Modeling Forest Biomass Using LiDAR Remote Sensing on an Urban Landscape

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Background

The urban forest provides numerous ecological goods and services and as such is becoming increasingly recognized as a critical component of the urban landscape. Urban natural areas, often being remnants of native vegetation, are also the most cost effective and long-term sustainable component of urban forests. Their structure, measured and mapped as live tree biomass, is an expression of the ecosystem services and ecological functions they provide. Biomass mapping can be improved by incorporating Light Detection and Ranging (LiDAR) data in model development and extrapolation. While research and operational application of using LiDAR to inventory the structure of managed forests has grown over 25 years, application of these methods has not been well studied in urban areas.

Study Area

The City of Kitchener (Figure 1) is one of the first municipalities in Ontario with enough field data to establish a comprehensive baseline condition of its natural cover, with 549 permanent sampling plots.

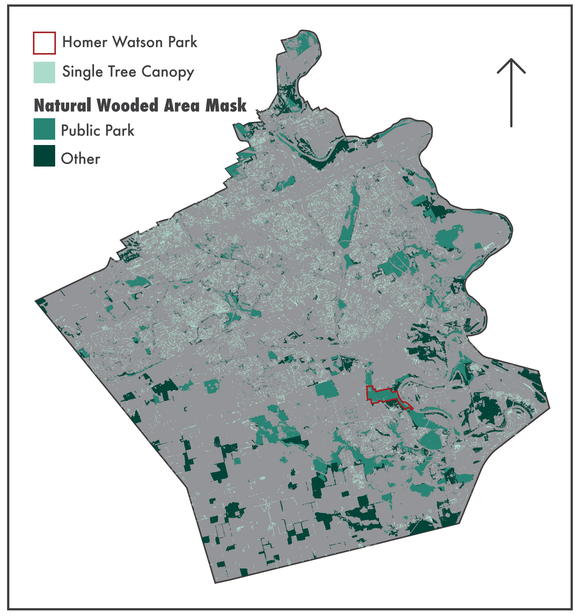

Figure 1. Study area map of the City of Kitchener's Urban Tree Canopy (UTC), based on a LiDAR derived canopy model. Natural Wooded Area Mask contains UTC that overlays Kitchener's Park and SOLRIS wooded area polygons.

Objective

While biomass averages can be readily derived and extrapolated from plot data, our objective is the improvement of biomass estimates and mapping them across natural wooded areas by utilizing LiDAR and an area-based regression-kriging model.

Methods

Data

- **VSP Plots**: 400 m² DBH Species
- **LiDAR**: Normalized Tree Canopy Point Cloud
- **Grid Cells**: 20 x 20 m to Match Plot Area
- **Wooded Area Mask**: (Figure 1)

Data Processing

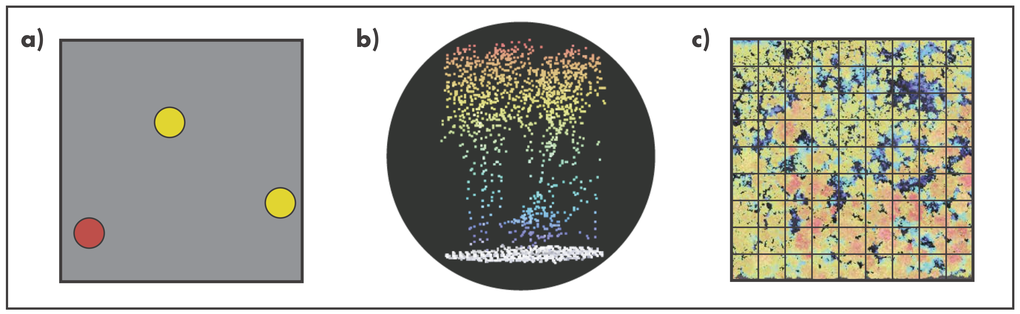

Figure 2. Data was processed using an area based approach as described in White et al. (2013); VSP data was used to calculate plot level biomass (a), VSP plot area polygons were used to clip the LiDAR data so co-located metrics could be calculated (b), and wall-to-wall LiDAR metrics were calculated across the city of Kitchener using a 20 x 20 m grid.

Field measurements in the City of Kitchener's natural areas, collected by the Vegetation Sampling Protocol (VSP) and Forests in Settled and Urbanized Landscapes research program from 2015-2019, will be used to estimate urban forest above-ground biomass (Figure 2a). Total above-ground biomass will be calculated using (i) Lambert et al. (2005), (ii) Ter-Mikaelian and Korzukhin (1997), (iii) Chojnacky et al. (2014) updated from Jenkins et al. (2004), (iv) Nowak and Crane (2000). Over 50 LiDAR metrics representing various components of forest structure will be calculated (Figure 2b & c), and run through a PCA analysis to reduce the number of variables and derive composite metrics for use in a Regression-kriging model (Figure 3). The LiDAR metrics that explain the majority of variation will be used as the independent variables and the dependent variables will be the plot based biomass estimates. Biomass estimates from the selected model will be extrapolated across Kitchener's natural areas based on the wooded area mask.

Predictive Modeling

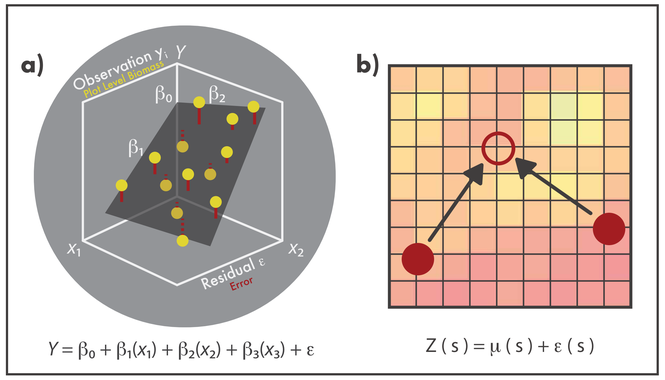

Figure 3. Biomass modeling using Regression-kriging. Multiple linear regression (Fortin & Dale, 2009) (a) will be used to create a regression surface. The residuals of the regression analysis will then be kriged (b) using universal kriging (Hudack et al., 2002).

LiDAR Metrics

- Mean Height
- Standard Deviation
- Absolute Deviation
- Skew
- Deciles of Canopy Height
- Maximum Height
- Coefficient of Variation
- Density

Conclusions

The outcomes of this research will not only enhance the baseline forest inventory for publicly owned parks (Figure 4), it will also provide a baseline forest inventory for Kitchener's privately owned natural areas. Biomass estimates from four different sets of allometric formulas will also be compared to help determine the most accurate allometric formulas for this location and modeling technique.

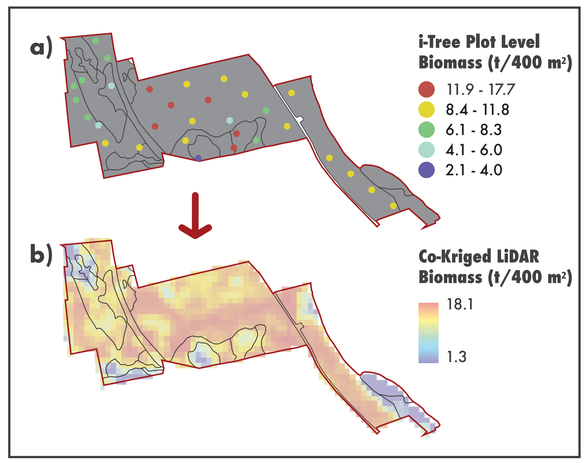

Figure 4. Kitchener's current forest inventory (a) with ELC stand level polygons and VSP plot area biomass in Homer Watson Park compared to an enhanced forest inventory (b) where LiDAR data is used to extrapolate VSP plot area biomass across the entire wooded natural area.

Research Applications

A detailed baseline condition of wooded natural area structure and function supports diverse applications including:

- Land use carbon inventory
- Natural heritage planning
- Forest management
- Habitat protection
- Biodiversity conservation
- Ecological restoration
- Impact and risk assessment

This research will also provide a reproducible methodology that could be scaled up to the regional level.

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