Methodologies of tropical forest carbon monitoring: Development and state-of-the-art for REDD+

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Contents

• Introduction

• Methods for estimating forest carbon stock
  – Choices
  – A case study of estimating nationwide forest carbon stock in Cambodia

• A brief introduction of REDD-plus cookbook by FFPRI

How to measure and monitor forest carbon
What will we do by REDD+?
Reducing Emissions from Deforestation in Developing countries and REDD-plus are new mechanisms.....

...to foster reduction of “deforestation and forest degradation (DD)” by inputting international support funds using market mechanisms etc. into developing countries under DD. The UN-rules are not yet determined. However, the trend in amount of anthropogenic GHG emissions from DD will be needed to be predicted, reduced by anthropogenic effort, and monitored with MRV. International support funds will be provided based on the emission reduction.
What will we do by REDD+?

As a conclusion, REDD+ does not only control vegetation, but also replace people’s present land-use.

The balance of nature (incl. anthropogenic activities) is a key to REDD+.

The success of REDD+ also depends on whether it is managed and run properly in collaboration with local people, who are supposed to play the primary role.
Requirements for forest c. monitoring methods for REDD+

• Accuracy
  – Less errors in each element
  – Covering all important elements

• Large-scale

• High frequency (semi-real time)

• Choices
  – Cause of DD, data availability, cost, etc.
Importance assessment
Modified from Kiyono et al. (2011)

Dry-land forest

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Estimates with the project data (Mg-CO₂ ha⁻¹ 10 y⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (aboveground and belowground)</td>
<td>377 (108-517)</td>
</tr>
<tr>
<td>CO₂ Deadwood, litter</td>
<td>16 (0-19)</td>
</tr>
<tr>
<td>SOM</td>
<td>13 (5-22)</td>
</tr>
<tr>
<td>Fire</td>
<td>2 (0.3-3)</td>
</tr>
<tr>
<td>N₂O SOM mineralization</td>
<td>0</td>
</tr>
<tr>
<td>CH₄ Fire</td>
<td>17 (3-31)</td>
</tr>
<tr>
<td>Total</td>
<td>425 (116-592)</td>
</tr>
</tbody>
</table>

Drained peat swamp forest

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Estimates with the project data (Mg-CO₂ ha⁻¹ 10 y⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (aboveground and belowground)</td>
<td>60 (39-83)</td>
</tr>
<tr>
<td>CO₂ Deadwood, litter</td>
<td>37 (29-43)</td>
</tr>
<tr>
<td>SOM</td>
<td>762</td>
</tr>
<tr>
<td>Fire</td>
<td>1 (1-1)</td>
</tr>
<tr>
<td>N₂O SOM mineralization</td>
<td>9 (0-37)</td>
</tr>
<tr>
<td>CH₄ Fire</td>
<td>9 (7-11)</td>
</tr>
<tr>
<td>Total</td>
<td>878 (838-937)</td>
</tr>
</tbody>
</table>
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How to measure and monitor forest carbon
A flow for estimating GHG emissions/removals in forest and REDD+ effects

Forest carbon stock = Forest area x Averaged carbon stock per land area

Base map ← Ground truth
↓
Series of remote sensing images
↓
DD areas detection by monitoring forest land
↓ ← Carbon stock per land area for main forest types
Estimates of carbon stock change (GHG emissions/removals)
↓ ← Scenarios emissions/removals without REDD+
Estimates of REDD+ effects (GHG emission reduction)
<table>
<thead>
<tr>
<th>Objective variables</th>
<th>Approaches</th>
<th>Requirements</th>
<th>Costs</th>
<th>Getting data in a large land area</th>
<th>Technical difficulties</th>
<th>Applicability of the method in estimating anthropogenic GHG emissions by each activity</th>
<th>Improvement in accuracy expected by local people participating in the monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest area</td>
<td>Land cover classification</td>
<td>Optical spaceborne remote sensor with medium or higher resolution</td>
<td>Medium</td>
<td>Easy</td>
<td>Not applicable when clouded</td>
<td>Partly possible</td>
<td>Partly possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAR with microwaves longer than L-band</td>
<td>Medium</td>
<td>Easy</td>
<td>Not applicable to areas with steep slopes</td>
<td>Partly possible</td>
<td>Partly possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airborne LiDAR, Aerial photograph</td>
<td>High</td>
<td>Medium</td>
<td>Nothing in particular</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>PSP data</td>
<td>Measurement on the ground</td>
<td>High</td>
<td>Difficult</td>
<td>Limitation in representativeness and secretness of plot</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Community age</td>
<td>Remote sensor with medium or higher resolution</td>
<td>Medium</td>
<td>Easy</td>
<td>Applicable to land use with periodical naked land stages e.g. slash-and-burn farming</td>
<td>Impossible</td>
<td>Possible</td>
<td>Impossible</td>
</tr>
<tr>
<td>Crown diameter</td>
<td>Remote sensor with high resolution Aerial photograph</td>
<td>High</td>
<td>Medium</td>
<td>Not applicable when clouded - Crowns are hardly recognized in some forests</td>
<td>Partly possible</td>
<td>Impossible</td>
<td>Partly possible</td>
</tr>
<tr>
<td>Stock difference method</td>
<td>Multi-polarization SAR</td>
<td>Low</td>
<td>Medium</td>
<td>Methods are not tested - Applicable to small parts of globe</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Airborne LiDAR</td>
<td>High</td>
<td>Difficult</td>
<td>Nothing in particular</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td></td>
<td>Stereo mapping remote sensor (DSM)</td>
<td>Medium</td>
<td>Easy</td>
<td>Not applicable when clouded - Methods are not tested</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Measurement on the ground</td>
<td>?</td>
<td>Difficult</td>
<td>Methods are not tested</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td></td>
<td>SAR with microwaves longer than L-band</td>
<td>Low</td>
<td>Medium</td>
<td>Not applicable to areas with steep slopes - Not applicable to high biomass</td>
<td>Partly possible</td>
<td>Partly possible</td>
<td>Impossible</td>
</tr>
</tbody>
</table>
3 approaches are available for monitoring forest area

1) **Spaceborne optical sensors**  
   Pa: cloud problem

2) **Spaceborne microwave sensors**  
   Pa: topog. problem

3) **Airborne media (e.g. LiDAR)**  
   Expensive

5 approaches for monitoring carbon stock per land area,

1) **Permanent sampling plots (PSPs)**  
   Practical

2) Plant community-age  
   Pa

3) Crown diameter  
   Pa

4) Overstory height  
   Under test

5) Backscattering coefficients of PALSAR  
   Pa

Pa: partly or partially available.
A case study for estimating nationwide forest biomass carbon stock in Cambodia
### Forest Classification in Cambodia

<table>
<thead>
<tr>
<th>Type</th>
<th>Area (ha)</th>
<th>Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen forest</td>
<td>3,668,902</td>
<td>34.2</td>
</tr>
<tr>
<td>Semi-evergreen forest</td>
<td>1,362,638</td>
<td>12.7</td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>4,692,098</td>
<td>43.7</td>
</tr>
<tr>
<td>Bamboo forest</td>
<td>35,802</td>
<td>0.3</td>
</tr>
<tr>
<td>Wood shrubland (evergreen)</td>
<td>37,028</td>
<td>0.3</td>
</tr>
<tr>
<td>Wood shrubland (deciduous)</td>
<td>96,387</td>
<td>0.9</td>
</tr>
<tr>
<td>Other forest</td>
<td>837,926</td>
<td>7.8</td>
</tr>
<tr>
<td><strong>Forest total</strong></td>
<td><strong>10,730,781</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Modified by the authors from Forestry Administration (2010).

Forest cover of Cambodia and PSPs by Forestry Administration

PSP data and equations for biomass estimates

- **100 permanent sampling plots**
  - 85 in evergreen forests (including semi-evergreen forests)
  - 15 in deciduous forests
- **Plot size:** 50 m x 50 m (2,500 m²)
- **DBH of trees ≥ 7.5 cm** in DBH, species

**Equations and parameters for estimating biomass carbon**

Tree biomass = \(4.08 \times ba^{1.25} \times D^{1.33}\)  
(n = 530, \(R^2 = 0.981, p < 0.0001\))

Applicable generically to tropical and subtropical trees with 1<DBH<133 cm.

- **ba**: basal area (calculated from DBH), m²;
- **D**: basic density (determined with information of tree species);
- **Carbon fraction**: 0.5

# The nationwide forest carbon stock in Cambodia (A tentative figure)

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Forest area In 2006 ha</th>
<th>Averaged carbon stock In 2000-2001 Mg-C ha(^{-1})</th>
<th>Total carbon stock Tg-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen forest*</td>
<td>5,031,540</td>
<td>163.8 ± 7.8</td>
<td>824.2 ± 39.2</td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>4,692,098</td>
<td>56.2 ± 6.7</td>
<td>263.9 ± 31.3</td>
</tr>
<tr>
<td>Total</td>
<td>9,723,638</td>
<td></td>
<td>1,088.1 ± 50.2</td>
</tr>
</tbody>
</table>

* Including Semi-evergreen forest. Carbon stocks are shown in mean ± standard error.

Required number of sample plots for av. carbon stock at a 5% level of precision and a 95% confidence level

- **336 plots**
  - 260 for evergreen forest, 76 for deciduous forest
- Since most developed countries designed their NFIs (national forest inventories) at the same precision and confidence levels, a sampling design using 336 plots may be acceptable for most countries.
- However, forests in the PSPs are sometimes destroyed in the region under pressure of DD. A sufficient number of extra plots are vital and required number of plots should be monitored to be able to add extra plots if necessary.
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How to measure and monitor forest carbon
“Cook-book - How to measure and monitor forest carbon” compiles our latest knowledge in forest carbon measurement.

The book will be available at COP18-Doha Climate Change Conference - November 2012
REDD+ cookbook aims:

- To be a manual like an easy-to-understand cookbook.
- For governments (introduction), experts & their C/Ps, private consultants, NGOs (planning), researchers (technology) etc.
- Not only explaining each technology, but also piloting the procedure in combination with the technologies related to REDD+.
Conclusions

1. CO₂ emissions from biomass are the most important in the dry land forest, while in the drained peat swamp forest, CO₂ emissions from soil organic matter are the most important.

2. **Considering requirements for carbon monitoring methods for REDD+,** spaceborne optical sensors and microwave sensors are partly or partially available for monitoring forest area. Ground-based measurement is a practical approach for monitoring carbon stock per land area.

3. We estimated the nationwide forest carbon stock and required number of sample plots in Cambodia. By repeating this calculation, we could monitor the (historical) trend of forest carbon stock on a national scale and such data are useful to make reference (emission) levels.

4. More varied field data must be collected for improving methods.
Thank you for your attention.

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