

Fine-root Growth and Dynamic in Five Cocoa Production Systems Affect Biomass and Yield

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Background & Objectives

Trees in agroforestry systems and leguminous cover crops in organically managed systems provide benefits like carbon storage, infiltration and biodiversity [1] but reduce cocoa yield [2]

→ Trade-offs between production goals and ecosystem services

→ Competition for resources are feared by producers

Aim: To compare belowground fine-root production with aboveground performance of different cocoa production systems

Hypothesis: Complementarities between plant components may increase resource use efficiency

→ System yield and biomass may reflect spatial soil resource utilization

Research Design & Methods

Study site 'Sara Ana' in Alto Beni, Bolivia (Fig. 1): 380 m a.s.l., 1439 mm, 25.2° C

Long-term trial of 5 different cocoa production systems (Fig. 2) (n = 4); established in 2008; 48 m x 48 m plots; species and stem density in Table 1; greater objectives of the trial see [2]

Sampling and analysis (2015):

- Cocoa fine-root (< 2 mm) vertical distribution: 3 distances from stem (0.4 m, 1.2 m and 1.7 m), 10 cm depth (Fig. 3)
- Total fine-root production in ingrowth-donuts over 1 year (2015) in 2 depths (0-25 cm, 25-50 cm) (Fig. 3)
- Standing aboveground biomass: allometric formula [3]
- Yield: cocoa, bananas, tubers and fruits

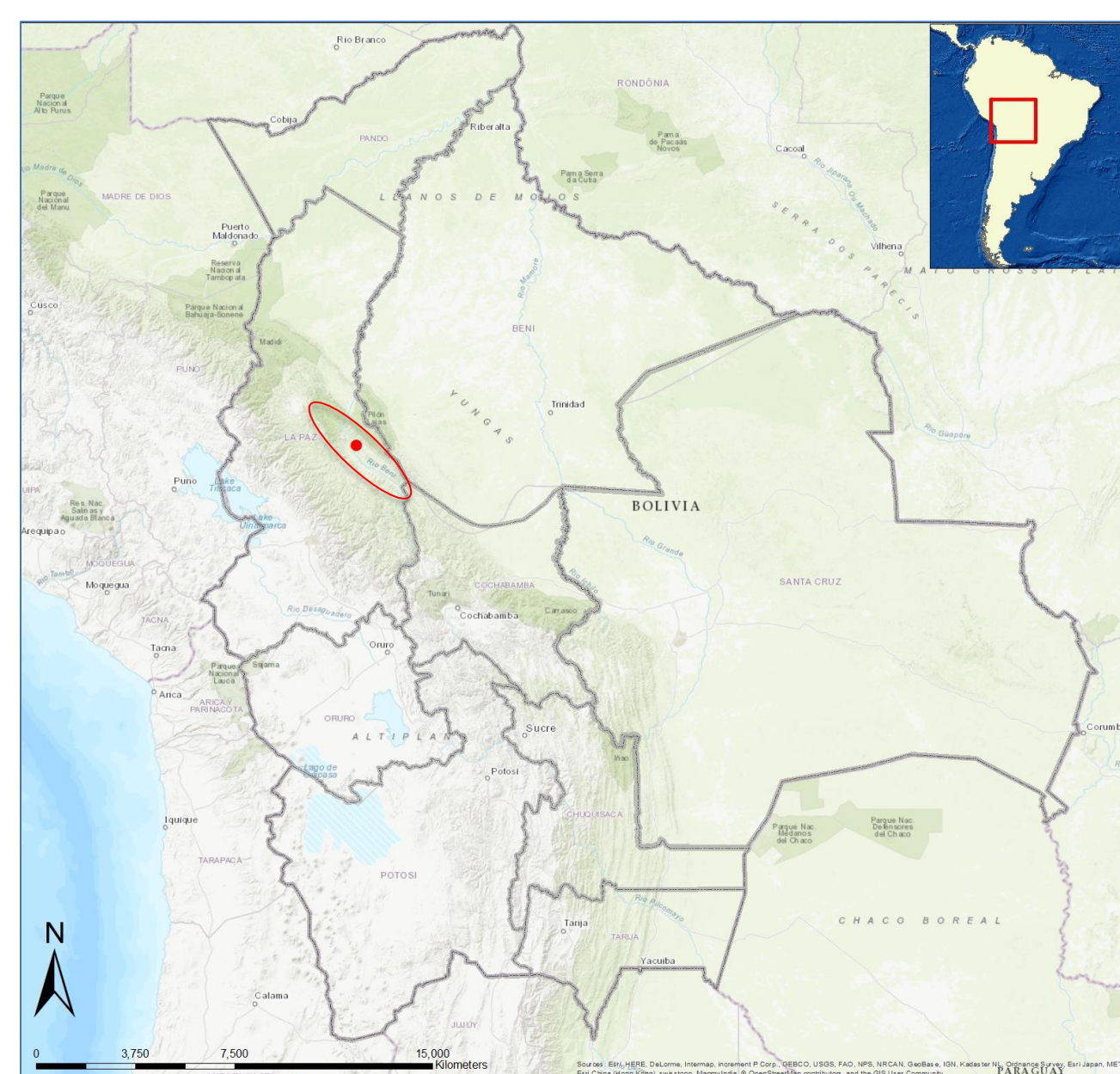


Fig. 1 Map of Bolivia showing the region Alto Beni and the study site 'Sara Ana', Dpmt. La Paz

Table 1 Planting design of cocoa production systems (2015)

Cocoa production systems	Planting density (stems ha ⁻¹)			Leguminous cover crops
	Cocoa trees	Associated trees	Banana (> 1m)	
Monoculture conventional (MONO CONV)	625	-	-	No
Monoculture organic (MONO ORG)	625	-	-	Yes
Agroforestry conventional (AF CONV)	625	282	866	No
Agroforestry organic (AF ORG)	625	282	866	Yes
Successional agroforestry system (SAFS)	625	2708	634	Herbal crops



Fig. 2 Organic cocoa monoculture with cover crop (left) and cocoa agroforestry system (right)



Fig. 3 Cocoa fine-roots around the stem (left), preparation of 0.5 m deep ingrowth-donut

Results & Discussion

Table 2 Cocoa fine-root properties in distance from stem (mean over systems)

Distance from stem	length density [cm cm ⁻³]	volume [mm ³ cm ⁻³]	surface area density [mm ² cm ⁻³]	mean diameter [mm]	biomass density [g dm ⁻³]
0.4 m	8.8 ± 0.9	4.8 ± 0.5	6.3 ± 0.6	0.94 ± 0.04	0.34 ± 0.05
1.2 m	9.6 ± 0.9	4.4 ± 0.4	6.5 ± 0.5	0.83 ± 0.03	0.34 ± 0.03
1.7 m	8.1 ± 0.6	4.0 ± 0.5	5.5 ± 0.5	0.84 ± 0.03	0.30 ± 0.04

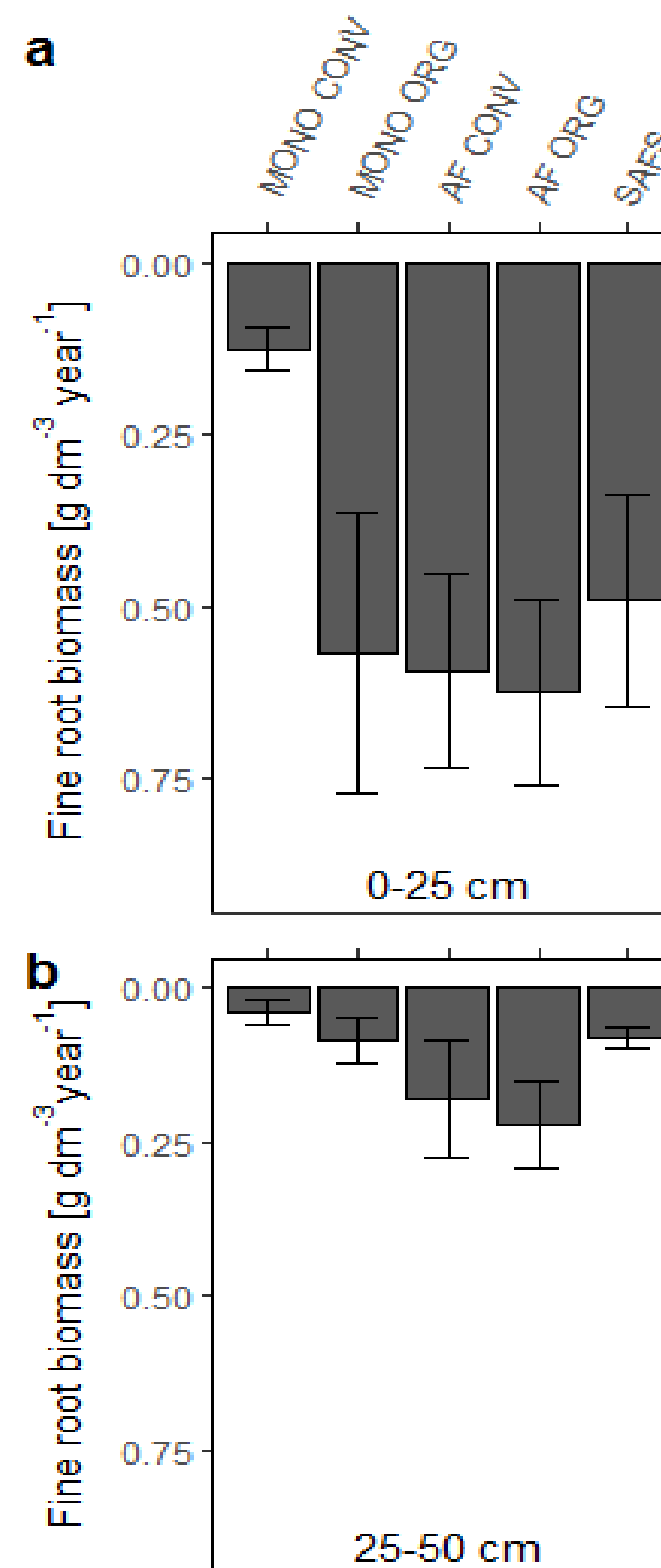


Fig. 4 Total systems fine-root biomass production

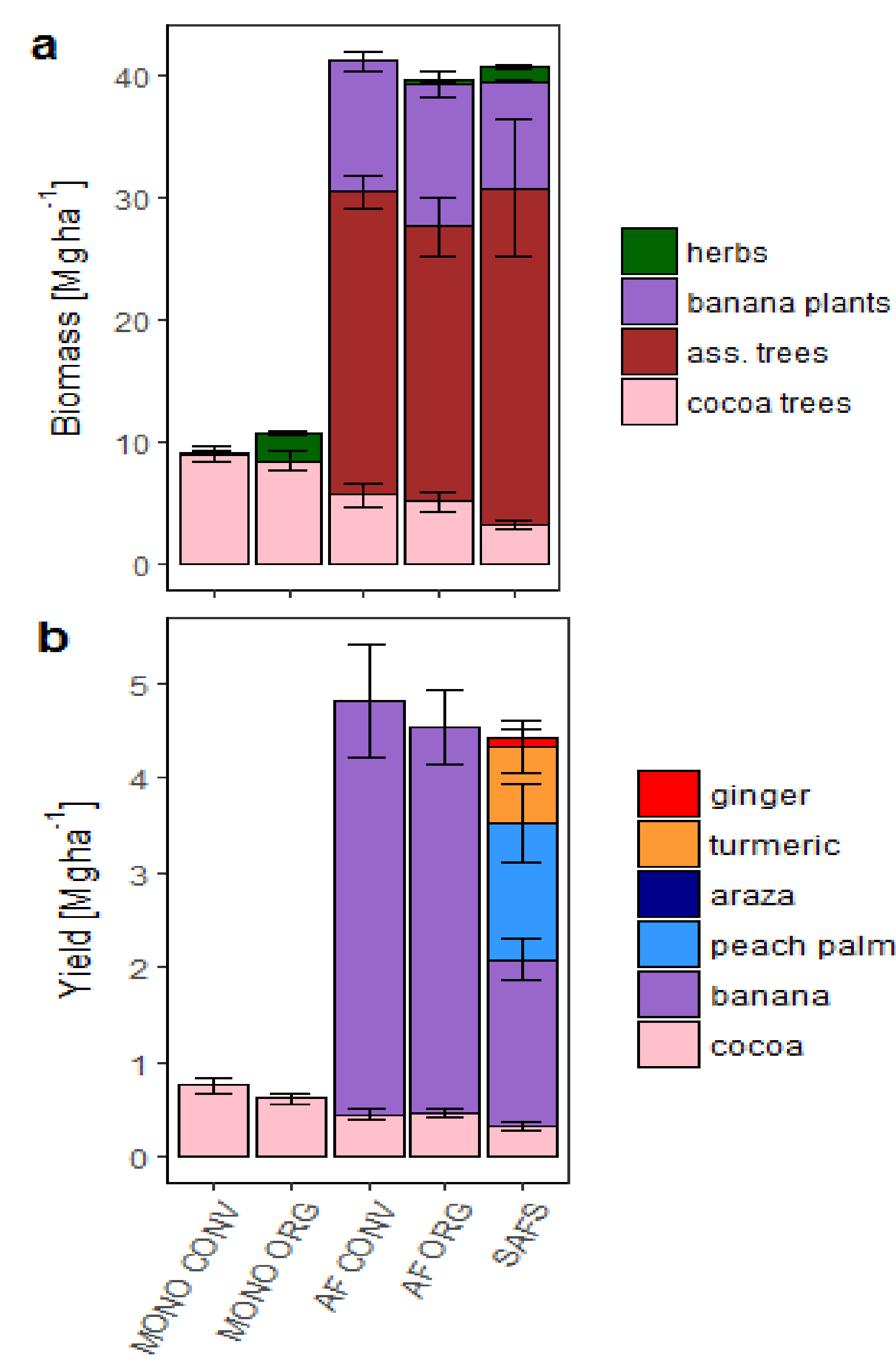


Fig. 5 Aboveground standing biomass (a) and total harvested yield as dry weight (b)

- As cocoa fine-root properties are not significantly different between the systems, the overall mean is shown (Table 2) → Differences in total fine-root biomass between systems refer to roots of other species
- Cocoa fine-roots are homogenously distributed independently from distance to stem (Table 2) → Differences may occur in further distance to the stem (not in common cocoa stem densities of < 4 x 4 m)
- 80 % of total fine-root are located in the upper 25 cm (Fig. 4) → Competition between roots likely
- Lowest total fine-root production in MONO CONV (Fig. 4) → Only cocoa fine-roots because of herbicide application
- High total fine-root biomass in MONO ORG (Fig. 4) together with high herbal biomass (Fig. 5a) → Fine-roots of cover crop occupy the same space as the cocoa fine-roots (Fig. 4a)
- Highest cocoa yield and cocoa tree biomass in MONO CONV (Fig. 5) → Highest total biomass and yield in AF CONV, AF ORG and SAFS

Conclusions

- Homogenous distribution of cocoa roots across systems and distances implies that cocoa root system is not the main factor for cocoa yield differences
- Higher tree root biomass in the lower soil level in AF systems may exploit resources below the cocoa roots and act as a safety net for leached nutrients
- Bananas make up a high portion of the total yield and biomass in agroforestry systems, but also occupy the same soil space and may compete strongly with cocoa
- Organically and conventionally managed agroforestry systems provide high system yield and great potential for carbon storage and other ecosystem services
- Leguminous cover crops in organically managed monocultures may compete with cocoa for nutrients

Literature

- (1) Tschamtker et al. 2011: J Appl Ecol 48, 619-629
- (2) Schneider et al. 2017: Expl Agric 53 (3), 351-374
- (3) Schneidewind et al. 2018: Expl Agric online first

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