Remote sensing of tree structure and biomass in north Australian mesic savanna

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THE MAIN GOAL OF THIS STUDY IS TO DETERMINE THE OPTIMAL PROCEDURE FOR THE ESTIMATION OF ABOVE-GROUND BIOMASS IN NORTH AUSTRALIAN MESIC SAVANNAS BY USING LIDAR REMOTE SENSING BASED METHODS.

To achieve this goal, we:

(1) ***explore the allometric relationships between field-derived individual tree AGB and LiDAR-derived crown area and tree height;***

(2) ***use the allometric relationships to inform an individual tree delineation algorithm;***

(3) ***integrate individual tree and area-based methods for savanna biomass estimation; and***

(4) ***evaluate uncertainty in savanna biomass estimates at different plot scales.***

Two main approaches for deriving forest biomass information from LiDAR data have been applied so far: the area-based approach (also known as the raster-based approach) and the single tree approach:

Individual Tree Detection (ITD)	Area-Based Approach (ABA)
relying on individual tree detection and estimation of tree attributes using sets of allometric models	based on plot statistical LiDAR points height distributions (e.g. mean, median or percentiles of canopy heights)
usually relies on a raster-based canopy height model (CHM) interpolated from the ALS height data (ind. tree segmentation)	explaining plot-level biomass and regression models
high-density LiDAR data (>5 points m^{-2}) are necessary	low-density LiDAR data (~1 points m^{-2}) are necessary
At least ~100 reference trees should be used for allometric equations creation	considerable field data are required (>5 ha) to establish the relationship between LiDAR height metrics and forest characteristics
most successful in open-spaced homogenous coniferous forests	more efficient and cost-effective for both computation and laser data acquisitions

In this study, we integrate both area-based and individual tree LiDAR methods for estimating the AGB of tropical savanna in northern Australia.

Individual tree detection and biomass estimation results:

LiDAR tree heights were strongly correlated with field-estimated AGB (R^2=0.754, RMSE = 90 kg, 239 tr.) based on the power function:

$$AGB = 0.0109*(H_{Lidar})^{3.58}$$

The overall accuracy of the LiDAR canopy maxima points to validate our individual tree approach was 75.3 % for trees > 10m which account for 91 % of the biomass in this system.

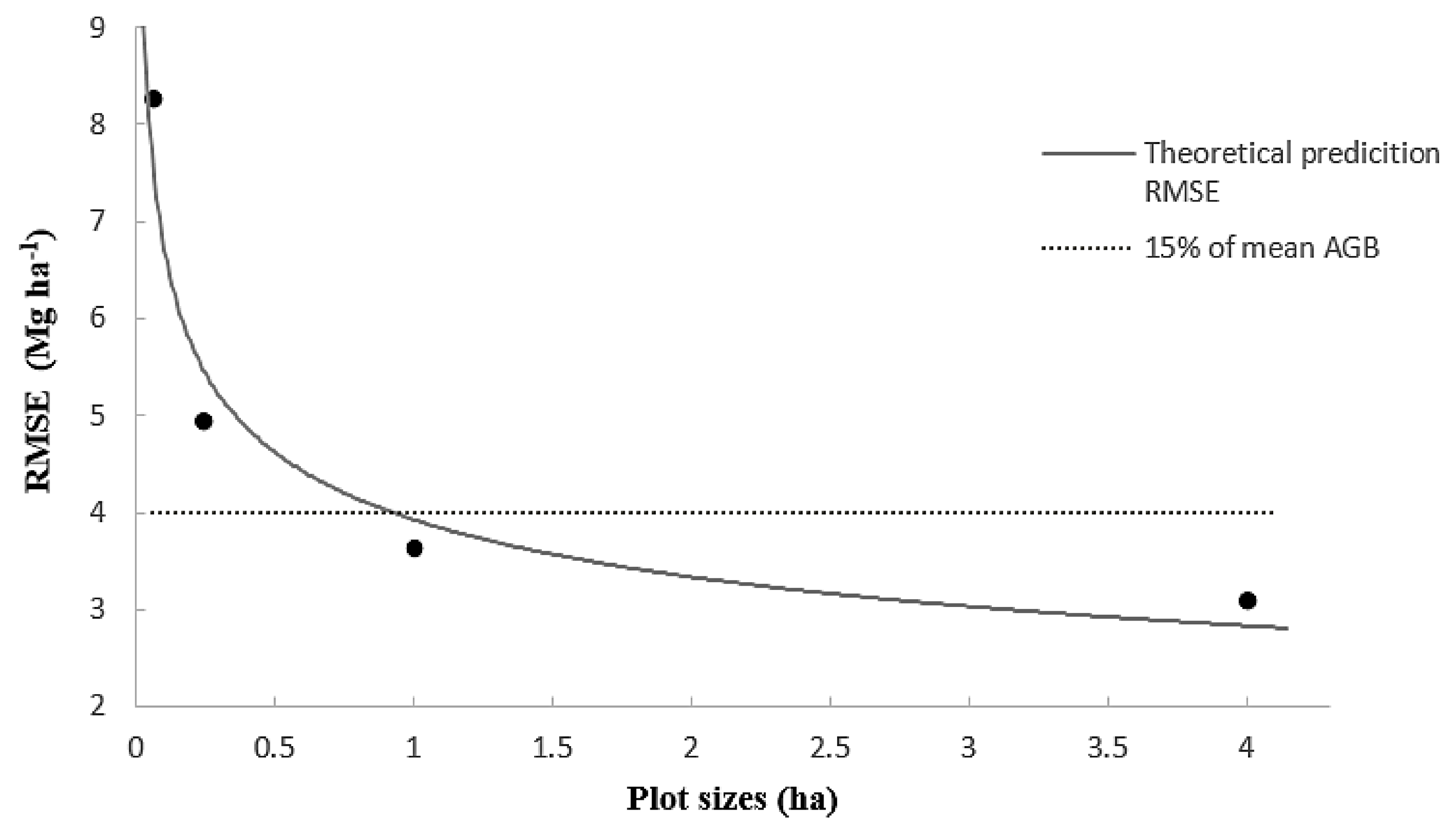
Integration of individual tree and area-based approaches:

To bypass common restrictions related to considerable field data required for ABA, in each plot, individual trees were identified using the local maxima method from the previous step (ITD). The AGB of every detected individual tree was calculated inside each plot by using the power function. The total AGB of each plot was calculated as the sum of the AGB of detected trees in a plot and was used as the reference biomass value.

Stepwise regression analyses identified the quadratic mean of canopy height (QMCH) as the best single predictor variable of AGB in all cases including all LiDAR points in the analysis:

Plot size(ha)	Regression Equation	R^2	RMSE (Mg/Ha)
4	AGB= EXP(9.08+1.39*ln(QMCH))	0.86	3.09
1	AGB= EXP(7.73+1.37*ln(QMCH))	0.835	3.63
0.25	AGB= EXP(6.37+1.36*ln(QMCH))	0.77	4.93
0.0625	AGB= EXP(5.00+1.37*ln(QMCH))	0.65	8.28

The large 1-4 ha sample plot sizes with a lower perimeter-to-area ratio reduce the error caused by edge effects and is recommended for LiDAR-derived biomass estimations. Observed stem localized AGB estimates RMSE for plot sample sizes from 0.0625 to 4 ha, based on QMCH regression analysis against AGB with no cut-off point cloud threshold in 12km2 study area:



The two-phase procedure can be applied in remote areas, where road networks are non-existent or sparse, and is a cost- and labour-effective method as it requires less measurement in the field to calibrate LiDAR estimates than previous remote sensing techniques. This provides a framework for regional forest inventories, monitoring and mapping.

**** Status of research:*** The paper with title "*Hierarchical integration of individual tree and area-based approaches for savanna biomass estimation from airborne LiDAR*" submitted to "Remote Sensing of Environment" journal (March 2017).

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