Measuring the Effect of Selective Logging on Tropical Forest-Atmosphere Exchange

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0. Introduction

1. Selective-Logging Effect on CO2 exchange (preliminary)
   - 15,000 km$^2$/yr in Brazilian Amazon (Nepstad et al., 1999)

2. Annual Carbon Budget (year prior to logging)
   - Are these forests storing carbon?
   - Is eddy flux reliable for calculating sums in these forests?
LBA-Ecology Sites

Santarem, Para

LBA = Large Scale Biosphere-Atmosphere Experiment in Amazonia
Logged Site

60 km

16 km

Experimental Plan

Tapajos River

Control Site

Wind dir

INDEX MAP
Sankaree, PA

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

60 km

16 km
Select site

Infrastructure Installed

Ground-Based Measures begin

Tower measure begins

Additional equipment, second tower, automated soil chambers installed after cut

Tower and ground-based measurements continue after cut to quantify effects of logging on CO₂ and Energy exchange

## Tower Measurements

### METEOROLOGY

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAR (up/down)</td>
<td>LiCor Quantum</td>
</tr>
<tr>
<td>Solar</td>
<td>Kipp &amp; Zonen</td>
</tr>
<tr>
<td>Net Radiation</td>
<td>REBS Q*7</td>
</tr>
<tr>
<td>Rain</td>
<td>Tipping Bucket</td>
</tr>
</tbody>
</table>

### PROFILES

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind (6 hrs)</td>
<td>Cup, 2D Sonics</td>
</tr>
<tr>
<td>Temperature (6 hrs)</td>
<td>Campbell 107</td>
</tr>
<tr>
<td>CO₂/H₂O (12 hrs)</td>
<td>LI-7000 (Closed Path)</td>
</tr>
</tbody>
</table>

### FLUXES

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Momentum/Heat</td>
<td>Campbell CSAT3</td>
</tr>
<tr>
<td>1) CO₂/H₂O</td>
<td>LI-7500 (Open Path)</td>
</tr>
<tr>
<td>2) CO₂/H₂O</td>
<td>LI-7000 (Closed Path)</td>
</tr>
</tbody>
</table>
Sonic anemometer looks **East**, the most common wind direction.
Elevator to raise and lower eddy flux sensors.
Carbon Budget

Ideally, the forest atmosphere coupling is 1-dimensional, such that the Net Ecosystem Exchange (NEE) of CO2 is given by:

\[ \text{NEE} = F_c + S \]

\[ S = \frac{dC}{dt} \]

\( F_c \) - turbulent CO2 flux

\( S \) - rate of change of CO2 in the air-column.
Eddy Covariance

Directly measures exchange (flux) of CO$_2$ between forest and atmosphere. Averaging interval is of order 1 hour.

$$F_c = \langle w \rho_c \rangle$$

$F_c$ = co2 flux
$w$ = vertical wind component
$\rho_c$ = co2 density
**CO₂ Storage**

The rate of change of CO₂ beneath the eddy flux sensors is measured via the mean profile of CO₂. Averaging interval is of order 1 hour.

\[
S_z = \frac{d}{dt} \rho_c \int_0^z d_-
\]

- \(S_z\) = rate of storage beneath \(z\)
- \(\rho_c\) = CO₂ density
1. SELECTIVE LOGGING (R. Pereira et al., 2002, in press)

- Few percent of marketable trees are cut

1. Conventional Selective Logging:

- Large percent of canopy/soil can be damaged

2. Reduced Impact Selective Logging:

- Pre-cut inventory and vine cutting
- Planned roads, log decks, skid trails
- Planned felling and low impact extraction methods
RESPONSE TO LOGGING

Requires measurement **PRECISION**.

Eddy covariance is a high precision measurement.
Hypothesis: Short-Term Response to Logging

Net Ecosystem Exchange
**Hypothesis:** Short-Term Response to Logging

**Net Ecosystem Exchange**

1. Immediate reduction in photosynthesis & respiration.
**Hypothesis:** Short-Term Response to Logging

Net Ecosystem Exchange

1. Immediate reduction in photosynthesis & respiration.

2. Lagged increase in decomposition.
Pre- and Post Logging

Preliminary data **do not support** this hypothesis.
POSSIBLE SCENARIOS

• The fluxes shown are raw without known important corrections.

• The cut is not complete - may be sampling a mix of logged/intact forest.

• Dense understory takes advantage of newly available PAR.

• Reduced Impact Logging and/or Light Harvest resulted in little disturbance.

• These are dry season data - chambers indicate decomposition is water limited.
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PRELIMINARY GAP MAP

10-15% gaps

600 m
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Soil respiration (presumably decomposition) strongly affected by rain (presumably litter moisture)

Heavy rains interrupt 2001 dry season

Autochamber measurements of soil respiration
2. SITE CARBON BUDGET

Requires **ACCURATE** measurement of **NEE** for all meteorological conditions.

But, eddy covariance **accuracy** is **uncertain** during calm, stable nights.
Large **measured** carbon uptake of almost 4 TC/ha/yr!

Above Ground Biomass about **100 TC/ha**

*Closed Path IRGA w/high frequency loss corrections*
Is this apparent carbon sink real?

• Ground Based Inventories

• Micrometeorological Biases
  • Below Canopy Dynamics
  • Gap Dynamics (2nd tower)

• Methodological Biases
  • Is a u* correction warranted?
  • Open vs. closed path IRGA
Ground Based Inventories

- Trees > 55 cm DBH inventoried 1984 and again in 2000.
- Difference between inventories indicates forest growth.
- Also have dendrometers for short term wood increment.

1984 Tree biomass: 105 tC ha\(^{-1}\)
2000 Tree biomass: 106 tC ha\(^{-1}\)
Net wood increment: 0 \(\pm\) 1 tC ha\(^{-1}\)
Probable Delta soil C: 0 \(\pm\) 0.5 tC ha\(^{-1}\)
Annual C balance: 0 \(\pm\) 1.5 tC ha\(^{-1}\)
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Sub Canopy Micrometeorology

Above canopy wind easterly, night and day

Night-time low level (1.3 m) wind not aligned with above canopy wind.
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**u* Correction**

**Assumption**: NEE and $u*$ are independent

**Difficulty**: Most nights are very calm.
**u* Correction**

A dramatic effect!

CUMULATIVE CARBON EXCHANGE (NEE)

- **u* = 0.1 m/s correction**
- **No u* correction**

DAY SINCE JAN 1, 2000
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Open/Closed Path IRGA

Comparisons “Look Good”

CO2 FLUX

H2O FLUX
Open/Closed Path IRGA

But, they give different answers!

Which is right?

CUMULATIVE CARBON EXCHANGE (NEE)

Closed Path

Open Path
Conclusion: Annual Sums over Tropical Forests are Very Sensitive to Measurement and Processing techniques

Closed Path: $u^* = 0.1 \text{ m/s}$

Closed Path: $u^* = 0.2 \text{ m/s}$

Closed Path: no $u^*$ corr

Open Path: no $u^*$

Open Path: no $u^*$, 240 min
Conclusions

• High quality data set - original plus targeted additional measurements.

• Logging Effect on CO2 exchange is not obvious.

• Annual CO2 Budget is sensitive – eddy flux alone is not enough.

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