Using TLS-measured Tree Attributes to Estimate Aboveground Biomass of Small Black Spruce Trees

Steven Wagers[1,2], Guillermo Castilla[1], Michelle Filiatrault[1], Arturo Sanchez-Azofeifa[2]

[1]Natural Resources Canada, [2]University of Alberta

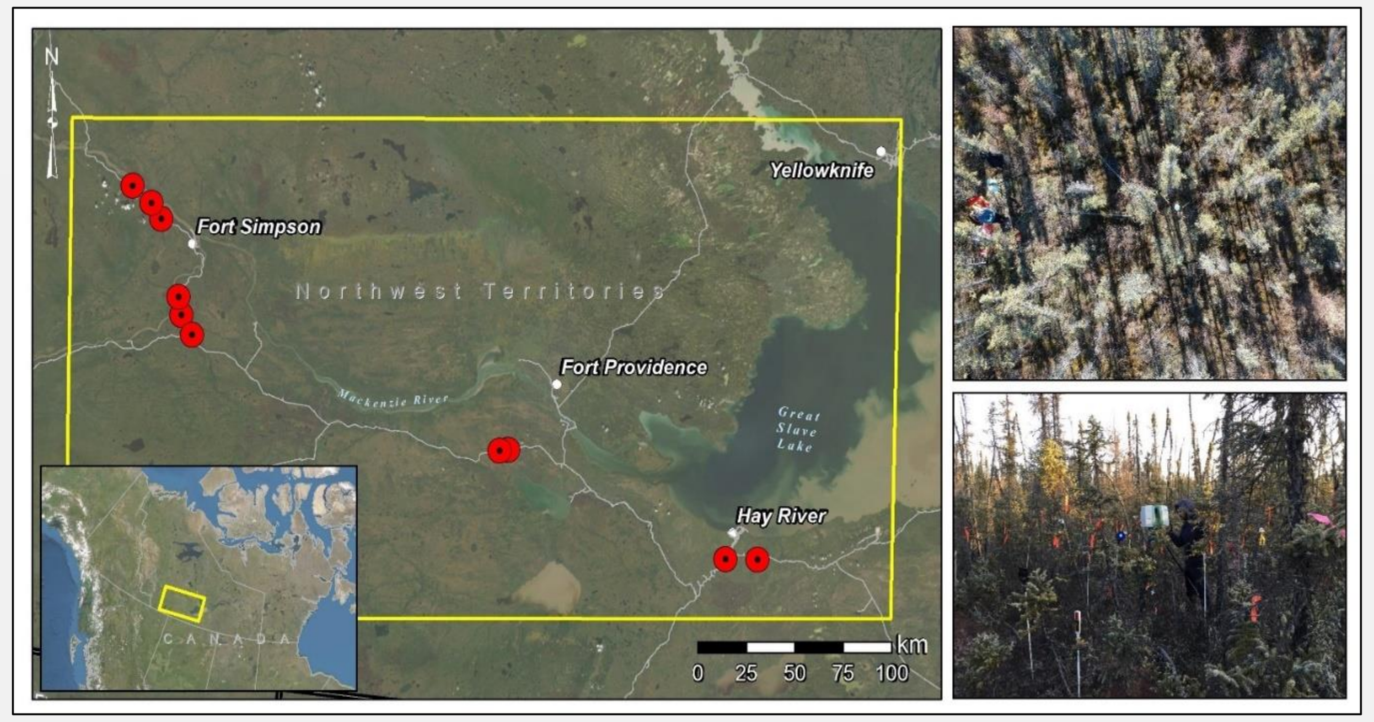
Introduction

Treed peatlands make up a quarter of Canada's boreal forest. Billions of small black spruce populate those remote, hard-to-negotiate areas. Accurate estimation of aboveground biomass (AGB) in treed peatlands requires a number of plots where the height (H) and diameter at breast height (DBH) of all trees in a plot are measured. This is laborious and time consuming, but what if similar or better results could be obtained with no plots using a drone or low-flying plane with LiDAR? In this study, we used ground-based LiDAR (TLS) to estimate AGB of destructively-sampled, small black spruce trees, and as predictors, tree attributes derived from the TLS data that could potentially also be measured from an airborne LiDAR, hence without having to set foot on the ground.

Objectives

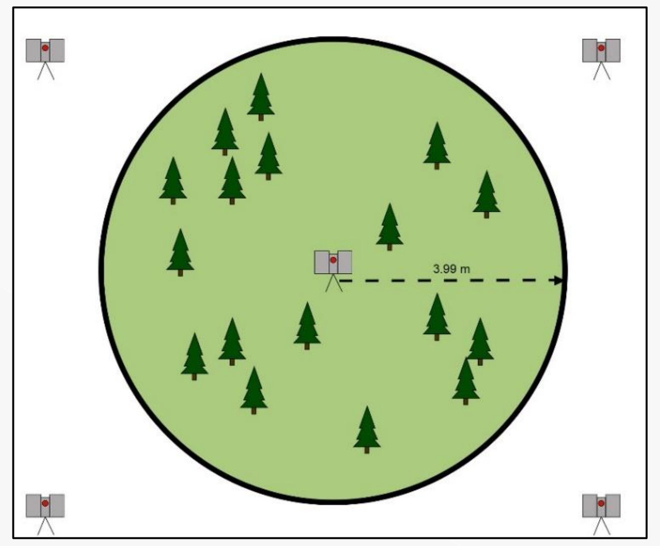
- Develop allometric equations specific to small black spruce (1.3 m to 5 m tall) from boreal peatlands using multiple tree attribute variables measured with TLS and 3 model types.
- Compare performance, using leave-one-plot-out cross-validation, of our best TLS model with the most-used allometric model (Ung et al. 2008, hereafter the national model), and with a similar model to the national, specific to peatland small black spruce that we developed in a subsequent study (Wagers et al. in review).
- Assess potential impact of point density for models relying on crown area.

Study Area



Field plots used in this study. Bottom left: location of the study area within Canada. Left (large): location of the plots within the study area. Top right: an overhead view of one of the plots. Bottom right: ground view of a plot, also showing the TLS, targets, and reflective poles used.

Materials and Methods



Typical plot layout for scan stations used in this study.

- 10 circular plots (radius 3.99 m) in black spruce (< 7 m tall) peatlands near Hay River and Ft Simpson, NT.
- 10 trees harvested per plot, brought in sacks to the lab for drying and weighing to obtain ref. AGB data.
- Plots scanned with a Leica C10 TLS before harvesting (5 scan stations per plot).
- Point clouds of plots post-processed, individual trees segmented, and TLS tree attributes measured.
- 3 model forms: quadratic, power, and multiple regression power.
- 9 predictors tested: crown area (CA), TLS H, TLS DBH, bounding box volume, and 5 more.
- Model performance assessed with Root mean square error (RMSE), mean absolute error (MAE), and adjusted R^2.
- Leave-one-plot-out (LOPO) cross-validation to assess transferability.
- Models ranked by mean Adj-R^2, RMSE and MAE (mean of 10 LOPO iterations).
- Best model compared with national model and with a subsequent model with same form and predictors as the national we derived based on 500 destructively sample trees, of which the 100 TLS'd trees in this study were a subset.
- Point density was simulated by using crown area raster cell sizes from 1 cm to 50 cm in 5 cm intervals.

Results

$$AGB = 0.73 \cdot CA^{0.54} \cdot H^{1.68}$$

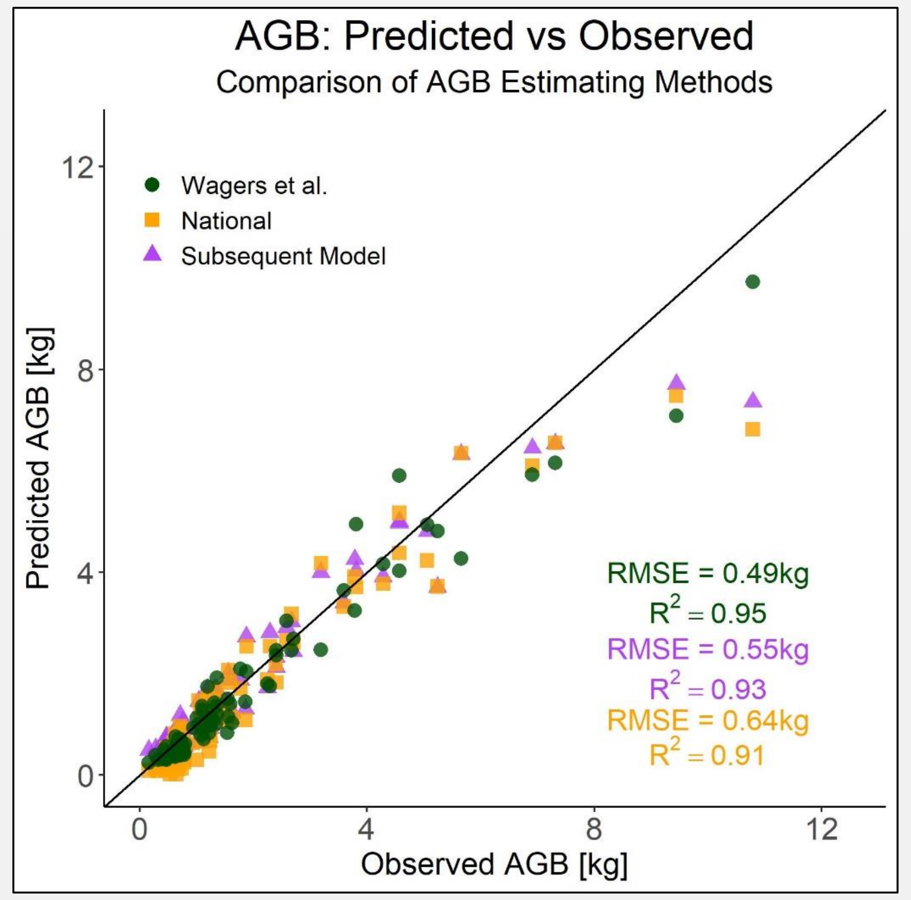
Best Model: Crown Area and Height Multiple Regression Power model

Avg MAE (kg)	Avg RMSE (kg)	Avg adj. R^2
0.22	0.34	0.94

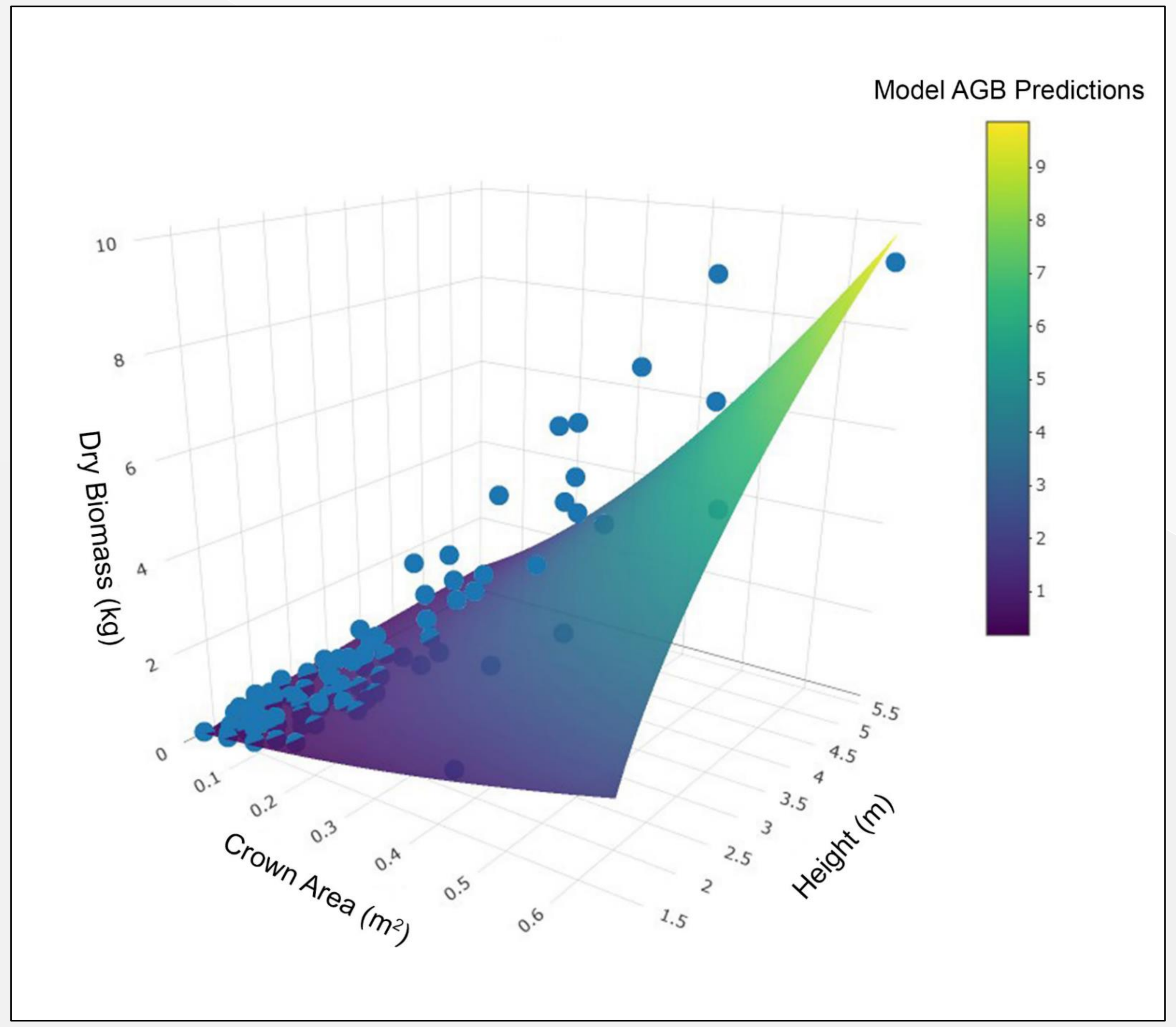
Best model performance calculated from leave-one-plot-out (LOPO) cross-validation.

Model	RMSE (% of avg sample AGB)	Adj. R^2
CAxH Model	27	0.95
National	35	0.91
Sub-sequent Study	30	0.93

RMSE and Adj-R^2 for our best model and for the traditional allometric models.



Comparison of AGB estimates made by our model with those made using the DBH-reliant equations in the national model and a subsequent study.



Graphical representation of our best model: crown area and height multiple regression. The sail-like surface represents predictions, and the blue dots represent reference values for trees in this study.

Conclusions

- The best model to estimate AGB of small black spruce using TLS-measured tree attributes was the multiple regression power model that relied on crown area and height, both of which can be measured with airborne LiDAR.
- Models using crown area and height as predictors estimated AGB better than models that use DBH and height, such as the Canadian national equations, and also those from a subsequent study we did based on ~500 small black spruce trees. A possible explanation is that crown area are less correlated with height than DBH ($r(CA, H)$ = 0.65; $r(DBH, H)$ = 0.96).
- Based on the decreasing point density simulation, our best model could still perform well at point densities as low as 16 points/m^2, which are also sufficient for tree height. This could potentially enable plotless airborne creation of reference AGB data.
- We are testing that possibility in a new study that includes 12 plots for which we have, in addition to TLS, drone and airplane LiDAR flown at different altitudes.

References

1. Ung, C.-H.; Bernier, P.; Guo, X.-J. Canadian National Biomass Equations: New Parameter Estimates That Include British Columbia Data. *Can. J. For. Res.* 2008, 38, 1123–1132, doi:10.1139/X07-224.
2. Wagers, S.; Castilla, G., Filiatrault, M.; Sanchez-Azofeifa, G. A. (2021). Using TLS-measured tree attributes to estimate aboveground biomass in small black spruce trees. *Forests*, 12(11):1521. https://doi.org/10.3390/f12111521
3. Wagers, S.; Castilla, G.; Voicu, M.; Rea, T.; Sanchez-Azofeifa, G. A. New aboveground biomass equations by components for small black spruce in peatland ecosystems of Western Canada. *Can. J. For. Res.*, in review.

Acknowledgments

This research was funded by the collaborative research agreement between CFS and GNWT, CRA-R00893. The Leica C10 was a loan from the Centre for Earth Observation Sciences (CEOS) of the University of Alberta.

Natural Resources Canada Ressources naturelles Canada
Canada

UNIVERSITY OF ALBERTA

Government of Northwest Territories Gouvernement des Territoires du Nord-Ouest