Remote sensing of tropical forest canopy structure and dynamics

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Importance of tropical forests in global carbon cycle

- **Area**: 13% tropical forests, 87% other terrestrial biomes
- **Biomass**: 46% tropical forests, 54% other terrestrial biomes
- **Net primary productivity**: 35% tropical forests, 65% other terrestrial biomes

Roy et al. 2001
Unresolved issues

- How much of a carbon sink do tropical forests provide?
- What are the environment drivers?
- How does carbon respond to changes in climate, CO₂ and disturbance?

Potter et al. 1998
Climate response of forests is critical
Mechanistic models of forest dynamics to understand changes in carbon balance

Forest inventory plots + Remote sensing

Mechanistic relationship

Growth

Mortality

Secundity

Canopy

Understory

$Z^*$
Remote sensing used to map biomass

LIDAR

Regression between Carbon and LIDAR metric

Good for inventory and monitoring, but not for mechanistic understanding or prediction

Asner et al. PNAS 2010
Biomass calculations

- Trunk diameter
- Tree height
- Wood density

How can we get these from remote sensing?
Diameter

Barro Colorado Island, Panama

- Cannot measure directly from remote sensing
- Strong relationship with crown area

Bohlman unpubl. data
Crown size distribution

- Stereophotos
- Lidar
- High resolution satellite images
- Automated mapping

Panama crown map from stereophotos
Crown size distribution

- Equal-sized areas in IKONOS images from Amazon

Larger crown sizes

Barbier et al. 2010
Tree height

Asner et al. 2011
Functional group – wood density relationship

- **Pioneer trees**
  - Low wood density
  - Short-lived
  - Fast growing
  - Thin leaves
  - Higher leaf nitrogen

- **Shade tolerant trees**
  - High wood density
  - Long-lived
  - Slow growth
  - Thick leaves
  - Lower leaf nitrogen
Hyperspectral remote sensing

Leaf mass per area (LMA or leaf thickness) can be mapped with hyperspectral images

Asner et al. 2011

Important spectral region for detecting LMA

Asner et al. 2011
Large blowdowns in Amazon

Nauta Peru

300 ha blowdown

- Change in biomass through smaller trees, but also more pioneers with lower wood density
- Dynamics can be modeled

Sami Rifai AGU 2010
Forest dynamics model to synthesize field and remote sensing data

- Perfect Plasticity Approximation (PPA)
- Simulates growth, mortality and reproduction of individual trees
- Applicable to landscape scale
- Input from remote sensing
- Multiple-layered structure
The PPA model parameterized from forest inventory in the US Midwest reproduced changes in biomass and species composition through succession.
Old = Rigid Crowns
No crown displacement

New = Crown displacement
and plasticity allowed

Lots of empty space

All space filled
Perfect Plasticity Approximation (PPA):

$\sum A_i = \text{ground area}$

$\sum A_i = \text{ground area}$

$\sum A_i < \text{ground area}$
PPA – simplified structure leads to simplified dynamics

- Canopy
  - growth
  - mortality

- Understory
  - growth
  - mortality

- Fecundity
High Precision Stereophotos of BCI taken in 2000

- Tree heights/crown areas (1900 trees/10 ha)
- Crowns linked to stems so trunk location, species identity, diameter history known
- Determine canopy vs. understory

Tag 2328
*Prioria copaifera*
height = 25.6 m
dbh 2000 = 34 cm
Three outcomes from images for PPA model

- Allometries between dbh, height and crown area
- Canopy status (canopy vs. understory) to test model (separate field-based data set from Joe Wright)
- Crown displacement
Map of crown displacement of individual trees

Strigul et al. (2008) assumed 5° angle of displacement between trunk and center for PPA model.

Observed average angle = 10°
PPA canopy structure reproduced observed canopy structure in a tropical forest

Bohlman & Pacala 2012
2000 & 2008 crown boundaries

mortality

growth

displacement

growth

mortality
Next steps

- Use canopy layer structure with growth and mortality to simulate succession and response to disturbance
Next steps

• Use hyperspectral data to assign growth and mortality rates based on functional groups
Mapping dispersed tree cover in tropical agricultural landscapes

- Mexico
- Florida
- Cuba
- Nicaragua
- Costa Rica
- Panama
- Azuero peninsula
- Canal
Use high resolution lidar/hyperspectral to map dispersed tree cover and develop methods for quantification in coarser resolution images.
Collaborators: Patrick Jansen, Carol Garzon, University of Gronigen
Helene Muller-Landau, Joe Wright, Smithsonian Tropical Institute
Drew Purves, Microsoft
Steve Pacala, Princeton University
Greg Asner, Stanford University

Stereo photos: Rich Grotefendt / Grotefendt Photogrammetric Services,

Funding: Princeton Carbon Mitigation Initiative, Center for Tropical Forest
Science, NASA Earth Science fellowship
Low tech aerial photos 2005 – 2008
wall-to-wall coverage of BCI

Jansen, Bohlman et al. 2008