Europe Economics

The economic benefits of woodland

A report for the Woodland Trust prepared by Europe Economics

January 2017

WOODLAND TRUST

Contents

Europe Economics is registered in England No. 3477100. Registered offices at Chancery House, 53-64 Chancery Lane, London WC2A 1QU.

While every effort has been made to ensure the accuracy of the information/material contained in this report, Europe Economics assumes no responsibility for and gives no guarantees, undertakings or warranties concerning the accuracy, completeness or up-to-date nature of the information/analysis provided in the report and does not accept any liability whatsoever arising from any errors or omissions.

© Europe Economics. All rights reserved. Reproduction is authorised provided the source is acknowledged.

January 2017.

1. Executive Summary

Forest cover in the UK was three million hectares in 2013, considerably lower as a share of land area than in other EU Member States such as France and Germany. Increasing the level of woodland cover to meet or exceed current targets will depend on a large number of decisions based on individual plans to plant more trees or protect those which are already there. The broad range and nature of the benefits associated with woodlands might mean that their full value is not understood and reflected in important decisions.

Our objective is therefore to consider as comprehensive a range of benefits associated with trees and woodlands as possible. We consider benefits under three categories:

- **Direct use value.** Enjoying goods and services produced by or in woodlands:
  - Business. Producing goods and services with a market value, such as timber – output of forestry goods tends to increase by over £200 a year with each additional hectare of woodland; and
  - Recreation. Visiting woodlands – there are 700 visits for every hectare of woodland valued at £1 to £3.50 per visit.
- **Indirect use value.** Benefiting from positive externalities provided by woodlands:
  - Flood management. Reducing the extent of damage in floods – the potential value in terms of flood risk reduction of managing a hectare of woodland located in the upper Thames catchment could be £350 to £500 per hectare, per year;
  - Health benefits. Particularly improving air quality – air pollution mitigation benefits in urban areas have been estimated at around £240 a year for each hectare of woodland;
  - Water management. Improving water quality – estimated to provide €489 in benefits for each hectare in a Danish study; and
  - Aesthetic value. Seeing trees, either at home or while travelling – commuters value views of woods at £227 a year and views of woodlands near cities from their homes at £268 a year.
- **Non-use value.** Appreciating goods and services that woodlands may provide to others or in the future:
  - Climate change mitigation. Reducing the extent of global climate change – at the current official carbon price, the value of the carbon dioxide locked up in UK woodlands is around £16,000 per hectare; and
  - Option, existence and bequest value. Safeguarding woods and their associated biodiversity for future generations – valued at, for example, £1,848 per hectare, per year, for lowland broad-leaved native forest.

On those values, and excluding flood and water management benefits and health benefits beside air pollution mitigation, the **total value of UK woodlands is around £270bn**.

There are a range of areas in which trees and woodlands might in themselves, or as part of a mix of policies, compete against other options which do not have the same wider benefits or might even have wider disbenefits. Those areas range from flood defence, to rural regeneration, to facilitating housing development. It might be easy for an appraisal process which did not include any or all of the wider benefits and disbenefits to allocate fewer resources to trees and woodlands than would be optimal given a more complete consideration of their effects.

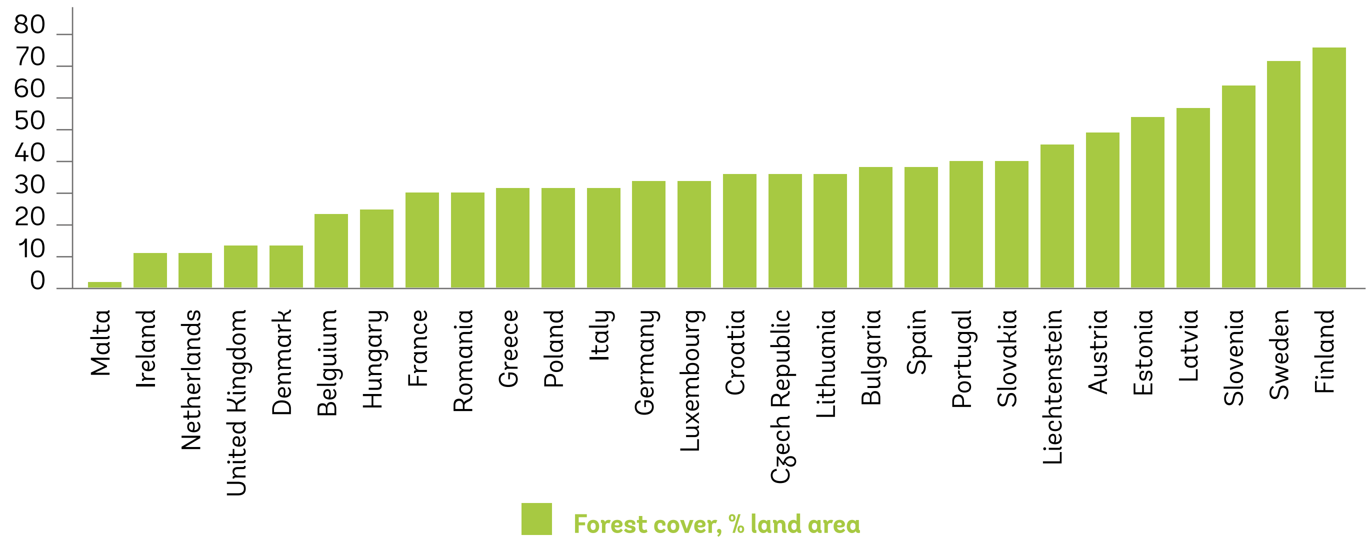
WTPL / Nick Spurling

2. Introduction

The Woodland Trust has asked Europe Economics to review and synthesise the available evidence for the economic benefits created by woodlands. The research will support the Trust's work with government, other landowners and like-minded organisations, using its experience and authority in conservation to influence others who are in a position to improve the future of native woodland.

Forest cover in the UK was 3 million hectares in 2013, according to the National Forest Inventory, or around 13 per cent of the UK's land area.[1] Forest covered 29 per cent of the land area in France and 32 per cent of the land area in Germany in 2010. Of the twenty eight EU Member States, the share of the land area covered by forest was only lower in Malta, Ireland and the Netherlands (FAO, 2010).

Figure 2.1: Forest cover, 2010



Source: FAO (2010)

In its response to the final report of the Independent Panel on Forestry in 2012, which was itself established in response to public concern over now abandoned proposals to sell or transfer a large proportion of the public forest estate to private ownership, the Government set a target to increase woodland cover in England from 10 per cent of land area to 12 per cent by 2060, continuing a path of recovery from 5 per cent at the beginning of the 20th century. The Government also pledged to protect existing trees, woods and forests, "especially our ancient woodland" (DEFRA, 2013).

Increasing the level of woodland cover and protecting ancient forests will depend on a large number of decisions on individual plans to plant more trees or protect those which are already there. It would be easy to agree that more forest cover is desirable in theory and few would wish to destroy ancient woodlands for the sake of destroying them. Planners are faced with more difficult decisions where the result may not be so obvious at face value, for example:

- Should resources be devoted to creating woodlands or to other means of improving the natural environment?
- Is it worth damaging 37 ancient woods in the construction of a high speed rail line from London to Birmingham? Or a further 46 ancient woods in order to extend that line to Manchester and Leeds?
- Is it worth destroying an ancient wood in order to allow the construction of a motorway service station?

The interests of woodlands are weighed in the balance of costs and benefits associated with any significant planning decision, either because woods are threatened with destruction or because there might be an opportunity to create or extend them. Those interests may not be given fair weight if the benefits associated with woodlands are not well-understood.

Trees are planted and protected for a range of reasons. Those different reasons are sometimes only considered in isolation and trees are therefore often compared to alternative means of securing the same objectives without considering their full range of wider benefits.

1 10% in England, 15% in Wales, 18% in Scotland and 8% in Northern Ireland

Urban planners might choose between trees and open grassed areas as alternative means of making a new development more aesthetically pleasing, for example, and in balancing the costs and benefits of those two options, miss the other benefits that trees might bring for their residents, such as the control of air pollution; and wider society, such as locking up carbon dioxide emissions that might otherwise contribute to climate change. The broad range and nature of the benefits associated with woodlands might mean that their full value is less likely to be understood and reflected in important decisions.

Our objective is therefore to consider as comprehensive a range of benefits associated with trees and woodlands as possible. Of course, that does not mean that all of those benefits will be relevant in every case. The potential for trees to mitigate air pollution may not be relevant if the woodlands in question are being planted or protected in a remote rural area. In rural areas other benefits – such as the potential to encourage forestry businesses – may be more relevant. However, there are some benefits that result from any woodland planted or protected – such as the carbon dioxide captured and therefore not contributing to greenhouse gas emissions – and in most cases woodlands will address multiple objectives.

In this report we will consider benefits under three broad categories: direct use value; indirect use value; and non-use value. For each of the benefits we will give an account of the evidence for the scale of that benefit; discuss the extent to which it constitutes an internalised private benefit or a positive externality to broader society; and consider whether that benefit can be quantified as a monetary amount based on the existing data available.

We then consider how those benefits can be aggregated into an aggregate value for woodlands as a whole, or specific existing or prospective woodlands. As a part of that aggregation, we will consider to what extent the different benefits might combine to make them particularly productive in addressing certain policy challenges. For example, perhaps the aesthetic benefits of woodlands might combine with their contributions to flood management to produce a particularly pronounced impact in terms of facilitating new development.

Finally, we conclude by discussing the implications of our work and the most promising areas for further research.

WTPL / Robin Miller

3. Benefits of woodlands

In this section of the report, we will assess the literature on a range of benefits produced by trees and woodlands. Those benefits fall under three categories, direct use value, indirect use value and non-use value.

- **Direct use value.** Enjoying goods and services produced by or in woodlands:
  - Business. Producing goods and services with a market value, such as timber; and
  - Recreation. Visiting woodlands.
- **Indirect use value.** Benefiting from positive externalities provided by woodlands:
  - Flood management. Reducing the extent of damage in floods;
  - Health benefits. Particularly improving air quality;
  - Water management. Improving water quality; and
  - Aesthetic value. Seeing trees, either at home or while travelling.
- **Non-use value.** Appreciating goods and services that woodlands may provide to others or in the future:
  - Climate change mitigation. Reducing the extent of global climate change; and
  - Option, existence and bequest value. Safeguarding woods and their associated biodiversity for future generations.

For each of those types of benefit, we will need to consider a number of questions:

- **How dispersed are the benefits?** The benefits may be enjoyed by the person who plants or protects the woodland; the local community; the wider nation; or the world. The scope of the benefits is crucially important to the governance arrangements needed in order for those social benefits to be reflected in private decisions, as it affects the transaction costs involved (Coase, 1960). It will also be crucial to any attempt at quantifying those benefits.
- **How do the benefits vary between different types of woodland?** The existence value of ancient woodlands may be particularly pronounced, for example, as they are scarcer and cannot be replaced in the same way as newer woodland.
- **How do the benefits vary between different geographical areas?** It is only valuable to moderate the effects of urban heat islands in urban areas, for example.
- **How robust is the evidence?** There are some areas in which the benefits of trees and woodlands are relatively well-studied and others in which they are relatively poorly-understood.

3.1 Business

Trees and woodlands have many business uses, from the straightforward (such as the sale of timber and woodland berries and fungi) to the more indirect such as party locations or renting for film sets. In the Government's Policy Statement on Forestry and Woodlands, it notes that the forestry and primary timber processing sector contributed £1.7bn in gross value added and employed around 14,000 people directly in 2010 and pledged that it was "committed to sustaining, managing and improving our national woodland assets in ways that contribute to economic growth and realise benefits for people and nature" (DEFRA, 2013).

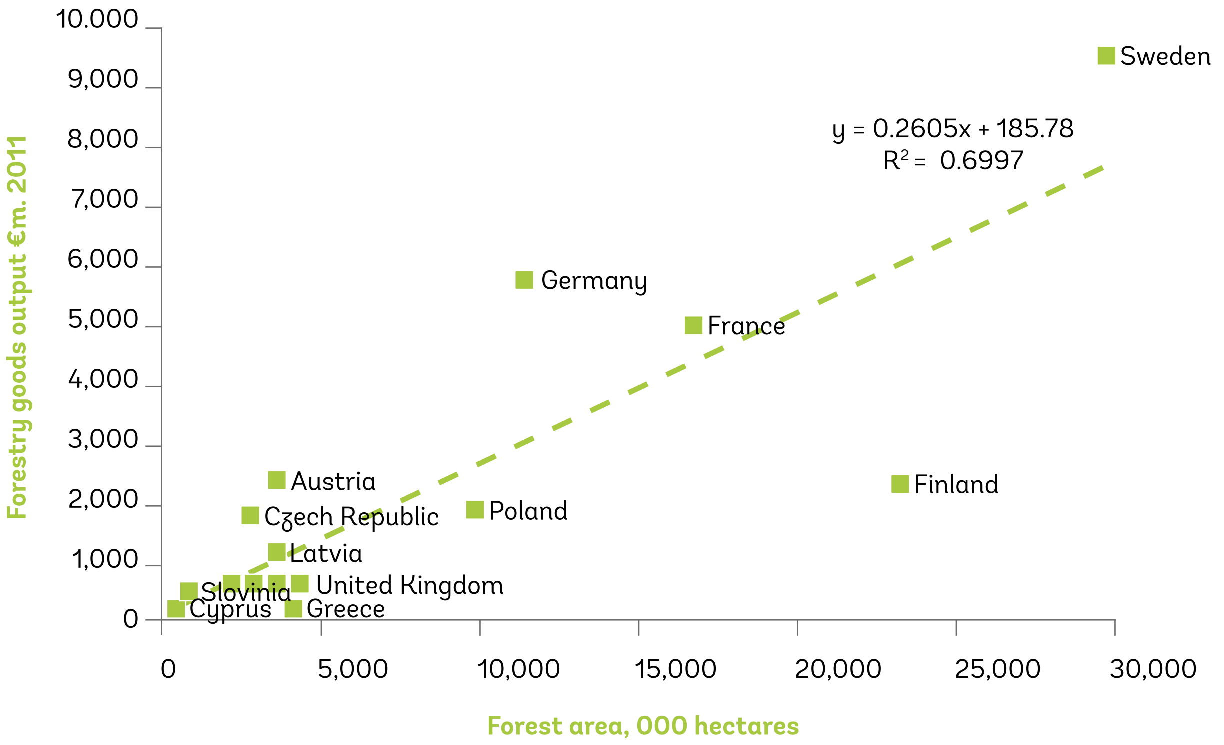
It is not possible to capture data on all of the business uses associated with forests. However there is data recorded on the production of identifiable forestry goods. Eurostat data shows that the UK produced £635.8m of forestry goods in 2011 (Eurostat, 2014). If we compare the production of forestry goods with forest cover at the latest survey (FAO, 2010) then there is a clear positive relationship between the amount of forest cover and the output of forestry goods, accounting for around two thirds of the variation in forestry goods output between the fifteen EU Member States for which forestry goods output data is available. The results are shown in **Figure 3.1**.

While a more complex econometric exercise may refine such a rough estimate, perhaps by estimating the increase in gross value added associated with an increase in forest cover and then applying that to an input-output model to gauge the indirect and induced effect on output, it suggests that a one hectare increase in forest cover leads to an approximate €260 (£230) increase in the production of forestry goods. The value of that increase in forestry production is approximately £6,500 on a perpetual basis at a discount rate of 3.5 per cent,[2] or around £6,800 in 2013 after adjusting for GDP growth.

It is important to note that this benefit is likely to accrue to the owners of the woodland concerned. While there may be an element of small-scale public foraging, often as a cultural activity as much as a means of market production, the businesses will either own the land in which they are producing forestry goods or lease it from another owner, paying a market rate which reflects the contribution of the woodland to production.

2 3.5 per cent is used as the discount rate throughout this report as it is the standard for policy appraisal. However environmental benefits such as the mitigation of air pollution may warrant a lower discount rate. The Health and Safety Executive (2007) argues that the value of preventing a fatality has a constant utility value over time and should therefore be uprated in real terms each year by real GDP per capita growth. If real GDP grows at 2 per cent a year then – combined with the 3.5 per cent standard discount rate – the effective discount rate would be 1.5 per cent (or even lower in the future). The estimates can therefore be seen as conservative. We have adjusted older estimates to reflect GDP growth to 2013 (Officer & Williamson, 2014) as most of the benefits discussed in this report are likely to have a constant utility value over time.

Figure 3.1: Forest cover and forestry goods output



Sources: FAO, Eurostat

3.2 Recreation

Woodlands are places of play. People walk their dogs; they cycle; they play with their children; they race dirt bikes. Leisure is a fundamental driver of economic utility, and is studied and modelled in detail. In its Policy Statement, the Government stated that it wants "as many people as possible to be able to access green space, including woodlands, for exercise, leisure and recreational purposes and, in particular, we are keen to see greater multi-use access to woodland in and around our towns and cities." They propose to continue to use the Woodland Trust Access Standard to measure progress. Around half of UK woodland was accessible in 2009 on that measure, or around 1.4m hectares out of 2.8m hectares (Woodland Trust, 2009).

Recreation around woodlands may be particularly valuable. Experimental research suggests, for example, that recreational activities in "greener" settings are more effective in mitigating the problems of children with Attention Deficit Disorder, relative to activity in other settings (Faber Taylor, Kuo, & Sullivan, 2001).

Many recreational visits will be a part of the value which those who live around woodlands enjoy. Local people might enjoy walking their dogs or going for a run in woodland more than they would on urban streets. The value for those visits should be captured in hedonic estimates of the value of woodlands to local people using house prices. Many people also travel to access woodlands, however.

Studies focused mostly on "purposeful trips to major forests" find values between £1 and £3.50 per visit (CJC Consulting, 2009), although some specific purposes have larger values attached (for example, £14.55 for visits to Scottish forests and woodland for the purpose of horse riding). The bottom of that range - £1 per visit – seems like a reasonable value to attach to the average woodland visit given that most visits are likely to be casual. For research into the economic contribution of the Mersey Forest, willingness to pay was estimated at 60p for very regular visits and £1.80 or more for those who travelled more than 10 miles, suggesting a similar value (Regneris Consulting, 2009).

Visiting woodlands is a very common form of tourism and the England Leisure Visits survey reported that 40 per cent of adults had visited woodland in the last year, with a total of 290m visits. Of those visits, 25m were classed as tourism visits. There were around 400,000 hectares of accessible woodland in England in 2009. Ignoring any changes in either the accessible area or the number of visits between 2005 and 2009, for the sake of simplicity, there were therefore more than 700 visits for every accessible hectare of woodland in England. At a perpetual value, and a 3.5 per cent discount rate, the value of the recreational benefits is therefore nearly £21,000 per hectare of accessible woodland at 2008 prices, or around £23,000 in 2013 adjusting for GDP growth.

The attraction for visitors will vary depending on the type of woodland, its geographical location and the

Table 3.1: Accessible woodland

Country/Government Office region	Area (ha)	Total woodland area	Area accessible woodland	% of woodland area that is accessible
Country				
UK	24,872,566	2,795,827	1,377,560	49
England	13,295,236	1,059,728	398,523	38
Wales	2,122,450	281,171	113,557	40
Scotland	8,023,384	1,339,736	791,784	59
Northern Ireland	1,431,496	115,192	73,696	64
Region				
East Midlands	1,581,477	74,443	31,371	42
Eastern	1,957,502	117,004	42,430	36
London	159,472	6,074	4,311	71
North East	867,642	104,460	68,288	65
North West	1,491,831	94,314	44,195	47
South East	1,941,293	267,756	83,636	31
South West	2,439,224	213,612	62,169	29
West Midlands	1,300,380	88,667	26,830	30
Yorkshire and Humber	1,556,415	93,398	35,294	38

Source: (Woodland Trust, 2009)

amenities available in that wood. For example, more people might visit and the visits might have a higher value if a greater range of leisure activities is possible within an area of woodland. However existing research has had quite limited success in predicting visitor numbers (CJC Consulting, 2009, p.4) and a general estimate for all accessible woodlands therefore seems the most appropriate at this stage.

The recreational value associated with woodlands could, in theory, be a private good which people pay to enjoy. It is generally thought to be inefficient to charge people for woodlands though, as many cover large areas with a number of potential entrances that would need to be covered. If only some woods are charged for, that might mean an unsustainable increase in numbers visiting free woods. For those reasons, most accessible woods are maintained as community assets, generally supported either by public bodies (often local authorities) or as an essentially philanthropic endeavour (perhaps with some hope to recover costs from ancillary businesses).

3.3 Flood management

The UK Committee on Climate Change (2014) has found that: "Increased flood risk is the greatest threat to the UK from climate change. Historical emissions and global warming are likely to have already increased the potential for flooding in England." They argue that "underinvestment in flood prevention increases the potential for avoidable flood damage, especially with climate change". If well-positioned and designed trees and woodlands can contribute to flood defence, alongside other measures, while also providing some of the other benefits described in this report, then that is a significant source of additional value.

Conventional wisdom suggests that greater forest cover reduces flood risk. Trees intercept rainfall before it reaches the ground; evaporation from the leaves acts to reduce total runoff; and there is increased infiltration into the soil and retention of infiltrated water (van Dijk, et al., 2009). Though it is subject to some very important limitations which we shall set out below, this conventional argument is relevant in some local contexts and with respect to established natural woodland. Sustainable management of woodlands, such as by directing surface water from roads and trails back into the forest area (Humann, et al., 2011), and well placed interventions such as woody debris dams (Odoni & Lane, 2010) can act to reduce flow peaks.

Detailed hydrological modelling (e.g. Odoni and Lane (2010); Dixon (2013); Pattison et al. (2014)) could be used to determine what upstream interventions would act to reduce flood risk in downstream towns and cities. Such efforts could be costly, but for catchments such as the Thames where annual expected flood damage is in excess of £10m, they may provide good value for money. The Pont Bren study (Jackson, et al., 2008) (Wheater & Evans, 2009), carried out within an uncertainty framework, found that full woodland cover reduced the median peak flow by 50 per cent, though this was reduced to 36 per cent for an extreme rainfall event (the Carlisle January 2005 rainfall). McIntyre et al. (2012) note that even with this understanding of local flood responses, the effect on downstream flooding cannot be determined due to the complexities associated with how flows from different tributaries would integrate together. For the River Hodder in NW England, the median effect of a number of land use management measures was thought to be only a 2 per cent reduction in a major flood peak (McIntyre, et al., 2012). Another study of the River Parrett in SW England found that tree planting might have more impact in reducing summer peak flows due to the higher evapotranspiration rates and on-average drier antecedent conditions, though it did not look at the benefit of existing woodland. However, although indicative and relevant, these three case studies are limited in terms of their application to the wider UK, where the impacts of woodland will be dependent upon soils, geology and other local features (Humann, et al., 2011).

While (as noted above and for reasons explored in further detail below) significant hydrological modelling would be required to determine where any interventions should be placed to reduce flood risk, attributing a flood risk value to woodland also requires an estimation of flood impact — information that is not currently openly available in the UK at catchment level.[3] Nonetheless, a very rough calculation can be carried out to illustrate the potential value of well-placed interventions,

WTPL / Niall Benvie

3 The Environment Agency's National Flood Risk Assessment (NaFRA) estimates the annual expected damage from floods in England to be c. £1.1bn, though other estimates put it as £0.25bn (Penning-Rowsell, 2014). These figures include coastal flooding, for which forests would have no impact. However, there are assets worth £82bn at risk from river flooding (Hardaker & Collier, 2013).

For example, if we assume that:

- the annual expected damage for fluvial floods on the Thames is in excess of £10m (though there is considerable uncertainty over this figure);
- the total catchment area upstream of the River Thames at Kingston is approximately one million hectares, every hectare representing around £10 of the total annual expected damage;
- a linear link exists between flow and damage, i.e. a one per cent reduction in flow would result in a one per cent reduction in damage;
- effective management could reduce runoff by between 50 per cent and 36 per cent (for an extreme flood) across each area of woodland, as found by the Pont Bren study; and
- effective woodland management is put in the 'right' place in terms of synchronicity of tributaries; then
- the value of effectively managed woodlands in reducing expected flood damage would be around £3.5 – £5 per hectare, or around £100 – £150 per hectare in perpetuity at a 3.5% discount rate.

Flood defence is currently primarily the responsibility of the Environment Agency – an agency of central government – though affected local authorities and individual property owners (particularly the owners of large and critical infrastructure assets such as airports) are also often involved. With proper assessment of individual catchment areas, and with the wider benefits of woodlands in mind, they could consider woodlands as a part of wider efforts to mitigate flood damage.

One qualification to the above is that many studies have shown that while forest removal causes an increase in the annual flood it does not have much impact on peak flows (Robinson & Dupeyrat, 2003) (Robinson, et al., 2003). But care should be taken in extrapolating results from studies of locations with different climate and soil types, and even studies that have taken place in the UK will have little relevance beyond the context of that specific catchment (Pattison, Lane, Hardy, & Reaney, 2014). Studies of the impact of woodlands for a specific catchment should not be used to infer conclusions about other catchments due to differences in soil type, geology, water and land management and scale. As such, any attempt to quantify the impact of a hectare of woodland on flood risk should be location specific, and would need to involve detailed hydrological modelling to determine where and what interventions would best act to reduce flood risk.

Furthermore, although, as explained above, trees and woodland can be relevant to reducing flood risks in some local contexts and with respect to existing natural woodland, it is important to understand that it does not follow from this that aggregate UK-wide flood risk should be expected to be left untouched if, say, a certain volume of existing natural woodland were to be felled and replaced by an equivalent volume of new commercially-exploited woodland in some other location, even within the same broad catchment area. There are at least two reasons for this. First, there is a growing body of scientific evidence that suggests that at the large-scale the benefits of woodlands with respect to flood risk are less certain. One of the main reasons for this is that while, at the small-scale, a change of land-use will change the arrival time of the flood peak, at the large scale the aggregated effect is complicated by these different arrival times (Calder & Aylward, 2006). For example, slowing the flow peak in one tributary could synchronise the arrival of the peak from a different tributary, or could make them asynchronous. This effect is likely to be specific to the particular flood event as well as the catchment. As such, large-scale hydrological modelling is needed to be able to determine the effect of land-use change for a specific catchment.

Second, care should be taken when extrapolating benefits from well-established natural woodland to the planting of new woodlands or plantation woodlands. The soil of afforested land, even with trees 30 years old, may maintain the infiltration properties of its former land use (Humann, et al., 2011). Additionally, forestry management activities such as logging with heavy machinery, networks of forest roads, creation of drainage and logging trails can actually increase the magnitude of flood peaks due to soil compaction and an effective increase of the stream network (LaMarche & Lettenmaier, 2001).

3.4 Health

Trees and woodlands are associated with a wide range of improved health outcomes, including improved air quality, mood improvements and even improved health outcomes such as enhanced birth-weight. Dadvand et al. (2012) find that higher surrounding greenness is associated with increases in weight and head size at birth of around 44g and 2mm respectively. Donovan et al (2011) find that a 10 per cent increase in tree cover within 50m of a house reduces the number of small-for-gestational-age births by 1.42 per 1000 births.[4]

Many of the specific health benefits have been identified in the existing research literature:

- There is a range of air-borne pollutants which can exacerbate respiratory and heart conditions or carry carcinogens into the lungs, which can be adsorbed by trees in the right circumstances. In particular, PM_{10} (particulate matter 10 microns in size or smaller) and

4 It seems preferable to value health benefits associated with woodlands, rather than changes in health outcomes, as changes in health outcomes may result from some of the other benefits identified in this report, thereby introducing an element of double-counting, and also result from selection bias as the more fortunate are able to live near woodlands.

finer fractions such as $PM_{2.5}$ and $PM_{1.0}$ are thought to contribute to poor health. While any green space may reduce air pollution, suitably-planted woodlands may be particularly effective as they increase the surface area adsorbing the pollutants (CJC Consulting, 2009, p.9). In 2013, the Supreme Court declared that the UK was in breach of the EU air quality directive and "the way is open to immediate enforcement action at the national or European level." (ClientEarth, 2014) Improved air quality might mean fewer early deaths and fewer hospital visits.

- It might reduce the extent of the urban heat island effect. Heat waves can create a range of social harms, but increased mortality and physical discomfort are likely to be among the most pressing. If their frequency and the resulting harm increases over time (McGregor, Pelling, Wolf, & Gosling, 2007) then trees and woodlands could mitigate the harm through evaporative cooling; increased reflectance; and shading.
- Physical activity which takes place in woodlands may be associated with a range of health benefits. However it is difficult to know how much of that physical activity is additional as people might otherwise have exercised elsewhere. There is evidence that improved rights of way might increase levels of physical activity, but that is difficult to connect to a particular volume of woodlands and may be more closely related to access rights in existing woodlands (Regneris Consulting, 2009, p.18). While those living near forests might exercise more than those living elsewhere, it could be that those who prefer a higher level of physical activity choose to live near forests, which are a more valuable amenity to them than those who expect to use it for recreation less often. We will therefore not account for this benefit separately from the recreation value estimated earlier.
- If people are happier as a result of the more aesthetically-pleasing environment associated with trees, or for other reasons such as a reduced risk of flooding, they may be less vulnerable to conditions associated with stress. There have been some attempts to quantify this impact, for example by showing people videos of various environments and asking them to describe their mood afterwards (van den Berg, Koole, & van der Wulp, 2003), but it is difficult to generalise from those specific findings to estimate an aggregate value associated with planting or protecting a certain area of woodland.
- Trees and woodlands might also play a related role in combating other forms of mental illness. An early pilot project – "Wandering in the woods" – found that people living with dementia saw a range of benefits from visiting woods, which the research found might help "to dramatically reduce the use of anti-psychotic medication" and reduce "the frequency and severity of anxiety, apathy, anger and depression" which many experience in long-term care (Mapes, 2011). While that research is currently at an early stage, it provides one example of the kind of environmental services that woods provide which might become apparent over time with further research.

In this research, we will consider in more detail two specific health benefits in more detail, where the evidence for the effects of woodlands is relatively clear: the mitigation of air pollution and urban cooling to moderate summer heatwaves.

3.4.1 Air pollution

Powe and Willis (2004) estimate that the air pollution absorption of larger woodlands (over two hectares) within 1km square to be around £900,000 a year, in total. That results from trees and woodlands saving between five and seven early deaths each year and between four and six hospital admissions. They note that the health benefits of woodlands are, if that estimate holds, "relatively small in comparison to other non-market forestry benefits."

That estimate may seriously understate the true benefits as many areas of trees and woodland in close proximity with population centres are smaller than two hectares. Earlier research for the Woodland Trust (Townsend, 2012) has set out how the ideal might be two or three rows of trees which, so long as they are planted carefully to avoid creating "street canyons" which prevent the dispersion from local pollutant sources such as busy roads, can maximise the extent of pollutant scrubbing. Powe & Willis (2004) therefore note that estimating such benefits would "require more detailed data than [was] available [...] for a national study".

More detailed studies looking specifically at urban areas have found more substantial effects. For example, McDonald et al. (2007) find that increasing total tree cover in the West Midlands from 3.7 per cent to 16.5 per cent reduces PM_{10} concentrations by 10 per cent, while in Glasgow increasing tree cover from 3.6 per cent to 8 per cent reduces PM_{10} concentrations by 2 per cent.

Tiwary et al. (2009) find that the establishment of urban green space, in that case comprising 75 per cent grassland, 20 per cent sycamore maple and 5 per cent Douglas fir, led to a 0.009 tonnes per hectare per year reduction in PM_{10} concentrations over the 10 by 10 km study area. They estimate that would lead to a reduction of two deaths and two hospital admissions a year.

Table 3.2: Air pollution performance, Torbay

Pollutant	Tons removed per year	Value
Carbon monoxide (CO)	0.0005	£0.47
Nitrogen dioxide (NO_2)	7.9	£52,000
Ozone (O_3)	22.9	£149,000
Particulates (PM_{10})	18	£1,315,000
Sulphur dioxide (SO_2)	1.3	£2,000

On that basis, if we assume well-planted woodland would reduce mortality and hospital admissions by a similar amount and that each prevented death is delayed by one year, a well-located hectare of urban woodland can improve health to a value of nearly £150,000 a year, or over £4m on a perpetuity value at a 3.5 per cent discount rate.[5] However the value of that land may, in turn, be much higher than in rural areas, meaning that the opportunity cost of devoting land to woodland is higher, and a large proportion of the health value, potentially all of it except the cost to the NHS of more frequent hospital admissions, may be reflected in higher property prices in areas close to urban woodlands. To the extent that this value is realistic, it would dominate the economic case for woodlands in urban areas.

Rogers, Hansford, Sunderland & Brunt (2012) estimated values for the removal of a range of airborne pollutants in Torbay. Their estimates are based upon estimates from the US for the value of removing carbon monoxide, nitrogen dioxide and ozone and UK estimates – from the Interdepartmental Group on Costs and Benefits – Air Quality – for the value of removing PM_{10} and sulphur dioxide, and are reproduced in **Table 3.2**.

Those results confirm that PM_{10} is by far the most important form of air pollution that can be mitigated by trees and woodlands. The total value is, if those results hold, around £1.5m across around 6,500 hectares of woodlands in Torbay or around £240 per hectare per year. That would give a perpetuity value, at a 3.5 per cent discount rate of around £6,800 per hectare for urban woods in 2013, adjusting for GDP growth, although the actual value is likely to vary considerably depending on the characteristics of the woods and the density of the population of the surrounding area. This estimate seems to be the most reasonable compromise between the very high values that could be implied by Tiwary et al. (2009), although that may simply reflect a particularly dense urban area, and the very low values reported by Powe & Willis (2004).

Air quality is generally maintained by a series of rules which limit developments, industrial activity and motoring (e.g. the London Low Emissions Zone) that might contribute to air pollution. One limitation of the present approach may be that it is overly focused upon reducing the extent to which pollutants are emitted, whereas woodlands can complement that approach by mitigating harms created by the remaining pollutants that are emitted.

3.4.2 Urban cooling

Handley & Carter (2006, p.9) describe how urban greenspace can help to moderate the impacts of climate change through "providing shade and evaporative cooling, and by decreasing rainwater runoff through interception, storage and infiltration." They report modelling which finds that, in Manchester at least, increasing green space cover by 10 per cent in areas that currently host little green space such as the town centre, can eliminate the effects of climate change on increasing surface temperatures", even on high emissions scenarios out to 2080 (Handley, Gill, Ennos, & Pauleit, 2007). Woodlands in urban areas may therefore make cities both more comfortable and healthier.

At this stage there is no obvious existing literature that would allow us to translate the mitigation of the urban heat island into a value per hectare or in aggregate for urban woodlands, particularly in the UK where spending on air conditioning is rare. There are estimates in the international literature of the economic value of the urban heat island effect, which found that it added AU$300m to the cost of hot weather in Melbourne (AECOM, 2012), but given the generally much hotter temperatures there it seems inappropriate to apply those results to the UK.

There are a number of potential complications which should be considered:

- Mitigation of the urban heat island might affect the threshold beyond which significant temperature and mortality rates are experienced. Estimates for that threshold vary between as low as 12 degrees in Finland and up to 31 degrees in Lisbon, Portugal, and there is a clear pattern which indicates that the estimates are higher in warmer climates (McGregor, Pelling, Wolf, & Gosling, 2007, p.13).

5 This estimate is based on two times the mid-point of people's willingness to pay for a small reduction in risk aggregated so as to apply per death averted for one year (£32,000-£110,000) and for avoiding a hospital admission (£170-£735), adjusted for the NHS costs averted with early mortality (£200-£2,500) and added with increased hospital admissions (£1,400-£2,500). Those estimates are intended to represent mortality and hospital visits specifically associated with air pollution (Department of Health, 1999).

This might reflect that people adjust to higher temperatures physiologically or that they are more likely to take defensive measures when high temperatures are frequent.

- The extent to which high temperatures in the urban environment translate into higher mortality may be highly contingent on the size of the vulnerable population (the elderly are normally seen as particularly vulnerable) and the circumstances (e.g. characteristics of their homes) in which those vulnerable people live.
- While most estimates focus on the impact on mortality, the impact on quality of life could be at least as important, as many more people may be affected. In order to best reflect that, and match general practice in other project appraisals, an estimate of the impact of trees and woodlands should be framed in terms of the impact on quality-adjusted life years.

A maximum value on the potential health impact of cooling urban heat islands, at least under present climatic conditions, could be estimated by multiplying the value of the 8 to 11 extra deaths which are estimated to occur each day for each degree increase in air temperature during summer heatwaves; the 2 to 8 degree reduction which Forestry Commission research finds could be achieved with "informed selection and strategic placement of trees and green infrastructure" (Doick & Hutchings, 2013); and a plausible value per fatality averted.

Another important impact may be on workplace productivity. There are established findings which suggest that productivity in a range of office tasks is lower at higher temperatures, by around 2 per cent per degree between 25 and 32 °C (Seppanen, Fisk, & Lei, 2006). In a report for the Mayor of London, it was reported that evapotranspiration associated with planting trees and vegetation can result in the reduction of peak summer temperatures by between 1 and 5 °C (Mayor of London, 2006).

If we assume that the observed reduction in office task productivity would be matched with a general 2 per cent decline in production per degree of indoor temperature above 25 °C (temperatures above 32 °C are rare in the UK), the average reduction in production would be around half of one per cent.[6] Given gross value added in London is around £310bn a year, it would imply that the cost of the high temperatures to productivity in the capital is around £1.7bn. If that could be reduced by half of the 1 to 5 °C envisioned in the report to the Mayor, that would reduce the loss to under £300m (i.e. a £1.4bn reduction), or by nearly 85 per cent.

It might be possible to translate the findings of this section into values either for current trees and woodlands in aggregate or planted or protected woodlands per hectare, but doing so goes beyond our scope here.

However the impact on urban temperatures – particularly during summer heatwaves – is a potentially material source of value which should be borne in mind in policy decisions relating to urban woodlands.

3.5 Water management

In response to public concern about water pollution, the European Union has instituted a series of policies intended to mitigate water pollution, of which the most important is the Water Framework Directive. The Water Framework Directive is intended to address water quality problems caused by nutrients and hazardous chemicals which can create risks to human health, make water unsuitable for use and be aesthetically unattractive. There have been numerous studies which have found that trees and woodlands, forming "riparian buffers" (i.e. land-to-river/stream interfaces), can reduce pollution (specifically in the form of sediment, pathogen and nutrient loads into surface and groundwater in agricultural catchments), although that does depend on both the design of the wood and the characteristics of the catchment area (Polyakov, Fares, & Ryder, 2005). Townsend & Atkinson (2012) describe how woodlands work to improve water quality by "increasing water infiltration rates and slowing the flow of transported sediments" and how "organic matter from leaf litter and root debris can also promote soil structure, reducing surface water run-off."

In the Impact Assessment for the Water Framework Directive, DEFRA (2007) commented that: "There is very limited information on the benefits of WFD improvements." The assessment therefore based its assessment of the value of the benefits on a single total benefits valuation exercise, based on the National Water Environment Benefits Survey. The survey findings suggested that the willingness to pay to bring 95 per cent of water bodies up to good status by 2015 was between £45 and £87 per household, per year.

On a similar basis, using another scenario judged to be similar to the Department's preferred option for implementation, they find that the average annual benefits of the directive would be between £650m and £1,200m for England and Wales, or a midpoint of around £900m.

An update to the survey itself (Environment Agency, 2013) found that the average annual value of change in the status of rivers in England and Wales, per kilometre at 2012 prices, was £17,500 from a bad to a poor condition; £20,000 from a poor to a moderate condition; and £23,200 from a moderate to a good condition. The average value of improving coast, lake and transitional waters, per square kilometre and again at 2012 prices, was £6,400 from a bad to poor condition; £7,400 from a poor to a moderate condition; and £8,500 from a moderate to a good condition.

Research by the Forestry Commission has set out how woodlands can assist in meeting the requirements of the Directive and realising those benefits (Nisbet, Silgram, Shah, Morrow, & Broadmeadow, 2011). They give case studies in other EU Member States and the United States of woodland being used to protect water resources. For example, in France, "the bottled drinks manufacturer, Perrier-Vittel, demonstrated that reforestation in sensitive infiltration zones under the guise of protection forestry, alongside co-operative agreements with farmers, proved a cost-effective measure in the protection of French aquifers from agricultural nutrient and pesticide run-off and leaching."

However those benefits are both very dependent on the way that the woodland is planned, with a certain area of forest around a river being required for many benefits to be felt, for example and difficult to value separately from other benefits. Many of the cost benefit analyses cited by the Forestry Commission research did not distinguish between the water treatment benefits and other benefits associated with woodlands. However key land areas were purchased for water protection and recreation by the Danish city of Aalborg, with farmers whose land was bought offered land outside the drinking water catchment area. The benefits in terms of the costs saved in treating drinking water were estimated at €489 per hectare, per year in a 2002 study.

If that were representative, then the value in perpetuity of an improvement might be around £16,000 per hectare, adjusting for GDP growth to 2013. However that should be seen as particularly conditional on the location of planting.

WTPL/Jane Corey

6 This is based upon data for the average indoor temperature in Westminster from March 2009 to October 2014, with time periods varying from one to thirty minutes. For those time periods where the temperature was over 25 °C, between 9am and 5pm, the number of minutes was multiplied by the number of degrees over 25 °C. That total number of degree minutes was then divided by the total number of minutes in the sample and multiplied by the two per cent impact on productivity. The temperature never passed the point beyond which the impact on productivity was found to no longer apply. We assume for the purposes of this simple estimate that Westminster indoor temperatures are representative of broader London indoor temperatures and that the reduction in productivity in office tasks found in the existing literature will be matched by a proportional reduction in value added.

That would in theory be the benefit to water companies, in the form of a reduced need for other treatment to ensure the quality of water, which they are required to provide at certain standards. An alternative, and more robust, means of measuring the wider value – at least for those improvements that could be related directly to rivers and other bodies of water – would be to use the values found in the National Water Environment Benefits Survey.

3.6 Aesthetic

People like trees and woodlands. They like the horse chestnut and the hawthorn, the bluebells and the berries, the squirrels and the sparrows. They value them aesthetically as things to look at; to buy depictions of in paintings; to hear about on the radio. The aesthetic improvements associated with woodlands may even alter behaviour and research has found that trees in the public right of way are associated with lower crime rates (Donovan & Prestemon, 2010).

Those benefits vary substantially based on the kind of woodland though, in two ways: first some woodlands may have a greater aesthetic value, as they are felt to be more aesthetically pleasing by more people; second some woodlands will be seen by more people.

That aesthetic value will partly accrue to those who live in the proximity of woodlands and partly to those who visit or just pass through them. Garrod (2002) found that the willingness to pay for broad-leaved woodland views from homes in peri-urban areas was £268 a year, for example. That category of woodland seemed to be important as: "These landscapes attract the highest [willingness to pay] values and impact on large proportions of the population of Great Britain." The value for seeing the same views while travelling to and from home was £227 a year.

There were some settings in which the willingness to pay for woodland was negative (implying that those surveyed would pay to reduce woodland cover) but that applied to relatively rare settings. For example, there was a £442 a year welfare loss with broadleaves in a mountain setting. This may be relevant for some, very specific, circumstances but relatively few people in the UK live or commute in a mountain setting and conifers are more likely on mountains.

He concluded that the aggregate value in Great Britain of woodland views from houses – capitalised at a discount rate of 3.5 per cent into perpetuity – was around £1.7bn (based on around 215,000 urban fringe households with woodland views) and the value of seeing woodland on journeys to and from home was around £2.6bn (based on around 410,000 households seeing woodlands on their journeys to and from home). The total value of woodland views was therefore over £4bn.

The value for the average additional household able to see broad-leaved urban woodlands from their homes is therefore around £7,500 and the value for those travelling is around £6,500 for the average additional commuting household that encounters such woodland (Garrod, 2002). Adjusting for GDP growth since 2002, those values are around £11,000 and around £9,500 respectively in 2013.

These values can potentially be very large if woodlands are added to the views of large numbers of people. In practice, exposing new people to woodland views from their home or on their commute would only be possible with entirely new areas of woodland in populated areas, which would come with similarly high costs (as the land might have to be diverted from use for residential property).

As the aesthetic value of woodlands affects property prices, it could be possible for private organisations to find it worthwhile to create and maintain woodlands for their aesthetic value. However that might be difficult with high transaction costs, particularly in preventing free-riding, and the woodlands most likely to serve this purpose are therefore often maintained as public assets by local authorities and other public bodies.

3.7 Climate change mitigation

Governments of all parties have committed to reduce the UK's greenhouse gas emissions in order to contribute to the mitigation of global climate change. The costs of the Climate Change Act 2008 – the main legislation in which targets to mitigate climate change were enacted – were estimated at between £324bn and £404bn and the benefits at between £457bn and £1,020bn (DECC, 2009). There is therefore considerable value in a contribution to mitigating climate change, either in the benefits provided (less climate change) or the other costs avoided (other actions that might be needed in order to avoid climate change, which might be more expensive or not produce other benefits).

Trees sequester carbon when they first grow, reducing the amount of carbon dioxide in the atmosphere. They also tend to increase the carbon content of non-peat soils (CJC Consulting, 2009). However if they subsequently die or are burned that carbon will then be released back into the atmosphere. The net contribution to mitigating climate change therefore depends on the types of trees and the maturity of the woodland in question.

Other attempts to value the contribution of trees and woodlands to climate mitigation have been based on assessing the net amount of carbon sequestered each year. Our view is that a better approach is to assess the carbon dioxide equivalent of the stock of carbon in woodland and assign that as a perpetuity value to each hectare of woodland. That approach better reflects the nature of the process in question, in which the net result (despite considerable dynamic movement) is essentially a stock of carbon locked up over time, rather than a steady reduction in the net flow of carbon dioxide emitted.

The decision to plant or protect an area of woodland determines whether or not a stock of carbon will be locked up or not.

The carbon stock in UK woodlands and forests has been studied by the Forestry Commission who found a total volume per hectare equivalent to 1,131 tCO_2 (Morison, et al., 2012, p.15). That estimate includes the averages in standing trees, litter and deadwood and the soil (to 1 metre in depth). However the net contribution is complicated by the question of what the soil content is of that land (either other plants that might have grown in place of the woodland or what the soil content might otherwise have been). The simplest reasonable and conservative approach seems to be to exclude the impact on the soil (which is more uncertain, particularly in terms of the net effect (p.33)) and count the average in trees and litter, at 272 tCO_2 per hectare.

In valuing emissions, the UK Government recommends a target-consistent approach, based on estimates of the abatement costs that will need to be incurred in order to meet the specific emissions reduction targets set in the Climate Change Act. Those values rise over time and, while the time profile of the net reduction in emissions resulting from woodlands being planted or protected is uncertain, the current value seems most appropriate (again, ensuring a relatively conservative estimate). The non-traded value would then be appropriate as this is not a reduction in emissions subject to the EU Emissions Trading System. That value is £60 /t CO_2-e in 2014. The value per hectare of the carbon dioxide locked up in UK woodlands can therefore be estimated at around £16,000 per hectare.

3.8 Option, bequest and existence

The existence value of woodlands is the value that we place on their mere existence, even if we personally never see them at all. Another common example of "existence" value is the value people place on whales, and the popular aversion to a decline in their number, despite the fact that only a relatively small number of people will ever see them.

Existence value can exist for woodlands and the biodiversity associated with them. The destruction of the Amazon rainforest has been an issue of public concern, to the extent that there has been substantial pressure on prominent firms, and some – such as the fast food firm McDonalds – have pledged to no longer use soya from sources thought to contribute to deforestation. Very few people in developed countries such as the UK who are concerned over the destruction of the Amazon rainforest, are ever likely to visit it, and it seems unrealistic to explain that concern purely in terms of the global amenities provided by that rainforest (for example, the potential for deforestation to contribute to climate change). Concern over destruction of the rainforest predated widespread concern over global warming.

WTPL / Michael Clarke

The same principle can be applied to woodland and forests within the UK, particularly with respect to ancient woodland which cannot be replaced in the same way as can more recent woodland.

It is possible to estimate the existence value of woodland, albeit imperfectly. For example, Amirnejad et al. (2006) estimated the existence value for forests in the north of Iran using a form of willingness-to-pay survey, using a method known as contingent valuation which is standard in this field. They found that around two thirds of those surveyed were willing to pay for those forests, but of those willing to pay around 20 per cent had never visited and 40 per cent rarely visited them. They estimated the mean existence value at $30 per household.

In considerations of the economic value of forests, the existence value is often grouped with the option and bequest values of forests to give the total value attributed to the desire of these forests to exist not for your own use or enjoyment but as a long term asset that you wish to preserve for future generations.

Woodland provides a resource of relatively high biodiversity (at least versus other dry-land environments) and as such is often the subject of scientific research. This can take many forms, from the use of tree rings to produce historical records of temperature change or the impact of natural disasters such as volcanoes; through the discovery of new herbs or other biologically-based medical treatments; to the more straightforward pure study of the processes of life. Each of these forms of research (as many others) can be of great economic value. DG Environment (2011) reports research which has found that more than half of all new drugs are based on or connected to natural products. In large part the economic value of woodlands for research may not be a matter of the research being undertaken now but, again particularly in the case of ancient woodlands, the value of the option to conduct such research in the future.

Estimates of the option, bequest and existence value of woodlands have been produced for a number of countries in Europe (Merlo & Croitoru, 2005). In France, estimates based on a contingent valuation method found an existence value of €362m for French forests. In Turkey, the option value of Turkish forests (based on their potential contribution to research) was estimated at around €110m. In other countries, spending on forest protection has been used as a proxy for the existence value. For example, in Lebanon between 1996 and 2005, €4.3m was allocated by international funding agencies to protecting forests, and a further €4.4m for the protection of biodiversity, often including forest-related projects.

In the UK, estimates produced for the Forestry Commission (Hanley, Willis, Powe, & Anderson, 2002) suggest that appropriate option, bequest and existence values for the biodiversity in woodlands, vary depending on the type of woodland. The values were produced per household, per 12,000 hectares. Those estimates have been used to calculate a total value per hectare in **Table 3.3**.

Table 3.3: Biodiversity existence value

	WTP per household, 12,000 hectare increase, £	Total value, per hectare, per year, £	Total perpetuity value, 3.5% discount rate, £ 2002	Total perpetuity value, 3.5% discount rate, £ 2013
Upland conifer forest	0.35	770	22,000	32,400
Lowland conifer forest	0.33	726	20,743	30,550
Lowland ancient semi-natural broad-leaved forest	1.13	2,486	71,029	104,600
Lowland new broad-leaved native forest	0.84	1,848	52,800	77,770
Upland native broad-leaved woods	0.9	1,980	56,571	83,320
Upland new native broad-leaved woods	0.61	1,342	38,343	56,470

4. Quantification

Table 4.1 summarises the various sources of value associated with woodlands included in Section 3 and the approximate values associated with them. They are all values in perpetuity at a 3.5 per cent discount rate.

As noted above, these values are approximate and the actual values will depend to a significant extent on the particular characteristics of an individual wood. However the results do show the extent that, for example, new broad-leaved native woodland in an urban area which substantially increased the numbers of people with woodland in their commute and was accessible to the public, would have a value many times that of lowland conifer woodland in an isolated location.

The largest component which will apply to almost all woods is the contribution to climate change mitigation, at around £16,000 per hectare. However other elements may be more relevant for specific woods, for example the existence value of broad-leaved native woods or the aesthetic value of distinct areas of woodland through which people might commute.

Table 4.1: Summary of planted/protected source of value

For every…	Value
Hectare of woodland	
Business	£6,800
Climate change mitigation	£16,000
Hectare of woodland that is… – accessible to the public	
Recreation	£23,000
in or around an urban area	
Health	£6,800
well-sited to effectively treat drinking water	
Water management	£16,000
upland conifer	
Option, bequest and existence	£32,400
lowland conifer	
Option, bequest and existence	£30,550
lowland ancient, semi-natural broad-leaved	
Option, bequest and existence	£104,600
lowland new broad-leaved native	
Option, bequest and existence	£77,770
upland native broad-leaved	
Option, bequest and existence	£83,320
upland new native broad-leaved	
Option, bequest and existence	£56,470
Additional households that will see woodlands from their home	
Aesthetic	£11,000
Additional household that will see woodlands while commuting	
Aesthetic	£9,500

In order to transform those per hectare, or per household exposed values into approximate aggregate values for UK woodlands as a whole, our next task is to set out several representative woodland types, and then assign those to approximate proportions of the UK woodland. The objective is not to cover even close to the full range of variation in UK woodlands, but instead to arrive at a reasonable rough approximation of the true value by covering the most important distinctions between different types of woodland. We try to balance overly pessimistic assumptions in some cases (in reality, many commercial woods are accessible) with overly optimistic assumptions in others (not all other woods are accessible).

- **Urban or peri-urban wood**. These are woods in or adjacent to urban centres. Their amenity value is particularly high but the opportunity cost of the use of the land for woodland, expressed in terms of the land's value, is also particularly high. We will assume they are lowland new native broad-leaved.
- **Commercial forest**. These woodlands are particularly significant to the business value of woodlands, but their aesthetic and existence value is likely to be less pronounced. In this case, we will assume that they are upland conifer forests and not accessible to the public (although in practice many upland forests have open public access).
- **Lowland, broad-leaved woodland**. These woodlands are particularly important in terms of their existence value, but they might be used less than urban woods and produce fewer commercial benefits than commercial forests. We will assume they are accessible to the public (although in practice some lowland woodland does not have open public access). We assume half are ancient.

Those woodland types are assigned to shares of Great Britain's nearly three million hectares of total woodland cover in order to estimate the total value of UK woodland in **Table 4.2**.

We will also assume that around 215,000 households on the urban fringe have woodland views; and around 410,000 see woodlands on journeys to and from their home. The total value of those aesthetic benefits is a little over £6bn. The assumed accessible area (1.2m hectares) is similar to that estimated by the Woodland Trust at 1.4m hectares (Woodland Trust, 2009). We will exclude flood and water management values from these calculations, as the aggregate scale is unclear and at this stage we are only aiming at a conservative approximate estimate. On those assumptions, the total value is around £270bn.

While this figure is obviously substantial, and is considerably higher than the most recent Forestry Commission estimate at £65bn (Nisbet, Silgram, Shah, Morrow, & Broadmeadow, 2011, p.88), as a major fixed asset it could be compared to others like dwellings at £1.4trn, and therefore seems realistic. The main difference to the Forestry Commission estimate seems to be that business use is not included in that estimate (as it is intended to be a study of the externalities associated with forestry) and that a cost is included for water lost for potable uses (although the authors point out that "British water companies perceive little impact, in general, of existing forests on water supply costs").

Any estimate of the total aggregate economic value of UK woodlands is necessarily an approximation. For the purposes of policy formation, the most important consideration is how the full range of individual benefits associated with the planting or protection of particular woodlands stack up.

4.1 House prices

Estimates of the economic value of woodlands are often based on estimates of the impact on property prices. Typical results – consistent with willingness-to-pay surveys (Garrod, 2002) – are that woodlands increase property prices by between 4 and 6 per cent in the local area:

- Anderson & Cordell (1988) find a 3.5 per cent to 4.5 per cent rise in value for those properties where trees can be seen in the estate agent adverts. They studied homes in Athens, Georgia.
- Morales (1980) found properties with trees on the lot were around 6 per cent more valuable, in a survey of properties in Manchester, Connecticut. The tree cover factor was included in a multiple regression alongside other variables such as the size of the lot and the number of fireplaces in the property.
- Willis and Garrod (1992) found that a 1 per cent increase in the proportion of forest cover in the 1km grid square in which a property was located led to a £43 increase in the expected price of a property. (based on 1988 house prices). They estimated that 20 per cent tree cover added 7.1 per cent to house prices.

There are two important points to note about such studies:

- We can expect that impacts on property prices measure a number of different sources of value to local residents, such as the recreation value and the health benefits, not just the aesthetic improvement.
- Existing studies mostly focus on very narrow geographical areas, like an individual property or a one kilometre grid square, whereas the impacts of woodlands might be diffused over a wider area (even if they are less pronounced further away). It is entirely plausible that forests could be a selling point for homes 5 or 10 kilometres away, but that would not be captured in any of the studies listed above.
- Existing studies do not capture the differences very well between types of woods. Broad-leaved or ancient woodlands may be associated with a greater degree of aesthetic value.

The Garrod & Willis (1992) estimate seems the most relevant to this study, as the data is from the UK and it addresses forest cover around a property rather than trees on a property itself. But this should be an area where further research, taking advantage of developments in spatial economics, can identify impacts over broader areas with a greater degree of detail; and account for variations in the types of woodlands concerned and other circumstances.

Table 4.2: Total value of woodlands

Woodland type	Value per hectare, £	Area, %	Area, hectares	Total value, £bn
Urban or peri-urban wood	£130,000	10	0.3m	£39bn
Commercial forest	£55,000	60	1.8m	£99bn
Lowland, broad-leaved woodland	£140,000	30	0.9m	£122bn

WTPL/Katherine Jaiteh

5. Woodlands as a policy tool

5.1 The broad nature of the benefits from woodlands

There is a range of policy areas in which trees and woodlands might in themselves, or as part of a mix of policies, compete against other options which do not have the same wider benefits or might even have wider disbenefits. It might therefore be easy for an appraisal process which did not include any or all of those wider benefits and disbenefits to allocate fewer resources to trees and woodlands than would be optimal given a more complete consideration of their effects.

To illustrate the point, consider the following illustrative table, in which we explore a number of potential policy areas in which woodlands might be a policy tool versus some alternative policies.

5.2 Facilitating housing developments

It is widely expected that the next couple of decades will see a step increase in UK house building. As well as improving development (e.g. through the health benefits mentioned in Section 3.4) woodlands can also contribute specifically to facilitating increased housing development in at least two ways.

First, they can ease resistance to it. Housing developments can be unpopular where local communities believe new housing will fundamentally change the character of an area from being rural or edge-of-town to being central urban or suburban. Incorporating woodlands into housing developments can soften such resistance, diminishing the sense of "lost nature".

Second, woodlands can facilitate house building on more marginal land — e.g. land in flood plains, as discussed in Section 3.3. Further research in this area could ask respondents to a survey whether they would support two different developments, of equal density, one based around relatively dense developments (perhaps through traditional urban streets (Boys Smith & Morton, 2013)) with provision for woodland and another based on a less dense development (perhaps with green spaces instead between the buildings as in many contemporary developments).

Policy area	Tool	Relevance	Side benefits								
			Business	Recreation	Flood management	Health	Water management	Aesthetic	Climate change mitigation	Option, bequest and existence	Other
Facilitating housing development											
	Local referendum	Direct									Democratic buy-in
	Section 106	Direct	Possible	Possible							
	Woodlands	Part of the mix	X	X	X	X	X	X	X	X	
Air pollution											
	Tighter car emissions standards	Direct	Negative			X			X		
	Invest in electric buses	Direct	X			X			X		
	Woodlands	Direct	X	X	X	X	X	X	X	X	
Rural regeneration											
	CAP	Part of the mix					Negative				
	Regional policy	Direct	X					Possibly negative			
	Woodlands	Part of the mix	X	X	X	X	X	X	X	X	
Flooding											
	Flood walls	Direct			X			Negative			
	Restrictions on building houses on flood plains	Part of the mix	Negative								Bad for meeting housing need
	Woodlands	Direct	X	X	X	X	X	X	X	X	

There are a number of other ways in which policymakers have attempted to weaken barriers to development, for example by limiting the scale of the development, but doing so may involve a greater sacrifice in terms of the economics of the housing project, while not reassuring residents that green space will be protected. Other green space options may also not produce the same wider benefits as, for example, grassland alone may not have the same aesthetic value.

5.3 Combating air pollution

Woodlands might improve human health in a number of ways, some of which have already been identified, such as encouraging recreation or improving air or water quality. However, almost all of the benefits associated with woodlands are likely to contribute indirectly to improving human health. Improved employment opportunities thanks to forestry industries might improve someone's quality of life and thereby their health. Greater protection against flooding may cause people to be relaxed and thereby improve their health. Any economic benefit is likely to be felt in improved health and the overall benefit to people's health may therefore be much greater than an analysis of the more direct connections to health – such as air pollution – might suggest.

There has been research on the overall impact of woodlands on human health, though it is difficult to separate cause and effect when the more fortunate are likely to exhibit a range of healthy behaviours and also more likely to be able to afford to live near amenities like woodlands.

There are other means of combating air pollution which governments can pursue. For example, plans were recently considered to lower the speed limit on the M3 motorway between junctions 3 and 4; older, more polluting vehicles are charged for operating within the Low Emissions Zone in London; and a number of investments have been made in – for example – retrofitting buses in the hope of reducing tail pipe emissions. To the extent it is necessary to choose between those options and planting woodlands, trees and woodlands in urban areas may require a larger initial capital investment – primarily in terms of the particularly valuable land needed – but the wider benefits will be much larger, particularly in terms of the aesthetic improvements which are likely to benefit large numbers of households.

5.4 Rural regeneration

Rural incomes often vary sharply, based on agricultural prices and productivity, from season to season. Many financial products are intended to limit the vulnerability of farmers by insuring them against that risk in some way, but communities can still suffer if earnings from the principal crop do not meet expectations.

There are a wide range of measures which are often considered to encourage rural regeneration and a diversification of rural incomes, including:

- agricultural price support (e.g. via the Common Agricultural Policy);
- allowing new development projects, from recreational facilities to business locations;
- supporting the development of new small-scale industries;

Woodlands might offer an additional means to diversify the earnings of rural communities thanks to the combination of direct business uses and the recreational value of woodlands bringing new visitors to an area, supporting local retail businesses. At the same time, they would provide a range of wider benefits.

5.5 Mitigating flooding

With many climate policies there are difficult choices to be made between attempting to mitigate climate change and avoid it happening, or accepting that it will happen to some extent and adapting. Wind farms will not make the UK less susceptible to flooding and flood defences will not reduce greenhouse gas emissions.

In the case of trees and woodlands, there is not necessarily such a trade-off as woodlands can assist in mitigating climate change (by locking up stocks of carbon) and in adapting to climate change (by reducing the extent of the damage resulting from floods, for example). They therefore might represent a particularly valuable climate policy, especially if there was uncertainty – perhaps because it was unclear to what extent the international coordination problems inherent in most policies intended to mitigate climate change could be overcome – about whether mitigation or adaptation were preferable.

Other means of mitigating flooding also do not exhibit the other benefits associated with trees and woodlands. Large concrete flood defences and other direct physical defences might minimise their visual impact, but they will not have the positive aesthetic value associated with most woodlands. They will also not have potential business or recreation value independently of their primary purposes of mitigating flooding.

Woodlands are unlikely to represent a complete flood management policy, and direct defences will still be needed, but their wider benefits should be considered as a powerful case for giving them a greater role.

6. Conclusions

This report has considered and quantified a wide range of benefits associated with trees and woodlands. However it is necessarily incomplete and there will certainly be benefits which we have missed. Despite that, our approximate estimate is that the aggregate value of UK woodland is over £250bn.

The evidence summarised in this report reinforces the need for decision-making to embed the wider impacts in order to ensure that other options are not taken instead of planting or protecting woodlands because of an incomplete understanding of the benefits they create. In assessing any project, policymakers should consider whether woodland, existing or potential, might provide a range of benefits that are not obvious, but could be of profound importance to the community.

Our results also provide useful background to the consideration of new funding mechanisms that might support an expansion in woodland cover, to meet or extend current Government targets. There are public bodies, businesses and households that might pay in order to secure each of the benefits described. However in many cases, particularly with respect to indirect or non-use values, there are formidable transaction costs. It is not really practical for each household to pay the fraction of a penny they might be willing to pay for an area of woodland's contribution to mitigating climate change, although when the value to every household, now and in the future, is added together the total is significant. Well-designed institutions should help to overcome those transaction costs and prevent the under-supply of woodlands that might be the result otherwise.

Finally it is notable that at the aggregate, trees and woodland supply a number of goods that we might expect will be needed more in the future. Air pollution is becoming a more pressing issue as the threat of legal enforcement of EU air quality rules rises. Flooding is expected to be the major domestic challenge posed by climate change. The urban heat island might become a considerably more pressing challenge with increased urbanisation and global warming.

There is every reason to think that, even without those new pressures, people would want to allocate greater resources to trees and woodlands as their incomes continued their long-term growth (Huber, 1999). As other, more immediate needs are met people move up a hierarchy: from food to manufactured goods; from manufactured goods to services like education for their children and better healthcare (Fogel, 2009); and from personal services to a beautiful and well-protected natural environment. It is no accident that, by contrast, the greatest environmental disasters of the 20th century were associated with periods of economic desperation.

Hopefully, this report has helped to articulate how people value forests and illustrates a range of reasons why policymakers might want to ensure they are given proper priority. That should encourage the development of new mechanisms to support the planting and protection of trees and woodlands which we can expect a great many people to appreciate.

WTPL / Steven Kind

7. Bibliography

AECOM. (2012). *Economic Assessment of the Urban Heat Island Effect.* Melbourne: City of Melbourne.

Amirnejad, H., Khalilian, S., Assareh, M., & Ahmadian, M. (2006). Estimating the existence value of north forests of Iran by using a contingent valuation method. *Ecological Economics*, 665-675.

Anderson, L. M., & Cordell, H. K. (1988). Influence of trees on residential property values in Athens, Georgia (U.S.A.): a survey based on actual sales prices. *Landscape and Urban Planning*, pp. 153-164.

Boys Smith, N., & Morton, A. (2013). *Create Streets.* London: Policy Exchange.

Calder, I., & Aylward, B. (2006). Forest and floods: Moving to an evidence-based approach to watershed and integrated flood management. *Water International*, 87-99.

CCC. (2014). *Managing climate risks to well-being and the economy.* London: UK Committee on Climate Change.

CJC Consulting. (2009). *The value of benefits arising from trees and woodland in the UK.* Grantham: Woodland Trust.

ClientEarth. (2014, February). *Recap on ClientEarth's air pollution ase against the UK government.* Retrieved August 12, 2014, from ClientEarth: http://www.clientearth.org/201402202455/health-environment/clean-air/recap-on-clientearths-air-pollution-case-against-the-uk-government-2455

Coase, R. H. (1960). The Problem of Social Cost. *Journal of Law and Economics*, 1-44.

Dadvand, P., Sunyer, J., Basagana, X., Ballester, F., Lertxundi, A., Fernandez-Somoano, A., . . . Nieuwenhujisen, M. (2012). Surrounding Greenness and Pregnancy Outcomes in Four Spanish Birth Cohorts. *Environmental Health Perspectives*, 1481-1487.

DECC. (2009). *Climate Change Act 2008: Impact Assessment.* London: Department of Energy and Climate Change.

DEFRA. (2007). *Overall Impact Assessment for the Water Framework Directive (2000/60/EC), adopted by the European Union Council and European Parliament on 22 December 2000.* London: Department for Environment, Food and Rural Affairs.

DEFRA. (2013). *Government Forestry and Woodlands Policy Statement.* London: Department for Environment, Food and Rural Affairs.

Department of Health. (1999). *Economic Appraisal of the health effects of air pollution.* London: Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollution.

DG Environment. (2011). *Biodiversity and Health.* Brussels: DG Environment News Alert Service.

Dixon, S. (2013). *Investigating the effects of large wood and forest management on flood risk and flood hydrology, doctoral dissertation.* Southampton: University of Southampton.

Doick, K., & Hutchings, T. (2013). *Air temperature regulation by trees and green infrastructure.* Edinburgh: Forestry Commission.

Donovan, G., & Prestemon, J. (2010). The Effect of Trees on Crime in Portland, Oregon. *Environment and Behavior*, 1-28.

Donovan, G., Michael, Y., Butry, D., Sullivan, A., & Chase, J. (2011). Urban trees and the risk of poor birth outcomes. *Health & Place*, 390-393.

Environment Agency. (2013). *Updating the National Water Environment Benefit Survey values: summary of the peer review.* London: Environment Agency.

Eurostat. (2014). *Economic accounts for forestry and logging - values at current prices - for_ieeaf_cp.* Brussels: European Commission.

Faber Taylor, A., Kuo, F., & Sullivan, W. (2001). Coping with ADD: The Surprising Connection to Green Play Settings. *Environment and Behaviour*, 54-77.

FAO. (2010). Global Forest Resources Assessment. Rome: Food and Agriculture Organization of the United Nations.

Fogel, R. (2009). Forecasting the Cost of U.S. Healthcare. The American.

Garrod, G. (2002). *Social & Environmental Benefits of Forestry Phase 2: Landscape Benefits.* Edinburgh: Forestry Comission.

Garrod, G., & Willis, K. (1992). The amenity value of woodland in Great Britain: A comparison of economic estimates. *Environmental and Resource Economics* , pp. 415-434.

Handley, J., & Carter, J. (2006). *Adaptation Strategies for Climate Change in the Urban Environment.* Manchester: Centre for Urban & Regional Ecology.

Handley, J., Gill, S., Ennos, A., & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 115-133.

Hanley, N., Willis, K., Powe, N., & Anderson, M. (2002). *Valuing the benefits of biodiversity in forests.* Edinburgh: Forestry Commission.

Hardaker, P., & Collier, C. (2013). Flood Risk from Extreme Events (FREE) - a National Environment Research Council directed programme. *Quarterly Journal of the Royal Meteorological Society*, 281-281.

HSE. (2007). *HSE principles for Cost Benefit Analysis (CBA) in support of ALARP decisions.* Bootle, Merseyside: Health and Safety Executive.

Huber, P. (1999). *Hard Green: saving the environment from the environmentalists, a conservative manifesto.* New York: Basic Books.

Humann, M., Schuler, G., Muller, C., Schneider, R., Johst, M., & Caspari, T. (2011). Identification of runoff processes - the impact of different forest types and soil properties on runoff formation and floods. *Journal of Hydrology*, 637-649.

Jackson, B. M., Wheater, H. S., MacIntyre, N. R., Chell, J., Francis, O. J., Frogbrook, Z., & Solloway, I. (2008). The impact of upland land management on flooding: insights from a multiscale experimantal and modelling programme. *Journal of Flood Risk Management*, 71-80.

LaMarche, J., & Lettenmaier, D. (2001). Effects of forest roads on flood flows in the Deschutes River, Washington. *Earth Surface Processes and Landforms*, 115-134.

Mapes, N. (2011). *Wandering in the Woods: A Visit Woods pilot project.* Dementia Adventure.

Mayor of London. (2006). *London's Urban Heat Island: A Summary for Decision Makers.* London: Greater London Authority.

McDonald, A., Bealey, W., Fowler, D., Dragosits, U., Skiba, U., Smith, R., . . . Nemitz, E. (2007). Quantifying the effect of urban tree planting on concentrations and depositions of PM10 in two UK conurbations. *Atmospheric Environment*, 8455-8467.

McGregor, G., Pelling, M., Wolf, T., & Gosling, S. (2007). *The social impacts of heat waves.* Bristol: Environment Agency.

McIntyre, N., Ballard, C., Bulygina, N., Frogbrook, Z., Cluckie, I., Dangerfield, S., & Wheater, H. (2012). The potential for reducing flood risk through changes to rural land management: outcomes from the Flood Risk Management Research Consortium. *Eleventh National Symposium* (pp. 9-11). Dundee: British Hydrological Society.

Merlo, M., & Croitoru, L. (2005). *Valuing Mediterannean Forests: Towards Total Economic Value.* Wallingford: CABI.

Morales, D. J. (1980, November). The Contribution of Trees to Residential Property Value. *Journal of Arboriculture*, pp. 305-308.

Morison, J., Matthews, R., Miller, G., Perks, M., Randle, T., Vanguelova, E., . . . Yamulki, S. (2012). *Understanding the carbon and greenhouse gas balance of forests in Britain.* Edinburgh: Forestry Commission.

Nisbet, T., Silgram, M., Shah, N., Morrow, K., & Broadmeadow, S. (2011). Woodland for Water: *Woodland measures for meeting Water Framework Directive objectives.* Edinburgh: Forestry Commission.

Odoni, N., & Lane, S. (2010). *Assessment of the impact of upstream land managment measures on flood flows in Pickering Beck using Overflow.* Edinburgh: Forestry Commission.

Officer, L., & Williamson, S. (2014). *Five Ways to Compute the Relative Value of a UK Pound Amount, 1270 to Present.* MeasuringWorth.

Pattison, I., Lane, S., Hardy, R., & Reaney, S. (2014). The role of tributary relative timing and sequencing in controlling large floods. *Water Resources Research*, 9-11.

Penning-Rowsell, E. (2014). A realistic assessment of fluvial and coastal flood risk in England and Wales. *Transactions of the Institute of British Geographers.*

Polyakov, V., Fares, A., & Ryder, M. (2005). Precision riparian buffers for the control of nonpoint source pollutant loading into surface water: A review. *Environmental Review*, 129-144.

Powe, N. A., & Willis, K. G. (2004, February). Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. *Journal of Environmental Management*, pp. 119-128.

Regneris Consulting. (2009). *The Economic Contribution of the Mersey Forest's Objective One-Funded Investments.* Altrincham, Cheshire: The Mersey Forest.

Robinson, M., & Dupeyrat, A. (2003). Effects of commercial forest felling on streamflow regimes at Plynlimon, mid-Wales. *Hydrological Processes*, 1213-1226.

Robinson, M., Cognard-Plancq, A., Cosandey, C., David, J., Durand, P., Fuhrer, H., . . . Zollner, A. (2003). Studies of the impact of forests on peak flows and baseflows: a European perspective. *Forest Ecology and Management*, 85-97.

Rogers, K., Hansford, D., Sunderland, T., Brunt, A., & Coish, N. (2012). *Measuring the ecosystem services of Torbay's trees: the Torbay i-Tree Eco pilot project.* Polegate: Treeconomics.

Seppanen, O., Fisk, W., & Lei, Q. (2006). *Effect of Temperature on Task Performance in Office Environment.* Berkeley, CA: Ernest Orlando Lawrence Berkeley National Laboratory.

Tiwary, A., Sinnett, D., Peachey, C., Chalabi, Z., Vardoulakis, S., Fletcher, T., . . . Hutchings, T. R. (2009, October). An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: A case study in London. *Environmental Pollution*, pp. 2645-2653.

Townsend, M. (2012). *Urban air quality.* Grantham: The Woodland Trust.

Townsend, M., & Atkinson, S. (2012). *Planting trees to protect water: The role of trees and woods on farms in managing water quality and quantity.* Grantham: Woodland Trust.

Türker, M. F., Öztürk, A., & Pak, M. (2003). Total Economic Value of Forest Resources in Turkey. *XII World Forestry Congress* (pp. 0410-A2). Quebec City: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/docrep/article/wfc/xii/0410-a2.htm

van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental Preference and Restoration: (How) Are They Related? *Journal of Environmental Psychology*, pp. 135-146.

van Dijk, A., van Noordwijk, M., Calder, I., Bruijnzeel, L., Schellekens, J., & Chappell, N. (2009). Forest-flood relation still tenuous - comment on 'Global Evidence that Deforestation Amplifies Flood Risk and Severity in the Developing World. *Global Change Biology*, 110-115.

Wheater, H., & Evans, E. (2009). Land use, water management and future flood risk. *Land Use Policy*, 251-264.

Woodland Trust. (2009). *Space for People: Targeting action for woodland access.* Grantham: Woodland Trust. Retrieved from http://www.woodlandtrust.org.uk/mediafile/100083906/space-for-people.pdf

WOODLAND TRUST

The Woodland Trust, Kempton Way, Grantham, Lincolnshire, NG31 6LL. woodlandtrust.org.uk 0330 333 3300

The Woodland Trust is a registered charity in England and Wales no. 294344 and in Scotland no. SC038885. A non-profit making company limited by guarantee. Registered in England No. 1982873. The Woodland Trust logo is a registered trademark. 9512 01/17