Litterfall and nutrient cycling in cocoa

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Cocoa nutrition in smallholder farms heavily depends on inherent soil fertility.

Litterfall:
- major nutrient flow from tree to soil
- provides energy to soil biota

Earthworms and other invertebrates can speed-up litter break-down, but their role in nutrient cycling is poorly quantified in cocoa.
Objectives

*Better understand nutrient flows through litter in low-input cocoa agroforestry systems*

Quantify carbon and nutrient transfers through litterfall

Understand the role of soil macrofauna on leaf litter disappearance and nutrient removal rates
Study area

- Climatic condi
### The cocoa agroforestry system

<table>
<thead>
<tr>
<th>Tree population characteristics</th>
<th>Location</th>
<th>Location</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age of plantation (years)</strong></td>
<td>Ago-Owu 18</td>
<td>Akowonjo-Akoko 15</td>
<td>Ijebu-Itele 23</td>
</tr>
<tr>
<td><strong>Shade tree density (trees ha(^{-1}))</strong></td>
<td>27</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td><strong>Cocoa tree density (trees ha(^{-1}))</strong></td>
<td>985</td>
<td>1087</td>
<td>1162</td>
</tr>
<tr>
<td><strong>Cocoa stem diameter (cm)</strong></td>
<td>14.2 ± 2.8</td>
<td>18.1 ± 3.7</td>
<td>13.8 ± 2.8</td>
</tr>
<tr>
<td><strong>Cocoa canopy diameter (cm)</strong></td>
<td>221 ± 48</td>
<td>337 ± 62</td>
<td>154 ± 61</td>
</tr>
<tr>
<td><strong>Tree height (cm)</strong></td>
<td>488 ± 79</td>
<td>407 ± 71</td>
<td>440 ± 65</td>
</tr>
</tbody>
</table>

### Soil physical & chemical properties

| Clay content (%)                      | 23 ± 1.4          | 18 ± 5.7          | 16 ± 2.8          |
| pH\(_{H2O}\)                           | 6.85 ± 0.1        | 6.20 ± 0.3        | 6.70 ± 0.7        |
| Organic carbon (mg g\(^{-1}\))        | 11.80 ± 0.7       | 8.53 ± 0.7        | 9.60 ± 2.2        |
| Total nitrogen (mg g\(^{-1}\))        | 1.21 ± 0.0        | 0.79 ± 0.1        | 0.86 ± 0.1        |
| Available P\(_{Olsen}\) (mg kg\(^{-1}\)) | 35.07 ± 14        | 8.24 ± 14         | 28.01 ± 4.0       |
Dry matter and nutrient flows through litterfall

- Annual litter production

Nutrient transfers through cocoa leaf litterfall
Temporal variability in litterfall

- Linking litterfall to weather data
Disappearance of cocoa leaf litter

- Effect of macrofauna on gradual litter mass loss

\[ R^2 = 0.54 \]

\[ M = M_0 e^{0.0016t} \]

\[ M = M_0 e^{0.002t} \]
Patterns of nutrient removal from cocoa leaf litter

<table>
<thead>
<tr>
<th>Time after incubation (months)</th>
<th>Losses from litter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>62</td>
</tr>
<tr>
<td>18</td>
<td>69</td>
</tr>
<tr>
<td>4</td>
<td>≤0</td>
</tr>
<tr>
<td>7</td>
<td>78</td>
</tr>
</tbody>
</table>

**Residual nutrient in cocoa leaf litter, %**

**Access**
- **with**
- **without**

**Time, days after incubation**

![Diagram showing nutrient removal patterns](image)
## Table 4: Concentrations and Amounts of Nutrients in the Litter Fall and Standing Litter of Cocoa and Shade Trees Combined, Nutrient Transfer Through Fine Root Turnover of Shade Trees in Cocoa Systems, and Nutrient Transfer Through Rainwash in Shaded and Unshaded Systems

<table>
<thead>
<tr>
<th>Nutrient concentrations in litter (g/kg)</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Source</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients returned to the soil through litter (kg/ha/yr)</td>
<td>84–175</td>
<td>5.8–17</td>
<td>16–124</td>
<td></td>
<td></td>
<td>Hartemink and Donald (2005)</td>
<td>Range of several studies around the world</td>
</tr>
<tr>
<td>Offtakes for 1 Mg ha⁻¹ beans</td>
<td>N</td>
<td>P</td>
<td>K</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With husks (kg ha⁻¹)</td>
<td>35</td>
<td>6</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without (kg ha⁻¹)</td>
<td>20</td>
<td>4</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Connect-the-dots...

- Resorption efficiency: $P > N$
  - $N:P \approx 9-14$ in green leaves  
    

- MRT in litter: $P > N$
  
  #Fontes et al., 2014. Plant Soil 383: 313-335

  - Fine roots growing upwards $<$ $P$ trapped in humus?

- What about:
  
  - Pruning residues and root turnover
  
  - Fungicide use, AMF, & cocoa $P$ nutrition
Considerable cycling of N and K through litterfall: ~ 100 kg ha$^{-1}$ yr$^{-1}$

Small amounts of P recycled: ~ 5 kg ha$^{-1}$ yr$^{-1}$

P further immobilized in the litter layer during decomposition

Different mechanisms govern dynamics of N, P, K with a role of C

Macrofauna significantly increases cocoa leaf litter loss rates

- Fractionation effect ($k_{\text{with}}/k_{\text{without}}$) = 1.25

- Enhances C, N, and P removal from the litter layer... but not before 6 months.
Litterfall and nutrient cycling in cocoa

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Dr Stefan HAUSER
Dr Moses O. OGUNLADE
Dr A. G. Tom SCHUT
Dr Lotte S. WOITTIEZ
Prof Ken E. GILLER
Additional slides
Litterfall & nutrient recycling in cocoa

- Decomposition rates with/without macrofauna access
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter mass loss (mean ± std dev)
Litterfall & nutrient recycling in cocoa

- Elemental concentrations in remaining litter (mean ± std dev)
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter C loss (change in litter quality)
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter nutrient loss (change in litter quality)
Decomposition of cocoa leaf litter

- Cocoa leaf litter nutrient loss (change in litter quality)
Decaying litter quality

- Nutrient release patterns: progressive change in stoichiometry
Decaying litter quality

- Cocoa leaf litter nutrient loss (change in litter quality)
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter nutrient loss (change in litter quality)
Litterfall & nutrient recycling in cocoa

- Predicted C and nutrient release patterns
Litterfall & nutrient recycling in cocoa
Litterfall & nutrient recycling in cocoa

- Effect of macrofauna on litter decomposition
Litterfall & nutrient recycling in cocoa

- Predicted cocoa leaf litter mass