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An urban forest-inventory-and-analysis investigation in Oregon and Washington

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ABSTRACT

The U.S. Department of Agriculture (USDA) Forest Service, Forest Inventory and Analysis program recently inventoried trees on 257 sample plots in the urbanized areas of Oregon and Washington. Plots were located on the standard grid (≈1 plot/2428 ha) and installed with the 4-subplot footprint (≈.067 ha with 4 circular subplots). Using these data, we examined: 1) use of the land use classification data from the National Land Cover Database (NLCD) for post-stratification; 2) the resolution of the inventory data to make inferences about subdomains (specifically sub-regions) and subgroups (species and diameter classes); and 3) the i-Tree Eco software as a tool for data compilation, estimation, and reporting.

Ideally post-stratification would enable us to achieve greater precision in sub-regions (Seattle, Portland, and eastern Oregon and Washington), but our analyses indicated that NLCD land use classes did not aid us in estimation of trees per ha and basal area in Oregon and Washington urbanized areas. Due to the small sample size and lack of effective post-stratifying variables, the data support few inferences about sub-regions. It is likely, however, that another set of stratifying variables can improve precision and enable a greater diversity of sub-region inferences from these data.

1. Introduction

Urban forests provide a myriad of environmental, social, and economic benefits for what the US Census estimates is approximately 80 percent of the U.S. population. The term "urban forest" is used to define all trees within an urban area, including those along parking strips, in yards, and on public lands such as parks (Cumming et al., 2008). It is a mosaic of both the planted landscape and native forest remnants that have been left behind, intentionally or unintentionally, as our cities have developed. Even vacant or previously cleared land, when left long enough, can revert back to forest by natural processes. Research conducted in the last several decades has begun to quantify many of thebenefits provided by urban trees, which include reduced storm water runoff (Sanders, 1986), cleaner air (Nowak, 1994; Nowak et al., 2006), support for better mental and physical health (Ulrich et al., 1991; Dwyer et al., 1991; Donovan et al., 2013; Kardan et al., 2015), reduced crime (Kuo and Sullivan, 2001; Donovan and Prestemon, 2012), reduced home energy costs (Akbari, 2002; Donovan and Butry, 2009), and trees make neighborhoods more desirable places to live and work (Westphal, 2003; Wolf, 2003; Kinzig et al., 2005; Nowak and Dwyer, 2007). The Arbor Day Foundation reports that more than $1 billion is spent on planting, maintaining, and managing the urban forest in the over 3400 cities awarded Tree City USA status ("Arbor Day Foundation," n.d.). Given the importance of urban forests, and the large amounts of public funds spent to manage them, very little is actually known about the health, extent, and characteristics of the nation's urban forest resource. To help remedy this situation, the Forest Inventory and Analysis (FIA) program of the USDA Forest Service has recently begun several projects to collect data in urban areas for the purpose

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of preforming analyses and informing the public on the status and trends of urban forests.

The FIA program originated in 1930 as an effort to "make and keep current a comprehensive inventory and analysis of the present and prospective conditions of, and requirements for, the renewable resources of the forest and rangelands of the U.S." (U.S. Department of Agriculture Forest Service, 1992). Every year, in every U.S. state, the FIA program collects data from a set of permanent ground plots, then analyzes and later reports information on the extent and health of states' forest resources. While the FIA plot sample grid covers all the land area in each state, for a plot on the grid to be installed it had to intersect a forested area, defined as at least 0.4 ha in size, at least 36.5 m wide, and at least 10 percent stocked with tree canopy and containing an understory that is undisturbed by another land use (U.S. Department of Agriculture Forest Service, 2012). The plots located outside of these conditions have been considered nonforest or developed, and they were not installed. In the last decade, an effort has begun to include urban land in the sample. This is based on the understanding that across the landscape there is a gap in the ability to account for trees and their potential benefits outside of the traditional forests. As part of an all-lands approach, FIA acknowledged the importance of urban trees and they have focused recent efforts on installing plots located in several urban areas.

Many cities rely on ground based tree inventories of street and park trees, or on aerial based canopy coverage studies to obtain data for planning and management purposes. Effective forest inventory design, analyses, and reporting typically require a suite of specialized skills that may not be available within an organization. Some cities look to contractors and volunteers to assist in inventory collection, and it is common for cities to perform minimal inventories that are on decade intervals and on limited land use types. This can prove problematic for data continuity if different contractors or measurement protocols are used between inventories. Additionally, since the inventories are not standardized among cities, they may prove useless for policy and planning at the state, regional or national level (Cumming et al., 2008).

The difficulties described in implementing a forest inventory suggest that there is a need for infrastructure to support consistent urban inventory practices, as well as to provide inventory analyses and to communicate inventory results. Software packages that provide inventory guidance, analyses, and reporting capacity may help alleviate some of the difficulties associated with urban inventory and reduce the overhead associated with planning and maintaining an inventory system. In addition, if municipalities across the region adopted a standard methodology, reporting and planning may be feasible at a larger scale.

The first FIA inventory of nonforest conditions in urban areas was in 1999, when FIA initiated an assessment of all non-forest plots in the 5 counties surrounding the city of Baltimore, including both urban and rural lands (Riemann, 2003). In 2001, the USDA Forest Service, Forest Health and Monitoring (FHM) program initiated an assessment of urban forest conditions (Cumming et al., 2001). This assessment delimited urban boundaries and then collected tree information from established plots within the urban boundaries. This was the first attempt to apply national forest health monitoring protocols to aid in the planning and management of the urban forest. Statewide urban pilot studies were later conducted by FIA incorporating the protocols developed by the FHM program. More recently, urban areas in five states were inventoried by FIA including Indiana, Wisconsin, Colorado, New Jersey, and Tennessee (Nowak et al., 2011; Cumming, 2007; Lake et al., 2006). Data obtained from plots can be used to monitor the health, condition, and trends of the urban forest, giving managers an important tool for long range planning.

In 2009, with funding from the America Recovery and Reinvestment Act of 2009, the USDA Forest Service Pacific Northwest Research Station (PNW) and the Oregon Department of Forestry (ODF) entered into an agreement to conduct an FIA inventory project in the 'urbanized areas' of five Pacific coast states (Alaska, California, Hawaii, Oregon, and Washington). Urbanized areas are defined by U.S. census to contain a core population of 50,000 people. This classification was chosen because 88 percent of the U.S. urban population lived in urbanized areas in 2010 and funding was not sufficient to install plots in the less densely populated land classification "urban clusters" (for classification information see: https://www.census.gov/geo/reference/ua/urban-rural-2010.html). In coordinating with the PNW FIA Program, ODF appointed a project manager, project coordinator, and quality assurance forester to help manage the project, and hired private urban forestry and forest inventory firms to collect the data. PNW formed an agreement with California Polytechnic State University, San Luis Obispo to collect the California urban data. The Hawaii and Alaska data will be published by the PNW FIA, but their relatively small urban areas limit analyses.

The objective of this study is to investigate our ability to make inferences about the character of the urban forest from urban FIA field data collected in 2010 and 2011 for Oregon and Washington. Initially we investigate whether NLCD data can be used to improve the precision of our estimates. We then investigate whether the collected inventory data support estimation within sub-regions and for subgroups. Finally, we examine i-Tree Eco (Nowak et al., 2013) software as a tool for estimation and reporting of selected base inventory estimates.

2. Methods

2.1. PNW urban inventory overview

Plots on the national FIA grid are spaced so each represents roughly 2428 ha. According to GIS layers provided by the U.S. Department of Commerce, Bureau of the Census (2011), there are 163 K ha of urbanized land in Oregon state and 460 K ha in Washington state. A total of 67 plots from the FIA grid fall within Oregon's urbanized areas and 190 fall within Washington's urbanized areas. Plot locations were mapped using coordinates derived from maps, aerial photos, and satellite imagery. Landowners were determined using GIS layers available from public agencies. All the plots in urban areas are part of the national FIA plot grid, and some plots on the edges of urban areas were already installed because they fell in area that met FIA's definition of forest. The majority of urban plots, however, were previously classified as nonforest and had not been installed. Forested FIA plots in the PNW region are measured on a panel system in which one-tenth of all the plots within a State are measured in a given year. Because this study was funded with a one-time grant, all plots in the urban areas were measured as urban plots in a two year window.

2.2. Data collection and field protocols

Field data were collected in the summer of 2010 and 2011. The standard FIA plot design was used, in which each plot consisted of four subplots, each 0.017 ha in size with a nested microplot covering 0.0013 ha (Fig. 1).

Urban protocols were based on a supplement to the standard FIA field manual that included a subset of tree health variables from Forest Health plots (Tallent-Halsell, 1994), and variables unique to the urban environment (e.g., poor pruning, conflicts with tree roots, etc.) (U.S. Department of Agriculture Forest Service, 2012). The spatial locations of plots were obtained in the field using GPS