Toward Distribution of Aboveground Forest Carbon Stock from ALOS PALSAR and Data Fusion

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OUTLINE

• Results from field campaigns
• Limitations of ALOS PALSAR
• Data Fusion Approach
• Summary and Conclusion
Field Data

Variable plot sizes: 0.1-1.0 ha

- Mbam Djarem National Park (NDNP), Cameroon: Forest-savanna ecotone contiguous with Congo Basin: (24 plots)

- Budongo Forest Reserve (BFR), Uganda
  Remnant patches of tropical forest, farmland, savanna: (129 plots)

- Nissa National Reserve (NNR), Mozambique:
  Miombo Woodland: (42 plots)

- Nhambita Community Carbon Project (NCCP), Mozambique:
  Miombo Woodlands: (58 plots)
a) HH response to AGB

R² = 0.55
p < 0.0001
n = 253

Cameroon - MDNP
Mozambique - NCCP
Mozambique - NNR
Uganda - BFR

b) HV response to AGB

R² = 0.73
p < 0.0001
n = 253
AGB < 150 Mg/ha
Estimation Accuracy: ~ ±20%

\[
\sigma^0_{HV} = -22 + 2.73 \ln(AGB) - 0.156(\ln(AGB))^2
\]

\[
AGB = \exp\left[\frac{-2.73 + \sqrt{7.45 - (0.623(22 + \sigma^0_{HV}))}}{-0.311}\right]
\]
Assessment of Changes of Biomass from Disturbance and Recovery

Mbam Djarem National Park (NDNP), Cameroon: Forest-savanna ecotone contiguous with Congo Basin: (24 plots)
$r^2 = 0.76$
$p < 0.0001$

$\text{Basal area (m}^2\text{ ha}^{-1}\r)\$

$-14$

$-20$

$\text{ALOS HV } \sigma_0^\circ (\text{dB})$

$\text{Basal area (m}^2\text{ ha}^{-1}\r)\$

$-6$

$-11$

$\text{ALOS HH } \sigma_0^\circ (\text{dB})$

$\text{Basal area (m}^2\text{ ha}^{-1}\r)\$

$-6$

$-11$

$\text{ALOS HH } \sigma_0^\circ (\text{dB})$

$\text{Basal area (m}^2\text{ ha}^{-1}\r)\$

$-6$

$-11$

$\text{ALOS HV } \sigma_0^\circ (\text{dB})$

$\text{Average height (m)}$

$-14$

$-20$

$\text{ALOS HV } \sigma_0^\circ (\text{dB})$

$\text{Average height (m)}$

$-6$

$-11$

$\text{ALOS HH } \sigma_0^\circ (\text{dB})$

$\text{Average height (m)}$

$-6$

$-11$

$\text{ALOS HH } \sigma_0^\circ (\text{dB})$

$\text{Average height (m)}$

$-6$

$-11$

$\text{ALOS HH } \sigma_0^\circ (\text{dB})$
a) Location of cross-calibration points overlaid on ALOS biomass map

![Biomass map]

b) JERS HH backscatter against ALOS HV-derived AGB

![Graph with regression line and statistics]

\[ r^2 = 0.95 \quad p < 0.0001 \]

<table>
<thead>
<tr>
<th>Biomass Range</th>
<th>Minimum spatial scale at which change can be detected <strong>annually</strong></th>
<th>Minimum spatial scale at which change can be detected <strong>decadally</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100 Mg ha(^{-1})</td>
<td>±1 Mg ha(^{-1}) yr(^{-1})</td>
<td>±5 Mg ha(^{-1}) yr(^{-1})</td>
</tr>
<tr>
<td>100-200 Mg ha(^{-1})</td>
<td>2.5 km</td>
<td>500 m</td>
</tr>
<tr>
<td>&gt; 200 Mg ha(^{-1})</td>
<td>4 km</td>
<td>800 m</td>
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</tbody>
</table>
Assessment of Biomass Change Measurement from Disturbance and Recovery
Field Data

• La Selva: 28 1-ha plots

• BCI: 50-ha plot & 52 single 1-ha plots

• Mbam Djarem Cameroon: 18 1-ha plots

• Pearl River, Katrina: 38 0.1 1-ha
The document presents a model for estimating Aboveground Biomass (AGB) using L-band HV polarization of the ALOS PALSAR sensor. The model is given by:

\[ \text{LHV (dB)} = -22.5 + 3.0 \log(\text{AGB}) \]

The scatter plots show the relationship between L-band HV backscatter and aboveground biomass for different locations:

- **Cameroon** with an adjusted coefficient of determination \( r^2 = 0.84 \) and \( p < 0.0001 \).
- **La Selva** with \( r^2 = 0.79 \) and \( p < 0.0001 \).
- **Pearl River, Katrina** with \( \text{HV (dB)} = -21.79 + 2.26 \log(\text{AGB}) \) and \( r^2 = 0.79 \).
- **BCI < 250 Mg/ha** with \( y = -20.782 + 2.241 \log(x) \) and \( r^2 = 0.85418 \).
Radar Backscatter Derived Biomass
Tropical Forest
Comparison of AIRSAR & ALOS PALSAR Data

La Selva Biological Station

Incidence Angle: 45-55 degrees

Ground Radar Measurement of Attenuation

Lang et al., 2008

AIRSAR

\[ R^2 = 0.42 \]
\[ P < 0.001 \]

ALOS

\[ R^2 = 0.79 \]
\[ P < 0.0001 \]
Impact of Geolocation Error on Biomass Estimation

Impact of 1 pixel (25 m) geolocation error: The overall relationship stays the same but the backscatter variability increases.
Impact of Resolution on Biomass Retrieval

Polarimetric Measurements
Estimation using HH, HV, VV

For 0.5 ha:
- \( R^2 = 0.58 \)
- RMSE = 39 Mg/ha
- Pixel Size: 0.5 ha

For 1.0 ha:
- \( R^2 = 0.7 \)
- RMSE = 28 Mg/ha
- Pixel Size: 100 m
Assessment of Carbon Stock and Emission
Borneo
ICESAT GLAS Lidar Measurements
Forest Height

Waveform recording lidar

\[ AGBM = 20.7 + 0.098 \times H^2 \]

\[ R^2 = 0.73 \]
Radar & Lidar Fusion Approach to Map Biomass

1. A probabilistic framework
2. Develop incomplete empirical probability distribution based on the occurrences
3. Approximate with a probability distribution of maximum entropy
4. Use environmental variables as constraints
5. A rule classifier to produce forest biomass map

Maximum Entropy Estimation Model

\[ H(\pi) = \sum_{x \in X} \pi(x) \ln \pi(x) \]
Distribution of Aboveground Forest Biomass in Borneo

AGLB Mg/ha

- Bare
- Savanna
- 0-25
- 25-50
- 50-75
- 75-100
- 100-150
- 150-200
- 200-250
- 250-300
- 300-350
- 350-400
- > 400
Assessment of Biomass Class Accuracy

Lidar Estimated Biomass (Mg/ha)

Estimated Biomass Class

AGB Class

AGB Mg/ha

- Bare
- Savanna

0-25
25-50
50-75
75-100
100-150
150-200
200-250
250-300
300-350
350-400
> 400
ALOS Imagery
HH, HV, HH-HV
Monitoring Deforestation and Forest Degradation

2007

2007
SUMMARY

• L-band PALSAR can measure AGB<\((100-150)\) Mg/ha with 20% Accuracy and may classify high biomass forests. Seasonality of moisture and phenology, scale of estimation, geolocation errors will impact the accuracy.

• L-band PALSAR can measure forest disturbance and recovery at 100 m spatial resolution. Seasonality of moisture and phenology will impact the estimation.

• Fusion of radar and lidar can provide estimates of above-ground biomass at resolutions > 100 m and with variable accuracy over high biomass forests.