



Trees in suburban streets, London

Street tree valuation systems

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Street trees and urban woodlands provide a number of environmental and social benefits, including contributing to climate change adaptation and mitigation and providing urban green space. This Note presents the results of a review of three approaches to estimating the amenity value of street trees: CAVAT, Helliwell and i-Tree. The review showed that the three valuation systems differ significantly in methodology, data requirements and outputs. At one end of the spectrum the Helliwell system is entirely based on expert judgement, focuses solely on visual amenity value and has very low field data requirements. At the opposite end of the spectrum i-Tree requires data collected from a sample or a complete inventory of the street tree population as well as community-specific information (e.g. programme management costs, city population size, and price of residential electricity) to output customised benefit and cost data. CAVAT falls somewhere in between, focusing on wider benefits of trees to communities rather than purely visual amenity, but not outputting detailed benefit and cost data. The CAVAT and i-Tree systems can meet the needs of both small communities and large metropolitan areas. However, if limitations on data availability can be overcome, i-Tree offers significant advantages of flexibility, detailed output and permits a wide range of benefits to be assessed. The Helliwell system seems best targeted to single tree and small-scale community evaluations, but can also handle urban woodlands.

Introduction

The role of trees and forests in climate change adaptation and mitigation strategies has been firmly on research agenda since the Rio Earth Summit in 1992. Street trees and urban forests play an important role in climate change adaptation by helping to mitigate extreme weather events such as floods and heat waves. Urban forests help moderate urban climates, for example by cooling the air, reducing wind speeds and by providing shade, which may help reduce costs of heating buildings in winter. Trees and forests contribute to climate change mitigation by sequestering carbon, helping to protect soils and by supporting biodiversity. Urban greenspace also provides a setting for physical exercise, reduces ultraviolet radiation and air pollution, and helps relieve stress – benefiting physical and mental health (Konijnendijk and Randrup, 2004).

In the UK, section 198 of the Town and Country Planning Act (1990) covers the public amenity value of trees, and places a duty on local authorities to protect trees in the public interest. However, it does not prescribe how their value should be estimated. A number of urban street trees valuation systems have been developed. The term 'street trees' is often used in the literature to mean all trees within urban areas and not just those on the street. However, each of the valuation systems reviewed could be applied to trees in settlements in rural areas as well.

Methodology

A literature and methodological review was carried out to assess different approaches to estimating the amenity value of street trees in terms of coverage, data input requirements, outputs and uncertainties. Three systems were considered and compared: Capital Asset Value for Amenity Trees (CAVAT) and Helliwell (both developed in the UK) and i-Tree (developed in the USA).

The review was carried out with a focus on the three valuation systems mentioned. This does not imply that they are the only ones in existence or use. Many countries have their own systems tailored to national specific needs. For example, the valuation methods produced by the Council of Tree and Landscape Appraisers in the USA which have been used widely (including in the UK). Other methods of stated and revealed preferences (hedonic and travel cost approaches) have been developed.

Results

Helliwell was first developed and published in 1967 and is the oldest of the three street tree valuation systems reviewed. It has been endorsed by the Tree Council and the Arboricultural

Association. Revised periodically, the most recent version available for this review was released in 2008. Its main stated aim is to aid practical planning and management (e.g. felling, pruning and planting) of woodlands and urban trees by evaluating their relative contribution to the visual quality of the landscape.

The CAVAT system is targeted primarily at local authorities and publicly-owned trees, providing a method for managing trees as public assets rather than liabilities. It was developed and first applied in London in 2007 and is based on the depreciated replacement cost approach. CAVAT also takes into account the contribution of location, relative contribution to amenity, social value and appropriateness, as well as an assessment of functionality and life expectancy.

The i-Tree peer-reviewed software suite was developed by the United States Forest Service which recommends its use by communities of all sizes to strengthen their urban and community forest management efforts. i-Tree Tools are in the public domain and are freely accessible.

Two of the three valuation schemes, CAVAT and i-Tree, take substantial account of the social and cultural component of the value of street trees. The Helliwell system puts an emphasis on visual amenity and, being explicitly based on expert judgement, also appears to produce the most variable valuation outcomes of the three systems (Watson, 2002).

The internal workings and logic of valuation systems are presented briefly below. It is followed by comparative analysis and a summary of benefits.

Capital Asset Value for Amenity Trees (CAVAT)

Valuation starts by estimating the replacement cost of a tree (termed its basic value). It is then adjusted by a number of factors accounting for a tree's health, amenity and social value.

CAVAT works by calculating a unit value for each cm² of tree stem by extrapolation from the cost of a newly planted standard tree, using the ratio between respective trunk areas as the critical measurement. This element of the approach is similar to the Council of Tree and Landscape Appraisers (CTLA) 'trunk formula method' (a widely accepted approach in the USA). The trunk formula method yields the replacement tree cost as a starting point of valuation. Next the replacement cost is adjusted using a depreciated replacement cost approach. The benefits flow from an 'idealised' replacement is adjusted to reflect those of the tree being appraised.

In the case of CAVAT the replacement cost is adjusted by taking into account the contribution of location, accessibility, relative

contribution to amenity, social value and appropriateness, as well as an assessment of functionality (based on crown size and condition) and life expectancy. Unlike the standard CTLA approach CAVAT allows appreciation as well as depreciation. The planting cost basis is adjusted to take into account the impact of factors contributing to expected public benefits.

The CAVAT method has five steps:

1. A basic value is computed as the product of a unit value factor (UVF), and the size of trunk area. UVF represents the full cost of a newly planted tree in a given area, divided by its trunk area, and has two components. These are the nursery gate price (or unit area cost) in cost per square centimetre of stem and the planting cost including transport, materials, immediate care and management costs, but excluding subsequent care (Neilan, 2009). In 2009 the UVF was about £13.
2. A CTI/location and accessibility-adjusted value is computed by adjusting the basic value by a Community Tree Index (CTI) to take account of the population density and discounting by up to 60% depending how publicly accessible or visible the tree is in the particular location.
3. A functional value is then estimated by adjusting the CTI/location and accessibility-adjusted value to take into account a tree's functionality. This involves expert judgement of how well the tree is performing biologically by comparison with what would be expected of a well-grown healthy tree of the same species and thickness in the same location.
4. An amenity adjusted value is then computed by adjusting the functional value to take into account the surveyor's assessment of any special amenity factors (both positive and negative) and the tree's appropriateness to the location. The combined ad-justment made at this stage can be up to +/- 40%. The amenity adjustment takes account of features of special benefit to the community and can be based upon up to four special factors (with a 10% adjustment for each, other than veteran/ ancient trees: 30%). Suggested categories are townscape and visual importance (integral part of a designed landscape), national or local designations or connections (e.g. a commemorative tree or in a conservation area), species characteristics (rare or unusual species, or shape) and nature conservation (particular wildlife importance or a veteran/ancient tree).
5. Finally, the full value is estimated by adjusting the amenity value for Safe Useful Life Expectancy (SULE) (Barrell, 1993) whereby trees with a SULE greater than 80 years retain 100% of their adjusted value, whereas those with a SULE of less than 5 years lose 90% of their adjusted value.

In summary, valuation is based upon the following formula:
Full value = Basic value × CTI-location-accessibility factor × Functional factor × Amenity and appropriateness factor × safe life expectancy factor

Helliwell

Helliwell is based on expert judgement and focuses on valuing the visual amenity of a tree.

Helliwell (2008a) argues that there is a need for a tree valuation method that is independent both of the cost of originally growing the tree and of the potential replacement cost. For example, a majestic historic tree of great beauty may have grown at no cost and without human intervention, while an expensive tree can be ugly or inappropriately located. Furthermore, it can be very expensive or sometimes impossible to purchase a comparable replacement tree (except for relatively small, young trees). The system focuses on evaluation of the relative contribution of woodlands and urban trees to the visual quality of the landscape.

The Helliwell method has three steps:

1. Trees are scored according to their attributes. The method focuses on visual amenity and scores the factors mainly on a scale of 0 to 4. The six factors are: tree size (maximum 8 points), useful life expectancy, importance of position in the landscape, presence of other trees (scarcity issue), relation to setting (each of these factors may contribute a maximum of 4 points) and form (maximum 2 points). Previously the system also contained special factors which were not purely visual such as historical association or exceptional rarity. These are no longer included (Helliwell 2008b).
2. The factor scores are multiplied together, and scores are tested for internal consistency.
3. A conversion factor from points to monetary value is derived from the knowledge of the assessed tree's effects on property, and the costs of retaining or replacing trees. A conversion factor assigning a monetary value per point of £25 is recommended in 2008 version. The monetary value is not linked to nursery prices but determined by expert consensus and can be adjusted for inflation. The decision on monetary conversion factor is linked to property prices, the value of tourist trade, effects on mental health and well-being as well as on the amount of money available for reasonable expenditures on tree planting, conservation and management.

Given a base value of £25 and a maximum achievable overall score of 4096 (8 x 4 x 4 x 4 x 4 x 2) a single tree can be valued at most at £102 400.

The Helliwell system is explicitly expert-based with many of the factors (e.g. useful life expectancy, importance of position in the landscape and relation to setting/context) scored on the basis of expert judgement (Price, 2007).

i-Tree

i-Tree is the most demanding of three valuation systems reviewed in terms of data requirements but it also yields the most detailed outputs in terms of annual street trees benefits and various management costs.

i-Tree, uses tree inventory data as an input to quantify the monetary value of annual environmental and aesthetic benefits (energy conservation, air quality improvement, CO₂ reduction, stormwater control, and property value increases). It allows users to answer an important question relating to their tree programmes: Do the accrued benefits of street trees outweigh their management costs?

Three kinds of benefit and cost analyses (listed below) and fourteen kinds of resource structural analyses are available.

1. Annual benefits: each benefit is quantified in terms of resource units and dollar value assigned to resource units. Reports show a standard error function that describes the uncertainty for sample inventories. The five annual benefits assessed are:
 - (i) Energy conservation – the sum of energy savings due to reduced natural gas use in winter (measured in MBtu per tree per year) and reduced electricity use for air conditioning in summer (measured in kWh per tree per year).
 - (ii) Stormwater – a measure of reduced annual stormwater run-off due to trees (measured in hundred cubic feet [CCF] per tree per year).
 - (iii) Air quality improvements – the sum of air pollutants (O₃, NO₂, SO₂, PM₁₀) deposited on tree surfaces and reduced emissions from power plants (NO₂, SO₂, PM₁₀ and VOCs) due to reduced electricity use (measured in £ per tree per year). The model accounts for potential negative effects of trees on air quality due to BVOC emissions.
 - (iv) CO₂ reduction - the sum of decreased atmospheric CO₂ due to sequestration by trees and reduced emissions from power plants due to reduced energy use. The model accounts for CO₂ released as trees die and decompose and CO₂ released during the care and maintenance of trees.
 - (v) Aesthetic/other – a measure of the tangible and intangible benefits of trees reflected in increases in property values due to trees. Based on the study by Anderson and Cordell (1985) every large front-yard tree increases house sale price by 0.88%, for other trees reduction factors are applied (see, for example, Maco and McPherson (2003), McPherson (2007) and Vargas *et al.* (2007)).

In addition a Summary is provided of the total of energy, stormwater, air quality, carbon dioxide, and aesthetic/other benefits. This is reported as \$ per tree or Total \$.

2. Management costs: total expenditures are summed based on costs associated with street tree management (e.g. planting, pruning, tree/stump removal and disposal, pest and disease control, establishment/irrigation, price of repair/mitigation of infrastructure damage, cost of litter/storm clean-up).
3. Net Annual Benefits: citywide benefits and costs are considered, net benefits (benefits less costs) determined, and the benefit–cost ratio (benefits/costs) calculated.

Comparative analysis

The comparison of the three reviewed street tree valuation systems in terms of origin, aims, applicability, valuation methods, data requirements and outputs is summarised in Table 1. The environmental and social benefits that are assessed by the three street trees valuation systems are summarised in Table 2. Two of the three valuation schemes: CAVAT and i-Tree, take substantial account of the social/cultural value component of trees. CAVAT does it by adjusting the tree value using population density and relative accessibility (to serve as a rough proxy of social importance). i-Tree considers aesthetic and other benefits reflected in property prices. i-Tree also covers a wider range of environmental benefits (such as shading from sun/wind in summer/winter, reduction in stormwater runoffs, air quality and CO₂ impacts) than the other two systems.

None of the three systems is able to comprehensively quantify the biodiversity or social/cultural benefits of the trees despite these value components often being considered the most important in terms of their intrinsic value to society. The street tree valuation systems reviewed also omit the following ecosystem services expected to be covered by the UK National Ecosystem Assessment (NEA) in valuing the benefits of woodlands:

- Fuel provision (wood fuel from arboricultural operations)
- Genetic resources provision (biodiversity)
- Noise regulation
- Spiritual
- Recreation
- Tourism
- Community development

Both Helliwell and CAVAT valuation methods are intrinsically capped. Helliwell yields a maximum value of £102 400 for a single tree (given a base value of £25 recommended in 2008). CAVAT is more open ended in that its base value depends significantly on tree trunk area size (RICS, 2010).

Table 1 Comparative analysis of the three systems.

	CAVAT	Helliwell	i-Tree
Purpose	To provide 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.	To aid practical planning and management (e.g. felling, pruning, planting) of woodlands and urban trees by evaluating their relative contribution to the visual quality of the landscape.	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.
Applicability	Applicable at all scales from an individual tree (use Full method) to a whole stock of trees in a given metropolitan area (use Quick method).	Originally developed to value a single tree or a group the methodology was extended to cover urban woodlands as well.	at all scales from individual trees, parcels, neighborhoods, cities, to entire states.
Methodology	Consider the value of a tree over its remaining expected life time. Applies adjusted replacement cost approach similar to one used in the Council of Tree and Landscape Appraisers (CTLA). The 'trunk formula method' yields an initial replacement cost value.	Expert judgement (argues that there is a need for a tree valuation method that is independent both of the cost of originally growing the tree and of the potential replacement cost). Consider the value of a tree over its remaining expected life time.	Value (benefit) transfer. Focuses on the annual flow of current costs and benefits provided.
Data inputs	Relies on tree measurements, government data for the Community Tree Index (CTI) calculation, and expert assessment (for functional value, amenity and safe life expectancy).	Minimal field data requirements (basic tree measurements), view of tree(s) and surroundings.	Complete or sample inventory of the community's street trees. This must include species, diameter at breast height (dbh) and tree ID data. Over ten additional tree attributes can be utilised.
Outputs	Monetary value of tree(s).	Monetary value of tree(s).	Monetary value of tree(s): by type of benefit (five categories: air quality, energy conservation, stormwater, CO ₂ reduction, aesthetic/other), total benefits, management costs, and net benefit.
Origin	2007 Christopher Neilan United Kingdom www.ltoa.org.uk/cavat.htm	1967 Rodney Helliwell United Kingdom www.trees.org.uk/publications/guides	2006 USDA Forest Service United States of America www.itreetools.org

Table 2 Matrix of environmental and social benefits for street tree valuation systems.

	CAVAT	Helliwell	i-Tree
Environmental	<ul style="list-style-type: none"> Nature Conservation, including 'particular wildlife importance' or veteran/ancient tree aspect and species characteristics (rare or unusual species, or shape). 	None.	<ul style="list-style-type: none"> Energy conservation due to reduced natural gas use in winter (wind shield effect) and reduced electricity use for air conditioning in summer. Reduction of annual stormwater runoff. Air quality improvements (O₃, NO₂, SO₂, PM10, VOCs and BVOC). Carbon dioxide sequestration.
Social and cultural	<ul style="list-style-type: none"> Relative population density potentially able to benefit from the trees (measured by a Community Tree Index, CTI). Relative accessibility to the public. Townscape and visual importance. National or Local designations or connections. 	<ul style="list-style-type: none"> Importance of position in the landscape. Presence of other trees. Relation to setting. 	<ul style="list-style-type: none"> Aesthetic/other – a measure of the tangible and intangible benefits of trees reflected in increases in property values due to trees.

Conclusions

The review showed that the three valuation systems differ significantly in methodology, data input requirements and outputs. At one end of the spectrum the Helliwell system is entirely based on expert judgement, focuses solely on visual amenity value and has very low field data requirements. At the opposite end of the spectrum i-Tree requires data collected from a sample or a complete inventory of the street tree population as well as community specific information (e.g. programme management costs, city population size, and price of residential electricity) to output customised benefit and cost data. CAVAT falls somewhere in between by focusing on wider benefits of trees to communities rather than purely visual amenity, but not outputting detailed benefit and cost data. In addition:

- The systems do not comprehensively cover the ecosystem services covered by the UK NEA framework (e.g. noise reduction, woodfuel provision and biodiversity preservation). However this omission is likely to be more significant when valuing inventories of street trees than for individual trees.
- Both CAVAT and i-Tree amenity trees valuation systems can meet the needs of both small communities and large metropolitan areas. However, if limitations on data availability can be overcome, i-Tree offers significant advantages of flexibility, detailed output and allowing a wide range of benefits to be assessed. The Helliwell system seems best suited to single tree and small scale community evaluations, but can also handle urban woodlands.
- Valuation under CAVAT and Helliwell differs fundamentally from that under i-Tree as the former consider the value of a tree over its remaining expected life time, while the latter focuses upon the current annual benefits provided.
- i-Tree seems to be the most flexible and developed system with strong emphasis on assessing economic and environmental annual benefits. It has the benefit of being a free, non-proprietary open-source software package that supports the entire valuation process from field inventory data input to generating final reports but requires considerable preparatory work. CAVAT is also openly available and is simpler to implement if data are limited.

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