case for both the 'substitute availability' and 'site' characteristic variables.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: $\log \sigma^2_{2u}$ = natural logarithm of the variance of the random intercept term in the multilevel model. The random intercept term captures the unobserved heterogeneity between the different sites.

Estimated using a Multilevel Poisson regression model

Source: SEER project (n.b. the TGF reported above is an updated version of the results reported in Sen et al., 2011)

ANNEX 3 - APPENDIX B

Meta-analysis (MA) model of recreational value estimates (£, 2010) (Sen et al., 2011)

Variable	Variable definition	Coefficient	t-stat
Good characteristics¹			
Mountains & heathlands	1 if recreational site valued is mountain or heath; 0 otherwise	1.771*	(1.834)
Grasslands, farm & woods	1 if recreational site valued is Grasslands, farm and woodlands; 0 otherwise	0.579*	(1.886)
Freshwater, marine & coastal	1 if recreational site valued is Freshwater, marine & coastal; 0 otherwise	0.222	(0.763)
Designated site	1 if recreational site holds some official designation; 0 otherwise	0.0225	(0.121)
Study characteristics			
Published	1 if study published in peer-reviewed journal or book; 0 otherwise	0.133	(0.468)
Survey year	Discrete variable: 1 = published in 1975, to 29 = published in 2008	0.0360	(1.364)
Log sample size	Logarithm of sample size	-0.493**	(-2.143)
in-person interview	1 if survey mode is in-person; 0 otherwise	0.130	(0.469)
Use value only	1 if use value study; 0 otherwise	0.372*	(1.787)
Substitutes considered	1 if substitute sites included in the valuation study; 0 otherwise	-0.117	(-0.570)
Valuation unit²			
Per household per year	1 if value in terms of per household per year; 0 otherwise	2.825****	(8.583)
Per person per year	1 if value in terms of per person per year; 0 otherwise	2.090****	(6.251)
Other valuation unit	1 if value in terms of per household/person, per day/ month; 0 otherwise	2.101****	(4.648)
Valuation method³			
RPM & mixed valuation	1 = revealed preference or mixed valuation methods; 0 otherwise	1.494**	(2.335)
Open-ended format	1 = stated preference using open-ended WTP elicitation format; 0 otherwise	-0.363*	(-1.838)
Payment vehicle-tax	1 = payment vehicle is a tax; 0 otherwise	0.351	(1.316)
Study country characteristics			
Log of population density	Population density of state/country in which the site is located	0.360	(1.206)
Non-UK countries ⁴	1 = study conducted overseas; 0 otherwise (UK)	1.193***	(3.215)
Constant		-0.110	(-0.123)
Observations		193	

Dependent variable is logarithm of recreational value (WTP or consumer surplus) (£, 2010)

1. Omitted land use base case = urban environments

2. Base case for valuation units is per person per visit

3. Base case for valuation method is close-ended stated preference methods

4. Non-UK countries considered: North America, Western Europe, Australia and New Zealand.

Estimated using OLS with Huber White standard errors * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$