Assessing the wider benefits of the Woodland Carbon Code

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LIST OF ABBREVIATIONS

CCS	Continuous cover system
CNCA	Corporate Natural Capital Accounts
CO_2e	Carbon dioxide equivalent
CSR	Corporate Social Responsibility
DECC	Department for Energy and climate change
DfT	Department for Transport
ETS	Emissions Trading Scheme
EU	European Union
EVL	Environmental Look-up Values
FC	Forestry Commission
FEGS	Final Ecosystem Goods and Services
FSC	Forest Stewardship Council
FTE	Full Time Equivalent
GIS	Geographic Information System
GVA	Gross Value Added
IEGS	Intermediate Environmental Goods and Services
IMD	Index of Multiple Deprivation
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs)
LEEP	Land, Environment, Economics and Policy Institute
LSOA	Lower Super Output Area
MIMES	Multiscale Integrated Models of Ecosystem Services
NEA	National Ecosystem Assessment
ONS	Office of National Statistics
ORVal	Outdoor Recreation Valuation Tool
PBRS	Public Benefits Recording System
PDD	Project Design Document
PFE	Public Forest Estate
SDG	Sustainable Development Goals
SRF	Short Rotation Forest
SSSI	Sites of Special Scientific Interest
TIM	The Integrated Model
UK	United Kingdom
UKNEAFO	UK National Ecosystem Assessment Follow-on
WCC	Woodland Carbon Code

EXECUTIVE SUMMARY

This report for the Forestry Commission assesses the wider (non-carbon) benefits of the Woodland Carbon Code (WCC). It is based on information from 220 WCC projects as of December 2015, which cover 15,841 ha of land in the UK.

The purpose of this study is to identify and measure the wider social, environmental and local economic benefits of WCC projects in the UK, also referred to as 'co-benefits'. The need to assess the co-benefits or wider effects of carbon emissions reduction strategies is highlighted in the Paris Climate Change agreement[1]. It aims to provide evidence on how action to tackle climate change can help deliver other policy objectives.

A robust and replicable approach is developed for assessing the co-benefits of the WCC, both for individual projects and for all WCC projects collectively. The assessment of co-benefits considers the *gross* benefits flowing from WCC projects. The assessment of *net* benefits at a site, after deduction of costs, can be informed by the results, but is not the purpose of this study. In addition, determining whether the benefits identified are additional (or 'added value') at a national level after allowing for any displacement would require detailed modelling of baselines. Such analysis is beyond the scope of the study. However, there is confidence that the majority of WCC impacts are additional, due to the qualification criteria for the scheme; it only includes projects that are enabled to go ahead as a result of the extra carbon finance provided through the WCC.

This study aims to measure co-benefits in monetary terms where possible, as this is considered the best way of communicating them to the vast majority of potential investors in projects using the WCC, such as businesses wishing to gain co-benefits when they offset emissions. Economic valuation can be summarised as a three stage process of qualitative assessment, quantitative assessment and valuation in monetary terms. Valuation results can then be aggregated and reported, accompanied by discussion of the underlying assumptions and caveats. Monetary valuation is particularly relevant to moving beyond carbon reduction driven by Corporate Social Responsibility (CSR) reasons.

However, the monetary valuation of some impacts is not possible, either because they cannot be adequately captured in qualitative terms (e.g. landscape impacts) or due to a lack of monetary valuation evidence. For some of the latter, quantified description of impacts is nevertheless possible. The approach adopted therefore organises the results on the value of WCC projects' co-benefits in a variety of monetary and other metrics:

- The value of some impacts are given as monetary values: recreational use, non-use value of biodiversity, and air quality regulation are estimated to generate an average of £18 – 25m per year of benefits;
- The economic impacts on jobs (70 – 160 FTE created) and turnover (£4.8m/yr contribution to GDP) are also measured;
- Quantified evaluation of some non-monetised impacts: 12.5% and 2.2% of WCC projects' area are in priority areas to manage river catchments and address social deprivation, respectively.

These data provide the best available summary of WCC's positive social and environmental impacts for decision-makers. They show that the WCC generates significant levels of co-benefits. By summarising these benefits, this approach could in future facilitate comparison of these benefits to the costs of schemes and project investments (although assessment of such costs is not within the

[1] http://unfccc.int/paris_agreement/items/9485.php

scope of this study). The data also help to understand the wider role that WCC projects can play, for example through connections to the Sustainable Development Goals and impacts in priority catchments that contribute to climate change adaptation.

Table S.1 shows the approach taken to valuing each co-benefit, and the format of the result ('Qualitative, Quantitative or Monetary' as noted in the right column). It summarises the identified benefits for all WCC projects, and the current/potential future approach for assessing co-benefits at individual WCC sites. It should be noted that the impacts in Table S.1 are expressed in different units, including different types of monetary values, that cannot necessarily be compared. In particular, the impacts of GVA turnover should not be compared, or added to, the welfare-based monetary values for other impacts, such as recreation. The level of uncertainty associated with the different impacts is also identified. Although most of the monetary values are classified as amber, indicating significant uncertainty, they are considered adequate to give a guide to the scale of benefits that WCC projects deliver, and inform policy accordingly.

This study's approach is similar to those used to estimate the co-benefits of other carbon emissions reductions initiatives worldwide. In general, the aim is to establish benefits per project through standardised metrics, such as benefits per ha, and benefits per tonne of carbon or CO_2 impact. The last of these is useful for comparison with other approaches to mitigating carbon emissions.

The air quality, biodiversity and recreational value of the co-benefits of WCC projects are estimated to be £93 - £212 per tonne of CO_2e across the project lifetimes. This is worth \$124 - \$283 per tonne of CO_2e, which is lower, but of a similar order of magnitude (\$100's dollars per tonne) to those of \$480 per tonne of CO_2e sequestered for Gold Standard projects. However, it should be noted that these valuations capture different types of co-benefits and locations, and the timescales used in calculations may be different.

It is noted that a 'buffer' (as described for the WCC in Section 2) is used in providing carbon credits from the WCC to carbon markets. This buffer is introduced to protect the scheme against the severe negative consequences of losses of credits in this market context, and does not represent the expected outcome of WCC projects. Therefore, the buffer is not utilised to assess the co-benefits in the calculations in Table S.1. No other carbon reduction initiatives (such as the Gold Standard) mention using a buffer in their assessment of co-benefits, nor in the calculation of impacts per tonne of carbon.

Ways in which the assessment of co-benefits can be incorporated into the WCC itself are suggested, through links between project information and semi-automated evaluation tools and methods for different co-benefits. However, any such assessments need to be proportionate to the costs of gathering the required information, including the opportunity costs of time to project developers. The significant differences in the scale of co-benefits between different WCC sites, in particular due to differences in location and size, mean that different levels of effort to assess co-benefits are appropriate at different sites. As a result, suggested evaluation approaches should remain optional for WCC projects.

Recommendations on key issues and gaps identified for further consideration relate to automation of the calculations, including potentially through using earth observation data. Key gaps in evidence include:

- Evidence on the role of tree planting in catchment management across the UK, including qualitative understanding of their role in regulating the quantity of water supply over time (throughout the year, rather than during extreme events), and quantification and valuation of impacts of flood risk management and water quality regulation;

- Spatial identification of the areas for tree planting to reduce flood risk and water pollution in parts of Scotland and the whole of Northern Ireland;
- Evidence on the landscape (aesthetic) impacts of woodland planting; and
- Evidence on air quality impacts in different areas, particularly in remote rural locations.

Recreation activities, which are known to be a potentially significant co-benefit of woodland creation projects, are valued using the recently launched (in September 2016) ORVal tool from the University of Exeter for Defra. This study is believed to be the first application of the ORVal tool for policy advice. The ORVal tool provides results for England, which are extrapolated to the rest of the UK based on the rurality and area of woodlands.

Analysis at a site level is demonstrated through four case studies. These show that some valuation calculations can be applied at site level, but others are still hampered by data limitations. Examples include the difficulties in quantifying the impacts of individual woodlands on water regulating services in individual catchments and on social deprivation.

Table S.1: Approach and Results of Valuing Co-Benefits of WCC projects

Impact	Approach	Valuation		Proposed Future Site Approach	Valuation & Uncertainty*
		All WCC Projects	Site-level Approach		
Ecosystem Service Impacts					
Recreation	Modelling using prototype of ORVal	Estimated value supported by WCC sites in the UK of £15m - £17.0m per year, based on an estimated 3.8m - 4.4m visits per year. Over lifetimes of projects this is £410m - £490m in present value terms.	Valuation using ORVal for projects in England only. Extrapolation on per ha basis for projects with different rurality in rest of UK.		**Monetary** **Green - Amber** - Green for England, although ORVal model is new. Amber for rest of UK due to extrapolation
Air quality Regulation	Estimates of pollution (PM10) absorption by trees, using unit values from DfT (2013) data.	Estimated to generate £57m (range of £41m-£240m) over lifetimes of WCC projects, which is an average of £1.9m per year of benefits.	There are significant variations between rural and urban locations due to different levels of air pollution and size of exposed population.	Automated valuation possible using this calculation approach. Requires 'zones' to automatically lookup value of absorbing 1 tonne PM10.	**Monetary** **Amber** - relevance of data to remote rural sites uncertain.
Timber	Not covered as large majority of WCC projects do not currently involve timber extraction.				
Biodiversity	Challenging to assess in particular due to risk of double counting with other services, notably recreation. Willis et al (2003) present results based on values for remote woodlands that can be considered to represent non-use values only.	£660m over lifetimes of WCC projects, if aggregating non-use values over UK population, or £130m if aggregating for each site over the relevant national (England, Scotland, Wales or Northern Ireland) populations. This gives an average value of £1.5 – £6.4m per year.	Following the approach of Willis et al (2003), non-use values per ha per year can be estimated for native broadleaf and conifer planting respectively.	Non-use values based on the first two 'types' considered by Willis et al (2003, pp17-18), updated to current prices. Range of values generated by aggregating over UK households or regional households.	**Monetary** **Amber - Red** - There is significant un-certainty related to the correct population for aggregation purposes, and how biodiversity values for woodland types.

Water pollution regulation and flood control.	Assessed through % of projects lying in priority catchment areas (using separate England and Wales, and Scotland data sets).	12.5% of the area planted under the WCC lies within areas identified as a priority to reduce water pollution and/or flood risks.	"All / XX%" of this project lies within areas identified as a priority to reduce water pollution and flood risks.	Identification of whether in priority areas can be automated. Requires similar GIS layer for Scotland and Northern Ireland.	**Quantitative. Amber** - exact role of woodlands in catchments highly context specific.
Economic Impacts					
Economic activity supported	Transfer of impacts identified for non-timber related woodland management in Scottish forestry sector.	70 - 160 FTE jobs. £4.8m/yr contribution to GVA	Not relevant at smaller sites (as impact is fractions of FTE jobs).	Not recommended for individual sites, but could be assessed at largest sites (although project business plans are more appropriate for this).	**Monetary Green - Amber** - transfer from Scotland to UK uncertain (e.g. management for recreation).
Social Impacts					
Social deprivation	Analysis in GIS of whether WCC projects are accessible to communities in 20% most deprived areas, as assessed in each of England, Scotland and Wales.	12 WCC projects (5.5% of total), covering 349 ha (2.2% of the area planted) under the WCC lies within areas accessible to communities in the lowest 20% of social deprivation in their respective UK countries.	The project is/is not accessible*** to communities in the lowest 20% of social deprivation in their respective UK countries.	Assessment of whether serving a deprived community can be automated. Would be improved by UK data set merging country data. Use of further metrics** can be optional for projects.	**Quantitative. Green.**

* A proposed "traffic-light" assessment of the reliability of the range of data used: Green = reliable for decision making; Amber = Moderate uncertainty, but still informs decision-making; Red = Unreliable for decision-making. This judgement primarily relates to assessment of WCC projects as a whole, and there is higher uncertainty at individual site level.

** Such as the Public Benefit Recording System http://www.pbrs.org.uk/, and Sustainable Development Goals http://www.un.org/sustainabledevelopment/sustainable-development-goals/

*** Accessible is defined as boundaries within 500m. See Annex D.6.1.

The benefits of carbon sequestration and storage are not included in this table as it is for co-benefits alone.

1 INTRODUCTION

This report for the Forestry Commission assesses the wider benefits (or co-benefits) of Woodland Carbon Code (WCC) projects. The report reviews current literature on the economic impacts of woodland and summarises methods that can be used to help determine the value of these co-benefits, in monetary terms where possible. Data on the WCC projects, supplied by the Forestry Commission, provides their expected carbon sequestration and other evidence from which their co-benefits are estimated.

The need to assess the co-benefits or wider effects of carbon emissions reductions strategies is highlighted in the Paris Climate Change agreement[2]. This study aims to provide evidence on how action to tackle climate change can help deliver other policy objectives. As a result this report also considers the analyses of bio-carbon credit schemes such as the Gold Standard so that these findings can be compared to those identified for Woodland Carbon Code projects. Such comparisons are considered relevant to provide information to potential purchasers of WCC credits.

1.1 Objectives and Scope

The purpose of this study is to identify and measure the wider (non-carbon) social, environmental and local economic benefits of Woodland Carbon Code (WCC) projects in the UK. These are all also referred to as 'co-benefits'. The study aims to develop a robust and replicable approach for identifying and measuring these benefits in future, both for individual projects and for WCC projects collectively.

The scope of the study, as agreed with the Forestry Commission, is:

1. To develop, and demonstrate in case studies, a method for assessing the co-benefits – local economy, social, and other environmental – of individual projects under the WCC;
2. To assess the benefits of all projects under the WCC 'portfolio'; and
3. To explore ways of incorporating the measurement and management of the co-benefits into the WCC itself.

1.2 Report Structure

This Section sets out the approach and analysis undertaken to determine the co-benefits of WCC projects in the UK. Following this introduction:

- **Section 2: Approach** – sets out the proposed approach to determine the co-benefits, as agreed with the Forestry Commission;

- **Section 3: Evidence review** - provides a summary of the current literature on the wider impacts of woodland and summarises tools and frameworks that can be used to help determine the monetary value of these benefits (co-benefits). This section informs the analysis in terms of the values and methods that will be used in the benefits estimation and the evaluation of the co-benefits;

[2] http://unfccc.int/paris_agreement/items/9485.php

- **Section 4: Data on WCC activity** – sets out the data provided for WCC projects including information on management regime, carbon sequestration rates, and the costs associated with the projects;

- **Section 5: Assessment of co-benefits** – sets out the typology of woodlands which determines the best structure for proportionate analysis and valuation of the identified benefits. This section then presents the results of valuing the environmental, social and local economic impacts associated with WCC projects (full calculation in Annex D), and the rates at which WCC projects achieve co-benefits. Finally, it evaluates the cost effectiveness of analysing the co-benefits of individual WCC sites in future;

- **Section 6: Case studies** – applies the above methodology to assess the benefits of four different sites within the WCC. Site level information is provided for each case study in addition to information on recreation, air quality, biodiversity, water pollution, and social deprivation.

- **Section 7: Conclusions** – summarises the social, environmental and local economic benefits of WCC projects, the key findings, recommendations, and next steps for continued implementation of the WCC.

In addition, four Annexes describe similar assessments of carbon project co-benefits elsewhere in the world (Annexes A and B) and the details of the typology and calculations used in the assessment here (Annexes C and D).

2 APPROACH

This Section describes the context for the work, then considers methodological requirements, and finally summarises the approach applied.

2.1 Context

The 2011 Natural Environment White Paper described an ambition to leave the natural environment in a better state for future generations. It was published alongside the UK National Ecosystem Assessment (UKNEA) (2011), which highlighted the significant value to society of the goods and services obtained from nature. The White Paper suggested that greater emphasis on these instrumental values of nature would help achieve its environmental protection objectives.

This approach is based on the same principles as the concept of natural capital, for example in supporting new accounting approaches at corporate (eftec *et al.*, 2015a) and national levels (eftec, and Cascade Consulting 2015). At the root of these approaches is the concept of economic value, which is the key feature of the analysis required to deliver the objectives of this project.

The potential for carbon offsets markets to fund ecosystem restoration, such as native woodland planting, is significant. For example, if adequately incentivised, the European Union Member States could achieve a combined additional effect of as much as 400 Mt CO_2/yr by 2030 on top of the existing sink and substitution; with the existing sink and substitution this comes to an equivalent of about 22% of the current EU CO_2 emissions (Nabuurs et al, 2015). Nabuurs et al note that the potential for EU forests to contribute to climate change mitigation and adaptation is currently not used in an optimal way and is not incentivised under EU policies. Looking ahead, however, there is great scope to enhance the role of EU forests in tackling climate change.

Forest carbon offsets have significant potential in the UK, and an Ecosystem Marketplace Report (Peters-Stanley 2012) found that, globally, corporate social responsibility (CSR) drivers are currently the key motivation for this market. They note that carbon offset trends are influenced by buyer preferences, and that different buyers have different motivations for offsetting. Different types of buyers include:

- Voluntary: end-users make up the largest proportion of all buyers and are considered by suppliers to be the 'real' audience for the majority of offsets generated internationally; and
- Pre-compliance buyers: 13% of the market share was transacted by these buyers, who are entering the market in anticipation of having to make purchases in future to comply with regulatory requirements.

Breaking down these buyers by profit types, it shows that 92% of all credits were transacted for profit-making corporate buyers. The largest proportion of these buyers (54%) voluntarily purchased offsets to attain corporate greenhouse gas targets that were established for CSR or public relations and branding purposes.

2.2 Project Process and Scope

To achieve the three project objectives identified, this analysis has needed to:

1. Identify the relevant co-benefits that are significant in the context of UK WCC projects;
2. Review options for assessing and valuing these co-benefits drawing on:

  - Existing literature including for example (eftec 2010a, 2011, 2013), Valatin and Starling (2010), URS (2014);
  - Recent work on ecosystem accounting for woodlands (eftec *et al*. 2015a, and eftec and Cascade Consulting 2015) and the "Scoping study on valuing the social and environmental benefits of trees and woodlands in England, Scotland and Wales" (Binner et al 2016);
  - Work on 'lookup' values for environmental impacts for use in public sector appraisal (eftec, 2015); and,
  - Lessons learned from recent theoretical and applied analysis of the co-benefits of bio-carbon projects (such as evaluations of the Gold Standard[3], and assessment of the Peatland Code[4]);
3. Assess how existing WCC documentation, and practical extensions to it, could be linked to the measurement of these benefits; and,
4. Prioritise proportionate actions to integrate measurement of co-benefits into the WCC.

The most direct approach to valuing the co-benefits of WCC projects would be to evaluate each project in terms of its outputs, taking account where appropriate of complementary and substitution relationships across sites. However, this would be an intensive approach with the drawbacks of not directly revealing or using generalities across the portfolio, and therefore of giving no guidance on a practical (rather than bespoke and intensive) way of extending the valuations to new sites.

To efficiently adjust values to different woodland types, a typology of woodlands needs to be applied. This study develops a simple typology of WCC projects and derives typical valuations for each type. This focuses on the common features and impacts of woodland types, and on the ability to extend valuations to additional projects – to a first approximation - without the need for further specialist input in future.

This study's typology is based on the classifications from eftec (2010a). The typology was developed for assessing WCC benefits in consultation with the client and used information on existing evidence and mapping of WCC projects. The typology reflects WCC projects' size, location in relation to human populations, tree ages and species mix, and visitor access. This typology and analysis also sought to be consistent, where appropriate, with recent and ongoing studies on the value of woodland management in the UK. These studies are reviewed in Section 3.

The values identified in this study are estimates of the total value (gross benefits) of WCC projects. In other words they are not adjusted to estimate impacts against a specific counterfactual that accounts for additionality or displacement, and they do not adjust for costs to assess net impact. The assessment of *net* benefits at a site, after deduction of costs, can be informed by the results, but is not the purpose of this study.

The assessment of *additional* benefits or 'added value' associated with the WCC at a national or site level is similarly not within the scope of the study. Although an interesting question, it would require significant research which is not feasible within this project. This research would include issues of robustly determining counterfactuals and finance flows in the absence of WCC. It would be a complex undertaking requiring (at the least) extensive survey work, and quantification of the impacts of the WCC in terms of:

[3] The Gold Standard: http://www.goldstandard.org/ accessed 12/04/16
[4] Peatland Code: http://www.iucn-uk-peatlandprogramme.org/peatland-code

- Improved benefits or reduced costs from individual projects through better management and siting decisions;
- Benefits from increased number of projects through enhanced financing/incentives, and
- Subtracting the additional costs associated with implementing and following the WCC.

The additionality of land management change impacts, including through WCC projects, is a complex issue. This is whether the impacts of a project would have happened anyway, in the absence of involvement with the WCC. However, there is confidence that the majority of WCC impacts are additional, due to the qualification criteria for the scheme; it only includes projects that are enabled to go ahead as a result of the extra carbon finance provided through the WCC and where woodland planting activity is not driven by legal requirements.

Case studies testing the methods developed at a site level have been constructed by updating existing information through desk-based research as this was considered to be a more effective use of limited resources than a process based on site visits and detailed interviews. This also limits the risk of 'fatigue' at good practice sites, highlighted by URS (2014). Managers of case study sites were contacted to inform them of our proposed approach, and three responded approving the case study text.

2.3 Valuation Methodology

An economic valuation approach is adopted in this study because its potential limitations are considered to be outweighed by the advantages afforded. These advantages derive from the commensurability of monetary values and the direct link to an extensive valuation literature, and include enhanced *consistency*, *comparability*, *transferability*, and *transparency* of assessments, as well as facilitating their use for *prioritisation*.

Economic valuation, including the work in this study, can be summarised as a three stage process (Ozdemiroglu and Hails, 2016): first, the way a decision or activity will influence the environment needs to be understood (qualitative assessment); second, the change in the environment and the related benefits need to be measured (quantitative assessment); only then can the third step of valuation in monetary terms take place.

This report assesses benefits to society (i.e. welfare values), whether or not those values are captured, now or in future, in market prices. The exception to this is carbon, which is measured under the WCC to enable it to be traded in markets in future. Therefore, valuing it using the social cost of carbon would double-count whatever price it was traded for in the future.

Assessing monetary values is especially important for the WCC because:

- Measurement of returns in monetary terms is the best way of communicating them to the vast majority of potential investors in projects using the WCC, such as businesses wishing to gain co-benefits when they offset emissions. This is particularly the case in moving beyond the Corporate Responsibility (CSR) space: CSR motivations are useful for demonstration projects, but likely to be a limited driver for buyers' demand for Payments for Ecosystem Services (PES) (which is an important part of what the WCC achieves) due to the rapidly diminishing public relations returns when scaling up within or across investments (Lammerant *et al.*, 2013);
- It enables comparisons of benefits across different WCC projects in a more transparent and consistent manner, based on transparent assumptions and with less reliance on expert judgement (either explicitly, or implicitly through weighting or scoring criteria used);

- It enables comparison of benefits between a WCC project at a site and other potential uses of that site; and
- It enables aggregation of the benefits of WCC projects across the UK (e.g. each year), allowing their comparison to other environmental management initiatives, integration into 'natural capital accounting' approaches (e.g. the UK woodland ecosystem accounts), and comparison to other (environmental and non-environmental) policy interventions, using metrics such as co-benefits per tonne of carbon, or total benefits per £ invested.

While priority for this study has been to use monetary value estimates, not all benefits can be reliably expressed in monetary terms. For these qualitative and quantitative assessments of value are made.

This study draws on:

- The existing literature and other evidence on the values associated with woodlands and experience in interpreting these values;
- The information already recorded in WCC (in theory and in practice); and
- Practical consideration of how a WCC co-benefits valuation approach could be applied, including through case study examples.

Information about WCC projects provided in project documentation supports the definition of the baseline used in the assessment of co-benefits. This study adopts a zero baseline (as opposed to a baseline that takes into account impacts of preceding land use). This avoids the problem of wrongly counting reductions in negative impacts that are in fact (at least partly) displaced to another location. However, this could also overestimate some values: for example the gross biodiversity value of the new woodland is greater than the net increase if the preceding land use already had some biodiversity value.

Most farmland typically does have biodiversity value, of course, however the relevant concepts here are marginal values rather than average (since we are dealing with relatively small changes in land use, at the national scale). It is likely that the marginal biodiversity value of the mixed and broadleaved woodlands typically developed under the WCC is significantly higher than the marginal biodiversity value of farmland in most areas (in part because there is about 7 times more land under agriculture than woodland. It could also underestimate some values, if the impact of the preceding land use had been negative and those negative impacts were not displaced: for example, nutrient and agrochemical pollution from agricultural land adjacent to water courses.

Economic values are relative, i.e. assessed for a particular change in the provision of a good or service against a baseline. Just like prices in the wider economy, economic values for environmental impacts are context-specific. The baseline and context for assessing values for site management actions, such as in WCC projects, are not always easy to assess.

For example, recreation benefits are particularly sensitive to displacement. That is whether an increase in the numbers and/or value of recreation at a given site is a net increase or displaces the same elsewhere. If recreation at one site moves to another, this creates a loss at the former and a gain at the latter. Detection of such displacement of benefits from WCC projects is improved through the use of the ORVal[5] developed for Defra. This takes into account substitutes in

[5] ORVal (Outdoor Recreation Valuation tool) is a publically accessible online tool that allows a user to explore the recreational use and welfare value of accessible open spaces in England. https://leep.exeter.ac.uk/orval/

determining recreational values, and distinguishes between displaced and additional recreational activity.

As exemplified by recreation, economic values for environmental impacts are usually highly spatially sensitive. This is because factors that influence value, such as the number of beneficiaries, biophysical conditions, and the availability of substitutes, vary significantly by location. As a result, spatial mapping and analysis through geographical information systems (GIS) are a significant aspect of robust valuation of land-use change. This mapping enables adjustments to value transfers to account for local conditions. For example, the valuation of air quality regulation is adjusted based on the remoteness of sites, which influences both the pollution load that can be mitigated and the numbers of people benefiting from improved air quality.

The values identified in this study are estimates of the total value of WCC projects. In other words they are not adjusted to estimate impacts against a specific counterfactual that accounts for additionality or displacement, and they do not adjust for costs to assess net impacts.

The values of WCC project impacts need to be assessed rapidly and consistently. This means the assessment, at least in the first instance, needs to be based on existing and readily available information, and use semi-automated processes. The values identified can inform the option for individual WCC projects to record further information to reduce uncertainty and/or justify higher than typical valuations – a judgement which can be left to individual projects to decide on.

The co-benefits for WCC projects are also presented on a per ha and per tonne of CO_2 basis. This normalisation enables comparisons between sites and with other schemes to mitigate carbon emissions worldwide.

The literature review has not identified comparable co-benefits valuations for most types of carbon mitigation projects. The following calculations of co-benefits allow approximate comparisons to WCC projects' co-benefits:

- The value of projects enabling households in Africa to switch to clean cookstove fuels has been estimated at $50-$380 per tonne of CO_2. This valuation is based on the value of a statistical life, reflecting the health benefits of lower air pollution for the lower-carbon fuels[6].
- The Gold Standard reports its impacts across 1,100 Climate and development projects in 70 countries as saving 46 m Tonnes of CO2 and delivering $2.2bn in co-benefits[7]. This gives an estimated co-benefit of $480 per tonne of CO2, although the timescales this is assessed over is not made clear.

2.4 Summary of Methodology

The method adopted in this study can be summarised as:

1. An assessment of the co-benefits of WCC projects, including local economic, environmental and social impacts beyond the direct economic benefits for project investors;

[6] http://www.ecosystemmarketplace.com/articles/gold-standard-says-it-can-now-value-the-co-benefits-of-your-carbon-buck/ accessed 02/9/16.
[7] http://www.goldstandard.org/#our-projects accessed 02/9/16.

2. Economic valuation through a three stage process of qualitative assessment, quantitative assessment; and then valuation in monetary terms;
3. Calculation of values taking into account WCC site characteristics, based on a woodland typology that accounts for factors, such as rurality, that influence values (e.g. for air quality regulation and recreation);
4. The use of spatial analysis/mapping approaches, and value transfer where monetary valuation is feasible, to assess the values of total co-benefits in per hectare terms, and at the level of individual WCC sites;
5. Estimating the gross value of WCC projects. This is assessed since identification of the net impacts of WCC projects, and adjustment of values to account for likely continuation of preceding land uses is not within the scope of this study; and,
6. Presentation of co-benefits figures in per tonne CO_2 and per ha terms.

3 BACKGROUND EVIDENCE REVIEW

This review aims to identify existing approaches to classifying and valuing the benefits of woodland management relevant to the WCC. It starts with woodland economic impact studies, and considers other woodland carbon co-benefit methods from overseas. Other woodland management evidence is considered in Section 4.

3.1 Evidence on Economic Impacts of Woodland

This Section reports on some relevant evidence in development the assessment of WCC co-benefits. It draws on a review of related literature in Annex D.

3.1.1 Woodland ecosystem accounts for the Public Forest Estate

In August 2016 Forest Enterprise published a corporate natural capital account (CNCA) that considers both the costs (liabilities) and benefits (coverage of natural capital assets) of the Public Forest Estate (PFE - approximately 254,000 ha of mainly woodland, Forest Enterprise England, 2016). The purpose of the account is to:

1. Demonstrate the benefits that the PFE delivers;
2. Understand the link between PFE management and the benefits that it delivers; and
3. Contribute to the strategic decision making of the organisation.

To aid consistency in forest management decisions, it is important that evidence used in assessment of the co-benefits of WCC sites is consistent with that used in the assessment of benefits from woodlands in the PFE CNCA approach. Therefore the unit values used in the PFE CNCA are examined. It should be noted that the same evidence may be applied differently in different contexts.

For WCC projects, the focus is on welfare values at sites, and benefits will be estimated over the time-frame that carbon credits are identified (up to 100 years), and then valued accordingly. The various reporting statements in the PFE account are estimated across the PFE, and not at a site level. Therefore, the values may or may not be applicable to WCC projects, depending on the nature of the impact being valued, and their degree of spatial sensitivity. Importantly, the assessment of benefits in CNCA then seeks to isolate resource rent (i.e. the value from the environment as distinct from the contribution from other capitals) and it therefore deducts costs of production and natural capital maintenance costs. This needs to be borne in mind in comparing natural capital accounting results to WCC co-benefits.

The main goods and services (and associated ecosystem services terminology, included in brackets) that are assessed in the PFE woodland account are as follows:

- Timber (provisioning services);
- Carbon sequestration (climate regulation);
- Recreation (physical and intellectual interactions with biota, ecosystems, and landscapes - cultural services);
- Plant and seed supply (genetic material production);
- Wild game (nutrition/food production); and
- Minerals extraction (provisioning services).

It is important to note that this list only includes those goods and services for which benefit estimates can be made in monetary terms using readily available data and that can be generalised/scaled-up across the entire PFE area. Therefore, the PFE natural capital account is partial in its monetised assessment of benefits at this stage.

Other benefits that are highly dependent on their location would require carefully selected, scientifically grounded assumptions to be made, or local level modelling (e.g. using tools like iTree or InVEST) to provide estimates that could be reported with a justifiable level of certainty over the entire PFE. These benefits include air quality, water quality and flood risk mitigation. This is important in the context of this study, as WCC projects are specific sites, often involving small pockets of woodland across Great Britain, which differ in location, extent and management regime (See Section 5.1).

The corporate natural capital accounting framework sets out a 'forward-looking' perspective for understanding the condition and value of natural capital assets, i.e. the expected benefits over time. The calculations undertaken for the PFE CNCA account are useful to this project, as the intention of WCC projects is that they are managed sustainably with benefits continuing to be provided into the very long term (often 50-100 years[8], and in principle in perpetuity).

The unit values used for the ecosystem goods and services that were monetised in the PFE CNCA are presented in Table 3.1.

Table 3.1: Benefits included in the account with their unit value and further information (2015 prices)

Benefits	Unit value	Notes
Timber	£26.5/m^3	• Private value. • Gross income from the estate.
Carbon	£62/tCO_2e	• Carbon sequestration is an external value (an income is not received for this service). • DECC non-traded carbon values are used for the relevant years the account covers.
Recreation	£ site specific £2.15/visit	• Private value: income received through car parks and lease agreements, concerts, and so on. • External value: visits involve non-market value (Willis *et al.*, 2003)
Plant and seed supply	£ site specific	• Private value through income.
Wild game	£ site specific	• Private value through income.
Minerals	£ site specific	• Private value through income.

The CNCA study chose to use these values for the following reasons:

- The Department for Business, Energy & Industrial Strategy (formerly DECC) non-traded price of carbon (2015) is used as no income is received from the carbon sequestration from the estate. The markets that trade emissions under the Kyoto Protocol, such as the EU Emissions Trading Scheme (ETS), cannot include carbon sequestered in ecosystems. However, credits from this sequestration can be traded in voluntary markets, which the WCC is designed to address for additional woodland planting.

[8] This represents the very long term in economic timescales. It is noted that in ecological considerations for woodlands, timescales may be assessed differently.

- To determine the value of recreation, it used willingness to pay values from Willis *et al.*, (2003) based on consultation with the Forestry Commission.
- Plant and seed supply, wild game, and minerals were all valued using market prices identified by Forest Enterprise England. Their total values across the PFE were estimated at approximately £1 million per year or less.

The values for plant and seed supply, wild game, and minerals meant they each comprised less than 0.5% of the total value of ecosystem service flows from the estate that the study captured. Furthermore, only 2 WCC project descriptions identify possible contributions to game values. This suggests that they are unlikely to be a priority for valuation in this analysis of WCC co-benefits, but can be included in the 'enhanced value flags' (see Table 5.1) for the few specific sites for which game values may be significant.

3.1.2 Environmental look up values tool for Defra

The Environmental Value Look-up (EVL) tool (eftec, 2015c) was developed for Defra to provide indicative values for environmental impacts for use by analysts from Government departments, non-departmental public bodies, and other organisations.

This tool provides indicative values for a first-cut, rapid analysis of environmental impacts, and valuing secondary or incidental impacts in appraisals and assessments that might otherwise overlook environmental impacts. The indicative values included in the tool are based on a review of over 350 UK studies that have estimated the value of impacts and goods and services associated with the natural environment. Based on the available literature, indicative values were determined for the following goods and services of woodlands:

- Aesthetic value: % reduction in house price;
- Cultural heritage: £/residential property/1% increase in land type within the 1km^2 grid;
- Fibre and fuel (valuation relates to timber provision): £/m^3; and
- Recreation and tourism: £/visit.

Air quality regulation, climate regulation, local environmental quality, natural hazard regulation (flood and coastal erosion) and noise pollution are covered by other Government guidance. They are therefore not covered in the lookup tool, to prevent duplication of effort.

Values for biodiversity are not included in the tool, and present a complex area of economic valuation. Some of the value of biodiversity is captured in valuations for other final goods and services – for example the contribution to the provision of agricultural crops, timber, carbon sequestration, and recreation (including wildlife watching). Further elements of biodiversity value (e.g. the benefits associated with species diversity and resilience value) are not currently included in the lookup tool.

In general, woodlands are well covered in valuation literature, particularly with regards to the provision of cultural services such as recreation and tourism. However, the majority of these studies tend to have been conducted at least five and sometimes 10 or more years ago. Given the ongoing changes to environmental and socio-economic circumstances, and to the application of economic valuation methods, this introduces some uncertainty to their application in this study. Economic valuation theory has not changed substantially in this time period. However, the data and tools used to apply it, such as ecosystem services frameworks and computing capacity including GIS software, and thus spatial analysis and ability to account for substitution and displacement effects, have progressed substantially. These developments are partly included in the study via the use of ORVal, which accounts for substitution and displacement in recreation. Future developments in spatial analysis could allow improved valuations for other categories, including air pollution, water and flood-related services, and biodiversity conservation.

3.2 Co-benefits of Other Carbon Credit Schemes

This Section summarises lessons that can be drawn from the methods used by other carbon credit schemes to measure their co-benefits (The Gold Standard[9] and Social Carbon[10]). These schemes are described in Annex A, and related methodologies are summarised in Annex B.

Each of these methods can be seen as a response of these schemes to demand from buyers to know more about the impacts of their carbon-reduction investments. Helping WCC projects meet such requests for information is the ultimate purpose of this project.

The Gold Standard and Net Balance work provide the best comparable methods for assessing co-benefits of forest carbon projects. These methodologies have broad similarities in aiming to establish structured processes for assessing co-benefits. The details of the different approaches vary, primarily due to differences in the types of projects and locations, and therefore impacts, they cover. They all face similar challenges of capturing additional impacts, with different degrees of measurability, across heterogeneous issues and locations. The SOCIALCARBON standard is different from most other co-benefits standards because it is not designed as an extension of a particular carbon-offset measurement methodology or standard.

Each of these measures aims to establish benefits per project through standardised metrics (e.g. benefits per ha or per £ of expenditure) and then convert these to figures per tonne of carbon or CO_2e impact. None of the methods reviewed gives any explanation of whether a buffer (as described for the WCC in Section 2) is applied to the assessment of carbon or co-benefits, nor whether this is taken into account in the calculation of impacts per tonne of carbon.

3.3 Review of WCC Documentation

The WCC application process[11] lays out criteria for compliance with the Code. These are relevant to this study because they are intended to ensure that WCC projects are additional, and because the time/costs involved to provide information to comply are relevant to any additional information requirements associated with assessing project impacts. Compliance with the Code includes requirements that projects are responsibly and sustainably managed, and are publicly registered and independently verified.

This verification takes place 5 years after the project start date[12], with a second verification 15 years after the start date, and then at a minimum every 10 years, during the project[13]). Project registration to meet the requirements of the code means projects provide a location, have a long-term management plan to deliver stated objectives, and demonstrate that the project delivers additional carbon benefits than would otherwise have been the case.

[9] The Gold Standard: http://www.goldstandard.org/ accessed 12/04/16
[10] Social Carbon: http://www.socialcarbon.org/
[11] See: http://www.forestry.gov.uk/forestry/infd-88g2ca accessed April 2016.
[12] For projects starting before July 2011, the first verification is 5 years after the validation date.
[13] See: http://www.forestry.gov.uk/forestry/infd-8w5hyn accessed May 2016.

To be efficient, the assessment of co-benefits of WCC projects needs to complement the existing process of WCC project documentation. Information already recorded by projects can link to assessment of the key ecosystem services from woodland identified in this study. An understanding of how existing WCC data collection works is also needed to propose any optional extensions to this process to allow individual WCC projects to assess their co-benefits in more detail.

Existing WCC documentation has some mandatory requirements for projects to submit information (in forms provided), and gives the option to projects to submit additional evidence. This information is subject to initial validation and regular verification, and is held in a publicly accessible registry. The mandatory information recorded includes location, woodland type and long-term management, project duration (years) and carbon sequestration:

- Total predicted carbon sequestration over project lifetime (tCO_2);
- Predicted claimable carbon sequestration over project lifetime (tCO_2), and
- Predicted contribution to buffer over project lifetime (tCO_2).

The claimable carbon is equal to the total predicted carbon minus the buffer. The buffer is used to protect investors from any losses of verified credits due to environmental pressures (such as wind, fire, pests or disease), woodland management beyond the agreed plan, or development. Therefore the buffer is not considered relevant to analysis of co-benefits and, in line with co-benefit analyses elsewhere in the world (see Section 3.2) is not considered further in this analysis.

The projects are also able to submit a project description, even though this does not have a standardised structure. While the description can help to identify co-benefits (see Section 5), it therefore has limited direct value for comparing the benefits across projects.

3.4 Conclusions from Evidence Review

The evidence reviewed shows that there are existing practical ways of classifying different woodland types to distinguish the differences in values of the benefits they provide. The existing documentation on WCC projects within the scheme provides information to help assign individual projects to the typology in Section 5.1, either directly using project data (e.g. size, woodland type), or indirectly through automated/cost-effective approaches (e.g. determining rurality from project locations). The typology used in this study is developed from these existing approaches, as described in Section 5.1.

4 DATA ON WOODLAND CARBON CODE ACTIVITY

This Section summarises information provided by the Forestry Commission on the projects that are currently registered with the WCC. It informs selection of the woodland typology, and the choice of which benefits to value (i.e. in terms of what is material) in Section 5, and for case study selection in Section 6.

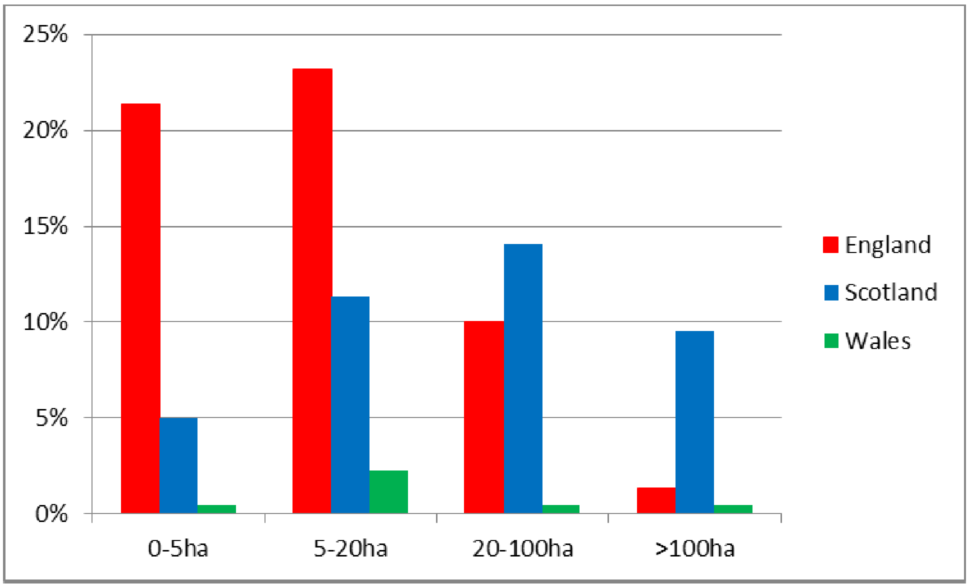
4.1 Overview of WCC projects

As of December 2015, there were 220 projects registered with the Forestry Commission under this scheme. Of these, 114 were classified as 'active projects' (that have been validated) with 104 'under development' and two projects classified as 'under validation'.

Information provided for these projects includes the duration of each project (i.e. how long carbon will be claimed). Information on the location, total area (ha), woodland type and management regime are provided and summarised below. In addition, the total predicted carbon sequestration (tCO_2) is estimated over the lifetime of each project.

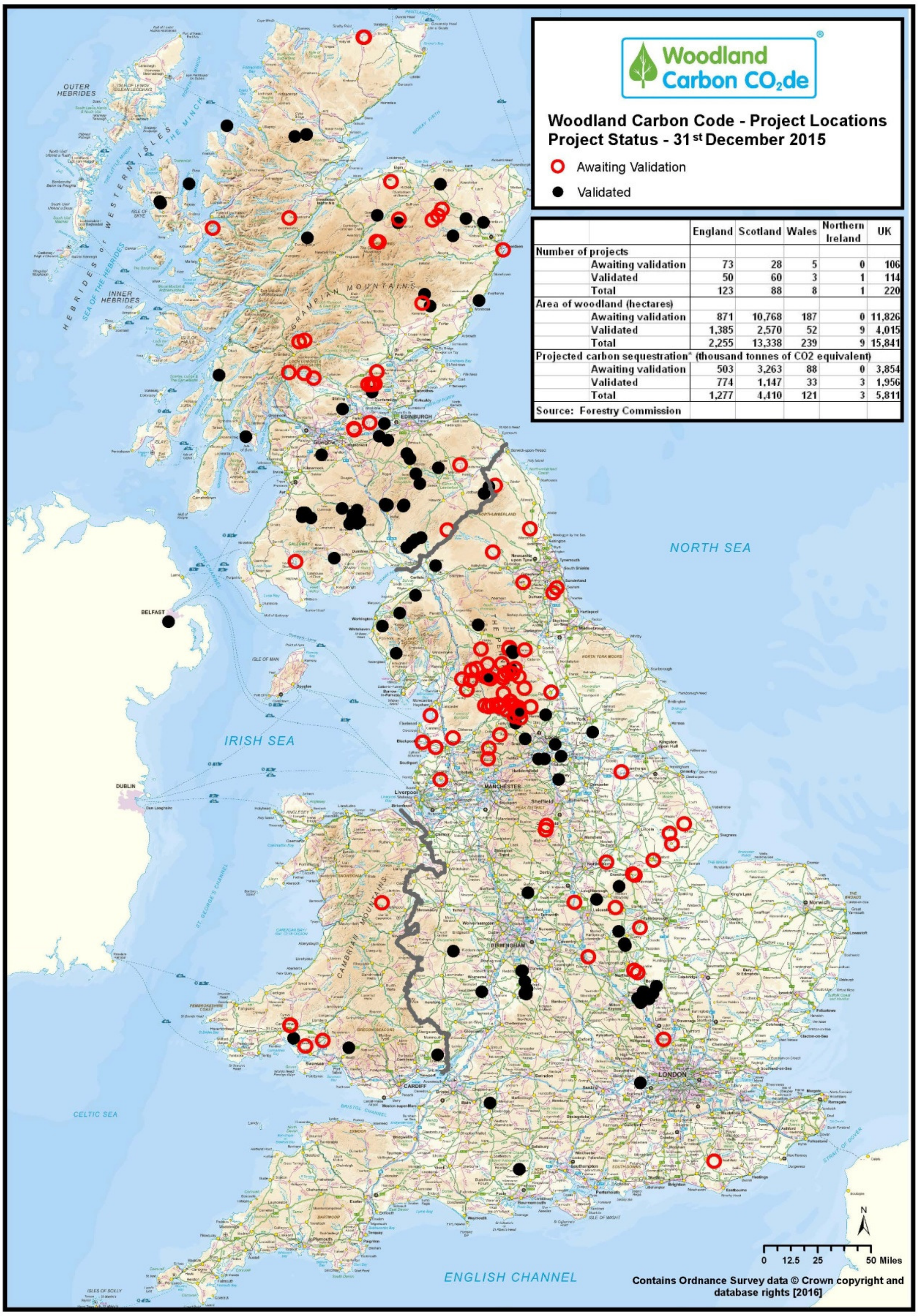
Just over half (56%) of registered sites are located in England, with 40% in Scotland, 8% in Wales and a single site in Northern Ireland. However, most of the area (84%) is located in Scotland. This is partly due to a single outlier in size terms (5,923 ha at Loch Katrine) which alone accounts for 37% of the WCC area, and more generally because most of the large sites, and almost all the very large sites, are in Scotland (Figure 4.1)[14]. The locations of 220 sites are plotted in Figure 4.2.

Figure 4.1: WCC project sites by country and size (ha)



[14] The size classes have been developed for the typology (Section 5) as explained further in that section.

Figure 4.2: Location of WCC sites[15]

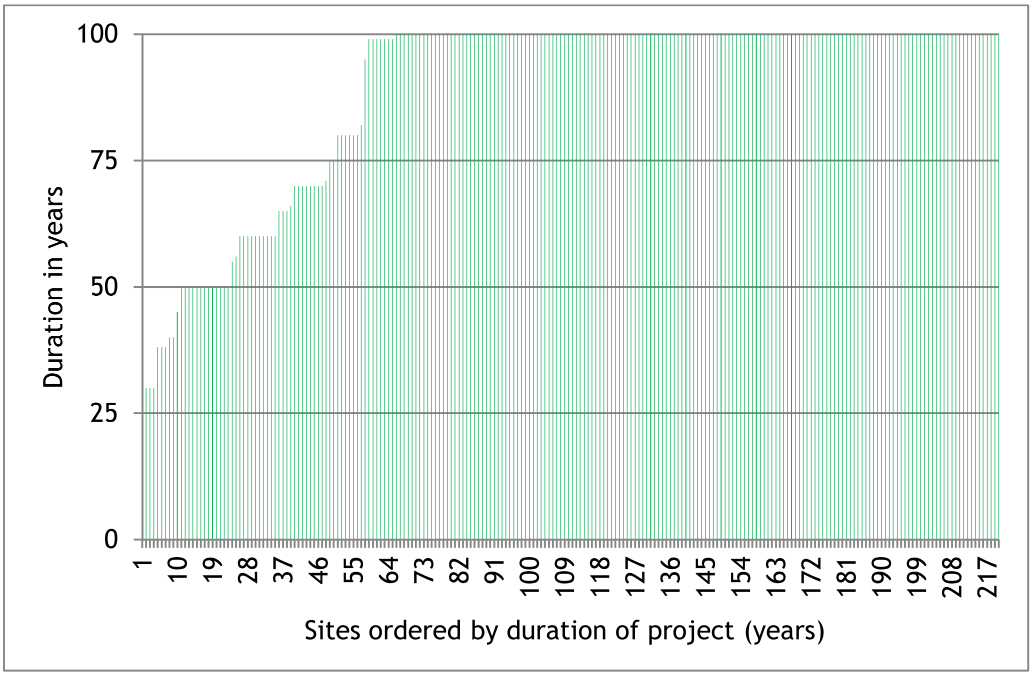


		England	Scotland	Wales	Northern Ireland	UK
Number of projects						
	Awaiting validation	73	28	5	0	106
	Validated	50	60	3	1	114
	Total	123	88	8	1	220
Area of woodland (hectares)						
	Awaiting validation	871	10,768	187	0	11,826
	Validated	1,385	2,570	52	9	4,015
	Total	2,255	13,338	239	9	15,841
Projected carbon sequestration* (thousand tonnes of CO2 equivalent)						
	Awaiting validation	503	3,263	88	0	3,854
	Validated	774	1,147	33	3	1,956
	Total	1,277	4,410	121	3	5,811
Source: Forestry Commission						

[15] Source: http://www.forestry.gov.uk/pdf/UK_WCC_map_2016.03.31.pdf/$file/UK_WCC_map_2016.03.31.pdf accessed 19/7/16.

Most of the projects (162, 74%) have a duration of 100 years, with most of the rest being between 50 and 80 years (Figure 4.3). The project duration determines for how long carbon is accounted for and therefore the amount of carbon that can be sold. The average (unweighted) time period across all WCC projects is approximately 89 years. It can be safely assumed that the land use will remain woodland after the project duration. This is because felling licenses granted under the Forestry Act have a condition that re-planting takes place. The WCC effectively commits a land owner to maintaining the 'final' amount of carbon stock once the project is over.

Figure 4.3: Duration of WCC projects



To determine the wider (non-carbon) social, environmental, and local economic benefits of the WCC, it is important to understand the type of woodland that is being grown as part of each project, and the management applied. The data on woodland types with WCC projects are summarised in Table 4.1, expressed as the proportion of total WCC area. 'No thinning or clearfell' is clearly the dominant type of management. In terms of species mix, there is more variety, but it should be noted that most (86%) of the mixed broadleaf area is the single site at Loch Katrine.

For the purposes of the typology (see Section 5.1) and for simplicity we have focused on the 'main' categories of management. Similarly, for each site we focus on a single woodland type. The large majority (over 90%) of sites list the full area under one of the four types (the column headers in Table 4.1). The other sites have been classified, in consultation with the Forestry Commission, to the category that best represents the planting mix they report. Figure 4.4 shows the information by number of sites (rather than by total area). Although the dominance is not quite as stark as in area terms, it remains clear that a 'typical' WCC project involves predominantly broadleaf planting and little or no timber extraction.

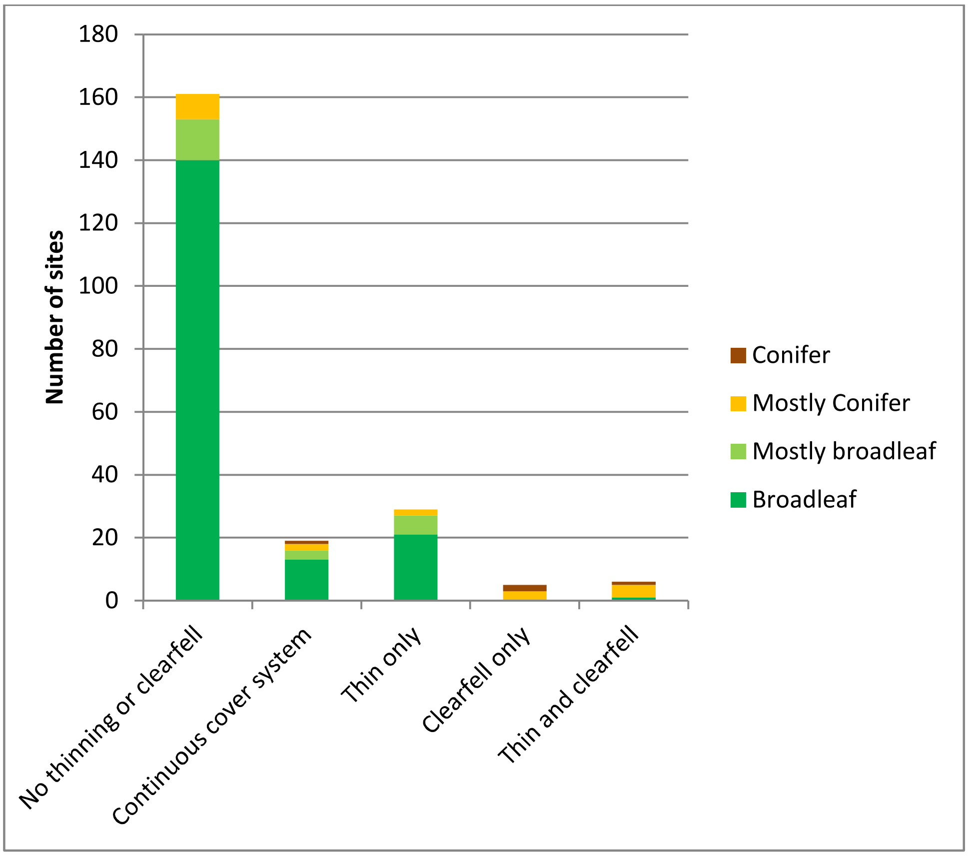
Table 4.1: Types of management and woodland, by proportion of total WCC area

Management Regime	WOODLAND TYPE				Total
	Conifer >80%	Mixed conifer 50-80%	Mixed broadleaf 50-80%	Broadleaf >80%	
No thinning or clearfell	0.6%	11.7%	42.8%	38.2%	*93.3%*
Continuous cover system	0.3%	0.1%	0.1%	1.6%	*2.0%*
Mixed mainly thinning				0.6%	*0.6%*
Mixed mainly thin and clearfell	0.2%	0.5%			*0.7%*
Thin only		0.2%	0.6%	0.7%	*1.5%*
Mixed mainly no thin or clearfell	0.2%			0.7%	*0.8%*
Mixed mainly CCS*	0.1%		0.0%	0.0%	*0.1%*
Mixed mainly clearfell	0.1%				*0.1%*
Clearfell only		0.5%	0.0%		*0.5%*
Thin and clearfell	0.2%			0.1%	*0.3%*
TOTAL	***1.6%***	***13.0%***	***43.5%***	***41.9%***	***100.0%***

Notes:

1. A blank means zero area of this type; 0.0% means an area that is equal to zero when using 1 decimal place
2. CCS = continuous cover system

Figure 4.4: Types of management and woodland, by number of WCC sites



4.1.1 Carbon sequestration rates

The carbon sequestration predicted for different types of WCC projects in the WCC registry is shown in Table 4.2, both as a total amount and an average per hectare per year. This uses total carbon sequestered. The sequestration rates per ha vary across woodland types in part due to differences in management (lower sequestration for woodlands that will see thinning or clearfell) as well as through lower sequestration for projects with shorter lifetimes. There is rather less variability when expressing average sequestration per ha per year of project life (with the exception of mixed conifer that has a lower rate due to two large projects with particularly low sequestration estimates). Due to its dominance within the WCC projects, broadleaf woodlands also dominate the total carbon sequestered, being responsible for around 2/3[rds] of this impact.

Table 4.2: Predicted carbon sequestration rates by types of woodland

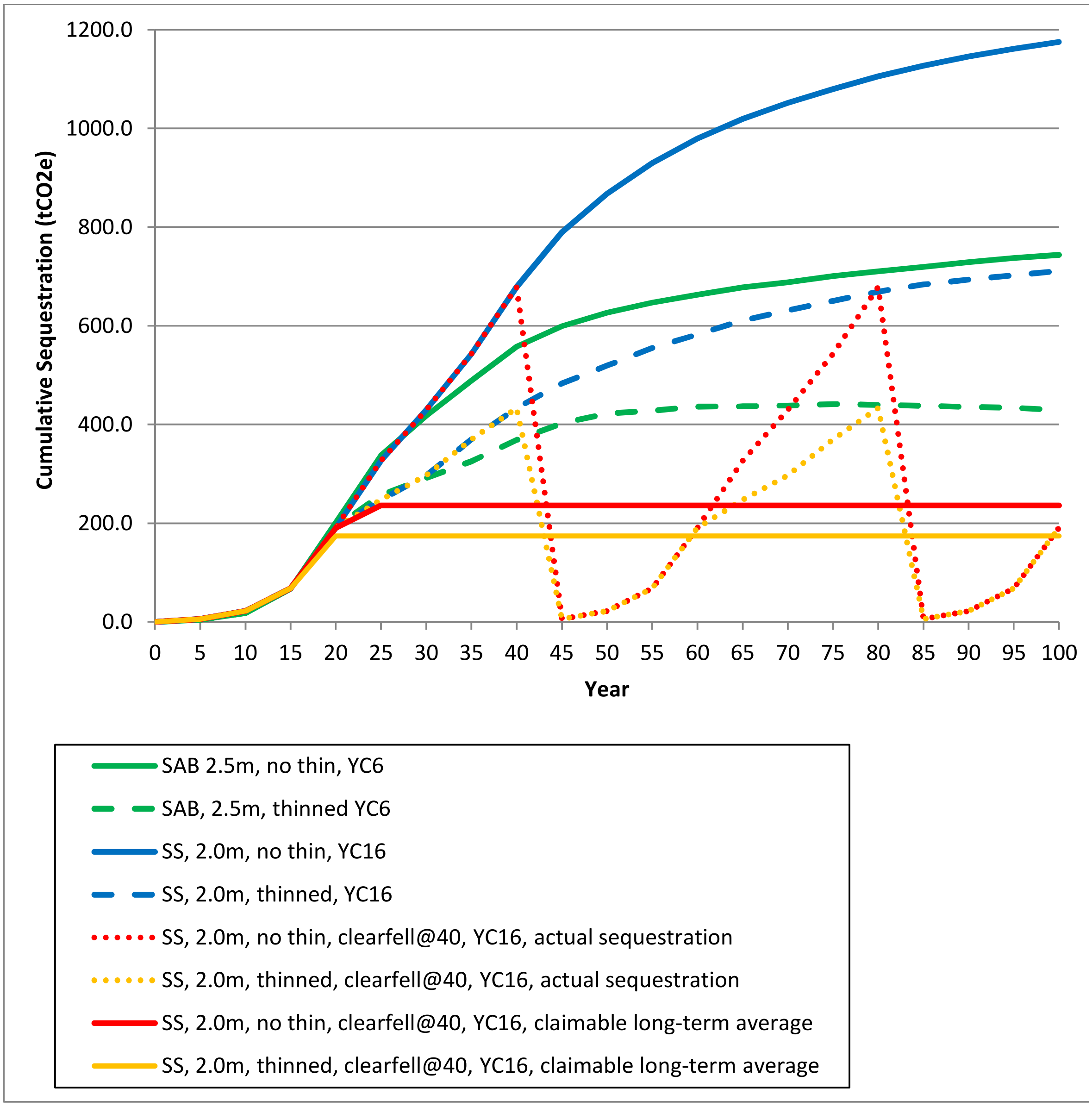
Type of woodland	No. of projects	Total predicted carbon sequestration over projects' lifetimes (tCO_2)	Total predicted carbon per hectare over lifetimes (tCO_2/ha)	Average project lifetime (years)	Average predicted carbon sequestration per ha per year (tCO2)
Conifer	4	19,192	188	43.8	4.29
Mostly conifer	19	364,818	172	71.1	2.41
Mostly broadleaf	22	2,329,441	325	86.2	3.77
Broadleaf	175	3,097,194	481	92.6	5.20
ALL	220	5,810,645	4.10	89.1	4.11

Figure 4.5 shows the predicted carbon sequestration over time of different types of woodland defined under the WCC. A typical pattern for WCC projects (and a lot of mixed broadleaved woodland generally) is represented by the SAB, YC6, no thin, 2.5m spacing (which stands for Sycamore-ash-birch, yield class 6, trees spaced at 2.5m and not thinned).

Figure 4.5 demonstrates how the rate of sequestration changes over time. All scenarios follow a similar curve (solid lines) during their first 20-25 years. Sequestration rates then slow at different rates for different woodland types. There are generally small increases in carbon sequestered in years 70 to 100. As a result, although shorter projects can claim less carbon in total, developers are starting to favour shorter projects as it's more cost-effective (i.e. the additional costs of verifications beyond approximately year 70 are not worthwhile given the small additional carbon that is claimable as a result).

It is also noted that project developers may prefer 70, rather than 100, year contracts as individuals are often unwilling to sign contracts for activities well beyond their own lifetimes (Vicky West, pers com, September 2016). Finally, if a project is clearfelled (which is not the norm for WCC projects) then carbon cannot be claimed past the length of the first rotation, and only to a cap representing the long-run average carbon content of the woodland (see Red and Yellow solid lines in Figure 4.5).

Figure 4.5: Carbon sequestration per ha in WCC projects (total = claimable + buffer)[16]



Source: Forestry Commission.

4.2 Costs

The costs of applying the WCC to woodland creation projects is an important consideration. This is because the costs of gathering information to assess the co-benefits of WCC projects (i.e. the resources used to apply the Code and identify its impacts), must be proportionate to the potential scale of the co-benefits that they produce, both at a site level and for WCC projects as a whole. Costs are considered here for the Forestry Commission as administrators of the Code, and for project developers.

These costs of monitoring and verification are important context for designing assessments of co-benefits. The costs of effort put into assessing co-benefits should be proportionate to any

[16] Note: There may be errors in the database, since the low values seem very low.

additional costs of validating and verifying schemes. These costs are calculated below, but this is only an estimate as it does not account for the opportunity costs of time to project developers, which may increase at the margin with any additional assessment requirements.

The facilitation costs to the Forestry Commission (FC), estimated at £1.3m over approximately 4 years of its operation, have been higher than originally envisioned (FC, pers comm., November 2015). However, compliance costs (validation and verification), which are passed on to projects, have turned out to be lower, at £0.2m. Hence, overall the total costs have been similar to the original expected level, at around £1.5m.

Costs include validation, verification, review, and facilitation costs. Validation and verification costs have been lower than anticipated, at £430 per project. This reduction is partly due to a group discount that is available and which approximately half of the schemes have used. The validation costs are currently £730 for an individual project, with a 60% group discount available offering a cost of approximately £290 per project. Verification costs are estimated to involve a similar cost to validation (i.e. £430 per project), plus the cost of a site visit in year 5 of the project.

The costs to project developers are estimated based on expert judgement about the time taken to apply the WCC to a site (FC and project developers, pers comm., February 2016). These time estimates are for the time required to get a project through the validation stages and for each verification. These estimates are shown in Table 4.3. They suggest that for individual sites, validation requires 2 days and verification 6 days, and for sites in a group, validation requires 1 day per site and verification 4 days per site.

Table 4.3: Time estimates for validation and verification steps for project developers

Stage of the process	Activity	Number of days	
		Single Site	Per Site in a Group
Validation	Draft PDD (single project and 'average' group)	2	1
	Corrective actions during validation	30 min (average, but can vary hugely)	
Verification	Monitoring pre-verification	2	2
	Draft monitoring report and progress reports	2	1
	Corrective actions during verification	2	1
	Verification - Total	6	4

The calculation to determine the cost of time is based on using hourly wage rates. As a result the time estimates provided in Table 4.3 are converted into hours. A high and low estimate of the number of work hours in a normal day is provided in Table 4.4. The low estimate is based on the average 9am – 5pm working day (7.5 hours), and the high estimate is based on government guidance on the maximum hours worked in a week (48 hours).

Table 4.4: Total working hours per day

Working hours	Low (hours)	High (hours)[1]
Total working hours in a day	7.5	9.6

Notes:
1. Maximum of 48 hours in a week, divided by 5 working days.

In order to determine the cost of the validation and verification processes to forest developers / managers, the average wage rate for skilled trade occupations in agriculture and related trades, and for forestry and logging workers is determined. Information from the ONS (2015a) indicates that the average wage rate for 'skilled agriculture and related trades' is £9.76/hr, which forms the low estimate for this analysis. The ONS (2015b) indicates that the average wage rate for all workers involved in 'forestry and logging' is £14.81 which forms the high estimate for this analysis as shown in Table 4.5.

These rates are multiplied by the low and high estimates of hours in a working day to give a range of costs of £73 - 142 per day.

Table 4.5: Average wage rates for forestry workers in the UK and cost per day of time

	Skill level for similar work	Average wage rate for all workers (£/hr)	Cost per day (£)	
			Low	High
Low estimate[1]	Skilled agriculture and related trades	9.76	73	94
High estimate[2]	Forestry and logging	14.81	111	142

Notes:
1. ONS (2015a): Occupation (2 digit SOC) - ASHE: Table 2. Available online.
2. ONS (2015b): Industry (2 digit SIC) - ASHE: Table 4. Available online.

The cost of time is then calculated for each of the steps involved in the validation and verification stages as shown in Table 4.6.

Table 4.6: Cost of time for validation and verification for forest developers

Site(s)	Activity	Days	£ Cost	
			(low: £73/ day)	(high: £142/ day)
Single Site	Validation	2	146	284
	Verification	6	438	852
Per Site in a Group of Sites	Validation	1	73	142
	Verification	4	292	568

The estimated costs per site for validation and one verification range from £365 for one site within a group, up to £1,000, when carried out for a single site. It is important to note that the estimates for the verification apply to each instance where verification is sought over a project's lifetime. They are therefore not the total cost per project, which will depend on the frequency of verifications.

The costs of assessments are a particularly relevant consideration for individual sites. For some sites co-benefits may be low (especially for very small rural sites, e.g. of under 10 ha), and so additional valuations are not recommended. For other sites, (e.g. larger sites nearer larger numbers of people) values may be higher, and therefore more likely to justify an increment in assessment effort and costs to in order to more accurately assess the co-benefits.

5 ASSESSMENT OF CO-BENEFITS

This Section considers a typology of WCC projects, categorises the co-benefits and tries to establish the relationship between the two. A simple typology is proposed, based on those reviewed in Section 3, as a basis for assessing the value of different co-benefits.

5.1 Typology for WCC projects

Existing woodland typologies, and their extension to the case of the WCC, are discussed in Annex C. The conclusions from the assessment of existing typologies, and comparison with data available for the WCC projects suggest that the typology should be based partly on the categories in the WCC database, extended with GIS information where feasible to account for location-specific services. The proposed typology to assess WCC project co-benefits is shown in Table 5.1 below.

The different characteristics covered in the typology enable distinction of different levels of co-benefits for different sites. These are described in the calculations of each co-benefit in Annex D.

Table 5.1: Woodland Typology for Assessing WCC Project Co-benefits

Management	Species mix	Size	Location	Enhanced value flags
No thinning or clearfell (including Mixed mainly no thin or clearfell); Continuous cover system (including Mixed mainly continuous cover system); Thin only (including Mixed mainly thinning); Clearfell only (including Mixed mainly clearfell), and Thin and clearfell (including Mixed mainly thin and clearfell)	Conifer (>80%) Mixed mainly conifer (55-80%) Mixed mainly broadleaf (55-80%) Broadleaf (>80%)	Small: less than 5ha Average: between 5ha and 20ha Large: between 20ha and 100ha Very large: above 100ha	Urban woodlands, on land in or immediately adjoining residential, industrial or educational areas in a conurbation; Peri-urban woodlands, in areas in or around the fringe of conurbations or sizeable settlements, and Rural woodlands, further outside urban areas but still near villages and habitations; Remote woodlands, far from human residences	Biodiversity: **Native trees**; **Habitat**; **Network**. Recreation: **Access**; **Facilities;** **Sporting (game); Visual/landscape**; Special **educational** benefits Special **community** benefits Water-related benefits: **Water Quality**, **Flood**; **Riparian.** **Shelter** for animals or others. **Regeneration / Employment** **Land restoration** **Air quality** **Noise reduction.**

5.2 Co-benefits of WCC projects

This Section summarises the co-benefits of WCC projects valued in Annex D, and assesses the rate at which they accrue across projects. The valuation approach is then used to analyse the impacts of individual sites in the selected case studies in Section 6.

A number of benefits from WCC projects were considered in this analysis. Some potentially beneficial impacts were not considered appropriate for detailed analysis for the following reasons:

- Landscape: The landscape benefits of woodland, although positive and significant in many locations, are highly subjective and relative to the local and regional landscape and cultural context. In some situations there are cultural objections to the landscape effects of increasing woodland cover. There is also limited valuation evidence available, and no scope to use it in transfer. This is partly to the highly subjective nature of the values and partly to risks of double counting with recreation values. There is little doubt that well-designed woodlands contribute to landscape value in many cases, and a number of sites do identify visual amenity/ landscape improvements among their objectives or benefits. Therefore, visual/landscape benefits have not been included in quantitative terms, but are included in the 'enhanced value flags' in Table 5.1.
- Health: There is evidence of both physical and mental health benefits associated with increasing woodland cover. However, this evidence remains difficult to interpret systematically. There are national health datasets that are mapped spatially that WCC site locations could be linked too. For example, self-reported General Health[17], which is also available by LSOA[18] for England and Wales and for Scotland (on request) and so could be compared with social deprivation impacts and linked to WCC projects. There is also relevant data available for Obesity by Local Authority[19], and mental health data sets that need to be requested from the NHS[20]. These data sources may merit further investigation, but the health impacts from natural environment changes are highly correlated to recreation and social deprivation, and dependent on existing provision of accessible green space in communities, so detailed work will be required to identify distinct impacts.
- Education: There is also evidence of woodlands having educational value, including through initiatives such as forest schools. However, this value is likely to be more dependent on relevant facilities (access, shelter, educational materials) rather than the land use type (woodland or otherwise). Its impacts may also be correlated with social deprivation.

Analysis to quantify and value these impacts is not considered practical, except on a bespoke case by case manner that is not feasible in this study, nor for most WCC projects in future. Their monetary valuation would also bring a risk of double-counting of benefits with the measure of social deprivation impact used (see below).

The valuations of ecosystem services in Annex D are summarised in Table 5.2 under the 3 step (qualitative, quantitative and monetary) approach described in Section 2.3.

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17 http://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandwellbeing/articles/generalhealthinenglandandwales/2013-01-30#animated-youtube-video

18 Lower Super Output Area: a boundary used to organise local socio-economic data. See Annex D.6.1

19 https://data.gov.uk/dataset/statistics_on_obesity_physical_activity_and_det_england

20 http://digital.nhs.uk/mhsds/access

Table 5.2: Summary of Valuation Approaches for WCC Co-benefits

Impact	Qualitative	Quantitative	Monetary
Recreation	Woodland creation usually increases recreational values, but provision of access to new sites is a more important driver of value.	Visitor estimates produced using ORVal, a GIS based tool using primary survey data to model outdoor recreation across England.	Value estimates for England from ORVal model. For rest of UK, extrapolation from these.
Air quality Regulation	Trees absorb air pollution, resulting in health benefit to people.	The scale of air quality regulation can be estimated using the quantity of air pollution absorbed per ha of trees and by the area of projects in ha, to get the total pollution reduction in tonnes.	The value of air quality regulation can be calculated by multiplying the total pollution reduction in tonnes, by the value per tonnes in different locations from DfT (2013).
Timber	Robust valuation possible, but not covered since (1) values internal to project owner and (2) most projects envisage no thinning or clearfell.		
Water pollution regulation and flood control.	Trees help regulate water runoff, but impacts and values are highly sensitive to local conditions and difficult to model.	Use maps of priority areas to develop physical indicator of extent of WCC planting in priority areas of catchments.	Robust monetary valuation not feasible.
Biodiversity	Very complex area, but possible to use various flags of situations likely to enhance biodiversity values, notably planting native species, providing specific habitats and/or forming a part of a larger habitat network	The main quantitative feature is the area of habitat created, along with the planting type (conifer-broadleaf) and, at site level, information on the areas of specific habitats	Approximate estimations of non-use values are possible using the values/approach of Willis et al (2003). There is some uncertainty regarding who the values arise to, leading to ranges of values.
Economic Activity	Woodland planting and management creates jobs and the expenditure involved supports turnover.	Data for forestry impacts in the UK (from Scotland) are extrapolated to WCC project activity, taking into account their different management regimes (e.g. WCC projects feature limited timber extraction).	
Social Deprivation	Trees provide a range of social benefits, but impacts and values are highly sensitive to local conditions and difficult to model.	Use maps of priority locations (areas of social deprivation) to develop physical indicator of extent of WCC planting in priority areas.	Robust monetary valuation not feasible.

It should be noted that only non-use values are assessed for biodiversity, since valuing its total economic value risks double-counting the values of other ecosystem services (e.g. recreation, water regulation) that it plays a role in providing. The values for WCC project co-benefits identified in Annex D are summarised in Table 5.3. Where available, values are given per year and as capitalised values over the lifetimes of projects.

Table 5.3: Valuation of Total Potential Co-benefits from 220 WCC Projects Registered in December 2020.

Impact	Valuation	
	All WCC Projects	**Site-level Approach**
Ecosystem Service Impacts		
Recreation	Estimated value supported by WCC sites in the UK of £15m - £17.0m per year, based on an estimated 3.8m - 4.4m visits per year. Over lifetimes of projects this is £410m - £490m in present value terms.	Valuation using ORVal for projects in England only. Extrapolation on per ha basis for projects with different rurality in rest of UK.
Air quality Regulation	Estimated to generate £56.8m (range of £41.1m-£237m) over lifetimes of WCC projects, which is an average of £1.92m per year of benefits.	Air pollution benefits per ha can be estimated for projects with different rurality. OR bespoke calculations possible.
Biodiversity	£656m over lifetimes of WCC projects, if aggregating non-use values over UK population. £130m if aggregating for each site over the relevant national (England, Scotland, Wales or Northern Ireland) populations. This gives an average value of £1.5m – £6.4m per year.	Following the approach of Willis et al (2003), values of £1,480 per ha per year and £1,030 per ha per year can be estimated for native broadleaf and conifer planting respectively. A slightly more detailed assessment at site level could be feasible.
Water pollution regulation and flood control.	12.5% of the area planted under the WCC lies within areas identified as a priority to reduce water pollution and flood risk in their respective countries.	All / XX% of this project lies within areas identified as a priority to reduce water pollution and flood risks.
Economic Impacts		
Economic activity supported	70 – 160 FTE jobs. £4.8m/yr contribution to GVA	Impacts can be estimated at larger sites. Less relevant at smaller sites (as impact is a fraction of a full-time job).
Social Impacts		
Social deprivation	12 WCC projects (5.5% of total), covering 349 ha (2.2% of the area planted) under the WCC lies within areas accessible to communities in the lowest 20% of social deprivation in their respective UK countries.	The project is/is not accessible to communities in the lowest 20% of social deprivation in their respective UK countries.

The 220 WCC projects in the registry as of December 2015 are expected to sequester a total of 5.8m tonnes of CO_2 over their lifetimes.

The co-benefits achieved by WCC projects can be described per tonne of CO_2 absorbed or per ha of land managed. Examining these factors allows comparison to co-benefits and other impacts of alternative carbon-reduction options. These figures are shown in Table 5.4. The calculation per tonne of CO_2 is made by dividing the total co-benefits by the total predicted CO_2 sequestration, (without any adjustment being made for the buffer). Some benefits (e.g. Gross Value Added (GVA)) are an annual impact, so are divided by the estimated average annual CO2 sequestration of 65,000 tonnes of CO2 per year. To calculate per ha values, the co-benefits are divided by the 15,841 ha covered by the WCC projects assessed.

Table 5.4: Valuation of Rate of Potential Co-benefits from 220 WCC Projects Registered in December 2015.

Impact	Valuation	
	Per tonne of total CO2e	Per ha of woodland
Ecosystem Service Impacts		
Recreation	Impact of all projects is equivalent to £2.50 – 2.90 of benefits per year per tonne of CO_2e. Over lifetimes of the projects this is £64 – 75 per tonne of CO_2e	Average per ha values, over the lifetimes of projects, for different rurality (see Annex D.1): • Urban: £44,193 • Peri-urban: £8,850 • Rural: £2,748 • Remote rural: £377
Air quality Regulation	Over lifetimes of the projects £9.80 of benefit per tonne of CO_2e (range £7.10-£40.90) Air pollution benefits per tonne of CO_2 can be estimated for project locations as follows (low-high range): • Urban: £111 (£100-£158) • Peri-urban: £53 (£40-£75) • Rural: £37 (£26-£46) • Remote rural: £0 (£0-£37)	Over lifetimes of the projects £2,980 of benefit per ha (range £2,160 - £12,400) Average benefits per ha per year over 100 years can be estimated for project locations (low-high range): • Urban: £1,630 (£1,465-£2,317) • Peri-urban: £1,033 (£780-£1,465) • Rural: £634 (£447-£780) • Remote rural: £0 (£0-£447)
Water pollution regulation and flood control.	0.004 ha lying within areas identified as a priority to reduce water pollution and flood risks per tonne.	0.125 ha in every ha supported by the WCC lies within areas identified as a priority to reduce water pollution and flood risks.
Biodiversity	Over lifetimes of the projects estimated non-use value of £22 – 97 per tonne of CO_2e	Non-use values of £1,480 per ha per year and £1,030 per ha per year are estimated for native broadleaf and conifer planting respectively.
Economic Impacts		
Economic activity supported	0.0001 – 0.00025 FTE jobs per tonne of claimable CO_2	0.044 – 0.001 FTE job per ha
	£7.38 of GVA per tonne of CO_2	£303 of GVA per ha per year
Social Impacts		
Social deprivation	0.001 ha per tonne of CO_2 lies within areas accessible to communities in the lowest 20% of social deprivation in their respective UK countries.	0.0022 ha in every ha supported by the WCC is in areas accessible to communities in the lowest 20% of social deprivation in their respective UK countries.

The rate at which benefits occur are used to guide the case study analyses. They will also potentially allow data on co-benefits to be summed (e.g. the value for recreation and air quality) and allow predictions to be made of future scheme impacts (but see also Table 5.3 for this).

Estimation of such future values, and at site level of individual WCC projects, are recommended to use per ha values rather than per tonne of CO2e values. This is because the tonnes of CO2e sequestered per ha are variable across different projects, for reasons only partly captured in the typology (species, duration, management) and the reasons for this variation are not all thought to be a strong influence on the values of co-benefits.

The recreational use, non-use value of biodiversity, and air quality regulation co-benefits of WCC projects are estimated to be worth £93 - £212 per tonne of CO_2e across the project lifetimes. This is equivalent to $124 - $283 per tonne of CO_2e[21].

This $ value enables comparison to the co-benefits of Gold Standard carbon mitigation projects (described in Section 2.3) which are estimated at $480 per tonne of CO_2e. The WCC projects co-benefits are therefore lower, but don't include exactly the same co-benefits. Nevertheless, they are of a similar order of magnitude ($100's dollars per tonne) to those for Gold Standard projects.

[21] Using £1 = $1.33 exchange rate, as of 5/9/16.

6 CASE STUDIES

6.1 Introduction

This Section applies the methodology set out in Section 2 to assess the benefits of four representative WCC projects. The projects were firstly selected based on their inclusion in URS (2014), as this meant that site information was already checked and available to publish, avoiding the requirement of input from project managers and potential 'consultation fatigue'. The project case studies are:

- Drumlanrig, Buccleuch Estates;
- Cwm Fagor, Monmouthshire;
- Upton Court Jubilee Wood, Slough, and
- Rectory Wood Forest of Marston Vale, Bedfordshire.

They represent a variety of locations, sizes and types of WCC projects, in order to test the method developed.

Case study 1: Drumlanrig, Buccleuch Estates

Coshogle I

- Project ID: 103000000004479
- Location: Dumfries, Scotland
- Total area: 17.2ha
- Woodland type: broadleaved
- Project duration: 71 years

BACKGROUND / INTRODUCTION

The Buccleuch Estates, located near Dumfries in Scotland comprises 11 separate woodland sites, covering a diverse portfolio of projects and investors. The Buccleuch woodlands are primarily timber oriented, and are mostly situated in a remote area. The woodland of interest, Coshogle I applied for woodland creation grant funding, and was used as a case study site in previous studies (URS, 2014).

This site is used for native hardwood timber production, but also aims to enhance biodiversity and habitat linkage, and has is considered by its developers to have a high landscape value which were the main reasons that led to further development of this site.

WOODLAND CARBON CODE INFORMATION

The native woodland planting will result in a productive hardwood element of 44% Oak, and 24% Ash, which will be managed on a continuous cover basis. Motivation for planting includes emphasis on landscape and environmental stewardship, particularly: "*Expansion of high value biodiversity sites across the estate (e.g. expanded to provide a buffer to native woodland, and ambition to further increase woodland cover)* (URS, 2014)."

Management plans for the 11 individual sites are documented in the Buccleuch Estate-wide Forest Plan. This is updated every ten years and covers the whole 2,600 ha estate. The Forest Plan is produced with input from statutory bodies, NGOs and local communities. It is important to note that this Plan does not cover social aspects such as footpath maintenance.

The main certification scheme that Coshogle I is in compliance with is the UK Woodland Assurance Scheme (and therefore Forest Stewardship Council (FSC)), which supports labelling of timber purchased by consumers.

For FSC accreditation, the estate has to produce an annual report of its activity, which can include monitoring for certain site features such as those designated for biodiversity interest. Environmental issues and reporting are felt to be more important to retailers and consumers than to the estate's direct customers who tend to be intermediaries, such as sawmills. Sale of FSC certified timber provides the main source of forestry income to the Buccleuch Estate.

Woodland planting and management are driven by a commercial perspective, with a long term view of returns. There is currently no formal reporting internally as the estate owners are well informed, and there are no shareholders.

Sources: URS (2014)

CALCULATIONS

Total predicted CO_2 over project lifetime	8,522 tCO_2
Predicted contribution to buffer project lifetime	1,534 tCO_2
Total CO_2 per ha	495 tCO_2 per ha
Project duration	71 years

The total benefits of this project that can be evaluated are:

Recreation: This site is in Scotland so direct ORVal analysis is not possible. Extrapolation using the average per ha value for a remote rural site in England suggests 1,700 visits with a value of £6,500 per year. Its relatively small size and rural location suggest that bespoke analysis of its recreational analysis is not worthwhile. Over 71 years, the present value of this flow is **£170,000**.

Air quality: The site's relatively small size and rural location suggest that its positive impact on air quality is likely to be low, and the value of any improvement in air quality for humans exposed is likely to be very low. The central estimate using the methodology outlined in the report being £0. For sensitivity analysis, the 'high' end of the valuation range gives possible values up to £181,000.

Water pollution regulation and flood control: This woodland is not within the Scottish priority pollution areas.

Biodiversity: The 17.2ha of broadleaf planting with native species can be expected to enhance biodiversity values in the area. Using the Willis et al (2003) approach as explained in the main report, the present value over the 71 years of the project of the non-use value of biodiversity enhancement at the Coshogle site is estimated to be up to £702,000 when aggregating values across all UK households. If instead aggregation is carried out only over Scottish households, the value would be **£63,000**.

Social deprivation: This project is not accessible to communities that are in the 20% most deprived in Scotland.

The recreation and biodiversity values of the site are estimated (using the values highlighted in bold above) as a capitalised value of £233,000 (present value over its 71 year lifetime), giving a value of £27 per tonne of CO_2 over the lifetime of the project.

Case study 2: Cwm Fagor, Monmouthshire

Cwm Fagor

- Project ID: 103000000004447
- Location: Monmouthshire, Wales
- Total area: 29 ha
- Woodland type: Mixed broadleaved
- Project duration: 100 years

Source: FC (2015)

BACKGROUND / INTRODUCTION

Cwm Fagor is a rural site in Monmouthshire, close to the Wye Valley AONB. This site was previously improved grassland and semi-improved pasture that had no statutory land designations and was predominantly used for grazing. The initial phase of the project targeted 29 hectares, with the remaining 51 ha to be planted over the next 15 – 20 years. The whole wood is planted on rolling fields that slope south and west which are bisected by streams. The wood will provide great wildlife and walking links between three isolated Ancient Semi-Natural Woodlands. (FC, 2016a[22])

WOODLAND CARBON CODE INFORMATION

The broad aim of the site, which is owned by Thorlux Lighting, is to mitigate emissions that are generated by the company, but also to allow their customers to capture their own lighting based CO_2e emissions. Thorlux want to create a native woodland that is able to capture carbon dioxide and provide good quality timber.

The planting regime at this site is planned in stages. Planting has been restricted in the first 5 years to 4 – 6 ha/yr, and they aim to have the full 80 ha planted over 20 years. Thorlux will undertake partial and successive coppicing along stream sides. Whilst there are known populations of deer, rabbits and squirrel, theses will be monitored to ensure they do not damage the young trees. Some areas will be managed as small pockets of semi-improved grassland and maintained as open habitat, and basic infrastructure such as paths will allow access for walkers to enjoy the woodland over time.

Every 5 years the amount of carbon captured by the woodland is assessed using Method B of the Carbon Assessment Protocols (Jenkins *et al.*, 2011). This will provide a good case study in terms of being able to predict the amount of carbon captured in young woodlands for future work.

There are a range of environmental benefits that are expected from this woodland in addition to atmospheric carbon capture. It is expected to help create habitat corridors which will allow isolated ecological communities to move through this area, and that woodland birdlife will increase. It is also expected to have water quality impacts as a result of preventing further pollution from improved grassland (such as fertilisers) which will contribute to the improvement of wildlife diversity along stream and riverside zones.

Thorux Lighting are aiming to gain UK Woodland Assurance Scheme (and therefore Forest

[22] Forestry Commission (2016a) http://www.forestry.gov.uk/forestry/infd-8uhhek

Stewardship Council (FSC)), certification for the woodland which is driven by CSR priorities. The site has Better Woodlands for Wales Creation Scheme[23] funding which provides the means for investment in its carbon sequestration.
Sources: URS (2014), FC (2016a)

CALCULATIONS

Total predicted CO_2 over project lifetime	18,102 tCO_2
Predicted contribution to buffer project lifetime	2,715 tCO_2
CO_2 per ha	620 tCO_2 per ha
Project duration	100 years

The total benefits of this project that can be evaluated are:

Recreation: This site is in Wales so direct ORVal analysis is not possible. Extrapolation using the average per ha value for a remote rural site in England suggests 2,755 visits with a value of £11,000 per year. Its relatively small size and rural location suggest that bespoke analysis of its recreational analysis is not worthwhile. Over 100 years, the present value of this flow is **£310,000**.

Air quality: The site's relatively small size and rural location suggest that its positive impact on air quality is likely to be low, and the value of any improvement in air quality for humans exposed is likely to be very low. The central estimate for the present value over the 100 year duration of the project, using the methodology outlined in the report, being £0. For sensitivity analysis, the 'high' end of the valuation range gives possible values up to £389,000.

Water pollution regulation and flood control: This woodland falls within a priority area for both water quality and flood risk management.

Biodiversity: The 29ha of mixed broadleaf planting with native species can be expected to enhance biodiversity values in the area, in particular through linking the existing ASNW sites. Using the Willis et al (2003) approach as explained in the main report, the present value over the 100 years of the project of the non-use value of biodiversity enhancement is estimated to be up to £1,285,000 when aggregating values across all UK households. If instead aggregation is carried out only over Welsh households, the value would be **£63,300**. Willis et al give higher values for ASNW, double the value for broadleaf planting: while this site is new planting, not ASNW, its role in linking three existing isolated ASNW sites could be seen as justification for using a higher value.

Social deprivation: This project is not accessible to communities that are in the 20% most deprived in Wales.

The recreation and biodiversity values of the site are estimated (using the values highlighted in bold above) at £373,000 over its 100 year lifetime, giving a value of £21 per tonne of CO_2 over the 100 year lifetime of the project

[23] Better Woodlands for Wales Creation Scheme: http://www.forestry.gov.uk/fr/INFD-92ADEV

Case study 3: Upton Court Jubilee Wood, Slough


Source: FC (2016b)

Upton Court Jubilee Wood

- Project ID: 103000000004505
- Location: Slough, England
- Total area: 5.8 ha
- Woodland type: Mixed Broadleaved
- Project duration: 100 years

BACKGROUND

Upton Court Jubilee Wood was developed by Slough Borough Council to commemorate the Queen's diamond jubilee. The site, which is situated on the outskirts of Slough alongside the M4 motorway, was previously used for agriculture and grazing, but was also used as a landfill site resulting in high levels of contamination. This site is also near Heathrow, an area where levels of air pollution are controversial, and therefore air pollution mitigation by trees could have additional value.

This project aims to reverse the environmental decline by creating new woodland with a focus on improving wildlife and biodiversity in a peri-urban setting. It will also improve the landscape from the M4 as well as for users of the park. They planted 1,600 trees per ha, with woody shrubs planted throughout, and wildflower meadows and paths also part of the design; these are very valuable habitats for wildlife.

Expected benefits of the woodland will be restoration of former landfill areas, removal of air pollutants from the M4, as well as providing a sound barrier between the M4 and nearby houses.

Once established, the woodland will be thinned occasionally and will be managed mainly for amenity purposes, with unrestricted public access, improving opportunities for physical activity and improving the health and wellbeing of users.

WOODLAND CARBON CODE INFORMATION

Slough Borough Council are both the landowner and user of the carbon. The do not plan to sell Woodland Carbon Units but will use them in the organisation's own corporate Greenhouse Gas accounting. This is a good example of how an organisation can use its assets to generate carbon units and to compensate for their own emissions (Forestry Commission, 2016b) [24].

This project has received funding through the English Woodland Creation Grant Scheme (EWGS[25]) in addition to direct funding by the council. The council is interested in monitoring the social and environmental benefits of the woodland, but has not yet put in place any specific measures or reporting framework

Sources: URS (2014), Forestry Commission (2016b)

[24] Forestry Commission (2016b) http://www.forestry.gov.uk/forestry/beeh-9uynec

[25] EWGS: http://www.forestry.gov.uk/ewgs

CALCULATIONS

Total predicted CO_2 over project lifetime	1,990 tCO_2
Predicted contribution to buffer project lifetime	318 tCO_2
CO_2 per ha	343 tCO_2 per ha
Project duration	100 years

The total benefits of this project that can be evaluated are:

Recreation: The recreational value of this site has been estimated at £131,350 per year, based on an estimated 34,139 visitors per year, using ORVal. Over 100 years, the present value of this flow is £**1,720,000**.

Air quality: Although the site is small, its peri-urban location and proximity to the M4 motorway mean both that it is likely to contribute to improved air quality and that human populations will benefit significantly from the improvement. Using the assumptions for peri-urban woodlands, as explained in Annex D, the central estimate for the present value of air pollution benefits over the 100 years of the project works out as £**179,000**. The low-high range around this central estimate is from £135,000 to £253,000.

Water pollution regulation and flood control: This woodland falls within a floodplain so is a high priority in terms of flood risk management. It is also located within a biodiversity priority area for new woodland planting. This woodland is not within the priority areas for water quality.

Biodiversity: The 5.8ha of mixed broadleaf planting with native species can be expected to enhance biodiversity values in the area, in particular through the focus on diverse habitat creation in a periurban setting. Using the Willis et al (2003) approach as explained in the main report, the present value over the 100 years of the project of the non-use value of biodiversity enhancement at the Upton Court site is estimated to be up to £255,000 when aggregating values across all UK households. If instead aggregation is carried out only over English households, the value would be £**213,000**.

Social deprivation: This project is not accessible to communities that are in the 20% most deprived in England.

The recreation, air quality and biodiversity values of the site are estimated (using the values highlighted in bold above) at £2.11m over its 100 year lifetime, giving a value of £1,060 per tonne of CO_2 over the 100 year lifetime of the project.

Case study 4: Forest of Marston Vale, Bedfordshire

Source: Forest of Marston Vale

Rectory Wood

- Project ID: 103000000004497
- Location: Cranfield, England
- Total area: 42.4 ha planted of a total area of approximately 70ha.
- Woodland type: Broadleaved
- Project duration: 100 years

BACKGROUND

The Forest of Marston Vale is a 'Community Forest', which was established by Government in the early 1990's and has a target to achieve 30% woodland cover. This community based woodland project covers 61 square miles between Bedford and Milton Keynes. It includes 10 recently planted woodland sites which all contribute to the social regeneration (along with new roads, housing, industry etc.) of the local area that has been damaged by brick making and landfills over many decades.

There are other woodlands and non-woodland sites which have been created within the Forest, together with a number of existing isolated areas Ancient Semi-Natural Woodlands (ASNW's) along the ridges over-looking the Vale. New woodland creation will increase the total percentage of woodland cover and also help create connectivity between woodland areas for wildlife. The general landscape in this area is flat and open with the main land use being arable farming.

The majority of these woodlands are created near to expanding residential areas and aim to create new access and recreational opportunities. The Forest of Marston Vale offers limited guided educational visits at the Forest Centre and Millennium Country Park. Community engagement activities include encouraging schools to use sites within the Group and they are designed/managed to facilitate this. There are numerous educational and social benefits that arise from developing educational areas in existing woodland, including better knowledge and understanding of the natural surrounding and respect for the environment[26]. The Forest of Marston Vale is providing 'Green Infrastructure' as part of the areas's regeneration – woodlands and greenspaces, tree planting, recreation areas, wildlife habitats, landscape features and general environmental enhancements.

Rectory Wood, is a good example of the Forest of Marston Vale projects. Located on the outskirts of the expanding Cranfield Village in central Bedfordshire, it was created as a community woodland on former arable farmland. The woodland has been planted in several phases between 2003 and 2013 and is bordered by ancient semi-natural woodland (SSSI) and a former landfill site.

Over 120,000 trees have been planted since 2003, with woodland shrubs, native grasses, and wildflower seeds also being included. Other habitats which are included as part of the development include small lakes and ponds which supports a diverse range of wildlife. The rough

[26] Forestry Commission (2005) http://www.forestry.gov.uk/fr/infd-5z3jvz

grassland cover supports small mammals which is evidenced through hunting activities of Kestrels and owl species (Forest of Marston Vale, 2016)[27].

This site has also focused on managing and improving existing rights of way, and have created an extensive network of new surfaced and mown access routes throughout the area; suitable for pedestrians, cyclists horse riders, pushchairs/mobility vehicles etc. Site information boards, picnic tables, horse riding routes, and other infrastructure has been developed to encourage access and use of this site (FC, 2016c)[28]. Access to Rectory Wood is permissible by invitation of the Marston Vale Trust.

WOODLAND CARBON CODE INFORMATION

The Forest of Marston Vale is planted in an area that has been degraded by past industrial activity. However, the main aim of the Forest of Marston Vale is about extracting all the benefits possible from the new 'forest' landscape being created – improved leisure opportunities, transformed perceptions, increased wildlife, engaged local communities and revitalized economies, plus a future timber supply (FC, 2016c).

The Forest of Marston Vale will sell the carbon credits from their woodlands as they develop to buyers listed on the Markit Registry[29]. These buyers will then be supporting the regeneration of this area which will create income and investment to support further woodland expansion.

The predicted claimable carbon sequestration over project lifetime is ~18,400 tCO_2.

Sources: FC (2016), Forest of Marston Vale (2016)

CALCULATIONS

These calculations relate to Rectory Wood only.

Total predicted CO_2 over project lifetime	22,991 tCO_2
Predicted contribution to buffer project lifetime	4,598 tCO_2
CO_2 per ha	542 tCO_2 per ha
Project duration	100 years

The total benefits of this project that can be evaluated are:

Recreation: The recreational value of this site has been estimated at £139,892 per year, based on an estimated 36,339 visitors per year, using ORVal. Over 100 years, the present value of this flow is £**3,930,000**.

Air quality: The peri-urban location of this site in a relatively populous area near major sources of traffic pollution mean both that it is likely to contribute to improved air quality and that human populations will benefit significantly from the improvement. Using the assumptions for peri-urban woodlands, as explained in the main report, the central estimate for the present value of air pollution benefits over the 100 years of the project works out as £**1,305,000**. The low-high range around this central estimate is from £986,000 to £1,850,000. The relatively

[27] Forest of Marston Vale (2016) http://marstonvale.org/cranfield/
[28] Forestry Commission (2016c): http://www.forestry.gov.uk/forestry/beeh-9r2kyt
[29] Markit Registry: http://www.markit.com/product/registry

densely populated area and the proximity of major traffic routes suggest that values from the higher end of the range might be justified.

Water pollution regulation and flood control: New woodland that is planted here would fall within the priority area for water quality and flood risk management. As wider woodland planting is occurring in the area, this woodland could be deemed to be medium priority rather than high priority for flood risk management. If new woodland is being planted, then it would satisfy the criteria as a biodiversity priority area.

Biodiversity: The 42ha of broadleaf planting can be expected to enhance biodiversity values in the area, in particular through the connectivity with the adjacent ASNW and inclusion of diverse open/water habitats and planting. Using the Willis et al (2003) approach as explained in the main report, the present value over the 100 years of the project of the non-use value of biodiversity enhancement at the Upton Court site is estimated to be up to £1,866,000 when aggregating values across all UK households. If instead aggregation is carried out only over English households, the value would be £**1,557,000**.

Social deprivation: This project is accessible to communities that are in the 20% most deprived in England.

The recreation, air quality and biodiversity values of the site are estimated (using the values highlighted in bold above) at £6.8m over its 100 year lifetime, giving a value of £295 per tonne of CO_2 over the 100 year lifetime of the project.

The case studies illustrate the extent to which the value of the impacts of individual WCC project's co-benefits can be captured. They show that quantification and monetisation is often possible for recreation, air quality and (non-use) biodiversity benefits. Some challenges in these valuations do arise, for several reasons:

- The value of some impacts at some sites is so low that it is approximately zero (e.g. for air quality impacts at some small remote rural sites);
- The quantification of some impacts is not possible (e.g. for social deprivation, resulting in a qualitative description of the impacts); and
- The lack of monetary valuation evidence at a local scale (e.g. for catchment benefits), resulting in a quantitative description of the impacts.

Potential steps to overcome these barriers are discussed in Section 7.2.

7 CONCLUSIONS

This Section summarises outputs and recommendations from the work. It also describes the next steps for the project.

7.1 Key findings

The aim of this project is to assess the co-benefits of WCC projects, and establish a method for doing so in future with minimal effort, both as a whole and individually. Therefore the values of project impacts need to be assessed rapidly and consistently, based on existing information.

Our approach to the evaluation of benefits is based on a typology of woodlands reflecting the variety of WCC projects to date. Typical WCC projects involve predominantly broadleaf planting and little or no timber extraction. This typology is used in the methods adopted and proposed for evaluating WCC project impacts (e.g. in accounting for rurality in recreation and air quality benefits). These impacts are summarised in Table S.1, which distinguishes between the analysis for all WCC projects as a collective group, and the analysis of individual project sites. It also suggests potential methods that can be used going forward, and notes the degree of uncertainty in any results obtained.

The results illustrate the value of WCC projects' co-benefits in a variety of monetary and other metrics:

- The value of some impacts are given as monetary values: recreational use, non-use value of biodiversity, and air quality regulation are estimated to generate an average of £18m – £25m per year of benefits;
- The economic impacts on jobs (70 – 160 FTE created) and turnover (£4.8m/yr contribution to GDP) are also measured. Note that this expenditure-based figure cannot be added to the welfare-based figures in the previous bullet, as they measure different things[30];
- The monetary valuation of many impacts is not possible, either because they cannot be adequately captured in qualitative terms (e.g. landscape impacts) or due to a lack of quantification of impacts (e.g. for contributions to catchment management) and/or of monetary valuation evidence. For the latter, quantification description of impacts is possible: 12.5% and 2.2% of WCC projects' area are in priority areas to manage catchments and accessible by communities in the lowest 20% of social deprivation, respectively.

These data provide the best available summary of WCC impacts for decision-makers.

The valued co-benefits of WCC projects are estimated to be worth £93 - £212 per tonne of CO_2e across the project lifetimes. This is worth \$124 - \$283 per tonne of CO_2e, which is lower, but of a similar order of magnitude (\$100's dollars per tonne) to those for Gold Standard projects. The co-benefits of WCC projects are an order of magnitude larger than the current sale value of WCC credits, which is in the region of £7 to £15 / tCO_2 (Vicky West, pers com, September 2016).

[30] Turnover / GDP figures are based on assessing expenditures that include costs and producer profits, but exclude added value for consumers (consumer surplus, the excess of willingness to pay over price paid). Welfare-based figures use total economic value, that excludes resource costs but includes profits and surplus for consumers.

The project also suggests ways in which the assessment of co- benefits can be undertaken by WCC managers, through links between project information they provide and semi-automated evaluation tools and methods for different co-benefits. However, any such assessments need to be proportionate to the costs of gathering such information, including the opportunity costs of time to project developers. The significant differences in the scale of co-benefits between different WCC sites, due in particular to differences in location, size, planting and management, mean different levels of effort to assess co-benefits are appropriate at different sites.

The data provide the best available summary of WCC impacts for decision-makers. It demonstrates the co-benefits of carbon mitigation through woodland planting in the UK, as required to identify cost-effective mitigation options under the Paris Climate Change Agreement. The data also illustrate impacts that contribute to delivering several sustainable development goals: as well as Goal 13 (climate action), it can have impacts for Goals 3 (good health and wellbeing), 8 (decent work) and 15 (life on land). Development of this approach is discussed further under recommendations, below.

The judgement as to whether such additional evaluation of co-benefits is justified for each WCC site will remain with project developers, but simplified guidance can be provided to them, based on this analysis.

7.2 Sensitivity Analysis

Sensitivity analysis is reported for a number of valuations within the data. For some impacts (e.g. FTE jobs), it is reflected in the ranges of data given. For other impacts, such as water pollution regulation and flood control, and social deprivation that are assessed qualitatively, it is not feasible.

Sensitivity analysis for air quality, biodiversity and recreation values is possible:

For air quality, low and high scenarios are based on different values per tonne of pollutant absorbed as specified in the DfT (2013) guidance. These are shown in Table 5.4 in Section 5. For the ‘low’ scenario this gives a value of £32.8m, equivalent to £7.40 per tonne of claimable CO_2. The high scenario gives £187m, or £42.9 per tonne of claimable CO_2. The high scenario gives £197m, or £43 per tonne of claimable CO_2. The difference from central to high is much greater than from low to central because the low and central cases both assume zero air pollution regulation value for remote areas, which represent half of the sites, but 82% of the total area. This suggests that a key sensitivity could be the issue of whether or not remote woodland sites provide air pollution benefits.

For biodiversity, value are highly uncertain, and therefore a large range of values is given. The £656m of value over lifetimes of WCC projects is obtained by aggregating non-use values over UK population. An alternative assumption is to aggregate values for each site over the relevant national (England, Scotland, Wales or Northern Ireland) populations. This gives a value of £130m. Further reduction of the beneficiary population could use only households in the relevant region (for English sites), which would keep everything at NUTS1 level. Results are highly sensitive to this assumption: for example in the Jubilee Wood case study in Slough the value would reduce by from £213,000 to £34,300. This lowest value may be more realistic in some locations, where woodland is only of non-use value for biodiversity to people in the same region of England or in Scotland, Wales or Northern Ireland. However, allocating English sites to regions is complex due to boundary effects: some sites may lie on the edge of a less populous region but have value to households in a neighbouring more populous one.

For recreation, sensitivity analysis is conducted by using an estimate per visit from Willis et al (2003) or £2.15 (2015 prices). This value is used in the FEE corporate natural capital accounts to value recreation on the public forest estate in England. Applying this value to the visitor estimates from ORVal gives significantly lower values for WCC projects as a whole, with an estimated benefit of approximately £2.4 million per year. This is approximately £3 million (over 50%) less than the values estimated from ORVal (of £5.5m per year). A further uncertainty is introduced by the extrapolation from England to other UK countries. This includes applying the average 'remote' value per ha to the Loch Katrine site (of over 5,900 ha). This large site may have diminishing returns so this extrapolation has particularly high uncertainty, and so has been removed from the calculation to give a lower range estimate. The range of recreational values supported by WCC sites in the UK is therefore estimated at £14.7 - 17.0m per year, based on an estimated 3.8m - 4.4m visits per year.

In conclusion, there are significant uncertainties is each of the value calculations, particularly the beneficiaries for biodiversity values. These are reflected in the 'Amber' classification of results in Table S.1.

7.3 Recommendations

Key issues and gaps identified for further consideration in analysis of WCC projects are:

- For present purposes, the urban/peri-urban/rural/remote rural classification has been applied following manual checking of the grid-reference for each project, which served the additional purpose of checking the general level of woodland density in the area, the location with respect to watercourses and reservoirs, and additional features such as close proximity to school sites. Whether this process can be automated needs further investigation. If not, clear rules on how to classify projects going forward need to be established.
- Guidance can be given to projects on key evidence to include in their project descriptions that could aid appraisal and communication of their co-benefits. Guidance is suggested through the valuations in Table 5.3 (site level approach).
- Evidence should continue to be developed on the role of tree planting in catchment management across the UK, including qualitative understanding of their role in regulating the quantity of water supply over time (throughout the year, rather than during extreme events), and quantification and valuation of impacts of flood risk management and water quality regulation. Spatial identification of the areas for tree planting to reduce flood risk and water pollution in parts of Scotland and the whole of Northern Ireland is needed.
- WCC projects can potentially have significant value for biodiversity, and projects wishing to measure this value qualitatively or quantitatively could be provided with some guidance on this. One way to generate qualitative evidence would be to put WCC projects creating native woodlands in the context of relevant biodiversity action plan targets, at UK or regional level, for such woodlands. A quantitative approach would be to assess the role of WCC projects in providing woodland habitat connectivity at a landscape scale. Both of these approaches would require detailed GIS analysis combining WCC project and biodiversity data.
- The sensitivity of air quality values to assumptions about remote rural woodlands could be partly resolved through air pollution mapping (i.e. to resolve the question of whether or not the trees are in areas where significant air pollution is frequently present to be 'cleaned up').

This may be possible using national emissions inventory maps[31], but requires detailed air pollution modelling and research.

For further spatial analysis, detailed GIS mapping of WCC projects is important. For the purposes of evaluating the WCC portfolio, the ideal solution is a GIS shapefile for the sites. This allows the analysis of their impacts by systematically linking to other data (e.g. social deprivation, air quality, population) in GIS. For smaller WCC projects (< 20 ha), the analysis can use the grid reference point for the project as an acceptable proxy for its location. For medium and larger projects (20 ha or more), the analysis will be improved significantly by using a GIS polygon representing the boundaries of the woodland.

Analysis by individual sites of their co-benefits should remain optional, but can be assisted through guidance from FC based on the evidence in this report, on sources such as:

- ORVal for valuing recreation at sites in England, or the per ha values for different ruralities for sites in other countries;
- The per ha values for air quality regulation, based on rurality;
- The per ha non-use values for biodiversity based on woodland types, although these have slightly higher levels of uncertainty, and
- Quantification of impacts on social deprivation and catchment management, based on spatial priority areas.

This guidance can also inform projects of when their site values are likely to be significant, based on observation of the data. For example, guidance can be given for recreational importance of habitat types changing and accessibility from analysis in ORVal. It should be noted that the spatial analysis of social deprivation uses Lower Super Output Areas, but this data set has irregular boundaries which can contain both settlements and countryside. Therefore, it is not a good way to identify 'rurality' as required for air quality regulation valuation, and recreation values outside England.

In future, technical input is also likely to be required on how information technology can play a role in more accurate future measurement of co-benefits from WCC projects, including automated GIS tools.

[31] www.http://naei.defra.gov.uk/

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ANNEXES

A REVIEW OF OTHER CARBON CO-BENEFIT METHODS

This Annex reviews the methods used by three other carbon credit schemes to measure their co-benefits. Related methodologies are summarised in Annex B.

A.1 Gold Standard

The Gold Standard[32] is a standard and certification body that aims to help "every dollar of climate and development funding go as far as it can". Their methodology used to determine the environmental and socio-economic co-benefits of carbon reduction investments (The Gold Standard Foundation, 2014) aims to:

- Capture and monetise the environmental and socio-economic net benefits associated with Gold Standard (GS) projects, grouped under key project categories;
- Aggregate the benefits across the GS portfolio to demonstrate the value and impact created by the projects;
- Undertake further deep dives of selected case studies to capture and monetise these additional benefits line to specific carbon projects;
- Put forward a practical approach and methodology for discussion and for future refinement; and
- Assess the environmental and socio-economic net benefits associated with projects that have achieved the issuance of carbon credits (over 150 projects with credit issuance in the GS portfolio and 1,000 projects in the pipeline).

The projects analysed in their study on co-benefits were grouped into key project categories and those categories with the greatest number of projects, and the greatest number of carbon credits issued were considered as a result of there being more robust documentation available in these areas (The Gold Standard Foundation, 2014). The methodology adopted drew on:

- Economic market and non-market evaluation techniques;
- Environmental-economic accounting techniques (including TEEB, and SEEA);
- Net Balance understanding of carbon credit accounting; and
- The Social Return on Investment (SROI) methodology.

The main methodological steps were:

- **Step 1:** review and analyse the portfolio to identify key project types;
- **Step 2:** identify key (material) outcomes by project types;
- **Step 3:** link measurement metrics to outcomes identified and assess information available;
- **Step 4:** apply a value in an equivalent international currency ($) using benefit transfer and financial "proxies" to represent intangible outcomes; and
- **Step 5:** aggregate co-benefits across the whole portfolio based on assumptions about the similarities between projects.

[32] http://www.goldstandard.org/ accessed 12/04/16

A.1.1 Step 1: Portfolio Review

They note that it is highly likely that most registered projects within the following categories would present broadly the same benefits:

- Wind: 34% of GS portfolio by credits, mainly Turkey and China;
- Cook stoves and water filtration (23%): grouped together as 'Energy Efficiency';
- Biogas digesters (8%); and
- Afforestation / reforestation (3%);
- Landfill gas (3%);
- Methane recovery (8%);
- Hydro (8%);
- Solar (thermal-heat and PV) (4%), and
- Other (8%).

A.1.2 Step 2: Identification of outcomes

Outcomes for each category were identified, based on changes to social, environmental and economic indicators associated with the project types and formalised in a sustainable development matrix. The categories of outcomes identified included:

- Health improvement linked to air quality improvements;
- Health improvement linked to water quality improvements;
- Biodiversity enhancement (or protection);
- Provision of employment;
- Improved livelihood of the poor, and
- Improved balance of payments.

The study notes that this list does not represent all outcomes relating to GS projects, but those that are considered material and can be valued using the techniques described in the methodology. In addition, an absence of measurable outcomes for a given project does not mean that co-benefits do not exist, but simply that they may be difficult to evidence and measure, or may be multifaceted or dispersed (The Gold Standard Foundation, 2014). Also, it is recognised that only material impacts that could be extrapolated to all projects in a category were considered. Therefore the results are only a partial quantification and valuation of the co-benefits associated with Gold Standard projects.

A.1.3 Step 3 & 4: Measurement and valuation of outcomes

Desk based research was carried out to define measurement and valuation parameters for each category (The Gold Standard Foundation, 2014). The key points that were explored and analysed through the study are liste below. These are explained in much more detail in the appendix of the Gold Standard report.

- Exploration of the availability and suitability of measurement metrics to gauge the magnitude of these outcomes (or "change" occurring for the beneficiaries compared to the baseline or background trend);
- Definition of a "proxy" which allows a monetised figure to be assigned to the outcomes; this can refer to research undertaken in other regions on similar projects and deemed suitable for "benefit transfer" to the project being reviewed;

- Whenever appropriate, definition of any moderating parameter, in particular:
    - *Attribution:* other contributing factors that may explain the occurrence of the outcome apart from the project itself (e.g. campaign unrelated to the project)
    - *Deadweight:* the amount of change that would have happened anyway in the absence of the project; in some cases that may be captured in the baseline (e.g. people buying efficient cookstoves anyway);
    - *Displacement:* the benefit fails to eventuate because of other reasons than those addressed by the project (e.g. forest is still logged for other reasons than firewood);
    - *Drop-off*: the effect of the project diminishes with time (e.g. a cookstove may lose efficiency over time).

These moderating elements play an important role in guaranteeing the robustness of the co-benefits claim, as they demonstrate that overstatement of the benefits have been considered.

A.1.4 Step 5: Portfolio valuation

Outcomes for a sample number of projects were valued, which were then extrapolated to all the projects in the category (using an excel model).

- **Assumption:** projects of a similar nature in the same country or region would bring the same types of benefits.
- **Extrapolation** has been carried out on the basis of the most appropriate "functional unit" (or scaling metric), i.e. either the number of people benefitting or capacity of infrastructure or any other relevant metric.

Outcome values were consolidated per broad category of outcomes across the portfolio. No overall valuation was calculated because:

- Outcomes are very different in nature, the sources of valuation are heterogeneous and there are fundamental ethical issues in aggregating economic, social and environmental outcomes, and
- Providing "triple bottom line" values allows for richer information to be presented.

The study explored the availability and suitability of measurement metrics in carbon reduction project documentation to gauge the magnitude of the outcomes (or "changes" occurring for the beneficiaries compared to the baseline or background trend) (The Gold Standard Foundation, 2014). Use of value transfer was applied to estimate outcome values in a study area/population, using relevant valuation evidence from studies carried out in similar conditions elsewhere. The approach to value transfer:

- Attempted to use simple value transfer functions that are generic enough to be applicable to consistent co-benefit categories (i.e. human health impacts from cookstoves, ecosystem services, etc.);
- Linked these value transfer functions to variables that could be readily sourced from the project documentation, and
- Used source valuation studies that provide generic enough value to be applied across a fairly broad range of projects.

Despite these efforts, limitations remain: for example, the valuation of life and health benefits has frequently encountered difficulties due to the highly different socio-economic backgrounds in which people live (The Gold Standard Foundation, 2014).

The methodology standardises proxy values across the portfolio of GS projects, despite the vast differences in standards of living that may exist between regions where projects are implemented. The normalisation of outcomes valuation was done mostly through:

- The use of a single proxy value (in $) for outcomes that could be considered as "universal", such as health / survival.
- The use of Purchasing Power Parity equalisers for financial impacts.

Summary results are normalised by carbon credit to allow easy communication and comparison. They are expressed as a certain amount of benefit per carbon credit.

A.1.5 Limitations:

A number of limitations to the methodlogy used are recognised in the Gold Standard study:

- All co-benefits could not be explored and valued. Only those deemed to be material were included in the analysis. The following co-benefits were not valued:
  - Burden of disease (only value of life has been valued in terms of health impact)
  - Species diversity, and
  - Ambient air quality impacts.
- Harmonising values across all projects – translating into dollar equivalents taking into account Purchasing Power Parity -could be further refined (The Gold Standard Foundation, 2014). Values have been calculated per project or per valuation unit within each project then apportioned per carbon credit and per year for ease of communication. This process may result in distortions in the comparability of results.

A.2 Net Balance

This report[33] looks at how co-benefits could be delivered alongside carbon offset projects in Australia, and it reviews existing international standards and guidelines, and highlights where the co-benefits approach has been applied.

This report defines co-benefits as follows:

> *Co-benefits are direct positive outcomes associated with an offset project that are additional to the emissions avoided or carbon stored. They are the social, economic, and environmental benefits that occur as a result of an offset project, but which have been not automatically priced into the value of the offset[34].*

Co-benefits fall into 3 main categories:

- **Environmental:** including increased biodiversity, habitat protection, and improved environmental management;
- **Economic:** including increased employment, improved infrastructure, technology transfer and increased economic activity, and
- **Social:** including capacity building, access to services and enhanced utility.

[33] Net Balance (undated): http://static1.squarespace.com/static/52045752e4b0330b6437dade/t/52dcd54ee4b03ab35fd08cac/1390204238567/CoBenefits_Report.pdf

[34] Kollmus et al. (2008) in Net Balance (undated).

Within international markets, co-benefits have been pursued using specifically developed co-benefit standards. Key indicators have been developed for each category of co-benefits with the types of co-benefits delivered and measured. Table A.1 below shows one example for environmental, social, and economic co-benefits.

Table A.1: Key Indicators for co-benefits

	Description	Example indicators
Environmental	Biodiversity Usually refers to a number of genes species and habitats affected by a project or located on a project site	• Number of affected and/or threatened plants • Number of affected and/or threatened mammals, birds, reptiles, fish, and other species and habitats
Social	Quality of employment This can refer to changes in labour conditions such as job related health and safety (quantity measure) or value of employment such as highly or poorly qualified, temporary or permanent employment.	• Qualification certificates of employees
Economic	Technology transfer and self-reliance Measuring the transfer of technology and the training that enables the technology to be applied more broadly than the project. Under The Gold Standard, there must be evidence of technology transfer.	• Number of workshops, seminars organised, and training-related opportunities held • Number of participants who attend those capacity building activities • Research and development expenditure

Source: in Net Balance, undated.

Carbon offsets with demonstrable co-benefits are likely to be more attractive to business because of the associated reputational and brand benefits.

A.2.1 Barriers to adoption

All markets have an element of risk or uncertainty, which is especially true for delivery of co-benefits which require the establishment of new market structures to cater for the additional benefits from the carbon offset projects. Net Balance note the following barriers to establishing co-benefits markets:

Market Uncertainty

The global carbon market and individual schemes have experienced significant uncertainty in recent years. At the international level, the market has been destabilised by the twin issues of oversupply of credits, and inadequate demand for carbon reductions and the economic downturn. This has been compounded by the uncertainty surrounding the Kyoto Protocol and the long-term effectiveness of the overarching multi-lateral climate architecture enshrined in the United Nations Framework Convention on Climate Change (UNFCCC). The world's largest compliance market, the EU ETS, continues to face its own challenges, with oversupply again being a key issue.

Uncertain price premiums

There is also uncertainty associated with the price premiums available to co-benefits certified projects. There is evidence to suggest that internationally many land-based projects do not seek external verification regarding the delivery of co-benefits due to the higher costs associated with measuring and verifying these benefits (as well as risk of securing a price premium). However, this premise has been countered with some suggestion that the current low prices have encouraged more projects to seek co-benefit certification to access higher prices.

A.2.2 Methodology

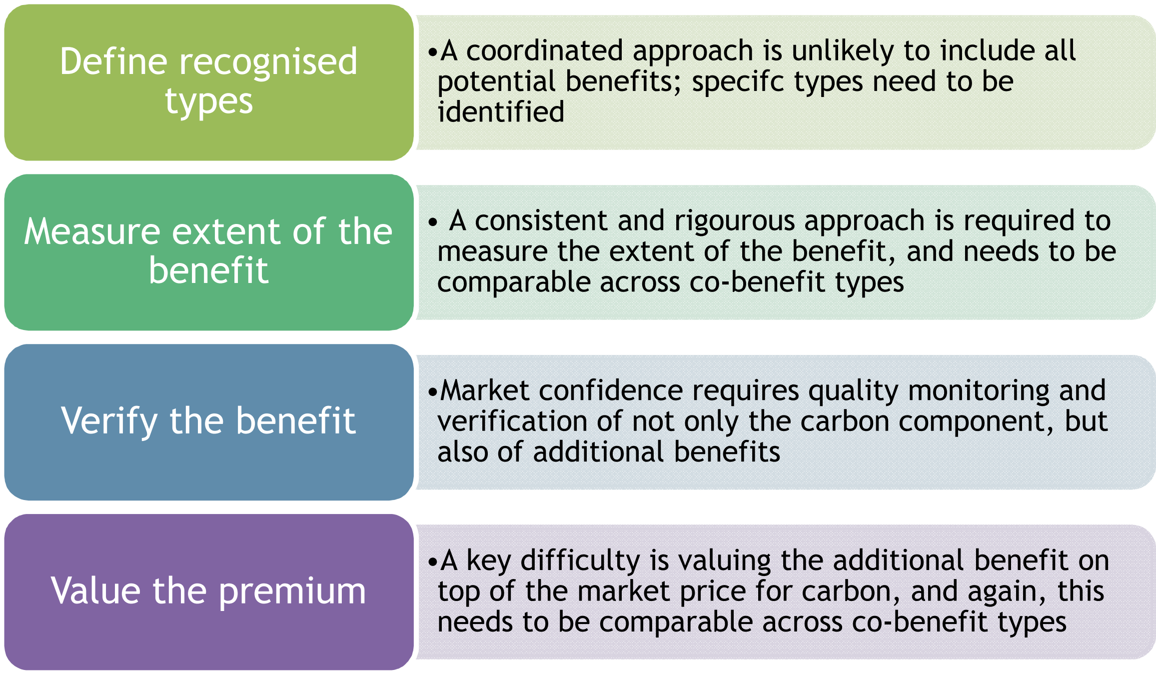
The process used by Net Balance for defining, monitoring, measuring and valuing co-benefits is outlined in Figure A.1. This process is applied to the 3 main benefit categories:

- **Social:** The measurement of social outcomes is potentially more complex than the measurement of environmental impacts. The complexity associated with measuring intangible social outcomes and the problematic nature of producing comparable results, can increase cost of data collection and decrease the usefulness in defining value to the marketplace, particularly for buyers. The different nature of environmental and social outcomes means that trade-off decisions regarding the achievement of these outcomes are subjective and difficult to replicate.

- **Environmental:** There are also difficulties measuring environmental outcomes, particularly when comparing local and regional benefits. For all co-benefits – environmental, economic and social – there are trade-offs involved in the qualitative versus quantitative measurement. These issues require careful consideration. If the process to evaluate and compare activities that generate co-benefits is not well defined, co-benefit outcomes will be highly contested. This will reduce the likelihood that these projects will attract a premium (in either the domestic or the international market) or encourage additional private sector investment.

- **Economic:** Monitoring, reporting and verification and subsequent quantification of the value of the co-benefit also presents potentially significant transactions costs. If these outweigh (or are perceived to outweigh) the potential premium the co-benefit may be able to attract, investment will not occur.

Figure A.1: Identifying, measuring, monitoring and valuing co-benefits



Source: Bumpus *et al*. (in Net Balance, undated)

A.2.3 Climate, Community and Biodiversity (CCB) Alliance Standard

The CCB standard focuses on community and biodiversity co-benefits. To obtain certification the projects must satisfy a list of 14 criteria that are grouped into four categories:

- **General:** Original conditions in the project area, baseline projections, project design and goals, management capacity and best practices, and legal status and property rights.
- **Climate:** Net positive climate impacts, offsite climate impacts, and climate impact monitoring.
- **Community:** Net positive community impacts, offsite stakeholder impacts, and community impact monitoring.
- **Biodiversity:** Net positive biodiversity impacts, offsite biodiversity impacts, and biodiversity impacts monitoring.

Three additional criteria are available to those looking to qualify for the Gold Level status - Exceptional Community Benefits, Climate Change Adaptation Benefits and Exceptional Biodiversity Benefits.

As suggested by the indicator names, community impacts, climate impacts and biodiversity impacts must all result in a positive outcome versus a 'without-project' situation. This differs from The Gold Standard in that neutral impacts for some indicators are accepted in The Gold Standard as long as the net impacts are positive.

Benefits need to be demonstrated using appropriate methodologies rather than reporting against specified parameters as in The Gold Standard. The methodologies are not prescribed giving the project developer the flexibility to choose one applicable to their context. A 'theory of change' framework is suggested as the most appropriate for identifying indicators. Once defined, all indicators must be monitored via a monitoring plan over the lifetime of the project. This plan and its reports are prerequisites for project verification. In terms of additionally, this must be proven but specific tools are not defined.

Ongoing stakeholder engagement is required during the project design and is not limited to the two consultations specified by The Gold Standard. The CCB standard provides a framework for recording and communicating greater co-benefits than those captured by the Gold Standard or Net Balance. However, it is less prescriptive in its methods, and therefore is likely to have higher transactions costs, for projects to assess co-benefits and for buyers to verify them.

A.3 Social Carbon

SOCIALCARBON® is a standard (SOCIALCARBON®, 2013) developed by the Ecologica Institute that certifies emission reduction projects for their contributions to sustainable development. It is founded on the principle that transparent assessment and monitoring of the social and environmental performance of projects can improve their long-term effectiveness and thus add value to the emission reductions generated. It was developed to strengthen co-benefits of carbon offset projects.

It is considered a complementary standard for assessing co-benefits, and does not include specific criteria for carbon emission reductions, such as additionality and baseline methodologies. It is therefore designed to be used with a carbon accounting offset standard (i.e. VCS, CDM, CAR, etc.). This contrasts with the Gold Standard and Net Balance methodologies which are designed to complement their respective carbon-reduction accounting standards.

A.3.1 Methodology

SOCIALCARBON® is defined as the carbon reduced due to actions that benefit and improve the living conditions for stakeholders who are involved or interact with climate change projects, in ways that strengthen the welfare and citizenship, without degrading their resources.

The theoretical framework is based in the Sustainable Livelihood Approach (SLA), and may be adapted to suit the initiatives of various project types, including Hydroelectric Power Plants, Landfills, Fuel-Switch, Forestry and others. Its basic guidelines are that it is:

1. Centred on stakeholders perception;
2. Values people’s potential and resources;
3. Participatory, holistic, dynamic and flexible;
4. Deals with local and global issues;
5. Geared towards analysis of local ecosystems and their biodiversity potential;
6. Geared towards problem solving and the pursuit of sustainability;
7. Strives for social inclusion and recognizes gender issues and other forms of social differences, and
8. Takes into account existing governmental relationships and political context

The Social Carbon Standard guarantees a transparent and participatory method of monitoring projects’ co-benefits through a tool box of indicators that point to degrees of sustainability correlated to six resources as shown in Table A.1.

Table A.1: Six resources used to monitor a project's co-benefits

Taken from the SLA framework	Additional to the SLA framework
- Social - Human - Financial - Natural	- Biodiversity or technology - Carbon

The Social Carbon methodology delegates assessment to an Authorised Developer who is responsible for creating indicators and reports. They need to follow the following steps:

1. Indicators should be outlined and used to detail the benefits and impacts generated by a carbon offset project encompassing the 6 resources shown above;
2. New indicators or the revision of existing indicators must be submitted for approval to a Certifying entity and the SOCIACARBON® team;
3. Data used to score the indicators must be collected through interviews, questionnaires and/or meetings with stakeholders, and
4. All information collected must be organised in the form of a report, following guidelines and a template provided.

In case a project´s activity presents characteristics which are not addressed by any of the approved indicators available, new indicators may be created and submitted for approval. Authorised Developers should list and assess the main:

1. Impacts;
2. Risks;
3. Stakeholders; and
4. Best practices or existing sustainability indicators for project activity.

After identifying all relevant aspects above that can be monitored over the project lifetime, the Authorised Developer must allocate each indicator to the corresponding categories: Social, Human, Financial, Natural, Biodiversity/Technology and Carbon.

Scenarios for scoring must be created for each new indicator. The scores should range from the worst scenario (level 1) to the ideal scenario (sustainable use of resource – level 6), according to the guidelines.

The Social Carbon Standard is different from most other co-benefits standards because it does not establish absolute requirements for scoring all indicators, but instead requires proof of commitment to continuously improve the project's social, environmental, and economic performance. Developers determine a baseline (Point 0), which is then certified (this is referred to as Validation). To maintain the Standard, the project must be periodically monitored according to the approved indicators and produce a new Report. This periodic ongoing reporting is referred to as Verification.

B REVIEW OF EXISTING INTERNATIONAL STANDARDS AND GUIDELINES

Table B.1: Matrix overview of international standards and guidelines (Net Balance, undated)

TABLE 14: MATRIX OVERVIEW OF INTERNATIONAL STANDARDS AND GUIDELINES

	UNFCCC CDM[100]	THE GOLD STANDARD[101]	SOCIAL CARBON[102]	CCBS[103]	PLAN VIVO[104]
Types of projects	Afforestation and reforestation, destruction of HFC-23 and N_2O, transportation improvements, renewable energy, energy efficiency	Renewable energy Energy efficiency A&R and IFM	Hydro-power plants, landfills, fuel switching, forestry etc. (same as CDM)	Land-based	Land-based
Type of co-benefits	Broadly sustainable development	Environmental, social, economic and technological	Environmental, social, economic and technological	Community Biodiversity	Livelihood and ecosystem benefits
Stakeholder decision makers	✓	✓	✓	✓	✓

	UNFCCC CDM[100]	THE GOLD STANDARD[101]	SOCIAL CARBON[102]	CCBS[103]	PLAN VIVO[104]
Stakeholder	✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Local experts		✓	✓		✓
Secondary research		✓	✓	✓	
MRV		Non-neutral sustainable development indicators, emission reductions, mitigation measures	Project-specific resource indicators (social, human, financial, natural, technology, biodiversity, carbon)	All indicators must be monitored.	
Qualitative/ quantitative	Quantitative	Quantitative	Qualitative	Qualitative	Qualitative/ Quantitative
Frequency of MRV	There are no timeframes. For afforestation/ reforestation projects it is every 5 years.	3 years	Not specified	5 years but the expectation is higher.	5 years
Additionality	The effect of the project activity to reduce anthropogenic GHG emissions below the level that would have occurred in the absence of the project activity.	UNFCCC or The Gold Standard-approved 'additionality tool'	Refers to other standards such as VCS, CDM or CAR	Project benefits not occurred in absence of project.	Would not take place in absence of project, due to financial, social, cultural, technical, scientific or institutional barriers

C WOODLAND TYPOLOGY

This Appendix considers typologies of woodland types that have been used to structure valuations of woodland benefits. A simple typology is then proposed as a basis for assessing the value of different WCC co-benefits in an efficient manner.

C.1 Typology of woodland types

In seeking a method for valuing the co-benefits of WCC projects, the most direct approach would be to take the current portfolio and evaluate each project in terms of its outputs, taking account where appropriate of complementary and substitution relationships across sites. However, this would be an intensive approach with the drawbacks of not directly revealing or using generalities across the portfolio, and (therefore) of giving no guidance on extending the valuations to new sites. The alternative approach is to develop a typology of WCC projects and derive typical valuations for each type. This focuses on the common features and impacts of woodland types, and on the ability to extend valuations to additional projects – to a first approximation - without the need for further specialist input in future.

For developing a typology, there is a basic choice between a simple list of types (as in Hanley *et al.*, 2002), or a more complex nested set of criteria (as in eftec, 2010a). The former has the merit of greater simplicity and can be more immediately understandable, especially if the types are described in familiar forestry terms. However, it is difficult for a simple list to be comprehensive in covering enough variation of interest across project types. The more complex nested list makes it easier to cover the full range of valuation-relevant variables, and can be simpler in isolating variables that are relevant only to certain services (such as access and facilities for recreation).

The approaches are not necessarily mutually exclusive. We can present a longer list of basic types that are 'recognisable' to forest managers (the type of forestry, species mix and management objectives), accompanied by a set of additional indicators relating largely to elements that are 'independent' of forestry management, but relevant to determining economic values, for a specific woodland (e.g. the location with respect to human populations, surrounding land-uses and alternative resources). Some of the second set can be simple binary indicators (e.g. "is the woodland in a priority zone for…").

C.1.1 Previously used woodland typologies

Hanley *et al.*, (2002) present a list of 'biodiversity forest types' which has the advantages of simplicity and application in existing research (see e.g. Willis *et al.*, 2003). The types are:

- 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.

However, although the typology served the biodiversity-focused purposes of the Hanley *et al.*, (2002) study, the authors themselves acknowledged that the typology does not represent the full range of forest types in the UK – essential for a comprehensive valuation. In particular, criticisms focused on the narrow range of ancient forest types and also the lack of reference to UK Biodiversity Action Plans (BAPs) (Hanley *et al.*, 2002).

CJC Consulting (2014) studied the cost-effectiveness of woodlands for CO_2 abatement, using a similar design but focused more on the forestry management system/objectives. Types are:

- Short rotation forest (SRF): managed for energy;
- Farm woodland: managed for mixed objectives;
- Broadleaf 1: management for game/biodiversity;
- Broadleaf 2: managed for timber/carbon;
- Upland conifer: managed for timber;
- Lowland conifer: managed for timber (England);
- Lowland conifer: managed for timber (Wales, Scotland); and
- Continuous cover forestry (CCF): managed for mixed objectives.

Each type is associated with a particular species mix, planting distance, rotation period, thinning regime and felling regime. This gives a list that is more recognisable to forest professionals, but that does not cover all possible plantation types – in particular, in the context of WCC plantations, many projects essentially focused on restoration of native species or riparian protection which do not fit clearly into any of these categories. In fact the CJC typology starts to become almost a composite typology, combining species mix and management objectives/regime in the list.

eftec (2010a) developed a long-list of possible woodland typology components, for the purpose of evaluating the costs and benefits of different future strategic scenarios for the PFE in England (Table C.***1***). This gives a detailed, but nevertheless incomplete, list of features that might be considered relevant. From this list, a short-list was developed. Some long-list elements were excluded because they were reflections of ecosystem services – e.g. carbon sequestration, number of visits - that need to be treated as *outputs* of a forest typology, i.e. these are the results the typology seeks to model. Others were impractical to apply, or too detailed, for the broad-scale approach envisaged. The final typology developed included five dimensions (Table C.2).

Other comparable woodland management standards are listed in Table B.1. They suggest other features in woodland typologies that can be measured within standards. The Gold Standard and other carbon management standards are reviewed in Annex A and discussed in Section 3.2.

The main omission from the typology is any reference to scale and availability of substitutes. This does have the slight advantage of making the typology scale independent, but we know that in reality some important services depend heavily on these factors – recreation, for example. These issues were impractical to address in the context of eftec (2010a) which did not involve spatially explicit modelling. More detailed spatial approaches, for example using TIM[35], would be better suited to dealing with these issues, though at the cost of significantly increased complexity of the exercise.

Using a full factorial design, the eftec (2010a) typology generates a large number of possible woodland and forest types: 3x3x3x3x2=162 possible combinations. However some of these categories are contradictory or extremely rare; in practice the number of feasible combinations is 88. Of these, several are closely related, in the sense that most of their ecosystem services and/or costs can be considered as very similar or identical. These related types often differ only in regards to specific services: for example the 'public access' dimension will only have a major impact on recreation services.

[35] The Integrated Model (TIM) of land use and ecosystem services values was developed under the UK National Ecosystem Assessment Follow-on (Bateman *et al.*, 2014).

URS (2014) use selection criteria for case studies that resemble a typology in many respects, including the following features:

- Project type;
- Developer type;
- 'Focus' of project (creation of native woodland for biodiversity or other environmental reasons, commercial woodland for timber production);
- Location (urban / remote);
- Productive timber / natural forest (note partial overlap with focus); and
- Diversity of investors and public profile.

These are all features that might have impact on woodland services, though for several the link is quite indirect.

EnviroMarket (2011) similarly differentiated types of investors according to their different interests or motivations for investment in forestry. They argue that this understanding is a necessary prerequisite for developing impact assessment and reporting frameworks that will serve the interests of potential investors. However, from the perspective of developing a practical method for valuation of ecosystem service benefits, the typology should focus on ecosystem and management characteristics captured in the attribute column in Table C.1, but not directly on the type of investor or their motivations – these may well be relevant, but influence services only indirectly, through their effect on the management decisions made.

Table C.1: Long List of Woodland Typology

Attribute	Short-listed?	Comments
Vegetation type: broadleaf/ conifer/open habitat/ other	Included in the attribute, 'Woodland Ecology' type.	The FC reports and data, as well as much of the literature, distinguish between broadleaf and conifer. Several studies (see Hanley *et al*., 2002 and Willis *et al*., 2003) have adopted the broadleaf/conifer split. The UKBAP broad classification distinguishes between 'Broadleaved, mixed and yew woodland' and 'Coniferous Woodland'. 'Open habitat' is increasingly seen as important for biodiversity/conservation reasons.
Upland/ lowland	Not included	Several studies (see Hanley *et al*., 2002 and Willis *et al*., 2003) have adopted the upland/ lowland split, but it is somewhat arbitrary, and primarily used as a proxy for other environmental characteristics such as soil type, temperature and wind.
Slope and aspect	Not included	Although these can be assessed via GIS, and will influence services and costs, they can also vary greatly within a forest unit. At the broad scale of application envisaged, these characteristics cannot be taken into account, though at a very local scale they will be relevant, and may need to be considered in individual cases.
Ancient/ Secondary	This has been excluded from 'Woodland Ecology' type, instead being considered under biodiversity.	Several studies (see Hanley *et al*., 2002 and Willis *et al*., 2003) have differentiated between ancient and new. A forest is 'ancient' if it is 400 years or older, otherwise it is a 'secondary' forest.
Location and Size	Information on the proximity to human population is included in the short-list typology. Other location aspects are not included. Size has been excluded.	A key aspect of the location and size attributes is that many services and costs, measured per hectare, are size and location independent. Some others however cannot be expressed per hectare but rather accrue 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). These issues could be addressed via the units used for cost and value estimates. Size/area could be important in any specific valuation exercise, but are not included in the broad forest typology. A GIS framework could allow a more sophisticated approach here.
Setting (urban/peri-urban/rural)	The location dimension is based on these types.	Proximity to population is an important indicator for different types of use values. A basic assessment is incorporated in the typology; more detailed analysis would be possible with GIS.

Attribute	Short-listed?	Comments
Availability of alternatives	This has been excluded from the typology but could be assessed on a case-by-case basis.	This attribute is not relevant to all service categories and is also correlated with scale/location. For categories where alternatives are relevant, the presence of alternatives will influence the value of the services, but not the physical nature of the services. This remains a problem for valuation, and might be considered in a GIS framework.
Age/class	This is excluded from the typology but may need to be assessed on a case-by-case basis.	Age/class is clearly relevant – to timber production, greenhouse gas storage and other categories - however at the broad scale of assessment envisaged age and class are likely to average out within forest types. For specific applications to small areas it may be necessary to take this into account separately.
Species	Species has not been directly included in the typology, but is partly considered via the basic woodland ecology type and biodiversity indicators	Categorising species individually would lead to an excessively large typology; the most important aspects can be captured via the broadleaf/conifer distinction and the biodiversity priority category.
BAP priority habitats	Partly included under the biodiversity indicator	In preference to detailed consideration of species or habitats, we use a binary indicator: high biodiversity priority or not.
ASNW, PAWS, OSNW[36]	These are partly reflected under the biodiversity indicator	These characteristics reflect whether or not woodland is ancient and/or semi-natural, both being important for biodiversity and cultural services.
Alternative Habitats; Soil Type	These were not explicitly included in the short-list typology.	Issues with data availability, necessity of GIS and the practical problem of including numerous categories make this too complex for a basic typology. But 'Woodland Ecology Type' is highly correlated and provides an indication of their relevance to valuation. Furthermore, the biodiversity category partly reflects the 'naturalness' of the forest, which is a relevant factor in the evaluation.

[36] 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).

Attribute	Short-listed?	Comments
Management practices	These are partly included in the short-list typology, though only a limited list of alternatives reflecting the most important aspects.	Long-term forest strategies provide an indication for the provision of relevant services for valuation. But practices may differ from objectives: this criterion is about what is actually the state of forest management, including future plans over a rotation, so although plans are relevant, a forest would not be classified (for example) as 'access encouraged, high facilities' merely on the basis of a stated aim, if in fact there are no facilities.
Ownership	This was not included in the short-list because it is thought that the identification of possible persistent differences between private and public woods and forests should be a conclusion of the research rather than an assumption.	Ownership type and funding form a central part of the typology used in Cogentsi and PACEC 2004. A particular issue is that many estate woods under leasehold may behave more like private woods due to a legal restriction on access. However this is dealt with under the 'public access' indicator.
Public access	This is included in the short list	The availability of public access is a key feature for recreation services.
Facilities and accommod-ation	Partly included under the access dimension.	This attribute is highly correlated with recreation and tourism. Major recreation centres such as Forest Holidays cabins and campsites need to be considered as special cases.
Certification	Not included in the typology at present.	1.3 million hectares of woodland in the UK were certified in March 2009, under the Forest Stewardship Council (FSC). This represented 45% of the total UK woodland area (Forestry Commission, 2009). These woodlands will be managed in particular ways that enhance their service values, for example biodiversity values.
Recreation activities; Number of visitors; Field sports; Community groups; Timber production	Not included in the typology	These are an output of, rather than an input to, the typology: the typology should help to estimate what these services are likely to be, but they do not themselves form part of the typology.
Watershed; regulation; Wind regulation; Carbon sequestration	Not included in the typology	These regulating services are outputs of forest type – the typology should help to estimate what these services are likely to be, but they do not themselves form part of the typology.

Source: based on eftec (2010)

Table C.2: Final Woodland Typology from eftec (2010)

Typology Dimension	Categories
Woodland ecology	• Broadleaved, mixed and yew woodland • Predominantly coniferous woodland • Open habitat
Proximity to users	• Urban community woodland • Peri-urban woods and forests • Rural woods and forests
Management practices	• Low intensity management • Managed primarily for timber • Managed for multiple objectives.
Public access	• No public access • Access encouraged with low level of facilities • Access encouraged with high level of facilities
Biodiversity importance	• Higher (= UKBAP priority categories, ASNW, restored PAWS, OSNW, SPA/SAC, SSSI) • Lower (= all other areas)

Table C.3: Standards and their relevance to woodland typology

Standard	Developer	Specific Criteria	Notes
Woodland Carbon Code (WCC)	Voluntary standard run via Forestry Commission http://www.forestry.gov.uk/forestry/infd-8hut6v	Criteria to ensure good practice/ additionality: • Eligibility • Carbon • Governance • Environmental quality • Social responsibility	Some mandatory forms of evidence plus optional additional evidence. Regular validation. Publicly accessible registry.
UK Forestry Standard (UKFS)	Forestry Commission http://www.forestry.gov.uk/ukfs	• biodiversity • climate change • historic environment • landscape • people • soil • water	
UK Woodland Assurance Standard (UKWAS)	Independent body (http://ukwas.org.uk/)	Not specified	Environmental benefits demonstrated via qualitative reporting and field studies. Community benefits via consultation with stakeholders and documentation of assets.
Verified Carbon Standard (VCS)	Verified Carbon Standard (VCS) http://www.v-c-s.org/	Forestry methodologies cover a variety of management and avoided damage scenarios, but not forest planting.	
Gold Standard	World Wide Fund for Nature *et al.*,	stringent and transparent set of criteria for	certification process requires involvement of local

Standard	Developer	Specific Criteria	Notes
	http://www.goldstandard.org/	projects in renewable energy, energy efficiency, waste management and land use & forest carbon offsets	stakeholders and NGOs, demonstrating actual carbon reductions and local benefits
Woodland Star Rating	Sylva Foundation https://sylva.org.uk/blog/tag/woodland-star-rating/	Input if action is implemented fully, planned, or not addressed. No independent verification.	Self-assessment scheme based on the UKFS

C.1.2 Assessment of WCC project database

Analysis of the 220 existing WCC projects is discussed in Section 4. Some features are consistently reported across the whole database: area, project duration, location, % bands for broadleaf/conifer, and 'long term management'. Although in some cases the long-term management is given as 'mixed, mainly …', these mixed sites form only 2.4% of the total WCC area. Therefore, it is an acceptable approximation to assume the main management category applies across such sites, for the purposes of an overall evaluation. Similarly the species mix is reported in approximate terms based on the % of dominate tree type (broadleaved or conifer).

The majority of projects are predominantly 'broadleaf (>80%)'; but in terms of the total area within WCC projects, 'mixed broadleaf (50-80%)' ha has the highest proportion, with 43% of the area, being slightly higher that broadleaf >80%. However, this is entirely due to the huge project at Loch Katrine. Excluding that site, the remaining projects are, by area two-thirds 'broadleaf (>80%)', one-fifth 'mixed conifer (50-80%)' and one tenth 'mixed broadleaf (50-80%)', with a small remainder in the 'conifer (>80%)' category.

The more detailed project descriptions also often include relevant indicators of likely values, citing for example biodiversity interests or specific community/educational needs. The specific location of projects, county and nearest town are also recorded and clearly relevant, but require additional information from other datasets for interpretation. The size of projects is obviously important and needs to be recorded as an input to valuation functions, but could also form the basis of categories in a typology – for example setting a threshold size below which some values are likely to be negligible (e.g. for 'small' projects defined as < 5ha in size).

The Hanley *et al.* (2002) categories would be relatively straightforward to apply to WCC projects, but only four of its categories are relevant to new planting. The CJC (2014) categories are all relevant to new planting, however it is sometimes quite difficult to match a WCC scheme to any given one of the CJC typologies, for example because the thinning/felling regime, species mix and management objectives don't match up, and/or because we lack information on distinguishing factors such as planting distance. Many of the schemes fit approximately under 'Broadleaf 1', which is the only CJC category with neither thinning nor clearfell. Some schemes have specific features and objectives, relevant to services and values, but not present in the CJC list. These include schemes explicitly aiming at native species restoration, riparian protection, community woodlands, and extensions to existing woodlands (connectivity for biodiversity). Some schemes are small scale woodlands, e.g. on school sites, and explicitly state the intention for little or no future management.

From the eftec (2010) typology, the woodland ecology and management type categories are represented in more detail by the species mix and long-term management variables in the WCC database. ‘Access’ remains important, but the categories might be revised to account for specific features of some WCC projects (for example location on/adjacent to school sites). The proximity to users is important, but may be better omitted from a typology since there is potential to map the specific locations of projects, with relevance to several services, including proximity to human populations for recreation, but also for flood risk mitigation, water purification and biodiversity services. The ‘biodiversity importance’ criterion from eftec (2010) is very approximate and could also be improved on by more location specific mapping.

C.1.3 Finding information about WCC land and surrounding areas

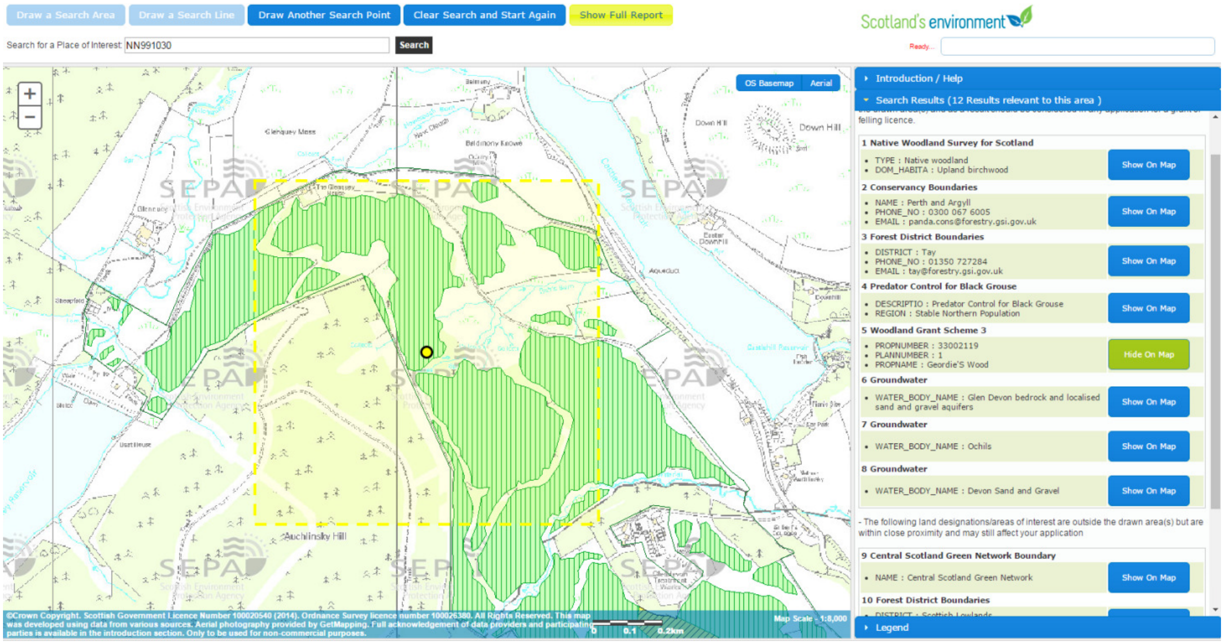
For the purposes of evaluating the WCC portfolio, the ideal solution is a GIS shapefile for the sites. This information is currently available only for about half of the validated projects (about a quarter of sites overall). However, for many purposes, and more so the smaller the site, a grid reference and site area will be sufficient for an approximation of values. In particular, the recreation value analysis using ORVal[37] will use the area and the grid cell within which the site falls, but not finer spatial detail.

Where GIS information is lacking, one option for finding some classifications and zones relevant for a project is the ‘Land Information Search’ tool[38]. A ‘basic search’ for a radius can be carried out around the grid reference of a WCC project, or by an ‘advanced search’ drawing the actual shape on the map. The latter requires specific spatial information but would be useful for investigating individual projects/proposals. For analysis of the WCC portfolio, the basic search could give an approximation (by selecting a radius around the grid reference that covers the approximate area of the site), but this is a very labour-intensive solution compared to the GIS option.

An example of the output from the Land Information Search (LIS) tool is shown in Figure C.1.

[37] A forthcoming tool to facilitate use of TIM (Bateman et al, 2014) for analysis of recreation values.
[38] http://www.forestry.gov.uk/england-lis;
http://map.environment.scotland.gov.uk/landinformationsearch/lis_map.html

Figure C.C.1: Example output for LIS (Scotland): Geordie's Wood, NN991030



C.1.4 Typology for WCC projects

The conclusions from the assessment of existing typologies and contrasting with data available for the WCC projects suggest that the typology should be based partly on the categories in the WCC database, extended with GIS information where feasible to account for location-specific services.

For a simplified typology applied across the whole portfolio, management categories can be limited to the main types, since mixed management is trivial in area terms. This leaves the potential for any more detailed assessment of an individual project to consider the specific breakdown if appropriate:

- No thinning or clearfell (including Mixed mainly no thin or clearfell);
- Continuous cover system (including Mixed mainly continuous cover system);
- Thin only (including Mixed mainly thinning);
- Clearfell only (including Mixed mainly clearfell), and
- Thin and clearfell (including Mixed mainly thin and clearfell).

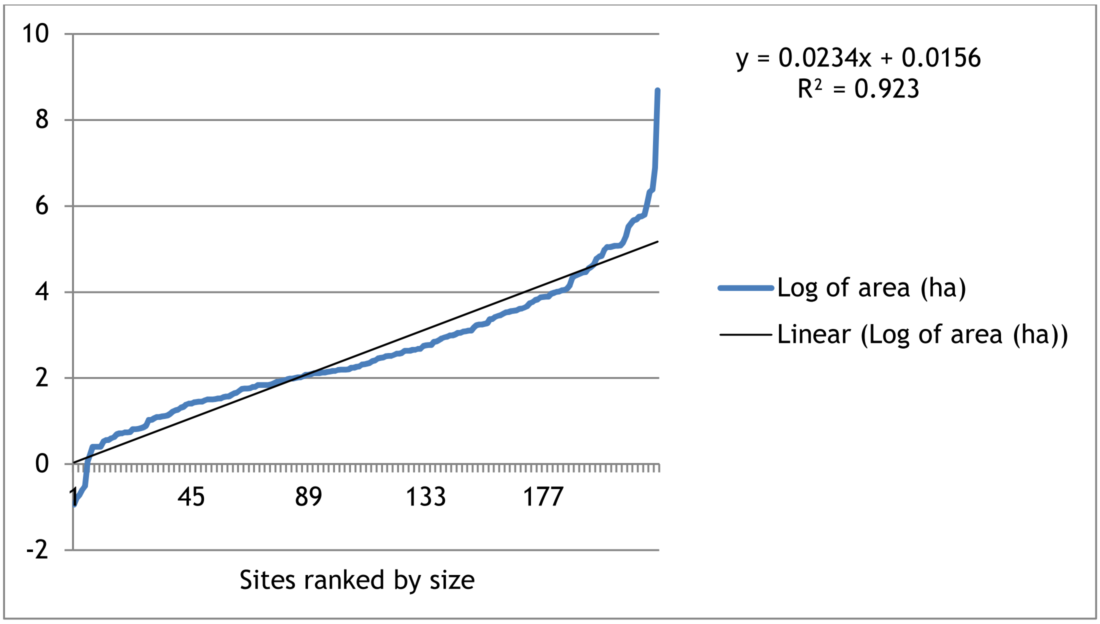
Likewise, we maintain essentially the four simple species mix categories (noting that project-specific notes of native species planting can be taken into account under the biodiversity category). There are only nine WCC sites with significant components in more than one category, and 205 (93%) of sites are all under a single category. Therefore for overall assessment we will classify each site to a single category, noting that detailed assessment of individual sites could use the actual breakdown. To deal with the handful of mixed cases, we consulted with the Forestry Commission and agreed a classification that best represented the actual planting.

For the area, there are a few outliers, and in particular Loch Katrine, a huge site which alone accounts for 37% of the WCC area. However the distribution of sites outside the extremes is close to log-linear, as shown in Figure C.2. The median site is 10.3ha, which is also the mean of the interior 99%[39] Based on the distribution and on practical considerations and the desirability of selecting round numbers, we derive the following categories:

- small: less than 5ha
- average: between 5ha and 20ha
- large: between 20ha and 100ha
- very large: above 100ha

It remains to be seen to what extent these categories could be useful from a valuation perspective. For example, it could be argued that 'very small' sites are unlikely to provide additional air quality regulation value, in the absence of specific evidence to the contrary (such as an urban location). Similarly, sites in the largest category (>100ha) are most likely to justify the trouble of considering spatial details in GIS - noting for example that TIM uses a grid with cells of 2km square, which is 400 ha.

Figure C.2: Log of area (ha)



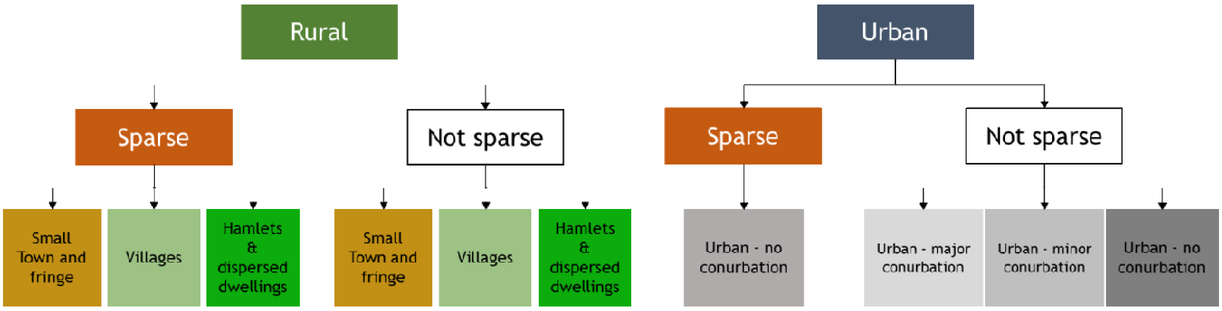
The location of WCC sites with respect to human populations is relevant for several services/values, including not only recreation but also for example air pollution, noise attenuation, visual amenity and social benefits. Details of the relationships between sites, populations and these values are highly location specific (depending for example on background levels of air pollution and noise) but for broad typology purposes a reasonably clear distinction can be drawn between:

- Urban woodlands, on land in or immediately adjoining residential, industrial or educational areas in a conurbation;
- Peri-urban woodlands, in areas in or around the fringe of conurbations or sizeable settlements, and
- Rural woodlands, further outside build up areas.

[39] The interior 99% removes the extreme outliers by excluding 0.5% above and 0.5% below – in this case, the main effect is to remove Loch Katrine, which alone accounts for 37% of the WCC area (and therefore exerts a very strong upwards influence on the unadjusted mean site size).

In fact the rural category could be further subdivided, as for example in the Rural-Urban Classification (RUC, 2011) (Figure C.*3*), and data for these classifications are available at the census area level. However, RUC takes no explicit account of any aspect of the land cover typical of a statistical unit other than settlement. RUC is not intended for the classification of land or land parcels (Bibby & Brindley, 2013). Rather, RUC is intended for the study of demographic and economic features, and the Output Areas (OAs) are determined such that each has approximately the same population. The vast majority are wholly or partly within urban areas. For example, an OA "may include a large tract of unsettled moor, but overlap the edge of an urban area. Under these circumstances the residents of the OA will typically live in the urban portion and it will be classified accordingly." (ibid) Hence, this dataset does not seem well suited to determining urban/rural categorisation for woodland planting, though further checking may be warranted.

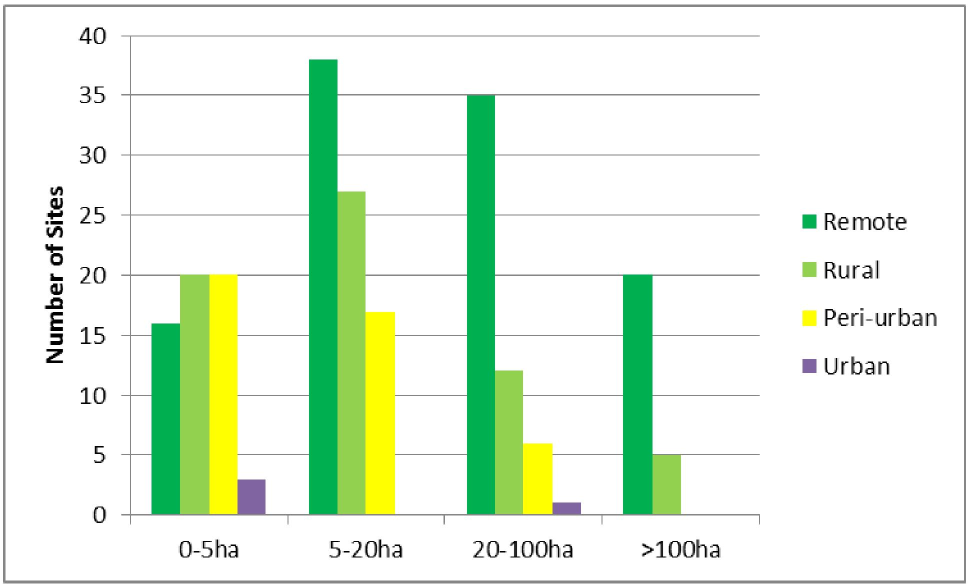
Figure C.3: Rural-Urban Categories in Rural-Urban Definition for Small Area Geographies



Source: Adapted from RUC, 2011

For present purposes, the urban/peri-urban/rural classification has been applied following manual checking of the grid-reference for each project, which served the additional purpose of checking the general level of woodland density in the area, the location with respect to watercourses and reservoirs, and additional features such as close proximity to school sites. For the purposes of assessing air quality regulation, a further category of 'remote rural' is also defined, since low pollution loads and/or exposed populations in such areas make valuation of this service unreliable in such locations. The breakdown of sites by size across such locations is shown in Figure C.4.

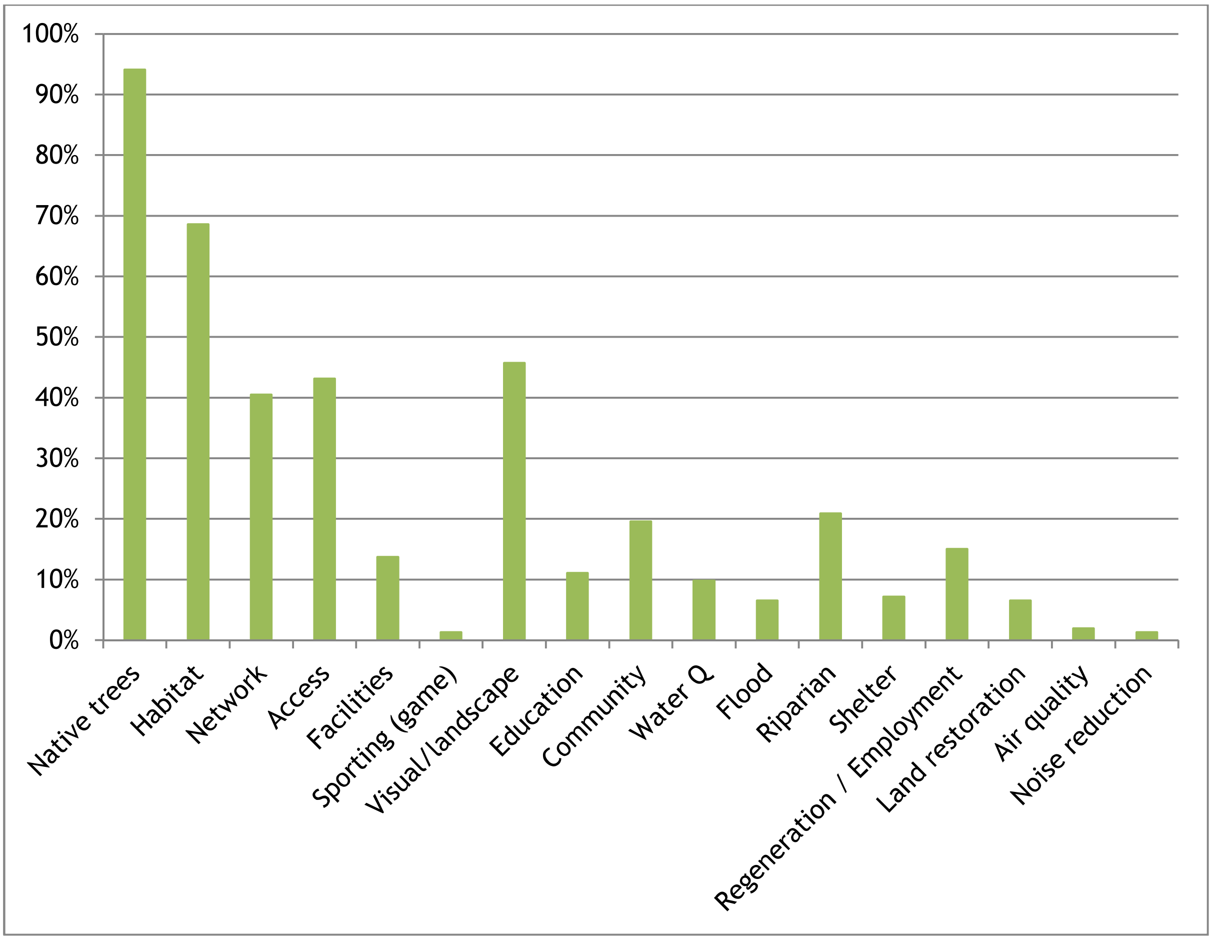
Figure C.4: Distribution of rural-urban sites across size classes in WCC projects



The remainder of the typology must take into account features that are identified as present at different sites (Figure C.5). However, it is also somewhat dependent on the methods used to identify the services from these features, and to value them. The ideal is to make use of geographical information to identify likely services and where possible values, as discussed further below. For recreation, for example, this involves use of the ORVal models; for biodiversity, water purity and flood risk benefits it involves use of maps of priority areas. The use of location specific information could, however, be augmented by typology features that identify (1) when benefits are/are not likely to arise, if the location is propitious and/or (2) when benefits are likely to be significantly higher, or lower, than average, given the location. The identification of such typology flags anticipates the discussion of benefits below. Based on the information contained in the WCC project descriptions, the following categories seem likely to be relevant:

- Enhanced biodiversity values: where the project description identifies specific biodiversity interest, such as planting native species, a focus on restoration of woodlands, or strategic contribution to biodiversity networks. Flags: Native trees; Habitat; Network;
- Enhanced recreation access: where the project description identifies access or facilities likely to increase the recreational use above the average (noting that TIM works at a 2km grid, so details of location with respect to populations at lower scales is not represented). Flags: Access; Facilities;
- Sporting values: where contribution to game values is cited. Flag: sporting (game);
- Aesthetic benefits, where specific contribution to the landscape or views from settlements or transport network is cited: Flag: Visual/landscape;
- Special educational benefits: where the project is identified as located on/adjacent to school site, or otherwise has educational value e.g. through involvement in planting. Flag: Education;
- Special community benefits: where particular need or proximity to residents is identified, suggesting values over and above ordinary recreation. Flag: Community;
- Water-related benefits: where the planting occurs along a watercourse or otherwise contributes to above-average values. Flags: Water Quality, Flood; Riparian;
- Specific contribution to shelter for animals or others. Flag: shelter;
- Important role in regeneration of post-industrial/degraded areas or provision of employment opportunities. Flags: Regeneration / Employment; Land restoration, and
- Specific contributions to reducing other environmental problems. Flags: Air quality; Noise reduction;

Figure C.5: Proportion of sites with feature (based on 153 sites with adequate descriptions)



D VALUATION OF WCC CO-BENEFITS

Recent work on woodland service assessment in the UK includes URS (2014), eftec and Cascade Consulting (2015), Binner *et al.*, (2016) and work using the ORVal model (for the NEA and ongoing). Wong *et al.,* (2015) identified four approaches to measure and evaluate the supply of ecosystem services from habitats: (1) metrics and indicators using primary data, (2) benefit transfer using secondary data and land cover proxies, (3) spatial mapping and (4) modelling systems which combine all three approaches. The relevance of each approach will differ depending on the scale of analysis, the habitat and ecosystem service being considered and the availability of data and resources.

As URS (2014) note, there is "a plethora of both cross-sectoral and sector-specific indicators, but many are not appropriate to the timeframe, nature, scale or variety of contexts for new woodland projects, or are insufficiently developed as reliable metrics." The Forestry Commission "Sustainable Forestry Indicators" contain numerous indicators of potential interest for the development of a typology and valuation of forestry outcomes. The 2002 document includes over 40 indicators grouped under six themes (woodland, biodiversity, condition of forest and environment, timber and other forest products, people and forests, economic aspects) while the 2010 indicators are somewhat differently grouped (forest resources and carbon, maintenance of forest ecosystem health and vitality, productive functions of forests (wood and non-wood), biological diversity in forest ecosystems, protective functions in forest management, and socioeconomic functions and conditions). These indicators are based on actual outcomes across the country, so do not help directly in establishing a typology linking woodland characteristics to specific outcomes, but provide guidance on the benefits to be measured.

The Gold Standard Foundation[40] reports on the benefits of various schemes against a wide range of criteria. Given the broad scope, it is unsurprising that the level of detail is less than we would require for the WCC evaluation: forest protection is reported in hectares, and valuation of associated services carried out on a lumped per-hectare basis.

URS (2014) identified two potential routes to assessing the benefits of woodland planting: "impact focused" and "output/outcome focused'. The 'Impact' focused framework is based on establishing ecosystem services baseline conditions, monitoring change, and developing an evidence base to demonstrate impacts. This more firmly establishes impacts for valuation, but is more complex and resource intensive, requiring specific forms of evidence. The 'Output and Outcome' focused framework is more based on reporting and presentational simplicity, grounded in questions on short term options and longer term monitoring. This is less complex and resource intensive, with relatively straightforward scoring methods and lower evidence needs, but gives less robust information, and in particular does not provide information in a form adapted to ecosystem service valuation. Due to time constraints, and in line with the steering group's emphasis on the need for simplicity, only the more flexible 'output and outcome' framework was taken forward" (Table D.1). Four broad category headings were identified under which more specific indicators were identified and grouped.

[40] The Gold Standard: http://www.goldstandard.org/ accessed 12/04/16

Table D.1: Routes to Impacts

Output category	"Routes" to impact
Wildlife	1. Create and manage a native woodland with the aim of delivering biodiversity gains
	2. Create a woodland with a diverse range of features in order to bring about ecological benefits
	3. Create a woodland that leads to an improvement in the surrounding ecological network
Water	1. Create and manage a woodland that protects and improves the site's aquatic or wetland habitats
	2. Create and manage a woodland that contributes to water quality or flood risk objectives
Community	1. Create an actively used woodland that delivers community facilities, particularly where there is demonstrable demand
	2. Ensure that all relevant communities have been actively engaged by the woodland project
	3. Create and manage a woodland in a manner that sustains economic development
Climate	1. Create a woodland that actively contributes towards climate change mitigation
	2. Create a woodland that actively contributes towards climate change adaptation.

Source: URS (2014)

The URS 'output and outcome' approach involves identifying "routes to impact" under each of four key outcome categories: wildlife, water, community and climate. For each route, there are detailed questions for woodland managers to complete before, during and after woodland creation. For our purposes, some of the detailed questions could be answered based on readily available data (e.g. "Will woodland creation on the planned site expand an existing woodland, or otherwise connect valuable habitats?") but others would be harder to assess without quite detailed information on the management objectives and plans for each project (e.g. "Is the woodland being managed with the goal of delivering a range of woodland features?", "Does the woodland include an area of minimum intervention?"; "Does the management of the woodland allow for a proportion of deadwood to remain?"). The URS framework is quite appropriate for individual woodland managers, but much less suited to a desk study assessing the benefits of the WCC overall.

Binner *et al.,* (2016) present a scoping study that reviews work on the state of knowledge regarding the economic valuation of benefits derived from trees and woodlands in the UK with particular (although not exclusive) attention being paid to extensions to the literature since previous reviews (in particular eftec, 2011). They find that "The existing literature is patchy, incomplete and uses a plethora of different units, years and scales. This makes a coherent approach to valuation extremely difficult, particularly because study design plays a large role in determining the valuation estimates. An integrated, consistent and comprehensive approach to valuing all of the benefits and costs associated with tree and woodland land use and management is needed" (pages 4-5).

Ninan and Inoue (2013) report that "evidence from a cross section of forest sites, countries and regions suggests that not only the total valuation of ecosystem services varies widely across studies but also the valuation of individual services. This variation suggests that policies to conserve ecosystems and their services should emphasise local contexts and values" (page 137). We would expect variation in the value of ecosystem services to be significant where the location of forest sites is a key determinant of their value. For example, the recreational value of woodland is dependent upon its proximity to woodland users (i.e. a large population) and the value of flood risk mitigating services is dependent on at risk buildings and infrastructure, whereas carbon sequestration and timber values vary less by virtue of location per se (eftec *et al.,* 2015b).

Ecological production functions offer one "integrated and consistent approach" to addressing these issues. They are essentially 'modelling systems' (as defined by Wong *et al.,* 2015) which link ecosystem characteristics and final services and are parametrised models that estimate the provision of final services based on the specific characteristics at a particular site. Few studies employ the parametrised method because of data limitations and interdisciplinary challenges. As discussed further below, many production function approaches are data-intensive and quite suited to application at a broad scale (i.e. large areas of woodland as part of a production function), but is less easy to apply to relatively small scale (i.e. small changes in woodland provision) unless robust production functions already exist at large scale and marginal values can be estimated.

The ecological production functions can also be simple conceptual outlines of the link between ecosystems and the economy. Binner *et al.,* (2016) stress that "an adequate understanding of the biophysical pathways influencing the physical provision of those goods heavily dependent upon the natural world is just as crucial an element of robust valuation as is the contribution of appropriate economic methods" (page 3). Their scoping study ends with "a clear, prioritised set of realistically actionable options for enhancing the evidence base to generate valid, robust, and comprehensive valuations of the social and environmental benefits of trees and woodlands" (page 3). In developing the production function framework, they make a clear distinction between (see Figure D.1):

- Intermediate environmental goods and services (IEGS), which are environmentally produced goods and services that act as inputs to some other environmental process; and
- Final environmental goods and services (FEGS), which are environmentally produced goods and services that enter household or firm production functions without further biophysical translation. In other words, FEGS are those particular subset of environmental goods and services that have direct and immediate consequences for productive activities in the (human) economy.

The forest typology (species mix, soil, management, location etc.) will influence FEGS and in turn influence production functions, but could also influence production functions directly, if the typology includes any elements relating to location with respect to user populations or even management methods. These arguments lead Binner *et al.* (2016) to adopt a valuation approach based on a range of production functions that translate the FEGS associated with woodland systems to productive goods and services that are valued by consumers and firms. The production functions are based on the characteristics (the nature of the FEGS as it is delivered by the environmental production function), the context (how the FEG is produced and consumed in perhaps complicated human production functions that have many other arguments) and aggregation (how many people enjoy value, and how this is mediated by proximity).

However, we need to recognise that some functions could be/provide both IEGS and FEGS on these definitions. Although Binner *et al.* (2016argue that "While the supply of those FEGS is underpinned by environmental processes that draw on a variety of IEGS, people do not have preferences for IEGS any more than they have preferences for intermediate economic goods and services" (page 14), this is far from obvious. People may have strong preferences about the processes behind their FEGS – e.g. they are prepared to pay a premium for FSC timber. It could of course be argued that a FSC table is technically a different good from a non-FSC table; nevertheless, the preferences for FSC timber are still reflecting preferences for IEGS. Again, it could be argued that they are actually preferences for other FEGS (people like FSC because that implies biodiversity provided/protected) but this seems to stretch the definition of “household or firm production functions” more than is practically useful. The question is, does limiting attention to FEGS as defined here make it less or more likely that some values will be overlooked?

Figure D.1: FEGS and production functions

		Production Functions															
		Timber products	Food (agriculture and subsistence)	Industrial production	Pharmaceuticals	Hydropower	Drinking water	Transportation	Flood alleviation	Housing	Physical health	Mental health	Recreation	Artistic	Learning	Spiritual and cultural	Non-use value
FEGS	Water quality		x	x		x	x	x		x	x		x	x	x	x	x
	Water quantity		x	x		x	x	x	x	x			x	x	x	x	x
	Air			x						x	x	x	x		x	x	x
	Flora, fauna and fungi	x	x		x					x	x	x	x	x	x	x	x
	Environment									x	x	x	x	x	x	x	x
	Sound and scent									x	x	x	x	x	x	x	x
	Views			x						x		x	x	x	x	x	x
	Soil		x	x						x			x		x	x	x
	Timber and fibre	x	x	x	x					x			x	x	x	x	x

Source: Binner *et al.*, (2016).

As the number of ‘Xs’ in Figure D.1 shows, the approach leads to quite a complex and varied set of coefficients to be derived, relating particular FEGS to production functions that can have strongly different parameters depending on human demand features (i.e. details of location with respect to human populations, socio-economic characteristics, availability of alternative resources…). There is little doubt that this is a theoretically consistent approach to identifying all the paths from woodland functions to final values. However, for present practical purposes, as Binner *et al*. (2016) recognise, in many case there is substantial uncertainty about biophysical and/or socioeconomic characteristics that are relevant to the valuation.

At the same time, this reductionist approach may not fit so well with valuations of bundled FEGS, for example of recreation overall (ignoring the details of how the specific FEGS influence recreation demand). All the ‘cultural’ services face this problem - it is difficult to imagine stated preference respondents yielding robust valuations for coefficients on each of the FEGS – for example separating out ‘sound and scent’ from ‘air’ and ‘views’ - and the functional form of the production functions would be extremely hard to establish.

We also need to remain conscious of issues of scale. A full production function approach is likely to be suited to application at catchment scales or above. For smaller woodland investments, we would need to use value transfer, noting that the source values could be based, where possible, on catchment or higher scale production functions, in particular drawing on sophisticated modelling exercises. Binner *et al*. (2016) note the potential for existing but fragmented data relating to social and environmental benefits to be brought together and used to develop such models for valuation. Emerging examples include InVEST (Nelson *et al*., 2009; Sharp *et al*., 2015), LUCI (Jackson, et al. 2013), MIMES (Boumans & Costanza, 2007) and TIM (CSERGE, 2013). These tools incorporate biophysical models to reflect interactions between multiple ecosystem services at various spatial and temporal scales, and are complex to develop and apply. However there is scope to use them in relatively simple ways once they are set up and running for a particular area. TIM in particular has several advantages in this respect:

- Contains an economic behaviour model;
- Covers quantitative and monetary analyses of the integrated effects of land use change;
- Has an optimisation routine;
- Exists for the UK at a 2km grid, and
- Incorporates a recreation model based on analysis of the extensive MENE dataset.

Deriving the production functions set out in Binner *et al*. (2016) would be a huge advance for valuation, but also a huge undertaking involving many more variables than those related to woodlands.

Practically, for the purposes of evaluating the co-benefits of the WCC, we need to rely on value transfer methods, where possible using application of existing models such as TIM. In many cases the values available do not follow the full reductionist production function approach, but are rather focused on FEGS, bundles of FEGS or cost-based proxies. The practical options for valuing the FEGS of WCC projects are set out in Table D.2.

Table D.2: Valuation methods for final ecosystem goods and services / functions of WCC projects

FEGS/function	Description	Physical	Monetary	Overall	Summary
Timber	Timber/fibre form an input to many economic production functions (e.g. for timber products, paper, firewood…) but for the purposes of valuing woodland investments we can use either the standing sales or direct sale value.	WCC project data reveal intentions for thinning/felling and reasonable estimates of volumes/ha and time profile should be feasible.	Estimates of standing values (ignoring costs of extraction), or the first sale values (with separate deduction of costs of extraction). Estimates of thinnings values.	Good prospect for robust valuation. Benefits internal so may not be appropriate to include as 'wider benefit'.	Market values, but ignore since (1) internal to project owner and (2) most projects envisage no thinning or clearfell
Non-timber forest products	FEGS may include mushrooms, berries, flowers, artistic materials.	To a first approximation, we assume that in WCC projects these products are likely to be relatively minor	Assume these are subsumed within the values of recreational visits (i.e. they are picked by visitors for personal use).	Not valued directly, leaving option of adding this category for specific sites where values thought to be important.	Ignore unless strong evidence
Water supply (quality/ quantity)	Water supply (quality and quantity) enters a number of economic production functions, in particular related to drinking water, but also water for agricultural and in some areas industrial or hydropower uses. Important impacts include uptake/reduction of nutrients, pesticides and sediment run-off; coniferous woodlands can increase acidity.	Measuring these diverse impacts for specific woodlands is onerous, and it is difficult to generalise. However, there have been mapping exercises to identify the priority zones where woodland planting can have most impact in the catchments of water bodies at risk of failing quality standards for nitrate, phosphate, sediment, pesticides and faecal indicator organisms (see below).	The Woodland Valuation Tool (WVT – reference TBC) currently contains 18 valuation studies or reviews and 27 references to biophysical studies relating to water quality. These are diverse in coverage and none is ideally suited to valuation of specific benefits arising from planting under the WCC.	The most promising approach is to combine maps of priority areas for pollutant reduction with conservative value transfer. Ideally this would be coupled with mapping of the extent to which catchments are used for drinking water, water-based recreation, and hydropower. Monetisation remains a challenge.	Use maps of priority areas. Robust monetary valuation not feasible.

FEGS/function	Description	Physical	Monetary	Overall	Summary
Flood alleviation	The other main aspect of woodland interaction with water is the potential reduction in flood risks to downstream areas. The values are highly location specific, depending inter alia on the other land use in the catchment, on other flood risk management assets and strategies, and on the populations, human-made and natural assets exposed to flood risk.	A full production function approach could be implemented via integrated assessment modelling at catchment scale. Without this, the assessment of individual woodland creation projects is hampered by low transferability of values. However, mapping has been carried out in England and Wales, and for the Tay catchment in Scotland, identifying areas at risk from flooding from rivers and surface water and priority areas where runoff from soils is rapid.	Challenging but very broad ranges may be possible based on 'Slowing the Flow at Pickering' project (Nisbet, Marrington *et al.*, 2011; Nisbet *et al.*, 2015). Note though that activities here include storage bunds and debris dams, not just planting.	Again, the most promising approach is to combine these map layers with conservative value transfer, ideally coupled with mapping of the density of populations and assets at risk.	Use maps of priority areas. Robust monetary valuation not feasible.
Local air quality	Trees can filter some pollutants from the air, notably particulates, and some species can emit VOCs and/or allergens. Effects are highly location specific and further complicated by influences on wind speeds/airflow. Air quality enters many economic	Estimating the effectiveness of any specific planting project in terms of achieving reductions in exposures to pollution is challenging. Data is available from a rural monitoring station in Devon and the i-tree model to represent typical rural UK conditions.	UK Social Damage Costs are available for NO_2, PM10[41] and SO_2 (Dickens *et al.*, 2013) - but Binner *et al.*, stress that fixed values per tonne do not reflect marginal changes or the size of the population	The best realistic prospects for valuation in the context of WCC projects would be the use of unit values for pollutant damage avoided for specific urban pollutants transferred from the literature, coupled with	Use UK-relevant estimates from i-tree, and value transfer from DfT (2013) to value pollution reduction.

[41] PM = particulate matter. See: https://www.gov.uk/guidance/air-quality-economic-analysis

FEGS/function	Description	Physical	Monetary	Overall	Summary
	production functions.	Remote rural sites assumed to have approximately zero impact.	exposed to the change.	iTree modelling for rural and peri-urban areas.	
Local climate regulation	Trees provide local cooling, shade and wind-break services. Values are highly location specific. The most significant impacts are likely to be in densely populated urban areas where street trees and parks can reduce ambient temperatures and cooling needs during hot weather, and riparian trees providing shade to water courses where high temperatures can threaten fish and other species.	It is relatively straightforward to identify where these services may be important, but challenging to quantify them in any way without detailed analysis.	Binner *et al.*, report studies for the US but no values are well suited to transfer to the UK at present.	It should be possible to flag where these benefits may be significant, but not to quantify or monetise them for WCC purposes.	Map areas where important: - urban areas - riparian banks Otherwise ignore. No monetary valuation.
Global climate regulation (carbon)	A production function approach here is possible (climate change damage studies are generally based on how multiple production functions respond to temperature, precipitation and/or carbon concentrations). However it is an extremely complex exercise, and since the pool of GHGs in the atmosphere is a global, well-mixed pollutant, the location of	We have good data on the carbon profiles of the WCC schemes, and can use these.	Official government figures for valuation of carbon in traded and non-traded sectors; alternatively, estimates of the social cost of carbon might be used, or carbon credit prices from carbon trading markets.	Relatively straightforward to value; question remains regarding the most appropriate choice from the valuation approaches identified. Our default position would be the government non-traded values.	Already reflected in WCC data. Could be valued from surplus from official non-market rates compared to price of WCC credits.

FEGS/function	Description	Physical	Monetary	Overall	Summary
	emission/ sequestration makes little or no difference to the impacts.				
Recreation (as primary site)	There is considerable research into the role of woodlands as recreation destinations. Values are a combination of the number of trips and value per trip. Outdoor recreation can also have impacts on physical and mental health, which may not be fully represented in value per trip estimates based on individual willingness to pay for recreational experiences (for example since they may be unknown to the individuals).	The estimation of changes in trip numbers following changes in forest cover is challenging. The best available approach here relies on analysis of the MENE database (Sen *et al.*, 2014) and its implementation in the TIM model.	Value transfer methods allow reasonably robust estimation of the value per trip. Sen *et al.*, (2014) present meta-analysis that drawing on 297 values from 98 studies, combined with the MENE modelling of travel time & cost from outset areas to recreation site, accounting for availability of substitute sites and household characteristics.	Use of TIM to produce a map of values per ha of new planting, based on a new plantation equal to the average WCC size. This would need to be updated periodically.	Map layer from ORVal to give value estimates
Recreation (contribution to landscape)	Many WCC investments are relatively small and might not be the primary sites for recreation, but nevertheless contribute to recreation values either as features along a walking (cycling, riding) route, or as part of the general landscape within which recreation takes	A full production function approach here would be challenging, and values may be dependent on complex features such as species mix and planting density, as well as specific location in the landscape.	Reasonably robust evidence on values per trip for different destination types/activities, but linking this to woodland density in surrounding landscapes challenging.	The best prospect for according some value under this category would be a mapping of priority areas for native forest restoration, but data for value transfer are lacking, and risk of double-counting with other values.	Potential to flag if planting adjacent to major recreation routes (e.g. Pennine Way). No monetary valuation.

FEGS/function	Description	Physical	Monetary	Overall	Summary
	place.				
Impacts on physical/ mental health	Woodlands can influence physical/mental health directly through exercise and exposure to natural environments, and indirectly through their impacts on air and water pollution. However it is possible that these effects could be partly or even largely accounted for under recreation, water quality and air quality, so there is a risk of double counting.	Production functions for human health could be derived, though units can be challenging. Mourato *et al.*, (2010) present estimates of "health changes and contact with nature" based in particular on a preference-weighted utility score.	Mourato *et al.*, (2010) make a tentative estimate for the health benefit of local broadleaved/mixed woodland land cover, +1% within 1km of the home (i.e. + 3.14ha) at £8-£27 per person. Estimates also presented for use of outdoor space (but we assume this is covered in recreation) and for view of green space (but in most WCC cases original use is green space). Local enclosed farmland land cover is valued at £4-£12 per person so for most cases of WCC planting only the net impact should be counted.	Using the Mourato *et al.*, results for broadleaved/ mixed woodland would allow these impacts to be counted, though it ignores initial landcover (assumes constant marginal value). Will require population densities around sites. Optionally, could identify areas of especially high potential benefits (e.g. around hospitals, care homes, schools), and link to recreation values and identification of areas of social deprivation where impacts potentially higher.	Could create map layer for net benefits based on Mourato *et al.*, using population data. However risk of double counting with values for recreation.
Impacts on agriculture:	Binner *et al.*, (2016) identify five main pathways for agricultural benefits, relating to shelterbelt roles, wind-break roles, soil stabilisation, use of timber	Biophysical evidence remains very general, while impacts are likely to be highly location specific.	Valuation of agricultural outputs is straightforward, but the production function link to woodlands is hard to	Where woodlands are planted on farm land, the values will, to a large extent, be internal to landowners. Bateman *et al.*, (2014) report	Ignore unless strong evidence.

FEGS/function	Description	Physical	Monetary	Overall	Summary
	products, and providing habitat for pollinators and natural pest control.		establish. The Woodland Valuation Tool contains 3 valuation studies and 4 biophysical studies relating to agriculture.	farmers' WTA compensation of £300/ha (1991 GBP) suggesting the net value might be negligible.	
Impacts on game values	These impacts are similar in nature to those identified for agriculture, in that they will be highly location specific and often internal to the landowner involved in planting the woodland, where values relate to shooting rights in the woodland or on surrounding land held by the same owner.	Game values are mentioned briefly in Binner *et al.*, (2016) under 'biodiversity'. Deriving physical measures for impacts via production function not likely to be possible for WCC schemes without significant additional work.	Market prices exist for shooting days, and for purchase of wooded areas with shooting rights. It may be possible to derive estimates in this way but the physical link remains challenging.	Where woodlands are planted on estate land, the values will to a large extent be internal to landowners. External values (game moving from WCC land to a shooting estate) are possible but to first approximation we might ignore these values.	Flag where identified. No monetary valuation unless strong evidence.
Impacts on property values	Housing markets reflect a production function for residential property, that includes a huge variety of site and location specific factors. These include location with respect to woodlands, for views and recreational opportunities, and for other FEGS such as air quality.	Binner *et al.*, mention the housing production function in association with several woodlands FEGS. Markets are highly location specific and detailed modelling for WCC areas would not be feasible. It may be possible to identify numbers of households within direct sight and/or within certain distances of new sites.	In principle hedonic studies can reveal the WTP for proximity to woodlands. Mourato *et al.*, (2010) present a study including several land-cover variables from which implicit prices for coniferous and broadleaved woodlands can be derived (net of	Combining the implicit prices with the number of dwellings in the 1km square could give an estimate of the capitalised value via housing amenity. There is a risk of double-counting with recreation and health impacts.	Explore potential for map layer based on housing densities and Mourato *et al.*, results.

FEGS/function	Description	Physical	Monetary	Overall	Summary
			original land cover), at the regional level.		
Biodiversity conservation	Biodiversity conservation enters many production functions, but measuring the contribution of woodlands to conservation and making the link to production functions is very difficult.	Direct linking of specific woodland planting to measures of biodiversity at higher scales is challenging. A practical alternative is to identify particular priority habitats and specific locations where particular forms of planting (e.g. native species restoration, PAWS restoration, extensions to existing woodlands) are 'high value'.	Including separate values for biodiversity runs the risk of double-counting e.g. with recreation, health, cultural values. This can be avoided by using only non-use values. eftec (2016a) review current options for valuation and conclude that the most practical current option is cost-based proxy. However specifically for woodland, the results of Willis et al (2003) can be useful.	The potential for extracting a shadow value from TIM should be explored. Available grants/incentives for woodland planting may be used as proxies. The risk of double counting should be considered. Willis et al (2003) values can be used for now, but further work on the appropriate populations for aggregation / distance decay of values would be a great improvement. See also 'non-use' below (in practical terms, we will not be able to distinguish biodiversity non-use from any other non-use values)	Flag where planting is (a) native species, (b) contributing to specific conservation measures (e.g. specific species), and (c) contributing to woodland network. Use Willis et al values as very approximate non-use values for biodiversity
Other 'cultural' use (education, inspiration)	Woodlands and associated biodiversity and functions are an educational asset and source of artistic inspiration for many.	Deriving a full 'production function' for education or artistic outcomes using woodlands as an input variable is not a practical prospect. Proxy variables can be measured, for example	Mourato *et al.*, (2010) derive cost-based estimates of the contribution of the natural environment to education/knowledge	Valuation here is not a practical proposition, as numbers of educational visits cannot be estimated. Even if it were there could be a risk of double counting	Identify school/community sites. No monetary valuation.

FEGS/function	Description	Physical	Monetary	Overall	Summary
		based on school/educational trips, as discussed in Mourato *et al.*, 2010.	in the UK. The estimates are not suitable for deriving values for individual planting projects.	with recreation, amenity and non-use values. It would be possible to identify where educational/cultural values are likely to be high, e.g. in the case of WCC projects adjacent to schools.	
Non-use values	Binner *et al.*, (2016) show all the FEGS of woodlands entering the non-use production function. Non-use values include bequest, altruistic and existence values that individuals hold for woodlands and the biodiversity and functions they support, over and above any personal use or utility from the woodland and services it supports.	These values are considered directly in monetary terms, generally via stated preference (SP) studies. In practical terms the ecological variables used in SP studies relate to ecosystem and biodiversity features: it is difficult to separate out different sources of non-use value.	Mourato *et al.*, (2010) look directly at bequests to natural charities to derive estimates of bequest values. These are not suitable for application to individual sites however. Willis et al (2003) present non-use values for woodland biodiversity that are very approximate but nevertheless useful for present purposes.	We should not attempt separate valuation of non-use values for woodlands directly, but rather consider these as tied up with biodiversity values .	Cite as additional sources of value, but no robust monetary valuation that avoids double-counting problems.

D.1 Recreation

Recreation is a key aspect of the value of woodlands in the UK, as demonstrated by the importance of recreation in the Public Forest Estate's natural capital accounts (Forest Enterprise, 2016). This service is valued here using a prototype of the new ORVal tool, under development by the Land, Environment, Economics and Policy Institute (LEEP) at the University of Exeter. The tool is being developed for Defra, and a version was released for testing within this project in July 2016 (Brett Day, pers comm, March 2016). ORVal uses the recreation visits model developed within TIM for the UKNEAFO (Bateman *et al.*, 2014) and subsequent work, with an added user interface to improve ease of use.

eftec agreed to act as the first external testers of ORVal to:

- Ensure access to the tool asap when it is working and available;
- Provide feedback to Defra and LEEP to help establish the ORVal as a tool for environmental-economics analysis in the UK (this study inputted to an event on the 6th September at Defra);
- Connect analysis of WCC co-benefits to the best available methods and tools, and
- Establish analysis of the impacts of woodlands and woodland creation as one of the purposes of ORVal, encouraging it to accurately input to future woodland policy analyses.

The locations of WCC projects have been entered manually into the ORVal tool. In some cases, the land was already marked as being accessible for recreation, so the land use type was changed to woodland. In a small number of cases the WCC site was an extension of existing woodland recorded in ORVal, so was entered by adjusting the boundaries of an existing site.

When sites are entered, ORVal then calculates the results in terms of the expected numbers of visits and the welfare value of these visits. These figures are summed are reported in Table D.3 below.

Table D.3: Recreational Value of WCC Projects in England from ORVal

WCC projects in England entered into ORVal	123
Area of sites	2,255 ha
Total visits to these sites	310,686
Welfare value of visits	£2.47 million/yr

The site calculations for England were extrapolated to the rest of the UK based on the 4 rurality classes used in the air quality regulation valuation (see below). This is because population density is the key determinant of site recreation values. The other major determinant is the availability of substitutes, however, there is no systematic and automated way of assessing this for all WCC projects, so it was not considered feasible.

The values used for the extrapolation are shown in Table D.4. These values can also be used by WCC sites outside England to estimate their recreational values. However, they should note the additional uncertainties with this extrapolation, discussed below.

Table D.4: Extrapolated Recreational Values per ha of Woodland by Rurality

Rurality of Site	£/ha
Urban	44,193
Peri-urban	8,850
Rural	2,748
Remote	377

Using these values, the estimated recreational value supported by WCC sites in the UK is £16.95m per year, based on an estimated 4.4m visits. It should be noted that there is some uncertainty associated with this extrapolation, for example due to the greater rurality of many Scottish sites, and the potential for diminishing marginal return at the biggest WCC site, Loch Katrine. Also this value only captures residents recreation, not that of tourists, so is an underestimate of total recreational value.

To be conservative, the value of WC projects is also estimated without the values for the Loch Katrine site (which covers over 5,900 ha). This gives a range for the estimated recreational values supported by WCC sites in the UK at £14.7 - 17.0m per year, based on an estimated 3.8m - 4.4m visits per year.

Examination of recreational values for different sites in England are shown in the data below, and this reveals some interesting factors in how benefits are generated, for example:

- The values for changes the habitat at different sites from grassland to woodland, or from woodland to grassland can have a negative impact. This seems to depend on the relative availability of substitutes of these different types of habitats.
- The change in recreation value of a due to a change in its habitat type is usually around 10% of its total value, but can range of 5% to 20%.
- However, making introducing access to inaccessible natural environment sites is bigger source of value than changes to the type of habitat at an accessible site.

a This tabs considers the changing in value at a particular site when the land-use is changed
b This section looks at sites that have already been incorporated into ORVAL.
c This considers woodland which is converted to managed grassland (with the change stated) and
d It considers managed grassland which is converted to woodland (with the change stated)

ORVAL

	SOUTH EAST	Area (ha)	Welfare value (£/year)	No. of visits		Area (ha)	Welfare value (£/year)	No. of visits
1	Woodland	267	£396,440	49549	Grassland (managed)	88.69	£208,502	26,061
2	Grassland (managed)		-£43,525	-5,439	Woodland		-£3,262	-408

	MIDLANDS	Area (ha)	Welfare value (£	No. of visits		Area (ha)	Welfare value (£	No. of visits
1	Woodland	73	£85,669	10,708	Grassland (managed)	35.38	£707,721	88,445
2	Grassland (managed)		-£8,439	-1,055	Woodland		£80,469	10,053

	NORTH	Area (ha)	Welfare value (£	No. of visits		Area (ha)	Welfare value (£	No. of visits
1	Woodland	18.63	£289,051	£36,128	Grassland (managed)	123	£522,792	65,339
2	Grassland (managed)		-£13,946	-1,743	Woodland		£96,453	£12,052

a This section creates new sites at several locations where there are known WCC projects
b 3 landuse types are used to determine the difference in welfare values associated with different land uses.
c 2 sites with different total project areas are created in each region

NEW SITES (WCC) BEDFORDSHIRE

	Creating the following habitats	Area (ha)	Welfare value (£/year)	No. of visits
1	Grassland (managed)	6	£27,306	3,413
1	Grassland (natural)	6	£22,945	2,868
1	Woodland	6	£32,140	4,017
2	Grassland (managed)	40.62	£14,695	1,837
2	Grassland (natural)	40.62	£10,529	1,316
2	Woodland	40.62	£20,082	2,510

NEW SITES (WCC) YORKSHIRE

	Changing the existing land cover	Area (ha)	Welfare value (£/year)	No. of visits
1	Grassland (managed)	13.88	£3,943	493
1	Grassland (natural)	13.88	£3,097	387
1	Woodland	13.88	£4,943	618
2	Grassland (managed)	49.15	£2,138	267
2	Grassland (natural)	49.15	£1,507	188
2	Woodland	49.15	£2,968	371

NEW SITES (WCC) SOUTH EAST ENGLAND

	Changing the existing land cover (from grassland to	Area (ha)	Welfare value (£/year)	No. of visits
1	Grassland (managed)	5.1	£59,137	7,392
1	Grassland (natural)	5.1	£50,309	6,288
1	Woodland	5.1	£68,809	8,600
2	Grassland (managed)	55.38	£17,141	2,142
2	Grassland (natural)	55.38	£11,953	1,494
2	Woodland	55.38	£24,028	3,003

D.2 Air quality regulation

The impacts of trees on air quality depend on their location, in relation to:

i. The background levels of air pollution, and
ii. The size and characteristics of the population and their exposure to air pollution in the area where air pollution reductions will take place.

Item (i) requires data on pollution absorption that is representative of WCC projects. Data used here are sourced from a rural monitoring station in Devon, south-west England, inputted to the i-tree model[42]. While this location is not as remote as some WCC projects (particularly those in Scotland), it provides data that are considered a good representation of the rural areas in which WCC projects in the UK are typically located. The scale of air quality regulation can be calculated by multiplying the quantity of air pollution absorbed per ha of trees, by the area of projects in ha, to get the total pollution reduction in tonnes.

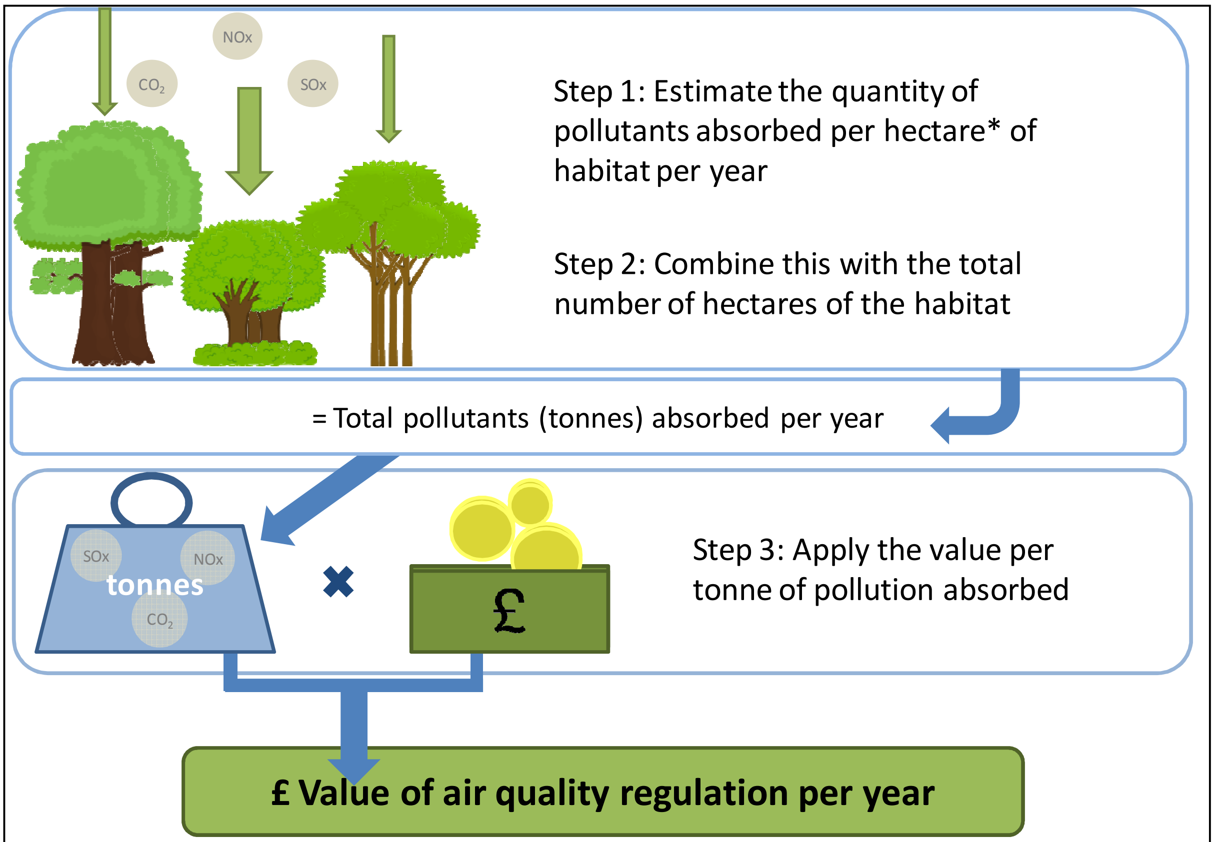
Item (ii), the characteristics of the affected population, are reflected in the DfT's (2013) standardised values for the damage per tonne of air pollution (of NOx, SO_2, NO_2 and PM10) which differentiates typical UK locations (in a classification which ranges from 'London-central' to 'rural'). The air pollution reduction (in tonnes) can be multiplied by the relevant values per tonne reflecting the locations of WCC projects. This process is captured in Figure D.2.

Different location types in the DfT database are used for this purpose (see Table D.4). For the central case, we assume no air pollution value for 'remote' sites, on the grounds that these sites are in areas where air pollution is not a significant problem and/or where few people experience the benefits of air pollution reductions. We use the central rural estimate as the base case for rural sites, the low central urban small as the base for peri-urban sites, and the low central urban medium as the base for urban sites. For sensitivity analysis, we go up or down a category, as illustrated in Table D.4. Other values in the DfT data set are available for more densely urbanised settings - these are not applicable to the current portfolio of WCC projects. However, should projects from more densely developed urban areas use the code in future, these data may be appropriate to use.

Note that these DfT data are designed for approximate calculations in relation to road schemes, and are considered suitable for the analysis being developed here to assess significance of this service from WCC projects. Where very high value changes (e.g. damages >£50m) are being assessed (e.g. due to major road schemes), bespoke modelling approaches are recommended.

[42] Kenton Rogers, pers com. April 2016.

Figure D.2: Methodology for estimating air pollution regulation values



The total estimate of the value of air quality regulation across the WCC sites in the 'central' case is £56.8m over the lifetimes of the WCC projects[43]. For the 5.81 million tonnes of CO_2 that WCC projects are expected to sequester over their lifetimes, this is equivalent to an average of £9.78 of air pollution benefits per tonne of CO_2, or £12.4 per tonne of claimable CO_2.

For sensitivity analysis, low and high scenarios are based on different values per tonne of pollutant absorbed as specified in the DfT (2013) guidance. These are shown in Table 5.6. The high scenario gives £187m, or £40.75 per tonne of claimable CO_2. The high scenario gives £197m, or £43 per tonne of claimable CO_2. The difference from central to high is much greater than from low to central because the low and central cases both assume zero air pollution regulation value for remote areas, which represent half of the sites, but 82% of the total area. This suggests that a key sensitivity could be the issue of whether or not remote woodland sites provide air pollution benefits.

This issue could be partly resolved through air pollution mapping (i.e. to resolve the question of whether or not the trees are in areas where significant air pollution is frequently present to be

[43] This is consistent for comparison with CO_2 and other figures but may underestimate slightly the total benefits, since trees will remain (or be replaced) after the project lifetimes. If instead we count benefits over 100 years for all sites, the total would be £59.1m. The difference is small because most are in the upper duration range (when discounting has a large impact anyway) and because most of the short duration sites are small. For individual short duration sites, however, the difference can be very big (correction factor as low as 18%, due to short duration plus no air pollution benefit counted during the first 10 years).

'cleaned up'), but there remains the issue of tracking the impact in terms of levels of pollution experienced by people living and working at some distance from these areas. There is also a benefit to absorbing air pollution in terms of protecting the natural environment (rather than human health) from it.

D.2.1 Global climate regulation

Providing verified carbon reduction credits is the main purpose of the WCC. Therefore, measurement and valuation of these reductions within appraisal would be double-counting.

Table D.4: Air pollution values per ha, present value over 100 years

Air Pollution Zones		Unit values, £ per t		Total values, £ per ha				
LOCATION	**DfT reference case**	**NOx/t**	**PM/t**	**PM10**	**PM 2.5**	**SO_2**	**NO_2**	**TOTAL**
REMOTE - central	none	0	0	0	0	0	0	0
REMOTE - high	*Rural - low central*	*3,126*	*14,083*	*11,570*	*33*	*144*	*1,571*	*13,317*
RURAL	Rural - central	7,815	17,988	14,778	42	144	3,926	18,890
RURAL - high	*Rural - high central*	*12,504*	*20,440*	*16,792*	*47*	*144*	*6,282*	*23,266*
RURAL - low	*Rural - low central*	*3,126*	*14,083*	*11,570*	*33*	*144*	*1,571*	*13,317*
PERIURBAN	Urban small - low central	7,260	32,771	26,922	76	144	3,648	30,790
PERIURBAN - high	*Urban small - central*	*18,150*	*41,777*	*34,321*	*97*	*144*	*9,119*	*43,680*
PERIURBAN - low	*Rural - high central*	*12,504*	*20,440*	*16,792*	*47*	*144*	*6,282*	*23,266*
URBAN	Urban medium - low central	11,495	51,790	42,547	120	144	5,775	48,586
URBAN - high	*Urban medium - central*	*28,738*	*66,148*	*54,342*	*153*	*144*	*14,438*	*69,078*
URBAN - low	*Urban small - central*	*18,150*	*41,777*	*34,321*	*97*	*144*	*9,119*	*43,680*

D.3 Water pollution regulation and flood control

Trees are known to play an important role in water regulating ecosystem services (ADAS & eftec, 2014). The three main water regulating services related to woodland planting in the UK are regulation of:

- Water pollution caused by particulate and nutrient runoff from land to water bodies;
- Fluvial flood risk caused by rainfall entering river systems in a volume that exceeds the capacity of river channels and therefore spills into floodplains where it can pose a danger to human life and damage buildings and other manufactured capital, and
- Regulation of the quantity of water supply, whereby increased infiltration of water into soil retains increases groundwater storage, thereby prolonging water supplies in times of low rainfall

These services rely on combinations of similar ecosystem functions and their value is also correlated with similar environmental conditions (e.g. steepness of slope, intensity of rainfall, other land uses in catchments, and importantly, socio-economic factors such as the extent of human population reliant on the catchment for these services). For example, increased filtration of surface water into the soil can reduce flood risk, increase groundwater recharge, and reduce surface soil erosion thereby reducing water pollution.

Only the first two services are analysed within this project. The third service (regulating the quantity of water supply) is not analysed in detail. This due to a number of factors that make its value highly location specific, including:

- The impact of trees on this ecosystem service is dependent on local conditions, both at the micro scale (e.g. steepness and soil type of the land, and the land use and runoff from land immediately up-slope of the trees) and catchment scale (extent of different land uses in the catchment and their ability to regulate runoff from the rainfall it receives), and
- Its economic value in the UK is highly location specific. This is due not only to significant differences in the availability of water supply in different parts of the country, but also differences in groundwater resources (e.g. due to geological factors), and water storage and supply infrastructure (e.g. reservoirs).

The valuation of co-benefits of WCC projects for the other two water regulating services also face similar challenges. However, a number of the environmental factors involved have been combined into a spatial data layer "priority areas for tree planting to reduce diffuse water pollution and flood risk in England and Wales" (Broadmeadow *et al.*, 2014). A similar dataset is used for Scotland (Source: W4W dataset), but this only covers the initial 14, SEPA diffuse pollution priority catchments. These reflect the best agricultural land under the greatest pressure from agricultural diffuse pollution.

FC Scotland are planning to do a new 'Woods for Water dataset which will include all catchments and have separate 'flood benefit' and 'diffuse pollution benefit' layers of data. Would be good to recommend for future use/ work.

These data sets do not place an economic value on water pollution and flood regulating services, but identifies spatial areas where planting is expected to have a greater physical impact in respect of diffuse water pollution and/or flood regulation. Due to the overlaps in the ecosystem functions, environmental conditions and socio-economic factors that determine the value of these three water regulating services, it is likely that this data set is a reasonably good proxy for areas where tree planting has value for water supply regulation. However, the extent of this correlation requires further assessment, and is an area for potential future work to develop the analysis of WCC co-benefits, and more generally for enhancing the usefulness of the prioritisation mapping by taking account of the value and spatial distribution of assets at risk.

The approach for water pollution and flood regulating services is to establish an indicator for WCC projects' co-benefits based on whether the project is in a priority area for these services. This is identified by comparing the location of WCC project to spatial data layers identifying priority areas for tree planting to help manage catchments. There are different data layers indicating this for each UK country:

- In England and Wales, the Broadmeadow *et al.*, (2014) data is used, and
- In Scotland, the mapping has only been done in 14 catchments that are a priority for tackling diffuse pollution.

For smaller WCC projects (< 20 ha), the analysis can use the grid reference point for the project as an acceptable proxy for its location. For medium and larger projects (20 ha or more), the analysis will be improved significantly by using a GIS polygon representing the boundaries of the woodland.
We could also use this as a recommendation for the FC – i.e. need to map priority planting areas nationally in Scotland and Wales.

At a project level this indicator can be expressed as either:

- "This project lies within areas identified as a priority for planting to reduce water pollution and flood risks" (for smaller projects), or
- "XX% of this project lies within areas identified as a priority for planting to reduce water pollution and flood risks" (for medium and larger projects).

For very large projects (i.e. Loch Katrine) it is worth considering a bespoke assessment of this process, as planting of several thousand hectares has potential to change a catchment's hydrology significantly, even if not all of it is in 'priority areas' identified in the GIS layer. Due to a lack of data in Scotland, this bespoke approach represents the only realistic option.

For an aggregate assessment of the WCC projects, the suggested metric for this co-benefit is:

- "12.5% of the area planted under the WCC in England, Scotland and Wales lies within areas identified as a priority for planting to reduce water pollution and/OR flood risks".

This metric can be calculated by summing the percentages identified for medium and larger projects and the total area of the relevant smaller projects. This effectively counts all of the area of these small projects, even though it may be the case that only part of them lies within priority areas for planting. This potential over-estimation of these benefits is counteracted by likely under-estimation for projects where the grid-point location is not in priority areas, as it is likely that for a proportion of these projects some part of their planting will be in priority areas for planting.

Priority planting areas differ between the three countries. To date, Scotland has only mapped priority areas in 14 initial diffuse pollution priority (DPP) catchments. Only 17 of the WCC schemes in Scotland are within the DPP catchments covering 20% (1,442 of the 5,122 ha) of WCC schemes in Scotland are included in this analysis. There is currently no spatial targeting of grant aid schemes within Wales, but the Forestry Commission's Opportunity Mapping exercise (2014) included an assessment of Wales. This dataset only identified priority areas for water quality and flood risk management in both England and Wales. The analysis was also able to identify priority areas for biodiversity and climate change adaption in England through the national opportunity mapping data that was used to create the Countryside Stewardship priority areas.

Table D.5 shows the total area in England, Wales, and Scotland of WCC projects that fall within the priority planting areas within each country. The total areas panted within priority areas for water quality and/or flood risk is 1,981 ha. This is 12.5% of the total WCC area.

Table D.5: Priority planting areas analysis for England and Wales and Scotland

	England Area (ha)	Wales Area (ha)	Scotland Area (ha)
Water quality	1,216	192	274
Flood risk	816	10	362
Water quality and flood risk	771	10	108
Water quality and/or flood risk	1,261	192	528
Biodiversity	5,488	-	-
Climate change adaption	217	-	-
DEFRA landscape scale projects	159	-	-

Notes: Figures have been rounded to the nearest whole number

D.4 Biodiversity

WCC projects can potentially have significant value for biodiversity, but this is challenging to quantify or to monetise. Using stated preference methods holds the potential to elicit public willingness to pay for biodiversity improvements, however it is difficult to avoid the risk of double counting with other benefits associated with biodiversity, in particular recreation. At the same time, some functions supported by biodiversity, such as air pollution regulation, are valued separately.

eftec's Environmental Value Lookup (EVL) tool (2015) reviewed current options for valuation and conclude that the most practical current option is a cost-based proxy. This could either be associated with grants/payments, or it may be possible to establish an implied value using the UKNEAFO (2014) method, where the cost incurred by accepting biodiversity objectives as a constraint is calculated. However, given that WCC projects have already chosen their planting and management options, modelling a future constraint is not considered appropriate for their appraisal.

For the specific case of woodlands, and in particular new woodland planting, Willis et al (2003) present an approach and empirical evidence that allow approximate valuation of the non-use benefits of biodiversity improvements. Their study draws on Garrod and Willis (1997) for values of biodiversity improvements to remote upland conifer woodlands. The argument made is that these values are almost entirely non-use values, since the areas in question are extremely unlikely to be visited or viewed by any respondents, nor to offer them any other direct ecosystem service benefits other than through such non-use values as they may hold. These results are then extended via Hanley et al (2002) who look at how people place relative weight on non-use aspects of biodiversity improvements of different sorts, for example comparing the remote conifer case with broadleaf planting and with maintenance of ancient semi-natural woodlands (ASNW).

Willis et al use these results to derive values for three reference cases. One of these, ASNW, does not apply in the case of new planting. The other cases, broadly, apply to conifer planting and to broadleaf planting respectively. Their values are expressed in terms of household WTP for

12,000ha of planting. Which is an appropriate order of magnitude to relate to WCC projects' impacts.

There is some uncertainty about the appropriate populations for aggregation of these value, and in particular whether for Scottish, Welsh and Northern Irish woodlands it is appropriate to aggregate over UK households or only over households in Scotland, Wales or Northern Ireland respectively. In England the same issue arises, but makes much less difference to the total (since over 80% of UK households are in England) – though if aggregation takes place at regional level (NUTS1 – which is also the NUTS category for Scotland, Wales and Northern Ireland) then the difference is quite similar. We have updated the 2003 values to current (2016) values, and calculated per ha values for different levels of aggregation; we report values at the UK level, on the grounds that these are non-use values for which proximity within the UK should not make too much difference, while presenting sensitivity results for lower levels of aggregation to allow for the possibility that people may be less WTP for biodiversity conservation outside their particular bit of the UK.

This approach is considered the most appropriate way to generate monetary values for the biodiversity impact of WCC woodlands. An alternative would be to generate qualitative evidence, for example by putting WCC projects creating native woodlands in the context of relevant biodiversity action plan targets, at UK or regional level, for such woodlands.

A more detailed approach could use the EEA's (2014) indicators for assessing "high natural value" forest based on:

- Naturalness;
- Hemeroby (the degree of human influence on the ecosystem);
- Accessibility (expressed by the steepness of terrain and thus how accessible the forest is for management – i.e. This is not about access for recreation);
- Growing stock (the volume of living trees); and
- Connectivity (forest availability and distance between patches of forests, i.e. the extent to which the landscape facilitates or impedes the movement of species).

D.5 Local economic impacts

Work by CJC Consulting (2015) in Scotland provides a recent assessment of the impacts in the market economy of forestry activities. It is used here as a basis for estimating the market economic activity that might be supported by WCC projects. In order to use these estimates for WCC projects, the key differences between the Scottish and the UK forestry sectors are identified and relevant adjustments are made.

D.5.1 Data

Relevant evidence on the Scottish forestry sector that is used to adjust the CJC values for extrapolation across UK WCC projects is set out in Table D.*6*.

Table D.6: Data on forestry sector in Scotland

Metric	Value	Unit	Year
Woodland coverage in Scotland	1,410,000	ha	2013
Timber production	7,030,000	tonnes	2013
	4.9	tonnes/ha	2013

Employment and gross value added (GVA) figures for Scotland from the CJC report are set out in Table D.7, which also gives estimates of 'average intensity of activity for forestry' in per hectare and per tonne terms.

Table D.7: Estimates of economic impacts of forestry in Scotland

Metric	Value	Unit
Direct employment in forest management	12,143	FTEs
	0.0086	FTE/ha
	0.0017	FTE/tonne timber
Total employment related to forest management[a] (excluding deer/game management and sport shooting activity)	19,555	FTEs
	0.0139	FTE/ha
	0.0028	FTE/tonne timber
Total employment associated with woodlands[b]	25,867	FTE
	0.0183	FTE/ha
	0.0037	FTE/tonne timber
Total GVA contribution of forest management	771	£m/yr
	807*	£m/yr
	573*	£/ha/yr
	115*	£/tonne timber/yr

Notes: * calculated for 2016. All other data is 2013 and sourced from CJC Consulting (2015)
a. Including indirect and induced employment related to forest management (estimated using employment multipliers adjusted for intra-forestry sector purchases) and recreational activity
b. Including indirect and induced employment related to forest management (estimated using employment multipliers adjusted for intra-forestry sector purchases) and recreational activity and deer/game management and sport shooting activity

D.5.2 Key differences for extrapolation

It is noted that extrapolating from all Scottish forestry activity, to woodland creation under the code across the UK introduces uncertainty into the analysis. Key reasons for this uncertainty are explained below and include: (i) geography; (ii) socio-economics; (iii) forestry activities; and (iv) structure of forestry sector.

i) The different geography of Scotland

Scotland includes a greater proportion of upland and remote rural areas than is typical for the UK.

ii) Socio-economic factors

Scotland has a lower population density and there are differences in the structure of the Scottish economy versus the UK economy.

iii) Different types of forestry activity

There are differences in forestry activity between Scotland and the UK as a whole, such as different sizes of individual sites, and different tree species reflecting soils, climate and other factors, and different management objectives (such as focus on recreation or timber). There are also differences between Scotland and Woodland Carbon Code projects, the majority of which are relatively small mixed or deciduous woodlands (See Section 4.1 above).

iv) *<u>Different structure of the forestry sector</u>*

In Scotland there is greater activity amongst specialist/commercial operators (as opposed to those managing woodland as part of wider rural industries, such as farming).

The main sources of direct forestry employment in Scotland are the Forestry Commission Scotland (including its agency Forest Enterprise Scotland which manages the National Forest Estate together with Forestry Commission Central Services and Forest Research staff located in Scotland), forest management, harvesting, and primary processing, especially sawmills.

For projects registered under the WCC, the supporting activities of the Forestry Commission and other forest management activities, occur amongst all projects. However, harvesting, and primary processing are only relevant to those projects where timber is extracted. Over 90%, by area of WCC projects do not extract timber - identified as long term project management of “no thinning or clearfell” and “Mixed mainly no thin or clearfell” as described in Section 4.1.

An adjustment is made to the CJC data, by removing the employment and GVA related to timber extraction and associated downstream activities (made up of those listed as: harvesting, sales of wood and timber; haulage/transport; saw milling; production of pallet slats, fencing posts; production of wood panels, board and pulp and paper; production of chips, pellets, (in Table 1.1 on page 2 of CJC, 2015).

The estimate of total employment related to forest management in Table D.7 includes GVA and employment related to deer and game management. It is possible that many WCC woodland projects are not managed specifically for game so this may create a risk of overestimating impacts. In particular, in smaller projects, as is typical of WCC activity, game/deer may be recreational benefits are less likely to co-exist. However, in some larger sites, deer and game hunting activity and recreation will co-exist.

Therefore, it is not possible to distinguish the impacts of deer and game management from those of recreation management across particular areas of forestry in Scotland. Excluding the impacts of deer and game management, but including the area on which they occur would effectively dilute the remaining impacts from other activities by dividing them across an unrealistically large area. Therefore, it is considered more accurate to include the impacts of deer and game management activities and recreation in the figures used. The impacts of deer and game management may differ from the management activities more commonly occurring within WCC projects. However, they differ less than the alternative assumption, which is that no deer and game management takes place.

D.5.3 Adjusted estimates

Given the adjustment and assumptions described above, the resulting estimates are shown in Table D.8. Note these data are not calculated per tonne of timber. This is not considered a relevant metric given that this data exclude jobs connected to timber extraction.

Table D.8: Adjusted estimates of economic impacts of Scottish forestry sector, excluding timber production

Metric	Value	Unit
Direct employment in forest management	6,240	FTEs
	0.0044	FTE/ha
Total employment related to forest management[a] (excluding deer/ game management and sport shooting activity)	11,336	FTEs
	0.0080	FTE/ha
Total employment associated with woodlands[b]	14,531	FTE
	0.0103	FTE/ha
Total GVA contribution of forest management	427*	£m/yr
	303*	£/ha/yr

Notes: * calculated for 2016. All other data is 2013 and sourced from CJC Consulting (2013)
a. Including indirect and induced employment related to forest management (estimated using employment multipliers adjusted for intra-forestry sector purchases) and recreational activity
b. Including indirect and induced employment related to forest management (estimated using employment multipliers adjusted for intra-forestry sector purchases), and recreational activity, deer/game management and sport shooting activity

The two sets of total employment figures both cover indirect and induced employment related to forest management and recreational activity, with the higher figure also including deer/game management and sport shooting activity. These data are considered to provide an acceptable range with which to estimate the total employment impacts of WCC projects. They may be an overestimate due to the inclusion of deer and game management, as discussed above. However, they may also be an underestimate due to the significantly higher population density in much of England, which is expected to result in higher impacts from recreational activity for WCC projects in England.

The total employment figure including indirect and induced effects of 11,336 FTE for forest management and 14,531 for woodlands, includes employment supported by woodland recreation. However, the total economic value of recreational activity to users is estimated separately in this report (see Section 5.2), and therefore the GVA figure above of £427m (which only includes market values) needs to be reported carefully to retain this distinction. It may be clearer to report employment figures, rather than GVA as an indicator of local socio-economic impacts.

Estimated socio-economic impacts of WCC projects

Based on the adjusted estimates in Table D.8, the estimated impacts of WCC projects is set out in Table D.9. These are calculated by multiplying the per ha figures in Table D.7 by the 15,688 ha area of all WCC project.

Table D.9: Estimates of economic impacts of WCC projects, 2016

Metric	Value	Unit
Direct employment in forest management	69	FTEs
Total employment related to forest management[a] (excluding deer/ game management and sport shooting activity)	126	FTEs
Total employment associated with woodlands[b]	161	FTE
Total GVA contribution of forest management	4.75	£m/yr

Notes: * calculated for 2016. All other data is 2013 and sourced from CJC Consulting (2013)
a. Including indirect and induced employment related to forest management (estimated using employment multipliers adjusted for intra-forestry sector purchases) and recreational activity
b. Including indirect and induced employment related to forest management (estimated using employment multipliers adjusted for intra-forestry sector purchases), and recreational activity, deer/game management and sport shooting activity

This data suggests that WCC projects currently support between 70 – 160 full-time jobs and approximately £4.75m of GVA each year in the UK. It should be noted that this data is averaged across the lifetimes of the WCC projects to give a picture of full-time equivalent employment. This means that impacts will not occur consistently at this rate, being higher or lower in particular years for project related reasons.

In addition to GVA from forest management, CJC Consulting (2015) also note the contribution of forest visitor expenditure to Scottish GVA. This mainly arises in businesses outside the forestry sector (e.g. accommodation and catering businesses) and is estimated to be £183m per year in 2013. However, this is not all an additional injection into the Scottish economy.

CJC Consulting (2015) estimate the additional economic impact of forest recreation on Scottish GVA is to lie in the range £120m to £164m per year. The exact figure is dependent on the proportion of overnight trips that are assumed to be additional as a result of forest recreation. Assuming 50% of resident overnight trips are additional gives an impact of £142m per year. They state that these estimates should be treated as indicative only because of uncertainty about the total forest visitor spend and aggregated nature of the business statistics for GVA. These data suggest an average contribution to Scottish GVA as a result of forest recreation, which is assumed to primarily occur in the local-economy of the forest sites, of £105 per ha per year in 2016 prices. This figure is based on the 1.4 million ha of forestry in Scotland identified in Table D.6.

D.6 Social Impacts

There are a range of methods available for recording social benefits from environmental enhancement projects such as woodland planting. This Section examines three:

i. Measures of social deprivation, that are proposed for assessment of the WCC's co-benefits;
ii. The Public Benefit Recording System, and
iii. the Sustainable Development Goals,

These are suggested as potentially appropriate frameworks for individual WCC projects to describe their impacts in more detail should they wish to do so.

D.6.1 Social Deprivation

Woodland creation can create a number of significant socio-economic benefits for local communities. These include economic activity (e.g. turnover and employment) supported (see Section 5.3). Other social impacts include effects on health and wellbeing, such as through increased levels of exercise in populations provided with quality accessible green space. Knowledge of these health and other benefits is improving, but it is not yet sufficient to quantify them.

The impacts involved are highly dependent on local factors, such as the health of the local population, and the availability of substitutes (i.e. existing areas of locally accessible green space). The impacts are also dependent on supporting interventions, such as management of the green space to ensure it is perceived as safe and useable by local communities, and initiatives to directly encourage its use (such as health walks and green gyms; eftec, CEH & Regeneris (2015)).

The benefits of providing accessible green space, are in general higher in areas of higher social deprivation. This is due to these communities' lower spatial mobility and therefore lower ability to access green space in different locations, and to higher incidence of the health and social problems that its provision can help address (eftec, CEH & Regeneris (2015)).

The proposed approach for assessing these social impacts is to determine how many WCC projects (and their area) are located in or near areas of high social deprivation to establish an indicator for WCC projects' proximity to such communities, as a proxy for this aspect of their co-benefits. This will identify WCC projects that are in areas in the bottom 20% of social deprivation in the UK.

The Index of Multiple Deprivation (IMD) is the official measure of relative deprivation for small areas (LSOAs) in England and Wales and data areas in Scotland. LSOAs are 'Lower Super Output Areas' for which census data is published. This data set has irregular boundaries which can contain both settlements and countryside. It should be noted that it is not always a good way to identify 'rurality' as required for other co-benefits valuation, such as air quality regulation and recreation.

It is common to describe how relatively deprived an LSOA is by saying whether is falls among the most deprived 10%, or 20% of LSOAs in that country. For this study, we have decided to report social deprivation and access to WCC projects in terms of the most deprived 20% of areas in each country.

The Natural England Accessible Natural Greenspace Standard (ANGSt[44]) determined the minimum distances that people would travel to the natural environment. Based on this information, ANGSt recommends that everyone, wherever they live, as a minimum, should have access to greenspace of at 2ha in size, no more than 300 metres (5 minutes' walk) from their house. Most WCC projects are significantly larger than 2 ha, so the next rung of the ANGSt standard (at least one accessible 20 hectare site within two kilometre of home), is also relevant.

The GIS analysis aimed to determine the total area of WCC projects that were accessible to highly deprived areas. This was done by assessing whether the WCC project boundary was within 500m of the boundary of an LSOA in the most deprived 20%. The distance of 500m was chosen as a compromise between the two ANGSt standards described above. It should be noted that this assumes that WCC project woodlands have some public access. This is predominantly the case

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44 http://webarchive.nationalarchives.gov.uk/20140605090108/http:/www.naturalengland.org.uk/regions/east_of_england/ourwork/gi/accessiblenaturalgreenspacestandardangst.aspx

where this information is reported in project descriptions. Access points may not be at the nearest point of the woodland to the deprived LSOA, but the average size of WCC sites mean that people are likely to travel further than 500m to access them (as per the two ANGSt standards described above).

This approach was used to identify WCC projects that are in areas accessible to communities in the bottom 20% of social deprivation in the UK. It should be noted that there are separate social deprivation data sets for England, Wales and Scotland. Therefore the analysis identifies whether the project is in the bottom 20% of Lower Super Output Area (LSOA[45]) in its country. This will differ slightly from the lowest 20% across the UK as a whole.

For smaller WCC projects (< 20 ha), the latitude and longitude coordinates for the project can be used as an acceptable proxy for their location. The analysis will identify whether this point is in a LSOA in the lowest 20% in the index of deprivation. For medium and larger projects, the analysis will be improved significantly by using a GIS polygon representing the boundaries of the woodland, and assessing what part of it lies in such wards.

At a project level this indicator can be expressed as: "This project is accessible to communities in the lowest 20% of social deprivation in the UK". Ideally, for larger sites, the proportion of the site accessible to deprived communities (i.e. within a certain distance) would be assessed, but this is not feasible with the current data sets.

As with water regulating services, this introduces some inaccuracy into the assessment. However, potential overestimation by counting the entire area of smaller projects is again likely to be counteracted by underestimation of projects where part of the woodland, but not the grid-reference point, are adjacent to the relevant communities.

For some projects it may be worth considering a bespoke assessment of this process, either because social impacts are specifically part of their design/motivation. In particular this can be the case where woodland creation is part of local landscape re-foresting initiatives, that are partly motivated by social goals, such as The National Forest, The Forest of Marston Value, and The Mersey Forest. At these locations individual WCC sites contribute to a project whose overall impacts may be greater than the sum of its component sites.

This is likely to be a challenging impact to capture systematically in the assessment of WCC co-benefits. It is suggested that the extent of WCC planting within such initiatives is monitored, and projects are encouraged to note this context within individual descriptions of benefits. For example, they could state "This WCC project is part of a local landscape planting initiative XXX".

The analysis of the WCC projects is that:

England

In England, nine WCC Projects are accessible to the 20% most deprived LSOAs. The total area of these is estimated to be 300 ha (approximately 6% of total area).

Scotland

In Scotland, 3 WCC Projects are accessible to the 20% most deprived LSOAs. The total areas of these is estimated to be 49 ha (~0.6% of total area).

[45] LSOA = lower super output area: a small spatial area which is used as a statistical unit to collect and analysed data from the national census in the UK. There are

Wales

There are currently no WCC registered projects in Wales that fall are accessible to the 20% most deprived LSOAs.

Overall 12 WCC projects (5.5% of all projects), covering 349 ha (2.2% of all projects' area) are in locations that are accessible to the 20% most deprived LSOAs in their respective UK countries.

D.6.2 Public Benefits Recording System

The Public Benefits Recording System (PBRS) aims to identify synergies between social, economic and environmental needs and opportunities, strategies and investments – thus ensuring value added results[46]. The PBRS lays out approaches for assessing impacts in economic, social, environmental and access terms. Many of these impacts are already captured in the valuation of individual services and economic impacts described above, and are best directly recorded by projects (e.g. accessibility in practice). The PBRS offers a method for examining certain impacts in more detail, such as habitat value for wildlife (e.g. through connectivity).

The PBRS suggests assessing impacts on social deprivation through the attributes of:

- Index of Multiple Deprivation (IMD);
- Proportion of housing within 500m of a site;
- Site area;
- Presence or absence of designated Health Action Zones and Education Action Zones, and
- Number of schools within 1 km of site perimeter.

These attributes do not combine to provide a monetary valuation of the impacts of projects. However, it builds on the proposed use of the metric for social deprivation (see Section 5.4.1) to examine other factors determining social impacts. It is suggested that introducing further social metrics to the assessment of WCC projects will make clear communication of their social benefits more difficult. However, should individual WCC projects wish to describe their social impacts in more detail, the PBRS represents a potentially suitable method for doing so. It has the advantage for this purpose of building on information already used (the index of deprivation) and in being automatically linked to spatial data layers, which should minimise the costs of more detailed assessments projects may wish to undertake.

D.7 Sustainable Development Goals

The United Nations published the Sustainable Development Goals (SDGs) in September 2015[47]. Woodland creation can potentially contribute to these goals in a variety of ways. However, as the 17 goals capture global sustainable development objectives, it is useful to be precise about which targets under each goal WCC projects are most likely to contribute to.

The objectives of this project are to capture the impacts of WCC projects in the UK and primarily in economic terms. Therefore, the SDGs are not the first choice for framing this assessment of impacts. However, **Table *D.9*** above shows that the links between WCC and the SDG's and their targets are significant in a number of areas.

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[46] http://www.pbrs.org.uk/

[47] http://www.un.org/sustainabledevelopment/sustainable-development-goals/

Table D.10: Links between WCC Assessment and SDG Goals and Targets

Goals	Targets	WCC Assessment Approach
3. Good health and wellbeing	3.4: By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being. Key non-communicable diseases in the UK (e.g. Diabetes) are related to lifestyles: diet and exercise, provision of accessible green space is essential action to address the later.	Partly captured in social deprivation assessment.
6. Ensure access to water and sanitation for all	6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	
8. Decent work and economic growth		Economic impacts assessed, but contribution to growth per se uncertain.
12. Responsible consumption & production		Purchase of WCC credits to offset impacts of consumption is example of taking responsibility.
13. Climate Action	13.2: Integrate climate change measures into national policies, strategies and planning	Reflected in carbon credits.
15. Life on land	15.1: By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally. 15.5: Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species. 15a: Mobilize and significantly increase financial resources from all sources to conserve and	Note WCC projects as direct contributor to these targets, including afforestation under 15.2. Relevant to (the majority of) WCC projects establishing natural/ native woodland WCC is an alternative financing contributing to

Goals	Targets	WCC Assessment Approach
	sustainably use biodiversity and ecosystems 15b: Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation	both these sub-targets.

Using the SDGs as a framework for describing the impacts of WCC projects may be useful for individual projects who wish to assess their social and other benefits in more detail and in an international context. It could also help put the overall impacts of WCC projects in an international context. This maybe particularly useful to inform decision makers at this scale, such as investors wishing to compare bio-carbon credit sources from different countries, or policy makers wishing to prioritise different carbon-abatement options.