Effects of Land Cover Change on Forest Ecosystem and Carbon Dynamics in Indonesian Borneo

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Big Questions

• What are the relative contributions of land use, natural ecosystem dynamics, fire and climate variability on forest and carbon dynamics in Bornean tropical forests?

• What are their synergistic effects and potential future trends?
Objectives

• Determine carbon storage variation across forest and land use types;
• Conduct remote sensing derived analyses of LCLUC and carbon dynamics;
• Input field and remote sensing derived data from case regions into models;
• Evaluate carbon source/sink dynamics using models: past, present and future
Land Use Across Kalimantan

Logging
Plantations
National Parks
Nature Reserves
LCLUC with Nested-Scale RS Analyses Linked to Spatial-scale of Ecological Processes

- Area: ~250,000 km²
- Every 2 yrs (1985-2002) for Two Case Study National Park Regions
- 10 IKONOS 1m & 4m resolution in case study regions;
- MODIS 250m Borneo-wide (540,000 km²) 2001-2005
From 1970-2003, 72 timber concessions once occupied 7.2M ha or 79% of forest area (<500 m a.s.l.) in West Kalimantan;

- March 2003, six holdings (8.3%) with active timber harvest;
- Only 416,280 ha; 94.3% reduction;
- <60,000 ha primary remain in timber concessions;
- Abandoned areas highly degraded 80-90% canopy removed; often entered coupe several times;
- Logging easily detected on Landsat (w/o cloud cover) coupled with maps/limited ground surveys;
- Patches of primary forest are all <500 ha in former logged areas

*Curran, Trigg, McDonald et al. in press Science*
Over-Capacity Wood-Based Industries

- W. Kalimantan: 130 wood-based industries: 5M m³ yr⁻¹;
- 14 plywood industries: 2.6M m³ yr⁻¹;
- Exceed concession capacity: ‘94-95: 22%; ‘99-00: 132%; ‘02-03: 162%
Industrial Oil Palm Proliferation

40-fold increase area since ’92

Clear logged forest w 77 to 111 t C ha⁻¹
1.2 to 10.5 t C ha⁻¹ in 1 to 10 yr plantations
3.5 M ha allotted 2002
Mapping oil palm plantations

Ikonos: resolves individual crowns, but over small areas

Challenge to mapping oil palm with TM:
Depending on age, oil palm is spectrally confused with bare soil and secondary regrowth.

So, to approach mapping oil palm, we:
• train detection methods on known plantations observed on Ikonos
• incorporate into the mapping method:
  • changes observed on TM (1990 – 2000)
  • proximity to dense road networks:
Carbon Measurements

- Four forest types: 4 yrs; NUE, biomass, growth (18 yrs);
- Logging Chronosequence: 12 yrs; before/after;
- Oil palm chronosequence; 10yrs;
- Secondary forest; 0-21 yrs; Lawrence et al. in press;
Peat Swamp Forest: Potential for Remote Sensing of Phasic Communities

A. Typical pattern of concentration zonation

B. Schematic transect through peat swamp forest

C. Zoning in Peat Swamp Forest as seen in classified ETM+ image

Phasic community (Ph.c.) number:
1 Gonystylus – Dactyocladus – Neoscortechinia association
2 Shorea albida – Gonystylus – Parastemon association
3 Shorea albida consociation
4 Shorea albida –Listea – Parasetamon association

Image date = 28 August 2002
Location = West Kalimantan
Classification method = Neural Net

(Source for figures A and B: Morley, 2000 after Brunig, 1990
Data from Sarawak, Borneo)
Matrix to Park

- 70% Park 10 km Buffer Deforested; <9% intact;
- 38% Park Lowlands Deforested;
- After 1999, when <26% buffer remained; deforestation within park rose 9.5% yr\(^{-1}\); \(r^2 = 0.99\)

Curran et al. *in press, Science*
Lowland Protected Areas in West Kalimantan in 1985
Spatial Distribution of Dipterocarp Forest Across Kalimantan 2002

- **Timber Concessions/Plantations (HPH/HTI)**
- **Intact Lowland Forest Within Protected Areas**
- **Intact Protected Lowland Forest With HPH/HTI Claims**
- **Elevation > 500m; Not HPH/HTI**
REGIONAL: 200,000 km²
- Even with ENSO variability removed, since 1950: Increased drought stress across region (+36 days w/ rain; $P < 0.0001$);
- Increase in min temp since 1976 Wet +1.4 C; Dry +1.6 C; $P < 0.0001$;

LOCAL: 2736 km²
- Disruption of La Niña rainfall patterns 1987-1991 vs. 1999-2003: 4 vs. 16 periods in 10+ days w/o rain ($P = 0.042$)

Curran, Paoli & Peay, in review
Timber Concessions/Plantations (HPH/HTI)
Intact Lowland Forest Within Protected Areas
Intact Protected Lowland Forest With HPH/HTI Claims
Elevation > 500m; Not HPH/HTI

1997-1998 ATSR Fire Hot Spots
Projected Land Cover Classifications for 2015

**Continued Fragmentation I**
- 2001-2002 transition
- Non-cumulative deforestation

**Continued Fragmentation II**
- 1999-2001 transition
- Cumulative deforestation

**Continued Fragmentation III**
- 2001-2002 transition
- Cumulative deforestation
Importance of Indonesian Borneo for Global Carbon Dynamics

- High carbon stock in primary, regrowth logging and esp. peat;
- Rapid & large-scale industrial conversion of logged dipterocarp forests to oil palm;
- Increased susceptibility to drought and fire with logging/logged roads and fire used for oil palm clearing.
Work in Progress

• Model past, present and future carbon dynamics in the region;
• Integrate with effects of LCLUC on biodiversity;
• Build on current cross-site comparisons of frontier governance (esp. with Amazon);
• Extend to policy and regional land use planning and fire prevention with Indonesian collaborators
Land Use Planning and Development BAPPENAS Dedy and Herman Heruman, Ning, BAPPEDA-KALBAR, Eka, Rusnawir Hamid, Nova Sirait, Department of Parks and Conservation (PKA) and national parks; University of Tanjungpura and Dean of Forestry, Heru were collaborative sponsors.

Eighteen timber concessions and seven oil palm plantations granted access and logistic support during surveys, local NGOs Biodamar, YPPN, WWF-Kalbar conducted community surveys and mapping,

Over 37 Indonesian students and eight faculty from University of Tanjungpura, KALBAR and six local NGOs participated in the surveying and mapping from 1999-2002.


Financial Support: NASA Earth Sciences Program, US Agency for International Development (USAID), World Bank (Indonesian Mission), NSF BE-CNS, Fulbright Foundation, Conservation Food and Health, Tropical Resources Institute, Santa Fe Institute, Southeast Asian Studies and International Studies, Yale FES, University of Michigan
Analysis of 10km Buffers Surrounding WCMC Protected Areas in West Kalimantan
Logging Roads Digitized from TM Within Bukit Baka National Park/
Bukit Raya Nature Reserve in West/Central Kalimantan