



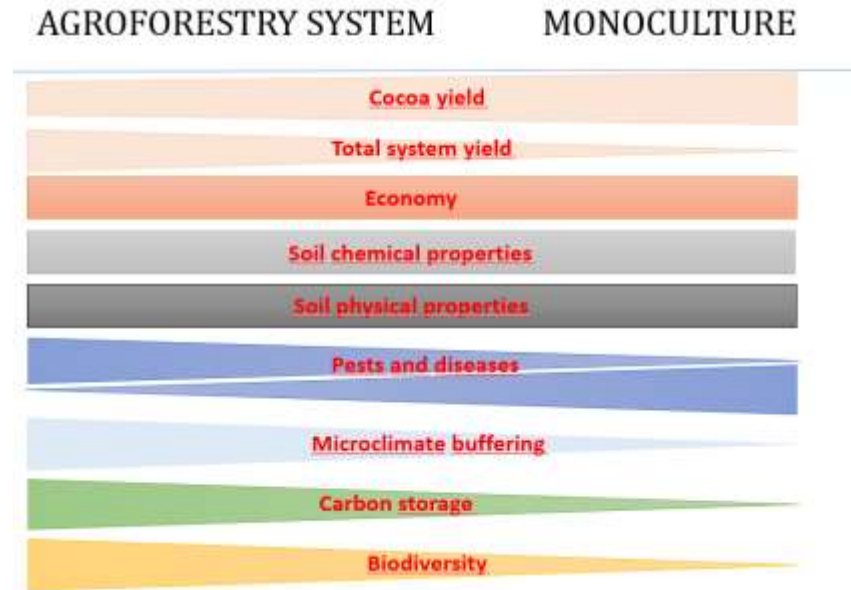
Cocoa and by-crop yields in three organic production systems entering mature stage

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Agroforestry for cocoa has environmental benefits



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

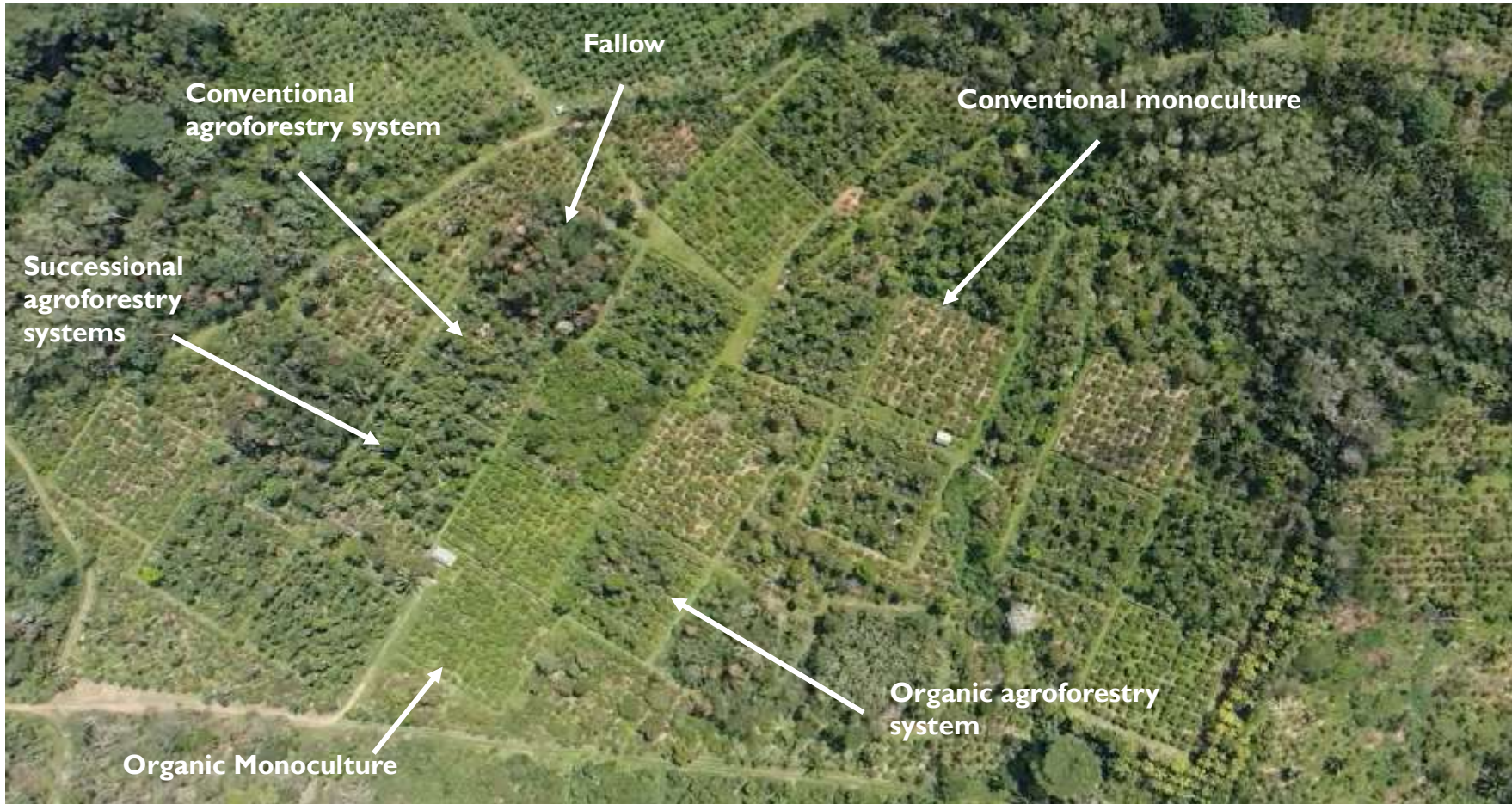
SysCom Bolivia Project

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 x 48 m
- 12 cacao cultivars, planted at 4 x 4 m
- 144 cocoa trees monitored per plot (2880 trees in total) every 2 weeks



Gradient of diversity of organic production systems



Monoculture MONO ORG

Compost (21 L/tree)
Cover crop/herbal cover
Mechanical weeding

Temporal shade: plantain



Agroforestry AF ORG

Compost until 2016 (10 L/tree)
Cover crop in beginning
Mechanical weeding
Regular shade tree pruning
Temporal shade: plantain, trees



Successional or dynamic agroforestry SAFS

No external inputs
Selective weeding & natural regeneration
Regular shade tree pruning
Temporal shade: plantain, trees
annual crops (cassava, maize, ...)

Agroforestry designs

Agroforests (About 300 shade trees/ha)

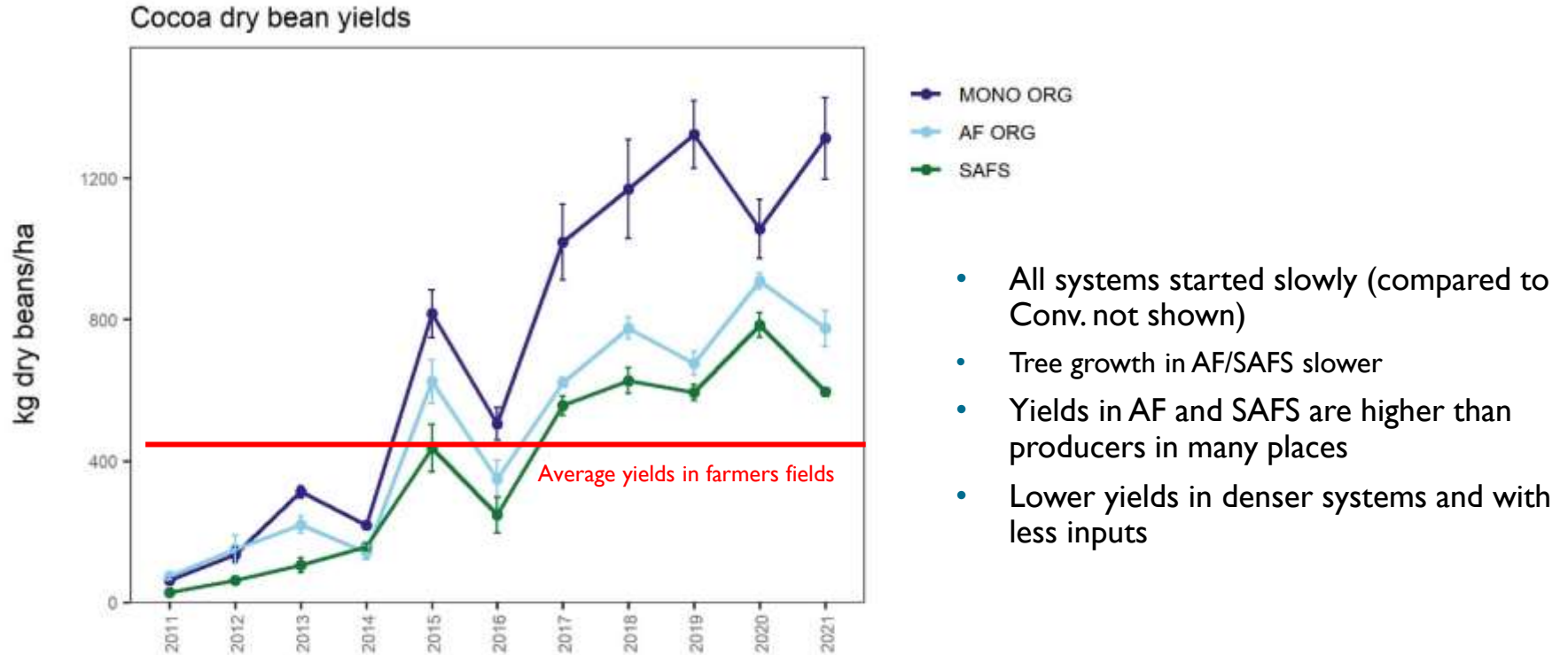
- Plantain (4 x 4 m) for the 3 first years
 - Since 2012 banana (4 x 4 m)
 - Since 2016 coffee (4 x 2 m)x2
 - Leguminous trees (8x8 m)
 - Fruit and timber trees (16 x16 m)
- 5 timber species, 4 fruit species, 2 biomass species, 1 palm



Successional agroforests (About 800 shade trees/ha)

- Plantain (4 x 4 m) for the 3 first years
 - Annual and short-life cycle crops
 - Since 2012 banana (8x8 m)
 - Since 2013 coffee (4 x 2 m)x2
 - 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



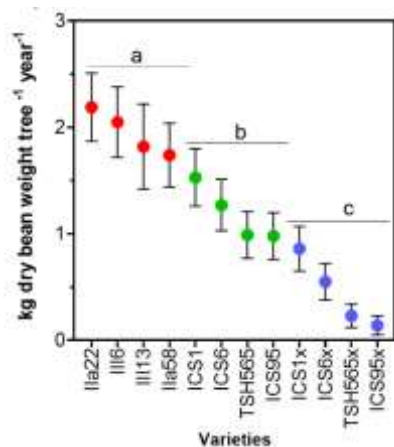
n=4, error bars represent standard error

- 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

| | MONO ORG | AF ORG | SAFS |
|------------------|----------|--------|-------|
| all 12 varieties | 1213.6 | 781.4 | 648.9 |
| 4 local clones | 1845.1 | 1140.5 | 975.1 |



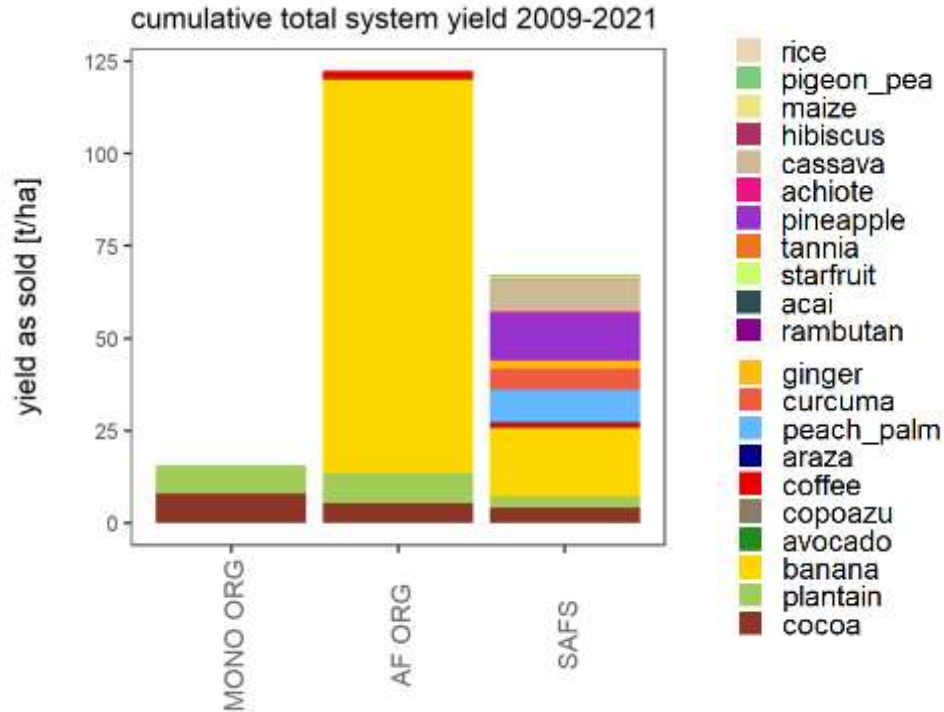
- Local clones
- International clones
- Full-sib families (xIMC67)

2015 - 2019
Picucci et. al, unpublished



- 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

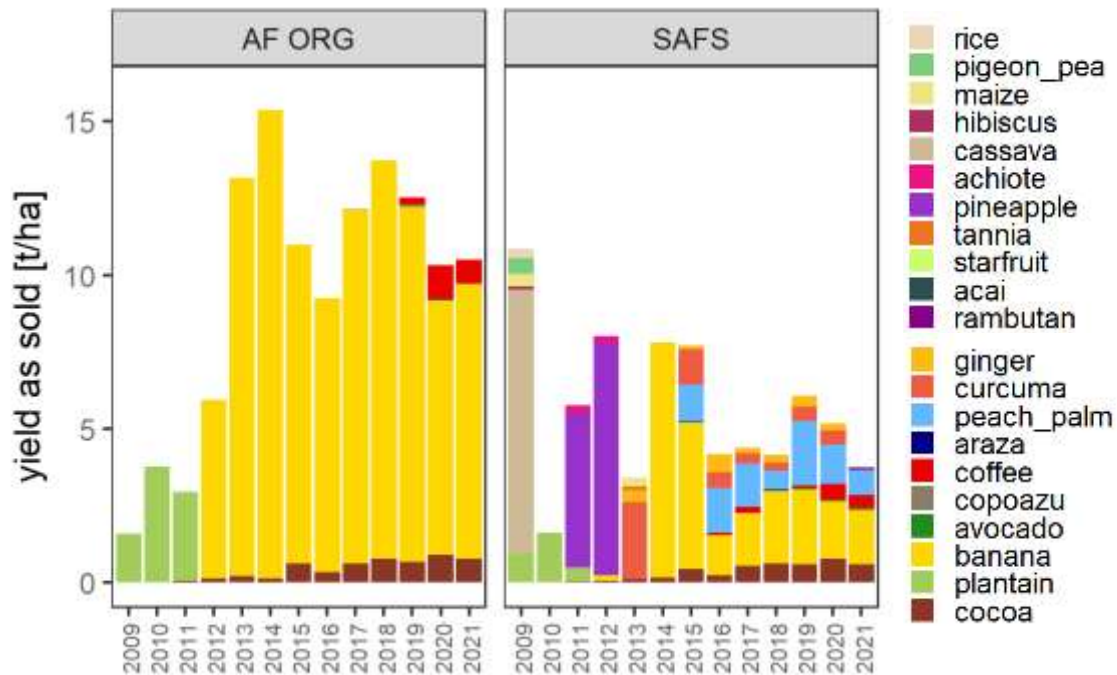
Cumulative total system yields



- 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

cocoa dry beans, coffee dry parchment, fruit as fresh weight, plantain/banana without peduncle

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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