Title: Using aerial image classification to prioritize urban tree plantings

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Trees provide essential services to the urban environment yet their quantification as well as planting prioritization can be complex and resource intensive. Sample tree inventories on the ground give valuable and detailed information but do not efficiently assess the entire area of interest. Although remote sensing and GIS analyses do not provide comparably detailed information, such as species or age class of trees, they allow for efficient assessment of large areas including urban tree canopy cover (UTC), impervious and pervious surfaces. Knowing a city's UTC and additional information, such as tree size and placement as well as tree species distribution, is fundamental to estimating benefits provided by the UTC. These benefits include; energy savings through shading, removal of carbon and other pollutants from air and soil, and property value increases. Not only current UTC conditions and the associated benefits can be quantified, but also the number of new trees the area might accommodate based on open spaces. This information can then be used to quantify future benefits. The objectives of three studies conducted by the authors from 2011 to 2013 were to 1) classify UTC, 2) identify vacant tree planting sites, 3) prioritize future tree plantings and 4) estimate the associated benefits.

The three studies took place in Metro Denver, Colorado (study area = 721 square miles), San Jose, California (study area = 151 square miles), and Marin County, California (study area = 77 square miles). Each study had a slightly different objective; Marin County was interested in targeting tree plantings to optimize energy use for cooling and heating. Thus, the focus of the planting scenario was the potential energy effects of tree selection and placement around residences. San Jose's main interest was to quantify current resources as a baseline for future planting plans and to prioritize tree planting locations for 100,000 trees to be planted by 2022 as part of their 'Green Vision' initiative. Denver's objective was to alleviate urban heat islands by targeted plantings in hot spots in conjunction with their plan to plant 1 million trees by 2025.

High resolution (1m) aerial multispectral (4 band) images, natural color images, LiDAR (for Denver and San Jose), GIS layers (e.g. buildings, roads, water bodies), and census data (e.g. blocks, block groups, population) were used to classify urban land cover using the object-based classification method. Eight land cover classes were determined: trees, shrubs, irrigated non-woody vegetation, dry grass and bare soil, roads, buildings, water, and other impervious, such as driveways and parking lots. Potential tree planting sites (PTPS) were calculated for irrigated and unirrigated grass. The number of existing trees and PTPS was estimated using typical crown size information from local inventories. For San Jose, the number of existing trees and PTPS within the public right-of-way and off-street was calculated and separated by land cover class. Tree planting targets were determined with the help from the respective local agencies.

Current and potential canopy data were used to calculate canopy-specific benefits for the existing canopy and for planting scenarios. Calculated benefits included; energy savings, air quality effects, stormwater reduction from rainfall interception, and property value increases.

San Jose: San Jose's urban forest covers 15% of the study area, ranging by council district between 12 and 20%. About 59% of the land cover is impervious, while 26% is irrigated or dry grass and bare soil. San Jose has approximately 1.6 million trees of which about 303,000 are within the public right-of-way. The total benefits provided by the current UTC within the study area for preserving energy for heating and cooling, filtering pollutants from air and soil, interception of rainwater, and increasing property values is estimated to be about $239 million annually. Planting an additional 100,000 trees would increase UTC by 1% and the associated benefits by about $16 million annually at maturity.

Metro Denver: Metro Denver's urban forest covers 16% ranging from 5 to 37% by jurisdiction. There are approximately 10.7 million trees providing $551 million in annual benefits. Planting 4.25 million of the available 10 million available vacant planting sites would increase UTC to 31% and annual benefit provision by $450 million to about $1 billion at maturity.

Marin County: Marin's urban forest is extensive, covering 37% of the study area. Depending on the jurisdiction, UTC ranged from 20 to 60%. Impervious and pervious surfaces (excluding trees) covered about 32% each of the area. Approximately 1.9 million trees are within the study area's urban forest producing annual ecosystem services and property value increases of about $273 million. Planting half of the estimated 425,000 PTPS would increase UTC to 56% and associated annual benefits to $329 million.

Determining the current state of the urban forest is a necessary first step in managing it to ensure health and longevity. After our project results were submitted, it was interesting to see how each city would use the information to support its programs. Ralph Mize, city arborist for the City of San Jose revealed that they envision incorporating the results into future master plans for the city that will prioritize tree planting by Council District.

Through the Mile High Million Program, approximately 250 thousand trees have been planted since the beginning of the program six years ago. Besides targeted plantings in hot spots, Denver is using the study results as an advocacy tool for legislators and homeowners. Denver's effort to increase the region's canopy relies on educating the public on the value of trees. Although tree care is largely in the hands of the homeowners, Denver is investing in ooze tubes to optimize irrigation and conserve water. Through the distribution of documents like 1-page infographics to legislators, Denver will bring the value of trees as well as budget needs for a sustainable UTC closer to those whose decisions will affect Denver's future UTC. Another step Denver is taking is the proactive planning of future plantings by acknowledging new potential diseases and pests, such as Emerald Ash Borer (EAB). Results from this study are used to estimate the value of ecosystem services at risk from EAB and areas with the greatest threat where work is needed to dodge the bullet of large UTC losses.

The results of the Marin study show extraordinarily high UTC and associated benefits compared to other sections of the Bay area. With 85% full stocking, little space is left for trees to be planted. Although trees can always be planted, Marin might take a new approach in using the study results. Rather than just trying to further increase UTC, Marin might focus on maintenance and necessary replacement of the existing trees to maintain the current UTC. In addition, a next research step might be to focus on those

land uses with low UTC to determine approaches for improvements. Marin will share project results with Marin Clean Energy, local government agencies, and nonprofits to encourage policy development around tree care.

Overall, results of these studies can lead to useful applications that improve the state of the urban forest in each area. It is important to recognize that localities incorporate such study results into their urban forest planning efforts to different degrees and in different ways. However, knowing the current state of the urban forest is important for any locality to improve future planning and planting efforts for a healthy and stable urban tree canopy cover.

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Resources:

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McPherson, G., Q. Xiao, J. Bartens, C. Wu, and J. Simpson. 2013. Marin County urban forest canopy cover assessment. Submitted to the California Urban Forest Council, San Francisco Bay Area.

McPherson, G., Q. Xiao, C. Wu, and J. Bartens. 2013. Metro Denver Urban Forest Assessment. Submitted to the Parks and Recreation Department, City and County of Denver, Co.