US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

NO. 13 | SUMMER 2011

Urban Tree Canopy Analysis Helps Urban Planners With Tree Planting Campaigns

Trees in cities may not look like parts of a typical forest, but they do provide valuable ecosystem services to urban and suburban dwellers. Tree canopies shade and cool sidewalks and buildings, thus reducing the urban heat island effect and saving energy and reducing air pollution. They also improve water and air quality and provide wildlife habitat. Trees make neighborhoods more livable and provide aesthetic and psychological benefits for human and other residents. For example, New York City's Central and Prospect Parks are havens for migrating birds as much as for New Yorkers.

City trees are termed the "urban forest" by foresters and researchers who specialize in them. The urban forest is defined as the system of trees and associated plants that grow individually, in small groups, or under forest conditions on public and private lands in our cities, their suburbs, and towns. This includes an estimated 74.4 billion trees across the United States. As the world's populations become more and more urban—current estimates put half the world's population living in cities—urban trees and their benefits become increasingly important.

Many city residents value their street trees and city governments and civic associations have become big boosters of trees and tree planting all over the United States. For example, New York City Mayor Michael Bloomberg has set in motion an ambitious tree-planting campaign called "MillionTreesNYC." Philadelphia has its "Greenworks" program, Boston its "Boston Tree Party," and Worcester (Massachusetts) is working to replace more than 25,000 trees cut down in the battle against the Asian longhorned beetle (ALB). Many other cities, large and small, are involved in similar projects. The recent outbreaks of invasive bark-boring beetles—such as the emerald ash borer in Detroit and other Midwestern cities and the ALB in New York City, Long Island, Chicago, Carteret (New Jersey), and Worcester—have made urban dwellers realize how precious and vulnerable their street, park, and yard trees are. Possible alterations in temperature and precipitation patterns from global climate change are also of concern.

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Photo by Joseph O'Brien, U.S. Forest Service

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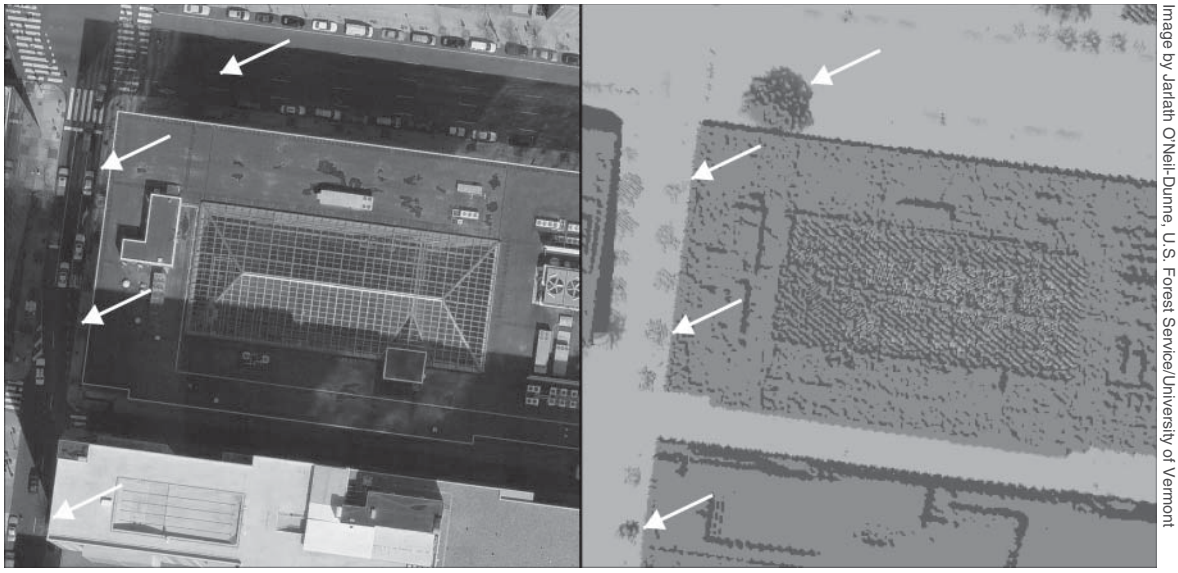

Image by Jarlath O'Neil-Dunne, U.S. Forest Service/University of Vermont

Mapping tree canopy is a challenge in urbanized areas as building shadows can obscure tree canopy by buildings when viewed using overhead imagery (left). LiDAR (right), which is not sensitive to shadowing, can detect these trees, allowing for detailed and accurate mapping of tree canopy.

HELPING CITIES MEASURE THEIR URBAN FORESTS

An important part of urban tree planting campaigns is measuring and evaluating current urban forests so that realistic tree-planting goals can be set. The term "urban tree canopy" (UTC) is used to describe the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Scientists now use various aerial and satellite reconnaissance methods to measure and evaluate the UTC. Northern Research Station (NRS) scientists have developed techniques to analyze and prioritize UTC data so that urban planners and parks departments can focus their efforts on locales that benefit most from tree planting.

Although aerial and satellite images can now show amazing detail, there are substantial shortcomings to using reflected light in mapping the UTC in urban areas—trees can be totally obscured by building shadows. A technology similar to radar is now being used instead to overcome these limitations—LiDAR (light detection and ranging). Unlike most aerial and satellite imaging systems, LiDAR sensors emit their own energy (near-infrared light) in the form of laser light, which is not sensitive to shadows. In addition, LiDAR data can provide estimates of height of features to within a few centimeters. Using advanced processing algorithms, NRS researchers are thus able to extract accurate and detailed estimates of the current tree canopy as well as find new locations to plant trees.

LiDAR is now about 20 years old, and has been used like radar by state troopers to catch speeders! Around 2005, NRS researchers—Morgan Grove (research forester at the Baltimore Ecosystem Study) and Jarlath O'Neil-Dunne (a geospatial analyst who is jointly funded by the U.S. Forest Service NRS and the University of Vermont's Rubenstein School of Environment and Natural Resources)—developed process protocols for using LiDAR to inventory and analyze the UTC. Their first city was Baltimore, MD, and the team has completed UTC assessments for over 50 cities and towns, encompassing over 300 communities, mostly in the mid-Atlantic and northeastern states.

UTC estimates made with LiDAR rather than reflected light are considerably more accurate. Individual trees cumulatively can contribute substantially to a city's overall tree canopy. In Philadelphia, previous estimates that ignored small trees put the total tree canopy at 10 percent of the city's total land area. The newer and more advanced techniques developed by NRS scientists and their university collaborators, which can accurately detect smaller patches of canopy, revealed twice that amount, or 16,884 acres of existing tree canopy.

BENEFITS FROM UTC ASSESSMENTS FOR LARGE AND SMALL MUNICIPALITIES

The NRS team of O'Neil-Dunne and Grove has used LiDAR to assess urban tree canopies as they do exist and also to project what could exist. Their assessments help urban planners set goals of several kinds, such as optimal, possible, and affordable. This information is invaluable in planning, setting budget priorities, and fundraising. So far, they have assessed UTCs mostly in cities and towns in the East. A summary of UTC programs in two of our nation's largest cities and two typical small regional cities/towns in Maryland and Vermont follow.

NEW YORK CITY

The Big Apple, largest city in the United States (2010 city population, 8.1 million; metro population, 19.3 million), has many programs to improve and enlarge its UTC. The NYC Office of Long Term Planning and Sustainability funded LiDAR data collection for assessing NYC's urban tree canopy, providing urban forest managers more detailed and accurate measurements of UTC than ever before. A partnership between the NRS and the New York City Department of Parks and Recreation, termed the "New York City Urban Field Station," hosted a workshop (2010) for city agencies and partners that leveraged the city's investment in LiDAR to educate users about potential uses for tree canopy mapping, potential flood mapping, and potential solar panel locations.

Dexter Locke at the NYC Urban Field Station has developed a set of UTC prioritization tools that combine urban ecological information at socially meaningful scales, based on stakeholder provided criteria. This toolset is the evolutionary next step and extends UTC analyses further by providing guidance on where to plant additional trees.

J. Morgan Grove, U.S. Forest Service

Newly planted trees in Baltimore.

Large-scale tree planting campaigns are on the rise in cities across the United States... An urban tree canopy assessment is essential to prioritizing planting areas, projecting long-term needs, and strengthening our collective capacity for stewardship.

Erika Svendsen, research social scientist, NRS New York Urban Field Station

PHILADELPHIA

The City of Brotherly Love, the fifth largest city in the United States (2010 city population 1.53 million; metro population 6.1 million), is creating a strategic plan to reach its Greenworks campaign goal of planting 300,000 trees by 2015. With the help of the U.S. Forest Service, the city has conducted an urban tree canopy assessment with LiDAR satellite technology that includes virtually every tree in Philadelphia and identifies the best opportunities for planting. In the meantime, the city is working to find nursery stock for its ambitious planting schedule and to revise its zoning code to encourage tree planting.

In April 2010, the Philadelphia Department of Parks and Recreation kicked off "Green Philly, Grow Philly" the first phase of a comprehensive tree-planting campaign. To achieve the tree coverage goal, the city has built on existing partnerships among Parks and Recreation, the Philadelphia Water Department, and the Pennsylvania Horticultural Society by working side-by-side with private organizations, nonprofits, neighborhoods, and individual residents. The University of Pennsylvania has signed on as the first institutional partner.

In an exciting new development, the NRS has signed a memorandum of understanding for establishing a Philadelphia Urban Field Station to be located at the headquarters of the Pennsylvania Horticultural Society in Center City. The urban field station will focus on promoting urban natural resources stewardship, adaptive management, technology transfer, and science to improve people's lives and the environment in the Philadelphia metropolitan area.

CUMBERLAND

Cumberland, Maryland, is a small city in the western, mountainous portion of this mid-Atlantic state; it has a population of 21,591 (2000) and an area of 9.1 square miles. Cumberland is a regional business and commercial center for western Maryland and the nearby Potomac Highlands of West Virginia. Historically it was a major transportation center with the terminus of the Chesapeake and Ohio Canal and a major freight yard of the C&O Railroad. Now, Interstate 68 runs through the city. Its population has declined since 1950 due to a string of industrial plant closures.

Cumberland is located at the junction of the West Branch of the Potomac River and Wills Creek, making it part of the Chesapeake Bay Watershed. The ecological health of the Bay, which depends on the health of its watershed, is of great concern ecologically and economically to almost the entire mid-Atlantic region. Government and private programs are actively working to reduce the pollution loads entering the Bay from its watershed. The Maryland Department of Natural Resources (DNR) is working with the federal Chesapeake Bay Program and the private Chesapeake Bay Foundation to fund and support programs to reduce both point-source and non-point-source pollution. Riparian forests reduce pollution from agriculture, but communities also need to reduce their storm water runoff. The UTC assessment provided by NRS showed that about half of Cumberland's area is UTC, but most of it comes from forested lands within the city limits. Developed land in the city has a much lower percentage of UTC, 27 percent; possible UTC is 46 percent. Cumberland received a grant from the Maryland DNR and is now planning programs to increase its UTC numbers since its 2007 assessment.

BURLINGTON

Burlington, Vermont, on the shores of Lake Champlain, is the Green Mountain State's largest city, with a city population of 42,400 and a metro population of 208,000. Lying 45 miles from the Canadian border and 94 miles from Montreal, it is the cultural, media, and transportation center of central and northern Vermont. Its economy depends on education, vacation travel, and small industries. Interstate 89 leads to Canada (Montreal is much closer than NYC or Boston) and Amtrak's Vermonter train brings New York skiers and vacationers to Burlington.

Burlington often ranks highly on "Top 10" lists in the USA for beauty, livability, retirement, etc., and has received the "Tree City USA" award from the National Arbor Day Foundation since 1991. Burlington's urban forest, a mosaic of planted landscapes, native plants, and forest, is an important part of the city's self-image and a reflection of its health, well-being, and livability. Because Burlington is the home of both the NRS Aiklen Laboratory and the University of Vermont's Rubenstein School of Environmental and Natural Resources Geospatial Analysis Laboratory, the city government was one of the first to request a UTC assessment.

BIOGRAPHIES

J. Morgan Grove is an NRS research forester at the Baltimore Ecosystem Study (BES). The BES is one of only two urban long-term ecosystem research (LTER) studies funded by the National Science Foundation, and one of two in NRS. BES research examines environmental features like trees, waterways, and soils; built structures like roads, ports, houses, and industrial facilities; and social factors like the distribution of people, health problems, wealth, and crime. Grove received his B.A. in architecture and studies in the environment in 1987, two masters' degrees in community forestry and social ecology in 1990 and 1994, and his Ph.D. in social ecology in 1996, all from Yale. His first Forest Service position (1994) was as a visiting scientist at Syracuse, New York, and then as a research scientist at Burlington, Vermont, in 1996, working with O'Neil-Dunne. He is now stationed in Baltimore, Maryland, at the BES facility on the University of Maryland's Baltimore City campus.

Jarlath O'Neil-Dunne is a geospatial analyst with the University of Vermont's (UVM) Spatial Analysis Laboratory with a joint appointment with the NRS George Aiken Laboratory in Burlington, VT. He earned a B.S. in forestry from the University of New Hampshire, an M.S. in water resources from the University of Vermont, and certificates in hyperspectral image exploitation and joint GIS operations from the National Geospatial Intelligence College. For over a decade, he served as an officer in the U.S. Marine Corps and co-directed the Corps' imagery intelligence assets during the early stages of Operation Iraqi Freedom.

His research focuses on the application of geospatial technology to a broad range of natural resource—related issues such as environmental justice, wildlife habitat mapping, high-elevation forest decline, land cover change detection, community health, water quality modeling, and most recently, urban ecosystems. He received the NRS 2010 award for Excellence in Science and Technology and is a member of the Board of Directors for AmericaView, a consortium of organizations working on geospatial mapping projects. (www.americaview.org).

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Websites:

Federal Government and Partners

US Forest Service, Northern Research Station, People and Their Environments Research Unit:
www.nrs.fs.fed.us/units/socialscience
US Forest Service, Northern Research Station NYC Urban Field Station:
www.nrs.fs.fed.us/nyc
US Forest Service, Northeastern Area, State & Private Forestry:
www.na.fs.fed.us/urban
University of Vermont Rubenstein School of Environment and Natural Resources:
www.uvm.edu.rsenr

New York City

NYC Parks Department: www.nycgovparks.org
MilionTreesNYC: www.milliontreesnyc.org
MillionTreesNYC Research Symposium: www.catejournal.org/
New York Restoration Project: www.nyrp.org

Philadelphia, PA

Pennsylvania Horticultural Society: www.pennsylvaniahorticulturalsociety.org/phlgreen
Philadelphia City Government: www.Phila.gov/green

Cumberland, MD, and the Chesapeake Bay Watershed

Cumberland City: www.ci.cumberland.md.us/new_site/index.php/contents/view/178
Maryland DNR: www.dnr.state.md.us/forests/programs/urbantreecanopygoals.asp
www.chesapeakenemo.net

Burlington, VT

Burlington Parks Dept.: www.enjoyburlington.com/trees.cfm
www.branchoutburlington.org

Baltimore, MD

Baltimore Ecosystem Study: www.beslter.org

Boston, MA

Boston Tree Party: www.bostontreeparty.org
www.cityofboston.gov/parks/streettrees/growboston.asp

Washington, DC

Casey Tree Foundation: www.caseytrees.org

Worcester, MA

www.treeworcester.org
www.aphis.usda.gov/newsroom/content/2009/04/alb_tree_restore.shtml

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Our research themes are (1) Forest Disturbance Processes, (2) Urban Natural Resources Stewardship, (3) Sustaining Forests, (4) Providing Clean Air and Water, and (5) Natural Resources Inventory and Monitoring.

There are 135 NRS scientists working at 20 field offices, 24 experimental forests, and universities located across 20 states, from Maine to Maryland, Missouri to Minnesota.