Using Sentinel Imagery in Modelling the Aboveground Biomass of Mangrove Forest and their Competing Land Uses

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Outline of Presentation

- Mangrove forest and land use conversion
- Methods
  - Field data
  - Remote Sensing data
  - Modelling and Mapping
- Results
  - Sentinel 1 (SAR)-based biomass map
  - Sentinel 2 (Optical)-based map
- Conclusion
Background

Mangroves
- “Forest of the sea”, interface of land and sea
- Provide many ecosystem services including huge Carbon reservoir

Source: ITTO Tropical Forest Update (2012)

Potentially large C emissions from biomass and soil due to mangrove conversion

Mapping and monitoring of biomass is important

Sentinel imagery is new and free of charge but not yet fully evaluated in mangrove biomass modelling and mapping
Method

- Honda Bay
- West Pacific
- Tropical climate
- 1,527 mm rainfall

Coastal land uses/land cover studied:
- Mangrove Forests
- Non-forest land uses in mangrove soil:
  - Aquaculture pond (abandoned)
  - Coconut plantation
  - Salt pond (abandoned)
  - Cleared mangrove
**Method: Field Data**

- Plots (7-m radius) to collect field data (species, DBH, etc)
- 90 plots total (51 mangrove)
- Plot coordinates - GPS
- Published allometric models for mangrove biomass

**Method: Remote Sensing data**

- **Sentinel 1** (SAR) and **Sentinel 2** (Multispectral)
- **SNAP** (Sentinels Application Platform) software (Open Source)
- Sentinel 1 (IW-GRD product): 3 dates
- Sentinel 2 (L1C product): processed to L2A (BOA reflectance) using **Sen2Cor** plug-in
- SRTM 30-m DEM
Sentinel 1
IW-GRD High Resolution: 10m

Sentinel 2
Spectral Band Resolutions (m)

<table>
<thead>
<tr>
<th>Band</th>
<th>Spectrum</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coastal aerosol</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>Blue</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Red Edge 1</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>Red Edge 2</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Red Edge 3</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>Near Infrared</td>
<td>10</td>
</tr>
<tr>
<td>8A</td>
<td>Red Edge 4</td>
<td>20</td>
</tr>
<tr>
<td>9</td>
<td>Water vapour</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>SWIR Cloud</td>
<td>60</td>
</tr>
<tr>
<td>11</td>
<td>Short Wave IR</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>Short Wave IR</td>
<td>20</td>
</tr>
</tbody>
</table>

Sentinel 1 SAR Image (VH Polarisation)
Method: Biomass Modelling and Mapping

- Modelling the linear relationships done in Weka machine learning software
- Model building: 75% of field plots; validation: 25%
- Best biomass model (highest r, lowest RMSE) then used in ArcGIS to develop biomass maps
- Prediction Map validation: 25% of plots + 10 plots more (i.e. 32 plots, 19 mangrove):
  - RMSE, % Prediction Accuracy
Results

Field data: Aboveground biomass were variable and highest in mangrove forest.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Mean aboveground biomass (Mg ha⁻¹)</th>
<th>Biomass range (Mg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangrove Forest</td>
<td>65.11</td>
<td>1.06 - 210.14</td>
</tr>
<tr>
<td>Non-mangrove</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abandoned aquaculture pond</td>
<td>0.04</td>
<td>0 - 0.40</td>
</tr>
<tr>
<td>Coconut plantation</td>
<td>11.36</td>
<td>0.20 - 19.74</td>
</tr>
<tr>
<td>Salt pond</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cleared mangrove</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
**Results**

**Sentinel 1** VV and VH polarisations moderately correlate with biomass; adding elevation data greatly improved the prediction.

\[
\text{AGB} = -37.702 + 4.3591 \times \text{VV}_{\text{Oct}} - 3.2955 \times \text{VH}_{\text{Jan}} + 12.6209 \times \text{Elevation}
\]

**SENTINEL 1 BASED ABOVEGROUND BIOMASS MAP**

Honda Bay

RMSE: 25.5 Mg/ha
Prediction Accuracy: 83.8 %
Results

Sentinel 2 Red Edge 1 and Red Edge 2 bands combination provided better correlation and prediction; adding elevation data improved prediction.

<table>
<thead>
<tr>
<th></th>
<th>Red</th>
<th>Red Edge 1</th>
<th>Red Edge 2</th>
<th>Red Edge 3</th>
<th>RE1+RE2</th>
<th>RE1+RE3</th>
<th>Red+RE1+RE2+NIR+Elev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$ (%)</td>
<td>36.75</td>
<td>43.98</td>
<td>35.23</td>
<td>49.8</td>
<td>29.35</td>
<td>50.14</td>
<td>22.85</td>
</tr>
<tr>
<td>RMSE (Mg/ha)</td>
<td>91.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

$$\text{AGB} = -3.2269 + 885.8416 \times \text{Red} - 1422.9515 \times \text{Red Edge 1} + 1320.47 \times \text{Red Edge 2} - 751.8883 \times \text{NIR} + 9.9243 \times \text{Elevation}$$

SENTINEL 2-BASED ABOVEGROUND BIOMASS MAP

Honda Bay

RMSE: 26.9 Mg/ha
Prediction Accuracy: 83.2 %
Results

**SENTINEL 2 NDI45 VEGETATION INDEX GAVE BETTER CORRELATION AND PREDICTION WITH BIOMASS**

![Bar chart showing correlation and prediction with biomass](chart.png)

NDI45 = Normalised Diff. Index 4 and 5 (Red Edge 1 - Red) / (Red Edge 1 + Red)
IRECI = Inverted Red Edge Chlorophyll Index (Red Edge 3 - Red)/(R. Edge 1- R. Edge 2)

AGB = 150.0705*NDI45

**SENTINEL 2 NDI45-BASED ABOVEGROUND BIOMASS MAP**

![Map showing aboveground biomass](map.png)

Honda Bay

RMSE: 27.9 Mg/ha
Prediction Accuracy: 82.2 %
CONCLUSION

- Sentinel 1 and 2 data, with SRTM elevation, useful in mapping aboveground biomass of mangrove in the coast of southern Honda Bay
- Derived maps for pinpointing high biomass areas for policy and management attention

Conclusion

- Where clouds are persistent, Sentinel 1 SAR imagery is a useful option to map coastal biomass as SAR are not weather-dependent

- RS/GIS users from developing countries would benefit from Sentinel imagery as they are high resolution (10-20m), available for free and with support user-friendly open source software (i.e. SNAP)
Thank You Very Much!