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Adam Berland

Reliably Estimating Street Tree Counts, Species Diversity, and Pest Vulnerability with Random Sampling 111

Abstract. Background: Practitioners rely on sample-based estimates of street tree population characteristics when complete inventories are not feasible. Selecting a sample size is a primary consideration when implementing a sample-based inventory, as it involves a tradeoff between costs and data quality. Methods: We used street tree inventory data from 16 municipalities in Indiana, USA, to assess how data quality improves with increasing sample size. Specifically, we conducted 1,000 random draws of street segments at increasing sample depths to observe how estimates improved for the number of total trees citywide, species richness, species diversity, and vulnerability to an invasive pest. Results: Compared to previous research, our results indicate that a larger percent of sampled street segments is needed to achieve relative standard error values below the heuristic target of 10%. We also calculated reliability thresholds that showed the percent of street segments that would need to be inventoried to achieve estimates within a given margin of the true citywide value in 95% of random draws. Again, relatively large random samples were needed to reliably achieve accurate estimates of street tree characteristics, especially in smaller municipalities. Conclusions: This study provides information that practitioners can consider when planning street tree sampling given the community’s size, capacity to inventory trees, and level of data quality needed for planning and management activities. In general, we suggest that municipalities may need to acquire larger samples than previously thought to achieve accurate estimates of citywide street tree characteristics, and smaller municipalities should conduct complete inventories when possible.

Keywords. Data Collection; Municipal Forestry; Tree Inventory; Urban Forest Management.

Xiaoyue Li, Yujuan Chen, Ge Sun, De’Etra Young, Steven McNulty, Marcus Williams, Chen Wang, William B. Sutton, Anjin Chang, Thomas D. Byl, and Michelle Johnson

A Systematic Review of the Cooling Effects of Urban Forests 125

Abstract. Urban forests have been widely recognized as a nature-based solution to address urban environmental changes like urban heat islands. Although previous studies have explored the cooling effects of urban forests, the extent of this effect and related influencing factors remain unclear and have not been comprehensively synthesized yet. To fill this research gap, we conducted a systematic literature review using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method with 20 keywords and their combinations in Web of Science to address 3 main research questions: (1) what is the cooling range of urban forests; (2) what are the factors that may affect the cooling effects; and (3) how can we better manage urban forests to optimize cooling effects? We systematically reviewed 73 peer-reviewed articles selected from an initial pool of 4,072 search results following the PRISMA method. We found that urban greenspaces generally have cooling effects, but it is challenging to draw a clear conclusion on the cooling range due to variation in study design, measurement approaches, spatial scales, and local climate contexts. Moreover, the main influencing factors include land cover compositions, tree cover and canopy structures, leaf area index, forest types and tree species, and spatial arrangements of urban vegetation. Additionally, the cooling benefits of urban forests might be affected by local background climate and weather conditions, as well as distances from water bodies. These findings can help guide urban greening efforts (e.g., land cover types, tree species selection, and spatial arrangements) to achieve a greener and cooler future.

Keywords. Air Temperature; Land Surface Temperature; Nature-Based Solutions; Urban Greenspaces; Urban Heat Islands.

Corinne G. Bassett, Dexter H. Locke, Nancy F. Sonti, Jesse Caputo, Brett J. Butler, Iris Montague, and J. Morgan Grove

Urban Residential Landowner Interest in Emerging Urban Wood Product Markets: Results from a Multi-City Survey 142

Abstract. Background: For the past 20 years, approximately twice as many trees were removed annually from urban areas in the USA as were harvested annually from the US National Forest System. Yet, most of this wood is treated as waste instead of as a valuable resource to generate economic growth and sustainable cities. Residential landowners are key actors in the establishment of local urban wood economies as both sources of material and users of urban wood products, yet they remain a difficult to reach group compared with others, such as tree care companies, mill operators, and public landowners. Methods: We analyze a representative survey of urban residential landowners in 6 United States cities. We assess (1) status of participation in urban wood systems; and (2) interest in and perceived importance of urban wood

products. Results: Overall, 15% of residential landowners reported purchasing or acquiring urban wood products in the past. Landowners were more likely to purchase—and were more interested in—lower value products like wood chips and compost than higher value products like lumber or furniture. Private sector actors, like landscaping and tree care companies, and social sources, like friends and family, were more often recognized as sources of trusted information for tree care advice than local or state government and nonprofit organizations. Conclusions: We present baseline results of, to our knowledge, the largest survey of urban wood perceptions and practices to date, which indicate a substantial group of landowners already engaged in urban wood economies, and discuss potential avenues to activate future participation.

Keywords. Local Economy; Private Landowner; Sustainable Timber; Wood Products; Wood Recycling.

Beatriz M. Shobe and Meghan Avolio

Identification and Validation of Microsatellite Markers for *Acer rubrum* 159

Abstract. Red maple (*Acer rubrum*) is one of the most commonly cultivated tree species and is often used in urban settings, as it is resilient, fast-growing, and tolerant of a wide variety of conditions. This study sought to understand the genetic variation between *A. rubrum* cultivars using microsatellites. Since *A. rubrum* is an autopolyploid that is often either hexaploid or octoploid, but can also be tetraploid, this species presents unique challenges for understanding population genetics, as many statistical tests assume diploidy. For these reasons, we cross referenced and verified genetic relationships with information regarding the development of the cultivars. We tested a total of 34 microsatellite loci that had been previously developed for closely related *Acer* spp. until we were able to validate 12 microsatellite loci that were consistently present in our *A. rubrum* samples, which included both wild-type and cultivated trees. Following validation, we then looked at the genetic relationships between 16 cultivars. These cultivars included some of the most popularly available, including Armstrong, Franks Jr.TM (Red-pointe), Franks RedTM (Red Sunset), and October Glory. We found that our genetic results from the microsatellite analysis were consistent with the histories of the developments of the various cultivars and therefore have confidence in using these microsatellite markers for analysis of *A. rubrum*.

Keywords. *Acer rubrum*; Cultivar; Genetic Diversity; Microsatellites; Polyploid.

Andrew K. Koeser, Jason Grabosky, Joseph Leone, and Sharef Farrag

Radial Expansion and Flattening in Woody Tree Roots: Assessing the Limits 169

Abstract. Background: Tree roots colonize cracks in rock and similarly confining spaces in built environments, contributing to natural weathering processes and urban infrastructure dysfunction. Methods: In this study, we assessed the limits of radial expansion in woody *Quercus virginiana* Mill. and *Taxodium distichum* (L.) Rich. roots grown in clamps under increasing tension. Results: After two growing seasons, a maximum stress threshold for radial growth in mature structural roots was identified and was similar for both species. These thresholds (0.173 MPa to 0.329 MPa) fall within the lower to middle range of values reported in previous studies and are notably lower than those observed in seedling radicles or in other woody species under more acute stress exposure. Conclusions: Our findings provide some of the first empirical estimates of pressure thresholds for deformation in mature woody roots, suggesting that structural root flattening can occur at relatively modest stress levels. These results offer important insights for the design of urban infrastructure aimed at minimizing root-related damage while also informing future biomechanical studies of species-specific responses to soil confinement.

Keywords. Root Biomechanics; Root and Soil Interaction; Tree Structure and Function.

Thomas E. Marler

Variations in Carbon Dioxide Efflux by Stem Height in Six Arborescent Palm Species 176

Abstract. Background: Stem respiration is influenced by elevation, but this phenomenon has not been adequately studied for palms. Therefore, the influence of stem height on carbon dioxide efflux (E_s) was determined for 6 palm species. Methods: Gas exchange protocols were employed to determine E_s . The lowest height was 35 cm above the root collar, and the greatest height was 20 cm below the oldest living leaf in the crown. Results: A consistent baseline flux was observed for the midlength of the stems, a moderate increase in E_s occurred at the lowest elevation, and a substantial increase in E_s occurred at the highest elevation. The midheight flux ranged from $0.9 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for *Coryph utan* to $2.3 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for *Carpentaria acuminata*. The basal increase in E_s averaged 63% and was greatest for *C. utan* and least for *Phoenix sylvestris*. The apical increase in E_s averaged 157% and was greatest for *Wodyetia bifurcata* and least for *C. acuminata*. A quadratic model described the influence of stem height on stem E_s . Conclusion: The moderate increase of E_s at the lowest stem height was consistent with the influence of root-respired carbon dioxide entering the stem in xylem mass flow then conducting radially to the stem surface. The substantial increase in E_s at the highest stem height was consistent with proximity to the growth respiration of the large primary thickening meristem of the pachycaulous palm stem. These findings confirm that the elevation of the stem influences palm E_s , and the elevation pattern is consistent among every species.

Keywords. Carbon Flux; *Cocos*; *Roystonea*; Stem Respiration; Strata; Stratification; Stratum.



Lara A. Roman, Adam Berland, Sabine Nix, and Dana Dentice

Virtually Tracking Planted Urban Tree Survival with Street-Level Imagery 186

Abstract. Background: Street tree plantings are common in urban greening programs, and these trees provide important ecosystem services that increase as trees survive to maturity. Field-based monitoring to understand mortality rates and causes is valuable for urban forest management but very time-consuming. Methods: We used street-level imagery to virtually monitor survival for 2,884 street trees over several years postplanting in Philadelphia, Pennsylvania, United States. Results: We observed similar mortality rates to other studies, with 7.5% of trees dead or removed by the first summer after planting and the mortality rate dropping to 3.5% between the third and fourth summers post-planting. Logistic regression models were constructed over various time horizons to understand which site, neighborhood, and species characteristics related to survival outcomes. These models showed that higher tree survival was associated with less impervious surface surrounding the tree; lower social vulnerability in the neighborhood; and tree planting in the fall season as opposed to spring. Conclusions: Our results point to management activities that could improve survival outcomes, such as planting site enhancements and establishment maintenance, as well as the use of monitoring data to drive decisions regarding planting season. This study demonstrates the value of street-level imagery interpretations to provide mortality data on a large number of street trees planted over multiple years.

Keywords. Civic Science; Street Tree; Street View; Tree Mortality; Tree Planting Initiative; Urban Forest Management.