Indonesia
Biomass estimation for epoch 2010

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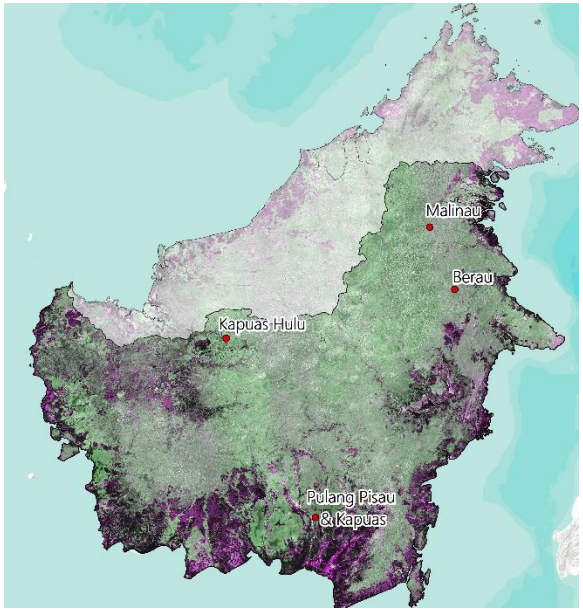
Borneo

- Area: Kalimantan
  540,000 km²
- Different forest ecosystems:
  - Mangrove forests
  - Peat swamp and freshwater swamp forests
  - Lowland, hill- and sub-montane dipterocarp forests



Three training sites across Borneo

- **Central Kalimantan**
  - 165 field inventory plots
  - 8,000 km² full-coverage LiDAR
- **West Kalimantan** (Kapuas Hulu)
  - 84 field inventory plots
  - 1200 km LiDAR transects
- **East Kalimantan** (Berau & Malinau)
  - 78 field inventory plots
  - 1500 km LiDAR transects

Data provided by:

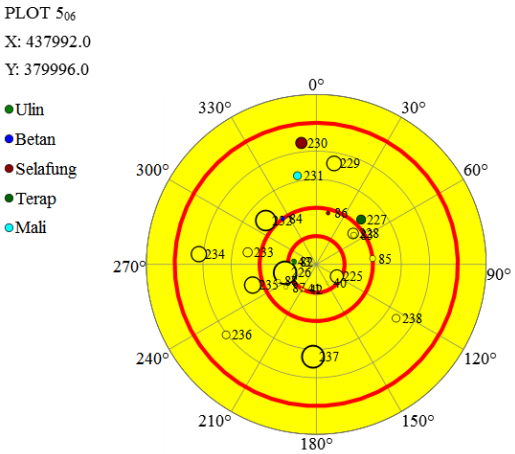
giz

FORCLIME
Forests and Climate Change Programme

WWF

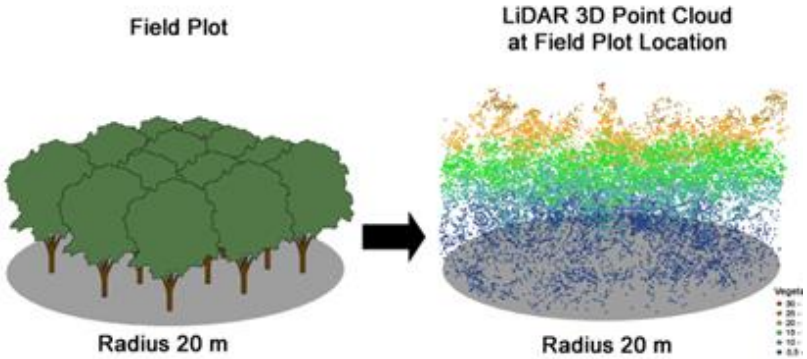
Australian Government
AusAID

Forest inventories & allometric modelling to estimate AGB

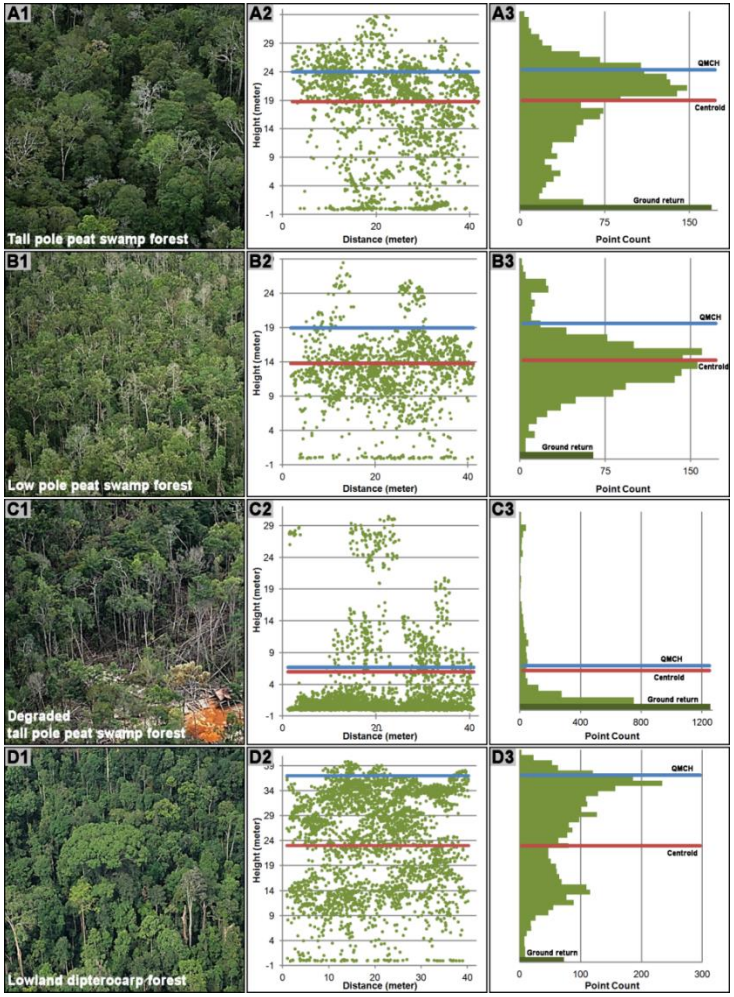


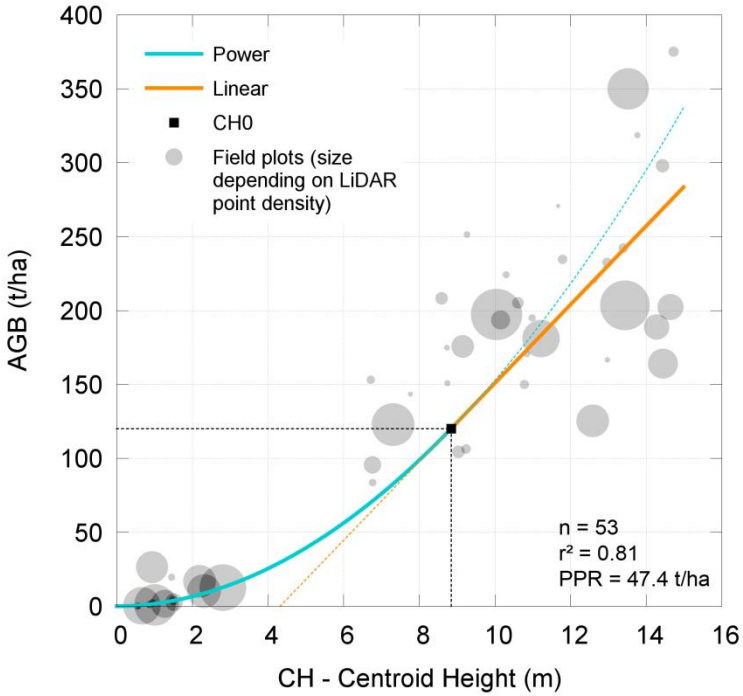
Nested plots

- Forest type - tree species – DBH – (tree height)
- Estimation of biomass and carbon per ha by allometric models (Chave et al. 2005 for moist tropical forests)



LiDAR height metrics for AGB estimation





LiDAR height metrics:

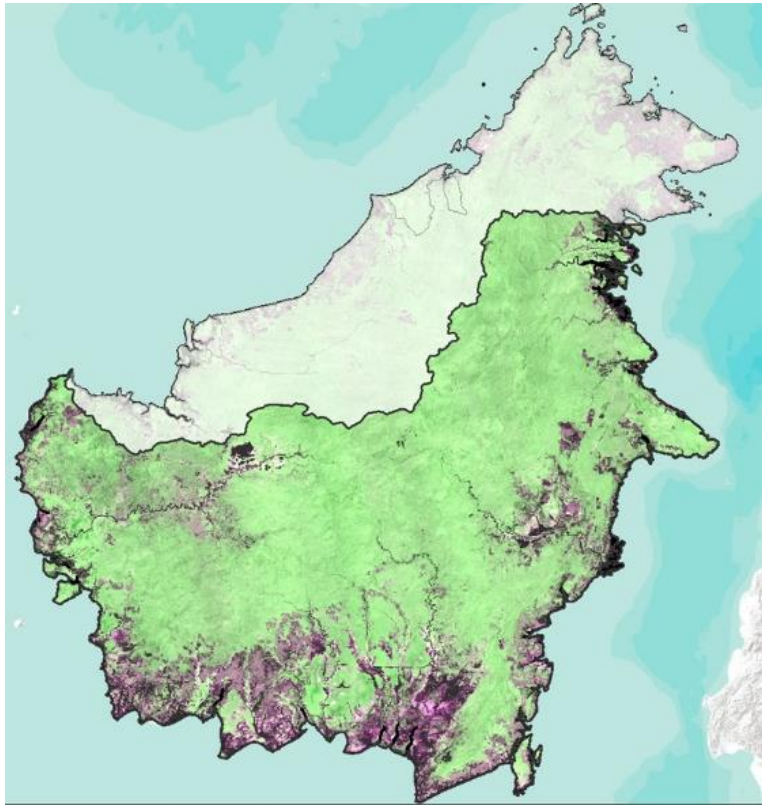
› Centroid Height (CH)

› Quadratic mean canopy height (QMCH)

Published: *Jubanski et al. 2013, Englhart et al. 2013*

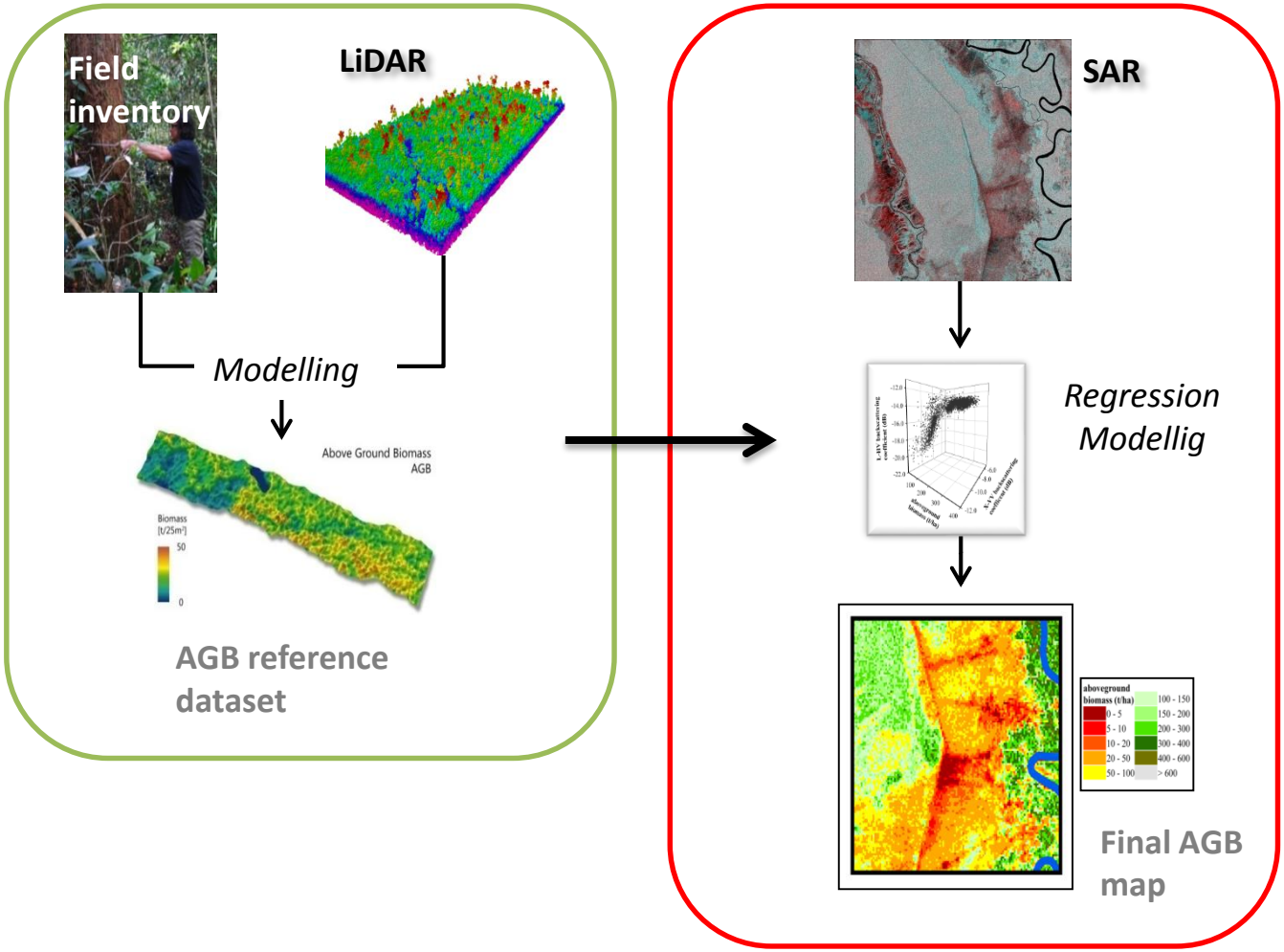
Satellite imagery

- **ALOS PALSAR mosaic**
  - 25 m spatial resolution
  - acquired in 2009
  - HH, HV polarization
  - Acquired during dry season (May-October)
- **SRTM**
  - 30m spatial resolution
- **Additional data**
  - ESRI Word Water Bodies
  - Modis Hotspots



Methodological approach: Upscaling of AGB field data using LiDAR

- Continuous aboveground biomass (AGB) reference data
- Accurate AGB estimations representing the whole biomass range

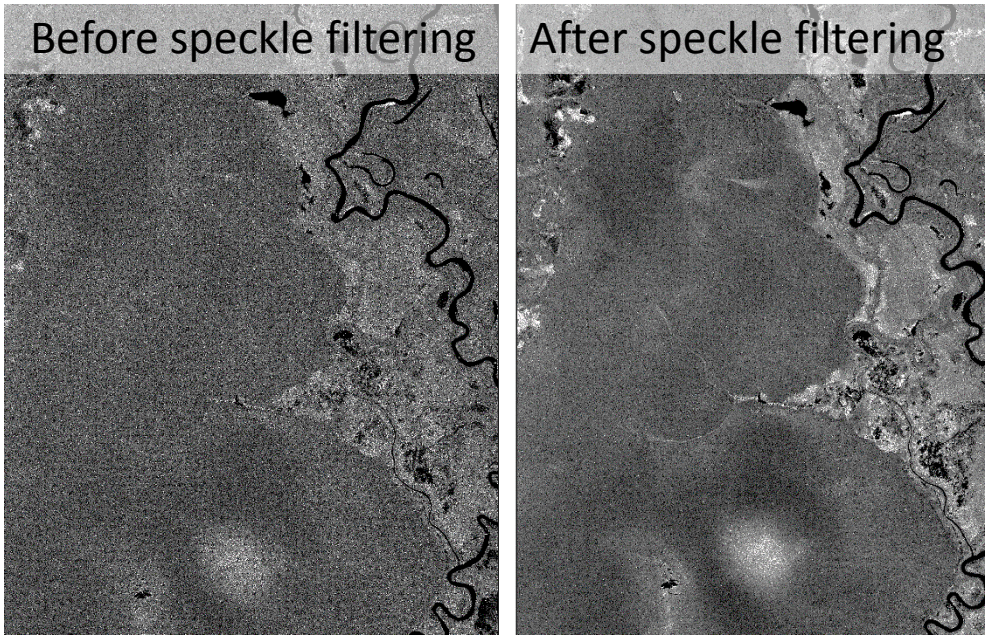


SAR pre-processing

- **Geo-referencing (if necessary)**
- **Radiometric calibration**

$$\gamma_0(dB) = 10 * \log_{10}(DN)$$

  - Gamma naught calibration including terrain correction
- **Speckle reduction**
  - Multi-temporal Filter (7 x 7 moving window)



SAR processing

- **Ratios**
  - R_{HVHH} = HV/HH
  - $SQRT_{HHHV}$=√(HH09 * HV09)
- **Simple texture: Gray Level Co-occurrence Matrix (GLCM)**
  - Correlation $$f(x) = \sum_{i,j} \frac{(i-\mu)(j-\mu)g(i,j)}{\sigma^2}$$
- **Higher texture: Gray Level Run-length Matrix (GLRM)**
  - Short Run Emphasis
  - Long Runs Emphasis
  - Run Length Nonuniformity
  - Run Percentage
  - High Grey-Level Run Emphasis
  - Short Run Low Grey-Level Emphasis

$$SRE = \frac{1}{n_r} \sum_{i,j} \frac{p(i,j)}{j^2}$$

$$LRE = \frac{1}{n_r} \sum_{i,j} p(i,j) * j^2$$

$$RLN = \frac{1}{n_r} \sum_{j} \left(\sum_{i} p(i,j) \right)^2$$

$$RP = \frac{n_r}{n_p}$$

$$HGRE = \frac{1}{n_r} \sum_{i,j} p(i,j) * i^2$$

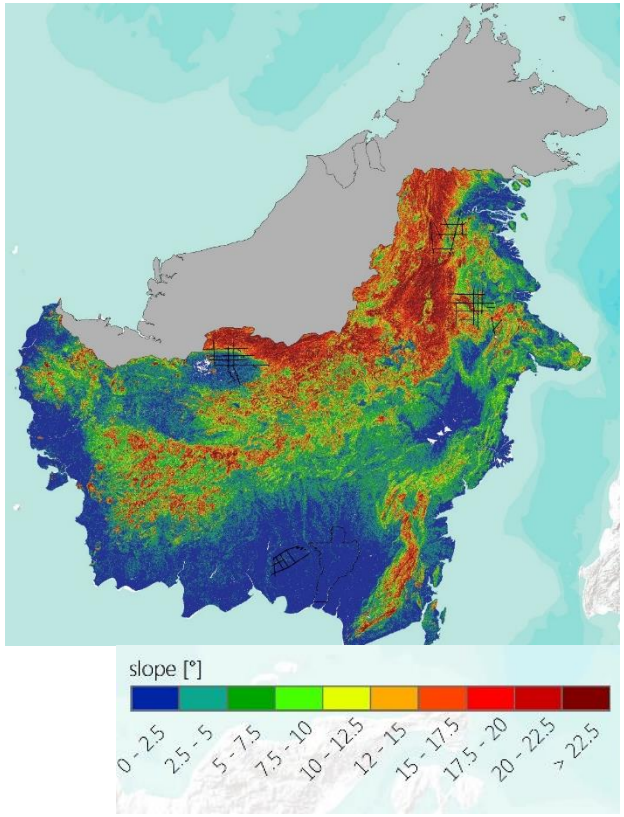
$$SRLGE = \frac{1}{n_r} \sum_{i,j} \frac{p(i,j)}{i^2 j^2}$$

(after Thapa et al. 2015 and Hamdana et al. 2014)

Reference data: LiDAR AGB

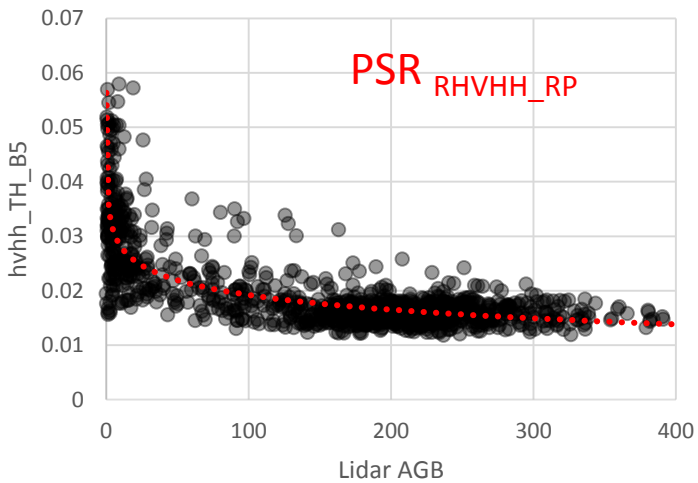
- Areas excluded:
  - Deforestation due to fire between LiDAR and SAR acquisition dates (MODIS hotspots)
  - SAR Layover and shadow (ALOS mask)

- Randomly selected and split for
  - Training (70%)
  - Validation & accuracy assessment (30%)

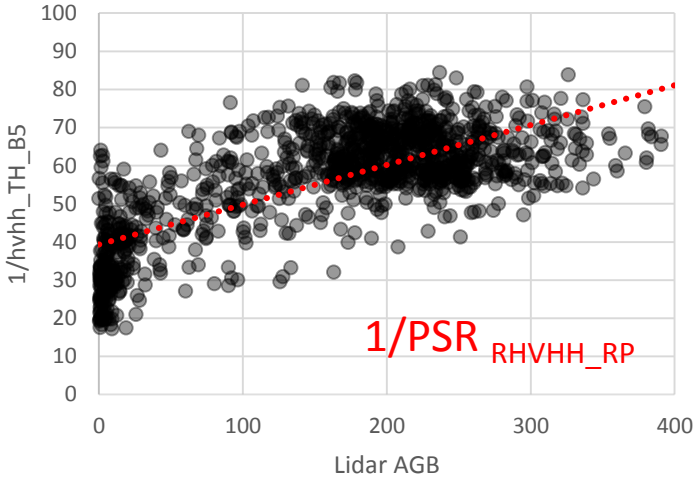


SAR AGB estimation

› Analysis of relationship between AGB and SAR input variables



linearization



› Multiple linear regression model

$$AGB = a_1 \cdot \mathrm{var}_1 + a_2 \cdot \mathrm{var}_2 + \ldots + a_n \cdot \mathrm{var}_n + c$$

- *Backward stepwise selection*
- *Reduction of variables (p-value, VIF: Variable Inflation Factor)*

SAR AGB model 2010

$$\boldsymbol{AGB} = -2366000 * exp(PSR_{HV}) - 105.2 * ln(PSR_{HV\_RP}) + 2.865 * \left(\frac{1}{PSR_{RHVHH\_RP}}\right) - 101.6$$

PSR_{HV} = ALOS PALSAR HV

PSR_{HV_RP} = ALOS PALSAR HV Run Percentage

PSR_{RHVHH_RP} = ALOS PALSAR Ratio (HV/HH) Run Percentage

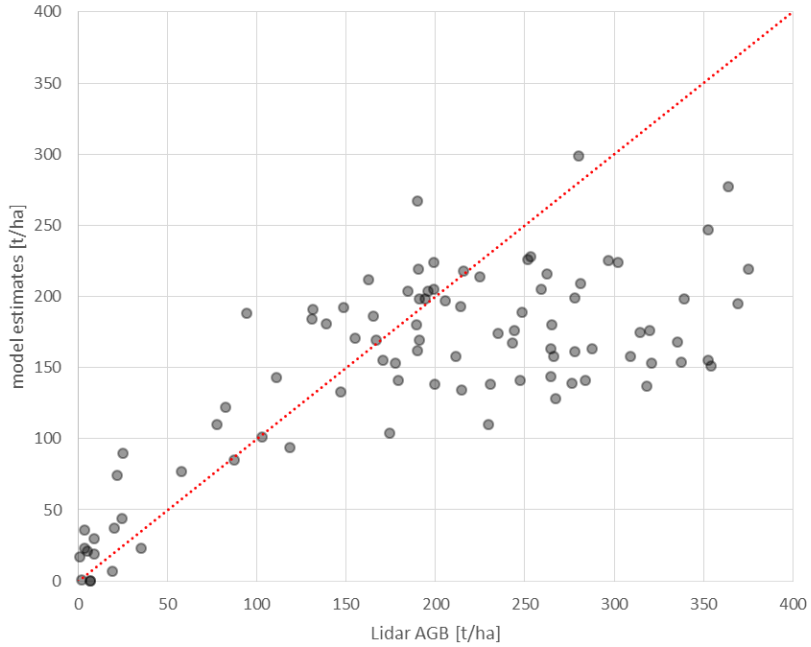
R^2=0.65

Residual standard error= 56.58 t/ha

AGB estimation accuracy depends on terrain

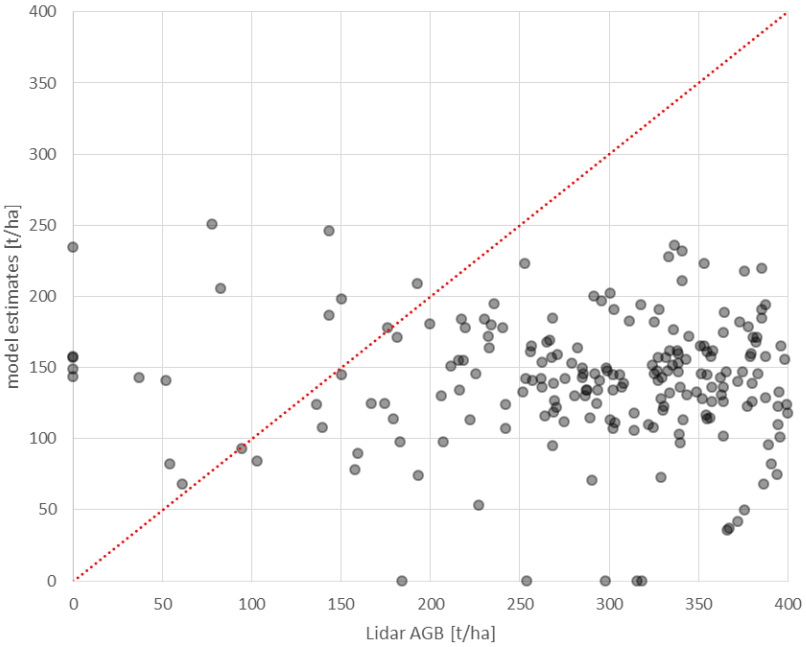
Slope < 10°

RMSE=80 t/ha



Slope > 10°

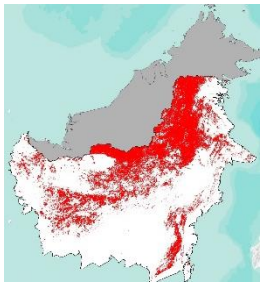
RMSE=238 t/ha



Modification of AGB estimations

- **Slope > 10°**

  Improvement of model in areas > 10° slope based on precise LiDAR AGB estimations



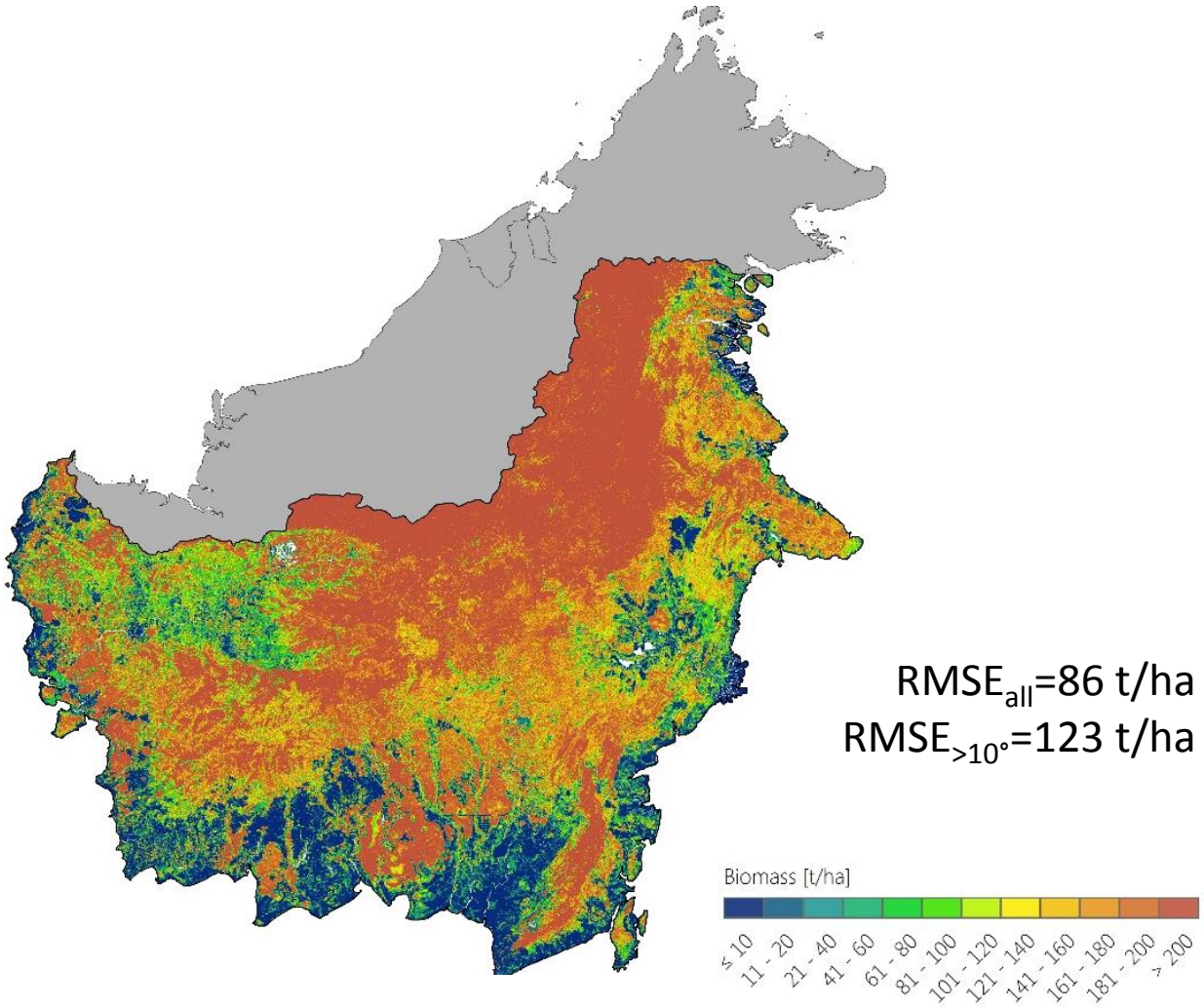
- **Negative AGB Values** = 0 t/ha

- **Water** = -1

  using ESRI water body mask

Modification of AGB estimations

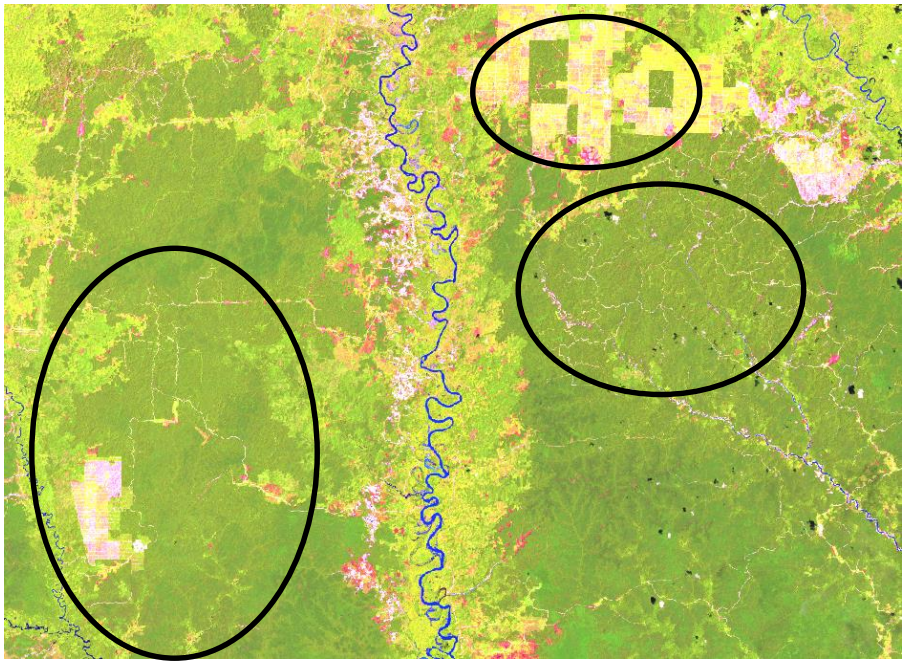
Correction of:
Slope
Negative Values
Water

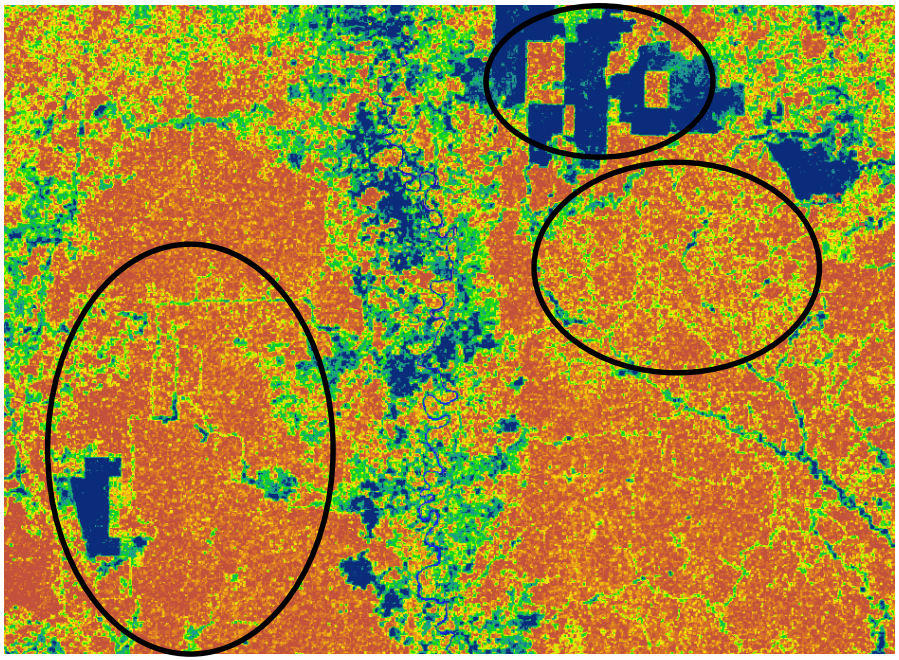


$RMSE_{all}$=86 t/ha
$RMSE_{>10°}$=123 t/ha

Strengths

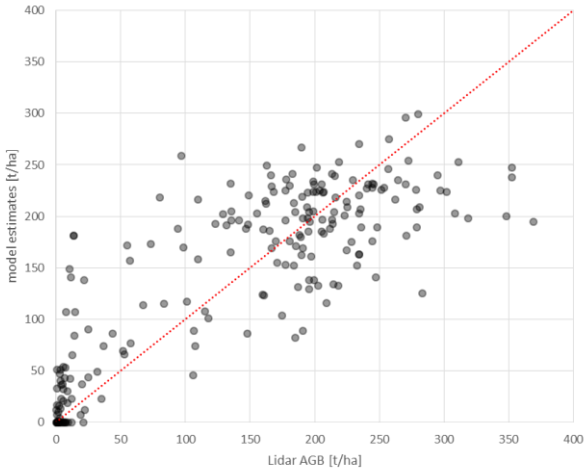
- AGB estimation up to 250 t/ha showing variability in lower and higher AGB ranges
- Change assessment and emission estimation feasible

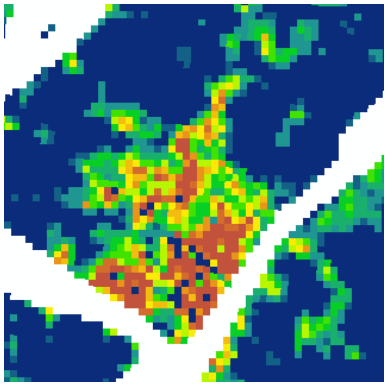




Limitations and error sources

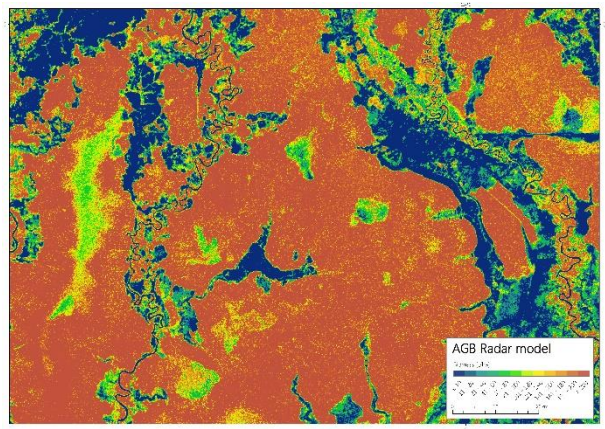
- SAR signal saturation ~ 250 t/ha
- Slope > 10°
- AGB overestimation in cities



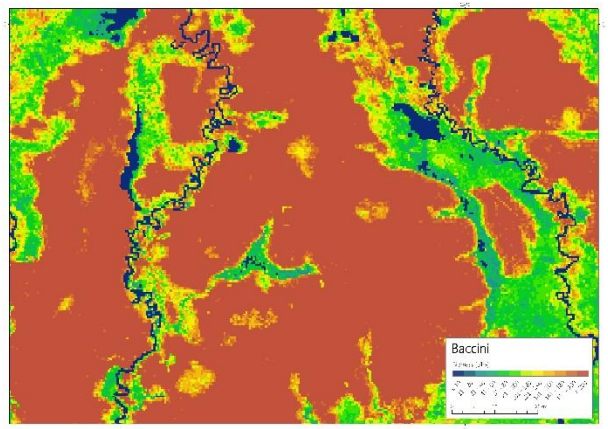


Comparison with other tropical AGB maps – Central Kalimantan

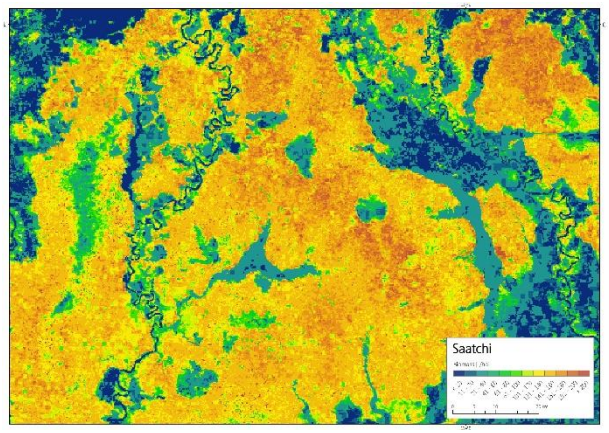
SAR AGB model

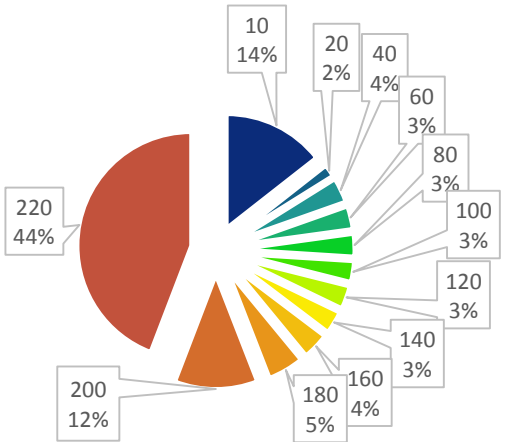


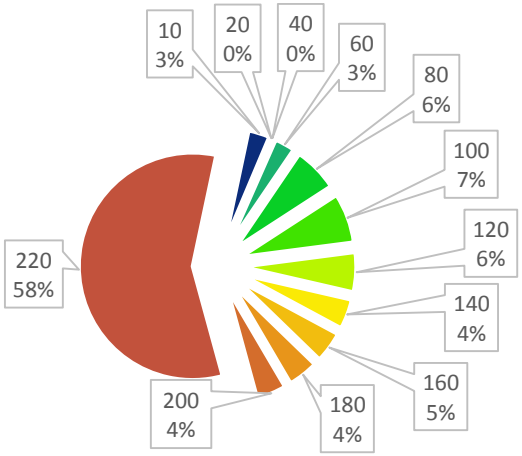
Baccini et al. 2012

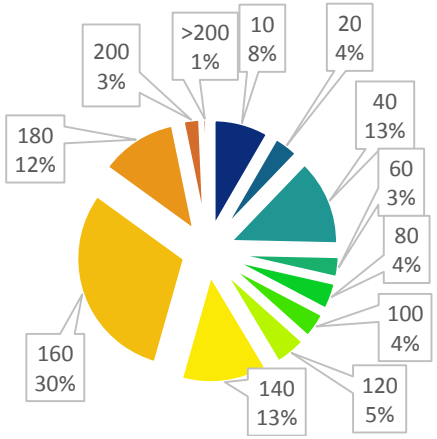


Saatchi et al. 2011





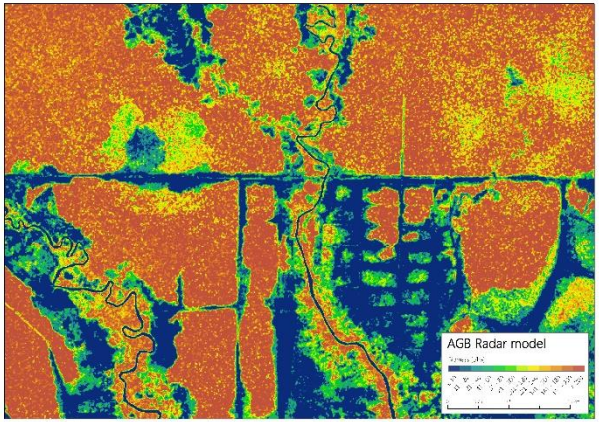




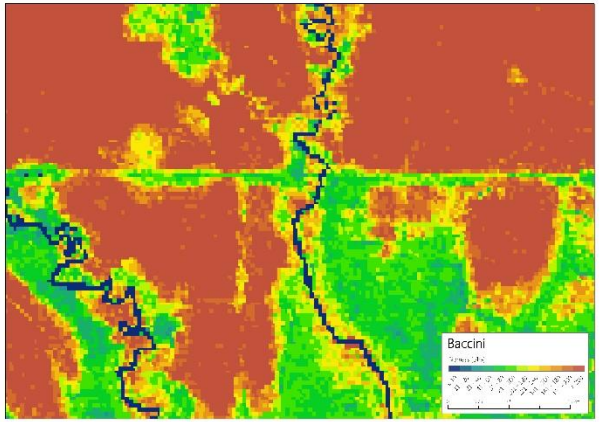
10 20 40 60 80 100 120 140 160 180 200 220

Comparison with other tropical AGB maps – Central Kalimantan

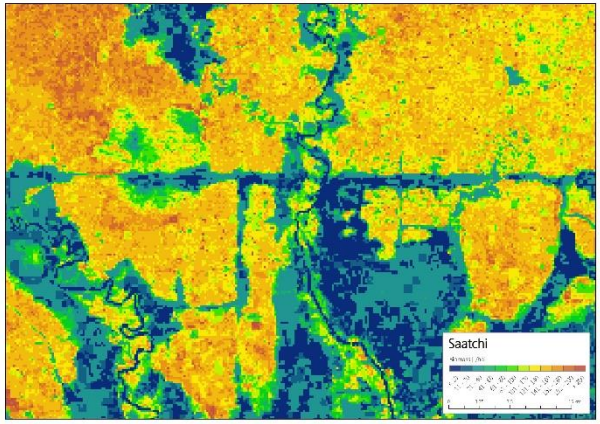
SAR AGB model

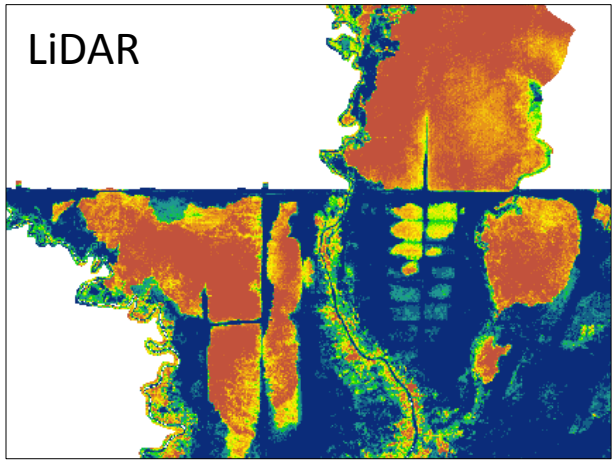


Baccini



Saatchi





Thank you for your attention!

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