Carbon-driven recovery of nitrogen cycling in fast-growing tropical tree plantations

Jim Raich
Iowa State University
July 2012
C-N Linkages

- Soil C: Jobbagy & Jackson (2000)
- Soil N: Chapin, Vitousek & Matson (2011)

60 PgC y\(^{-1}\) flows from Soil C to Soil N and NPP.

N uptake 0.4 Pg y\(^{-1}\) from NPP to CO\(_2\).

NPP is a key intermediate in the C-N cycle.
Given so much soil N:

- Why is <0.3% available to plants?
Today:

• Overview of research in Costa Rica
  ➢ Experimental tree plantations

• Comparisons
  ➢ to mature forests
  ➢ to successional forests
  ➢ to FACE experiments

• Hypotheses
Today:

• Overview of research in Costa Rica
  - Where $N$ is not limiting

• Comparisons
  - to mature forests
  - to successional forests
  - to FACE experiments

• Hypotheses
Study Site; La Selva Biological Station

• Costa Rica, Caribbean lowlands
• 4000 mm annual rainfall, with no month averaging <150 mm.
• ~26°C mean annual temperature.
• Volcanic soils
  ➢ (Mixed Haplic Haploperox)
Experiment established in 1988, on recently abandoned pastureland
Sixteen years later
Experimental Design

- Randomized Complete Block (N=4)
- Monospecific plantations
High rates of C cycling

Russell et al. (2010)
High rates of N uptake by Vegetation

- No data available from Mature Forest

- Puerto Rico tabonuco forest = 155 kg ha\(^{-1}\) yr\(^{-1}\)

Chestnut et al. (1999)
Also Large Amounts of N in Biomass

- Net annual accretion = 54 ± 17 kgN ha\(^{-1}\) yr\(^{-1}\)

Russell et al. (2012)
Why so productive AND N rich?

- age 16 years

Age 20 years
Litterfall

- Lowest in *Virola*

- Plantations: 0.8 – 1.2 times the MF rate
Total Soil Respiration

- Lowest in Mature Forest (MF)

- Plantations: 1.1 to 1.5 times the Forest rate
Belowground C Flux [$R_{\text{SOIL}} - \text{LF}$]

- 1.2 to 1.7 times the Forest rate
### Fine Root Biomass

- **3 to 4 times the Forest mean**

<table>
<thead>
<tr>
<th></th>
<th>MF</th>
<th>HIAL</th>
<th>PEMA</th>
<th>VIKO</th>
<th>VOGU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td>6.2</td>
<td>3.8</td>
<td>4.2</td>
<td>5.1</td>
</tr>
</tbody>
</table>

**Fine Root Biomass (Mg ha\(^{-1}\))**
Our sites are not unique.

- Globally, BCA averages 1.5 times greater in young than in mature forests.

Davidson et al. (2002)
A Response to Abundant N?

- Increased N supply:
  - Increases tree biomass (TB)
  - Decreases (n.s.) fine root prod. (and biomass)
  - Decreases $R_{\text{SOIL}}$ (SCE)

Figure 1 | Effect of experimental nitrogen addition on various forest carbon pools and fluxes as calculated by meta-analysis. Positive values indicate that nitrogen addition had a positive effect, negative values indicate a decrease. Error bars indicate the 95% confidence interval. Data

Janssens et al. (2010)
Hypothesis: a Carbon Cascade

Rapid Photosynthesis → Belowground C Allocation → Enhanced plant nutrient uptake → More Nitrogen-rich leaves → More Photosynthesis
In Light of Succession

Hypothesis:
Youthful Peak in Forest NPP (belowground)

Carbon Flux to Root Systems

Fig. 17. Hypothetical trends of gross production, stand respiration, net production and biomass in an age-series of dense pure stands

Kira & Shidei (1967)
In Comparison to FACE Results:

- Increased ANPP
- Increased $R_{\text{SOIL}}$
- More BCA
- More fine roots
- More canopy N
- Increased N Uptake

Drake et al. (2012)
Hypothesis:

- The Experimental Plantations are CO$_2$-rich forests

Drake et al. (2012)
Hypothesis:

- The Experimental Plantation are CO$_2$-rich forests
- or CO$_2$-enriched forests are “early successional”

Drake et al. (2012)
Acknowledgements

NSF DEB #0236502 and #0703561

• Ann Russell, collaborator
• Dick Fisher, Gary Hartshorn, Eugenio Gonzalez; established the Experiment
• Oscar Valverde; roots
• Ricardo Bedoya; local Project Manager
• Gary Hartshorn, ECOS and La Selva personnel, Organization for Tropical Studies