Changing Dynamics of Tropical Deforestation and Atmospheric Carbon: Science Meets Policy

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Michigan State University, March 18, 2008

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Wildlands, frontier clearings, and small-scale farms give way to intensive agriculture and urban settlements. Protected/recreational lands are depicted.

Greenhouse gases: Carbon dioxide, methane, and nitrous oxide are illustrated.

STAGE IN LAND USE TRANSITION (From Mustard et al., 2004; DeFries et al., 2004; Foley et al., 2006)
Historical Estimates of Carbon Emissions (1850-2000)

(From Houghton, WHRC)
Decision -/CP.13

Reducing emissions from deforestation in developing countries: approaches to stimulate action

The Conference of the Parties

Recalling the relevant provisions of the Convention, in particular Article 2, Article 3, paragraphs 1, 3 and 4, and Article 4, paragraphs 1(a)–(d), 3, 5 and 7,

Acknowledging the contribution of the emissions from deforestation to global anthropogenic greenhouse gas emissions,

Acknowledging that forest degradation also leads to emissions, and needs to be addressed when reducing emissions from deforestation,

Recognizing that efforts and actions to reduce deforestation and to maintain and conserve forest carbon stocks in developing countries are already being taken,

Recognizing the complexity of the problem, different national circumstances and the multiple drivers of deforestation and forest degradation,

Recognizing the potential role of further actions to reduce emissions from deforestation and forest degradation in developing countries in helping to meet the ultimate objective of the Convention,

Affirming the urgent need to take further meaningful action to reduce emissions from deforestation and forest degradation in developing countries requires stable and predictable availability of resources,

Recognizing that reducing emissions from deforestation and forest degradation in developing countries can promote co-benefits and may complement the aims and objectives of other relevant international conventions and agreements.
Estimates of carbon emissions from deforestation are highly uncertain.

<table>
<thead>
<tr>
<th></th>
<th>1980’s (PgC/yr)</th>
<th>1990’s (PgC/yr)</th>
<th>Spatial coverage</th>
<th>Method for area</th>
<th>Method for carbon flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houghton (2003)</td>
<td>2.0</td>
<td>2.2</td>
<td>Global, 9 regions</td>
<td>FAO and inventories</td>
<td>Bookkeeping</td>
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<tr>
<td>Fearnside (2000)</td>
<td>2.4</td>
<td>-</td>
<td>Pan-tropic, 6 regions</td>
<td>FAO and inventories</td>
<td>Bookkeeping</td>
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<tr>
<td>McGuire et al (2001)</td>
<td>0.9-1.6</td>
<td>-</td>
<td>Global</td>
<td>Cropland change</td>
<td>Ecosystem models</td>
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<tr>
<td>DeFries et al (2002)</td>
<td>0.6 (0.3-0.8)</td>
<td>0.9 (0.5-1.4)</td>
<td>Pan-tropics</td>
<td>AVHRR</td>
<td>Bookkeeping</td>
</tr>
<tr>
<td>Achard et al (2004)</td>
<td>-</td>
<td>1.1 ± 0.3</td>
<td>Pan-tropics, sample</td>
<td>Landsat</td>
<td>Bookkeeping</td>
</tr>
<tr>
<td>Houghton et al (2000)</td>
<td>-</td>
<td>0.2</td>
<td>Amazon</td>
<td>Landsat-derived</td>
<td>Bookkeeping</td>
</tr>
<tr>
<td>Fearnside (1997)</td>
<td>-</td>
<td>0.261</td>
<td>Brazilian Amazon</td>
<td>Landsat-derived</td>
<td>Bookkeeping, committed flux</td>
</tr>
<tr>
<td>Potter et al (2001)</td>
<td>-</td>
<td>0.2-1.2</td>
<td>Legal Amazon</td>
<td>Satellite-derived fire</td>
<td>Fire emission and ecosystem model, gross flux</td>
</tr>
</tbody>
</table>
C emissions = initial loss + respiration – uptake in regrowth

Annual balance vs committed flux approach

(Ramankutty et al, 2006)
WHAT TOOLS ARE AVAILABLE FOR MONITORING DEFORESTATION AREA?

<table>
<thead>
<tr>
<th></th>
<th>LANDSAT- like sensors</th>
<th>MODIS</th>
<th>AVHRR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial resolution</strong></td>
<td>30m</td>
<td>250m - 1km</td>
<td>8km</td>
</tr>
<tr>
<td><strong>Repeat frequency</strong></td>
<td>16 days</td>
<td>daily</td>
<td>daily</td>
</tr>
<tr>
<td><strong>Size of scene/tile</strong></td>
<td>185x185 km</td>
<td>1000x1000km</td>
<td>Global and subsets</td>
</tr>
<tr>
<td><strong>Length of record</strong></td>
<td>1970’s – present? intermittent</td>
<td>2000 - present</td>
<td>1981- present</td>
</tr>
</tbody>
</table>
Estimated Carbon Flux from Tropical Deforestation and Regrowth based on Satellite Observations for 1980-2000

- **1980’s**
  - Latin America: 0.1-0.15 (Pg/yr)
  - Tropical Asia: 0.05-0.1 (Pg/yr)
  - Africa: 0.05-0.1 (Pg/yr)
- **1990’s**
  - Latin America: 0.05-0.1 (Pg/yr)
  - Tropical Asia: 0.05-0.1 (Pg/yr)
  - Africa: 0.05-0.1 (Pg/yr)

**Total Tropics**
- **IPCC**: 1.7 (0.6-2.5) (Pg/yr)
- **Achard et al., 2002**: 1.6 (0.8-2.4) (Pg/yr)

**Tree cover**
- Circa 1980: 0%
- Circa 1990: 2%
- Circa 2000: 10%

CHANGING DYNAMICS IN 2000’s REFLECTED IN SPATIAL PATTERNS OF MODIS-DERIVED % TREE COVER AND FIRE EVENTS
“Brazil could increase its total cultivated land area by 170 million ha if key legal, technical, and financial developments occur...**without any new deforestation in the Amazon basin.**” –USDA 2003

**Diagram:**
- Forest
- Pasture
- Cropland

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**Graphs:**
- Chinese annual meat consumption per capita
- Brazilian annual soybean production
- Brazilian annual exports of soybeans and soy meal to China


(Naylor et al., 2005)
CHANGING LAND USE DYNAMICS IN 2000-05 IN MATO GROSSO: TRACKING WITH MODIS 250m DATA

 PRIMARY

Forest → Pasture

SECONDARY

Cropland → Pasture

Forest

Cropland Expansion

2000-2003 Time Series, Quality flag adjusted

2003 Conversion
Agriculture
Forest
Pasture

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(Morton et al., PNAS, 2006)
Conversion dynamics by post-clearing land cover for 2001-2004 deforestation events >25 ha in Mato Grosso State, Brazil from satellite-based phenology information: **Clearing for mechanized cropland is associated with soy price**

(Morton et al., PNAS, 2006)
IMPLICATIONS FOR CARBON EMISSIONS: VARYING AMOUNTS OF REMAINING BIOMASS FROM LAND USES FOLLOWING DEFORESTATION

Conversions of forest to cropland exhibit higher-frequency of MODIS-detected fires than pasture conversions.

(Morton et al., in press)
DECAF MODEL TO ESTIMATE GROSS CARBON FLUXES FROM DEFORESTATION FIRES AT 250m MODIS RESOLUTION

LAND USE FOLLOWING DEFORESTATION FROM MODIS

MODIS ACTIVE FIRES

LANDSAT-BASED DEFORESTATION

BURN SCARS FROM PASTURE MAINTENANCE FIRES

CASA

A=burned area
E=combustion completeness
M=mortality rate
D=detritus
B=biomass
F=fuelwood

RESPIRATION

FUELWOOD COLLECTION

HEATWAVE CONSUMPTION

ABOVEGROUND BIOMASS C

ABOVEGROUND LITTER C

BELOWGROUND BIOMASS C

BELOWGROUND LITTER C

Net Primary Production

Allocation of (recovered)

C EMISSIONS FROM FIRE

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Observation #1: Conversion fires are <50% of area but >80% of emissions
Observation #2: Small deforestation events contribute little to overall emissions
Observation #3: Emissions occur from deforestation fires over multiple years

2002 Deforestation
2,500 ha, 79 fire detections

2003
35 detections

2004
91 detections

2005
19 detections

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Observation #4: Emissions are not proportional to area and depend on land use transition type

Emissions from forest to cropland transition are in larger proportion than converted area

Secondary transition from pasture to cropland contributes substantial emissions

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DECAF COMPARED WITH BOOKKEEPING APPROACH FOR MATO GROSSO

FOREST TO CROPLAND

FOREST TO PASTURE

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INITIAL DEFORESTATION EMISSIONS + 5-YR COMMITTED RESPIRATION
DECAF COMPARED WITH GLOBAL FIRE EMISSIONS DATA (GFED) FOR MATO GROSSO

Mean annual emission (TgC/yr)

GFED DECAF

DEFORESTATION FIRE EMISSIONS + PASTURE MAINTENANCE FIRES

GFED from http://www.ess.uci.edu/~jranders/
Conclusions from High Resolution Analysis

• Clearing for mechanized production requires new methods for estimating carbon fluxes

• Multiple methods lead to similar estimates for 5-year aggregated emissions

• Need to include land use transitions and multi-year fires for accurate interannual variability and attribution to land use actors

• Scaling up to pan tropics remains a challenge
HALF OF AREA DEFORESTED IN BRAZILIAN AMAZON OCCURS IN LESS THAN 5% OF CLEARINGS

(data from INPE)
IS SOY EXPANSION PUSHING CATTLE RANCHING FURTHER INTO FRONTIER?

1990

Cattle by Municipality

The Legal Amazon - 1990

Legend (in Heads)
- No data or less than production
- 1 - 10,000
- 10,001 - 20,000
- 20,001 - 50,000
- 50,001 - 100,000
- 100,001 - 200,000
- 200,001 - 500,000
- 500,001 - 1,000,000
- 1,000,001 - 10,000,000

Source: IBGE, Pesquisa Pesca e Agropecuária

2005

Cattle by Municipality

The Legal Amazon - 2005

Legend (in Heads)
- No data or less than production
- 1 - 10,000
- 10,001 - 20,000
- 20,001 - 50,000
- 50,001 - 100,000
- 100,001 - 200,000
- 200,001 - 500,000
- 500,001 - 1,000,000
- 1,000,001 - 10,000,000

Source: IBGE, Pesquisa Pesca e Agropecuária

SOY

Soybean in the Legal Amazon

Planted Area - 1990

Legend (in Hectares)
- No Production
- 1 - 200
- 201 - 499
- 500 - 1,000
- 1,001 - 2,000
- 2,001 - 10,000
- 10,001 - 25,000

Source: IBGE, Pesquisa Pesca e Agropecuária

Planted Area - 2005

Legend (in Hectares)
- No Production
- 1 - 200
- 201 - 499
- 500 - 1,000
- 1,001 - 2,000
- 2,001 - 10,000
- 10,001 - 25,000

Source: IBGE, Pesquisa Pesca e Agropecuária

Pasture

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Census data compiled by R. Walker, Michigan State U
IS THERE A POSITIVE FEEDBACK BETWEEN DROUGHT AND CLEARING?

Fires per year:
- 0
- 1 - 250
- 251 - 500
- 501 - 1000
- 1000 - 2500
- > 2500

Number of MODIS fire detections

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Brazil Amazon deforestation soars

The Brazilian government has announced a huge rise in the rate of Amazon deforestation, months after celebrating its success in achieving a reduction.

In the last five months of 2007, 3,235 sq km (1,250 sq miles) were lost.

Gilberto Camara, of INPE, an institute that provides satellite imaging of the area, said the rate of loss was unprecedented for the time of year.

Officials say rising commodity prices are encouraging farmers to clear more land to plant crops such as soya.

See map of worst affected areas

The monthly rate of deforestation saw a big rise from 243 sq km (94 sq miles) in August to 948 sq km (366 sq miles) in December.

"We've never before detected such a high deforestation rate at this time of year," Mr Camara said.

His concern, outlined during a news conference in Brasilia on Wednesday, was echoed by Environment Minister Marina Silva.

Expensive soya

Ms Silva said rising prices of raw materials and commodities could be spurring the rate of forest clearing, as more and more farmers are finding the lure of cheap land and methods of efficient farming.

"The economic reality of these states indicate that these activities impact, without a shadow of a doubt, on the forest," she said.
**THE POLICY PERSPECTIVE**

**INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE**

**FOURTH ASSESSMENT REPORT**

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**Table 7.2. Land to atmosphere emissions resulting from land use changes during the 1990s and the 1980s (GtC yr⁻¹). The Fourth Assessment Report (AR4) estimates used in the global carbon budget (Table 7.1) are shown in bold. Positive values indicate carbon losses from land ecosystems. Uncertainties are reported as ±1 standard deviation. Numbers in parentheses are ranges of uncertainty.**

<table>
<thead>
<tr>
<th></th>
<th>Tropical Americas</th>
<th>Tropical Africa</th>
<th>Tropical Asia</th>
<th>Pan-Tropical</th>
<th>Non-tropics</th>
<th>Total Globe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1990s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houghton (2003a)</td>
<td>0.8 ± 0.3</td>
<td>0.4 ± 0.2</td>
<td>1.1 ± 0.5</td>
<td>2.2 ± 0.6</td>
<td>-0.02 ± 0.5</td>
<td>2.2 ± 0.8</td>
</tr>
<tr>
<td>DeFries et al. (2002b)</td>
<td>0.5 (0.2 to 0.7)</td>
<td>0.1 (0.1 to 0.2)</td>
<td>0.4 (0.2 to 0.6)</td>
<td>1.0 (0.5 to 1.6)</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Achard et al. (2004c)</td>
<td>0.3 (0.3 to 0.4)</td>
<td>0.2 (0.1 to 0.2)</td>
<td>0.4 (0.3 to 0.5)</td>
<td>0.9 (0.5 to 1.4)</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>AR4d</td>
<td>0.7 (0.4 to 0.9)</td>
<td>0.3 (0.2 to 0.4)</td>
<td>0.8 (0.4 to 1.1)</td>
<td>1.6 (1.0 to 2.2)</td>
<td>-0.02 (−0.5 to +0.5)</td>
<td>1.6 (0.5 to 2.7)</td>
</tr>
</tbody>
</table>

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*Large range in estimates of carbon flux from tropical land use change*
Reference:
Reducing GHG Emissions from Deforestation in Developing Countries: Considerations for Monitoring and Measuring.

Available at: www.fao.org/gtos/pubs.html
Bottom Line Conclusions on Technical Aspects of REDD

• Various methods are available and appropriate to measure change in forest cover at national level
  – Caveat: constraint of access to high resolution data and national capacity for analysis
  – National examples exist

• Forest degradation important but more challenging

• Carbon stock estimates and dynamics more uncertain but existing IPCC guidelines can be applied
Some national forest monitoring systems are in place in tropical countries.
STAGE IN LAND USE TRANSITION

- Should forest degradation be included in REDD?
- Should countries get credit for reforestation and afforestation?
- What is the baseline reference period?
- Market mechanism or fund?
- How to ensure permanence?
- How to ensure against international leakage?
- How to promote co-benefits?
- How to ensure equitable distribution of benefits from REDD?

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STAGE IN LAND USE TRANSITION
Conclusions

• Changing dynamic towards mechanized production increasing per area C emissions from deforestation

• Open science questions
  – Feedbacks
  – Relative contributions of deforestation actors
  – Scaling to pan tropics

• Policy challenges for REDD but technically feasible
SELECTED PUBLICATIONS


DeFries, R., et al. (2005), Monitoring tropical deforestation for emerging carbon markets, in *Tropical Deforestation and Climate Change*, edited by P. Mountinho and S. Schwartzman, pp. 35-44, IPAM and Environmental Defense, Belem, Brazil and Washington, DC.


THANK YOU

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