Biodiversity and ecosystem carbon budget in the upland landscapes following shifting cultivation by small-holder *kaingin* farmers in the Philippines

Sharif A. Mukul and John L. Herbohn,
Background – Shifting cultivation

- 1/3 of the tropics were under some kind of shifting cultivation (Dove 1983);

- About 40 million-1 billion people rely on shifting cultivation for food security and livelihoods (Mertz et al. 2009);

- Blamed as a major drivers of deforestation and biodiversity loss in most scientific and policy documents;

- As a consequence of shifting cultivation, regenerating secondary forests following SC are becoming prominent in the tropics;
A shifting cultivation landscape in the Chittagong Hill Tracts of Bangladesh
(Photo credit: MR Hasan)
**Background – Forest biodiversity & deforestation in the Philippines**

- Forest area – 7.17 million ha (24% of the total land);
- One of the worlds ‘17 mega-biodiversity countries’/‘34 global biodiversity hot-spots’ with about 20,000 endemic species;
- Experienced one of the highest rates of deforestation in the Southeast Asia;
- A pioneer countries to introduce massive reforestation program to address the issue of forest loss and degradation (Chokkalingam et al. 2006);
- 7620 plant species (77% endemic) (Sodhi et al. 2004)
Trends of deforestation in the Philippines

Source: RMPFD 2003
Shifting cultivation in the Philippines context

- Locally familiar as – *kaingin*;

- Blamed for majority of the country’s deforestation and forest degradation in the upland areas (Kummer 1992);

- Major forestry policies (e.g. *kaingin* Management and Land Settlement Regulation, 1971), tried to impose restriction on it assuming a minor or negative consequences on ecosystem and the environment (Harrison et al. 2004).
A complex mosaic of secondary regrowth following *kaingin* and other disturbances in the Philippines upland
Study context
Research question

“What is the tree diversity and carbon storage in post-kaingin secondary forests in the upland Philippines, and what implication they have for land-use policy development integrating small-holder farmers?”
Methodology

• Modified Gentry plot approach: transect (50 m x 5 m) surveys in 20 kaingin sites (> 1 ha), and in secondary forests (n=5);

• 4 transects from each sites of the following fallow categories,
  • Less than 5 years
  • More than 5 years and less than 10 years
  • More than 10 years and less than 20 years and
  • More than 20 years and less than 30 years under fallow
Study area

Barangy Gaas, Ormoc, Leyte Island
Methodology – cont.

Vegetation survey (@ transect level) -

- diameter of standing tree (≥ 5 cm at dbh); \( N = 2918 \)
- height of individuals, and respective position in transect (X/Y);
- diameter and length of dead trees (freshly cut; moderately decomposed, rotten, burnt; standing/lying on ground) with dbh ≥ 5 cm \( N = 1281 \);

Site parameters –

- fallow age, patch size, GPS coordinates, elevation, distance, slope, LAI, topographic position, adjacent land-use/cover, disturbances.
Data analysis

Biodiversity indices:

Species richness (S)
Shannon-Weiner index (H)
Species evenness / Pilou’s diversity index (J)
Stem number (N)
Considerations for ecosystem carbon budget

<table>
<thead>
<tr>
<th>Above ground</th>
<th>Below ground</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allometric relationships</strong></td>
<td><strong>Laboratory analysis</strong></td>
</tr>
<tr>
<td>Standing trees (≥ 5 cm dbh) (N= 2918)</td>
<td>Soil (0-30 cm) (N = 900)</td>
</tr>
<tr>
<td>Dead/burnt trees (≥ 5 cm dbh) (N=1281)</td>
<td>Fine roots (0-5 cm) (N= 300)</td>
</tr>
<tr>
<td>Tree ferns (&gt; 5 cm dbh) (N = 184)</td>
<td>Coarse root (15% of AGB)</td>
</tr>
<tr>
<td>Abaca (&gt; 5 cm dbh) (N= 124)</td>
<td>(Brown 1997, Chave et al. 2005; Ketterings et al. 2001)</td>
</tr>
<tr>
<td><strong>Destructive sampling</strong></td>
<td></td>
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<tr>
<td>Seedlings</td>
<td></td>
</tr>
<tr>
<td>Saplings</td>
<td></td>
</tr>
<tr>
<td>Leaf litter and</td>
<td></td>
</tr>
<tr>
<td>Woody debris</td>
<td></td>
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</tbody>
</table>
A newly opened site for *kaingin* in the area

A ~ 20 years *kaingin* fallow site

A ~ 30 years *kaingin* fallow site

A secondary forest site without any *kaingin*
Study finding

- 131 species belonging to 86 genera and 46 families;
- 12 late successional/climax; 58 intermediate; 61 pioneer species
- Moraceae (14 species); Dipterocarpaceae (10 species)
Diversity indices

<table>
<thead>
<tr>
<th>Diversity indices</th>
<th>Fallow category</th>
<th>Secondary forest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5 years</td>
<td>6-10 years</td>
</tr>
<tr>
<td><strong>Species richness</strong> ($S$)</td>
<td>6 (±7.38)</td>
<td>38.4 (±4.82)</td>
</tr>
<tr>
<td><strong>Shannon-Wiener index</strong> ($H$)</td>
<td>1.22 (±1.18)</td>
<td>3.17 (±0.28)</td>
</tr>
<tr>
<td><strong>Species Evenness index</strong> ($J$)</td>
<td>0.57 (±0.52)</td>
<td>0.87 (±0.06)</td>
</tr>
<tr>
<td><strong>Stem number</strong> ($N$)</td>
<td>10.8 (±13.52)</td>
<td>142.6 (±20.5)</td>
</tr>
</tbody>
</table>
Tree diversity
Tree diversity - cont.
Species compositional similarities

Species richness
Stress: 12.16

Species abundance
Stress: 13.61
Biomass and soil carbon

Above ground live biomass carbon (Mg C ha⁻¹)

Above ground dead tree biomass carbon (Mg C ha⁻¹)
Cont.
Carbon storage in above ground live tree biomass (Mg C ha\(^{-1}\))
Carbon storage in above ground live tree biomass (Mg C ha\(^{-1}\))
Carbon storage in above ground tree biomass (Mg C ha$^{-1}$)

The graph illustrates the distribution of carbon storage in above-ground tree biomass across different height classes. The x-axis represents height categories, ranging from ≤ 5 m to ≥ 31 m. The y-axis represents carbon storage amounts, measured in Mg C ha$^{-1}$.

The graph shows distinct lines for different height classes:
- ≤ 5 m
- 6-10 m
- 11-20 m
- 21-30 m
- ≥ 31 m

Each height class has a corresponding line color:
- SA0-5
- SA6-10
- SA11-20
- SA21-30
- SF

The lines indicate varying levels of carbon storage, with different colors representing different height classes. The graph helps in understanding the distribution of carbon storage across varying heights.
Organic carbon storage in soil (Mg C ha$^{-1}$)
Total carbon storage at the landscape level (Mg C ha\(^{-1}\))

- Above ground live tree biomass carbon
- Above ground dead tree biomass carbon
- Soil organic carbon
Above ground C in other common upland land-cover/use in Philippines

<table>
<thead>
<tr>
<th>Land-use</th>
<th>AGB carbon density (Mg C ha(^{-1}))</th>
<th>Carbon sequestration</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural forest</td>
<td>518</td>
<td></td>
<td>Lasco et al. (1999)</td>
</tr>
<tr>
<td><em>Imperata</em> grassland</td>
<td>8.5</td>
<td>0, burnt regularly</td>
<td>Lasco et al. (1999)</td>
</tr>
<tr>
<td><em>Sacharrum</em> sp.</td>
<td>13.1</td>
<td>0, burnt regularly</td>
<td>Lasco et al. (1999)</td>
</tr>
<tr>
<td>Rice paddy fields</td>
<td>3.1</td>
<td>0, burnt regularly</td>
<td>Lasco et al. (1999)</td>
</tr>
<tr>
<td>Plantations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mahogany</td>
<td>264</td>
<td></td>
<td>Lasco et al. (2000)</td>
</tr>
<tr>
<td><em>Acacia</em> sp.</td>
<td>81</td>
<td></td>
<td>Lasco et al. (2000)</td>
</tr>
<tr>
<td>Dipterocarp</td>
<td>221</td>
<td></td>
<td>Lasco et al. (2000)</td>
</tr>
</tbody>
</table>
Conclusion

- Comparable and rapid recovery of biodiversity;
- Carbon sequestration and storage are largely influenced by fallow length, and it takes as much as 30 years to recover ~40% C as in the undisturbed forests;
- Regenerating secondary forests can be a cost effective restoration strategy in tropical developing countries;
- Incorporation of REDD+ with this land-use can be beneficial for both small-holder rural farmers and for the local environment.
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