Cocoa and by-crop yields in three organic production systems entering mature stage

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Agroforestry for cocoa has environmental benefits

Niether et al. 2020 *Environ. Res. Lett.* 15 104085

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SysCom Bolivia Project

Objectives

• Do agroforestry systems and organic management perform better (agronomical, socio-economic and environmental indicators) compared with monocultures and conventional farming?
• What are the challenges of the different production systems?

• Start: End of 2008
• 5 different systems compared, replicated 4 times
• Plots measuring 48 m × 48 m
• 12 cacao cultivars, planted at 4 x 4 m
• 144 cocoa trees monitored per plot (2880 trees in total) every 2 weeks
Conventional monoculture

Fallow

Conventional agroforestry system

Successional agroforestry systems

Organic Monoculture

Organic agroforestry system

Picture: Eric Lohse
## Gradient of diversity of organic production systems

<table>
<thead>
<tr>
<th>Monoculture MONO ORG</th>
<th>Agroforestry AF ORG</th>
<th>Successional or dynamic agroforestry SAFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost (21 L/tree)</td>
<td>Compost until 2016 (10 L/tree)</td>
<td>No external inputs</td>
</tr>
<tr>
<td>Cover crop/herbal cover</td>
<td>Cover crop in beginning</td>
<td>Selective weeding &amp; natural regeneration</td>
</tr>
<tr>
<td>Mechanical weeding</td>
<td>Mechanical weeding</td>
<td>Regular shade tree pruning</td>
</tr>
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<td></td>
<td>Regular shade tree pruning</td>
<td>Regular shade tree pruning</td>
</tr>
<tr>
<td>Temporal shade: plantain</td>
<td>Temporal shade: plantain, trees</td>
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</tr>
</tbody>
</table>

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Agroforestry designs

Agroforests (About 300 shade trees/ha)
- Plantain (4 x 4 m) for the 3 first years
- Since 2012 banana (4 x 4 m)
- Since 2016 coffee (4 x 2 m) x 2
- Leguminous trees (8 x 8 m)
- Fruit and timber trees (16 x 16 m)

→ 5 timber species, 4 fruit species, 2 biomass species, 1 palm

Successional agroforests (About 800 shade trees/ha)
- Plantain (4 x 4 m) for the 3 first years
- Anual and short-life cycle crops
- Since 2012 banana (8 x 8 m)
- Since 2013 coffee (4 x 2 m) x 2
- Ginger and curcuma

→ ~19 timber species, 4 banana varieties, ~8 fruit species, ~20 biomass species, 3 palms
→ Natural regeneration of some species
→ Shade tree density changing over time
→ Different strata and life cycles
Cocoa yield development

Average yields in farmers fields

- All systems started slowly (compared to Conv. not shown)
- Tree growth in AF/SAFS slower
- Yields in AF and SAFS are higher than producers in many places
- Lower yields in denser systems and with less inputs
Cocoa yields in mature plantations depending on varieties

### Mean dry bean yields [kg/ha] between 2018 - 2021

<table>
<thead>
<tr>
<th></th>
<th>MONO ORG</th>
<th>AF ORG</th>
<th>SAFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>all 12 varieties</td>
<td>1213.6</td>
<td>781.4</td>
<td>648.9</td>
</tr>
<tr>
<td>4 local clones</td>
<td>1845.1</td>
<td>1140.5</td>
<td>975.1</td>
</tr>
</tbody>
</table>

→ Participatory selection process of el Ceibo selecting locally adapted clones, tolerant to diseases
→ Cocoa yields in MONO are 1.9 (SAFS) and 1.6 (AF) times higher
→ No systems effect
→ Breeding for agroforestry

2015 - 2019
Picucci et. al, unpublished
Cumulative total system yields

→ Total system yields in 7.8 (AF) and 4.3 (SAFS) times higher than in MONO
→ SAFS lower total yields than AF, but higher diversity
How do AF and SAFS differ in their development?

- SAFS higher yields in young systems
- AF higher yields in mature systems with 3 market oriented crops
- Fruit trees, ginger and turmeric with potential
Conclusions for agroforestry design and income

Diversity of crops for income

• Income strongly market dependent
• SAFS/temporal shade for quick income
• Diversity interesting for distribution of income over year
• Strategy to be ready for markets in the future (Emerging markets (Acai, Rambutan, Copoazu))
• Interesting for self-consumption (avoiding costs)

Optimization of the design depending on

• Specific goals (input or labour time intensive, extensive, economic, nutrition, …)
• Ressources and market opportunities
Conclusions for agroforestry management

Reducing shade trees over time vs. fixed design

- Selection of productive fruit and good quality timber trees
- Growth of timber trees
- Risk distribution for loss of fruit trees

Regular shade tree pruning

- Can replace external fertilizers
- Allows for high density of shade trees while reaching good cocoa yields
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