Increasing Urban Tree Canopy: A Suite of Geographic Information System Tools

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Urban Tree Canopy

is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Tree canopy provides many benefits to communities, improving water quality, saving energy, lowering summer temperatures, reducing air pollution, enhancing property values, providing wildlife habitat, facilitating social and educational opportunities, and providing aesthetic benefits. Establishing a tree canopy goal is essential for communities seeking to improve their green infrastructure.

Achieving a UTC Goal = Existing UTC + Planting + Growth (protection & maintenance) - Losses (mortality, removal, etc)

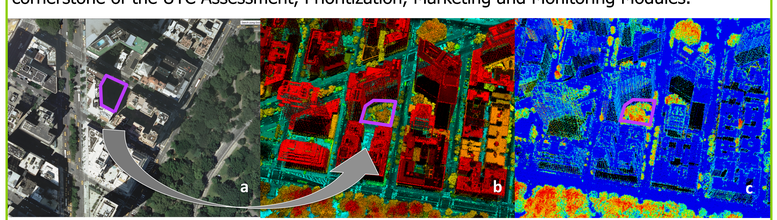
As Luley and Bond (2002) describe, reaching a tree canopy goal consists of exiting tree canopy, additional tree canopy from planting and growth minus the losses. We developed the Urban Tree Canopy (UTC) Suite, which supports urban sustainability and resilience policy, planning, and management by addressing each part of the equation (Table 1; http://www.nrs.fs.fed.us/urban/utc/).

Table 1. UTC Modules and the questions they were designed to answer.

Module	TYPES OF QUESTIONS
0. land cover	This requisite data set consists of an Object Based Image Analysis-derived high-resolution (< 1 m^2), high-accuracy (>95%), 7 class land cover. This provides a census of the landscape that can be summarized at any geographic scale.
1. Assessment	***i. How much do I have and how much could I have?*** These questions are answered in terms of owner, location, neighborhood, zoning, watersheds, and land uses.
2. Prioritization	***i. Where do I need trees to achieve my goals?*** Priorities are social, economic, or environmental and link to sustainability and resilience goals. Locations include public, private, and community lands. ***ii. Who shares my goals?*** ***iii. Who wants to work in the same location(s)?***
3. Marketing	***i. Who is being reached, where, and in relation to priorities?*** ***ii. Who is being missed, where, and in relation to priorities?*** ***iii. What messages and messengers might I need to be more effective?***
4. Monitoring	***i. Where has UTC increased, decreased, or stayed the same?*** Change is described in relation to people, place, and priorities. ***ii. Which social, economic, and environmental factors are associated with changes in UTC?***

0. Land cover.

High-accuracy, high-resolution, LiDAR-derived land cover data form the cornerstone of the UTC Assessment, Prioritization, Marketing and Monitoring Modules.



Urban environments exhibit extreme heterogeneity over relatively short distances and heights which complicates deriving accurate, precise, and realistic classifications of land cover. Shadows in aerial imagery derived from passive sensors (a) prevent the detection of tree canopy, for example. Light Detection and Ranging (LiDAR) data are collected with an active sensor that allows the analyst to 'see through' the shadows and find small and/or heterogeneous features like tree canopy (b). The vertical heterogeneity becomes a strength rather than weakness for detecting tree canopy when the LiDAR point cloud's z-deviation is displayed (c).

Key citations:

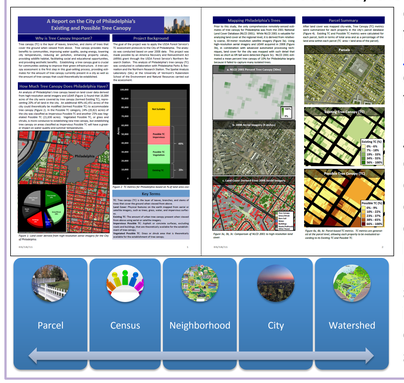
MacFaden, S.W., O'Neil-Dunne, J.P.M., Royar, A.R., Lu, J.W.T., & Rundle, A.G. (2012). High-resolution tree canopy mapping for New York City using LIDAR and object-based image analysis. *Journal of Applied Remote Sensing*, *6*. doi:10.1117/1.JRS.6.063567

O'Neil-Dunne, J.P.M., MacFaden, S.W., Royar, A.R., & Pelletier, K.C. (2012). An object-based system for LiDAR data fusion and feature extraction. *Geocarto International*, (June 2012), 1–16. doi:10.1080/10106049.2012.689015

Object-Based Image Analysis involves iteratively building context to improve classifications rather than relying on spectral signatures alone. The result is a high-resolution (< 1m), high-accuracy (> 95%), 7 class land cover data set ready for summarization at any scale. Land cover summaries directly support the first UTC Assessments.

1. Assessment.

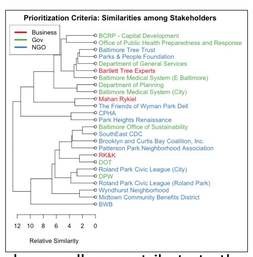
UTC Assessments summarize land cover data within areas of interest to calculate existing tree canopy as well as possible tree canopy. Possible tree canopy is the non-road, non-building, non-water, non-existing tree area. These places could hypothetically support tree canopy. Possible tree canopy can be further subdivided into possible impervious such as parking lots, and possible pervious like grass and shrubby areas or bare soil. More than 70 UTC Assessments have been conduced by the University of Vermont Spatial Analysis Lab. All of the reports and land cover data are made freely available for each assessment: http://gis.w3.uvm.edu/utc/ The results of UTC Assessments are frequently used set tree canopy goals.

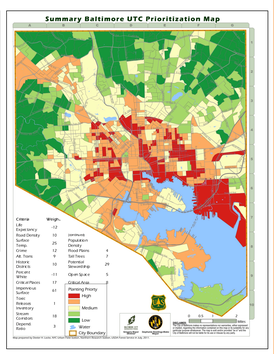


A sample report excerpt (left, top) shows the distribution of existing and possible tree canopy for the City of Philadelphia, and how estimates from high-resolution land cover differ from those derived from the National Land Cover Database which underestimates by half in this case. UTC Assessments summarize land cover data within areas of interest for different decision making organizations to meet the needs of different stakeholder organizations (left, bottom).

2. Prioritization.

Often after a tree canopy goal is set urban foresters, planners, and other decision makers want to know how to reach the their goal. UTC Prioritizations first identify the places lacking the benefits of trees, then help to identify organizations whose mission or mandate reflects that management priority. For example, trees reduce summer temperatures by blocking the sun and through evapotranspiration (exhaling water vapor). High temperatures in the summer can be lethal. Public health officials may then choose to prioritize places to plant trees that are hot in the summer and where the young and old live – those most vulnerable to heat. UTC Prioritization is both a set of GIS tools as well as a stakeholder engagement process. In Baltimore, MD representatives of 25 groups were asked to rank their management priorities as they pertain to the benefits of trees. Each attending organization was provided their weighted map, as well as a map generated by adding up all votes together (right). Organizations can see how to reach their own goals as well as contribute to the City's overall tree canopy goals. Further groups can see how similar their priorities are to one another. Prioritization helps institutions realize common cause.





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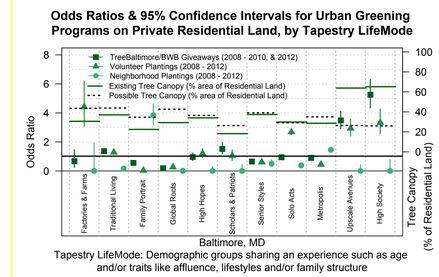
Locke, D.H., Grove, J.M., Galvin, M.F., O'Neil-Dunne, J.P.M., & Murphy, C. (2013). Applications of Urban Tree Canopy Assessment and Prioritization Tools: Supporting Collaborative Decision Making to Achieve Urban Sustainability Goals. *Cities and the Environment (CATE)*, *6*(1). http://digitalcommons.lmu.edu/cate/vol6/iss1/7/

Locke, D.H., Grove, J.M., Lu, J.W.T., Troy, A.R., O'Neil-Dunne, J.P.M., & Beck, B.D. (2010). Prioritizing Preferable Locations for Increasing Urban Tree Canopy in New York City. *Cities and the Environment (CATE)*, *3*(1), 1–18. http://digitalcommons.lmu.edu/cate/vol3/iss1/4/

3. Marketing.

UTC Assessments provide baseline information often used for goal setting, and UTC Prioritizations provide an implementation plan that identifies key areas for planting and common goals across organizations or institutions. However, residents across the low to high priority neighborhoods have different motivations, capacities, and interests in urban and community forestry initiatives. A goal of UTC Market Analyses is to understand how participation in existing programs varies by geodemographic segment or market group. These data are typically used to understand purchasing behavior and market consumer goods. However, previous research has shown that the amount of existing and possible tree canopy varies not just by household income, but also by family structure such as marital status and/or number of children living in the home. Research in Baltimore, MD and Washington, DC show that reduced-cost tree planting programs such as giveaways, coupons, or rebates designed to increase access to plant material actually are most effective in the highest income neighborhoods, which already have the most canopy cover on private residential lands (left). Comparable programs in NYC and Philadelphia appear far more equitably distributed both spatially and across social groups. An emerging hypothesis is that the role of delegation to local community groups explains this difference.



Key Citations

Locke, D.H., and Grove, J.M.. [*accepted*]. Doing the Hard Work Where It's Easiest? Examining the relationships between urban greening programs and social and ecological characteristics. *Applied Spatial Analysis and Policy*. doi:10.1007/s12061-014-9131-1

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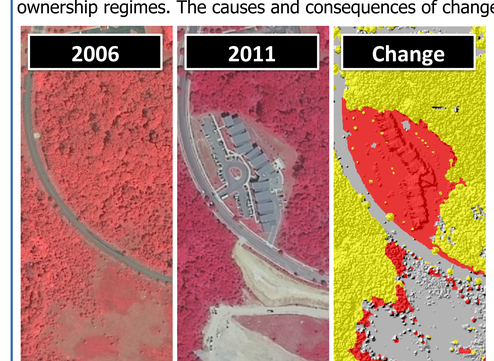
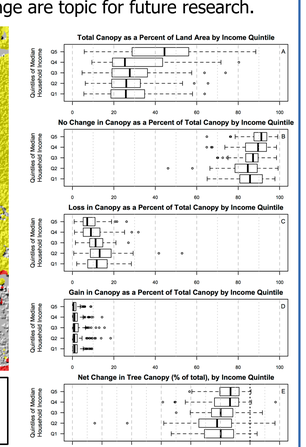
Troy, A.R., Grove, J.M., O'Neil-Dunne, J.P.M., Pickett, S.T.A, & Cadenasso, M.L. (2007). Predicting opportunities for greening and patterns of vegetation on private urban lands. *Environmental Management*, *40*(3), 394–412. doi:10.1007/s00267-006-0112-2

4. Monitoring

UTC Monitoring is the newest and therefore least developed module in the UTC Suite. Areas that were initially mapped for UTC Assessments have since been mapped a second time to show how much canopy changed and where. An unpublished set of analyses in Washington, D.C. using a freely available high-resolution canopy change dataset showed that 1) neighborhoods in the lowest income quintiles lost the most tree canopy from 2006 – 2011, even though 2) they had the least tree canopy as a percentage of land area to begin with, and 3) those changes were statistically significant – the changes were greater than chance alone could explain. This has important environmental justice and land management implications. Work in progress assesses how the changes are distributed across land uses and ownership regimes. The causes and consequences of change are topic for future research.





Key citations:

O'Neil-Dunne, J.P.M. (2012). Mapping tree canopy change in the District of Columbia http://bit.ly/1p2LqaE Letters from the SAL, Blog Post.

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