The effects of tree diversity on soil fertility and yields in cocoa farms of Sulawesi

Ariani C. Wartenberg

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COCOA MONOCULTURE

ONLY COCOA TREES

\+

higher initial yields

\-

less resilient

COCOA AGROFOREST

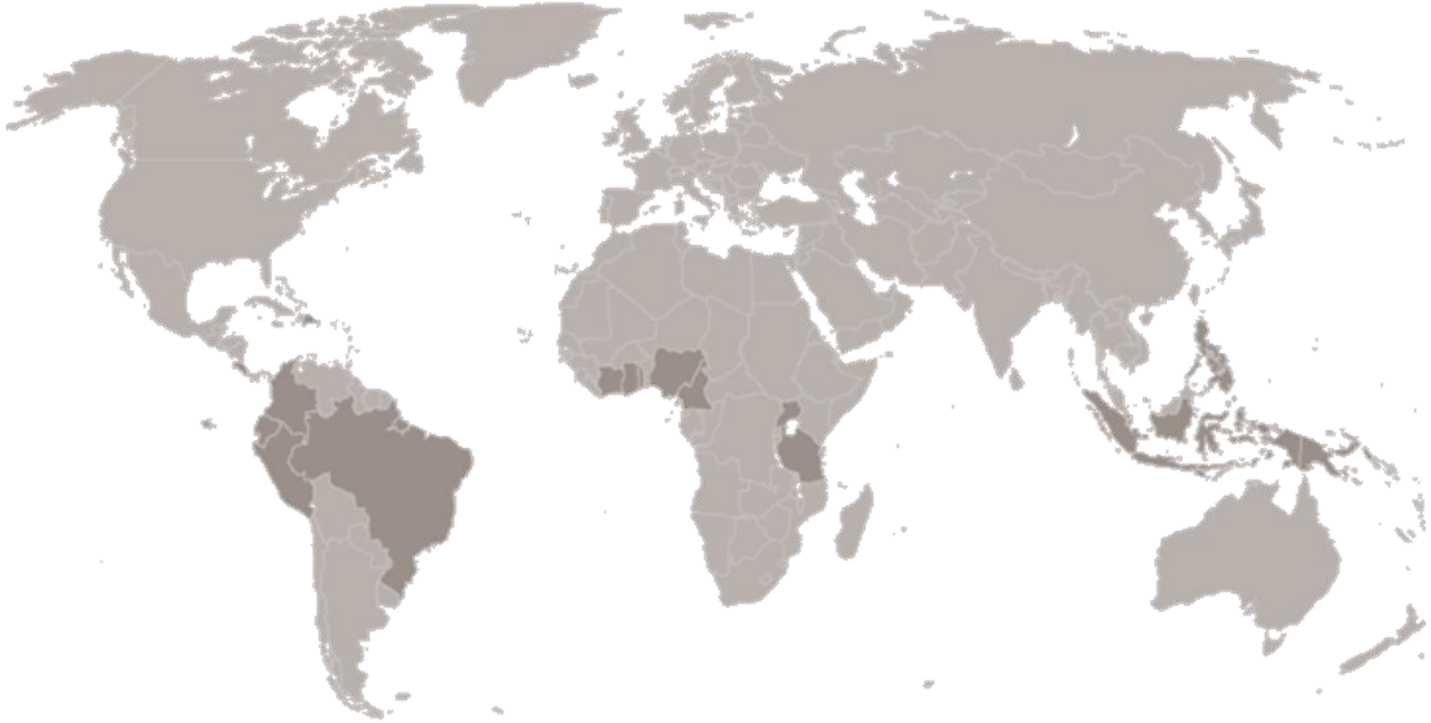
COCOA + “SHADE” TREE SPECIES

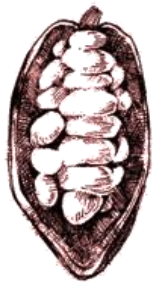
\+

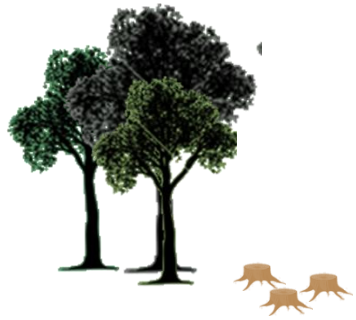
ecosystem services

\-

yield trade-offs?



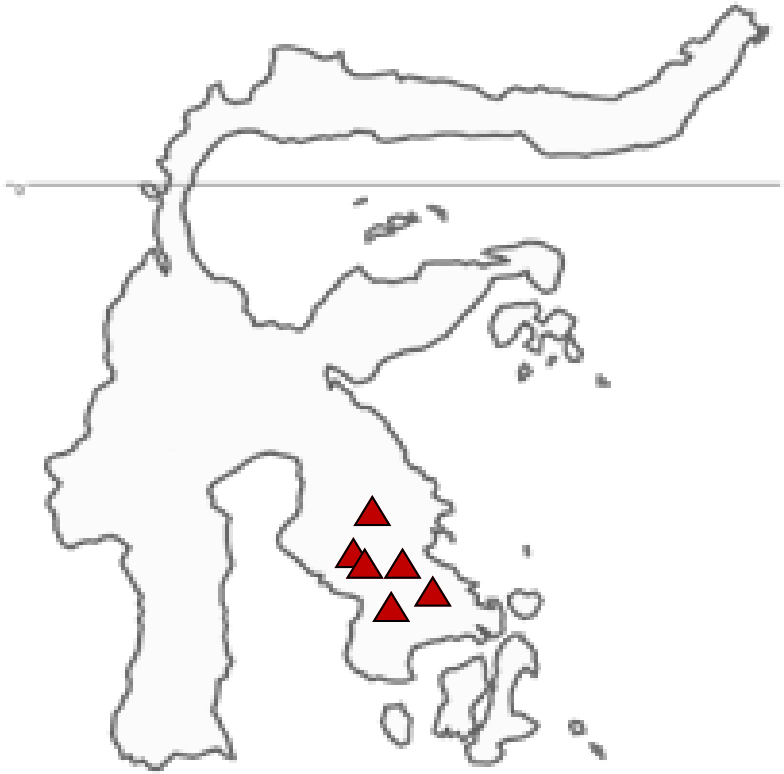




Research Question

Can increased tree diversity in cocoa agroforests increase the sustainability of cocoa cultivation by improving soil fertility and yields?

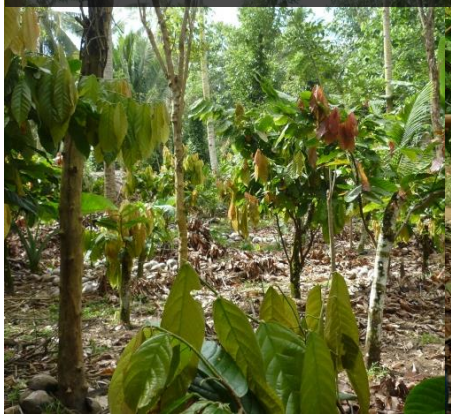
Southeast Sulawesi, Indonesia



Research Approach

1. Shade tree effects

2. Tree species diversity effects



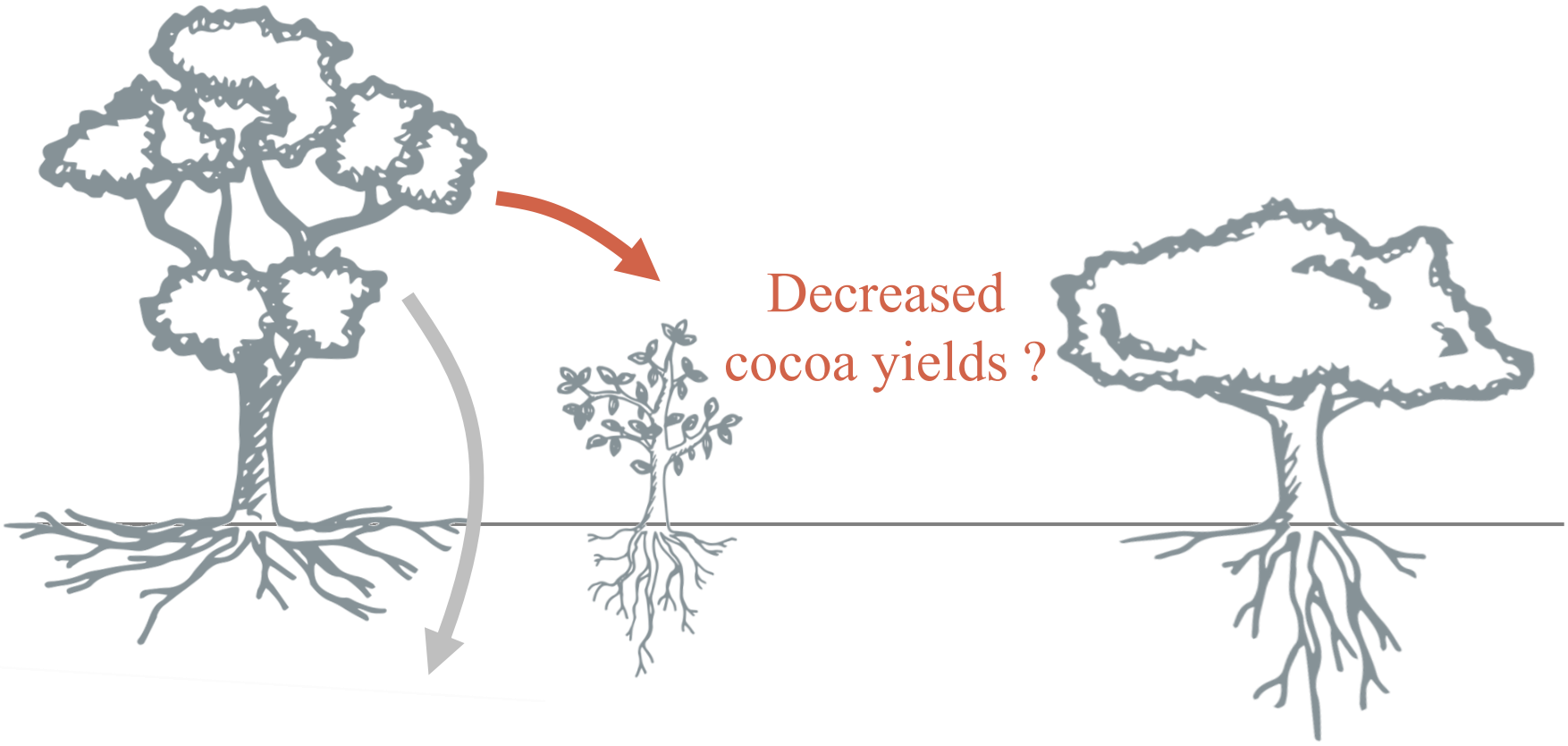
3. Farmer perceptions

Can individual shade trees improve soil fertility and cocoa health?

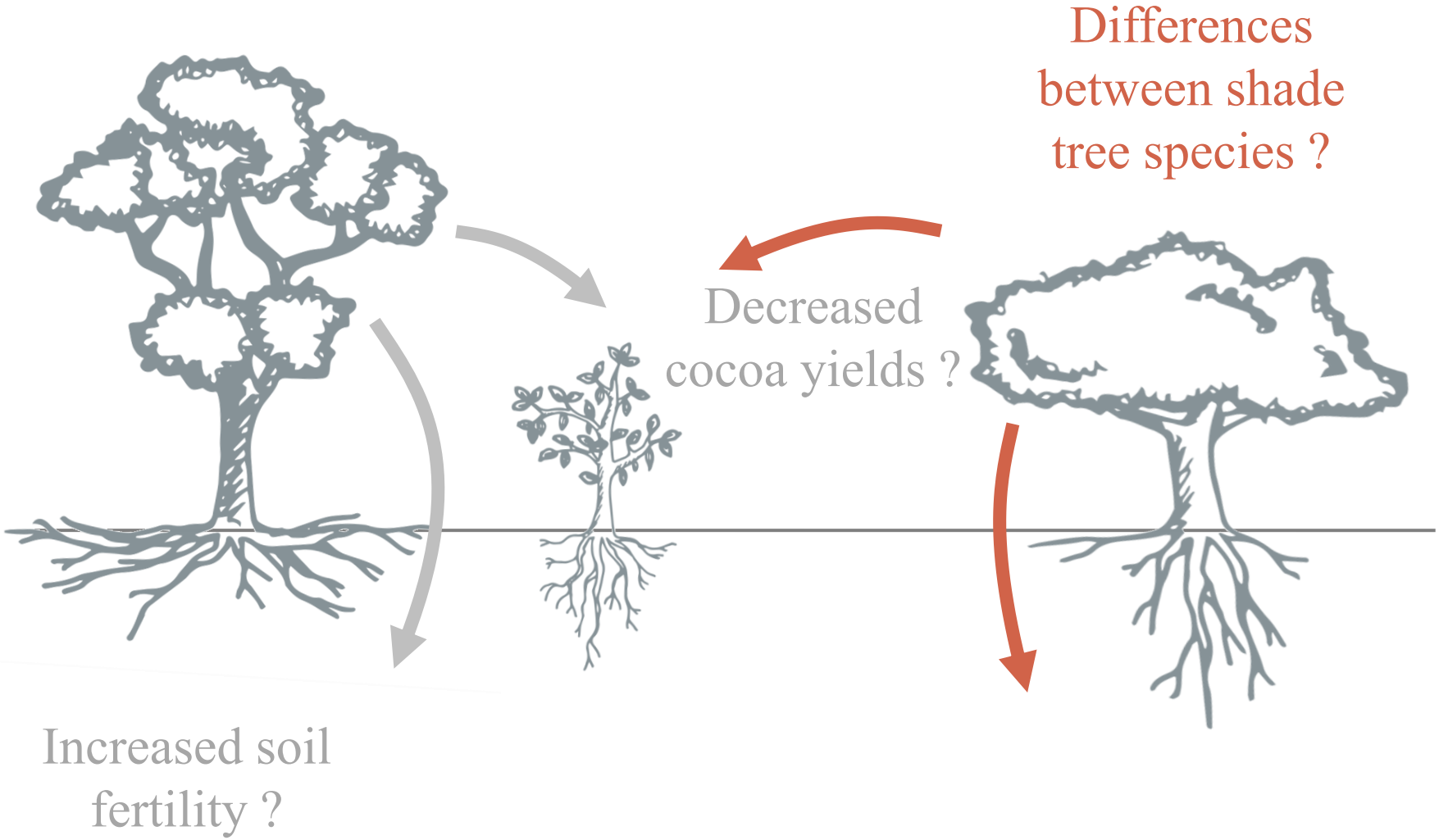
Can individual shade trees improve soil fertility and cocoa health?

Increased soil fertility ?

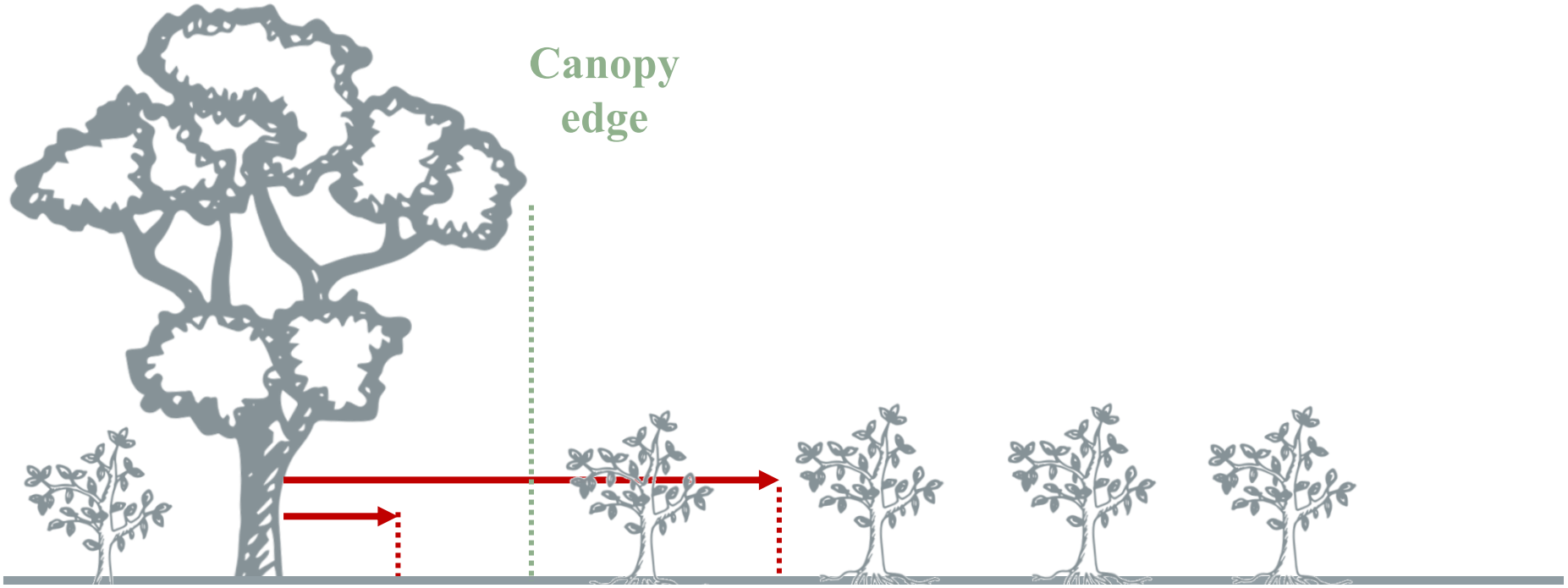
Can individual shade trees improve soil fertility and cocoa health?



Can individual shade trees improve soil fertility and cocoa health?



Can individual shade trees improve soil fertility and cocoa health?



values
UNDER CANOPY
(50% canopy width)

-

values
OPEN AREA
(200 % canopy width)

=

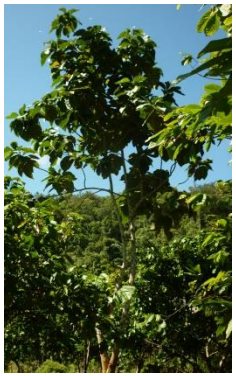
"EFFECT" of shade trees on
1. cocoa variables
2. soil variables

11 tree species commonly intercropped with cocoa in Sulawesi

COCOA

LANGSAT

JACKFRUIT



WHITE TEAK

GUAVA

GLIRICIDIA

COCONUT

RAMBUTAN

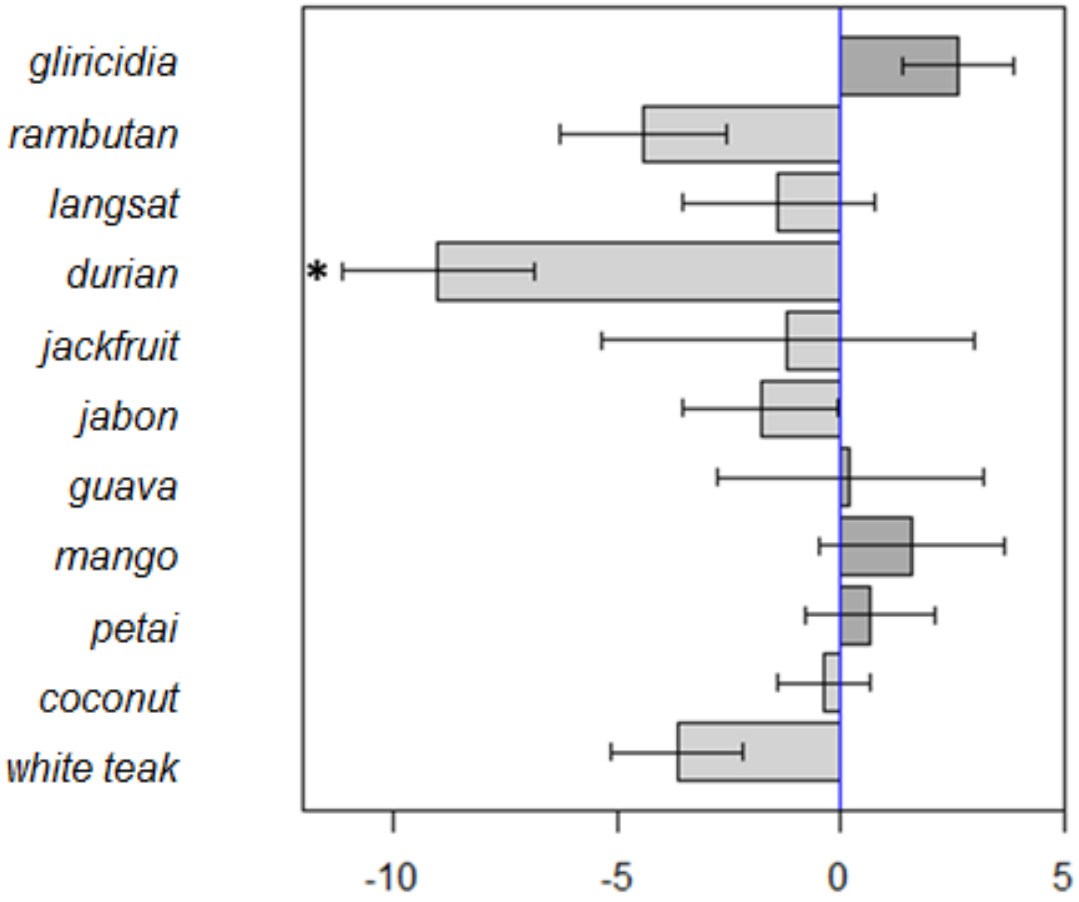
DURIAN

JABON

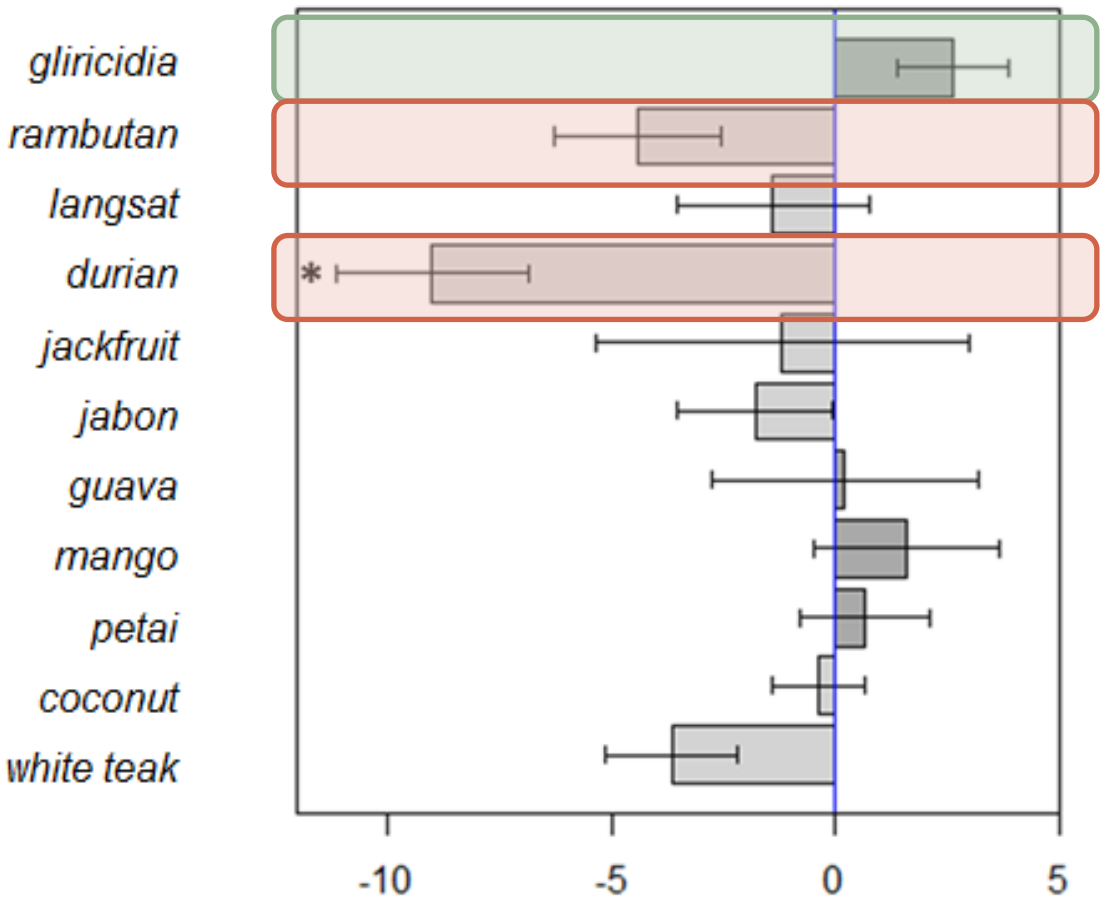
MANGO

PETAI

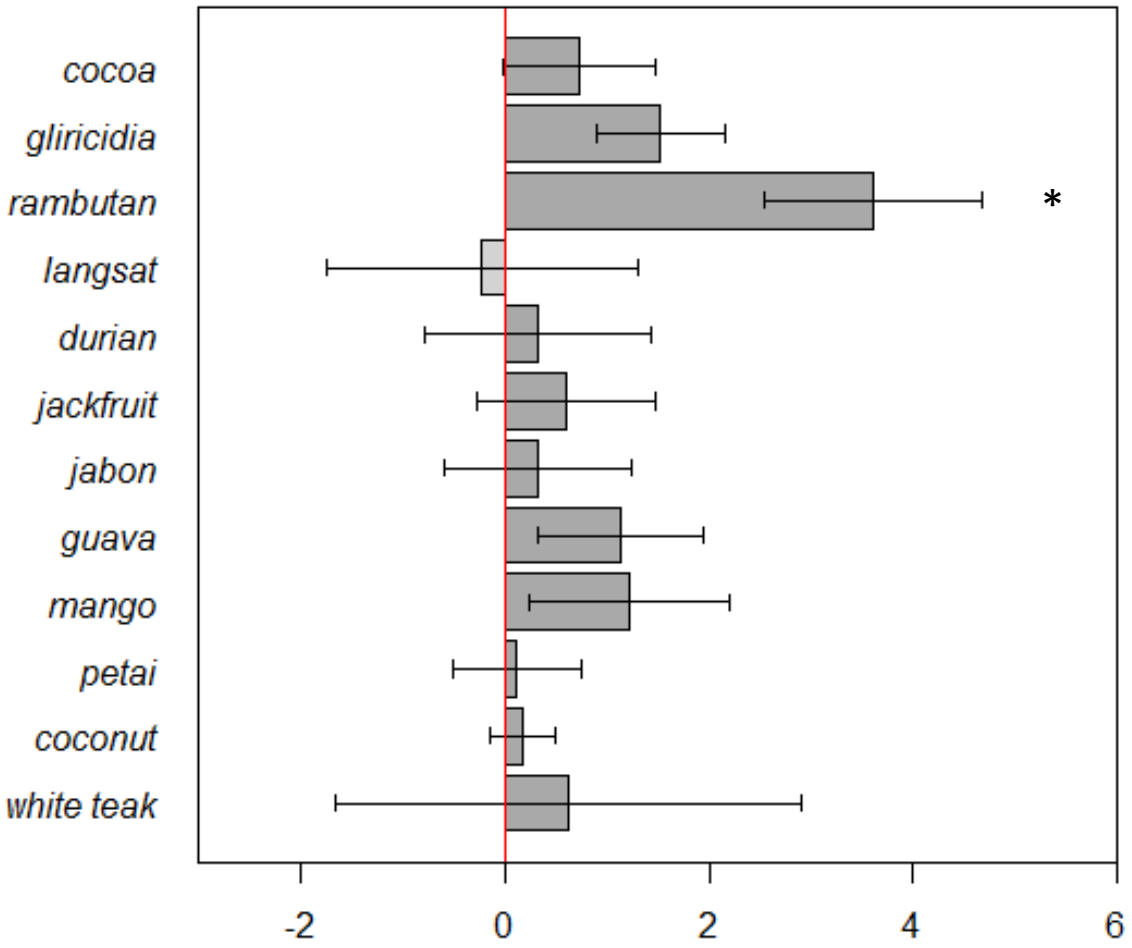
Shade trees had no effect on cocoa yields



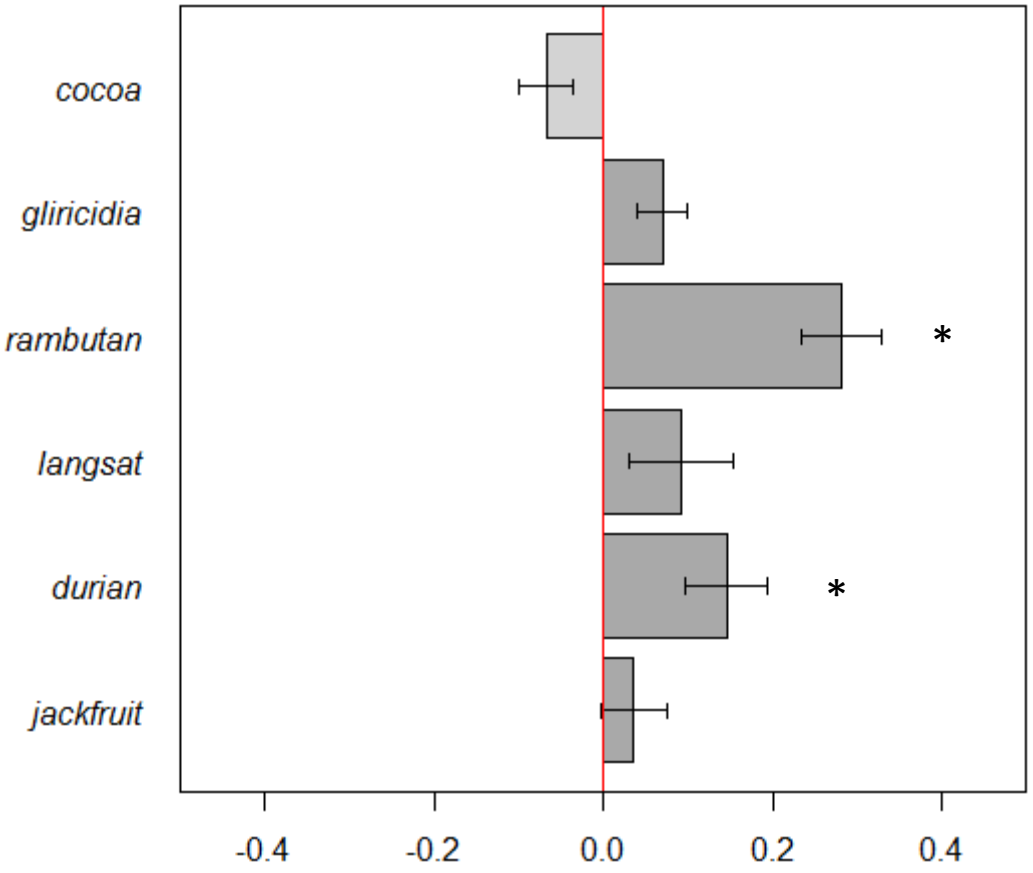
There was high variability in the effects of different species on cocoa yields



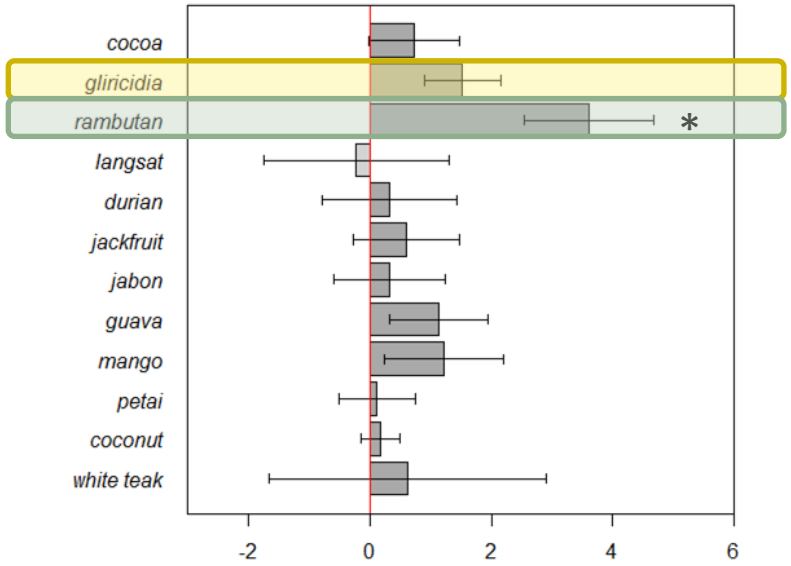
Net increase in soil C under shade trees



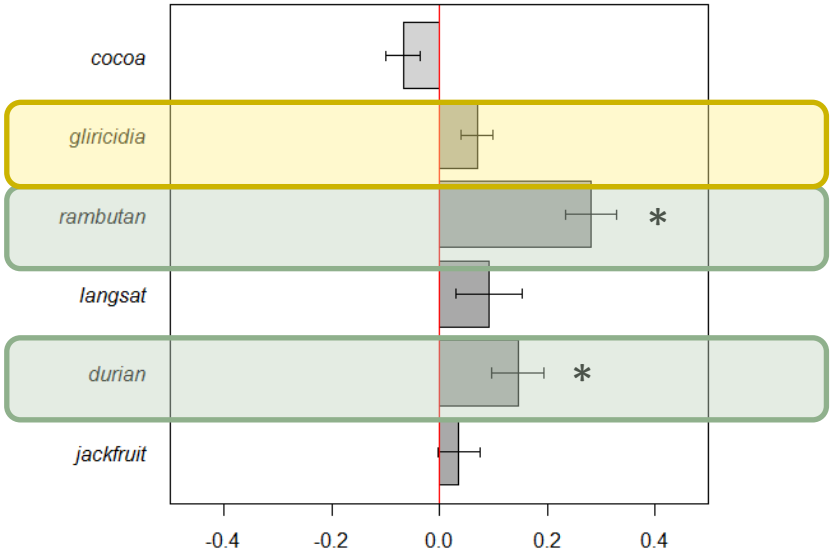
Net increase in soil aggregation under shade trees



There was high variability in the effects of different species on soil fertility



Change in soil Carbon (g kg^{-1})

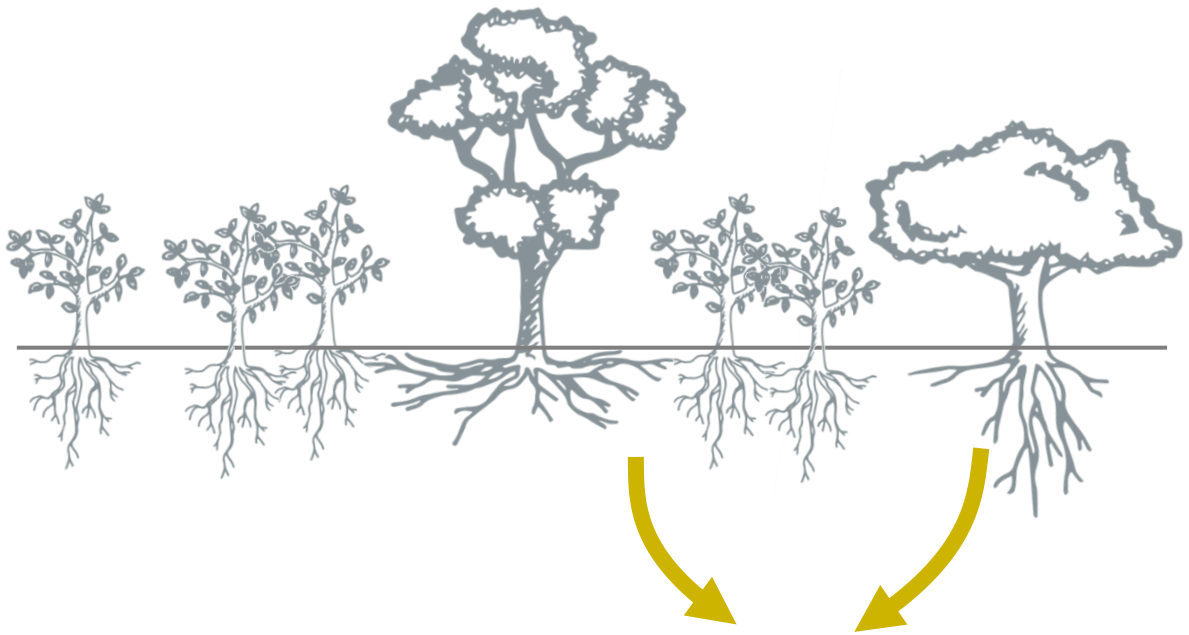


Change in soil aggregation (mm)

Can increased shade tree diversity improve soil fertility in a cocoa plantation?

Can increased shade tree diversity improve soil fertility in a cocoa plantation?

INCREASING TREE SPECIES DIVERSITY GRADIENT

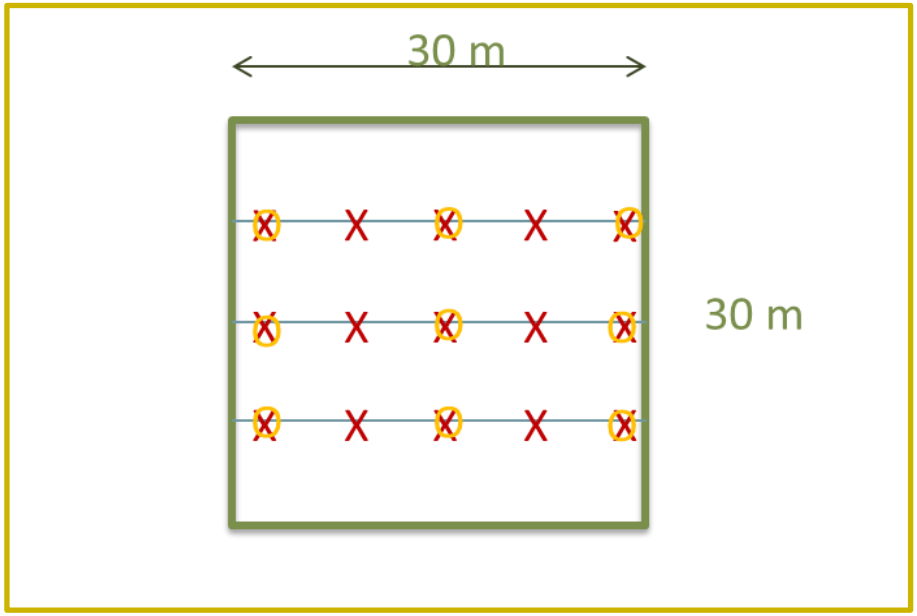


Increased
soil fertility

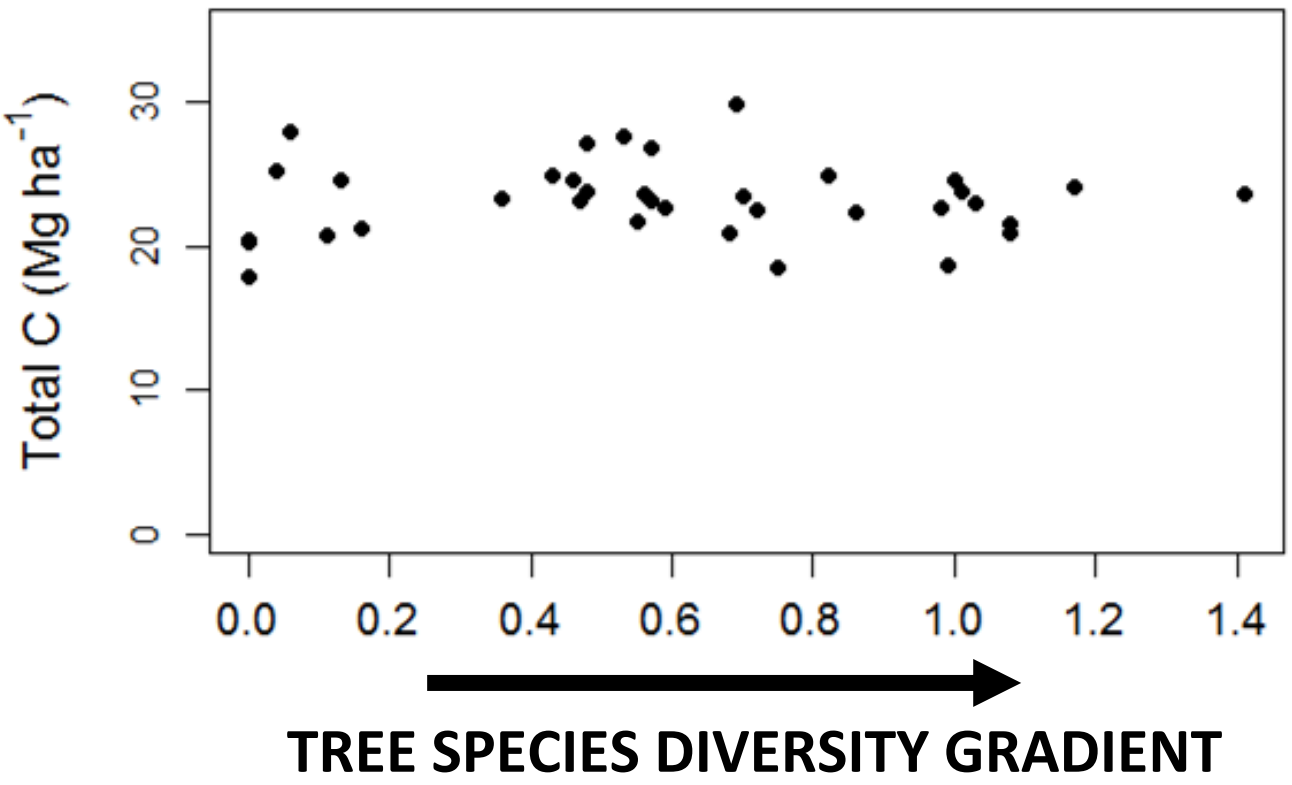
Can increased shade tree diversity improve soil fertility in a cocoa plantation?

TREE SPECIES DIVERSITY GRADIENT
(SHANNON-WIENER INDEX)

Can increased shade tree diversity improve soil fertility in a cocoa plantation?

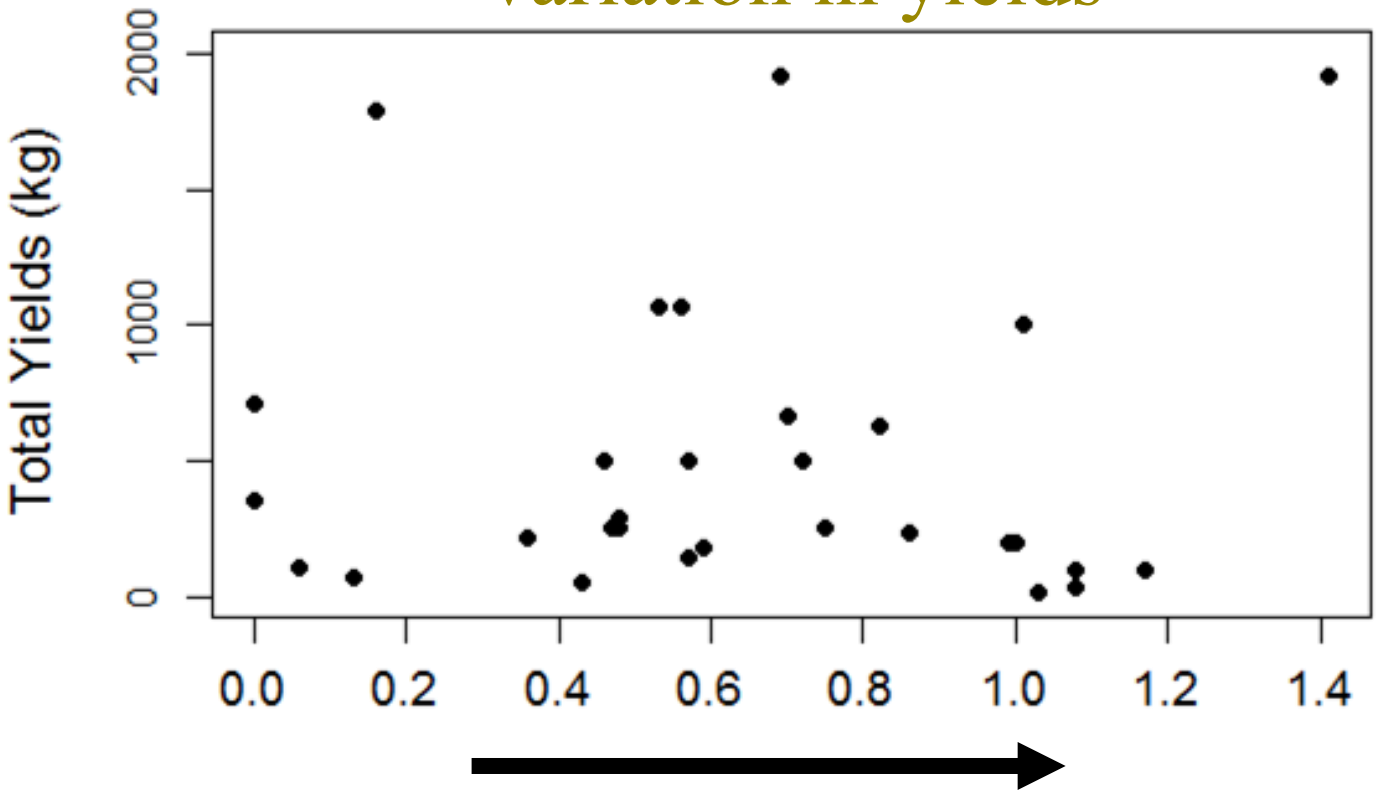


Increased tree diversity did not lead to increased soil fertility



- Total N
- Available P
- Aggregate size
- C, N and P storage in aggregates
- CEC
- Base saturation
- Total microbial abundance
- Gram + bacteria
- Gram – bacteria
- Arbuscular mycorrhizal fungi

Increased tree diversity did not lead to variation in yields



How can farmers' knowledge and perceptions of shade trees affect cocoa farm diversification?

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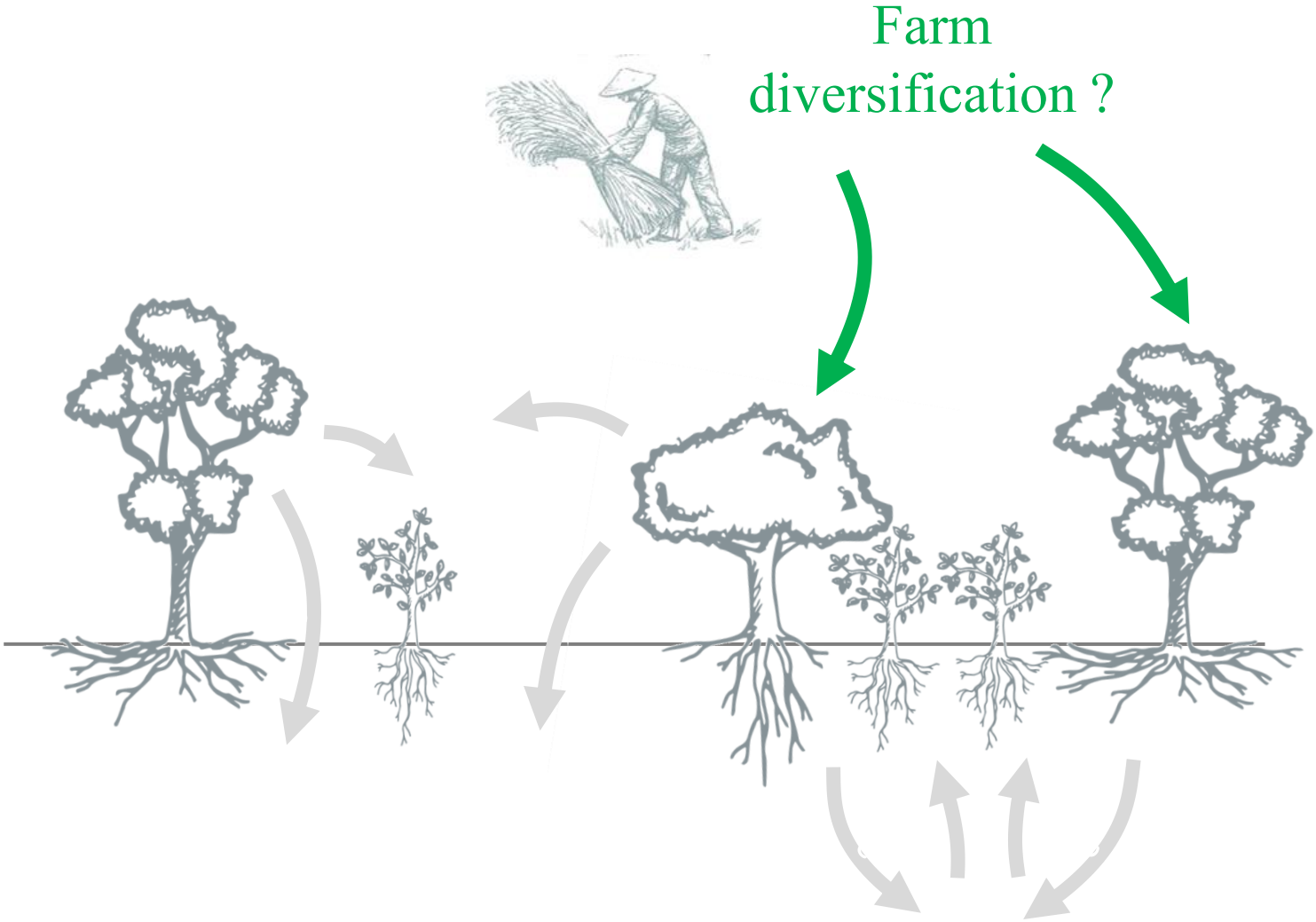


Farmer had extensive knowledge about interactions between soil, shade trees and cocoa

Ranking[1]	Soil fertility indicators	Description of good soil for cocoa cultivation for each indicator							
1	Soil structure	**Loose**	72%	**Medium:**	24%	**Hard**	4%		
2	Thickness of litter layer	**Thick layer**	51%	**Thin layer**	36%	**None**	13%		
3	Macro-fauna	**Some**	49%	**Many**	43%	**None**	8%		
4	Soil color	**Black-brown**	88%	**Yellow-white**	10%	**Red**	3%		
5	Water holding capacity	**Low**	61%	**None**	38%	**High**	1%		
6	Soil texture	**Gritty/sandy**	40%	**Smooth/silty**	49%	**Sticky/clayey**	18%	**Don't know**	1%
7	Stone content	**Some**	53%	**None**	39%	**Many**	6%	**Depends**	3%





Farmer had extensive knowledge about interactions between soil, shade trees and cocoa

+	-
"shade tree litter provides food for cacao trees"	**"shade tree roots can disturb cocoa trees"**
"shade trees cool down and loosen the soil"	**"there is a connection between too much shade and black pods"**
"gliricidia shade is good for cocoa seedlings"	**"rambutan takes water through its long roots"**

Farmer concerns about yield losses not necessarily addressed by scientific studies

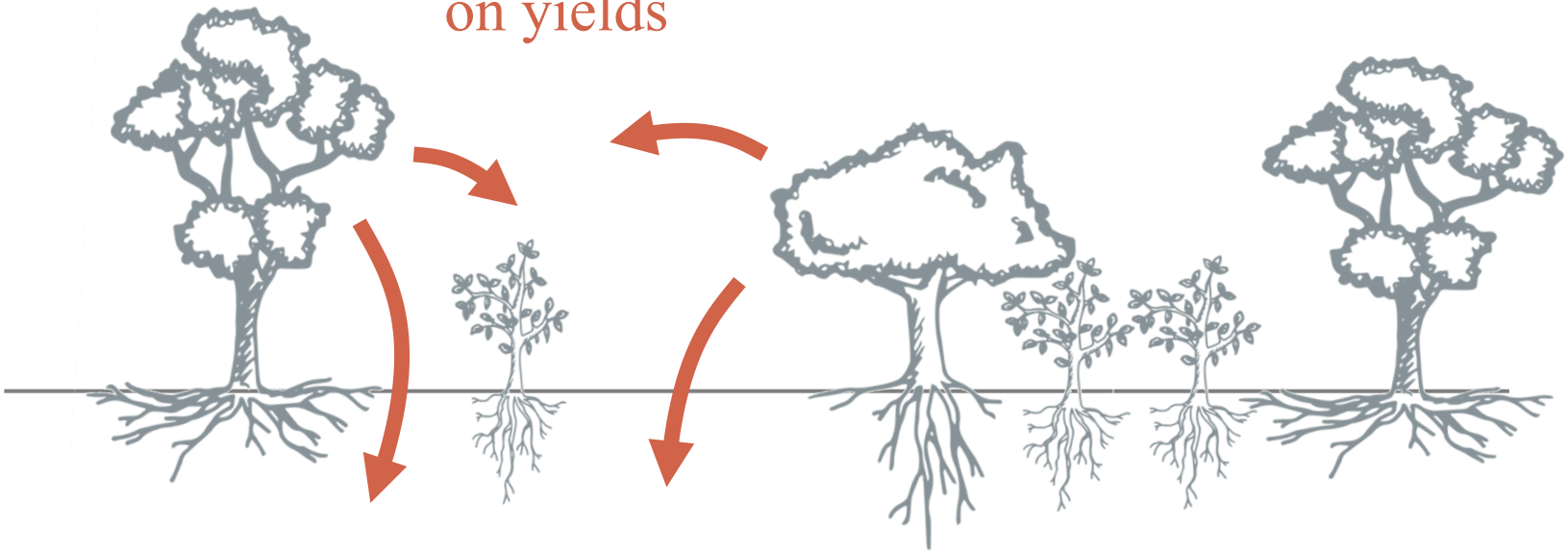
- Falling branches
- Wild boars
- Resource competition
- Pest & diseases

Conclusions

Can increased tree diversity improve the sustainability of cocoa cultivation systems in terms of soil fertility and yields?

Conclusions

No net effect on yields

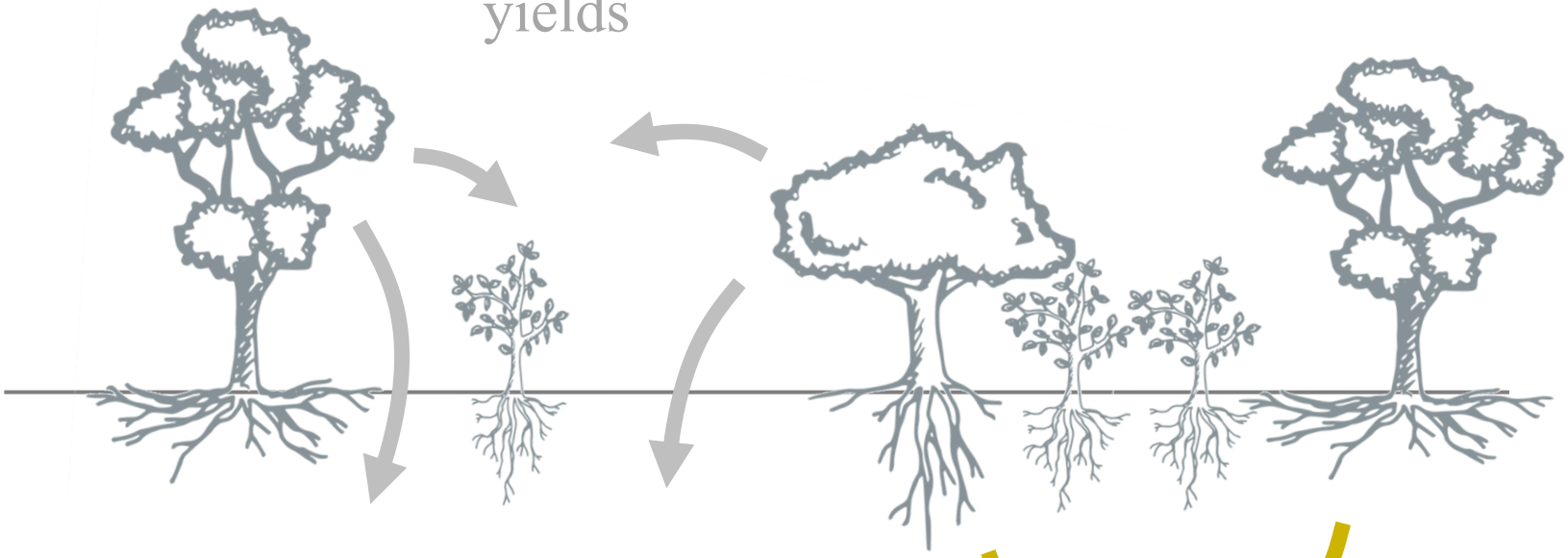


Improved soil fertility

Variability between species

Conclusions

No effect on yields

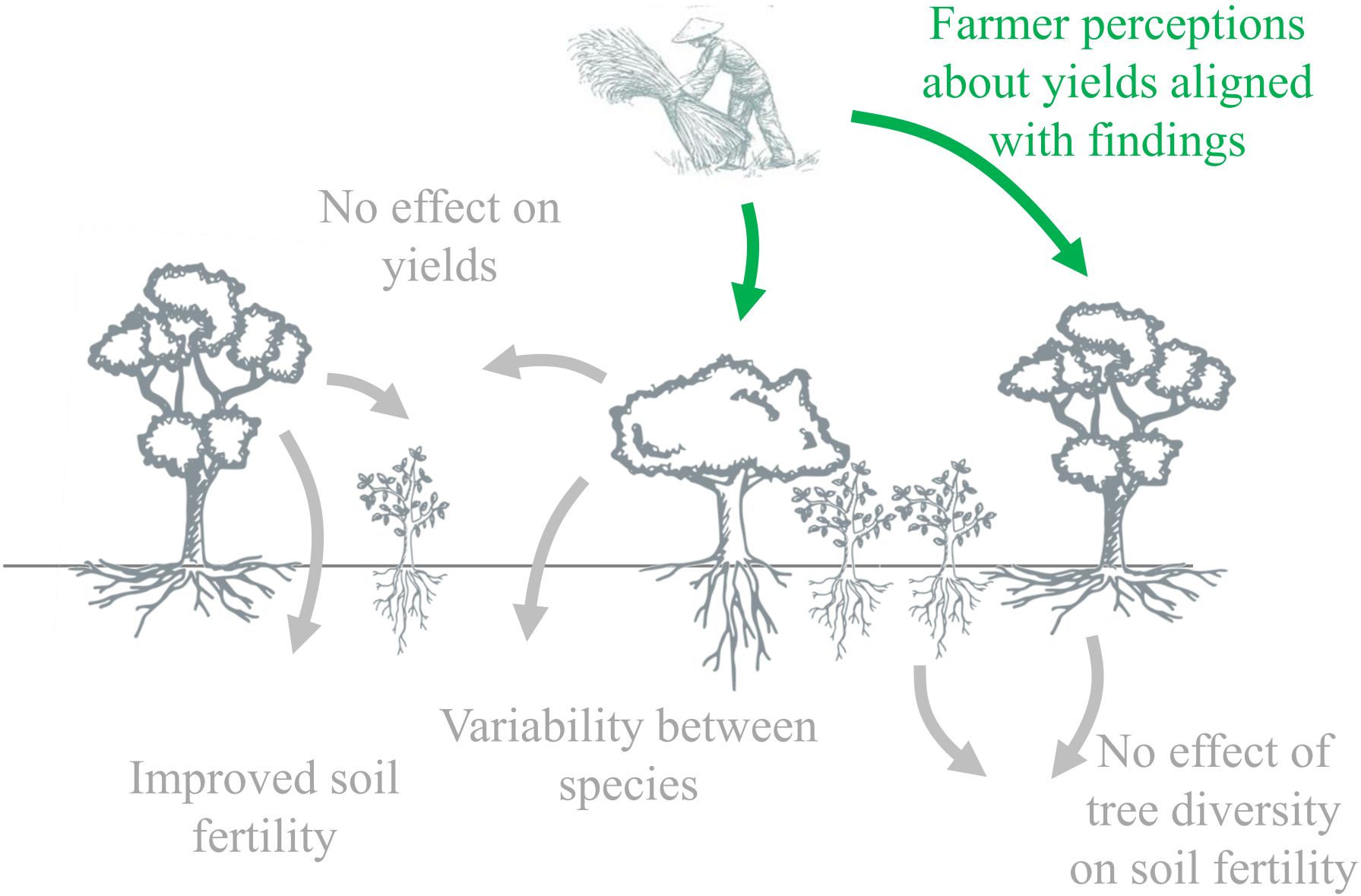


Improved soil fertility

Variability between species

No effect of tree diversity on soil fertility

Conclusions



Outlook

- Is increased plant diversity always good?
- Complexity in real farming landscapes
- Further research directions
    - Long-term dynamics of diversification
    - Impacts of diversification on other drivers of cocoa yields

Thank you!

ETH zürich

World Agroforestry Centre
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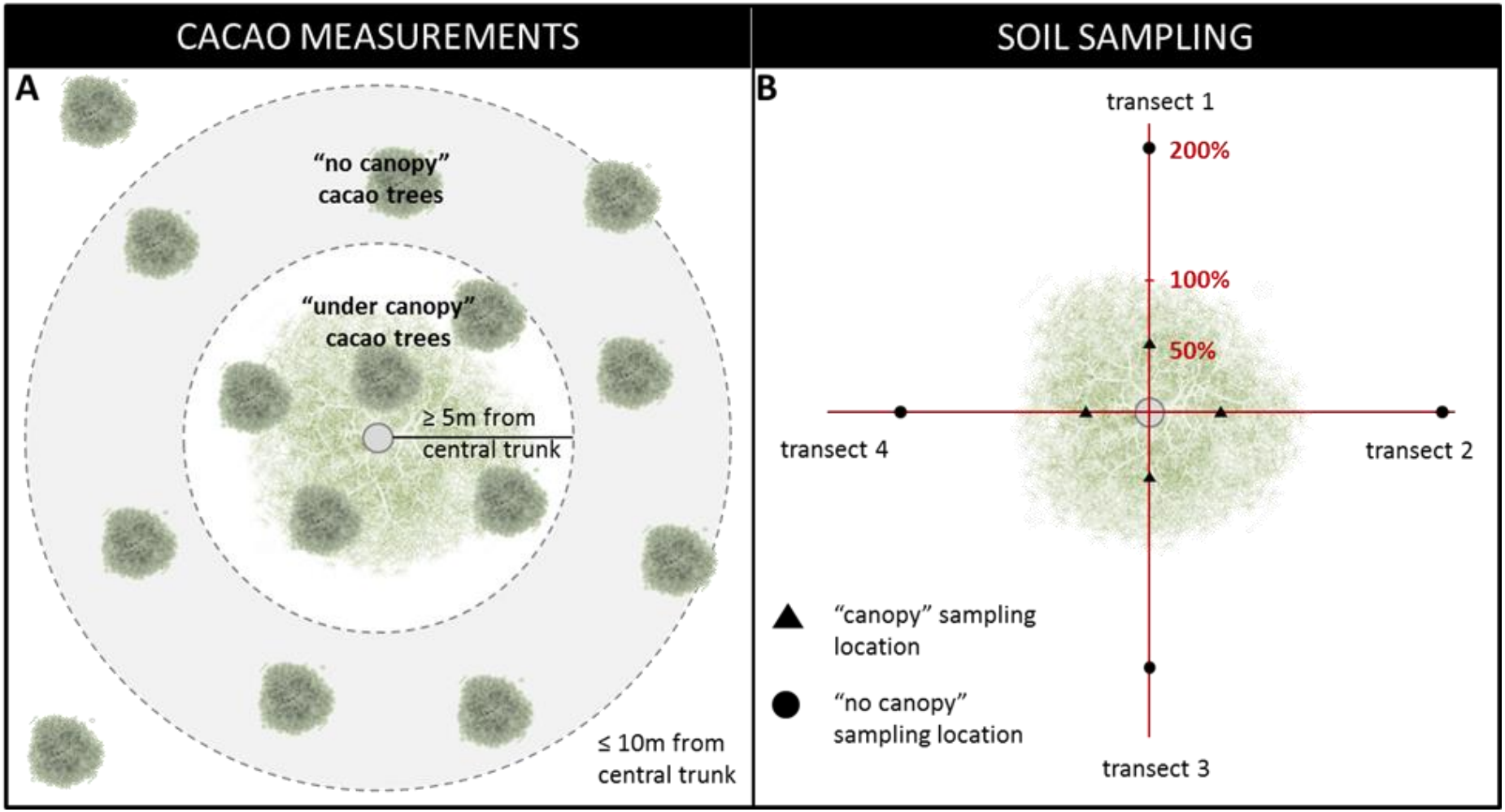
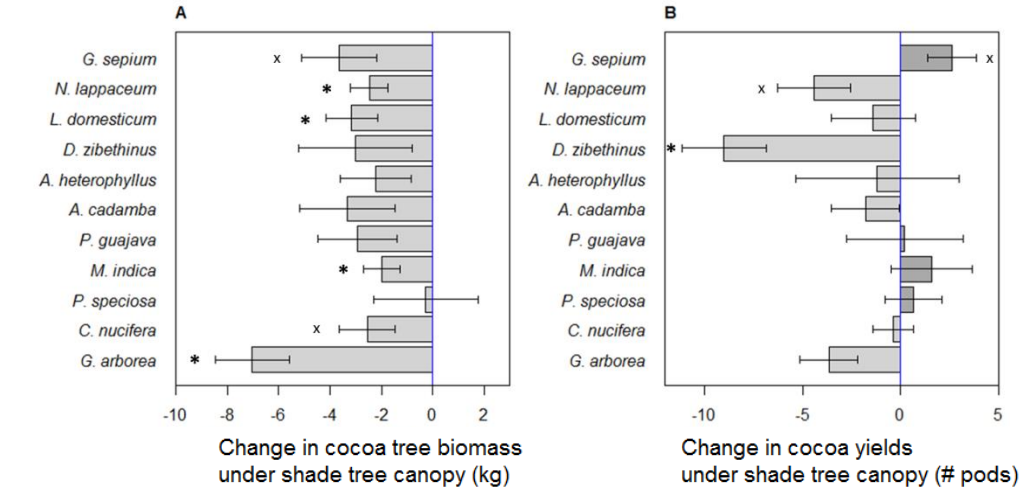
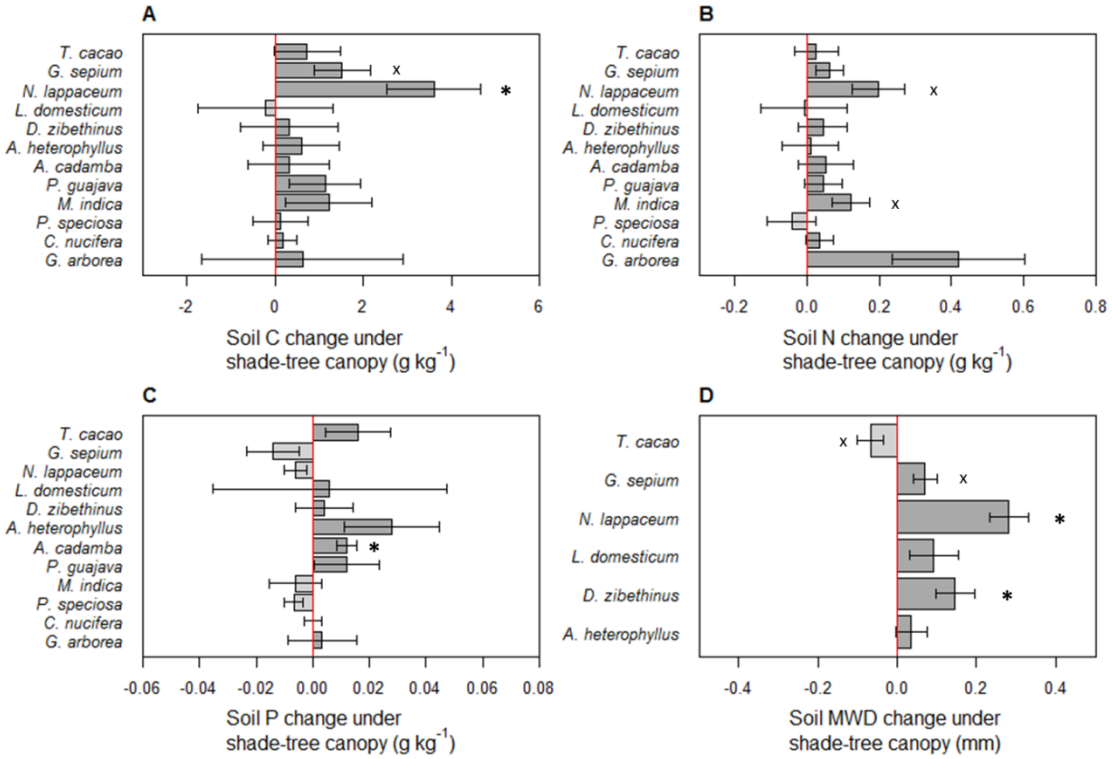
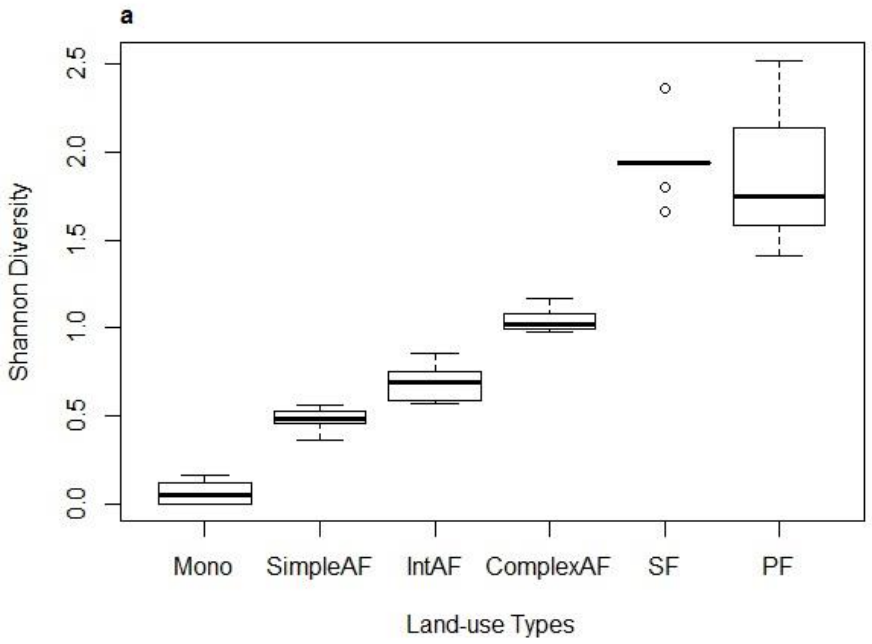
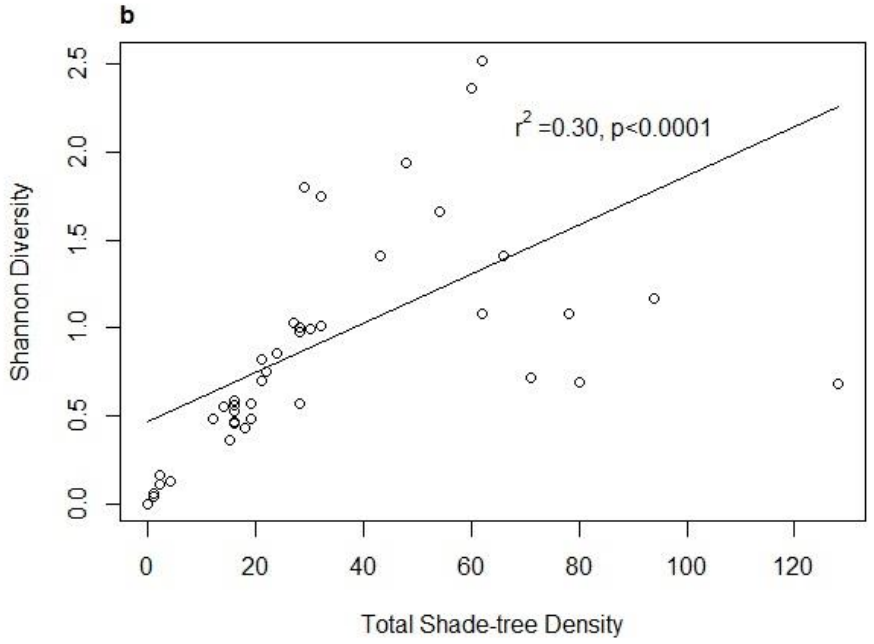

CACAO MEASUREMENTS
A
"no canopy" cacao trees
"under canopy" cacao trees
≥ 5m from central trunk
≤ 10m from central trunk
SOIL SAMPLING
B
transect 1
200%
100%
50%
transect 4
transect 2
transect 3
"canopy" sampling location
"no canopy" sampling location


A
G. sepium
N. lappaceum
L. domesticum
D. zibethinus
A. heterophyllus
A. cadamba
P. guajava
M. indica
P. speciosa
C. nucifera
G. arborea
-10 -8 -6 -4 -2 0 2
Change in cocoa tree biomass
under shade tree canopy (kg)
B
-10 -5 0 5
Change in cocoa yields
under shade tree canopy (# pods)


A
T. cacao
-2 0 2 4 6
Soil C change under
shade-tree canopy (g kg-1)
B
-0.2 0.0 0.2 0.4 0.6 0.8
Soil N change under
shade-tree canopy (g kg-1)
C
-0.06 -0.04 -0.02 0.00 0.02 0.04 0.06 0.08
Soil P change under
shade-tree canopy (g kg-1)
D
-0.4 -0.2 0.0 0.2 0.4
Soil MWD change under
shade-tree canopy (mm)


a
Shannon Diversity
0.0
0.5
1.0
1.5
2.0
2.5
Mono
SimpleAF
IntAF
ComplexAF
SF
PF
Land-use Types


b
Shannon Diversity
0.0
0.5
1.0
1.5
2.0
2.5
r2 =0.30, p<0.0001
0
20
40
60
80
100
120
Total Shade-tree Density

Can increased shade tree diversity improve soil fertility in a cocoa plantation?

TREE SPECIES DIVERSITY GRADIENT

PRIMARY FOREST

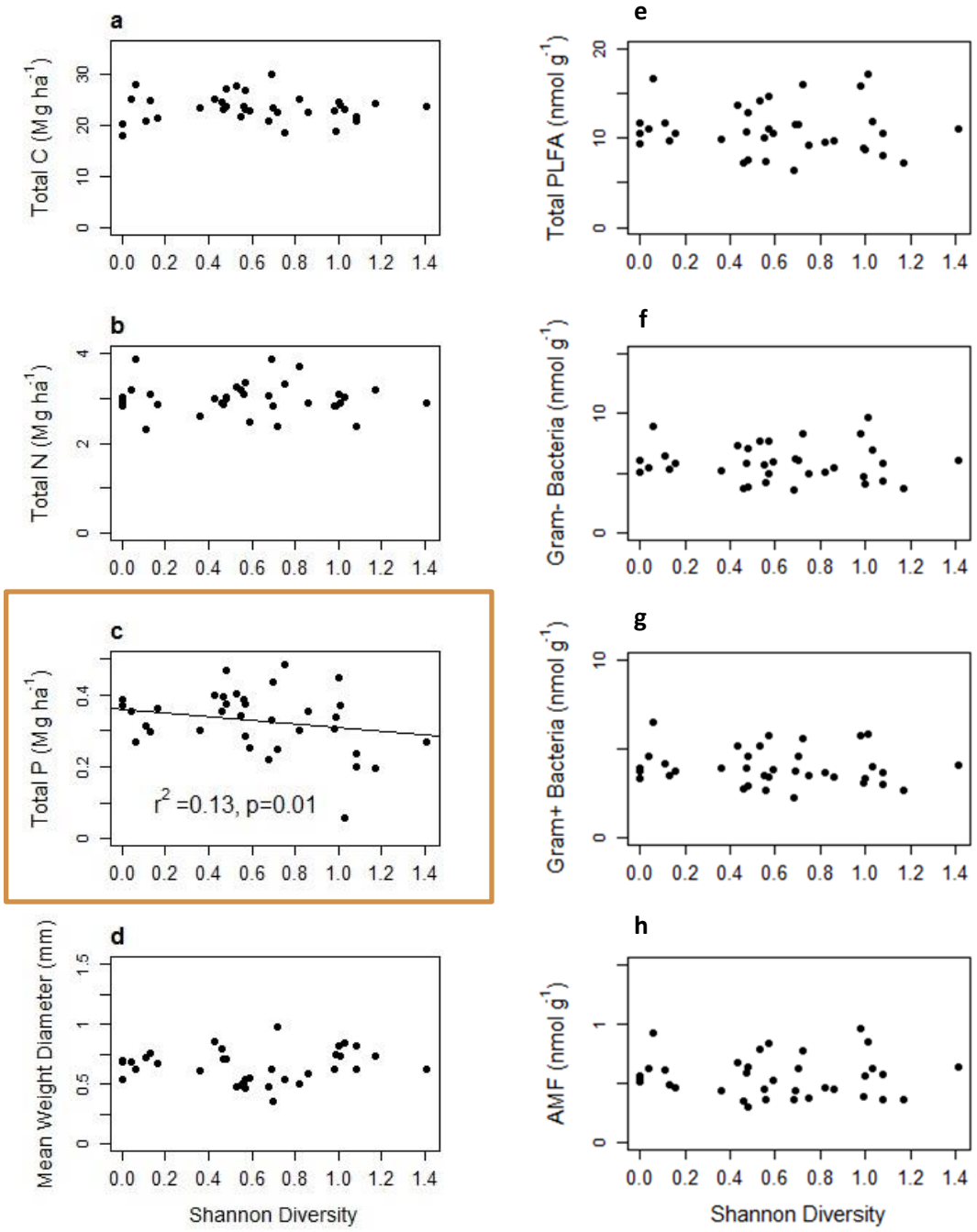
MONOCULTURE

LOW DIVERSITY SYSTEM

MEDIUM DIVERSITY AGROFOREST

COMPLEX AGROFOREST

SECONDARY FOREST



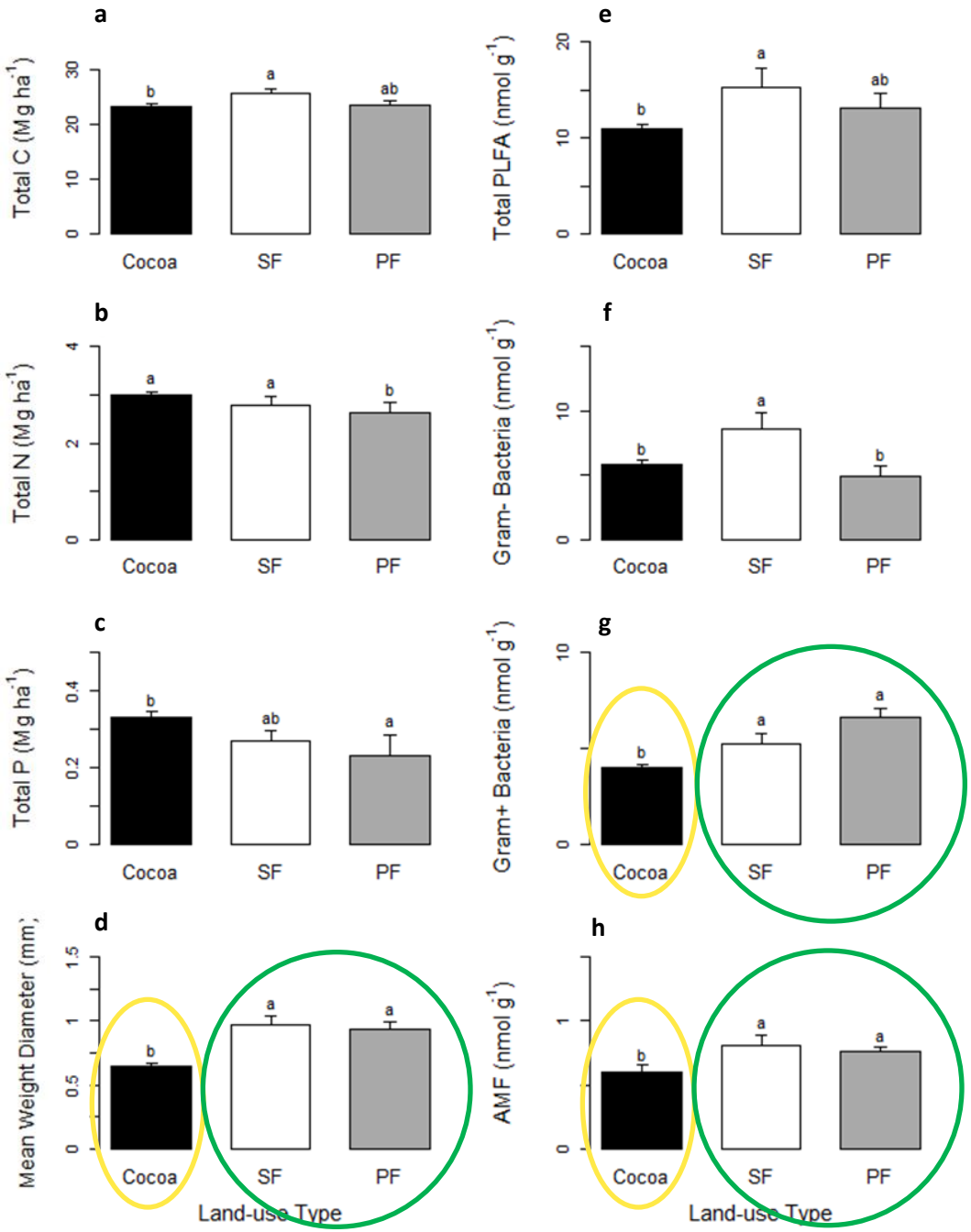
No effects of increased diversity in cocoa plantations

Soil Phosphorus

- Fertilizer effect
- Increased competition

Why?

- Previous land-use history
- Small effect of increased diversity on AGB, litter inputs etc.
- Cocoa plot age



Differences between land-use systems

Cocoa Plantations

- Decreased microbial activity
- Decreased soil aggregation

Secondary Forests

- Evidence of recovery of soil functions compared to cocoa plantations