Improving estimation of forest aboveground biomass at plot level using airborne Lidar data to estimate local height heterogeneity

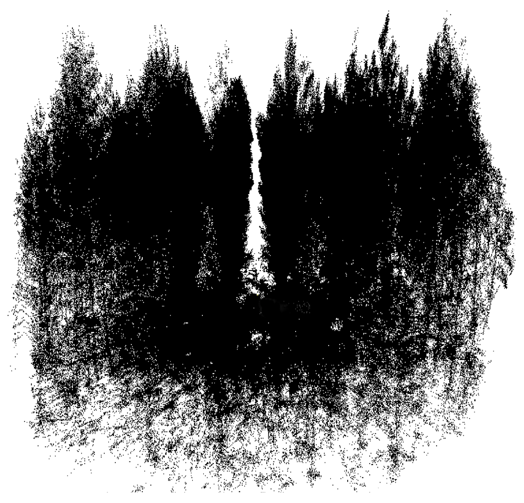
M. Bouvier, S. Durrieu, R.A. Fournier

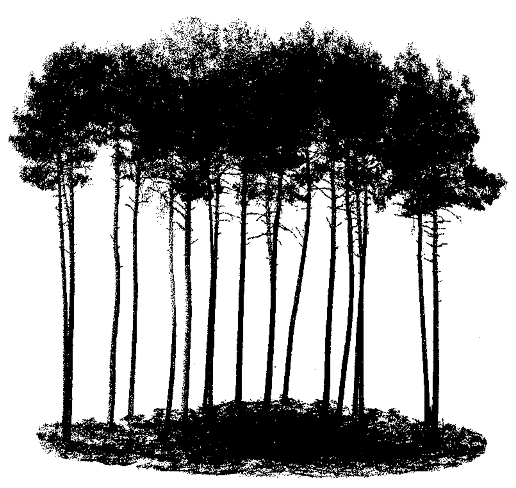
Improving estimation of forest aboveground biomass at plot level using airborne Lidar data to estimate local height heterogeneity

Marc Bouvier[1], Sylvie Durrieu[1], Richard Fournier[2]

Context

The potential of Lidar to assess Above-Ground Biomass (AGB) at plot level is widely acknowledged [Nelson et al. 1988, Næsset 2004, Van Leeuwen and Nieuwenhuis 2010]. In most studies biomass estimations are calculated from statistical relationships linking biomass values derived from field measurements to metrics extracted from the point cloud. In general, several height percentiles are selected to describe tree height distribution, with only a few remaining in the final model. In such approaches, biomass models do not take into account the horizontal heterogeneity of the canopy within the plot.





Mean tree height (m)	Number of trees	AGB ($t.ha^{-1}$)
14,6	78	151
28,5	18	156

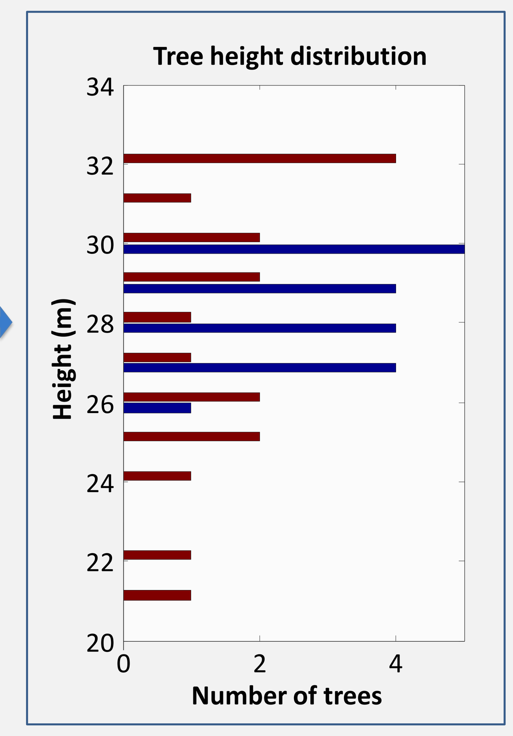
On those two plots: mean tree height cannot explain the approximately same AGB

Need to take into account tree density

Mean tree height (m)	Number of trees	AGB ($t.ha^{-1}$)
28,5	18	156
28,1	18	202

On those two plots: same density and approximately same mean tree height

Need to take into account heterogeneity of tree height distribution



Objective

The aim of this study is to improve AGB estimation models for mono-layer stands by including indicators of the spatial heterogeneity of tree height distribution derived from Airborne Laser Scanning (ALS) data.

Study Site

As part of the FORESEE project, a 70 km2 area covered mainly by Maritime Pine (*Pinus pinaster*) in the Landes forest (South-Western France) was sampled by a small footprint, full-waveform ALS system. Forty circular plots of 0.1 ha or 0.7 ha according to tree heights, were inventoried. Plot biomasses were calculated from tree height and diameter at breast height (DBH) measured in the field using an allometric equation [Shaiek et al. 2011].

Methodology

Investigating field data to determine key parameters that could synthesize tree height heterogeneity in a way compatible with biomass models at plot level led us to define the following Lidar based parameters:

- Gap fraction (P)
- Standard deviation of the canopy height model (CHM) excluding gaps (σ_{CHM})

Those two parameters were calculated with a spatial resolution of 1 m x 1 m.

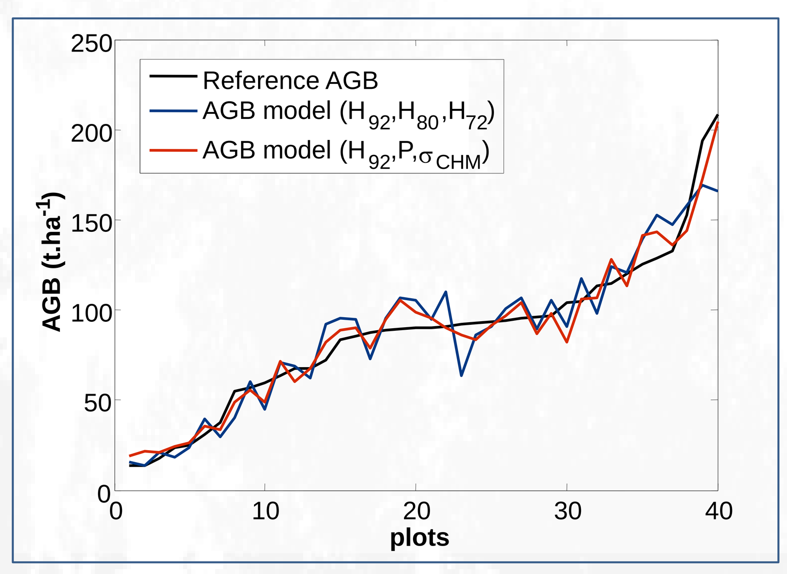
To assess the relevance of such parameters in biomass models, we then compared traditional models based on several height percentiles with models based on the combination of the P and σ_{CHM} parameters and the height percentile with the highest explanatory power (selected by a stepwise regression).

Before calculating height percentiles, point densities were corrected for occlusion effects by (1) weighing each point by number of echoes in the pulse associated with this point and (2) excluding points of upper layers to assess the density at a given layer.

A leave-one-out cross validation method was used to calibrate the AGB models.

Results

Adding a gap information and standard deviation of the CHM to a height percentile value was found to improve AGB estimation as evidenced by increase in R^2 and decrease in RMSE.



Predictors	R^2	RMSE ($t.ha^{-1}$)
H_{92}	0,87	17,8
H_{92},H_{80}	0,92	12,6
H_{92},H_{80},H_{72}	0,92	12,5
H_{92},P,σ_{CHM}	0,96	10,0

Models compared:

- $AGB = c_1 * H_{92}{}^{c_2} * H_{80}{}^{c_3} * H_{72}{}^{c_4}$
- $AGB = c_1 * H_{92}{}^{c_2} * P^{c_3} * \sigma_{CHM}{}^{c_4}$

The model obtained reduces error significantly (4%) compared to models based only on several height percentiles.

Conclusion

We propose introducing specific Lidar metrics (H_{92}, P and σ_{CHM}) to quantify the influence of vertical and horizontal heterogeneity in a model to calculate AGB of a monolayer stand. Tree height, gap fraction and standard deviation of the CHM were found to improve the AGB estimation model compared with the one using height values alone.

Further studies will be required to investigate the capacity of this model to predict AGB in complex forest stands. Full-waveforms data should also be analyzed in order to investigate new Lidar parameters.

References

Nelson, R., Krabill, W., Tonelli, J., 1988. Estimating forest biomass and volume using airborne laser data. Remote Sensing of Environment, 24 (2): 247-267

Næsset, E., 2004. Practical large-scale forest stand inventory using a small-footprint airborne scanning laser. Scandinavian Journal of Forest Research, 19 (2): 164-179

Van Leeuwen, M. and M. Nieuwenhuis, 2010. Retrieval of forest structural parameters using LiDAR remote sensing. European Journal of Forest Research 129(4): 749-770

O. Shaiek, D. Loustau, P. Trichet, C. Meredieu, B. Bachtobji, S. Garchiet, M. Hédi EL Aoun, 2011. Generalized biomass equations for the main aboveground biomass components of maritime pine across contrasting environments, Annals of forest science 68(3): 443-452

[1] UMR TETIS Irstea-Cirad-ENGREF, 500 rue J. F. Breton 34196 Montpellier, France

[2] Centre d'Application et de Recherches en Télédétection, Depart. of Applied Geomatics, University of Sherbrooke, Quebec, Canada J1K 2R1

Contact: marc.bouvier@teledetection.fr

first return
SilviLaser
VANCOUVER 2012