What Is Forest Degradation?

Forest degradation is the reduction of the overall capacity of a forest to supply goods and services; including carbon storage, climate regulation and biodiversity retention.

Parrotta et al. 2012
A Widespread Problem

- 850 million ha of tropical forests are degraded (ITTO 2002)
- Degradation equivalent to 33% of deforestation in Sumatra (Margono et al. 2012)
- Degradation affected twice the area that was deforested in the Brazilian Amazon in 2008 (DEGRAD 2013)

Most of the world’s tropical forests are already degraded

Parrotta et al. 2012
Anthropogenic Disturbances
Anthropogenic Disturbances

20 million ha of tropical forest burned in 1997-98 ENSO event (Cochrane 2003)

20% of humid tropical forest have been logged by 2005 (Asner 2009)

70,000 km new forest edges are created every year in the Amazon (Broadbent 2008)
Knowledge Gap

Research in disturbed forests:
- Few
- Small scale
- Only one type of disturbance
- Only one part of the carbon stocks

Limited hability to understand the magnitude of impacts of anthropogenic disturbances on carbon stocks
Objectives

What are the impacts of multiple anthropogenic disturbances on above- and belowground forest carbon stocks in a large-scale field assessment?

1 - How do distinct disturbances affect individual carbon pools and forest structure?

2 - Can variability in primary forests aboveground stocks be explained by differences in history of forest disturbance, landscape context and topography?
Study Regions – Santarém and Paragominas
Selecting Study Catchments — Santarém
Plot Classification – Disturbance legacy

○ Undisturbed Forest

● Secondary Forest
Plot Classification – Disturbance legacy

- Undisturbed Forest
- Logged Forest
- Logged-and-Burned Forest
- Secondary Forest
Sampling Design

1 - Aboveground pool – live trees, palms, lianas ≥2cm dbh

2 - Dead wood pool – dead trees, palms ≥2cm dbh, coarse woody debris

3 - Litter pool – litter and fine woody debris

4 - Soil pool

5 - Roots pool
## Sampling Totals

<table>
<thead>
<tr>
<th>Components</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees, palms, lianas</td>
<td>70,293</td>
</tr>
<tr>
<td>Coarse woody debris</td>
<td>8,611</td>
</tr>
<tr>
<td>Fine woody debris</td>
<td>1,125</td>
</tr>
<tr>
<td>Litter samples</td>
<td>2,250</td>
</tr>
<tr>
<td>Soil samples</td>
<td>4,725</td>
</tr>
</tbody>
</table>

225 plots (10x250m)
OBJECTIVE 1

How do distinct disturbances affect individual carbon pools and forest structure?
Disturbance effects on multiple carbon pools

Litter stocks (Mg C ha$^{-1}$)

Paragominas

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undisturbed</td>
<td>13</td>
</tr>
<tr>
<td>Logged</td>
<td>44</td>
</tr>
<tr>
<td>Logged-and-Burned</td>
<td>44</td>
</tr>
<tr>
<td>Secondary</td>
<td>16</td>
</tr>
</tbody>
</table>

Santarém

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undisturbed</td>
<td>17</td>
</tr>
<tr>
<td>Logged</td>
<td>26</td>
</tr>
<tr>
<td>Logged-and-Burned</td>
<td>24</td>
</tr>
<tr>
<td>Secondary</td>
<td>34</td>
</tr>
</tbody>
</table>
Disturbance effects on aboveground carbon stocks

Aboveground stocks (Mg C ha\(^{-1}\))

Paragominas
- Undisturbed
- Logged
- Logged-and-Burned
- Secondary

Santarém
- Undisturbed
- Logged
- Logged-and-Burned
- Secondary

- n=13
- n=44
- n=44
- n=16
- n=17
- n=26
- n=24
- n=34
### Disturbance effects on forest structure

<table>
<thead>
<tr>
<th>Paragominas</th>
<th>Santarém</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trees &gt;50cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Trees 40-50cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Trees 30-40cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Trees 20-30cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Trees 10-20cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Trees 5-10cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Trees 2-5cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lianas &gt;10cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lianas &lt;10cm</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Undisturbed</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Logged</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Logged-and-burned</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Mean %</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

### Mean %

- **Disturbance effects on forest structure**:
  - **Paragominas**
    - **Trees >50cm**
    - **Trees 40-50cm**
    - **Trees 30-40cm**
    - **Trees 20-30cm**
    - **Trees 10-20cm**
    - **Trees 5-10cm**
    - **Trees 2-5cm**
    - **Lianas >10cm**
    - **Lianas <10cm**
  - **Santarém**
    - **Trees >50cm**
    - **Trees 40-50cm**
    - **Trees 30-40cm**
    - **Trees 20-30cm**
    - **Trees 10-20cm**
    - **Trees 5-10cm**
    - **Trees 2-5cm**
    - **Lianas >10cm**
    - **Lianas <10cm**

- **Mean %**
  - **Undisturbed**
  - **Logged**
  - **Logged-and-burned**
  - **Secondary**

- **Stability and Productivity**: The graphs illustrate the distribution of tree and liana sizes across different disturbance levels in Paragominas and Santarém. The data suggest changes in forest structure post-disturbance, with notable shifts in the proportion of trees and lianas in different size categories.
Disturbance effects on forest structure
Disturbance effects on multiple carbon pools

Message 1 – High levels of disturbance can turn primary forests similar to secondary forests both in terms of the amount of carbon they store and in terms of forest structure.

Message 2 – Resistance of the dead wood, litter and soil pool to anthropogenic disturbance.
OBJECTIVE 2

What explains variability in primary forests aboveground stocks?
Mixed-Effects Model

Aboveground.carbon = lme(ABG ~ Elevation + Slope + Edge + Area + Time.Logging + Time.Fire, random = ~1|Catchment)

Topographic variables
- Elevation
- Slope

Disturbance Variables
- Area
- Time since the last fire event
- Time since the last logging event

Landscape Context
- Distance to edge
Variability in aboveground stocks

![Variability in aboveground stocks](image_url)
Conclusion

* High levels of disturbance (i.e. logged and burned forests) lead to degradation of carbon stocks and changes in forest structure – *secondarization*

* Assessments and monitoring of changes in tropical rainforests carbon stocks should focus on aboveground stocks

* Need for an urgent change in conservation policy paradigms: effective incorporation of avoided degradation measures (e.g. stimulating fire-free agriculture)
Rede Amazônia Sustentável
Unsung Heroes

In memorian 1985-2011

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