How important is the visible and invisible Biodiversity in the Cocoa Agroforestry Systems

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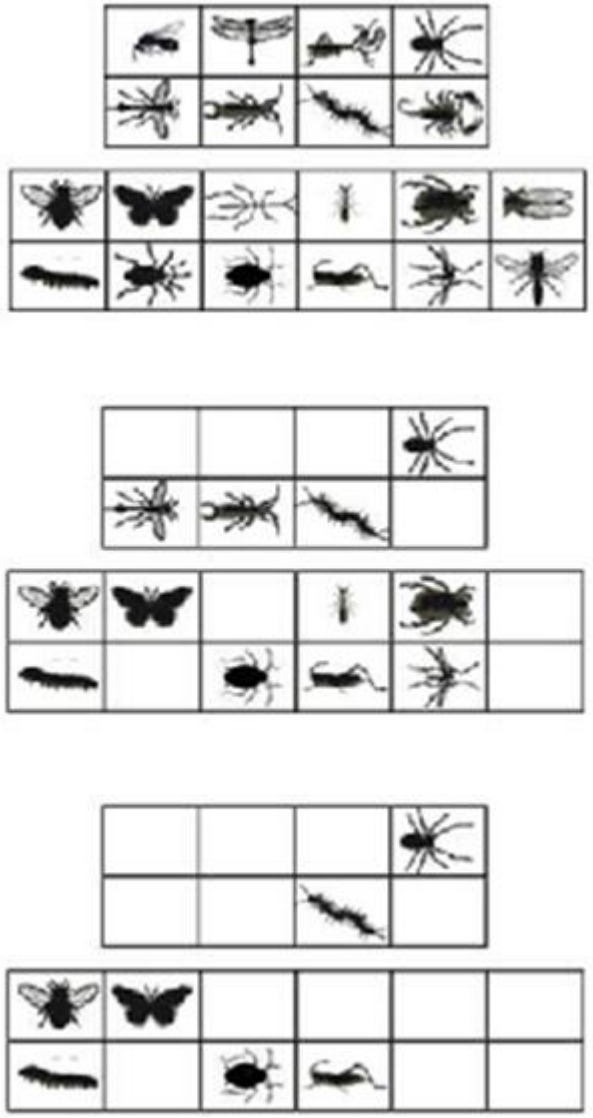
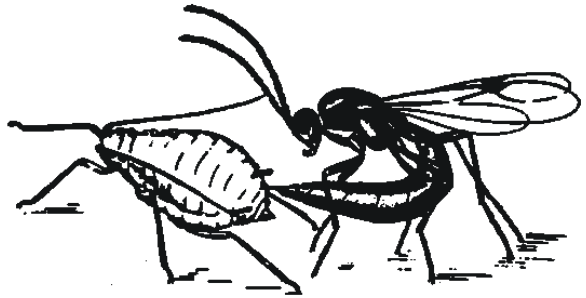
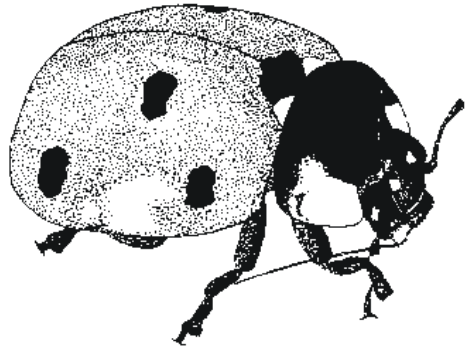
Tropical Agricultural landscape driven by global change

Planned agro-biodiversity







Unplanned agro-biodiversity

Planned Agricultural Biodiversity

Vegetation variables	Rustic	Shaded	Intermediate	Low Shaded	Full Sun
Tree species richness (no.)	11.0 (0.0)c	10.5 (0.7)c	9.5 (0.7)b	7.0 (0.6)b	**5.3 (1.8)a**
Herbaceous species richness (no.)	33.0 (3.0)d	25.8 (2.4)c	25.0 (1.8)c	16.0 (2.5)b	**2.5 (1.8)a**
Canopy cover (%)	92.8 (7.4)d	82.5 (5.7)c	67.7 (2.8)b	54.6 (0.8)b	**22.5 (6.7)a**
Herbaceous cover (%)	84.7 (15.3)d	78.2 (4.8)d	32.7 (1.5)c	22.2 (5.8)b	**8.2 (8.0)a**
Tree height (m)	55.5 (3.3)b	43.9 (3.3)a	65.6 (2.9)b	64.0 (3.6)b	**44.2 (1.5)a**
Cocoa tree density (tree/ha)	1250 (80.5)ab	1182.5 (80.5)a	1075 (96.8)a	1600 (208.2)b	**1095 (69.1)a**
Total Management Index (MI)[c]	**2.98 (0.14) a**	**3.63 (0.12)b**	**4.29 (0.10) c**	**3.45 (0.10)b**	**4.55 (0.03)c** **

Agroforestry: Important refuge for living organisms!

- Many endemic and unidentified species:
- Many bioagents (viruses, bacteria, fungi, nematodes, parasitoids flies and mites)
- Predators (ants, wasps, amphibians, birds, bats…)

Unshaded systems: short term yield, recurrent pest outbreaks, strong reliance on chemicals

Exacerbated by climate change, simplification threats sustainable cocoa production

- Social insects (bees, ants and termites) are the most affected by farm simplification

Bees

Loss of pollination services

Ants

Loss of Predation services

Termites

Strong reliance on inputs to achieve yield!

Disappearance of beneficial species (soil fertility)

Becoming pests

Proliferation of pests

Heavy shaded systems

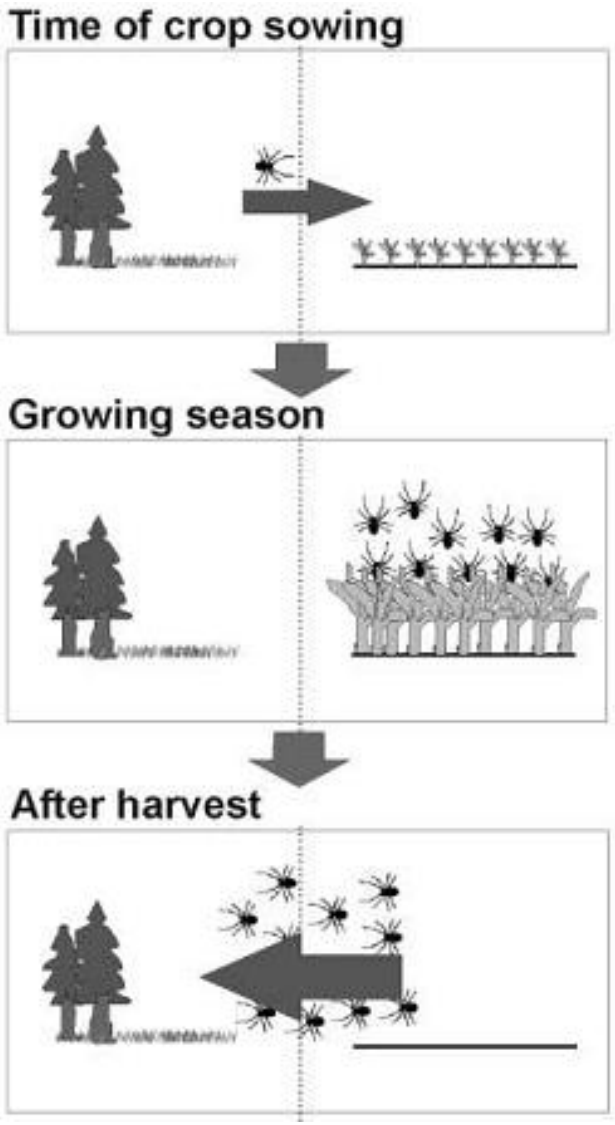
Simplification

Poorly shaded systems

Unidentified termite species, high diversity, high endemicity, low pest pressure (Boumnyebel and Obala)

Poor diversity, no endemic species, high pest pressure, heavy damage observed (Bakoa and Kedia)

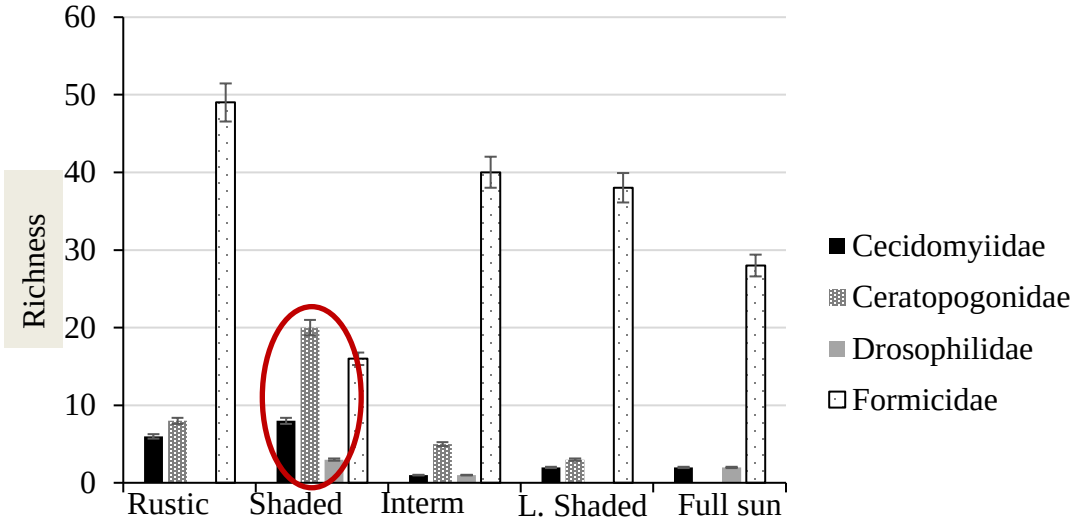
Shade trees facilitate beneficial interactions (Below and Above ground)

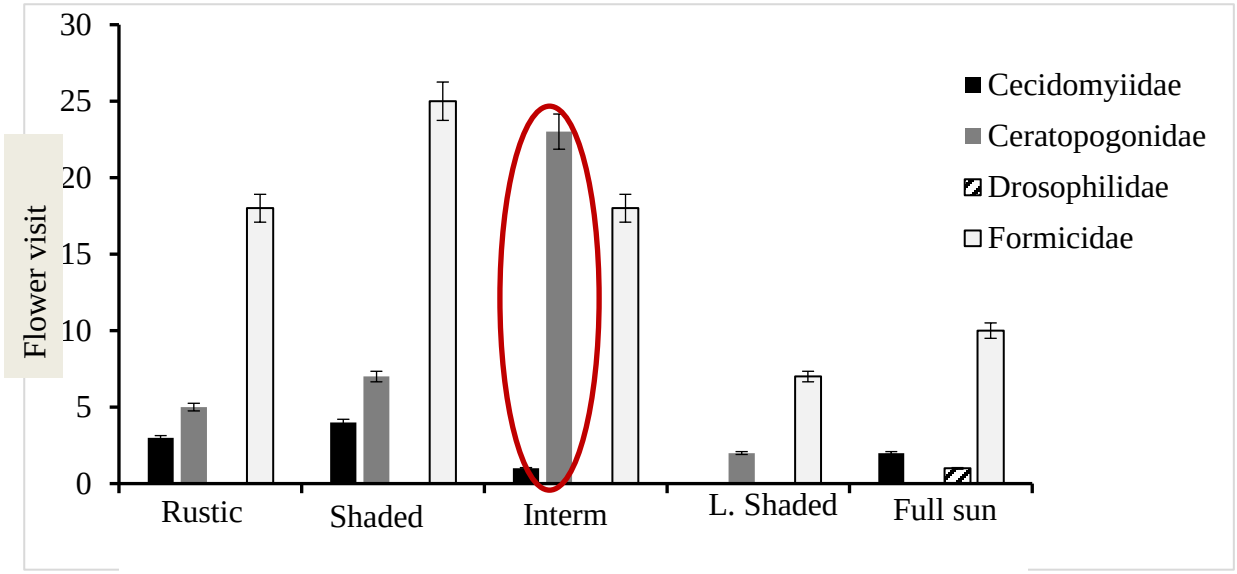


Spillover
from natural habitat to crop systems

but
crops may also export organisms
such as generalist predators

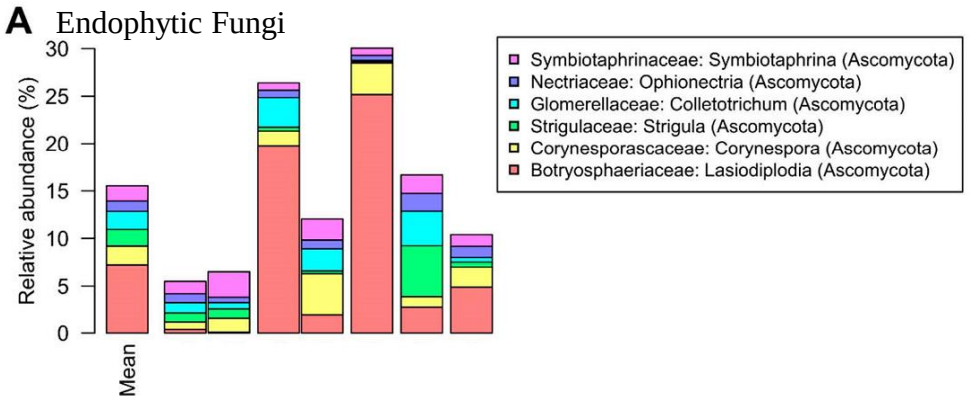
Pollination services

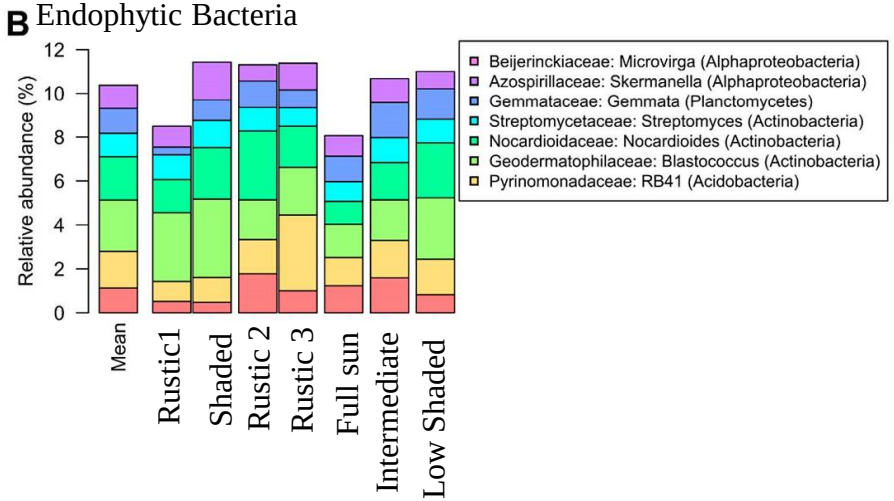




Conserv. Bio Control

Composition, Diversity, and Function of Fungal and Bacterial Endophyte Communities





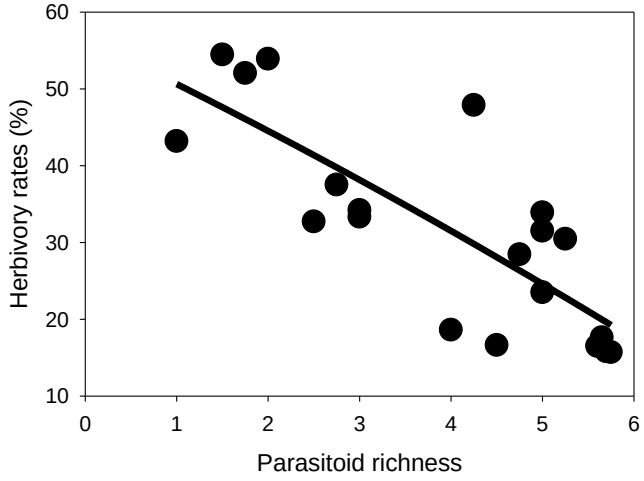
	Fungi		Bacteria	
	Richness	Diversity	Richness	Diversity
Obala	178 ± 76^{A}	3.04 ± 0.98^{A}	1729 ± 218	7.02 ± 0.31
- Ekabita Essélé	174 ± 72^{a}	2.85 ± 0.98^{a}	1672 ± 255	6.92 ± 0.4
- Nkolobang	182 ± 85^{a}	3.24 ± 0.99	1785 ± 172	7.11 ± 0.18
Boumnyébel	279 ± 106^{B}	4.09 ± 1.31^{B}	1820 ± 85	7.17 ± 0.1
- Pan Makak	250 ± 110^{b}	3.96 ± 1.47	1814 ± 88	7.16 ± 0.09
- Simanya	307 ± 101^{b}	4.22 ± 1.23	1826 ± 87	7.19 ± 0.1
Bakoa	231 ± 82^{AB}	3.48 ± 1.11^{AB}	1789 ± 160	7.15 ± 0.19
Talba	292 ± 55^{Bb}	4.44 ± 0.41^{Bb}	1804 ± 137	7.17 ± 0.13
Kédia	330 ± 87^{Bb}	4.42 ± 0.64^{B}	1782 ± 101	7.12 ± 0.11

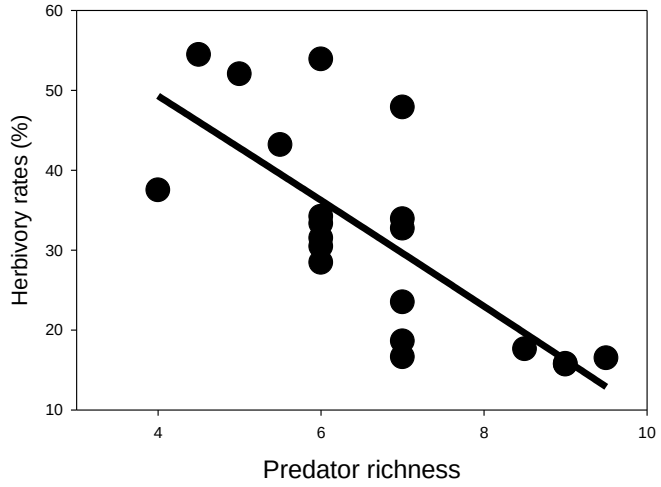
The diversity and richness of fungal but not bacterial endophytes differed among the five cacao regions, suggesting that fungal alpha diversity is more sensitive to agroforestry system type and/or environmental properties than bacterial alpha diversity.

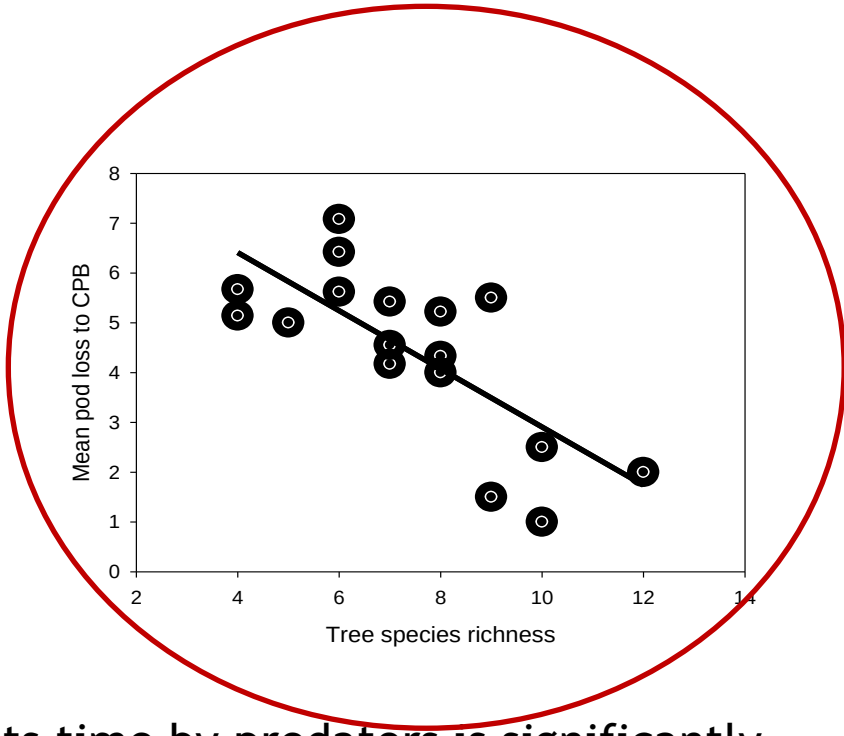
Wemheuer, Bisseleua et al. 2020. Microorganisms 8, 405

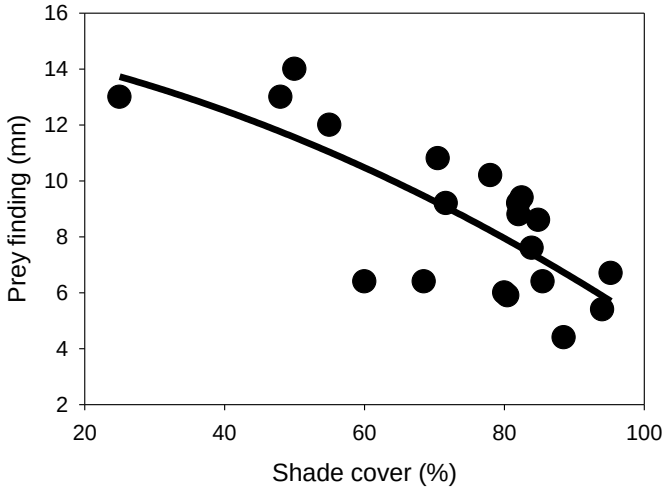
Conser. Biodiversity

Composition, Diversity, and Function of Predators.
Parasitoids and parasitic/social wasps



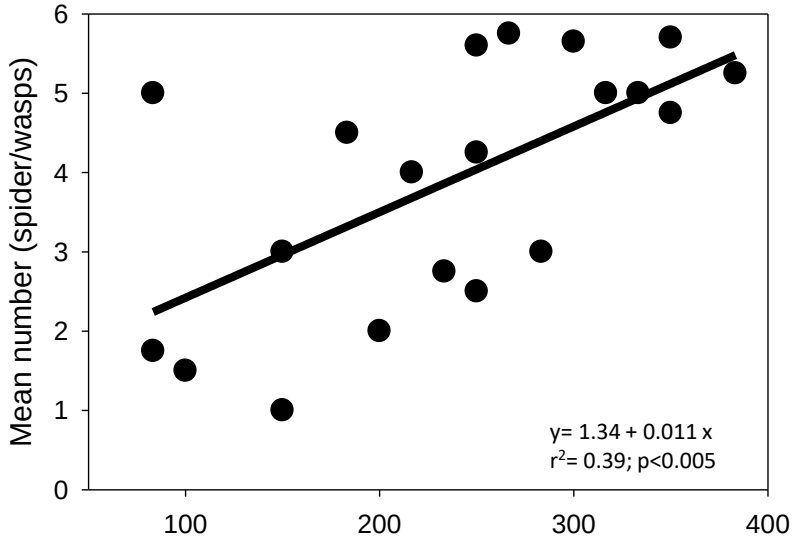


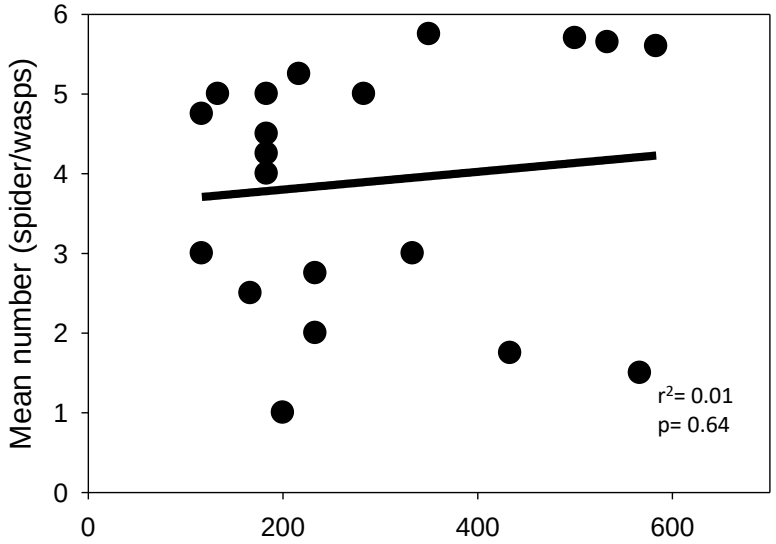


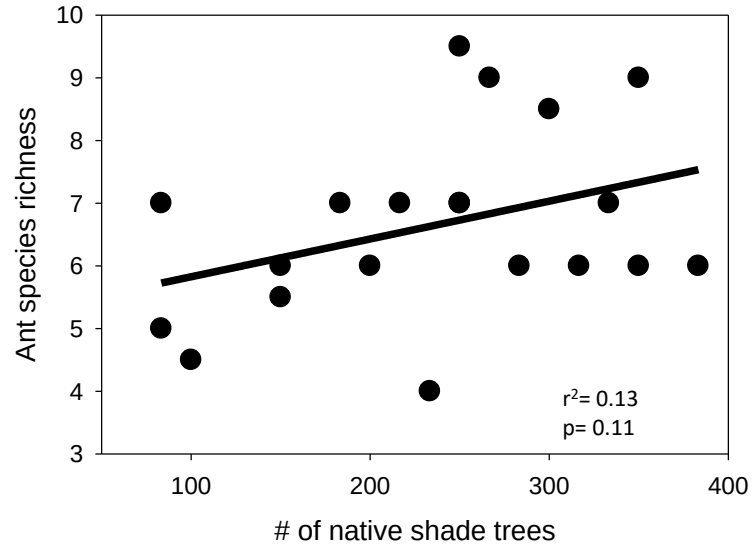


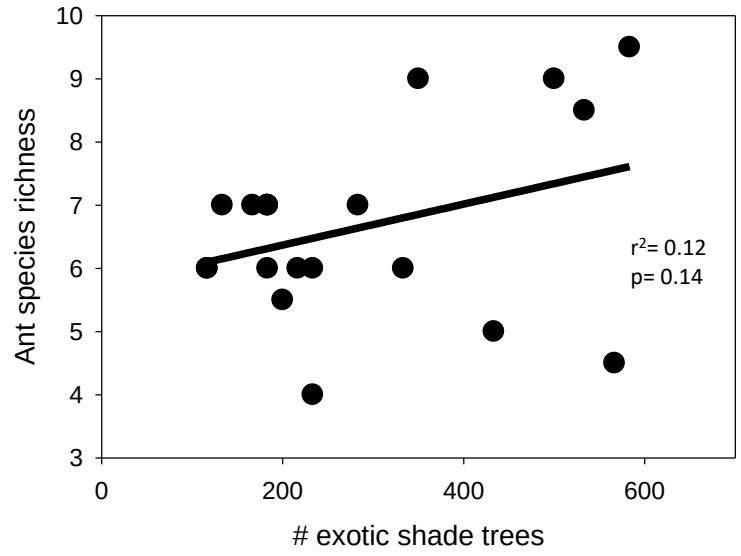
Prey finding by parasitoids and recruitments time by predators is significantly shorter in a more complex system.

Shade trees enhance functional biodiversity



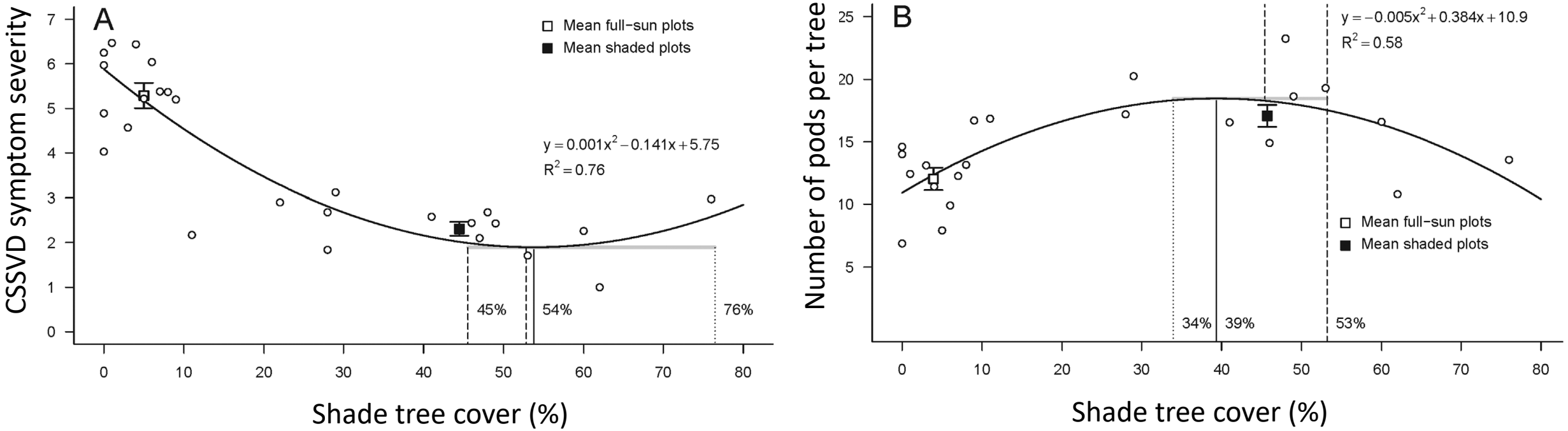






Native species enhances beneficial interactions than exotic shade tree species – *Bisseleua et al. 2013 and 2017*

Relationship between shade tree canopy cover (%) and A: CSSVD symptom severity and B: cocoa yield in the main harvest season 2016 (Ghana)



- Around 50% shade cover (overlap between 45%–53%) may be an optimal coping strategy to balance CSSVD symptom severity versus reduced cocoa yield

Andres C *et al.* 2018. Agroforestry systems can mitigate the severity of cocoa swollen shoot virus disease. Agriculture, Ecosystems & Environment, 252: 83–92. https://www.sciencedirect.com/science/article/pii/S0167880917304310

Below Ground Interactions

CAFS as refuge of new species (i.e. Rustic systems

→ Abundant and diversified beneficial species: *Cubitermes*, *Amicotermes*, *Anenteotermes*, *Proboscitermes*…

→ Refuge for undescribed species (**conservation of biodiversity**)

New species:

Apilitermes sp. nov. (Boumnyebel)

Alyscotermes sp. nov. (Boumnyebel, Talba)

Aderitotermes sp. nov. (Boumnyebel, Obala)

Apicotermitidae gen. nov. (Kedia)

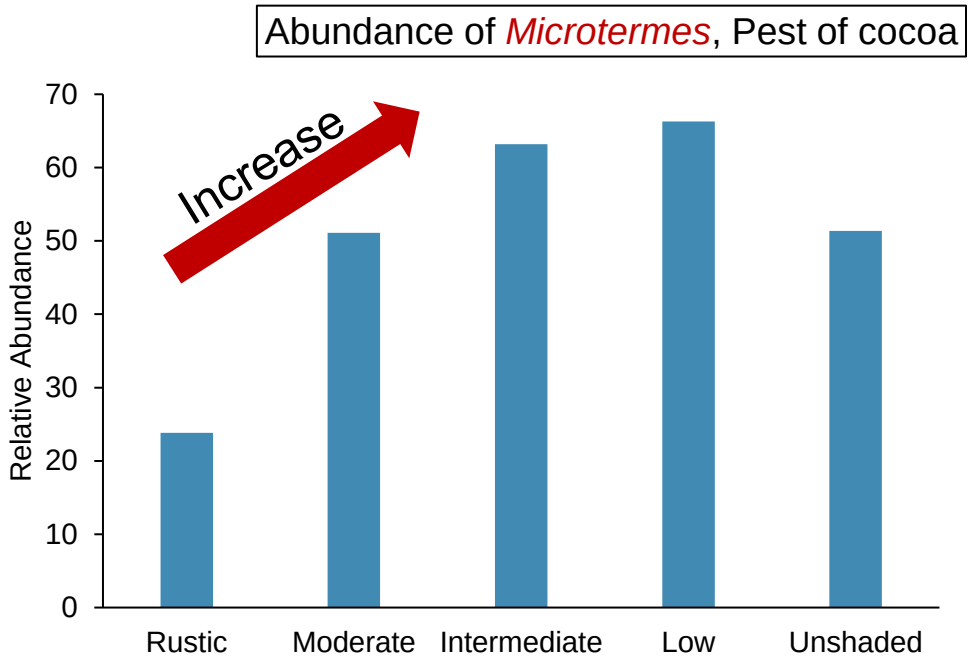
(Ambele et al. 2018b; Djuideu et al. 2020 and 2021)

First records in Cameroon:

Alyscotermes trestus (Boumnyebel)

Anenteotermes cnaphorus (Obala)

With removal of shade, we observe that:



- Pests population increase (e.g. *Microtermes*, *Ancistrotermes*)
- Disappearance of beneficial species: *Cubitermes*, *Amicotermes*, *Proboscitermes*…

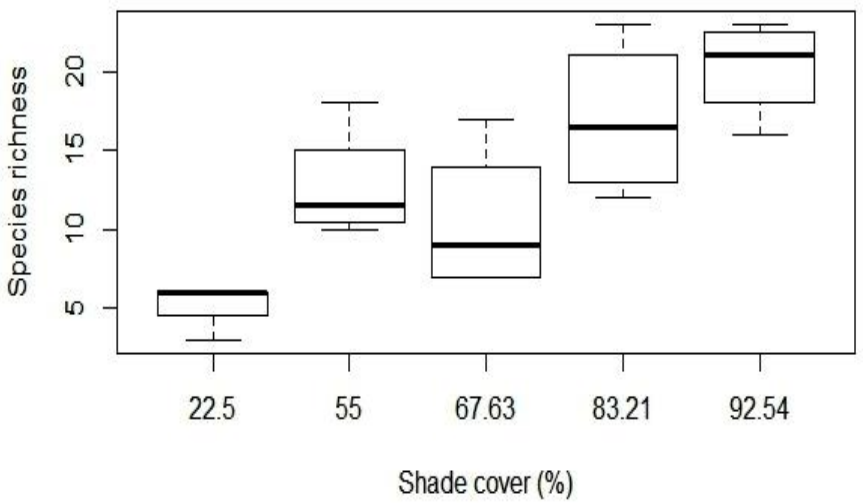
Amalotermes phaeocephalus

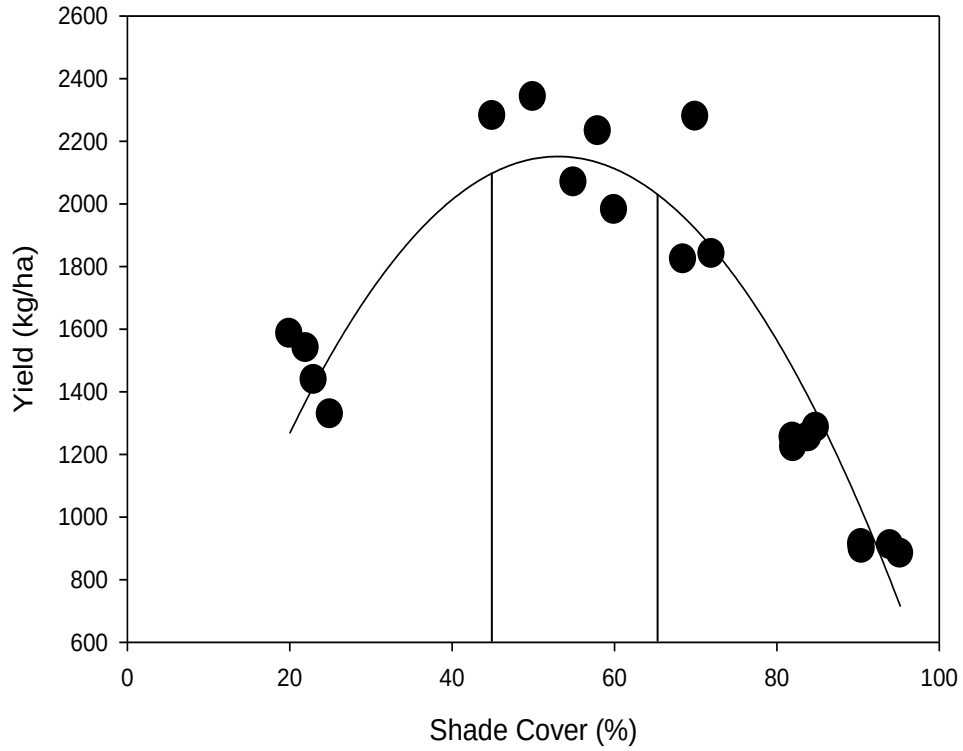
Procubitermes undulans attacking cocoa tree (nest)

- Non-pest species (soil feeders) become pests (wood feeders): case of *Amalotermes phaeocephalus* and *Procubitermes undulans*

(Djuideu et al. 2021)

The Yield relationship …..





Revenue (USD/ha/year)	Rustic	Shaded	Intermediate	Low shaded	Full sun
Fruits*	6901	11953	1386	5624	3631
Timber	348	490	2439	34	12
Cocoa	1020	1063	1536	1587	1678
Expenditures					
Agrochemicals	19	39	48	126	102
Labour	46	96	172	229	300
Net profit	1994	2618	3890	1828	1651

(Djuideu et al. 2019; 2021) - Agroforestry Systems and AEE

Take home message

- The cocoa agroforestry systems is composed of several interacting sub-systems and components (cocoa, associated crops, non-crop plants, pests/diseases, beneficial insects and farmers).
- Considering cocoa plants as active components of multitrophic level interactions is crucial to a total systems approach
- Management practices addressing one component or sub-system directly or indirectly affects the other components or the balance of the local ecosystem
- In these systems, plant functional traits may have important impacts on both the visible and invisible biodiversity
- Such mediated indirect interactions between the visible and invisible biodiversity may have a larger impact on biodiversity conservation and community structure than direct competition between these species
- Important when designing CAFS to be holistic and not to concentrate on single components of the system but on the whole set of components
- Important to avoid “sub-optimization” which is optimizing the performance of one component which may have consequences elsewhere creating a trade-off for the whole agroecosystem
- Managing complex and unpredictable variables in CAFS is similar to the management of other systems, including the human body or social systems – i.e. maximize the array of fundamental ‘built-in’ ecosystem preventive strengths, with therapeutic tactics serving strictly as backups to the natural regulators