New Approaches to Map Biomass

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Project Outcome: Pan-tropical Data Sets

I. 2007 pan-tropical forest cover (forest /nonforest) map derived from the ALOS/PALSAR mosaic

II. Pan-tropical medium-resolution (500-m) above-ground biomass/carbon map derived from the fusion of MODIS, GLAS lidar and field observations
Project Outcome: Capacity Building

I. Technical workshops: one on each continent (Latin America, Central Africa, S.E. Asia) in years 1-3 focused on technology transfer and engagement in calibration/validation activities.

II. Pan-tropical Forest Scholars Program: selected individuals from each continent spend several weeks each year at WHRC learning forest cover/biomass mapping tools/techniques from project scientists.
Objectives

- Cost effective methodologies for national and subnational level carbon stock and forest monitoring
- Policies applications (REDD)
- Identify key country partners to help build capacity for carbon mapping
- Outreach to existing RS / forestry groups
Field Campaign Plots on SPOT 5
High Resolution Biomass Maps

Map1
r:0.9 RMSE:
25 MgC/ha
Pan-Tropical Biomass Map

- Best quality MODIS mosaic
  - NBAR data for the period 2005 – 2006
  - cloud free

- Screened GLAS metrics
  - Series of metrics tree height, height of median energy (HOME)

- Co-located field measurements
Biomass

- DRC = 17 Billion t C

Deforestation

- CO₂ Emissions 1990/2000 (tC/ha)

Reduce uncertainty in carbon estimates

- Input for REDD/carbon market

See A. Cattaneo “Stock Flow Approach” for monetary value of carbon

CO₂ Emissions 1990/2000
Outline

- Above-ground forest biomass
  - Characteristics of existing data
- Remote sensing (RS) based studies
- Integration of field data with RS
- From local to regional above-ground biomass map
  - Methods
  - Examples
Uncertainty in Carbon Cycle

• Carbon Stock and deforestation estimates are key factors in carbon fluxes calculations

• 60% of the uncertainty in carbon fluxes from deforestation in the Brazilian Amazon are due to uncertainty in carbon stock\(^1\)

• estimates of aboveground carbon storage in tropical African forests vary by over 100% (46.9 Pg – 104.5 Pg) \(^2\)

• To reduce uncertainty we need to know the carbon stored in the forest that has been removed

\(^1\) Houghton et al. 2002, Lewis et al. 2009
Uncertainty in Carbon Cycle

Papua New Guinea, Sierra Leone, Burundi, Benin, Venezuela, Peru, Paraguay, French Guiana, Ecuador
Large Area Biomass Estimation

- **Forest Inventories**

- **Stratify & Multiply (SM) Approach**
  - Assign an average biomass value to land cover/vegetation type map (Asner et al. 2010)

- **Combine & Assign (CA) Approach**
  - Extension of SM, GIS and multi-layers information (Gibbs et al. 2007)

- **Ecological Models (EM) Approach**
  - Remote sensing to parameterize the model (Hurtt et al. 2004)

- **Direct Remote Sensing (DR) Approach**
  - Empirical Models where RS data is calibrated to field estimates (Baccini et al. 2004, 2008, Saatchi et al. 2007, Blackard et al. 2008)
Stratify & Multiply (SM)

- Adequate number of samples required in each class

- Errors in thematic map

- Land cover only partially related to biomass (e.g. within class variability)

Baccini and Friedl 2007, Asner et al. 2010
Available Forest Inventory Data

- Only few countries/regions have updated forest inventory data
- Measurements are not consistent (D.B.H, species sampled, design)
- Spatial distribution non optimal for remote sensing integration and scaling up

MODIS 500 m grid over Landsat data and FAO field transects (white lines)
Distribution of forest inventory data in Central Africa

Field biomass measurements

MODIS 1km NBAR (RGB 2,6,1)
The figure shows 30% of the GLAS L2A (year 2003) shots after screening procedures (1.3 million observations).

Screening for cloud attenuation, topographic slope (SRTM), waveform noise thresholds, etc.

30-40% remain after screening.
Vegetation structure from LiDAR (GLAS)

Lidar metrics have been extensively used to characterize vegetation structure (Sun et al. 2008, Lefsky et al. 2005, Lefsky et al. 1999)

Drake et al. (2003), Lefsky et al. 2005, Drake et al. 2002 found a strong relationship between AGB and Lidar metrics (HOME)
Data sets

• Co-located field measurements
• ICESAT – GLAS LiDAR measurements
• Moderate Resolution Imaging Spectroradiometer (MODIS) Nadir Bidirectional Reflectance Distribution Function (BRDF) adjusted reflectance (MCD43A4.V5) and (MCD43A2)
Co-located Field Measurements

Biomass = 205 (t/ha)
Biomass = 78 (t/ha)
Biomass = 30 (t/ha)
2009 NBAR one 8 days composite

2009 NBAR one 8 days composite from Earth Engine
Key Input Used:
NADIR, BRDF-Adjusted Reflectance
(Schaaf et al., 2002; RSE)

Removes artifacts associated with variable view geometry
NBAR compositing

Atmospherically corrected and cloud cleared

– Spatial resolutions at 500 (nadir)

However....

Artifacts due to clouds residuals and shadows are present

Compositing over time successfully remove artifacts
Composite 2007 - 2008
Composite 2007 - 2008

Composite based on Earth Engine
Pan-Tropical Biomass Map

- Best quality MODIS mosaic
  - Multiple years
  - Cloud free

- Screened GLAS metrics
  - Series of metrics (tree height, height of median energy, etc.)

- Co-located field measurements
Pantropical Forest Carbon Mapped with Satellite and Field Observations

Amazon Basin detail from the map
DRC detail from the map
PNG detail from the map

Error 25 Mg C ha\(^{-1}\)
Error 19 Mg C ha\(^{-1}\)
Error 24 Mg C ha\(^{-1}\)
National Level Biomass Map
High carbon density in Protected Areas
Summary

• For the first time we have consistent, spatially explicit, carbon stock baseline across the tropics

• Integration of local knowledge and field measurements with remote sensing provide estimates of carbon

• Collaborative activities to generate regional estimates, local information to guide national and regional processes

• National level carbon dataset available after COP16