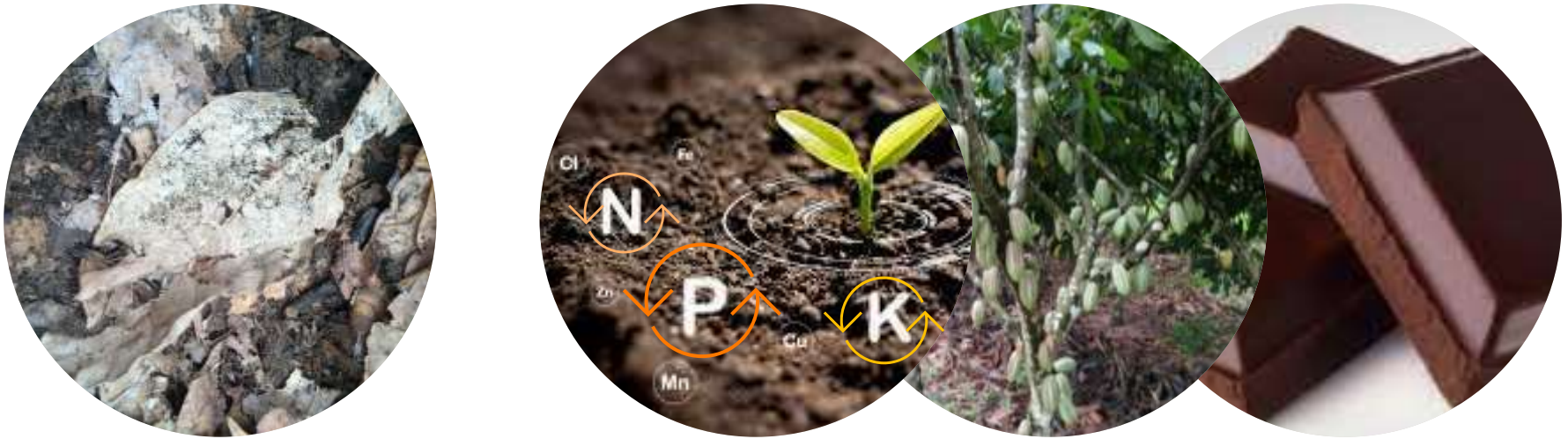
Litterfall and nutrient cycling in cocoa

International Symposium on Cocoa Research

Montpellier, 5th Dec. 2022



deo-gratias.hougni@wur.nl

Context

- Cocoa nutrition in smallholder farms heavily depends on inherent soil fertility
- Litterfall :
    - major nutrient flow from tree to soil
    - provides energy to soil biota
- Earthworms and other invertebrates can speed-up litter break-down, but their role in nutrient cycling is poorly quantified in cocoa.

WAGENINGEN
UNIVERSITY & RESEARCH

Objectives

Better understand nutrient flows through litter in low-input cocoa agroforestry systems

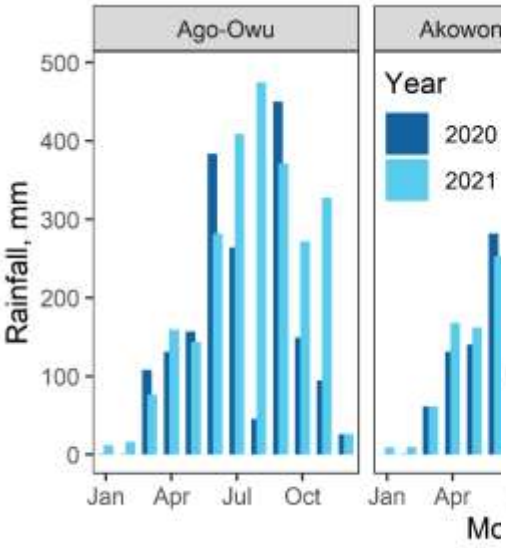
Quantify carbon and nutrient transfers through litterfall

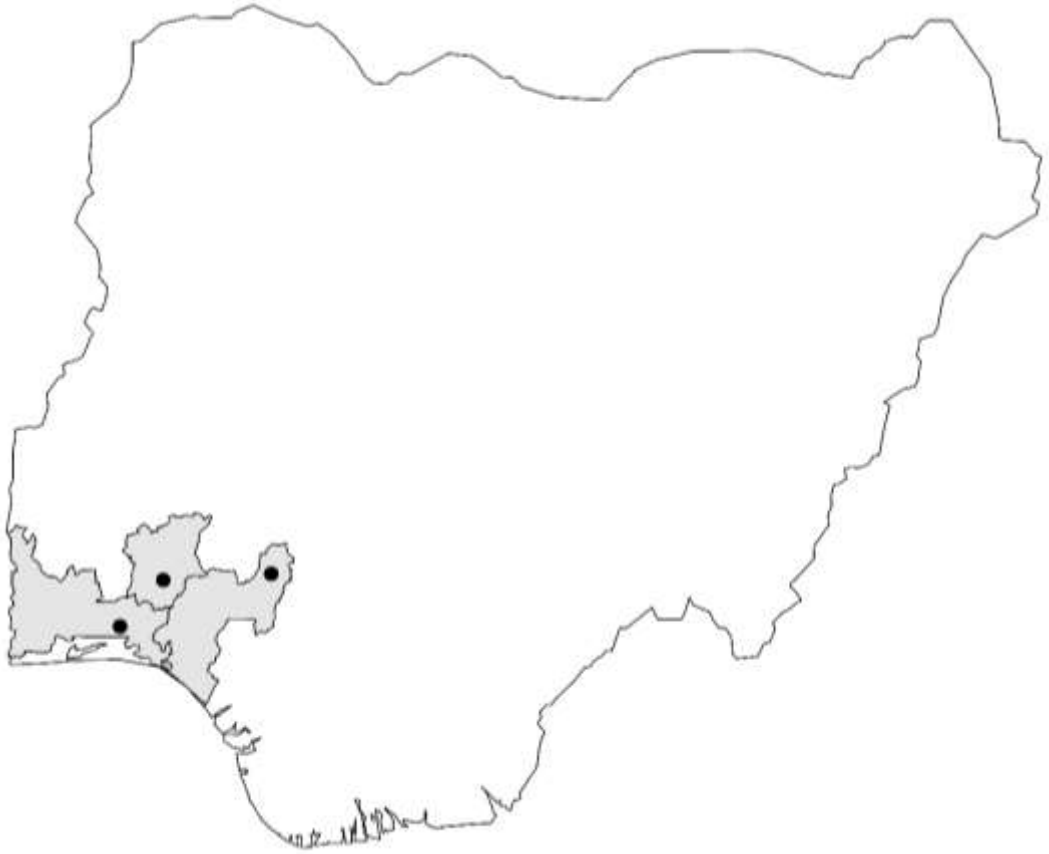
Understand the role of soil macrofauna on leaf litter disappearance and nutrient removal rates

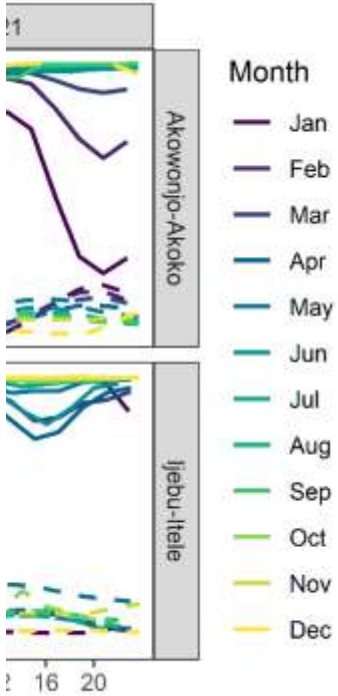
WAGENINGEN
UNIVERSITY & RESEARCH

Study area

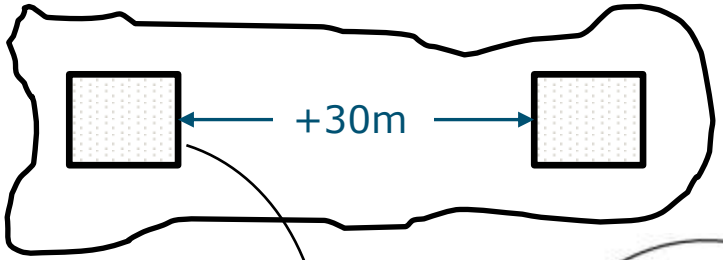
- Climatic condi



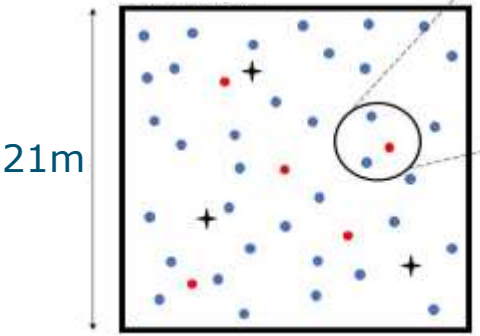


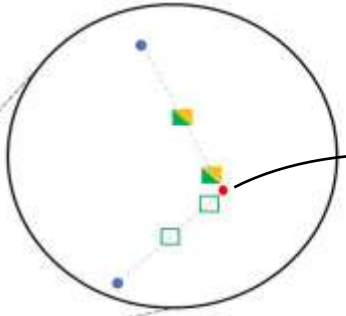


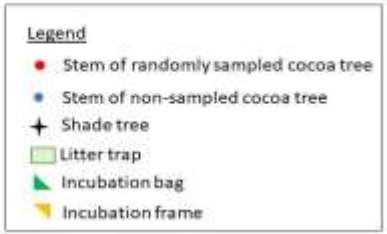
Experimental setup

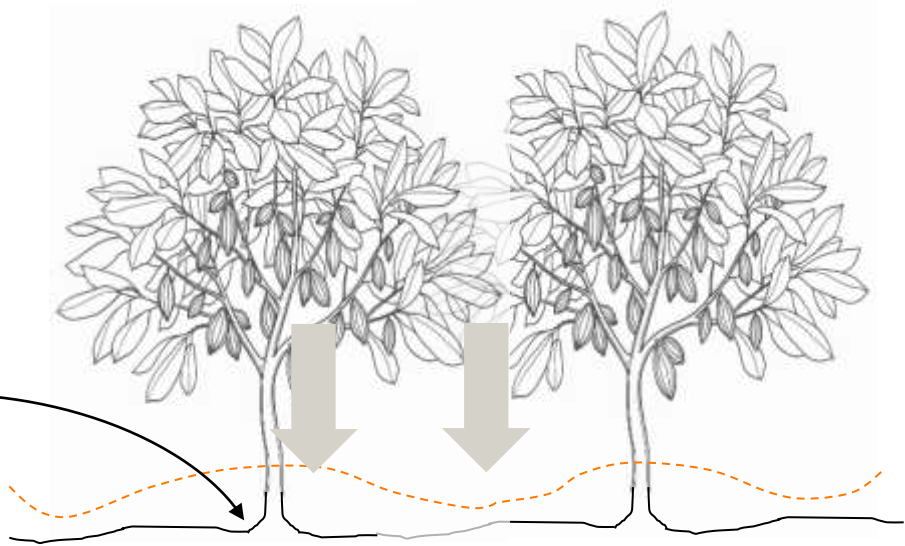


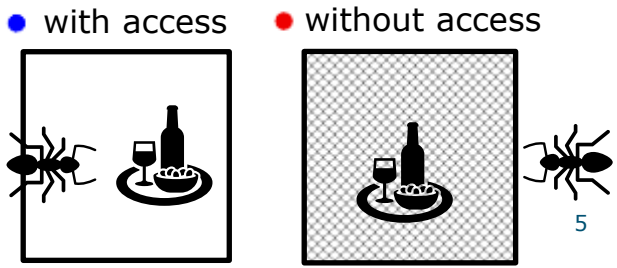
Experimental plot











WAGENINGEN
UNIVERSITY & RESEARCH

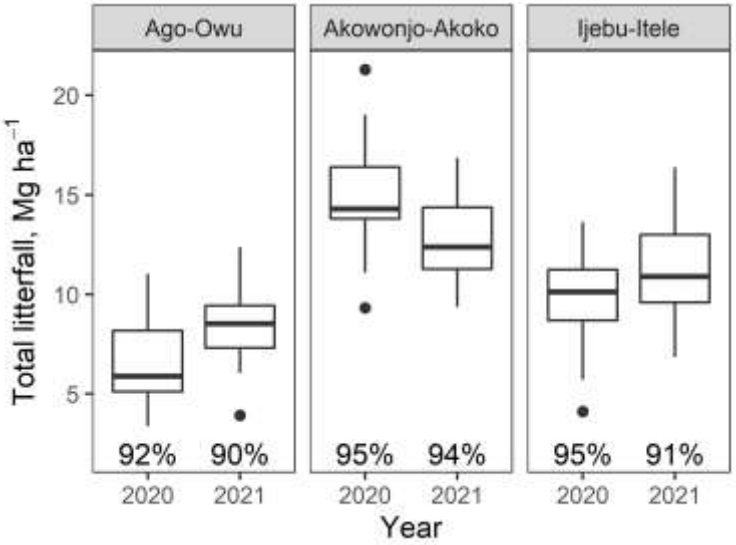
The cocoa agroforestry system

Tree population characteristics	Location		
	Ago-Owu	Akowonjo-Akoko	Ijebu-Itele
Age of plantation (years)	18	15	23
Shade tree density (trees ha^{-1})	27	8	56
Cocoa tree density (trees ha^{-1})	985	1087	1162
Cocoa stem diameter (cm)	14.2 ± 2.8	18.1 ± 3.7	13.8 ± 2.8
Cocoa canopy diameter (cm)	221 ± 48	337 ± 62	154 ± 61
Tree height (cm)	488 ± 79	407 ± 71	440 ± 65
Soil physical & chemical properties			
Clay content (%)	23 ± 1.4	18 ± 5.7	16 ± 2.8
pH_{H2O}	6.85 ± 0.1	6.20 ± 0.3	6.70 ± 0.7
Organic carbon (mg g^{-1})	11.80 ± 0.7	8.53 ± 0.7	9.60 ± 2.2
Total nitrogen (mg g^{-1})	1.21 ± 0.0	0.79 ± 0.1	0.86 ± 0.1
Available P_{Olsen} (mg kg^{-1})	35.07 ± 14	8.24 ± 14	28.01 ± 4.0

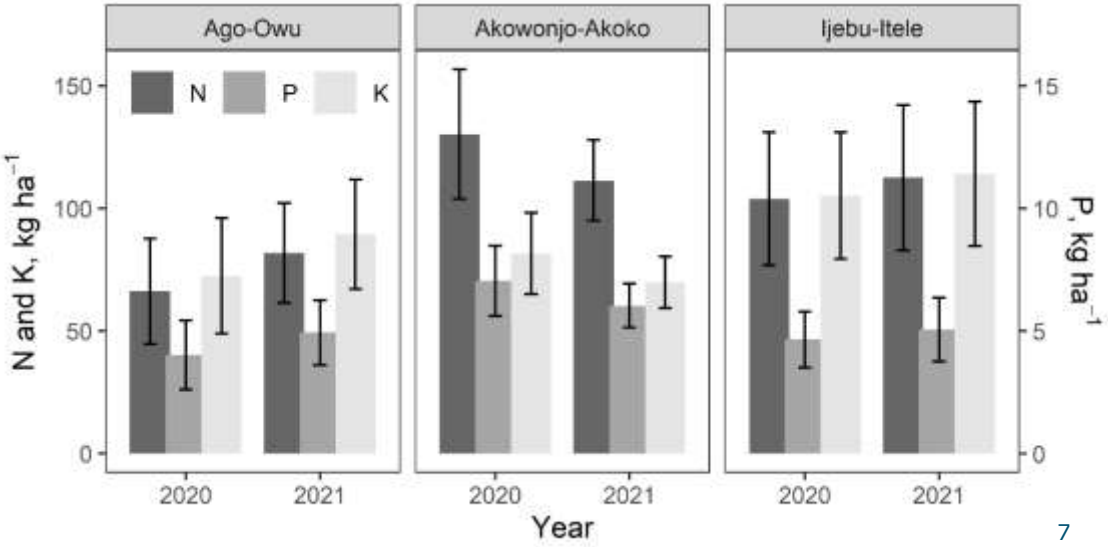
WAGENINGEN
UNIVERSITY & RESEARCH

Dry matter and nutrient flows through litterfall

- Annual litter production

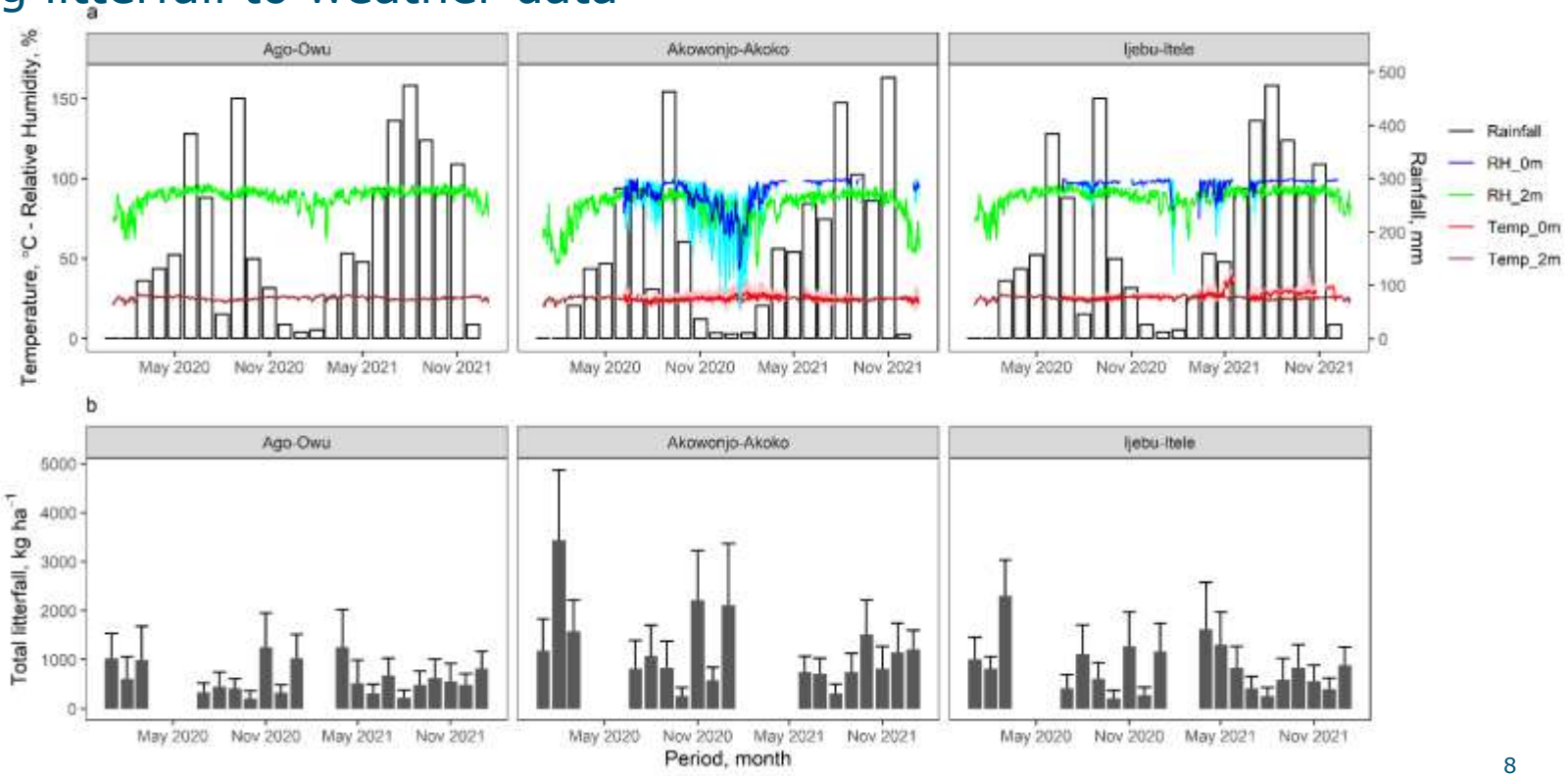


Nutrient transfers through cocoa leaf litterfall



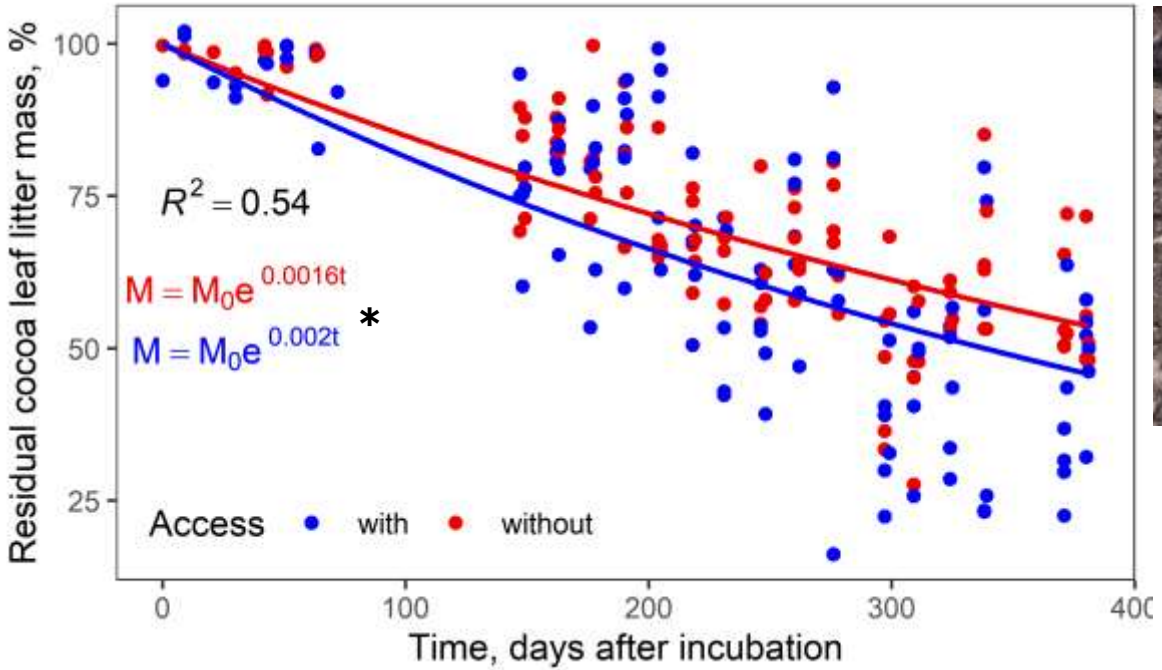
Temporal variability in litterfall

- Linking litterfall to weather data



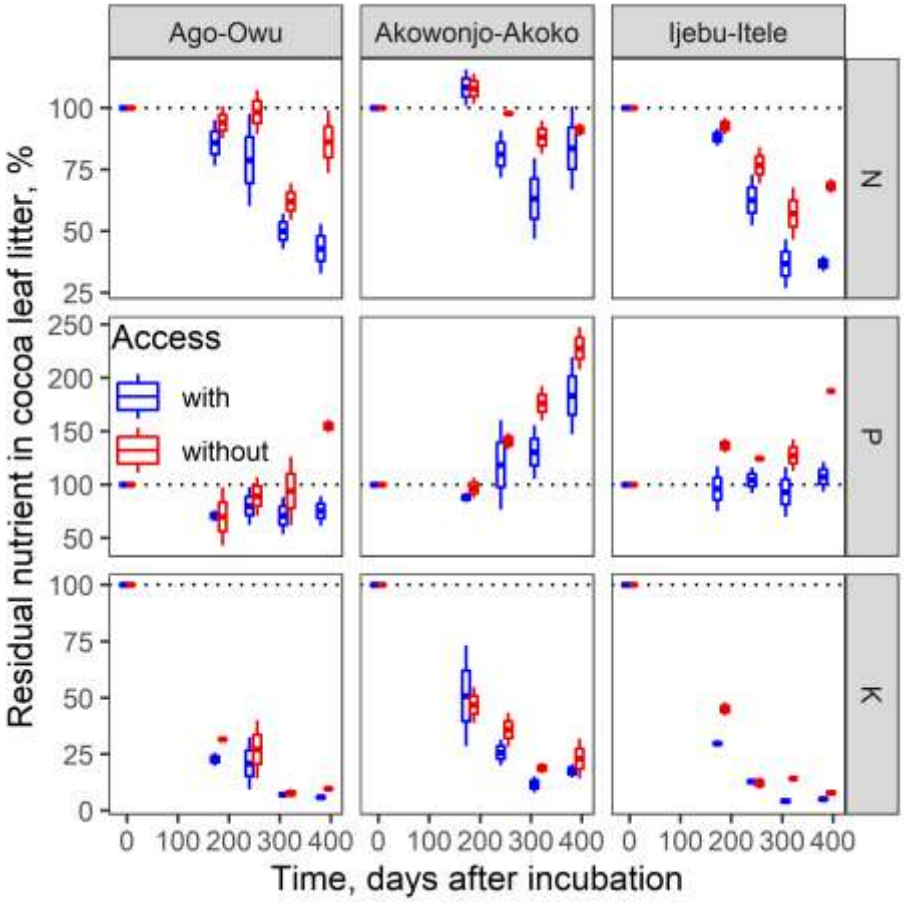
Disappearance of cocoa leaf litter

- Effect of macrofauna on gradual litter mass loss



WAGENINGEN
UNIVERSITY & RESEARCH

Patterns of nutrient removal from cocoa leaf litter



WAGENINGEN
UNIVERSITY & RESEARCH

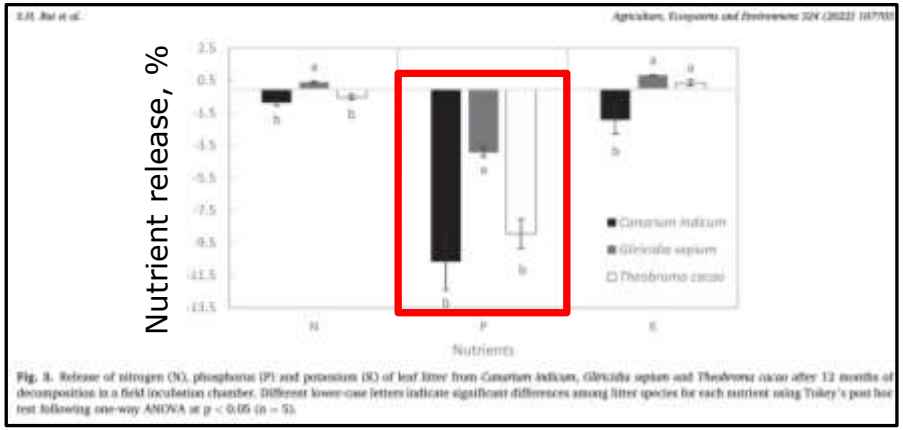
Connect-the-dots

Table 4 Concentrations and Amounts of Nutrients in the Litter Fall and Standing Litter of Cocoa and Shade Trees Combined, Nutrient Transfer Through Fine Root Turnover of Shade Trees in Cocoa Systems, and Nutrient Transfer Through Rainwash in Shaded and Unshaded Systems

	N	P	K	Ca	Mg	Source	Country
Nutrient concentrations in litter (g/kg)	11.1–19.6	0.8–2.0	2.1–15.3			Hartemink and Donald (2005)	Range of several studies around the world
Nutrients returned to the soil through litter (kg/ha/yr)	84–175	5.8–17	16–124			Fontes et al. (2014) and Hartemink and Donald (2005)	Range of several studies around the world

This study (kg ha^{-1})	100	5	89

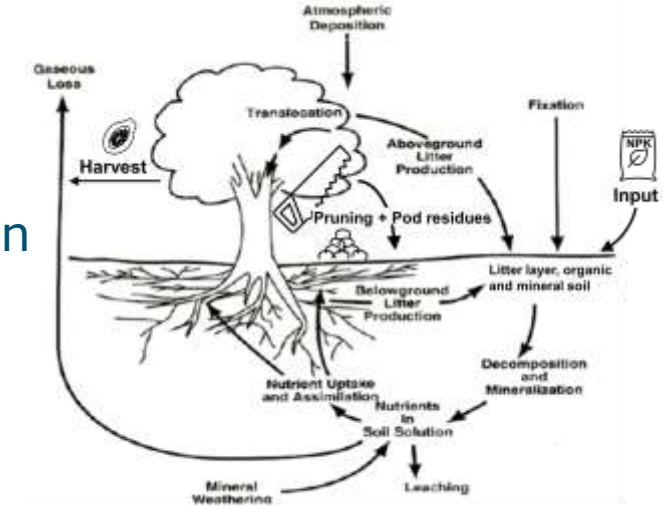
Offtakes for 1 Mg ha^{-1} beans	N	P	K
With husks (kg ha^{-1})	35	6	60
Without (kg ha^{-1})	20	4	10



WAGENINGEN UNIVERSITY & RESEARCH

Connect-the-dots...

- Resorption efficiency: P>N
  - N:P≈9-14 in green leaves **#van Vliet & Giller, 2017. *Adv. Agron. 141: 185-270***
- MRT in litter: P>N **#Fontes et al., 2014. *Plant Soil 383: 313-335***
  - Fine roots growing upwards <- P trapped in humus?
- What about:
  - Pruning residues and root turnover
  - Fungicide use, AMF, & cocoa P nutrition



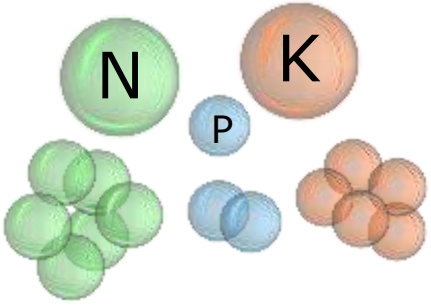
Nutrient cycling in cocoa agroforestry systems
Adapted from Journal of Forest Science 29 (1),38-48

WAGENINGEN
UNIVERSITY & RESEARCH

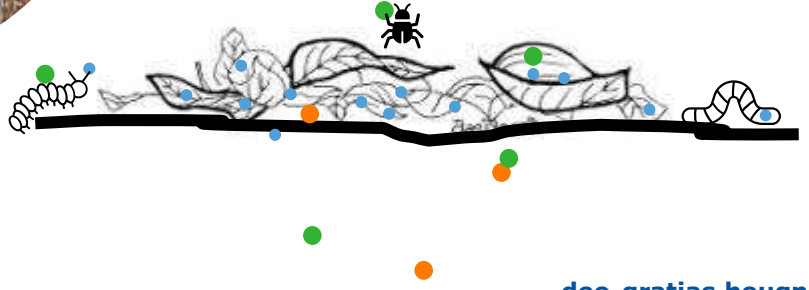
Conclusion

- Considerable cycling of N and K through litterfall: ~ 100 kg ha^{-1} yr^{-1}
- Small amounts of P recycled : ~ 5 kg ha^{-1} yr^{-1}
- P further immobilized in the litter layer during decomposition
- Different mechanisms govern dynamics of N, P, K with a role of C
- Macrofauna significantly increases cocoa leaf litter loss rates
    - Fractionation effect ($k_{with}/k_{without}$)= 1.25
    - Enhances C, N, and P removal from the litter layer... but not before 6 months.

Litterfall and nutrient cycling in cocoa



- **Mr Oluwafemi OYEDELE**
- **Dr Stefan HAUSER**
- **Dr Moses O. OGUNLADE**
- **Dr A. G. Tom SCHUT**
- **Dr Lotte S. WOITTIEZ**
- **Prof Ken E. GILLER**



deo-gratias.hougni@wur.nl

CocoaSoils

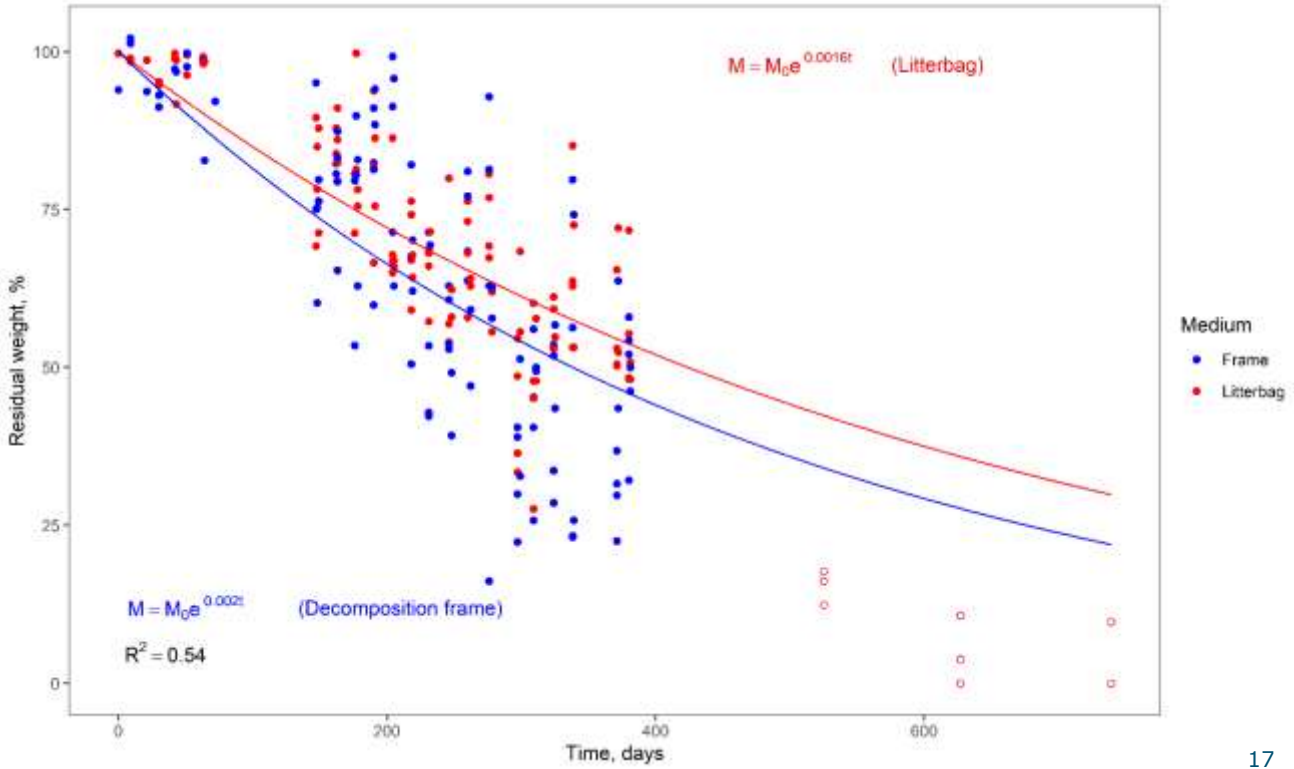
Partnership

Project Lead/Donor	IITA CGIAR · idh · WAGENINGEN UNIVERSITY & RESEARCH · Norad
National Research Institutes	· · · CNRA
Intl Research Centres	UN environment programme WCMC · IITA CGIAR · · WAGENINGEN UNIVERSITY & RESEARCH · Alliance: Bioversity International, CIAT
Private partners	Nestlé · Cargill · · BARRY CALLEBAUT · · · Olam · YARA · ICL · S&D SUCDEN · · Mars · OLATUNDE INT'L LTD. · Mondelēz International · ETG

Additional slides

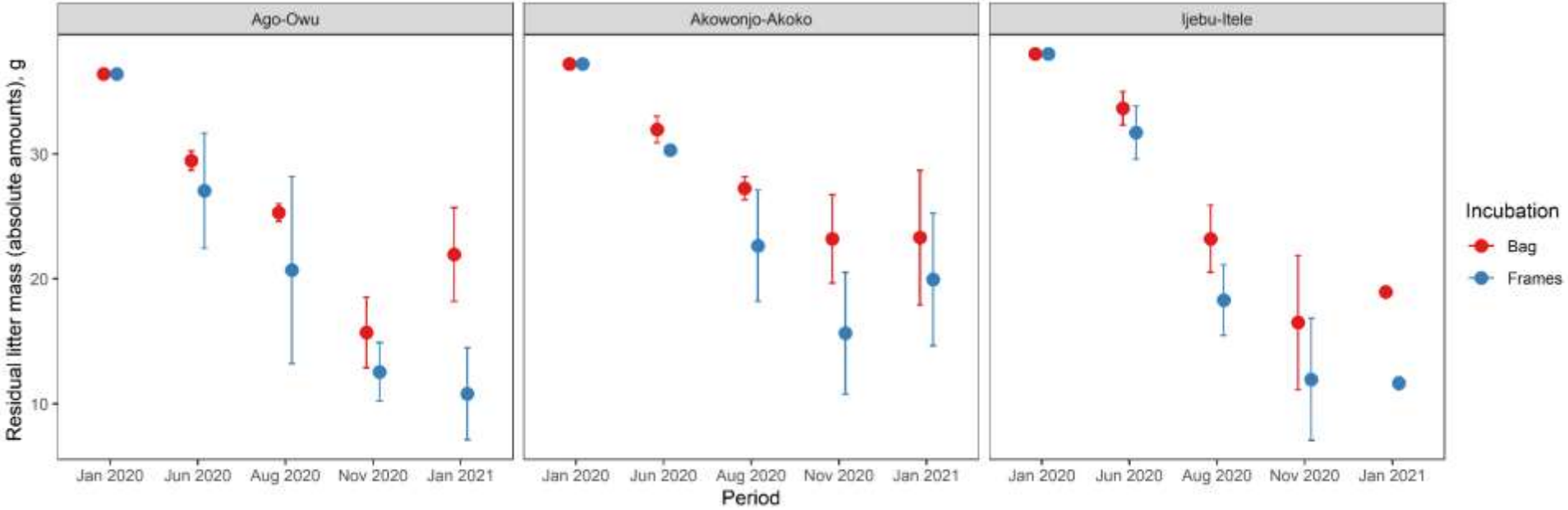
Litterfall & nutrient recycling in cocoa

- Decomposition rates with/without macrofauna access



Litterfall & nutrient recycling in cocoa

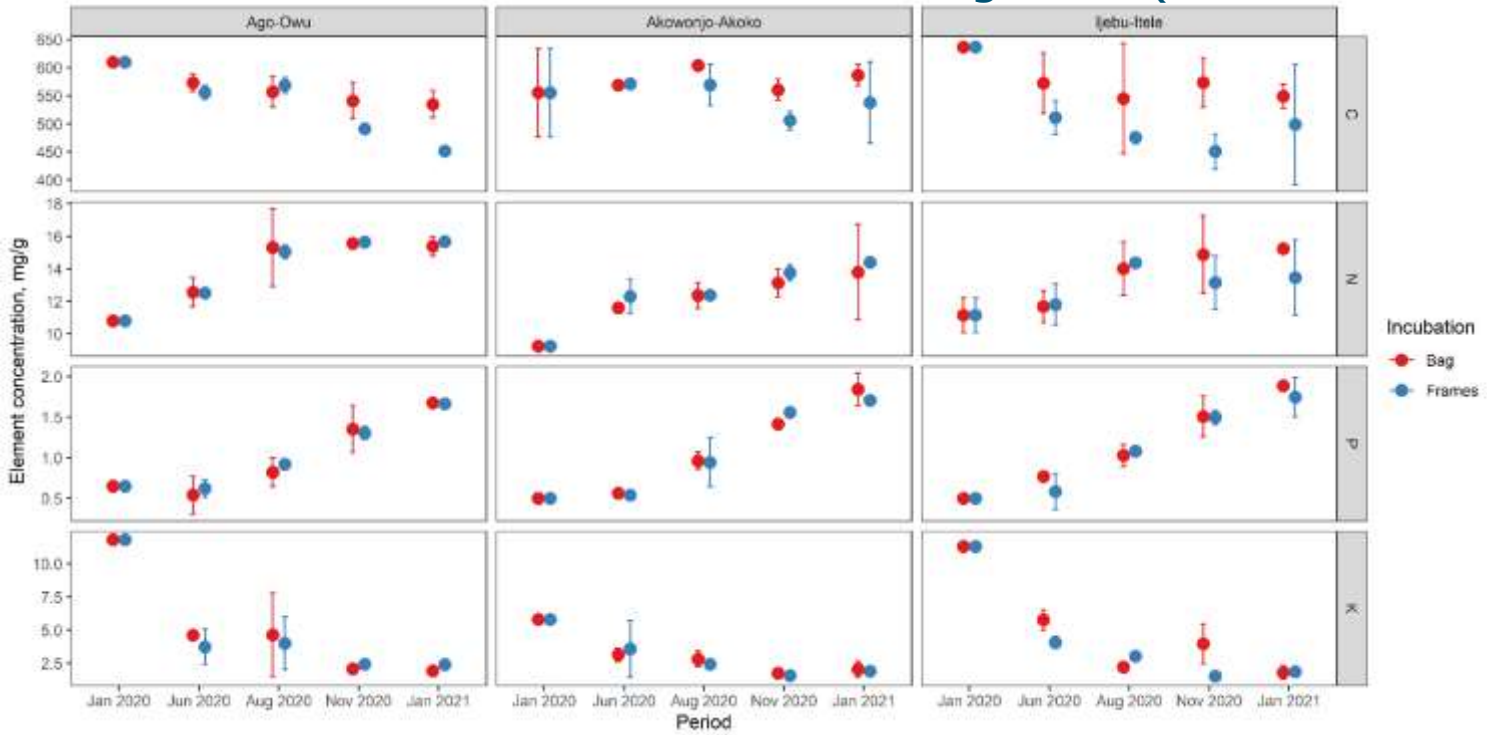
- Cocoa leaf litter mass loss (mean ± std dev)



WAGENINGEN
UNIVERSITY & RESEARCH

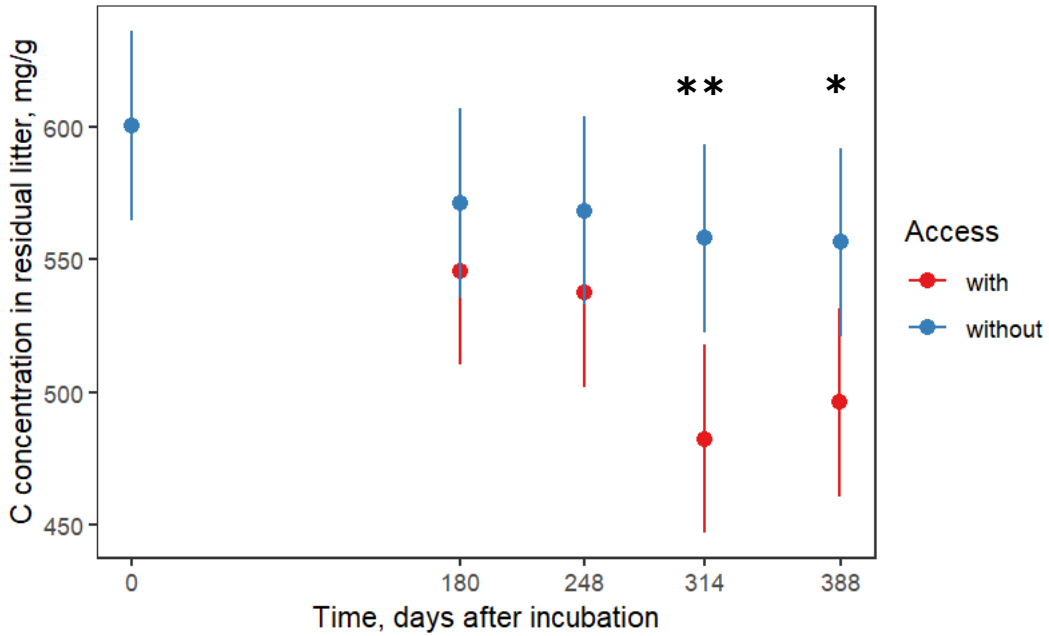
Litterfall & nutrient recycling in cocoa

- Elemental concentrations in remaining litter (mean ± std dev)



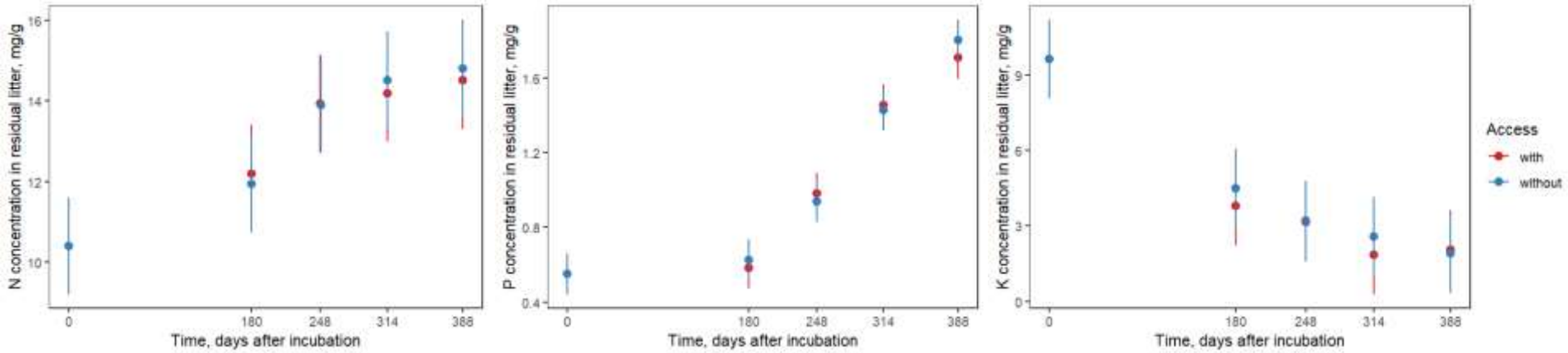
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter C loss (change in litter quality)



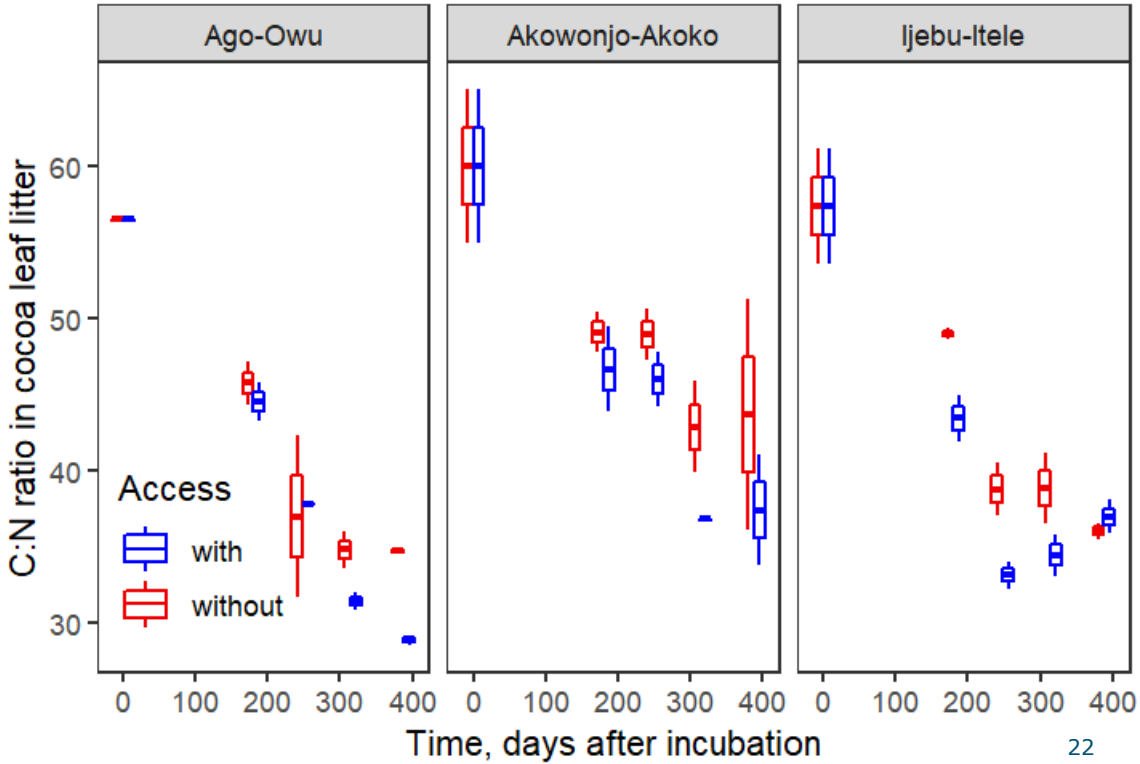
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter nutrient loss (change in litter quality)



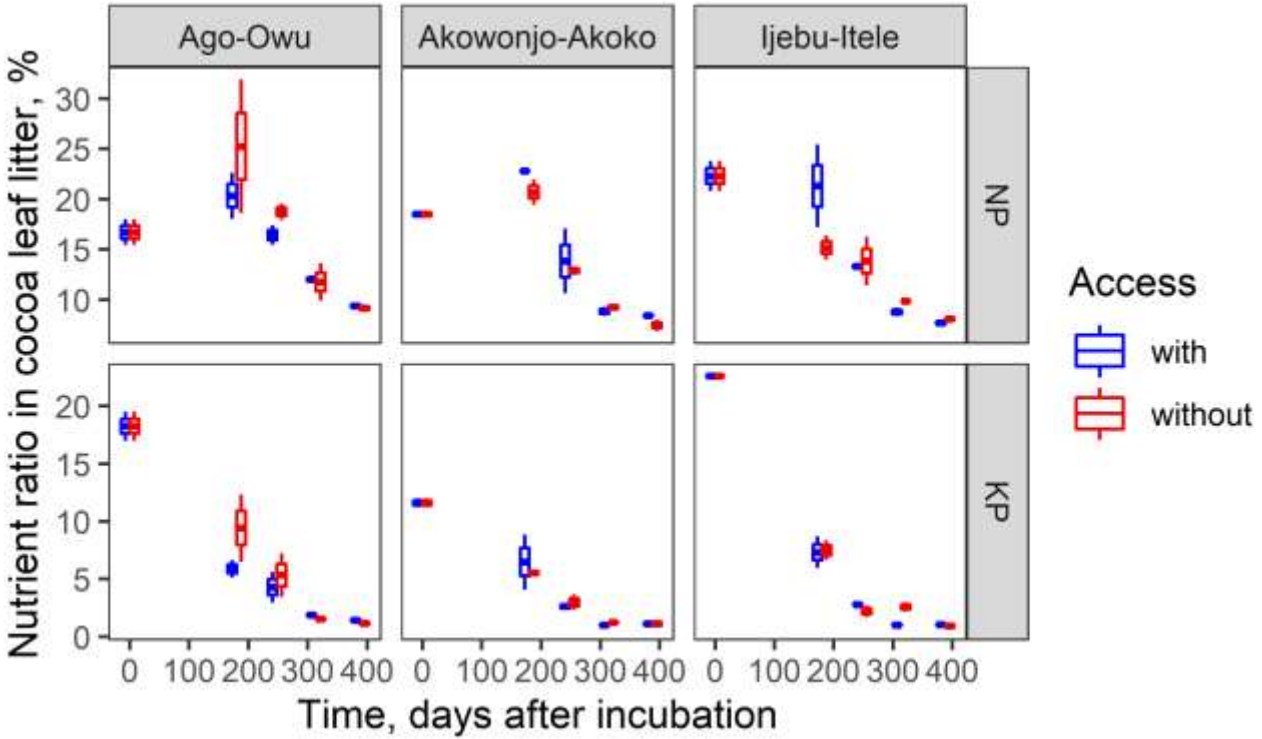
Decomposition of cocoa leaf litter

- Cocoa leaf litter nutrient loss (change in litter quality)



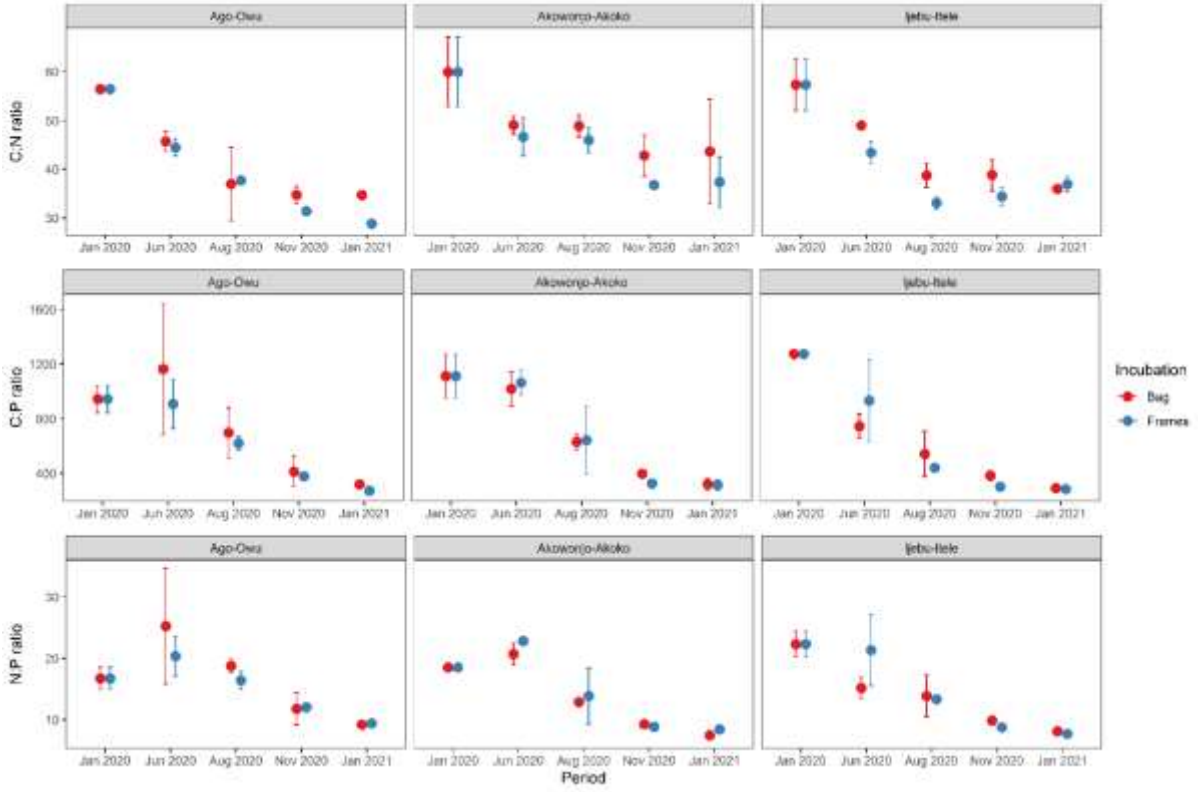
Decaying litter quality

- Nutrient release patterns: progressive change in stoichiometry



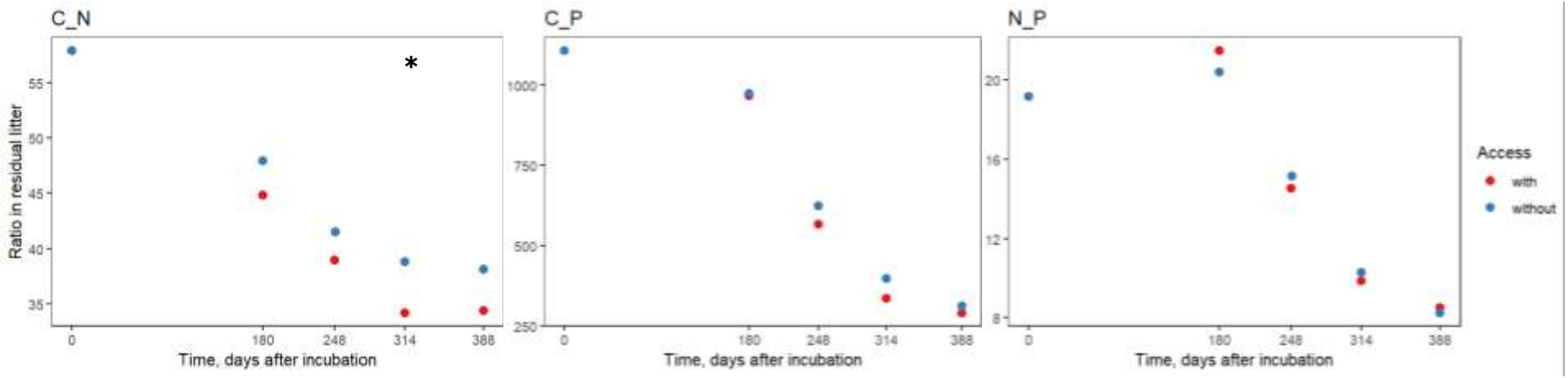
Decaying litter quality

- Cocoa leaf litter nutrient loss (change in litter quality)



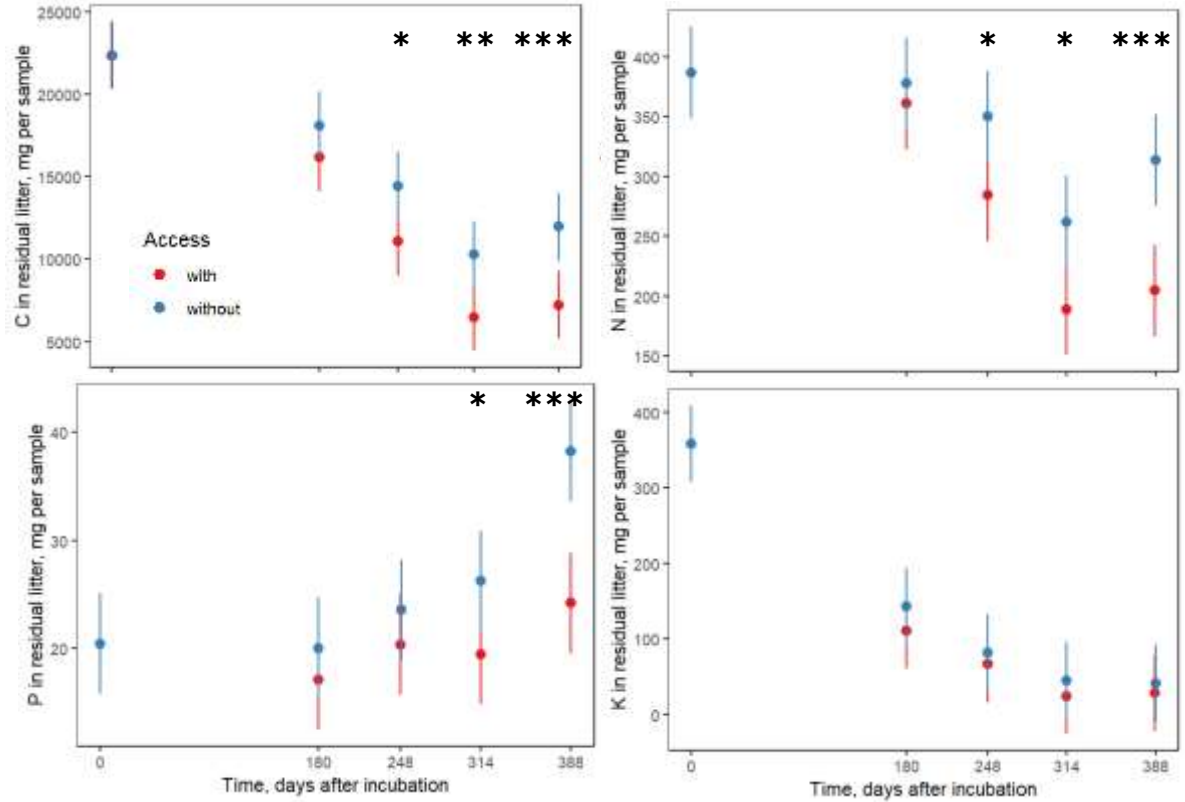
Litterfall & nutrient recycling in cocoa

- Cocoa leaf litter nutrient loss (change in litter quality)

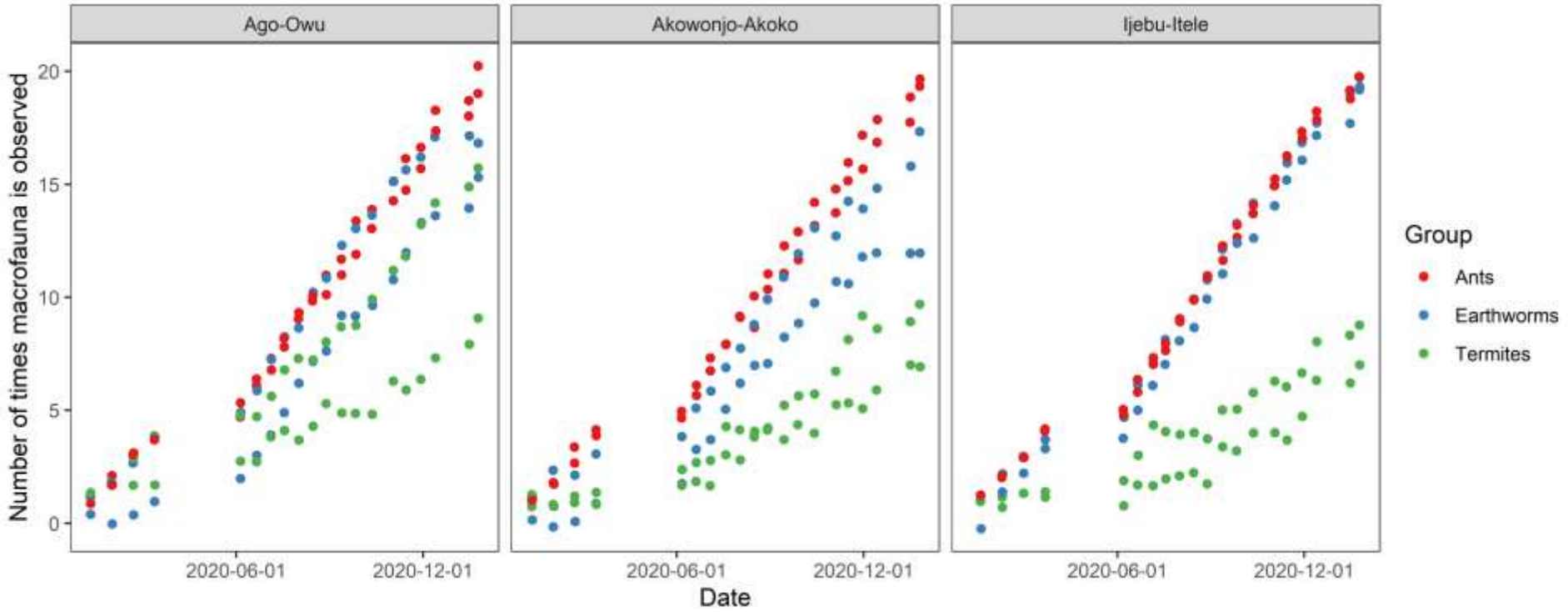


Litterfall & nutrient recycling in cocoa

- Predicted C and nutrient release patterns



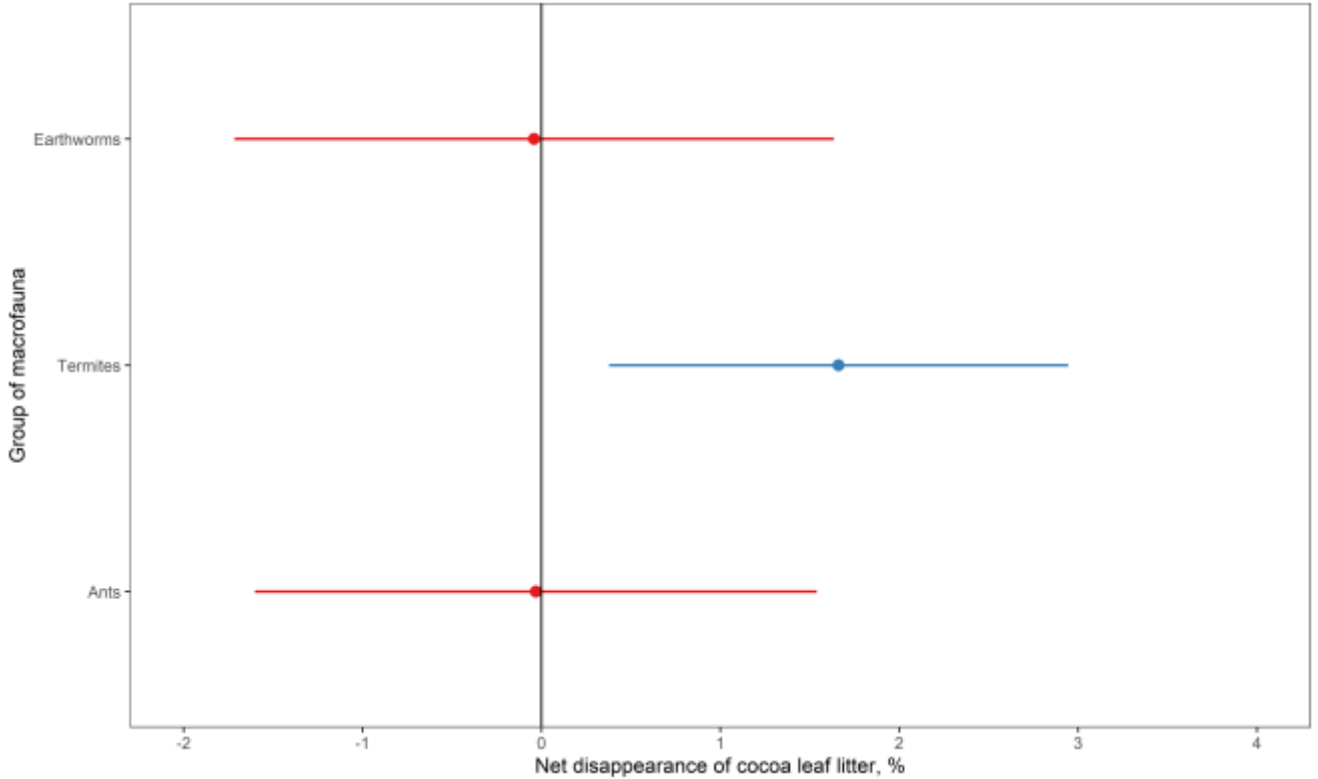
Litterfall & nutrient recycling in cocoa



WAGENINGEN
UNIVERSITY & RESEARCH

Litterfall & nutrient recycling in cocoa

- Effect of macrofauna on litter decomposition



Litterfall & nutrient recycling in cocoa

- Predicted cocoa leaf litter mass