Green Infrastructure – Valuation Tools Assessment

NATURAL ENGLAND

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

There are an increasing number of tools available that aim to value green infrastructure. Many of these focus on specific services provided by the green infrastructure and estimate the economic value of these services.

This report was commissioned to draw together a number of the most widely used tools and assess them against research standards for natural science and economics.

The aim of this work is to help people wanting to value green infrastructure choose the best tool for them. As well as descriptions and the assessment of the tools, links to further information and examples of the use of the tools are provided.

This report also points to the key gaps in the tools available highlighting areas for further work.

Green Infrastructure – Valuation Tools Assessment

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Acknowledgements

Table of Contents

1. Introduction

Green infrastructure is defined as "a network of multi-functional green space, urban and rural, which is capable of delivering a wide range of environmental and quality of life benefits for local communities." (Department for Communities and Local Government, 2012, p.52). It includes features such as:

- Street trees;
- Hedges;
- Grassland;
- Woodland;
- Ponds;
- Grass verges;
- Gardens and parks (including cemeteries and allotments);
- Green walls;
- Green roofs;
- Rivers and canals, and
- Some of the above and others used for sustainable urban drainage systems (SUDS)[1]

All of these features provide a variety of benefits to people. These benefits arise from services provided by the environment, also known as ecosystem services, and include the following (Defra, 2007):

- Food, fibre, and fuel (provisioning services);
- Storm water regulation, pollution clean-up, carbon sequestration, and local climate control (regulating services);
- Soil formation (supporting services), and
- Recreational activities and related health benefits, aesthetic values, and sense of place (cultural services).

These services, and the role of green infrastructure in providing them, are recognised increasingly in local and national decision making. Such decisions include assessing the costs and benefits of different land use options, selecting the most appropriate green infrastructure feature to meet given objectives, location of the feature and access and management options.

Assessing such decisions requires understanding and evidence of what the benefits are (scientific analysis using quantitative biophysical data) and how they are valued by those who receive them (socio economic analysis using economic data and qualitative analysis). Combination of these two types of analysis allows the benefits of green infrastructure, which are mostly provided free of charge, to be compared with other land use options which may provide financial returns. In particular, using economic data to express green infrastructure benefits in

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[1] SUDS are management practices and green infrastructure features designed to drain surface water to reduce the pressure on storm water and sewage collection infrastructure. Green infrastructure features used for this purpose include permeable surfaces, grass verges, street trees, wetlands, ponds etc.

monetary terms enables a direct comparison between the services provided, the costs of establishing and maintaining the green infrastructure, and the potential financial returns from other land use options. In the absence of such data, the benefits of green infrastructure may be assumed to be zero and/or ignored.

Economists have developed several valuation methods to estimate the benefits (i.e. economic value) of environmental resources in monetary terms (see Annex 1 for further discussion and some important caveats relating to these methods). In this report, the focus is on value transfer, which can be used to estimate values for smaller green infrastructure projects which have short timeframes and/or low budget or low risk. Value transfer is a process where values identified by primary research in one study area are used to infer values in the area of interest. Value transfer for green infrastructure requires an understanding of the green infrastructure feature, what benefits it provides, for whom, and how these will be changed by the project. There are several text books on value transfer and also official UK guidance on best practice published by Defra (eftec, 2010).

Value transfer can be complex and should only be undertaken with guidance from experienced practitioners. However, there are ready-made green infrastructure valuation tools that can be used by those who do not have specialist environmental or economics training or familiarity with the relevant literature. These valuation tools can be useful for understanding the implications of changes in green infrastructure service provision, and the subsequent changes in benefits. They incorporate scientific and economic data. Some of these tools provide the users with unit values[2] (to use for value transfer). Other tools require the user to input project specific data for the factors that the tool identified as affecting the value estimates.Total benefits are then estimated using this.

This study assessed a number of these tools in terms of their adherence to the principles of scientific and economic analysis, and applicability to the UK[3]:

- CAVAT: Capital Asset Value for Amenity Trees;
- Green Infrastructure NorthWest's Green Infrastructure Valuation Toolkit
- Guide to valuing Green Infrastructure from the Centre for Neighbourhood Technology Chicago;
- Health Economic Assessment Tool for walking and cycling (HEAT);
- Helliwell;
- i-Tree Design;
- i-Tree Eco;
- i-Tree Streets, and
- InVEST: Integrated Valuation of Environmental Services and Tradeoffs.

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[2] For instance, a value per hectare or per tree.
[3] For the long list of tools, see Annex A2 and for the screening process see Annex A3.

Section 2 of the report provides the results of our assessment and makes recommendations on how to select the most appropriate tool for a given case. Summaries of the assessments for each tool are presented in Section 3.

These 'valuation tools' are able to generate an order of magnitude (or ball park) estimates of the benefits they cover. Such estimates are appropriate for the appraisal of small scale green infrastructure projects, or to make an initial case at the outline stage of any project. Full scale appraisal (cost benefit analysis or impact assessment) of larger projects requires more location and feature specific research. The choice is case specific and partially depends on the information potential funders and other stakeholders require.

Finally, while most tools are designed for generalist users, some require crucial assumptions to be made at some key points. Users are encouraged to consult scientists or economists at these points which are identified in the detailed assessments in Annex 4.

The interested reader is referred to the Annexes accompanying the report for more information on the following:

1. Economic Valuation: overview of valuation methods, including value transfer, which the tools use, and key warnings you should keep in mind when applying valuation tools;
2. Methodology for selecting the short list of tools assessed and assessment criteria,
3. Initial long list of valuation tools considered for assessment; and
4. Detailed assessments for each tool.

2. Overview of the tool assessment

The tools assessed in this report cover a variety of green infrastructure features and some or all of the ecosystem services they provide.

There are four key questions that will help you select the most appropriate tool.
1. Is the tool recommended for use in the UK?
2. Does the tool cover the green infrastructure feature you are assessing?
3. Does the tool cover the ecosystem service you need evidence of?
4. In what context can the tool be used?

The answers to questions 1 and 4 are provided by this assessment. Questions 2 and 3 are for you to answer regarding the context for which you wish to use a valuation tool. We recommend those tools which pass the scientific and economic assessment (Question 1) and fit your purpose (those for which you can answer 'yes' to Questions 2 and 3). The answer to Question 4 shows the context to which each tool is most suited.

For further information to answer these questions, please see the summary assessments in Section 3, and the full assessments in Annex 4. The full assessments provide additional detail on content / standards, implementation and outcomes of using the tools assessed.

Table 1 provides an overview of the answers from the assessment for each tool. The table also shows where to find summary information (Section 3) and full assessments (Annex 4) for each tool.

It is worth noting that the valuation tools do not cover the cultural and provisioning services particularly well. This reflects a gap in the tools available rather than the scope of the report. Table 1 and 2 contain further information on the services covered by the tools.

QUESTION 1: Is the tool recommended for use in the UK?

Table 1 shows that a tool is recommended for use in the UK, if it

- Is sound both in terms of scientific and economic analysis – only *tools that are sound are recommended* - and

- Is applicable to the UK – *or can be made applicable by changing some of the information inputted into the tool[4]*.

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[4] A tool may not be applicable to the UK if it uses assumptions which are not applicable to the UK and which cannot be changed within the tool. For example, biophysical data, value estimates that do not reflect the factors prevalent in the UK such as the type, abundance and uses of green infrastructure and socio economic characteristics of the population. For

Soundness of the scientific analysis is assessed through:

- Compliance with academic standards for natural science – only *tools that are compliant are recommended*

- Similarity and compatibility with the structure of the UK Natural Ecosystem Assessment (UKNEA, 2011) – *some tools cover the same benefits but use a different terminology than UKNEA. These differences are explained and tools may still be recommended so long as they are based on sound scientific analysis.*

Soundness of the economic analysis is assessed through:

- Compliance with the economic analysis rules presented by the HM Treasury Green Book (2003) – only *tools that are compliant are recommended.*

QUESTION 2: Does the tool cover the green infrastructure feature you are assessing?

The green infrastructure features covered by each valuation tool are shown in Table 2. These are also listed in the summaries in Section 3 and full assessments in Annex 4.

QUESTION 3: Does the tool cover the ecosystem service you need evidence of?

The green infrastructure features covered by each valuation tool are shown in Table 2. These are also listed in the summaries in Section 3 and full assessments in Annex 4.

To answer questions 2 and 3 using Table 2, find the feature relevant to you across the columns and move down to see which tools cover which ecosystem services. Similarly, you can read across the rows if you are interested in specific ecosystem services.

QUESTION 4: In what context can the tool be used?

For the tools recommended for use, it is important to be clear about the context in which the tool can be used. This is because not all tools cover all green infrastructure features, ecosystem services and type or spatial scale of change.

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example a valuation tool that has been developed to estimate the climate regulation benefits of woodlands in Sub-Saharan Africa will not be applicable to the different climate, and other physical and biological conditions of the UK.

Tips

! If you aim to use more than one tool, you may not always be able to add the results together:

- o The results may be in different units which will need to be converted.
- o The results may be overlapping (e.g. Green Infrastructure Valuation Toolkit (GIVT) and Guide to Valuing Green Infrastructure by Centre for Neighbourhood Technology (CNT) both cover the climate regulation service implying that adding their results together will lead to an overestimate of the value). This would be double counting.

! Pay attention to the purpose of the tool and make sure it fits with the purpose of your own work. For example, CAVAT is designed to help estimate the financial compensation for damage to street trees. Therefore, it uses the cost of planting and maintaining a tree as its economic value. This is fit for the tool's purpose but it is not fit for the purpose of cost benefit analysis.

! Where you feel you are not sure about the suitability, process and results of a tool, you should get in touch with an appropriate scientist and/or economist. It is also possible to contact the developers of some tools. This is especially important where key assumptions need to be made, or the tools need to be configured for use in the UK.

! The results of a tool are only ever as good as the quality of the data you use.

Table 1: Headline summaries of valuation tools

	Q1. Is the tool recommended for use in the UK?			Q2. Which GI features?	Q3. Which ecosystem services?	Q4. In which context?
	Head line answer	Science assessment	Economics assessment			
Capital Asset Value for Amenity Trees (CAVAT) *Section 3.1 and Annex 4.1*	Not recommended for economic valuation.	No. Assessments dependent on expert judgement.	No. Measures cost of replanting and maintenance, not the value of ecosystem services	Trees	Does not value ecosystem services	Can be recommended for financial compensation for tree damage.
Green Infrastructure Valuation Toolkit (GIVT) *Section 3.2 and Annex 4.2*	Not recommended for economic valuation without input from expert economists.	Not clear. Biophysical analysis is either side-stepped or quantification of benefits is left to the user	No. Welfare and economic impact estimates are mixed, unit values are not always substantiated based on literature, there is a high risk of double counting	Any that can provide the ecosystem services covered	Amongst the 11 benefits covered the following correspond to ecosystem services: Climate change adaptation and mitigation; Water and flood management; Place and communities; Health and wellbeing; Tourism and Recreation and leisure.	The tool is a mix of benefits, value evidence and assumptions. While the format of the calculator is easy to use, it should not be used without expert economics input to determine robust unit values and disentangle different types of value to avoid double counting.
Guide to Valuing Green Infrastructure by Centre for Neighbourhood Technology (CNT) *Section 3.4 and Annex 4.3*	Yes. Prepared for the USA so input data and assumptions will need to be replaced with UK specific data (energy price, shadow cost of carbon)	Yes. Based on currently available research	Yes. Measures economic value using valuation methods	Green roofs Trees Rain gardens (bioretention and infiltration) Permeable pavements Water harvesting	Regulating services: climate regulation (inc air pollution), water regulation Cultural services: recreation and ecotourism	Investments in new GI feature or improvements to existing ones. Consult scientific and economic experts, where necessary.
Health Economic Assessment Tools (HEAT) for walking and cycling *Section 3.4 and Annex 4.4*	Yes. Should replace the default values with UK specific data.	Yes. Based on review of published scientific research and the tool itself is peer reviewed and tested.	Yes. Measures value of statistical life	Any feature that provides recreational (walking and cycling) opportunity	Health (reduced mortality risk) benefit of recreation	To estimate the mortality risk reduction benefits of regular exercise (walking and cycling) opportunities provided.

	Q1. Is the tool recommended for use in the UK?			Q2. Which GI features?	Q3. Which ecosystem services?	Q4. In which context?
	Head line answer	*Science assessment*	*Economics assessment*			
Heliwell (H) *Section 3.5 and Annex 4.5*	Not recommended for economic valuation	Original paper is from a peer reviewed journal but scaling factors[5] to use in the tool are based entirely on expert opinion.	There is no economic basis for the unit economic value used.	Individual trees woodland	Visual amenity (aesthetics)	The user may find the scoring process and factors taken into account useful for other purposes such as qualitative and quantitative descriptions of costs and benefits.
i-Tree Design *Section 3.6 and Annex 4.6*	No. Cannot be used in the UK as is.	The tool states that it is based on peer reviewed sources. But as it is a closed tool (underlying data and equations are not visible), it has not been possible for this study to assess its underlying data and assumptions.		Individual trees around a given property which can be marked on Google Maps™ for the USA and Canada	Regulating services: Carbon dioxide reduction, storm water capture, also Air pollution and Energy conservation due to tree shade	The annual and over project lifetime value of the selected ecosystem services of trees around a single given property.
i-Tree eco *Section 3.7 and Annex 4.7*	Yes, but with adjustments of the parameters to the UK.	The tool states that it is based on peer reviewed sources. But as it is a closed tool, it has not been possible for this study to assess the background. If applied to the UK, peer reviewed data should be inputted.		Individual trees or any size urban forest sizes	Regulating services: Carbon dioxide reduction, storm water capture, also Air pollution, Energy conservation due to tree shade and public health and several biophysical data results that support these services	Selected ecosystem services of a singly tree or any size tree population in an urban setting.
i-Tree Streets *Section 3.8 and Annex 4.8*	No. Not applicable to the UK	The tool states that it is based on peer reviewed sources. But as it is a closed tool, it has not been possible for this study to assess the background. The tool advises international users to use i-Tree Eco instead.		Street trees	Regulating services: Carbon dioxide reduction, storm water reduction Cultural services: Aesthetics as captured by property value increase Energy conservation due to tree shade	To estimate the economic benefits of ecosystem services covered by the tool and management needs and costs.

[5] *The tool scales the value of a tree depending on the following factors: tree size, life expectancy, suitability to setting, importance in landscape, presence of other trees and form.*

	Q1. Is the tool recommended for use in the UK?			Q2. Which GI features?	Q3. Which ecosystem services?	Q4. In which context?
	Head line answer	*Science assessment*	*Economics assessment*			
Integrated Valuation of Environmental Sciences and Tradeoffs (InVEST) *Section 3.9 and Annex 4.9*	Yes, though the intention of the tool is to be used for spatial planning.	Yes, the model uses methods that are scientifically tested and peer reviewed publications.	Yes, but depends on the type and robustness of the value data inputted to the model. The tool is designed to use market prices, cost of treatment and welfare estimates.	None specifically, but will generally cover GI features which cover area (e.g. a park or woodland rather than a single tree, ponds).	Biodiversity*; Regulating services: carbon storage and sequestration, water purification, sediment retention; Provisioning services: managed timber production, and Supporting services: crop pollination* *: not valued in monetary terms	Examples of the types of green infrastructure questions the tool could help to answer are: Where would reforestation or protection achieve the greatest downstream water quality benefits? Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values?

Table 2: Ecosystem services provided by green infrastructure features (table only includes tools recommended for use in the UK)

GI Feature/Type \ Ecosystem Service		Street trees	Hedges	Grasslands	Woodlands	Wetlands	Ponds	Grass verges	Gardens and parks	Green walls	Green roofs	Rivers & canals	Areas created for sustainable urban drainage
Provisioning services	Food												
	Fresh water												
	Fuelwood				InVEST								
	Fiber				InVEST								
	Biochemicals												
	Genetic resources				InVEST				CNT InVEST				
Regulating services	Climate regulation	CNT i-Tree Eco			InVEST				CNT InVEST	CNT	CNT		CNT
	Disease regulation												
	Water regulation	CNT i-Tree Eco							CNT InVEST		CNT	InVEST	CNT
	Water purification				InVEST	InVEST			InVEST			InVEST	
	Pollination				InVEST								
Cultural Services	Spiritual and religious												
	Recreation and ecotourism	CNT		CNT HEAT	CNT HEAT				CNT HEAT	CNT	CNT	HEAT	CNT
	Aesthetic	CNT							CNT	CNT			
	Inspirational	CNT							CNT	CNT	CNT		CNT
	Sense of place												
	Cultural Heritage												

3. Valuation tool summaries

This section summaries the key information and assessment of each tool. For more detailed assessments, see Annex 4.

3.1 Capital Asset Value for Amenity Trees (CAVAT)

CAVAT was developed by the London Tree Officers Association.

It does not value the benefits of ecosystem services but estimates the cost of replacing a tree. The cost can be adjusted for location, relative contribution to amenity value, and assessment of functionality and life expectancy.

See Annex 4.1 for a detailed assessment

Where to find it:

http://www.cavattreevalue.com/contact-the-author.html

http://www.ltoa.org.uk/component/docman/cat_view/98-capital-asset-value-for-amenity-trees-cavat

QUESTION 1: Is the tool recommended for use in the UK?

The tool is not recommended for economic valuation but it has been and can be used for its original purpose, to estimate the compensation claims for damage to individual trees.

The tool does not comply with academic standards for natural science, and is not recommended based on the scientific assessment. It does not give a value that fully reflects benefits from ecosystem services. The scientific assessment used in the tool is expert judgement on tree growth patterns, life expectancy and tree health and their contribution to public amenity. It does not attempt to estimate the ecosystem services at all so is not compatible with the UKNEA framework.

The tool is not recommended based on the economic assessment as it does not comply with the Green Book standards for estimating economic value.

However, the purpose of the tool is clear: estimate the financial cost of replanting a tree so that the cost estimate can be used for compensation claims. The tool can be recommended for this specific purpose only but not for the valuation of ecosystem services provided by green infrastructure features.

The tool is designed for use in the UK.

QUESTION 2: Which green infrastructure features are covered by the tool?

Trees

QUESTION 3: Which ecosystem services are measured by the tool?

CAVAT does not value ecosystem services.

QUESTION 4: In what context can the tool be used?

To estimate the financial cost of planting and maintaining a single tree.

3.2 Green Infrastructure Valuation Toolkit (GIVT)

The Green Infrastructure Valuation Toolkit was developed by a consortium of public authorities. The toolkit includes an Excel calculator and a very thorough guidance document explaining economic valuation and guiding the user through the process of valuation.

See Annex 4.2 for a detailed assessment.

Where to find it:

http://www.greeninfrastructurenw.co.uk/html/index.php?page=projects&GreenInfrastructureValuationToolkit=true

QUESTION 1: Is the tool recommended for use in the UK?

Not recommended for economic valuation without input from expert economists. An expert economist is likely to build their own approach to valuation using information from this tool.

The tool was prepared through workshops in the UK. It brings together a long list of benefits and estimates but due to the issues summarised below and in Annex 4.2, it is not recommended for use unless significant input from expert economists is secured.

There is little in the tool by way of scientific (biophysical) assessment, and hence it is difficult to judge its scientific basis. The user is asked to provide their own assessment of the type and quantity of benefits, which reduces the standardization of how the tool is used and ability to compare the results obtained between projects.

The tool has significant weaknesses with regards to its economic basis: benefits are a mix of welfare measures and (traded) economic impacts which are not comparable; unit values presented in the tool are not substantiated with evidence

(not fully referenced, 'judged based on literature' or out of date) and there is a significant risk of double counting (e.g. between health, recreation, tourism, labour).

QUESTION 2: Which green infrastructure features are covered by the tool?

The tool is designed around the types of benefits and not green infrastructure features. Potentially all features that can deliver the benefits covered by the tool will be covered by the tool.

QUESTION 3: Which ecosystem services are measured by the tool?

The tool covers a list of 11 benefits, some of which could be mapped to the UK National Ecosystem Assessment (2011) breakdown of ecosystem services:

1. Climate change adaptation and mitigation;
2. Water and flood management;
3. Place and communities;
4. Health and wellbeing;
5. Land and property values;
6. Investment;
7. Labour productivity;
8. Tourism;
9. Recreation and leisure;
10. Biodiversity, and
11. Land management.

This is a mixed list including ecosystem services (1, 2, 3, 4, 8, 9, and 10) and the contribution of green infrastructure to local economic growth (5, 6, 7 and 11). These measure different types of values for the same benefits and cannot be added together.

QUESTION 4: In what context can the tool be used?

The tool is not recommended for use, especially not without input from an expert economist.

3.3 Guide to Valuing Green Infrastructure by the Centre for Neighbourhood Technology, Chicago (CNT)

The Guide to Valuing Green Infrastructure is designed by the Centre for Neighbourhood Technology Chicago which aims to aid users to quantify and value the benefits from green infrastructure, which they describe as a network of decentralised stormwater management practices. The economic basis for this tool is assessed to be good; however the user should be careful of the values they use and to adjust them if needed, as well as being aware of the possibility of double counting. The natural science basis for this tool is assessed to be good.

See Annex 4.3 for a detailed assessment.

Where to find it:

http://water.epa.gov/infrastructure/greeninfrastructure/gi_costbenefits.cfm

QUESTION 1: Is the tool recommended for use in the UK?

Yes – with adjustment for transfer to the UK for which experts will need to be consulted.

The scientific basis is assessed to be good. The guide examines the steps necessary to calculate a variety of performance benefits gained by implementing GI strategies (such as reduced stormwater runoff or reduced atmospheric CO_2) and provides simplified examples that estimate the magnitude and value of these benefits where possible.

The economic basis is assessed to be good. The guide recommends using different methods for the valuation of benefits from green infrastructure, including market prices, value transfer, and hedonic pricing (the property price premium that green infrastructure can create). It helps the user to arrive at an annual monetary value for the benefits it covers.

Most of the calculations reported rely on local context and so could not be applied directly. Local information should be sought instead. The guide is clear about this. For example, the energy saving due to tree wind-blocking and shading reported is modeled on US building types. The UK estimates for some unit economic values such as energy costs (energy pool prices) and shadow cost of carbon (published by the Department for Energy and Climate Change) should be used.

QUESTION 2: Which green infrastructure features are covered by the tool?

- Green roofs
- Trees
- Rain gardens (bioretention and infiltration)

- Permeable pavements
- Water harvesting

QUESTION 3: Which ecosystem services are measured by the tool?

- Regulating services:
  - climate regulation,
  - water regulation,
  - air quality regulation (reduction in NO_2, SO_2, O_3, PM10 due to green roofs, trees and bio-infiltration).
- Cultural services: recreation and ecotourism

The tool also values:
- Energy conservation due to green roofs and trees.

QUESTION 4: In what context can the tool be used?

The tool can be used to value the environmental benefits of investments in new GI feature or improvements to existing ones. Where it is necessary to adapt the tool to the UK conditions (for both biophysical and economic parameters), expert scientific and/or economic advice should be sought.

3.4 Health Economic Assessment Tools (HEAT) for walking and cycling

The Health Economic Assessment Tools (HEAT) for walking and cycling are tools from the World Health Organisation Regional Office for Europe. They assess health benefits and are not specific to a certain type of green infrastructure feature. The benefit of these recreation activities is measured through reduced mortality. The tool is easy to use and comes with very good guidance.
See Annex 4.4 for a detailed assessment.

Where to find it:

http://www.heatwalkingcycling.org/

http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Transport-and-health/publications/2011/health-economic-assessment-tools-heat-for-walking-and-for-cycling.-methodology-and-user-guide

QUESTION 1: Is the tool recommended for use in the UK?

Yes.

The scientific basis of the tool is assessed to be good. It is based on review of epidemiological literature and the tool itself is peer reviewed and tested. The health impact relationship is applicable to the UK.

The economic basis of the tool is assessed to be good. Value of statistical life (VSL) is used as the measure of benefit of reduction in risk of mortality. A default value is given based on the standard European value, but this can be changed by the user. In the UK, VSL is estimated at around £1.6 million (Department for Transport, 2002). While this estimate is based on fatalities due to transport accidents, this is currently the only official estimate used across all policy areas.

Discounting is applied to get a net present value with the default rate of 5% but the user is allowed to select their own discount rate. For the official UK Treasury recommended discounting rates and procedure see Annex 3.3.

The guidance document also recommends the user carry out sensitivity analysis by applying different numbers to the tool to account for uncertainty.

The tool advises and allows users to think of additionality when inputting data into the tool (see Annex 1 for a discussion on additionality). The health benefits estimated will arise only for a change in habitual walking, and one-off activity will not generate the benefits estimated by the tool. Whether the green infrastructure change will lead to increased habitual exercise or one-off use needs to be considered when using the tool. It should also be noted that the tool covers mortality risk changes only, and the changes in the risk of non-fatal illnesses (morbidity) due to walking and cycling are not included.

The tool is applicable to use in the UK.

QUESTION 2: Which green infrastructure features are covered by the tool?

The tool focuses on health benefits which can be attributed to any green infrastructure feature that provides walking and/or cycling opportunities to the population.

QUESTION 3: Which ecosystem services are measured by the tool?

The tool covers the health benefits (mortality risk reduction only) of walking and/or cycling. This links to an aspect of cultural ecosystem services (recreation) within the NEA ecosystem services framework.

QUESTION 4: In what context can the tool be used?

To estimate the mortality risk reduction benefits of regular exercise (walking and/or cycling) opportunities provided – to add to other benefits when assessing a new green infrastructure feature or improvements to an existing one.

3.5 Helliwell

The Helliwell system is a methodology from the Arboriculture Association and is used to place a monetary value on the visual amenity provided by individual trees and/or woodland for court cases, insurance claims and public inquiries. The basic approach of the Helliwell system is to allocate points under a number of different factors of the individual tree or woodland, and combine these points to give an overall comparative score. This score is then multiplied by the same unit value (regardless of the type of tree or woodland) to arrive at a monetary value.

See Annex 4.5 for a detailed assessment.

Where to find it:

http://www.trees.org.uk/publications

QUESTION 1: Is the tool recommended for use in the UK?

The tool is not recommended for use in the UK. The original study on which the tree assessment is based is from a peer reviewed journal. However, the original reference article was published in 1967 and the scaling of relevant factors (tree size, life expectancy, suitability to setting, importance in landscape, presence of other trees and form) is based on expert opinion which is open to interpretation.

The economic basis of the unit value is not explained. Without such information, the tool is not recommended for economic valuation and cost benefit analysis.

The tool is tailored for UK use.

QUESTION 2: Which green infrastructure features are covered by the tool?

Individual trees and woodland

QUESTION 3: Which ecosystem services are measured by the tool?

Aesthetics (visual amenity).

QUESTION 4: In what context can the tool be used?

The tool has been used in court cases, public inquiries and insurance claims but it is not recommended for economic valuation.

The user may find the scoring process and factors taken into account useful for other purposes such as qualitative and quantitative descriptions of costs and benefits.

3.6 i-Tree Design

i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools are intended to help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the species, age and size of trees in the community and the ecosystem services that trees provide.

i-Tree Design is an application of the i-Tree suite that provides a platform for assessments of individual or multiple trees at the parcel level. This tool links to Google Maps and allows the user to see how tree selection, tree size, and placement around a home, affects energy use and other benefits.

See Annex 4.6 for a detailed assessment.

Where to find it:

http://www.itreetools.org/design.php

QUESTION 1: Is the tool recommended for use in the UK?

No. It is not possible to use the tool in the UK as it contains USA data and uses GoogleMaps^TM for the USA and Canada.

As it is a closed tool (calculations are not visible to the user), it has not been possible to assess the scientific and economic basis of the tool.

The tool uses US-based assumptions and values and is meant to be used in the US only due to US-specific climate zones.

QUESTION 2: Which green infrastructure features are covered by the tool?

Individual trees near private properties which can be identified on GoogleMaps^TM for the USA and Canada.

QUESTION 3: Which ecosystem services are measured by the tool?

- Regulating services:
    - Climate regulation: Carbon dioxide reduction
    - Water regulation: storm water capture
    - Air quality regulation: Air pollution
- Energy conservation due to tree shade

QUESTION 4: In what context can the tool be used?

To estimate the annual and over time value of the ecosystem services covered by the tool and provided by individual trees.

3.7 i-Tree Eco

i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools are intended to help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the species, age and size of trees in the community and the ecosystem services that trees provide.

i-Tree Eco is part of the i-Tree suite that provides a broad picture of the entire urban forest. It is designed to use field data from complete inventories or randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and values to communities.

See Annex 4.7 for a detailed assessment.
Where to find it:

http://www.itreetools.org/eco/index.php

QUESTION 1: Is the tool recommended for use in the UK?

Yes. The scientific basis of the tool is assessed to be good. It is best used with input from a skilled ecologist.

The tool was designed for the USA but can be adapted to the UK through changing the carbon and energy calculations. A suitable conversion of these has been produced by Rogers et al., 2012. General guidance for international users is also provided on the tool website[6].

QUESTION 2: Which green infrastructure features are covered by the tool?

From a single tree to any size tree population in urban settings.

QUESTION 3: Which ecosystem services are measured by the tool?

- Regulating services:
    - Climate regulation: Carbon storage and sequestration
    - Local climate control

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[6] http://www.itreetools.org/eco/resources/International%20Eco%20versions.pdf
http://www.itreetools.org/eco/resources/iTreeEcoUserInputManual0923.pdf

        ○   Water regulation: storm water management
        ○   Air quality regulation: air pollution,

- Cultural Services: public health

- Several biophysical outputs that contribute to the above services

The tool also generates the following biophysical outputs:

- Urban forest structure (e.g., species composition, number of trees, tree density, tree health, etc.), analysed by land-use type;
- Hourly amount of pollution removed by the urban forest, and associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns);
- Hourly urban forest volatile organic compound emissions and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year;
- Public health incidence reduction and economic benefit based on the effect of trees on air quality improvement;
- Total carbon stored and net carbon annually sequestered by the urban forest;
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants;
- Yearly tree canopy rainfall interception summarized by tree species or land use;
- Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration;
- Tree pollen allergenicity index, and
- Pests risk analyses based on host susceptibility, pest/disease range and tree structural value.

it is recommended that the user consult with ecologists and/or economists to assess the applicability of results to UK conditions. These estimates may not all be available depending on project configuration, data options and project country location.

QUESTION 4: In what context can the tool be used?

The assessment of the benefits of urban forestry from a single tree to any size project.

3.8 i-Tree Streets

i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools are intended to help

communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the species, age and size of trees in the community and the ecosystem services that trees provide.

i-Tree Streets is part of the i-Tree suite focuses on the benefits provided by street trees. It makes use of a sample or complete inventory to quantify and put a monetary value on the street trees' annual environmental and aesthetic benefits.

i-Tree Streets also describes urban forest structure and management needs to help managers plan for the future.

See Annex 4.8 for a detailed assessment.

Where to find it:

http://www.itreetools.org/streets/index.php

QUESTION 1: Is the tool recommended for use in the UK?

No. While the tool is based on peer reviewed sources, it is a closed tool which has not been possible to assess in detail through this study. The same applies to the economic basis of the tool.

The tool uses US-based assumptions and values and is meant to be used in the US only due to US-specific climate zones. The tool itself recommends international users use i-Tree Eco instead.

QUESTION 2: Which green infrastructure features are covered by the tool?

Street trees.

QUESTION 3: Which ecosystem services are measured by the tool?

- Climate regulation: Carbon dioxide reduction
- Water regulation: storm water reduction
- Cultural services (aesthetics as captured by increase in property values)
- Local climate control

QUESTION 4: In what context can the tool be used?

The tool web page states that the tool has been used by communities for the following purposes:

- To improve the return on investment by determining which trees maximise canopy cover and provide the benefits that are important to the community;

- To determine the management needs of street trees to foster and perpetuate a healthy municipal forest;
- To leverage investment from partners for carbon credits or energy conservation;
- To gain public support by demonstrating the value of trees to the quality of life in the community;
- To perform economic evaluations of tree performance using annual budget and expenditure data, and
- To assess costs of management to provide a platform for strategic planning.

3.9 InVEST: Integrated Valuation of Environmental Services and Tradeoffs

InVEST is a family of tools to map and value ecosystem goods and services provided by terrestrial, freshwater, and marine ecosystems. It can be used either with ArcGIS geographical information software[7] or as a standalone software package. *See Annex 4.9 for a detailed assessment*.

Where to find it:

http://www.naturalcapitalproject.org

QUESTION 1: Is the tool recommended for use in the UK?

Yes. The scientific basis of the tool is assessed to be good. It uses methods that are scientifically tested and data that are published in peer reviewed sources. It is modular in design and has specific packages for the terrestrial, freshwater and marine environment. There is a specific module for carbon sequestration, but the system does not specifically focus on green infrastructure.

The economic basis of the tool is assessed to be good. The calculations presented in the user guide are correct and values specific to the UK can be inputted to the model instead of using the default values (e.g. value of carbon, discount rate, cost of nutrient and sediment removal and market price of timber). It should be noted that the cost of nutrient removal is not strictly a measure of the benefit of water purification. It may be possible to use benefit estimates instead of the cost information.

The tool is not designed for a specific location and hence can be used anywhere so long as the necessary data are available for input into the models.

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[7]GIS software needs to be purchased – pricing depends on the buyer and purpose of use, ESRI should be conducted directly http://www.esri.com/

InVEST needs a lot of time and expertise to use the software and collect the necessary data, much more so than other tools assessed. It requires specialist input from ecologists and economists.

QUESTION 2: Which green infrastructure features are covered by the tool?

None specifically, but will generally cover GI features which cover an area (e.g. a park or woodland rather than a single tree, ponds).

QUESTION 3: Which ecosystem services are measured by the tool?

For terrestrial and freshwater habitats that correspond to green infrastructure features it assesses:

- Biodiversity (not valued in monetary terms);
- Regulating services: carbon storage and sequestration, water purification, sediment retention;
- Provisioning services: managed timber production, and
- Supporting services: crop pollination (not valued in monetary terms).

QUESTION 4: In what context can the tool be used?

INVEST has been used in a variety of contexts and with differing levels of data availability. It is best suited to answer spatial planning questions such as:

- Where would reforestation or protection achieve the greatest downstream water quality benefits?

- Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values?

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Economic Valuation

A1.1 Economic valuation tools

Economic valuation analyses individuals' preferences for ecosystem services. The UK Department for Environment, Food and Rural Affairs (Defra) defines ecosystem services as services provided by the environment that benefit people. These are generally divided into four categories (Defra, 2007; also shown in the figure below):

- Provisioning services – Physical resources provided by the environment such as food, water and wood;
- Regulating services – Benefits provided by ecosystem processes such as water purification, air quality maintenance and climate regulation;
- Cultural services – Non-material benefits from our interaction with the environment, such as recreation and education; and
- Supporting services – functions which are necessary for the production of other ecosystem services from which we benefit, such as soil formation and nutrient cycling.
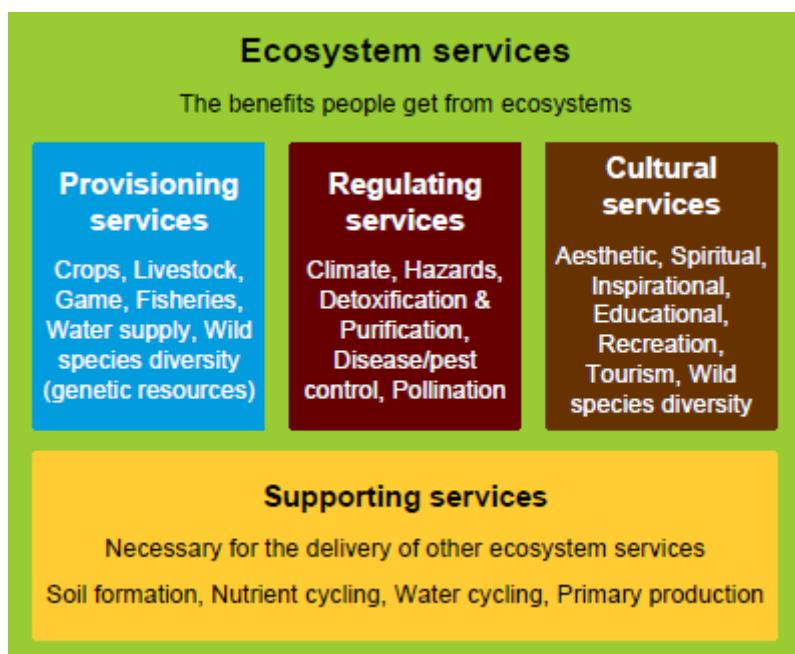
Individuals' preferences for some of these services are reflected in their behaviour such as taking recreational trips, purchasing organic produce and so on. For other services which individuals do not use directly, one can analyse other related behaviour data (e.g. people do not directly value hazard protection but spend more to avoid high flood risk in other ways) or ask their preferences through carefully worded and tested surveys. Regardless of what method is used, the output of economic valuation is preferences expressed in monetary terms: what individuals are willing to pay to secure an improvement or to avoid a loss in an

ecosystem and its services. Alternatively, it is possible to estimate what individuals are willing to accept as (monetary) compensation to tolerate a loss or to forgo an improvement. Individuals' preferences measured in these terms are the same as the 'economic value' individuals place on ecosystem services.

Economic value is not the same thing as economic impact. Economic impact is only concerned with the traded economy, i.e. money changing hands. Economic impact is normally used when the focus is on economic growth as measured by GDP or GVA[8]. In contrast economic value is concerned about welfare. Changes in welfare may be delivered by changes to the traded economy, such as the availability of new goods or price reductions. However, they can also be delivered by 'non-market' benefits such as improvement in local greenspace or air-quality.

Economic value evidence could be gathered through primary research. This requires three stages:

- *Qualitative evidence* such as expert judgment, anecdotal evidence or qualitative social research that demonstrates the benefits (welfare increases) provided by ecosystem services.

- *Quantitative evidence* such as changes in air quality, ambient temperature (reduction in heat island effect for example), noise levels, bird counts etc., numbers of visitors to a new park, number of businesses relocating to an area, number of people they employ etc.

- *Economic evidence* such as visitor spending, reduction in medical expenditure due to improved health, income from new businesses, individuals' willingness to pay or accept compensation for the changes in ecosystem services. Economic valuation methods are developed to collect and analyse the relevant data for this.

The cost of replacing a natural ecosystem service through investment (i.e. replacement cost approach) is strictly not a measure of economic value – as it does not measure benefits (welfare increase) but a type of cost. It is permissible to use only if there is a regulatory driver or consensus that replacement is required. In addition, few ecosystem services in few circumstances are in fact possible to replace in full.

Where primary research is not possible, 'value transfer' can be used, which is a process for selecting value evidence from the existing literature and adapting it to

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[8] The size of the economy is measured in the total value of goods and services purchased in a year. It is therefore equivalent to national income and is formally defined and measured using Gross Domestic Product (GDP) (or Gross Value Added – GVA). Economic growth can therefore be increased either through the increased consumption of resources by the economy, or increases in the quantity of machinery (capital) or labour, or increased efficiency in the production of goods and services. This increase is measured by economy-wide models that use market transaction data.

the characteristics of ecosystems and services of interest. In the UK, Defra has published official guidance on how to select and adjust the existing evidence (eftec, 2010).

There are two main strategies for valuing the benefits of green infrastructure regardless of which valuation data is used or whether values from the existing literature are selected:

- **Individual services** of an ecosystem (or green infrastructure feature) can be valued separately and the values can be added up. This is useful if services can be identified individually, and change differently (e.g. if a new woodland is planted for timber production with no other access, provisioning services would go up but cultural services could go down). As ecosystems produce a complex and inter-related set of services, separate analysis of each service needs to be undertaken carefully to avoid doublecounting or indeed underestimating the synergies between services.

- Identifying and quantifying **all the services** provided by an ecosystem and valuing them as a whole. This is useful when, say, a new green infrastructure asset is likely to provide all the services associated with it, or that an improvement in an existing asset will improve the quality of all the services it provides. This whole 'bundle' approach to valuing ecosystems would miss the nuances of different services provided at different levels but should suffice at generating ball park figures for initial planning stages.

A1.2 Be aware of common economic valuation caveats

Double-counting and displacement[9] are two common pitfalls in economic valuation and care should be taken to avoid or account for these problems.

Double-counting involves valuing benefits twice (or more) over in a single valuation. For example, if recreational benefits of a park are valued, it will most likely be double-counting if the 'landscape' is also valued. Users can use multiple tools to value different benefits of a green infrastructure feature but when doing so should be as clear as possible in explaining which services each tool values. Collaboration between environmental specialists who can explain ecosystem services and their multiple benefits, and economists who can value each is recommended. For an overview of ecosystem services and economic valuation, see the guidance issued by Defra (2007).

Displacement is the extent to which any increase in activity is not additional, but has simply moved from elsewhere. This affects the level of benefit that can be attributed to the green infrastructure project.   The tool user may need to make a judgement about how an individual's behaviour is likely to change as a result of the

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[9] Additionality is the opposite way of measuring displacement: any increase in economic activity is additional if it was created rather than moved from elsewhere.

green infrastructure project. If, for instance, 10% of users of the new park are likely to come from another park, the benefits associated with health/recreation in the new park should be scaled down accordingly.

A1.3 Be aware of the coverage of each tool

Users should be aware of the types of ecosystem services/benefits that their chosen tool(s) do and do not value. The user might be especially interested in a certain benefit provided by a green infrastructure feature, and therefore should be careful in choosing a tool that values this benefit. On the other hand, a user might not be aware of a benefit from a green infrastructure feature that may provide a relatively high value and may therefore choose to ignore this benefit, which could cause a large discrepancy between the calculated value and the true value of the green infrastructure feature. Therefore it is crucial to research and agree on the full list of benefits before choosing a tool (or with the help of different tools) before deciding on which ones to value.

Annex A1.   Methodology

A2.1 Identifying tools

There were two stages to identifying the tools to be assessed in this study: the first stage was to create a long list of tools and the second stage was a quick evaluation of the tools and a meeting with the project Steering Group to select which tools would be assessed based on the evaluation.

In the first stage an e-mail was sent out to the Green Infrastructure Partnership, Ecosystems Knowledge Network and the Valuing Nature Network e-mail groups to explain the study and request that members suggest tools or methods for assessment. Suggestions from members were compiled into a long list of tools (Annex A2).

In the second stage a quick scoping of the tools was carried out followed by a meeting with the project Steering Group for selection of the tools that will be assessed. Tools were selected for assessment based on the following criteria:

- The tool is a valuation tool and values or has the capacity to value green infrastructure as defined in this project – This criteria follows the scope of the project.
- Popularity/publicity – The more frequently a tool is used, the more the results of the tool are used in decision-making context. It is important to assess whether these popular tools are economically and scientifically robust.
- Applicability to the UK – Where it was possible to judge, tools applicable to the UK were prioritised.

The final list consisted of 11 tools for further investigation:

1. CAVAT (Capital Asset Value for Amenity Trees);
2. Helliwell;
3. i-Tree;
4. Green Infrastructure North West's Green Infrastructure Valuation Toolkit;
5. The Health Economic Assessment Tool;
6. Woodland Carbon Code;
7. InVEST: Integrated Valuation of Environmental Services and Tradeoffs;
8. Council of Tree and Landscape Appraisers;
9. Guide to valuing Green Infrastructure from the Centre for Neighbourhood Technology Chicago
10. LUCI, aka POLYSCAPE; and
11. MIMES – Multiscale Integrated Earth Systems Model.

Of these 11 tools, 4 of these tools were not assessed for the reasons stated below:

- Woodland Carbon Code – This is not a valuation tool;
- LUCI, aka POLYSCAPE – No access to this tool or to the methodology of this tool could be found;
- MIMES – Multiscale Integrated Earth Systems Model – No access to this tool or to the methodology of this tool could be found;
- Council of Tree and Landscape Appraisers – Detailed methodology for this tool could not be found.

The i-Tree tool was found to be a bundle of five tools, three of which fell under the above criteria (i-Tree eco, i-Tree Streets and i-Tree Design) and were assessed. i-Tree Vue was not assessed as it cannot be used outside of the US and i-Tree Canopy is not a valuation tool. i-Tree Design cannot be used outside the US and Canada either but it is a very easy online tool and may be interesting for UK users to try and hence is assessed.

A2.2 Reviewing the Tools

The review of the tools consists of twenty-two questions which are categorised into three categories: Overview; Content/Standards; and Outcomes. The questions with added descriptions if needed are listed here:

Overview
- What is the tool for? What does it assess and what features of GI does the tool relate to?
- What does the tool do and how does it do it? How does it define 'value'? Are there other similar tools?
- Where can you get the tool from?

Content/Standards

- What are the assumptions made by the tool for valuation and in the models used for quantification?
- Does the proposed tool meet Green Book national standards for economic evidence?
  - *See Section A3.3 for more detail on how this was assessed.*
- If not, does it relate to any other recognised national or international economic standards?
- Does it meet academic standards for natural science in the use of the supporting evidence to the economics?
  - *See Section A3.4 for more detail on how this was assessed.*
- Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?
  - *See Section A3.4 for more detail on how this was assessed.*
- What benefits or ecosystem services does the tool cover?
- In what context is it appropriate to use the tool, or elements of the tool? Is the tool tailored to the UK data or is it adaptable?
- Is the tool transparent or closed? – *Is it possible to see what calculations and assumptions are being used?*
- Does it require extra software? Is the tool proprietary (is a licence or fee required for the use of the tool)?
- Is the tool user-friendly and how easy to use is it? What level of assumed and actual expertise is needed to use the tool?
- How long does it take to use the tool?
  - *This was assessed in terms of magnitude – e.g. minutes, hours, days, weeks.*
- How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?
- What is the financial cost of using the tool in Pounds Sterling?
- Is the tool compatible with other tools?
  - *Can the tool be used in conjunction with other tools or can other tools be used to provide unit values for this tool?*

Outcomes

- Does it provide meaningful results?
  - *Does the tool provide results that can be used in any meaningful way, e.g. for cost-benefit analysis or for demonstrating value/comparisons with other values.*
- What sort of evidence can the tool produce? Can marginal changes be considered? Can future changes, such as climate change be considered?
- Can the tool be used to make assessments at a range of spatial scales and if so, what scales can it be used at (local, strategic, etc.)?
- What are the apparent strengths (with cautions)?
- What are the apparent weaknesses (with implications)?

A2.3 Does the proposed tool meet Green Book national standards for economic evidence?

The robustness of the tools was judged against the standards set out by economic theory and for scientific research. For the economic theory, *The Green Book: Appraisal and Evaluation in Central Government* (known as "The Green Book")[10] was used as the standard against which the tools were assessed..

"The Green Book is the guidance from HM Treasury for UK Central Government on economic appraisal and evaluation, and describes how the economic, financial, social and environmental assessments of a proposal should be combined. It sets out a framework for the appraisal of all policies, programmes and projects by setting out the key stages in the development of a proposal; moving from the rationale for intervention and setting of objectives for the intervention (Chapters 3 and 4) through to appraising options (Chapter 5), developing and implementing a solution (Chapter 6), and finally evaluation of the solution (Chapter 7). The Green Book also contains annexes which contain more detail on certain aspects of the development of a proposal, including valuing non-market impacts (Annex 2), risk and uncertainty (Annex 4), distributional impacts (Annex 5), and discount rates (Annex 6), which are all part of appraisal.

In the review table for the question "Does the proposed tool meet Green Book national standards for economic evidence?" we answered this by looking to Chapter 5, "Appraising Options" of The Green Book: Appraisal and Evaluation in Central Government, as this is the only chapter that focuses on appraisal, rather than other parts of the development of a proposal. References to Annexes 2, 4, 5 and 6 from Chapter 5 have also been included.

Chapter 5 outlined seven elements of appraisal:

1. Valuing the costs and benefits of options;

2. Adjustments to values of costs and benefits;

3. Discounting;

4. Adjust for differences in tax between options;

5. Adjusting for Bias and Risks;

6. Assessing uncertainty; and

7. Considering unvalued costs and benefits.

The following questions were used to assess whether a given tool follows the Green Book guidelines on valuation and appraisal:

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[10] http://www.hm-treasury.gov.uk/data_greenbook_index.htm

Financial costs

1) Are direct, indirect, attributable overheads, relevant opportunity costs and contingent liabilities included?

2) Are sunk costs, depreciation and capital charges excluded?

Valuing benefits

3) Do real or estimated market prices provide the first point of reference for the value of benefits, unless the market is distorted?

4) Where value transfer is used, are value transfer guidelines followed?

5) Where neither market prices nor value transfer are used, is revealed preference used, or where it is not possible, stated preference?

6) Does the tool take into account all benefits and collateral damage/costs to the UK?

Adjusting cost and benefit estimates

7) Are the distributional implications of the costs and benefits considered during appraisal?

8) Are relative price changes adjusted for?

9) If costs and/or benefits aggregated over time, is discounting used? If not, why not? If yes, are the rates different from the Green Book and why? If a very long period is concerned, does the tool use hyperbolic discounting?

   The Green Book recommended discount rates are as follows:

Period of years	0-30	31-75	76-125	126-200	201-300	301+
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

10) Are the tax differences between options relevant for the scope of the tool? If so, have they been adjusted?

11) Are there any adjustments embedded in the tool to deal with biases and risks?

12) How does the tool assess uncertainty? How does the tool report uncertainty (e.g. giving a central estimate with minimum and maximum values)?

Unvalued costs and benefits

13) Where costs and benefits cannot be valued, are they identified, weighted and scored?

A2.4 Does the proposed tool meet academic standards for natural science?

As there are no specific national standards available to inform this part of the evaluation – i.e. there are no specific criteria or published "standards" available to determine the format, data inputs, trialing and testing or reporting outputs of GI tools, it was agreed that the tools would be assessed against the "maturity" of science underpinning the tools development and the extent of peer review supporting this research.

The method developed was based on assessing the following components for each of the tools under review:

- Purpose – To define what the tool measures.
- Data - Inputs required, and the geographical scale and climate conditions the tool is intended for.
- Methodology - To assess how robust the tool is and its ease of use.
- Peer review - Did the tool specifically state it was peer reviewed? Or if not, is it based on peer reviewed research?
- Scientific assumptions (e.g.is the science behind a tool peer reviewed?) and is the tool's development based on any key scientific assumptions?
- Climate - What climate and landscape was the tool developed for (*e.g.* US or UK)
- Location - Has the tool been designed or adapted for use in England?
- Ease of use
- Outputs – To describe the relevance in relation to NEA and use in England.

In addition, a more general internet search was conducted to assess the underpinning literature for each tool, such as government publications, practitioner reports, case studies or other information from websites.

The required level of user expertise and access to data needed as input to operate each tool was evaluated from the manuals.

Where possible, consideration of tool reliability was taken into account by checking the methodology to see if the data was collected and analysed in a statistically robust manner. However, in many cases this was not possible to determine from the information available. In this case, an opinion was made of robustness based upon the complexity of the tool and the references to scientific literature and research identified in the relevant manual. Further consideration of the robustness of each tool was based upon whether or not case studies were available, or whether they were widely used by experts in the relevant field.

Tool application
Each tool was looked at to see what its purpose was and what it actually assessed. The main focus of the tools included for review was on trees, although some of the tools also included the capacity to assess a much wider range of features. For

trees, the tools were assessed on how they evaluated the structure and function of 'urban forests'. To compare how well this could be achieved by each tool, the manual was used to check whether the tool assessed species composition, tree density, tree health and age, *e.g.* diameter, breadth and height, biomass and benefits for ecosystem services.

For other green infrastructure components, the tools were evaluated to see if they could be applied in England. Very few tools included features for soil formation, nutrient cycling or water cycling (*e.g.* supporting services) or other features such as pollination, genetic diversity, spiritual and well-being etc. Those tools that include a wider range of green infrastructure features were based upon land use maps / data and produced outputs at a relatively coarse scale. For example, InVEST can be applied at a catchment scale, or in some cases with more data at a local scale; POLYSCAPE (not assessed) is designed to work at the small (10 km^2) to medium (1000 km^2) landscape context.

Data
The type and robustness of the data required for each tool was determined from referring to the manuals to understand the method of data collection, and how the data was used in the tool (*e.g.* did it provide a qualitative or quantitative assessment, were samples drawn randomly or was the tool based upon 'expert' subjective judgment).

Peer review
Based upon the information available, it was identified whether or not the tool specifically stated if it was peer reviewed. Most of the tools did not make any explicit reference to peer review, even though references to relevant peer reviewed scientific studies used in developing the tool were often provided. In the majority of cases, the type of organisation responsible for developing the tool (*e.g.* academic, state or company) and the extent of evidence used in tool development (*e.g.* accepted studies, peer reviewed papers) were used as a surrogate for peer review of the tool itself. The review also considered how widely the tool was used by practitioners and the tool's acceptance by the professional community.

Assessment of the science behind each tool demonstrated that although in many cases the tools were developed using the best information currently available, due to the inherent complexity of ecosystems the outputs are often generalisations and they may not always be robust.

For example, i-Tree has been peer reviewed and developed by the US Forestry Department. Although originally designed for use in the US it has been successfully applied to the valuation of green infrastructure in Canada and Australia. It has also been used in the UK (Torbay) by adjusting certain underlying assumptions to fit the conditions in the UK (see below). In addition, the UK carbon calculation can be derived using a suitable conversion of the energy values produced for the dominant species in England *e.g.* West and Matthews (2012).

Scientific assumptions

A primary concern was to consider how well each tool was supported by relevant science, peer review and its application under conditions in England. This was achieved by consulting the manuals and documentation provided for each tool and conducting an internet search using keywords and references for the original documentation. It should be noted however that it was not possible within the scope of this project to assess all the scientific literature in rigorous detail.

Complications due to scientific assumptions include tree growth and carbon sequestration. Tools such as i-Tree have been developed using values for the US, which will not be the same for UK conditions due to factors such as genetic stock, acclimatisation, regional climate conditions; and differences in the assumptions of energy use, which reflect the greater use of air conditioning units in the US. This tool was applied in Torbay using local temperature data to account for the climate and the species of tree existing in the area were inputted. While there may be other factors, these are assumed to include the key contextual factors.

The scientific assumptions applied in many of the tools may be refined as new data becomes available and the evidence base expands through case studies and practical experience in using the tools.

Climate and landscape

Climate conditions and landscape are important for understanding the context for which each tool was developed (*e.g.* the difference between US or UK biogeography, climax communities and species adaptation). This was primarily assessed from tool web pages and information on the internet, to determine the type of environmental conditions the tool had been designed to operate in. It is important that the tool is relevant for species present in England, and environmental conditions in England because genetic resources will be specific to the region.

In the assessment of ecosystem services and the functions provided by green infrastructure, scale is an important factor. Adaptation to climate change and the provision of ecosystem services is more likely to be achieved if the green infrastructure is not fragmented. Many of the tools evaluated were modular in design (*e.g.* InVEST) and they could be used to accommodate the range of scales relevant to ecosystem services, *e.g.* from the landscape scale to the individual tree. Tools such as InVEST and Polyscape include more sophisticated models and software libraries, and for the most detailed outputs they need high resolution GIS data layers, together with climate change predictions; and the results should acknowledge the uncertainty involved in modelling climate change.

Applicability to England

With each tool, a check was made using the manual and available on-line information to see if the tool had been designed or adapted for use in England. This was considered a basic requirement as ecosystems adapt to specific

biogeographical conditions. Therefore, in evaluating the tools both the original countries of intended use (relating to climate type, land use, species) and direct applicability to their use in England were considered.

Ease of use
The ease of use depends upon the sophistication of the tool, quantity and type of data required for use, complexity of the calculations and software required. Some tools such as the Helliwell system only require basic measurements but rely on expert judgement. Other tools such as InVEST are designed as a tool for quantifying, mapping, and valuing specific benefits provided by terrestrial, freshwater and marine systems.

Tools such as HEAT focus specifically on the health benefits related to infrastructure and urban planning and can be applied as a desk based study, if the required data is available (*e.g.* travel/route surveys, traffics counts). Although HEAT only relates to the health benefits of cycling and walking, it could be used in conjunction with other tools as required and form part of a package for assessing green infrastructure.

Outputs
The tools were looked at to assess how their outputs corresponded to the structure of the NEA and whether they could be used to assess the relevant ecosystem services. The list of broad criteria that was used as a reference point was taken from the Millennium Ecosystem Assessment (MA) framework (Defra, 2007), and includes:

Supporting services - the services that are necessary for the production of all other ecosystem services
Provisioning services - the products obtained from ecosystems
Regulating services - the benefits obtained from the regulation of ecosystem processes
Cultural services - non-material benefits such as health and wellbeing

For the tree tools being evaluated, a check was made to determine if they collected and applied the data in a way that was relevant to the ecosystem services identified above. The tools should give reliable outputs on the spatial extent and distribution of trees, condition and health of trees and their setting.

This was a high level comparison as many of the tools were relatively specific in their focus (*e.g.* on street trees or human health), whilst some were broad and included GIS modules for carbon management and climate change. There were also additional factors considered in the tool comparison such as whether they were developed for use in England or if not, would they be easy to adapt for use in England.

A2.5 Gaps in Valuation Tools

Table 2 shows that certain intersections between GI features and ecosystem services are not covered by the tools assessed:

- Provisioning service: Food; Fresh water and bio-chemicals
- Regulating Services: Disease regulation
- Cultural Services: Spiritual and religious services, sense of place and cultural heritage

The following green infrastructure features were not covered:

- Ponds;
- Grass verges; and
- Hedges

Of the ecosystem services not covered in the assessed tools: food, freshwater, and biochemical are classified as provisioning services. Their values can be estimated using market prices or market price equivalents (e.g. if the food is produced for the community rather than sold). Therefore, their omission from the tools does not constitute a major gap in the analysis.

The paucity of coverage for cultural services is a more important gap given that potential recreational uses of green infrastructure tend to be a strong benefit in favour of such investments. However, there is a large economic value literature on recreation in the UK and this can be consulted using Defra's value transfer guidelines.

Annex A2. Initial Long List of Green Infrastructure Valuation Tools

The table below summarises some key information about each of the tools in the long list of tools the assessment looked at: name, URL and application. The list was compiled from responses to a call for evidence (sent to various networks as detailed in the methodology Annex A3). An initial ranking of the tools is also shown with further information on the selection process reported in Annex A3.

	Name	URL	Applications
Included	CAVAT (Capital Asset Value for Amenity Trees) valuation	http://www.ltoa.org.uk/resources/cavat; http://www.cavattreevalue.com/	"CAVAT provides a method for managing trees as public assets rather than liabilities. It is designed not only to be a strategic tool and aid to decision-making in relation to the tree stock as a whole, but also to be applicable to individual cases, where the value of a single tree needs to be expressed in monetary terms." (http://www.ltoa.org.uk/resources/cavat). It has been used by tree officers in Islington to secure compensation for firms who have damaged their trees.
Included	i-Tree	http://www.itreetools.org/	A software suite from the USDA Forest service, providing urban and community forestry analysis and benefits assessment tools. It quantifies the environmental services that trees provide, and the structure of the urban forest. Examples of applications include determining the health of an urban forest, as well as to assess the amenity, air pollution, carbon storage and sequestration benefits of trees (http://www.itreetools.org/applications.php). Those versions of the i-Tree suite that use economic valuation and can potentially be applicable to the UK are included in the assessment.
Included	Green Infrastructure Valuation Toolkit	http://www.greeninfrastructurenw.co.uk/html/index.php?page=projects&GreenInfrastructureValuationToolkit=true	This is a valuation framework for assessing the potential economic and wider returns from investment in green infrastructure and environmental improvements. It has been used, for example, for the Royal Commission on Environmental Pollution, which focused on the ecosystem services provided by green infrastructure, and multifunctional green space.
Included	Helliwell	http://www.trees.org.uk/faqs/Helliwell-system-and-how-much-is-a-point	The basic approach of the Helliwell system is to allocate scores under a number of different factors such as tree size, life expectancy, suitability to setting etc. These scores are then combined to give an overall comparative score for a tree or woodland. As a further step, it is then possible to attach a value to this score by use of a monetary conversion factor. It has been used extensively in insurance claims, public inquiries to place visual amenity values on individual trees, court cases, and in court to place visual amenity values on woodland.

	Name	URL	Applications
Included	Health Economic Assessment Tool (HEAT)	http://www.heatwalkingcycling.org/	WHO/Europe's Health Economic Assessment Tool (HEAT) for walking and cycling is an online resource to estimate the economic savings resulting from reductions in mortality as a consequence of regular cycling and/or walking. HEAT can be used by walking and cycling campaigners, researchers and policymakers alike. It enables users to estimate the value to health of new infrastructure, policies or programmes. These can be used to make the case for new investment, or as inputs to comprehensive health impact assessments
Included	InVEST	http://www.naturalcapitalproject.org/	InVEST has been used to inform spatial planning and zoning, payments for ecosystem services, permitting and mitigation, multi-stakeholder planning, and climate adaptation around the world.
Included	Guide to valuing Green Infrastructure from the Centre for Neighbourhood Technology Chicago	http://www.cnt.org/news/2011/01/21/new-guide-helps-municipalities-monetize-the-value-of-green-infrastructure/	"'The Value of Green Infrastructure' brings together current research on green infrastructure performance and presents methods for calculating related benefits in water management, energy, air quality, climate, and community livability"
Not included	LUCI, aka POLYSCAPE: Multiple criteria GIS toolbox for negotiating landscape scale ecosystem service provision (renamed LUCI)	http://www.slideshare.net/CPWF/polyscape-multiple-criteria-gis-toolbox-for-negotiating-landscape-scale-ecosystem-service-provision#btnPrevious	Designed as a negotiation tool; has been applied at farm-scale up to landscape/catchment scales. It has been applied in case studies in England, New Zealand, Wales, Ghana, and Greece. No access to this tool or to the methodology of this tool could be found.
Not included	Woodland Carbon Code	http://www.forestry.gov.uk/forestry/INFD-88G2CA	Aims to offer clarity and transparency to customers about the carbon savings their contributions (i.e. tree planting) may realistically achieve. It does not have an economic valuation component.
Not included	CTLA (Council of Tree and Landscape Appraisers)	http://www.barrelltreecare.co.uk/services/tree-valuation.php	A tree valuation method developed over the past 50 years in the U.S., used to value single trees or large groups of woodlands. This tool has been used in legal and insurance cases, such as an insurance case for Disneyland Paris (after facing tree loss after a wind-storm), as well as a similar case for a golf and spa complex in Mallorca (again, a wind-storm damaged trees on the complex). Detailed methodology for this tool could not be found.
Not included	MIMES - Multiscale Intregrated Earth Systems Model	http://stage.pdx.edu/sites/stage.pdx.edu.sustainability/files/Boumans_Costanza_GWSP%20Chapter_2007.pdf	"The MIMES project aims to integrate participatory model building, data collection and valuation, to advance the study of ecosystem services for use in integrated assessments" (http://stage.pdx.edu/sites/stage.pdx.edu.sustainability/files/Boumans_Costanza_GWSP%20Chapter_2007.pdf). No access to this tool or to the methodology of this tool could be found.

	Name	URL	Applications
Not included	ARIES	http://www.ariesonline.org/	"ARIES can accommodate a range of different user needs, including scenarios, spatial assessment and economic valuation of ecosystem services, optimization of payments for ecosystem services schemes, and spatial policy planning." (http://www.ariesonline.org/about/applications.html). The use of the model requires contacting the ARIES team so while the model is said to answer some GI relevant questions, users cannot use the model on their own. There is very limited information available on the tool website. Therefore, it is not included in the assessment.
Not included	CALM (Carbon Accounting for Land Managers)	http://www.calm.cla.org.uk/	Developed by CLA (country land & business association) to allow farmers to calculate the carbon footprint of their business; it can be used to measure methane and nitrous oxide from a land-management business, carbon dioxide, and carbon stored in trees and soil. It does not have an economic valuation component.
Not included	COSTnz	http://www.costnz.co.nz/	COSTnz has been used to value the cost of stormwater treatment in New Zealand. "COSTnz is a simple, easy to use computer model which allows users to compare the relative life-time costs of various stormwater management devices. COSTnz was developed as part of a toolbox to help consultants, developers and decision-makers assess the relative performance and cost of different stormwater devices" (http://www.costnz.co.nz/About.aspx). The tool does not value the benefits of ecosystem services and hence not included in the assessment.
Not included	Water by Design	http://waterbydesign.com.au/	Has a large range of tools for designing, implementing and maintaining WSUD (water sensitive urban design) infrastructure. Their tools have been used, for example, to investigate the feasibility of treating stormwater for direct potable reuse. It does not have an economic valuation component.
Not included	music (Model for Urban Stormwater Improvement Conceptualisation)	http://www.ewater.com.au/products/ewater-toolkit/urban-tools/music/	A quality modelling tool used for the sizing of treatment systems, including bioretention systems/rain gardens, wetlands, swales, infiltration systems, and media filtration systems. It was created to help organisations plan and design, at a conceptual level, appropriate urban stormwater management systems for their catchments. It does not have an economic valuation component.

Annex A3. Detailed reviews of the valuation tools assessed

A4.1 Capital Asset Value for Amenity Trees (CAVAT)

<table>
<tr><td rowspan="6">Overview</td><td>What is the tool for?</td><td>CAVAT provides a method for managing trees as public assets. It is designed to be a strategic tool to aid in decision-making in relation to the tree stock as a whole, but also to be applicable to individual cases, where the cost of planting a tree is required. It is intended to be used by public authorities such as councils for publicly owned trees.</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>It assesses the cost of planting and maintaining a tree, adjusted to take account of functionality, life expectancy and social amenity value based on population density.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>Calculates the area of a cross section of the tree trunk at chest height and applying a unit value per square centimetre from the average installed cost of a 'basket' of commonly chosen street trees, then adjusts the value by multiplying it with a percentage prescribed by the methodology, for each of the factors listed above, based on the quantitative or qualitative value of these factors.</td></tr>
<tr><td>How does it define 'value'?</td><td>The tool defines the value as the financial cost of replacing a tree. This cost is different to the economic value of the ecosystem services provided by a tree, according to the definition of value as the increase in human welfare due to the benefits provided by these services.

The cost of a single tree is not a good indicator of the unit cost if many trees are planted. There will be economies of scale in the latter case, reducing the unit cost.</td></tr>
<tr><td>Are there other similar tools?</td><td>The CTLA (Council of Tree and Landscape Appraisers) method is a similar tool used in the US.

The Heliwell Method and i-Tree eco, street and design also attempt to value single trees, but using different methods.</td></tr>
<tr><td>Where can you get the tool from?</td><td>Contact the author of the CAVAT methodology for availability of training opportunities, and to access the tool: http://www.cavattreevalue.com/contact-the-author.html

Some of the CAVAT documents are available here: http://www.ltoa.org.uk/component/docman/cat_view/98-capital-asset-value-for-amenity-trees-cavat)

CAVAT documents and instructions are freely available, however, to calculate a valuation with confidence and accuracy a user needs a level of understanding of trees and of how they function that would normally be exclusive to a professional arboriculturist.</td></tr>
<tr><td rowspan="5">Content/ Standards</td><td>What are the assumptions made by the tool for valuation?</td><td>The tool uses a basket of commonly chosen street trees (planted in London) for the unit cost, rather than individual tree species.

The tool uses a multiplication factor based on population density, based on ONS data on population.</td></tr>
<tr><td>What are the assumptions made by the tool for natural science?</td><td>Assessment depends upon measurements of tree trunk. Expert judgment used in visual 'quality' etc. Data needed on tree stock, age, condition, visibility, Local Authority data (population density)</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>**No.**

The overall focus with CAVAT is on the capital value of trees. The tool also includes a broad assessment of location, amenity value, social value and appropriateness based upon expert judgment. CAVAT does not provide a specific assessment of biodiversity and social or health benefits.</td></tr>
<tr><td>What benefits or ecosystem services does the tool cover?</td><td>The tool does not value ecosystem services.</td></tr>
<tr><td>Does the proposed tool meet Green Book national standards for economic evidence?</td><td>**No for economic valuation. But internally consistent for its purpose.**

The tool is designed to estimate the cost of replacing a tree. This is useful in some contexts (in which the tool has already been used) but it is not a measure of change in human welfare, in other words, economic value of ecosystem services. Therefore, it does not meet Green Book standards for estimating the economic value.</td></tr>
</table>

	If not does it relate to any other recognised national or international economic standards?	**Assessed for its own merits, the tool follows national standards for economic evidence.**	
		It does attempt to take into account benefits to surrounding populations, applying a percentage factor according to the density of population surrounding it, implying a value including some sort of public benefit, however it is not made explicit what this benefit is, and this value is calculated as a multiple of the replacement cost.	
		The tool does use national inflation (RPIX) for valuation and depreciates the value of the tree by up to 90% to account for safe life expectancy.	
	Does it meet academic standards for natural science in the use of the supporting evidence to the economics?	**No.**	
		There is no evidence on what scientific standard has been followed. Assessment depends upon measurements of tree stem. Expert judgment used in visual 'quality' etc. Input data is taken from published studies.	
	In what context is it appropriate to use the tool, or elements of the tool?	**This tool does NOT give a value based on the ecosystem approach.**	
		It is appropriate to use the tool if the user wishes to find the financial value of a tree or trees, or the cost of a tree or trees if damage is incurred and compensation is being sought.	
	Is the tool tailored to the UK data or is it adaptable?	**Yes.**	
		The tool is tailored to be used in the UK and Ireland.	
Implementation	**Is the tool transparent or closed?**	**The tool is open.**	
		The CAVAT calculator that is available online (http://www.ltoa.org.uk/component/docman/cat_view/98-capital-asset-value-for-amenity-trees-cavat) does not allow the user to see the background functions, however, the guidance document runs the user through the process of how the value is reached, based on the user's inputs.	
	Does it require extra software?	The tool runs on Microsoft Excel.	
	Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No. The calculator is in the public domain.**	
		There is no fee for using the tool, however if you are interested in taking part in any training courses, you must contact the author of the methodology.	
	Is the tool user-friendly and how easy to use is it?	**Yes.**	
		The tool is very user-friendly, involving the input of values into Microsoft Excel and using downloadable tables to look up prescribed percentages based on the functionality, life expectancy and the geographical area the tree is located.	
	What level of assumed and actual expertise is needed to use the tool?	In order to use CAVAT, the user needs a certain level of understanding of trees and how they function at the level of a professional arboriculturist. "Most particularly a user needs to be aware of the normal form and growth patterns of difference species of trees, predict their life expectancy and be able to judge whether a particular tree is functioning normally or not."	
		There are training opportunities available to people who would like to use CAVAT (http://www.cavattreevalue.com/uses-of-cavat.html).	
	How long does it take to use the tool?	It should take **no longer than 1 hour** to use this tool, if the user has the appropriate information (tree stem diameter, population density in local area, health of the tree, any amenity factors to take into account).	
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	The cost of time would fall on a specialist with knowledge of tree growth patterns, life expectancy and health of the tree.	
	What is the financial cost of using the tool in GBP?	There is no financial cost for using this tool.	
	Is the tool compatible with other tools?	**The cost of replacing a tree cannot be added to the benefits of ecosystem services provided by the tree.** Caution is necessary if this tool is used in conjunction with another. CAVAT may be used to provide the Structural Value of trees in i-Tree.	

Outcomes	**Does it provide meaningful results?**	**Yes, for the financial cost of a single tree but No for ecosystem service valuation or the cost of more than a single tree.**
	What sort of evidence can the tool produce?	The tool estimates the financial cost of a tree that has been used in court cases. This can include the basic value, CTI (Community Tree Index) value, functional value, adjusted value, and value considering all these factors.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	It is not total economic value. It calculates the cost of replacing a single tree. Marginal changes are not considered.
	Can future changes, such as climate change be considered?	**No.** Future changes are not considered.
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	**Yes** CAVAT can determine the value of a single tree, or a number of trees.
	What are the apparent strengths (with cautions)?	CAVAT been used (successfully) for compensation for damaged trees; and can be used in insurance cases.
	What are the apparent weaknesses (with implications)?	CAVAT uses the replacement cost method, which does not take ecosystem services into account. It requires specialist knowledge, preferably from an arborist.

A4.2 Green Infrastructure Valuation Toolkit (GIVT)

<table>
<tr><td rowspan="7">Overview</td><td>What is the tool for?</td><td>The Green Infrastructure Valuation Toolkit is a framework to help demonstrate the value of green infrastructure projects.</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>Green infrastructure features the toolkit relates to include trees, green roofs and urban green space.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>The tool aims to help users to estimate 11 benefit categories associated with green infrastructure features: (1) Climate change adaptation and mitigation; (2) Water and flood management; (3) Place and communities; (4) Health and wellbeing; (5) Land and property values; (6) Investment; (7) Labour productivity; (8) Tourism; (9) Recreation and leisure; (10) Biodiversity and (11) Land management.

This is a mixed list including ecosystem services (1, 2, 3, 4, 8, 9, and 10 – though it is not clear if biodiversity provides services or is a service itself) and the contribution of green infrastructure to local economic growth (5, 6, 7, 11). These measure different types of values for the same benefits and cannot be added.

While the guide says further research is needed to quantify some of the benefits, these benefits appear in the Excel calculator. Some of the calculations are based on simplifying assumptions about factors that influence people's use of green infrastructure and values.These assumptions are not always substantiated with evidence, use of out of date evidence or evidence that covers more than one ecosystem service leading to double counting.</td></tr>
<tr><td>How does it define 'value'?</td><td>The toolkit presents the total economic value typology but some of the benefits included are local economic impact. Economic impact is only about the traded economy – property values, employment, tourism spending etc. Economic value is about economic welfare which goes beyond the traded economy. Cost Benefit analysis requires welfare measures. (see Annex 1).</td></tr>
<tr><td>Are there other similar tools?</td><td>Yes, somewhat.

The Guide to Valuing Green Infrastructure from the Centre for Neighbourhood Technology Chicago (CNT) has a similar purpose but instead of providing a calculator (and the associated problems with having to provide unit value estimates and other factors) provides the equations that should be used and encourages the user to find the relevant data.</td></tr>
<tr><td>Where can you get the tool from?</td><td>The toolkit can be downloaded from the Green Infrastructure NorthWest website
http://www.greeninfrastructurenw.co.uk/html/index.php?page=projects&GreenInfrastructureValuationToolkit=true</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="4">Content/ Standards Implementation</td><td>What are the assumptions made by the tool for valuation?</td><td>There are multiple unit values used in this tool which are referenced within the tool and toolkit user guide.

Most values are based on literature and unit values given for climate change adaptation and mitigation, water management and flood alleviation, and health and wellbeing do not need to be adjusted.

However the user should be careful with the unit values given for land and property values, tourism impacts, recreation and leisure, biodiversity and land management as these should be adjusted for socio-economic and geographic context.</td></tr>
<tr><td>What are the assumptions made by the tool for natural science?</td><td>The tool moves straight to valuation stage using monetary values for ecosystem services expressed as £ per hectare or other measure of the green infrastructure feature itself.</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>No.

While some of the 11 benefits listed above seem to match the UKNEA categorisation, the benefit definitions usually do not match. Other benefits included in the tool are due to the economic activity green infrastructure allows (e.g. investment) rather than the ecosystem services provided per se.</td></tr>
</table>

What benefits or ecosystem services does the tool cover?	(1) Climate change adaptation and mitigation; (2) Water and flood management; (3) Place and communities; (4) Health and wellbeing; (5) Land and property values; (6) Investment; (7) Labour productivity; (8) Tourism; (9) Recreation and leisure; (10) Biodiversity and (11) Land management.	
Does the proposed tool meet Green Book national standards for economic evidence?	**No.** The tool uses different concepts (economic value, economic impact) and different ways of measuring very similar impacts (health and wellbeing and labour productivity, and recreation and tourism) which has high risk of leading to doublecounting. Some of the value estimates used are not referenced correctly (e.g. referring to the environmental value reference index (www.evri.ca) which is a large database, or referring to 'judgment based on literature'). Some value estimates are out of date or used out of context. The local economic impact calculations do not take account of additionality (e.g. increase in tourism is not a net benefit to the national economy if the tourists replace a visit to another location in the UK with a visit to the local economy). The toolkit does not provide guidance on dealing with uncertainties, although this is explicitly stated. Unvalued costs and benefits are identified and quantified or qualified. Discounting is used, using 3.5% for 60 years. 3.5% is the Green Book recommended rate for the first 30 years, but the rate in the Green Book decreases after 30 years. The tool does not use this decreasing rate of discounting and does not explain why it is not used.	
If not does it relate to any other recognised national or international economic standards?	The user guide recommends the user to refer to the Defra value transfer guidelines (eftec, 2010), and users are able to change the default values should they wish.	
Does it meet academic standards for natural science in the use of the supporting evidence to the economics?	For most of the benefit categories, the tool does not provide any data on quantifying the benefits, but goes straight to economic benefits using proxies for benefits such as the area of green infrastructure feature. For other benefits, some references and default values are provided but the user would need to do the research to determine the type and quantity of the benefit.	
In what context is it appropriate to use the tool, or elements of the tool?	The tool is a mix of benefits, value evidence and assumptions. While the format of the calculator is easy to use, it should not be used without expert economics input to determine robust unit values and disentangle different types of value to avoid doublecounting.	
Is the tool tailored to the UK data or is it adaptable?	**Yes.** The tool is tailored to and designed through a series of workshops in the UK.	
Is the tool transparent or closed?	The tool is transparent - the toolkit guides the user through the valuation process, so the user is entirely aware of how the value has been calculated. The spreadsheet tool is transparent and it is clear how calculations are being made and where the assumptions for unit values come from.	
Does it require extra software?	The calculator runs on Microsoft Excel.	
Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No.** The calculator is in the public domain and there is no fee required for the use of the tool.	
Is the tool user-friendly and how easy to use is it?	**Yes.** Those familiar with Excel would find this calculator easy to use: input data is generally about the details of the project being assessed and, if possible, unit value estimates can also be changed. The real difficulty is in ensuring the default values are updated to correct values and deciding which benefit can be used for which type of analysis.	

	What level of assumed and actual expertise is needed to use the tool?	**An economist must be consulted** to clarify which benefits can be included in which economic analysis (cost benefit analysis versus local economic impact analysis), to judge if the default values in the Excel calculator are robust estimates, how to change the default values and to judge where doublecounting is possible.	
	How long does it take to use the tool?	The tool requires data gathering, which will take some time. How much time it takes depends on which tools the user wishes to use, how accurate the user wishes to be (e.g. values in the toolkit can be changed to suit the context of the particular project) and the specific project the user is carrying out.	
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	Most of the time will need to be spent by economists to address the issues listed above. It may be more efficient to refer to the user guide but set up a new spreadsheet for a project rather than use the calculator. Input from experts specialising in urban planning and environmental sciences may also be needed.	
	What is the financial cost of using the tool in GBP?	There is no financial cost for using this tool.	
	Is the tool compatible with other tools?	**Yes, possibly.** The tool can be used with other tools which may value benefits not accounted for within this tool, however the user should be wary of double counting which is already a problem for the benefits covered within the tool itself.	
Outcomes	**Does it provide meaningful results?**	**Possibly.** The tool provides monetary, quantitative and qualitative data for the benefits it covers. Benefits need to be further clarified to judge their suitability for the purpose of the assessment. There are several problems with default values recommended for each benefit category. However, it does not advise on accounting for counterfactuals, and therefore values are unlikely to be useable for cost-benefit analysis, unless an economist has assessed the counterfactual/additionality.	
	What sort of evidence can the tool produce?	The tool produces monetary, quantitative and qualitative values, however does state that these are broad assessments.	
	Is it total economic value?	**No.** Elements of total economic value are discussed and values of these are provided for different benefit categories. These are mostly use values. There are also economic impact estimates. However, it is not clear how to aggregate these values and distinguish welfare measures from economic impact measures.	
	Can marginal changes be considered?	Annual and net present values are calculated. Marginal changes can be considered if relevant quantitative and monetary estimates can be inputted.	
	Can future changes, such as climate change be considered?	**No.** Future changes cannot be factored in.	
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	**Not without input from an economist.** Without expert economics input to distinguish different values and avoid doublecounting, the tool should not be used at any scale.	
	What are the apparent strengths (with cautions)?	A long list of benefits is presented.	
	What are the apparent weaknesses (with implications)?	The evidence on quantitative and economic inputs to the Excel calculator is not sufficiently substantiated with evidence from the literature. Expert judgement is relied on more than it should be. The tool does not take into account additionality and is also subject to double counting if different benefits are aggregated. This means the calculated value could be a lot higher than the actual value of the green infrastructure and the user should be aware of this. This is stated in the toolkit.	

A4.3 Guide to Valuing Green Infrastructure by the Centre for Neighbourhood Technology (CNT)

<table>
<tr><td rowspan="6">Overview</td><td>What is the tool for?</td><td>This is a guide to assessing the economic merits of green infrastructure, to help communities decide where, when and to what extent green infrastructure should become part of future planning, development and redevelopment.</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>The tool defines green infrastructure as a network of decentralised stormwater management practices, and includes green roofs, trees and rain gardens.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>This tool provides guidance on how to calculate (i.e. actual equations) the quantity of benefits provided by a selection of ecosystem services and also provides some unit values that can be used in these calculations. Unit values are from the US and the user in the UK needs to use UK estimates.</td></tr>
<tr><td>How does it define 'value'?</td><td>The tool defines value as economic benefit derived from ecosystem services.</td></tr>
<tr><td>Are there other similar tools?</td><td>It is similar to the Green Infrastructure Valuation Toolkit from Green Infrastructure North West.</td></tr>
<tr><td>Where can you get the tool from?</td><td>The guide can be downloaded from the EPA website at http://water.epa.gov/infrastructure/greeninfrastructure/gi_costbenefits.cfm</td></tr>
<tr><td rowspan="5">Content/ Standards Implementation</td><td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td><td>The guide contains calculations and examples and lets the user to enter the necessary data. Therefore, the guide itself does not make any assumptions – except for using some USA specific unit estimates, which will need to be replaced with UK estimates for use here (e.g. DECC social cost of carbon, UK energy pool prices, building composition etc.) – **you should consider consulting an economist.**</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>The guide uses different terms but these essentially overlap with the UKNEA structure, if not cover all ecosystem services covered in the UKNEA.</td></tr>
<tr><td>What benefits or ecosystem services does the tool cover?</td><td>Regulating services: climate regulation, water regulation, air quality
Cultural services: recreation and ecotourism
Air pollution reduction (NO_2, SO_2, O_3, PM10) due to green roofs, trees and bio-infiltration.</td></tr>
<tr><td>Does the proposed tool meet Green Book national standards for economic evidence?</td><td>**Mostly yes.**

The guide recommends using different methods for valuation, including market prices, value transfer, and hedonic pricing. The tool only provides an annual benefit, so discounting rules need to be applied if aggregating these over a time period. The tool acknowledges that double counting may occur, and advises users to be wary of this. Benefits that are not valued are identified and guidance given on how to quantify them using biophysical or social data.

The users are advised to use UK based estimates wherever possible such as energy cost and shadow cost of carbon – **you should consider consulting an economist.**

Benefit estimates involving house price increase should be interpreted carefully. Such increases show households' willingness to pay for the amenities perceived to add value to property. However, they may not represent a welfare increase. Also such increases are specific to the housing market for which they are calculated and transfer may be limited.</td></tr>
<tr><td>If not does it relate to any other recognised national or international economic standards?</td><td>n/a</td></tr>
</table>

	Does it meet academic standards for natural science in the use of the supporting evidence to the economics?	**Yes.** The calculations recommended by the guide are based on scientific research, though not clear if all is from peer reviewed sources.
	In what context is it appropriate to use the tool, or elements of the tool?	This guide is appropriate to demonstrate an estimate of the value of a green infrastructure feature.
	Is the tool tailored to the UK data or is it adaptable?	The guide recommends inputting data from the USA as it is prepared for use in the USA. However, unit estimates for both biophysical and economic data from the UK can be used. **Unless the user is an expert already, consulting with a relevant scientific expert and economist is advised.**
	Is the tool transparent or closed?	The guide is entirely transparent as it presents how the calculations should be made.
	Does it require extra software?	**No.**
	Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No.**
	Is the tool user-friendly and how easy to use is it?	**Yes.** The guide is quite user friendly and walks users through methodology, with explanations of quantification and valuation. Project characteristics, biophysical data about the impacts and unit economic value data need to be inputted.
	What level of assumed and actual expertise is needed to use the tool?	The guide can be used by those without specialist knowledge of environmental science or economics, but with some basic knowledge of the benefits covered in the guide and values associated with them
	How long does it take to use the tool?	This tool would take between a day and a week depending on which ecosystem services will be estimated and how easy it is to find the information to input. The calculations are simple and quick; the time will be spent on gathering the information.
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	While no specialism is required, a user with good research skills and familiarity with urban planning, the environmental field or economics would be best suited to use this tool.
	What is the financial cost of using the tool in GBP?	This guide is free.
	Is the tool compatible with other tools?	**Yes.** The guide recommends that other tools be used as companion tools to the guide and lists a few, including i-Tree. However there is a high risk of double counting if other tools are used, and the user does not carefully check that the same benefits are being counted twice.
Outcomes	**Does it provide meaningful results?**	**Yes.** The tool does provide a wide picture of the monetary and quantitative value of benefits from green infrastructure, and this gives a good demonstration of the benefits which can be used in decision making for comparison to other projects or to costs.
	What sort of evidence can the tool produce?	The guide helps the user arrive at an annual monetary value from the four benefits it covers.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	The values used for the ecosystem services covered tend to be use values. Whether or not marginal values can be estimated depends on what type of information the user inputs into the calculations.

Can future changes, such as climate change be considered?	Yes if climate change does not affect the equations recommended by the guide, and information about future changes can be inputted into the equations.	
Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	The calculations presented in the guide should be applicable at all scales. The input data will differ. **You may want to consult scientific experts and economists to ascertain whether the unit values would need to be different for different scales.**	
What are the apparent strengths (with cautions)?	This is an easy to use guide which leads users through valuing a number of benefits with clear explanations and while it recommends that project-specific values are used, the guide gives users some suggestions based on best practice.	
What are the apparent weaknesses (with implications)?	The guide values different ways to provide some of the benefits (e.g. storm water run off reduction through green roofs, tree planting, bioretention and infiltration, permeable pavements, water harvesting. The user should only select the green infrastructure features that are applied in their case and not add the other benefits.	

A4.4 Health Economic Assessment Tools (HEAT) for walking and cycling

<table>
<tr><td rowspan="6">Overview</td><td>What is the tool for?</td><td>The Health Economic Assessment Tools (HEAT) for walking and cycling are tools to assess the economic health benefits from habitual walking and cycling a moderate pace (3 miles/hour) to the adult population (not individuals).</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>The results from the tool can be applied to all green infrastructure features that provide habitual walking and cycling opportunities.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>The tool estimates the economic value of reduction in risk of premature death (mortality) due to cycling or walking for a stated number of people for a stated number of minutes 'on most days'.</td></tr>
<tr><td>How does it define 'value'?</td><td>Value is discussed in terms of reduced mortality risk gained from walking and cycling.</td></tr>
<tr><td>Are there other similar tools?</td><td>There is epidemiological and economic valuation literature that can be used to estimate the health benefits from walking and cycling, but HEAT is the only tool that brings this literature together.</td></tr>
<tr><td>Where can you get the tool from?</td><td>The methodology and user guide can be downloaded from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Transport-and-health/publications/2011/health-economic-assessment-tools-heat-for-walking-and-for-cycling.-methodology-and-user-guide and the tool can be accessed here: http://www.heatwalkingcycling.org/</td></tr>
<tr><td rowspan="5">Content/ Standards Implementation</td><td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td><td>The tool assumes that it will be applied for adult populations, for habitual behaviour at population level, for walking of at least moderate pace (about 3 miles/hour), and NOT for populations with high average levels of physical activity. The tool does not take into account negative effects from air pollution. It assumes a 'build-up of benefits' (the time it takes for walkers/cyclists to realise the benefits in terms of mortality of the additional walking/cycling) of five years, based on expert consensus.</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>Yes, partial coverage.

The health benefits associated with recreational services from any green infrastructure that enables recreation. It does not cover any other ecosystem services.</td></tr>
<tr><td>What benefits or ecosystem services does the tool cover?</td><td>Health benefits in terms of reduced mortality. It does not cover reduced morbidity in the current version.</td></tr>
<tr><td>Does the proposed tool meet Green Book national standards for economic evidence?</td><td>Yes.

Value of statistical life is used as the measure of benefit of reduction in risk of mortality. A default value is given based on the standard European value, but this can be changed by the user. In the UK, VSL is estimated as around £1.6 million (Dft, 2002). While this estimate is based on fatalities due to transport accidents, this is currently the only official estimate used across all policy areas.

Discounting is applied to get a net present value with the default rate of 5% but the user is allowed to select their own discount rate. For the official discounting rates and procedure see Annex 3.3.

The guidance document also recommends the user carry out sensitivity analysis by applying different numbers to the tool to account for uncertainty.

The tool advises and allows users to think of additionality when inputting data into the tool. The health benefits estimated will arise only for habitual walking, one-off use will not generate the benefits estimated by the tool. So data on such habits need to be added.</td></tr>
<tr><td>If not does it relate to any other recognised national or international economic standards?</td><td>n/a</td></tr>
</table>

Does it meet academic standards for natural science in the use of the supporting evidence to the economics?Does it meet national government standards for natural science in the use of the supporting evidence to the economics?	**Yes.** Assessment of health benefit is based on review of peer reviewed epidemiological research.	
In what context is it appropriate to use the tool, or elements of the tool?	The tool should be used where the user has identified that green infrastructure will increase average walking and/or cycling amongst the local population most days of the week. The tool will help users value this increase in walking/cycling in health terms.	
Is the tool tailored to the UK data or is it adaptable?	**Yes.** Local data on walking and cycling (long term habits requiring surveys over sufficient period of time and locations); official UK discount rate and value of statistical life estimates	
Is the tool transparent or closed?	The tool itself is closed, but there is a general explanation of its calculations in the guidance document.	
Does it require extra software?	**No.** The tool is web-site based and does not require extra software. The user must input data through a survey-like interface.	
Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No.** The tool is web-based.	
Is the tool user-friendly and how easy to use is it?	**Yes.** The tool is very user-friendly and easy to use, and explains the data required and the implications of data input. The user needs to input (1) volume of walking / cycling per person (duration, distance, trips, steps); (2) adult population affected; (3) general parameters (intervention effect, build up period, mortality rate, time frame) – there are default values which can be changed and (4) economic parameters (value of statistical life, discount rate) – there are default values which can be changed. Surveys of actual behavior or modeling / expert judgment (if the assessment is that of a future project) to estimate the change in (1) due to the project and to determine (2) and (3). Official UK data can be used for (4). Data from a single point of time or before and after (e.g. a new cycling route) data can be inputted.	
What level of assumed and actual expertise is needed to use the tool?	No expertise needed, though good research skills would be advantageous.	
How long does it take to use the tool?	The tool itself takes about 10 minutes to use, and data gathering should take a couple of hours at the most.	
How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	Specialist knowledge is not required to use the tool but expertise may be required for finding UK related data and default values for discounting and value of statistical life. Consultation with the expert will require minimal time.	
What is the financial cost of using the tool in GBP?	There is no financial cost for using this tool	
Is the tool compatible with other tools?	**Yes.** The tool only values the reduced mortality risk due to sustained exercise. All other health and environmental benefits can be added to the results of HEAT.	

Outcomes	**Does it provide meaningful results?**	**Yes.** The tool provides an average annual benefit, total benefits, and maximum annual benefit from increase in walking/cycling to a population over a user-specified period of time. The tool assumes that any increase in habitual (regular) walking and cycling is associated with a reduction in mortality risk.
	What sort of evidence can the tool produce?	The tool produces an economic value of reductions in mortality from increased walking/cycling. Total benefits accumulated over a period of time are presented as a result, as well as annual benefits.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	Both total and marginal values can be estimated so long as the change in habitual walking / cycling behavior due to, say, an investment in a park, can be estimated.
	Can future changes, such as climate change be considered?	**Yes.** Future changes in the exercise rate and mortality risk can be included in the input data.
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	**Yes.** The tool can be used to make assessments at a range of scales, as it is based on the population involved.
	What are the apparent strengths (with cautions)?	This is a very easy to use tool with meaningful results. It calculates values that can sometimes be ignored in other tools, and variables are easy to change, therefore it is a good companion tool to use with other valuation tools that do not calculate health benefits from sustained walking/cycling.
	What are the apparent weaknesses (with implications)?	This tool does not currently calculate reductions in morbidity (illness), which means the value calculated is much lower than the actual value of health benefits. Therefore its results are lower bound estimates of the overall health benefits from sustained walking and cycling.

A4.5 Helliwell

<table>
<tr><td rowspan="6">Overview</td><td>What is the tool for?</td><td>The Helliwell System is used in court cases, insurance claims and public inquiries to place a monetary value on the visual amenity provided by individual trees and/or woodland.</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>The tool places a monetary value on the visual amenity provided by individual trees and/or woodland.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>The basic approach of the Helliwell system is to allocate scores under a number of different factors (tree size, life expectancy, suitability to setting, importance in landscape, presence of other trees and form). These scores are combined to give an overall comparative score for a tree or woodland, which is then multiplied by a conversion factor to arrive at a monetary value.</td></tr>
<tr><td>How does it define 'value'?</td><td>The tool defines 'value' as monetary value representing the visual amenity of the tree.</td></tr>
<tr><td>Are there other similar tools?</td><td>CAVAT, i-Tree and CTLA also value trees, albeit different benefits.</td></tr>
<tr><td>Where can you get the tool from?</td><td>The Guidance Note for the System can be ordered on the Arboricultural Association's website at <u>http://www.trees.org.uk/publications</u>. There is no digital format for the guidance note, and it must be bought in hardcopy.</td></tr>
<tr><td rowspan="8">Content/ Standards Implementation</td><td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td><td>The guidance note acknowledges that a tree may have negative visual amenity, but does not attempt to quantify this.</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>Yes, partial coverage.

The tool covers visual amenity only.</td></tr>
<tr><td>What benefits or ecosystem services does the tool cover?</td><td>This tool covers visual amenity only, which is a cultural service.</td></tr>
<tr><td>Does the proposed tool meet Green Book national standards for economic evidence?</td><td>No.

The tool does not have any economic basis for the way it assigns a value to the amenity factor of a tree/woodland. It is not clear where the unit economic value (called in the tool conversion factor value) comes from, and the tool assigns the same value to different factors of a tree, and without accounting for bundling effects where populations are less willing to pay for a bundle of goods than they would for individual goods.</td></tr>
<tr><td>If not does it relate to any other recognised national or international economic standards?</td><td>No.

This tool does not relate to any other recognised national or international economic standards.</td></tr>
<tr><td>Does it meet academic standards for natural science in the use of the supporting evidence to the economics? Does it meet national government standards for natural science in the use of the supporting evidence to the economics?</td><td>No.

While the key reference in the tool is from a peer reviewed journal, it is rather old (publication date 1967) and scaling factors are based entirely on expert opinion which is not substantiated with scientific evidence.</td></tr>
<tr><td>In what context is it appropriate to use the tool, or elements of the tool?</td><td>The tool is not recommended for economic valuation. The user may find the scoring process and factors taken into account useful for other purposes such as qualitative and quantitative descriptions of costs and benefits.</td></tr>
<tr><td>Is the tool tailored to the UK data or is it adaptable?</td><td>Yes.</td></tr>
</table>

	Is the tool transparent or closed?	The tool is semi-transparent - the calculations are clear and the user decides on scores, however it is unclear where the conversion factor comes from and what it represents.
	Does it require extra software?	**No**. The tool does not require extra software - it is a calculation that can be done on paper.
	Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No**. There is no licence or fee required for the use of the tool, however if you do not currently have access to the guidance you must purchase it from the Arboricultural Association for £12.50 (+£4.00 p&p)
	Is the tool user-friendly and how easy to use is it?	**Mostly yes.** The methodology is straightforward and easy to apply, however specialist knowledge is needed for assessing the condition and longevity of a tree.
	What level of assumed and actual expertise is needed to use the tool?	Specialist knowledge is needed for assessing the condition and longevity of a tree and it is recommended that valuation is carried out by a person with a sound knowledge of arboriculture and previous training in the tool.
	How long does it take to use the tool?	The tool should take a few minutes to use, and data gathering should take less than an hour of fieldwork.
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	The time spent on this tool should be allocated to an arborist.
	What is the financial cost of using the tool in GBP?	There is a one-off cost for purchasing the guidance book which is £12.50 (plus £4.00 for postage)
	Is the tool compatible with other tools?	**Mostly no.** It is not recommended that this tool be used with other tools due to its lack of economic basis.
Outcomes	**Does it provide meaningful results?**	**Mostly no.** This tool does not provide meaningful results in terms of monetary value, however it can provide results in terms of tree scoring, which can be used to compare trees against each other in a decision-making context.
	What sort of evidence can the tool produce?	The tool provides a value for a tree that is meant to encompass its lifespan.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	**No.** The value is not total economic value. Marginal changes cannot be considered.
	Can future changes, such as climate change be considered?	**No.** Future changes are not considered.
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	**Yes.** This tool is meant to be used for individual trees and for woodlands.
	What are the apparent strengths (with cautions)?	The tool does take into account a number of different factors about trees, which makes it a useful tool to compare values between trees.
	What are the apparent weaknesses (with implications)?	This tool does not have any economic basis to it and should not be used for economic valuation and hence cost-benefit analyses or in any context where the value is compared with other values obtained elsewhere.

A4.6 i-Tree Design

<table>
<tr>
<td rowspan="6">Overview</td>
<td>What is the tool for?</td>
<td>i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools are intended to help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.</td>
</tr>
<tr>
<td>What does it assess and what features of GI does the tool relate to?</td>
<td>i-Tree Design estimates the benefits individual trees provide to an individual property nearby.</td>
</tr>
<tr>
<td>What does the tool do and how does it do it?</td>
<td>With inputs of location, species, tree size and condition, users will receive an understanding of tree benefits related to greenhouse gas mitigation, air quality improvements and storm water interception. With the additional step of drawing a building footprint - and virtually "planting" a tree - tree effects on building energy use can be evaluated.

Annual benefits for trees are estimated for the current year as well as for a user-specified forecast year. Multiple trees can be added to compare benefits or to provide a full accounting of a property's trees.

This tool is intended as a simple and accessible starting point for understanding individual trees' value to the community.</td>
</tr>
<tr>
<td>How does it define 'value'?</td>
<td>Assesses an individual trees' value from carbon dioxide mitigation, air quality improvements, stormwater interception and effects on building energy use to the community.</td>
</tr>
<tr>
<td>Are there other similar tools?</td>
<td>Yes.

The method and models used for i-Tree (Design) is based on the i-Tree Streets methods and models.</td>
</tr>
<tr>
<td>Where can you get the tool from?</td>
<td>Available by request through the i-Tree website: http://www.itreetools.org/design.php</td>
</tr>
<tr>
<td rowspan="5">Content/ Standards</td>
<td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td>
<td>This is a closed tool. It is not possible to assess the assumptions. The only information given is that it is based on i-Tree Streets (see Annex 4.8)</td>
</tr>
<tr>
<td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td>
<td>Yes, partially.

The figures can be derived for energy conservation, air quality improvement, carbon dioxide reduction, storm water runoff reduction and increase in property values.</td>
</tr>
<tr>
<td>What benefits or ecosystem services does the tool cover?</td>
<td>Energy conservation from tree shade; contribution to stormwater drainage/capture; contribution to air quality and carbon dioxide reduction</td>
</tr>
<tr>
<td>Does the proposed tool meet Green Book national standards for economic evidence?</td>
<td>Unknown.

This is a closed tool. It is not possible to assess whether it meets Green Book national standards for economic evidence.</td>
</tr>
<tr>
<td>If not does it relate to any other recognised national or international economic standards?</td>
<td>With the current information it is not possible to say whether this tool follows any other recognised national or international economic standards.</td>
</tr>
</table>

	Does it meet academic standards for natural science in the use of the supporting evidence to the economics?Does it meet national government standards for natural science in the use of the supporting evidence to the economics?	**Yes according to the statement by the tool.** This tool is closed so it is not possible for users to see how the tool works (i.e., what functions are in the background of the tool to determine the various ecosystem services). However, information given says the ecosystem service calculations are done through an adaptation of the UFORE (Urban Forest Effects) model which was peer reviewed.
	In what context is it appropriate to use the tool, or elements of the tool?	This tool is intended as a simple and accessible starting point for understanding individual trees' value to the community.
	Is the tool tailored to the UK data or is it adaptable?	i-Tree (Design) can only value addresses in the USA and Canada. The scientific assumptions and data (about a tree's ability to deliver the ecosystem services covered) are based on the climate and local conditions in the USA. If the ratio of the relevant factors in the USA and UK is known, the results could be adjusted. A suitable conversion of the calculations has been produced by Rogers et al., 2012. Note that for the UK the 'non-traded price of carbon' should be used (DECC).
Implementation	**Is the tool transparent or closed?**	This tool is closed. It is not possible for users to see how the tool works (i.e., what functions are in the background of the tool to determine the various ecosystem services).
	Does it require extra software?	**No.** i-Tree (Design) can be used through a web browser.
	Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No.** There is no cost for using the tool and a licence is not required.
	Is the tool user-friendly and how easy to use is it?	**Yes.** The tool is very user friendly and can be used with limited expertise.
	What level of assumed and actual expertise is needed to use the tool?	Only knowledge of a where a tree is situated, the type of tree and the diameter of the tree is needed.
	How long does it take to use the tool?	The tool can be used within 5 minutes if all information is available.
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	No specialist time is needed for the tool, any user with information on tree species, location and width or circumference of the tree at 4.5 feet above ground.
	What is the financial cost of using the tool in GBP?	There is no financial cost for using i-Tree tools
	Is the tool compatible with other tools?	Tools that value other ecosystem services could potentially be used in conjuction with i-Tree (Design) but this is not relevant as the tool can only be used in the USA and Canada.
Outcomes	**Does it provide meaningful results?**	i-Tree (Design) provides users with the value of a single tree from its contributions to air quality improvement, storm water interception, greenhouse gas mitigation, and energy savings from tree shade. It is intended as a starting point to help users understand the value of a tree to a community, and can be used to help plan tree planting/removal/maintenance.
	What sort of evidence can the tool produce?	i-Tree provides the current year value and total value over project period of the ecosystem services it covered.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	**Yes.** The total and item values of the ecosystem services covered are presented in terms of US$ per tree.
	Can future changes, such as climate change be considered?	**Unknown.** The calculations behind the tool may be considering future changes but the user is not asked to input information on any changes over time.

	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	**Mostly not.** This application can be used to value an individual tree. Additional trees can be added, but it is not suitable for applications wider than estimating the benefits around an individual private property.
	What are the apparent strengths (with cautions)?	This is an easy to use tool to estimate the value of a select group of ecosystem services of a single tree.
	What are the apparent weaknesses (with implications)?	The tool can be used only for addresses in the USA and Canada. There is no information on assumptions used in this tool and it is not clear how valuation is carried out. The economic basis for this tool cannot be verified.

A4.7 i-Tree Eco

<table>
<tr><td rowspan="6">Overview</td><td>What is the tool for?</td><td>i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools are intended to help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>i-Tree Eco assesses the monetary value of the ecosystem services provided by individual or plots of trees in an urban setting and covered by the tool.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>i-Tree Eco uses field data from complete inventories or randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and the value to communities from the ecosystem services provided by trees.</td></tr>
<tr><td>How does it define 'value'?</td><td>The economic value of the ecosystem services provided by trees and covered by the tool.</td></tr>
<tr><td>Are there other similar tools?</td><td>Yes.

The method and models used for i-Tree (Design) is based on the i-Tree Streets methods and models. There are a number of other tools which value trees, such as CTLA, Helliwell, GiVT and CNT though not all are recommended.</td></tr>
<tr><td>Where can you get the tool from?</td><td>Available by request through the i-Tree website:
http://www.itreetools.org/eco/index.php</td></tr>
<tr><td rowspan="4">Content/ Standards</td><td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td><td>The model uses US climate types, building types, energy use and emission factors for calculating energy effects of trees. Key parameters for tree characteristics, climate and other local environmental conditions and monetary values can be inputted by international users as described in
http://www.itreetools.org/eco/resources/International%20Eco%20versions.pdf and http://www.itreetools.org/eco/resources/iTreeEcoUserInputManual0923.pdf

Input from expert ecologists and economists should be sought to help identify the appropriate input data. For data not possible to find for the UK, the model reverts to default US values.</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>Yes, partially.

The figures can be derived for energy conservation, air quality improvement, carbon dioxide reduction, and storm water runoff reduction.</td></tr>
<tr><td rowspan="2">What benefits or ecosystem services does the tool cover?</td><td>

Climate regulation: Carbon storage and sequestration
Water regulation: storm water management
Effects of trees on air pollution, building energy use and public health, and
Several biophysical outputs that contribute to the above services

The tool also generates the following biophysical outputs, though the user needs to check the applicability of these results to the UK conditions, for which ecologists and economists should be consulted:
</td></tr>
<tr><td>

Urban forest structure (e.g., species composition, number of trees, tree density, tree health, etc.), analysed by land-use type;
Hourly amount of pollution removed by the urban forest, and associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns);
Hourly urban forest volatile organic compound emissions and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year;
Public health incidence reduction and economic benefit based on the effect of trees on air quality improvement;
Total carbon stored and net carbon annually sequestered by the urban forest;

</td></tr>
</table>

		- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants; - Yearly tree canopy rainfall interception summarized by tree species or land use; - Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration; - Tree pollen allergenicity index, and - Pests risk analyses based on host susceptibility, pest/disease range and tree structural value. All these estimates may not be available depending on project configuration, data options and project country location.
	Does the proposed tool meet Green Book national standards for economic evidence?	**Yes.** The valuation methodology is compliant. The values generated would be applicable to the UK only if UK data are inputted as recommended in the international users guide referred to above. This is not possible to do for the building energy conservation benefits for which only USA values are available. As the difference between the USA and UK values will be different for individual benefit categories, it is difficult to assess how relevant the results would be if run with USA data. The results presented in an one off annual value will need to be aggregated over time for which Green Book guidance should be used.
	If not does it relate to any other recognised national or international economic standards?	n/a
	Does it meet academic standards for natural science in the use of the supporting evidence to the economics?Does it meet national government standards for natural science in the use of the supporting evidence to the economics?	This system has good potential to be used in part as supporting evidence for economic valuation of green infrastructure (trees). However, one basic consideration is that the system is designed for use in the US and therefore calculations are in US dollars. There is also a different understanding of carbon cost between the US and the UK, which obscures some of the potential for automatic transferability between the outputs. It is recommended that for use in the UK hourly local pollution data, hourly weather data, boundary layer height data and local biomass formulas are used. i-Tree cannot produce building energy effects for international cities. The model will produce estimates based on local international field data, but default to US equations without the additional desired information.
	In what context is it appropriate to use the tool, or elements of the tool?	To assess the economic value of the ecosystem services listed above from an individual tree or any size plot of trees.
	Is the tool tailored to the UK data or is it adaptable?	Although this was developed in the U.S., i-Tree Eco can be used by international users. It can be and has been used in the UK (Rogers et al., 2012). However full adaptation requires a long list of data which may have high time cost if not readily available for the location of the project assessed.
Implementation	**Is the tool transparent or closed?**	This tool is closed so it is not possible for users to see how the tool works (i.e., what functions are in the background of the tool to determine the various ecosystem services). However, information given says the ecosystem service calculations are done through an adaptation of the UFORE (Urban Forest Effects) model which was peer reviewed.
	Does it require extra software?	The i-Tree software suite must be downloaded in order to use the tool. There is no cost for using this tool.
	Is the tool proprietary (is a licence or fee required for the use of the tool)?	No.
	Is the tool user-friendly and how easy to use is it?	The tool can be used by state forestry agencies, municipalities, non-profit organizations or anyone interested in learning more about, and better caring for, their community forest resources. The tool itself is easy to use (an Excel like software for the user interface) but inputting UK specific data is likely to be time consuming and requires the involvement of specialist ecologists and economists.

	What level of assumed and actual expertise is needed to use the tool?	Specialised technical knowledge is not necessary to use the tool itself. There are i-Tree training sessions. Some are, for example, 2 day workshops. There are also webcasts. But one is not required to undertake training in order to obtain and use any of the i-Tree tools. What requires expertise is finding the right data to input to the tool as mentioned above.
	How long does it take to use the tool?	The amount of time it takes to use this tool depends on the amount of field work and other data collection required. If data are ready, inputting the data and running the tool will take up to a 1 day (also depending on the size of the plot). It is not possible to make an accurate guess of how much time required for data collection but it could be anywhere between a few days and a few weeks.
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	It is not indicated that specialist knowledge is required for this tool (the tools have been used by communities, non-profit organizations, consultants, volunteers, and students), thus there is no need to allocate time to specialists for use of this tool. We would, however, recommend specialist involvement in data collection as mentioned above, which would be majority of the time required.
	What is the financial cost of using the tool in GBP?	There is no financial cost for using i-Tree tools.
	Is the tool compatible with other tools?	**Yes.** The method and models used for i-Tree (Design) is based on the i-Tree Streets methods and models. The tool can be used with CNT (not for the same benefits to avoid doublecounting) and HEAT for health benefits of recreational opportunities if exist.
Outcomes	**Does it provide meaningful results?**	**Yes.** The results would be appropriate to the UK if UK data are inputted.
	What sort of evidence can the tool produce?	i-Tree quantifies the ecosystem services that trees provide, monetary evidence for some of these and biophysical data for others as listed above.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	This tool calculates the annual economic benefit of trees and, where applicable, the tree structural value. Marginal changes (additional benefit of an additional tree) can be considered.
	Can future changes, such as climate change be considered?	**Not immediately.** The tool can be run for different future values of the relevant parameters.
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	The study area for i-Tree Eco can range from a single tree, to any size of tree population. Therefore, this application can be used at all scales.
	What are the apparent strengths (with cautions)?	The tool provides a high level of detail including monetary and biophysical data for the ecosystem services it covers.
	What are the apparent weaknesses (with implications)?	A significant amount of data collection is required to adapt the tool for UK applications for which specialist input should be secured.

A4.8 i-Tree Streets

<table>
<tr><td rowspan="7">Overview</td><td>What is the tool for?</td><td>i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools are intended to help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.</td></tr>
<tr><td>What does it assess and what features of GI does the tool relate to?</td><td>i-Tree Streets assesses the monetary value of the ecosystem services provided by street trees and covered by the tool and management needs and costs.</td></tr>
<tr><td>What does the tool do and how does it do it?</td><td>i-Tree Streets is used to assess street tree populations. It uses tree inventory data to quantify the economic value of annual environmental and aesthetic benefits: energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increase. It uses tree growth and benefit models for predominant urban tree species in 16 national climate zones in the USA. Users import data collected in a sample or complete inventory and enter community specific information (e.g. program management costs, city population, and price of residential electricity) to customise the benefit-cost data. Results are reported in the four main categories: Benefit-cost analysis, resource structural analysis, replacement value, and pest analysis.

It is not intended for use outside of the US due to the way that quantification and valuation of ecosystem services are carried out (via use of US climate zones), and users are recommended to use i-Tree eco. McPherson (2010) describes how to select the best US reference city for international applications using Lisbon, Portugal as an example. However, the selection uses biophysical characteristics of trees and climate characteristics of the cities. It does not cover adjustments for economic values.</td></tr>
<tr><td>How does it define 'value'?</td><td>It uses tree inventory data to quantify the annual economic value of the following ecosystem services: air quality improvement, CO_2 reduction, stormwater control, energy conservation and aesthetic value through property value increase.</td></tr>
<tr><td>Are there other similar tools?</td><td>Yes.

The method and models used for i-Tree (Design) is based on the i-Tree Streets methods and models.</td></tr>
<tr><td>Where can you get the tool from?</td><td>Available by request through the i-Tree website:
http://www.itreetools.org/streets/index.php</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="5">Content/ Standards</td><td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td><td>No specific information on assumptions used by i-Tree Streets. STRATUM, which i-Tree Streets is based on, uses US tree species and climate zones to model tree growth for US street tree species. It is unclear what other assumptions STRATUM or i-Tree Streets uses, however it is indicated that this is US (national or zone) based too.</td></tr>
<tr><td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td><td>Yes, partially.

Estimates can be derived for energy conservation, air quality improvement, carbon dioxide reduction, storm water runoff reduction and increase in property values. However, noise reduction, wood fuel provision, biodiversity preservation (genetic resource), community development, recreation, tourism and spiritual meaning are not comprehensively covered.</td></tr>
<tr><td>What benefits or ecosystem services does the tool cover?</td><td>Contribution to stormwater drainage/capture
Contribution to air quality
Carbon dioxide reduction
Energy conservation from tree shade
Aesthetic benefits as reflected through property values</td></tr>
<tr><td>Does the proposed tool meet Green Book national standards for economic evidence?</td><td>Unknown

The tool is a closed tool and hence it has not been possible to assess the economic basis of the calculations. Property values are location specific with limited transferability to the UK.</td></tr>
</table>

	If not does it relate to any other recognised national or international economic standards?	**Unknown as above.**
	Does it meet academic standards for natural science in the use of the supporting evidence to the economics?Does it meet national government standards for natural science in the use of the supporting evidence to the economics?	**Yes according to the statement by the tool.** This tool is closed so it is not possible for users to see how the tool works (i.e., what functions are in the background of the tool to determine the various ecosystem services). However, information given says the ecosystem service calculations are done through an adaptation of the UFORE (Urban Forest Effects) model which was peer reviewed.
	In what context is it appropriate to use the tool, or elements of the tool?	The tool can be used for valuing the ecosystem services (covered by the tool) provided by street trees. The tool web page states that the tool has been used by communities for the following purposes: • Improve the return on investment by determining which trees maximise canopy cover and provide the benefits that are important to the community; • Determine the management needs of street trees to foster and perpetuate a healthy municipal forest; • Leverage investment from partners for carbon credits or energy conservation; • Gain public support by demonstrating the value of trees to the quality of life in the community; • Perform economic evaluations of tree performance using annual budget and expenditure data, and • Assess costs of management to provide a platform for strategic planning.
	Is the tool tailored to the UK data or is it adaptable?	**No** It is not intended for use outside of the US as it has very US-specific assumptions and the tool requires a US location for calculating the value of the street trees. McPherson (2010) describes how to select the best US reference city for international applications using Lisbon, Portugal as an example. However, the selection uses biophysical characteristics of trees and climate characteristics of the cities. It does not cover adjustments for economic values.
Implementation	**Is the tool transparent or closed?**	This tool is closed; it is not possible for users to see how the tool works (i.e., what functions are in the background of the tool to determine the various ecosystem services).
	Does it require extra software?	The i-Tree software suite must be downloaded in order to use the tool.
	Is the tool proprietary (is a licence or fee required for the use of the tool)?	There is no cost for using this tool, and it does not require a licence.
	Is the tool user-friendly and how easy to use is it?	It is not possible to test the tool online without request to download. It is likely to use the same design software as other i-Tree tools reviewed here and hence should be easy to use.
	What level of assumed and actual expertise is needed to use the tool?	Specialised technical knowledge is not necessary to use the tool itself. There are i-Tree training sessions. Some are, for example, 2 day workshops. There are also webcasts. But one is not required to undertake training in order to obtain and use any of the i-Tree tools. What requires expertise is finding the right data to input to the tool as mentioned above.
	How long does it take to use the tool?	The amount of time it takes to use this tool depends on the amount of field work that is put into the tool. If using the tool for one tree, for example, it is estimated that it would take 2 hours to 1 day to use the tool. If extensive field work is to be undertaken, for a number of trees, it may take over one week to use the tool.
	How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	It is not indicated that specialist knowledge is required for this tool (the tools have been used by communities, non-profit organizations, consultants, volunteers, and students), thus there is no need to allocate time to specialists for use of this tool.

	What is the financial cost of using the tool in GBP?	There is no financial cost for using i-Tree tools
	Is the tool compatible with other tools?	**Yes.** The method and models used for i-Tree (Design) is based on the i-Tree Streets methods and models. The tool can be used with CNT (not for the same benefits to avoid doublecounting) and HEAT for health benefits of recreational opportunities if exist
Outcomes	Does it provide meaningful results?	Mostly yes. i-Tree streets allows a user to quantify the annual economic value of ecosystem services (carbon sequestration and storage, improvements to air quality, stormwater catchment and energy conservation from tree shade) provided by an inventory of street trees. The tool can be used to quantify current existing inventories of trees and possible future ones (based on user's input of what the future inventory may be). In this way it is able to help users manage the current resource, set priorities and develop policy.
	What sort of evidence can the tool produce?	i-Tree quantifies the environmental services that trees provide and the structure of the urban forest.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	This tool seems to calculate the annual economic benefit of trees and, where applicable, the tree structural value. It is not possible to see if and how future and marginal values are considered.
	Can future changes, such as climate change be considered?	**No.** Future changes are not considered.
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	Tree populations can range from a single planting site on block in a particular neighbourhood, or an entire city street population. The tool can be used at a local and strategic level.
	What are the apparent strengths (with cautions)?	This is a relatively easy to use tool with a framework for valuing ecosystem services of street trees which covers a number of important ecosystem services.
	What are the apparent weaknesses (with implications)?	Application is limited to the UK. Reference US cities can be selected for application in international locations but the selection criteria are limited to biophysical and climatic conditions and do not include economic data.

A4.9 InVEST: Integrated Valuation of Environmental Services and Tradeoffs

<table>
<tr>
<td rowspan="7">Overview</td>
<td>What is the tool for?</td>
<td>InVEST quantifies, maps and values a large array of ecosystem services provided by terrestrial, freshwater and marine systems. It can be used with ArcGIS software package or as standalone software.</td>
</tr>
<tr>
<td>What does it assess and what features of GI does the tool relate to?</td>
<td>The tool does not relate to specific GI features, but will work on features which cover some area (e.g. a park or woodland rather than a single tree, woodlands, wetlands, rivers and canals).</td>
</tr>
<tr>
<td>What does the tool do and how does it do it?</td>
<td>The tool uses GIS to estimate the amount and economic value of ecosystem services that are provided for in the current landscape or in future scenarios. GIS is utilised so that maps can be used as information sources and can be produced as outputs. InVEST was initially developed for Arc GIS, but recently standalone software has been developed.</td>
</tr>
<tr>
<td>How does it define 'value'?</td>
<td>In terms of economic value of ecosystem services that are provided for in the current landscape or in future scenarios. Cost of clean-up or treatment is defined in the models but it may also be input welfare measures.</td>
</tr>
<tr>
<td>Are there other similar tools?</td>
<td>None of the tools assessed in this study is similar to InVEST. Polyscape is similar in that it uses GIS to quantify ecosystem services but focuses on farmland and tree planting and does not provide economic valuation. http://www.slideshare.net/CPWF/polyscape-multiple-criteria-gis-toolbox-for-negotiating-landscape-scale-ecosystem-service-provision</td>
</tr>
<tr>
<td>Where can you get the tool from?</td>
<td>The tool can be downloaded from the Natural Capital Project's website at http://www.naturalcapitalproject.org/InVEST.html</td>
</tr>
<tr>
<td rowspan="5">Content/ Standards Implementation</td>
<td>What are the assumptions made by the tool for valuation and in the models used for quantification?</td>
<td>This is a very large tool and a number of assumptions are made to construct the models used to quantify benefits, these are further detailed in the supporting documentation. The quality of outputs is expected to improve if an iterative process can be followed but will also need further data collection. Therefore, alternative models and additional analyses, including collection of field-based observations and model calibration, will be required to "ground-truth" InVEST for use in England.

For valuation, unit values are inputted by the user but the tool documentation recommends values from literature (e.g. for carbon values). Users would be advised to input values from the UK literature and official guidance. In addition, monetary values will not be calculated for all environmental attributes, such as biodiversity and crop pollination.</td>
</tr>
<tr>
<td>Does the division of the ecosystem services follow the structure of the National Ecosystem Assessment? If not, why not?</td>
<td>Yes, partially.</td>
</tr>
<tr>
<td>What benefits or ecosystem services does the tool cover?</td>
<td>

Biodiversity (not valued in monetary terms);
Regulating services: carbon storage and sequestration, water purification, sediment retention;
Provisioning services: managed timber production, and
Supporting services: crop pollination (not valued in monetary terms).

The ecosystem services that are relevant to green infrastructure that are covered by this model are biodiversity (), carbon storage, crop pollination, managed timber production, sediment retention and water purification.

Biodiversity and crop pollination services are not valued in monetary terms. It is not clear if should be valued as a separate ecosystem service or an ecological underpinning that these contribute to ecosystem services.</td>
</tr>
<tr>
<td>Does the proposed tool meet Green Book national standards for economic evidence?</td>
<td>Yes but partially.

The tool has facility to add unit values and suggests adding market price (for timber production) and cost of treatment (for other services valued) estimates. The latter is not a measure of welfare benefits but it may be possible to input welfare measures into the tool instead.
Discounting is allowed and user is advised to add the discount rate they wish to use. It is not clear if discount rate declining over time (see Annex 3.3) can be inputted into the tool. Scenario analysis is encouraged.</td>
</tr>
</table>

If not does it relate to any other recognised national or international economic standards?	N/A	
Does it meet academic standards for natural science in the use of the supporting evidence to the economics?Does it meet national government standards for natural science in the use of the supporting evidence to the economics?	This system has good potential to be used in part as supporting evidence for economic valuation of green infrastructure. It is modular in design and has specific packages for the terrestrial, freshwater and marine environment. There is a specific module for carbon sequestration, but the system does not specifically focus on green infrastructure.	
In what context is it appropriate to use the tool, or elements of the tool?	Examples of questions the tool is designed to answer that apply to green infrastructure include, but are not limited to: Where would reforestation or protection achieve the greatest downstream water quality benefits? Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values? Scenario analysis for variations in current and future parameters is encouraged.	
Is the tool tailored to the UK data or is it adaptable?	The tool is tailored to US data, but may be adaptable with different inputs. The science is based upon using habitat quality and structure as a surrogate for biodiversity and this could be adapted for application in the UK subject to agreement of habitat / biodiversity metrics. Economic value estimates relevant to the UK can be inputted.	
Is the tool transparent or closed?	The tool is transparent - the documentation accompanying the tool describe and explain the models used.	
Does it require extra software?	**No.** InVEST can be run within ArcGIS software or as standalone software. The InVEST tool and data must also be downloaded and installed, and some models require additional installations to support ArcGIS.	
Is the tool proprietary (is a licence or fee required for the use of the tool)?	**No** InVEST is a free piece of software. If to be used alongside ArcGIS the software must be purchased, and an ArcInfo level licence is needed to run one of the hydrology modules. (The cost of this license depends on the buyer and the purpose of use. Buyers should contact www.esri.com directly).	
Is the tool user-friendly and how easy to use is it?	User friendly for those with GIS experience.	
What level of assumed and actual expertise is needed to use the tool?	There is a high level of GIS expertise needed to use this tool and ecologist and economist input to collate input data.	
How long does it take to use the tool?	The data set-up for the tool would take approximately 1 to 2 days per module for an experienced GIS user. Research for inputs to the tool could take significantly longer: the guidance advises a team of 1-3 people could take from 2 months to a year.	
How is the time needed to use the tool allocated between e.g. specialists, local authority staff, volunteers, etc.?	A team of people researching information for this GIS tool may be composed of a GIS analyst, a hydrologist to review hydrological inputs and outputs, and a project coordinator to synthesize the analysis from the tool. Economists need to be consulted to collate the UK relevant data.	
What is the financial cost of using the tool in GBP?	There is no financial cost to use this tool. If GIS models are to be purchased, buyer should contact www.esri.com directly as it is not possible to obtain a general price.	

	Is the tool compatible with other tools?	The tool can be used in conjunction with other tools with careful attention to avoid doublecounting of ecosystem service and value type.
Outcomes	**Does it provide meaningful results?**	**Yes.** The tool produces monetary values based on user input and has the capacity to provide meaningful results, depending on the robustness of the information the user has inputted.
	What sort of evidence can the tool produce?	The net present value of the ecosystem service benefits is calculated and scenario analysis is allowed but all depends on the completeness of input data.
	Does the tool allow the consideration of marginal changes, in line with Green Book Guidance?	The model is set up for market prices and treatment costs for most services. It looks likely to add welfare estimates. Marginal changes should be possible to estimate.
	Can future changes, such as climate change be considered?	**Yes.** Future changes can be considered through scenario analysis using different data inputs.
	Can the tool be used to make assessments at a range of scales and if so, what scales can it be used at (local, strategic, etc.)?	**Yes.** The tool can be used at different scales, even though it is probably not sufficiently detailed to be used on a very site specific basis.
	What are the apparent strengths (with cautions)?	The tool is very detailed covering science and economic aspects. It has also been extensively used across the world.
	What are the apparent weaknesses (with implications)?	This is a difficult tool to use and requires users to be trained in GIS and would also require input from ecologists and economists to collate the UK relevant data. The Natural Capital Project (developers of InVEST) provides training , the details of which can be found at http://www.naturalcapitalproject.org/InVEST_trainings.html.