Tools for valuing tree and park services

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Arborists and urban foresters plan, design, construct, and manage trees and parks in cities throughout the world. These civic improvements create walkable, cool environments, save energy, reduce stormwater runoff, sequester carbon dioxide, and absorb air pollutants. The presence of trees and green spaces in cities is associated with increases in property values, perceived consumer friendliness, and a sense of well-being. They can create a distinct, memorable place identity and offer animal habitat. The value of these services is not lost on most arborists, because creating and managing multifunctional spaces that make cities more livable is at the core of what they do. But quantifying the value of these services is not the profession's lingua franca. Fortunately, several new tools have been developed that arborists can use to more effectively communicate the ecosystem services and other benefits trees and parks produce.

As interest in non-traditional "green infrastructure" solutions to managing stormwater, air quality, urban heat islands, and climate change grows, so does the need to better incorporate performance and cost-effectiveness into the planning, design, and evaluation process. By quantifying and valuing the ecosystem services produced by trees and parks, arborists can better assess the world they are creating and focus on what they need to do to improve that world, both now and in the future. This article describes three tools for measuring what truly matters, the value of trees and parks to quality of life in our communities.

Background

Trees and parks are pockets and ribbons of green meandering through a largely gray landscape. They form an interconnected network of "green infrastructure" that can be integrated into "gray infrastructure." The tools described here focus on trees and parks because they are the largest structural elements and responsible for most benefits and costs. Their value is equal to the net benefits that members of society obtain from them. A park or urban forest's structure and function contribute to its value. Here, 'structure' refers to the tree population's species composition, age diversity, and condition, as well as the way trees are arrayed in relation to other objects. 'Function' refers to impacts of trees and parks on variables such as air quality, energy use, property values, recreational opportunities, and mental well-being. When measured as outputs, functions are expressed in engineering units, such as kWh of electricity saved. 'Value' refers to the monetary benefits and costs society derives from goods and services produced by the trees and parks. Monetizing the value of these goods and services is difficult because they are not traded in the marketplace. No one pays a park to clean the air or a tree to shade a bench. As a result, value is estimated using avoided damage or control costs. For example, if a community or developer is willing to pay an average of $0.01 per gal of treated and controlled runoff to meet minimum standards, then the stormwater runoff mitigation value of a tree that intercepts 1,000 gal of rainfall, eliminating the need for control, should be $10 (McPherson 1992).

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Arborists often collaborate with planners, architects, engineers, and other stakeholders on urban greening projects. There are three types of stakeholders who benefit most from information on tree and park values: the general public, managers, and political leaders. Members of the public can become better advocates for urban greening projects when armed with data on the value of tree services. Park and urban forest managers use these data to identify management priorities, develop funding requests, estimate benefits from future projects, and educate partners about the value of their parks and trees. As stewards of the public welfare, politicians use information on tree and park values to support decision-making on public policies, programs, and budgets. Monetizing the value of ecosystem services and other benefits produced by trees and parks creates a more level playing field for policy decisions involving conservation and management of existing greenspace, as well as its expansion.

CUFR TREE CARBON CALCULATOR (CTCC)

What it does

Developed by the USDA Forest Service, Center for Urban Forest Research (CUFR) and first released in 2008, the CTCC is a free Microsoft Excel spreadsheet that provides carbon-related information for a single tree in one of 16 U.S. climate zones. It is the only tool approved by the Urban Forest Project Protocol for quantifying carbon dioxide sequestration from tree planting projects (Climate Action Reserve, 2010).

Tree size data are based on growth curves developed from samples of about 1,000 street trees representing approximately 20 predominant species in each of the 16 reference cities (Peper et al., 2001a, b). Most of the biomass equations and calculations used to derive total CO_2 stored, total stored above ground, and annual CO_2 sequestered are from open growing urban trees. To determine effects of tree shade on building energy performance, over 12,000 simulations were conducted for each of the 16 reference cities using different combinations of tree sizes, locations, and building vintages (McPherson and Simpson, 2000).

Why use it?

CTCC outputs can be used to estimate GHG (greenhouse gas) benefits for existing trees or to forecast future benefits for proposed planting projects. The CTCC can be used to quantify and report changes in carbon stocks from urban forestry projects to the CAR or other registries.

The tool is being used by the City of Santa Monica, CA in its pilot GHG tree project and by the Sacramento Tree Foundation to estimate GHG reductions associated with a voluntary carbon offset tree planting project.

How it works

Users enter information such as a tree's climate zone, species name, size or age. A dropdown menu shows a list of the most common tree species in each climate zone. Users that want to calculate carbon and energy results for a species not included in the list must choose the species from the same climate zone with the most similar growth rate and mature size. If tree age is unknown the user can measure and enter size as diameter-at-breast height (d.b.h.). Information is provided on measuring d.b.h and converting from tree circumference to d.b.h. The program estimates how much carbon dioxide the tree sequestered in the past year and over its lifetime (Figure 1). It calculates the biomass (dry weight) that would be obtained if it were removed. Trees planted near buildings to reduce heating and cooling costs require additional inputs because they also reduce GHGs emitted by power plants while generating electricity. These inputs include information on the tree's distance and compass bearing relative to a building within 50 ft of the tree, building vintage (its age, which influences energy use), and types of heating and cooling equipment. The CTCC automatically calculates annual heating and cooling energy savings, as well as associated power plant reductions using existing or user supplied emission factors for local utilities.

Table 1. Results from an assessment of Philadelphia's park system using the Park Value Calculator

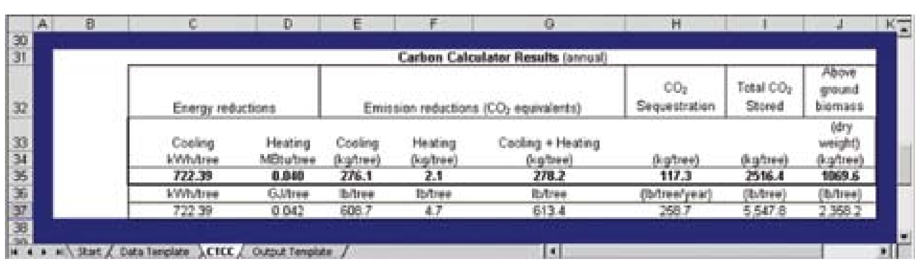
Park Attribute	Annual Value ($)
Property Value from Park Proximity	$688,849,128
Tourism	$40,263,000
Direct Use	$1,076,303,000
Health	$69,419,000
Community Cohesion	$8,600,000
Clean Water	$5,949,000
Clean Air	$1,534,000
Total	$1,890,197,128

Features and drawbacks

This computer application is simple to download from the web. The entire suite of inputs (for the project and the tree) and outputs are viewable at once. Drop-down menus and hot-links to the help documentation make it easy to use for persons with basic computer skills.

Carbon reporting currently uses a hybrid of SI and English units, for example kg/MBtu. The most common

Figure 1. Output section of the CTCC for an energy conservation and carbon storage project.



Carbon Calculater Results (annual)

Energy reductions		Emission reductions (CO_2 equivalents)			CO_2 Sequestration	Total CO_2 Stored	Above ground biomass
Cooling kWh/tree	Heating MBtu/tree	Cooling (kg/tree)	Heating (kg/tree)	Cooling + Heating (kg/tree)	(kg/tree)	(kg/tree)	(dry weight) (kg/tree)
722.39	0.040	276.1	2.1	278.2	117.3	2516.4	1069.6
kWh/tree	GJ/tree	lb/tree	lb/tree	lb/tree	(lb/tree/year)	(lb/tree)	(lb/tree)
722.39	0.042	608.7	4.7	613.4	258.7	5,547.8	2,358.2

unit for tree d.b.h. measurement is inches, which is used in the CTCC, while outputs are given in SI and English units (e.g., kilograms and pounds CO_2 equivalents).

Users should recognize that conditions vary within climate zones, and data from the CTCC may not accurately reflect their rate of tree growth, microclimate, or building characteristics. When conditions are different it may be necessary to apply biomass equations manually using adjusted tree growth data.

Application of this program is problematic when the tree or planting site is outside the U.S., lies on the border between two climate zones, or has a different climate or tree species composition than the U.S. reference city. Another drawback is limiting analysis to a single tree at a single time. The program lacks the capability to quantify carbon storage for a large-scale tree planting project and track change in carbon stocks over time. Also, there is no direct way to adjust estimated future storage rates based on historic tree growth measurements.

How to get it

The CTCC can be downloaded from the U.S. Forest Service Climate Change Resource Center web site **http://www.fs.fed.us/ccrc/topics/urban-forests/**. The website contains other resources on the topic of urban forests and climate change, including a link to the Urban Forest Project Protocol (CAR, 2010).

I-TREE

What it does

i-Tree is public-domain software developed by the USDA Forest Service and cooperators for urban forestry analysis and benefits assessment. i-Tree helps communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the ecosystem services that trees provide. i-Tree is supported through a collaborative partnership that includes Davey Tree Expert Co., Arbor Day Foundation, International Society of Arborists, and the Society of Municipal Arborists.

Within i-Tree, entire urban forest tree populations are assessed using Eco (formerly UFORE) whereas discrete street tree populations are assessed using Streets (formerly STRATUM). Several utilities provide additional functionality for species selection and storm damage assessment.

Why use it?

Since version 1.0 of i-Tree was released in August 2006, numerous communities, non-profit organizations, consultants, volunteers and students have used i-Tree to report on individual trees, parcels, neighborhoods, cities, and even entire states. By understanding the local, tangible ecosystem services that trees provide, i-Tree users can link urban forest management activities with environmental quality and community livability. Whether interest is a single tree or an entire forest, i-Tree provides baseline data to demonstrate value and set priorities for more effective decision-making. Both i-Tree Eco and Streets were used in New York City. Street trees were found to provide \$122 million in benefits annually, or \$5.60 in benefits for every \$1 spent on tree planting and care. Largely due to this new information, trees were the environmental cornerstone of newly elected New York City Mayor Michael Bloomberg's sustainability plan. His plan called for \$380 million in new funds for urban forestry efforts over the next 10 years (Kling, 2008).

How it works

i-Tree Eco quantifies urban forest structure, environmental effects, and value to communities from field data and local hourly air pollution and meteorological data (Nowak et al., 2008). Baseline data can be used to make effective resource management decisions, develop policy, and set priorities. Setting up Eco projects for small, complete populations of trees is relatively straightforward because no sampling is involved. Eco projects where all trees in the study area will be examined are usually associated with discrete properties such as apartment complexes or cemeteries, or park inventories. Eco sampling projects are typically used where the designated study area is too large to cost-effectively inventory the entire tree population. Sampling projects obtain estimates of the characteristics and benefits of a study area from a series of preselected sample plots. Such projects usually require project setup that can include characterization of land use and random selection of plot locations in a city using aerial photography or GIS. Sometimes access to sample plots on private property can be difficult.

i-Tree Streets is a street tree specific analysis tool for urban forest managers that uses tree inventory data to quantify structure, function and value of annual benefits. Using a sample or an existing inventory of street trees, this software allows managers to evaluate current benefits, costs, and management needs (Maco and McPherson, 2003; McPherson et al., 2005). The first step in creating a Streets project is defining the street tree population for the project. The population can range from a single planting site to a particular neighborhood, but it is more commonly the entire city street tree population. Users have the option of analyzing an existing street tree inventory or completing a new Streets-compatible inventory. If an existing street tree inventory is not available, users must decide whether a complete or sample inventory of their community's street trees will be conducted. A complete inventory provides a comprehensive picture of the urban forest, and a foundation for managing daily work activities. A sample inventory is quicker, less expensive, and can provide baseline data for decision making, but cannot be used for day-to-day management activities. For communities without an inventory, Streets data collection protocols provide guidance for data collection using the integrated PDA

Utility or paper and pencil. Designed to be flexible and adaptive, Streets can accept and analyze data provided species name and d.b.h. are present and that Streets inventory formatting protocols are correctly followed. While Streets can report on complete inventories, it is not intended to be a day-to-day inventory management application. i-Tree Streets includes tree care cost data, allowing users to produce annual benefit-cost ratios for the tree resource.

Eco and Streets produce tables and charts of information on urban forest structure, function, and value that can be exported in a variety of formats (e.g., pdf, xls, doc). Structural information includes relative abundance by species, size distribution by d.b.h., condition, and compensatory or replacement value. Eco calculates potential losses should various pests destroy susceptible tree species. Both models calculate the value of ecosystem services: carbon storage and sequestration, air pollution removal and release of biogenic volatile organic compounds (BVOCs), and building energy effects. Streets includes output on rainfall interception and property value increase (**Figure 2**).

Features and drawbacks

The integrated PDA Utility allows users to streamline data collection for selected data fields and then upload from the PDA to the PC. Streets data can be entered directly into the PC-based Streets software, where the user can immediately view analysis reports. Eco data are sent via the software program to the U.S. Forest Service laboratory in Syracuse for processing. Users are notified via email when the data have been processed and are ready for downloading. The Eco application is used for viewing, printing and exporting results.

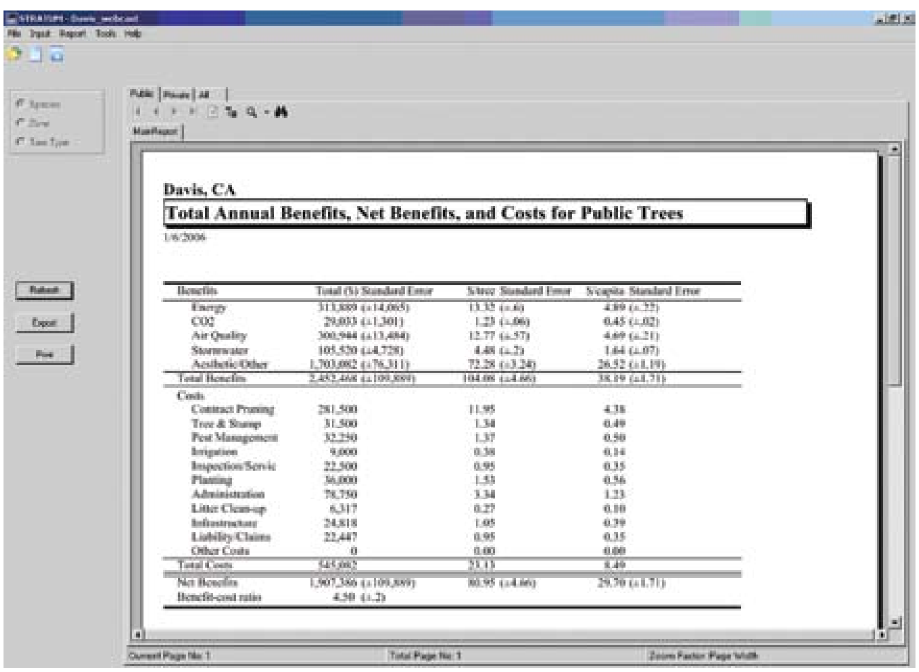
The i-Tree programs require specific types and amounts of data to accurately project the structure and benefits of urban vegetation. The validity of results depends on how closely users adhere to project setup and sampling protocols. Although the i-Tree programs are user-friendly, there is not much opportunity to adjust inputs or modify the calculations. This "black-box" design limits usefulness of the programs for customized applications.

i-Tree is used primarily in the U.S., there are approximately 6,000 users in 83 countries around the world. The percent of international users is about 20%, with Eco accounting for most of these. Eco uses local hourly meteorological and air pollutant data that the international user collects and formats. Tree size and growth data are based on adjustments for frost free days, crown light exposure, and condition to a U.S. base rate of 0.33 in/year d.b.h. i-Tree Eco requires intensive field data collection compared to Streets, however Streets uses environmental and tree size data that are specific to each of the 16 U.S. climate zones, a drawback for international applications. Results from Streets applied outside the U.S. can have high levels of uncertainty because tree growth and environmental data from the U.S. reference city may not be a good match for the international city. A recent paper uses Lisbon, Portugal as an example to illustrate a systematic process for selecting the U.S. reference city that best matches the user's city (McPherson, In Press).

How to get it

i-Tree manuals and software can be downloaded from the i-Tree web site at http://www.itreetools.org. The i-Tree cooperative maintains email, phone and an on-line forum to provide user support.

Figure 2. Output from i-Tree Streets for a street tree sampling project.



Davis, CA

Total Annual Benefits, Net Benefits, and Costs for Public Trees

1/6/2006

Benefits	Total ($) Standard Error	$/tree Standard Error	$/capita Standard Error
Energy	313,889 (±14,065)	13.32 (±.6)	4.89 (±.22)
CO2	29,033 (±1,301)	1.23 (±.06)	0.45 (±.02)
Air Quality	300,944 (±13,484)	12.77 (±.57)	4.69 (±.21)
Stormwater	105,520 (±4,728)	4.48 (±.2)	1.64 (±.07)
Aesthetic/Other	1,703,082 (±76,311)	72.28 (±3.24)	26.52 (±1.19)
Total Benefits	2,452,468 (±109,889)	104.08 (±4.66)	38.19 (±1.71)
Costs			
Contract Pruning	281,500	11.95	4.38
Tree & Stump	31,500	1.34	0.49
Pest Management	32,250	1.37	0.50
Irrigation	9,000	0.38	0.14
Inspection/Servic	22,500	0.95	0.35
Planting	36,000	1.53	0.56
Administration	78,750	3.34	1.23
Litter Clean-up	6,317	0.27	0.10
Infrastructure	24,818	1.05	0.39
Liability/Claims	22,447	0.95	0.35
Other Costs	0	0.00	0.00
Total Costs	545,082	23.13	8.49
Net Benefits	1,907,386 (±109,889)	80.95 (±4.66)	29.70 (±1.71)
Benefit-cost ratio	4.50 (±.2)		

PARK VALUE CALCULATOR

What it does

The Park Value Calculator (PVC) quantifies the annual monetary value of seven attributes of city park systems (Harnik and Welle, 2009). It has been applied in the cities of Washington, D.C., Boston, Sacramento, San Diego, Philadelphia, Wilmington, Charlotte, Denver, and Seattle by the Trust for Public Land's Center for City Park Excellence (CCPE).

Why use it?

Information from the PVC has been successfully used by park managers to focus attention of decision-makers on the value of park systems and the need to adequately fund their operation and maintenance. Park advocates have used results from the PVC analy-

Urban forests provide many environmental and economic benefits. View of Los Angeles taken from the Getty Center. ***Photo: Bruce W. Hagen***

ses to argue for increased investment in their local park systems. For example, the 2008 release of the CCPE's report for Philadelphia found that the park system provided services valued at $1.9 billion annually (Table 1) (Harnik and Welle, 2008). Newly elected Mayor Michael Nutter made restoration of the park system a cornerstone of his green agenda, in part because of its value as a community asset. Now Philadelphia is reorganizing its parks management programs, developing innovative uses of parks as green infrastructure for stormwater management, and planning strategic investments to restore this system to its former glory.

How it works

CCPE staff conduct the PVC analyses with assistance from cities. This involves initial presentations, data collection with help from city staff, modeling of park services, and presentation of the final report. A brief description of each of the seven park models follows.

Property value – the positive impact that parks have on nearby residential properties. Increased property values result in increased tax revenue for city services. This hedonic value is calculated based on the number of homes located within 500 ft of parkland and the quality of the park. Computer mapping of crime rates near parks is used to assess park quality.

Tourism – the economic impact of parks and special events that take place there and draw out-of-town visitors. The number of tourists attracted by park events and their spending due to distance traveled and days spent are factors used to calculate increase in wealth from park-based tourism.

Direct use – the value provided through such activities as team sports, bicycling, sledding, skateboarding, walking, picnicking, bench-sitting, and visiting a flower garden. Direct use value represents the amount of money residents save by not having to pay market rates for park activities. It depends on the number of users, types of uses engaged in, and the value of each use on the open market.

Health – the collective economic savings realized by city residents because of their use of parks for exercise. Lack of exercise has been shown to contribute to obesity, heart disease, and diabetes. The PVC uses information on the amount of active recreation occurring in parks and the age distribution of recreationists to estimate the value of parks promoting human health.

Community cohesion – the economic value of increased "social capital" produced when webs of human interactions are created to support parks systems. The value of institution-building on behalf of parks is determined by adding up financial contributions to park foundations, conservancies, and "friends of parks" organizations, as well as donations of time and volunteer labor.

Clean water – the value of reduced costs for stormwater management because parkland acts like a mini-reservoir to reduce runoff. The value of this benefit is based on the city's cost to manage stormwater and the annual volume of stormwater runoff reduction due to the park's soil type, tree canopy cover, and area of impervious surfaces.

Clean air – the value of vegetation in city parks in improving air quality. The amount of pollutant uptake depends on the number of trees and percent of tree canopy cover, as well as local pollutant concentrations. The monetary value of this service is based on the median U.S. externality value for controlling each pollutant.

Features and drawbacks

Results from the PVC broaden community thinking about the value of park systems because they incorporate a wide range of economic benefits. While most people recognize that parks are venues for recreation and relaxation, their contribution to the tourist economy and property values comes as a surprise. By quantifying the multi-dimensional services provided by parks, this tool increases awareness and stimulates discussion about what is needed to perpetuate park systems.

The biggest drawback of the PVC is the large amount of uncertainty associated with estimates of monetary value. Basic data on park use are often lacking and simplifying assumptions are necessary. As a result, it is impossible to determine how accurate the estimates of park value actually are. The PVC is based on recommendations from a panel of experts who convened in 2006, but the models and their application have not been peer-reviewed.

Although the PVC software is available to the public, implementing studies require special expertise that most cities don't have. Also, cities appreciate having experts from the CPPE conduct studies and present results. The cost is $40,000 to $60,000, which includes original research, such as a 600-person telephone survey and computer mapping of parks and nearby land.

How to get it

More information on the PVC is available from the Trust for Public Land's web site at **http://www.tpl.org**.

Conclusions

Other tools and models exist to support greenspace valuation and decision-making. American Forest's CITYgreen computer software quantifies effects of urban forests on stormwater runoff, air pollution removal, and carbon storage. An extension to ArcGIS, different versions of CITYgreen are available for educators, planners, and GIS professionals **http://www.americanforests.org/productsandpubs/citygreen/**.
The Center for Neighborhood Technology's Green Values Stormwater Calculator quantifies the hydrological and financial differences between a conventional landscape and a site with user-selected green interventions such as increased tree cover, porous pavement, and drainage swales. The analysis is performed on-line at **http://greenvalues.cnt.org/**.

Quantifying and valuing tree and park services will become easier and more accurate as analytical tools are improved. The emergence of multi-service platforms, such as Bay Bank in the Chesapeake Bay region, will promote more integrated assessments that include credits for forest conservation, habitat conservation, water quality, and carbon sequestration (Sample, 2010). Quantifying and verifying that these credits are real, additional, and permanent will require better tools that generate regulatory quality data. These tools will assist arborists and urban foresters in the process of integrating the green and gray infrastructure in our communities.

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