**Polarimetric SAR Interferometry:**

*Potential and Limitations for Biomass Estimation*

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**Biomass Estimation**

<table>
<thead>
<tr>
<th>Cylinder Volume</th>
<th>Form factor</th>
<th>Wood density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-section Area at breast height</td>
<td>1 = cylinder, 1/3 = cone</td>
<td>softwoods: 40–55, hardwoods: 55–80</td>
</tr>
</tbody>
</table>

Tree Biomass [1000kg] = \(\pi \cdot (\frac{1}{2}dbh)^2 \cdot \text{height} \cdot f_z \cdot \rho \)

Forest Biomass [t/ha] = Basal area \( \cdot \text{height}_{mid} \cdot f_z \cdot \rho_{mid} \)

\[ \text{Sum of all tree biomasses per area unit (ha)} \]

This formula is very easy to use for single-species single-layered forest systems (like in yield tables).

In heterogeneous forests, \( \text{height}_{mid} \) is difficult to calculate because it varies with forest structure, and for \( \rho_{mid} \) the softwood-hardwood ratio should be known at least.
Height is the only single forest parameter that allows biomass estimation with accuracies > 85%.

- Wood density has a diverging effect on the basal area-biomass allometry because softwood forests already grow with a lower height for a given basal area.
- The differences are mainly due to different tree densities.

... stand conditions affect the forest growth rate, but not the allometry between height and biomass. (extended low of Eichhorn)

... height and biomass are directly related => Allometry
Due to lower wood density, N. spruce has the same biomass/height ratio as beech, and oak (pine lower due to thinning).

"Unnatural" densities introduce a bias.

Height is the only single forest parameter that allows biomass estimation with accuracies > 85%.
Bayrischer Wald Test Site

Topography: 750-1300 m a.s.l.

Vegetation: Natural forest stands (National Park)
- Montane spruce forest (Picea abies – above 1100 m a.s.l.)
- Submontane mixed forest (600-1100 m a.s.l.)
  Picea abies / Fagus sylvatica / Acer pseudoplatanus
- Floodplain spruce forest

205 Inventory Points
27 Validation Stands
LIDAR Height Estimates

Lidar data:
Precise, continuous single tree heights

Problems:
stands with standing dead wood, heterogeneous stands

h100 Calculation stands:
Mean of highest 10% lidar heights

Lidar height Map
Lidar h100

Height Validation

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Biomass Validation
E-SAR / Test Site: Bayrischer Wald, Germany

**Graph 1:**
- X-axis: Usable biomass inventory [t/ha]
- Y-axis: Biomass PolInSAR-Atmospher [t/ha]

**Graph 2:**
- X-axis: Usable biomass validation sites [t/ha]
- Y-axis: Biomass PolInSAR-Atmospher [t/ha]

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**AIRBORNE SAR CAMPAIGN OVER TROPICAL FOREST**

**INDREX2**
**INDONESIA RADAR EXPERIMENT**
- November, 2004

**Indirect Validation**

**Validation Error Estimation**

**Validation Error:**
- Linear fit
- Error estimation

**Validation Methodology**
- Remote sensing
- Aerial surveys
- Ground truth

**Validation Result:**
- Biomass estimation accuracy
- Validation sites summary
E-SAR / Test Site: Sungai-Wain North, Indonesia

E-SAR / Test Site: Sungai-Wain North, Indonesia

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**Dual-Baseline RVoG Model Validation**

**Single-Baseline Pol-InSAR Forest Height Inversion**

**Forest Height Map**
- Max-Height: ~58m
- Mean Height: ~25-30m

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Summary

Height is the key parameter for biomass estimation.

Pol-InSAR → Forest Height & Forest Height (+ ...) → Biomass

Height estimation from Pol-InSAR at L-band has been validated over several test sites with very different forest conditions in Europe. The estimation accuracy lies between 10-20%.

Limitations / Open Questions:

- Penetration of L-band into dense vegetation layers (tropics).
- Height estimation in very sparse vegetation (tundra).
- Temporal Decorrelation in a repeat pass scenario.

Height-biomass allometry for temperate even-aged single-species forests shows a very unique relation (+/-20%) regardless of species, site conditions and (conventional) thinning practises.

Height-biomass allometry in tropical environments is not established / validated.

Tree Number is probably the most valuable partner for forest height towards biomass estimation.