Estimation of Aboveground Biomass Across Forest Types at Different Degradation Levels in Central Kalimantan (Borneo) using LiDAR and Field Inventory Data

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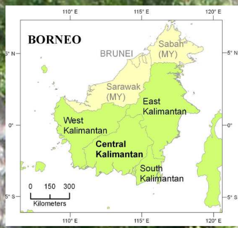
1 Context

- Insular Southeast Asia: highest deforestation rate worldwide (1.3% per year)
- Mostly anthropogenig reasons: shifting cultivation, industrial timber estates, illegal logging, large-scale plantations, peatland drainage for governmental resettlement activities
- Vast areas of the Indonesian peat swamp forest destroyed by forest fires

=> enormous amounts of carbon dioxide release

→ Reducing emissions of deforestation and forest degradation (REDD)-mechanism: potential to be a tool for saving tropical ecosystems



2 Objectives

- Estimation of above ground biomass (AGB) values for different forest types within Central Kalimantan (Indonesia)
- create a basic methodology for future REDD projects
- AGB estimation by LiDAR (Light Detecting and Ranging) data analysis, making use of collected field inventory data
- Two approaches:
  (1) linking single tree parameters via allometric equations
  (2) developing a multiple regression model at plot level using laser point cloud characteristics

3 Field inventory

- barely no inventory data for Kalimantan's forests
- requirement of a high number of field plots
- faster angle count sampling method (fixed-area plots as a control)
- 328 angle count plots and 64 nested plots recorded in lowland dipterocarp forest (LDF), peat swamp forest (PSF) and heath forest
- Degradation states: unlogged, logged, burned
- Calculation of AGB: widely accepted models by IPCC (2006), Brown (1997), and Chave et al. (2005) (including and excluding tree height)
- Chave-height-excluding model most accurate

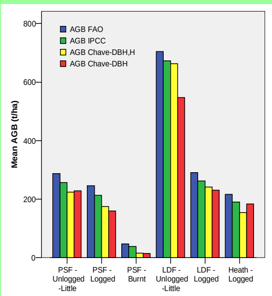
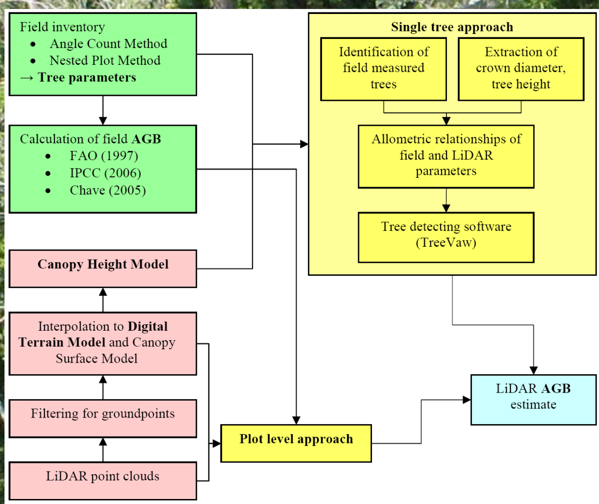


Figure 1 Average AGB values per forest-/ land use type derived from different formulas (including tree height: AGB Chave-DBH,H; excluding tree height: AGB Chave-DBH). (DBH = diameter at breast height; H = tree height)



4 LiDAR data

- 3D information of forest structure
- High sampling intensity, direct measurements of heights, precise geolocation, automated processing

=> useful for directly assessing vegetation characteristics and deriving forest biomass

- Scanning of 8,090 ha by a Riegl LMS-Q-560 Airborne Laser Scanner, providing small-footprint full-waveform data
- Groundpoint-filtering (Kraus & Pfeifer, 1998)
- interpolation to a digital terrain model (DTM)
- Subtracting the DTM from the canopy surface model gives the canopy height model (CHM)

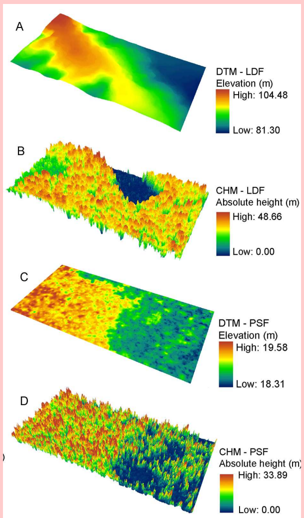


Figure 2 3D view of the surface models: DTM (A, C), and CHM (B, D). The LDF subset shows primary and secondary forest and an abandoned rice field. The PSF forest subset shows a transition zone from burned to forested (logged) area.

5 Single tree approach

- 415 out of 1034 field-positioned trees identified in the CHM (Fig. 3)
- Field and LiDAR derived height showed a significant correlation of 0.87 (0.1 level)
- Diameter at breast height (DBH) measured in the field and LiDAR derived crown diameter and height linked by allometric equations:
  - lowland dipterocarp forest: $R^2 = 0.63$
  - peat swamp forest: $R^2 = 0.77$
- TreeVaW, a tree detection software, used to identify individual tree parameters of whole LiDAR tracks
- These AGB values were generally underestimated due to the non-detectable understorey biomass

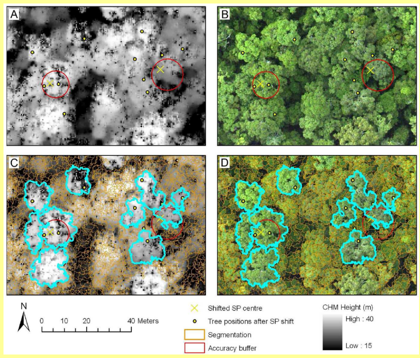


Figure 3 Crown identification by means of segmentation of CHM (A, C) and aerial photo (B, D) in LDF. Identified crowns are selected (bright blue).

5 Plot level approach

1) Extraction of 3D laser point clouds of 1-ha-plots (angle count) and 1256m²-plots (nested plots) and determination of height statistics of point clouds
   - Mean, maximum
   - Std. deviation, range, variance, std. error of mean
   - 5th to 95th percentile
   - Canopy cover

2) Multiple regression analysis (stepwise selection)

=> AGB-predicting models for each forest type

Plot size	Forest type	R^2	RMSE (%)
1-ha-plots	LDF+PSF	0.68	37.71
	LDF	0.82	21.75
	PSF	0.42	34.88
1256m²-plots	PSF	0.47	30.98

- 1256m²-plots: model validation weaker than for 1-ha-plots for both types and for LDF

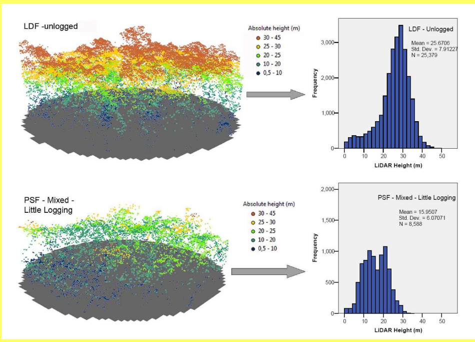


Figure 4 Example distribution of LiDAR point heights within two different 1 ha plots. 3D-view of the point clouds with the corresponding histograms.

6 Application

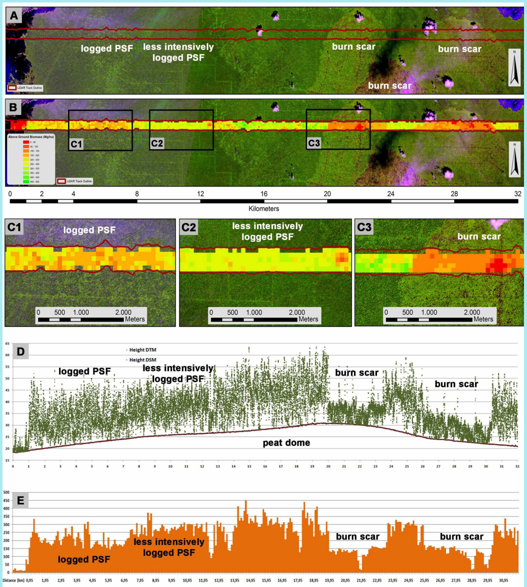


Figure 5 AGB calculation for a whole LiDAR track in PSF using the best regression model (grid cell size: 1 ha) **A** LiDAR track outline on a RapidEye image **B** AGB results of 1-ha-cells **C** greater extents **D** height profiles **E** histogram of AGB values

7 Conclusion

- Plot level approach more adequate and effective than the single tree approach
- Regression models able to estimate spatial variability within a degradation class

=> The models have high potential to be implemented in REDD projects which will contribute to the protection of forest ecosystems throughout Kalimantan, to ensure a sustainable way of living for the local people and improve their living conditions by the means of fair payments from the industrialized countries.

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