Nitrogen response efficiency and crop yield in alley-cropping agroforestry system compared with open croplands

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Introduction

Objective: To assess the effect of the alley-cropping agroforestry (ACA) system and open croplands on the nitrogen responsible efficiency (NRE) and crop yield of different crops from 2019 to 2022.

Research question: Is agroforestry more nutrient efficient than open cropland?

Hypothesis: NRE and crop yield between alley-cropping agroforestry(ACA) system and open croplands will not be significantly different.

- Due to tree-crop competition for light and water, crop yield near the tree row in ACA might reduce, while it can also be compensated by the increased crop yield in the crop alley further away from the tree row (Schmidt et al. 2021).
- The tree-crop facilitation effect will offset the tree-crop competition and might even contribute to higher NRE in ACA by acting as a 'nutrient pump'. Nutrient pump refers to trees transferring both mobile and relatively immobile nutrients from beneath the crop root zone to the upper soil layer in the forms of litter and tree fine roots that add higher nutrient availability in the transition zones (Pardon et al.2017).
- However, due to overlapping root systems, tree-crop competition for water and nutrients may increase when precipitation is a production-limiting factor, leading to lower crop yield and NRE in ACA than in open croplands (Livesley et al. 2000).
- Also, a light interception by trees and light reduction for winter crop seedlings due to leaf litter might increase as tree height increases in a long tree rotation cycle (Swieter et al. 2022).

Materials and Methods

Calculation of nutrient response efficiency (NRE)

NRE is defined as the following (Schmidt et al. 2020):

$$\mathrm{NRE} = \frac{\text{Crop yield } (\mathrm{kg\ ha-1yr-1})}{\text{Plant}-\text{available nutrient } (\mathrm{kg\ N, P, K, Mg, Ca\ ha-1yr-1})}$$

Plant-available N was measured bi-monthly during the growing seasons from 2018 to 2021. However, due to high costs, they were measured once a year, only in the spring (during March-May) in 2022. The measurement will take place either before the fertilizer application or six weeks after the application, during which the extant mineral N levels in the soil had gone down.

$$\text{Plant available nitrogen} = \text{Net N mineralization rate} + \text{fertilizer N}$$

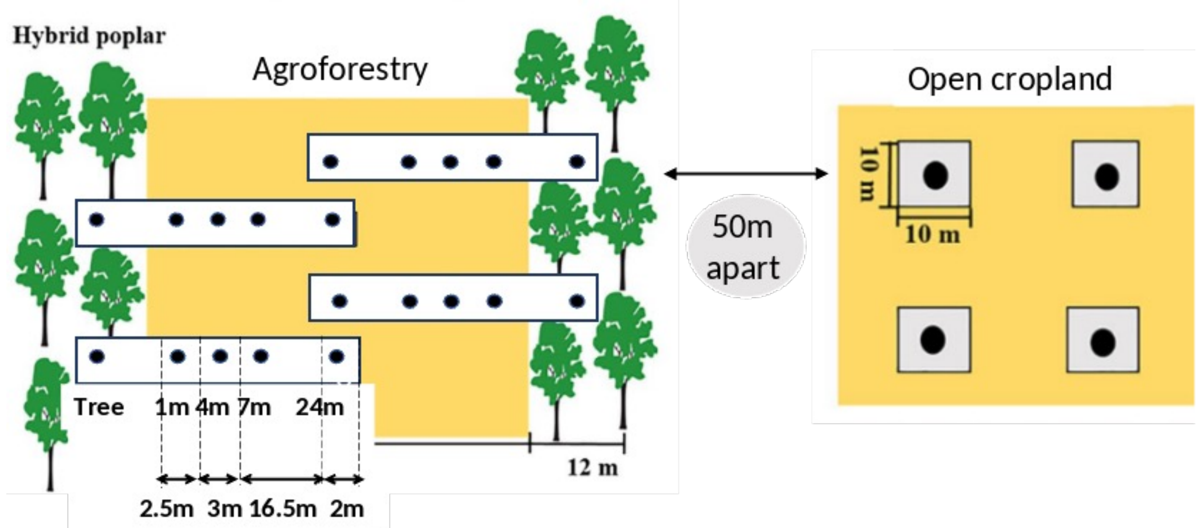
Buried Bag Method: In each sampling location within each replicate plot, two intact soil cores will be taken in the top 0.05 m depth. A part of the soil from one core (T0) (approx. 250-300 g) will be added to a prepared bottle of 150 ml 0.5 M K2SO4. The other soil core (T1) will be put in a plastic bag that is loosely tied for aeration an, inserted back into the soil to incubate in-situ for seven days, andtracted as the T0 core. In the absence of plant assimilation in the in situ incubated intact core, the net rate of N mineralization represents the mineral N available for plant uptake. The soil-K2SO4 bottles will be shaken for 1 hour and filtered through K2SO4 pre-washed filter papers. Extracts are immediately frozen until analysis.

$$\text{Soil N mineralization rate} = \frac{\text{mineral N at T1} - \text{mineral N at T0}}{\text{Incubation days}} \times \text{Bulk density} \times \text{Depth}$$

Crop yield will be measured using a plot combine harvester, by 1.5 m and 10 m at each sampling location at 1 m, 4 m, 7 m, 24 m from the tree row and the reference plot. The moisture content of crop yield will be determined to calculate dry mass, by oven-drying at 60 ℃ until constant dry weight is reached (about 7 days).

Crop yield (or NRE) of ACA weighted by the areal coverage : $\mathrm{Yield}_{ACA} = (\mathrm{Yield}_{1m} \times \frac{2.5}{24}) + (\mathrm{Yield}_{4m} \times \frac{3}{24}) + (\mathrm{Yield}_{7m} \times \frac{16.5}{24}) + (\mathrm{Yield}_{24m} \times \frac{2}{24})$

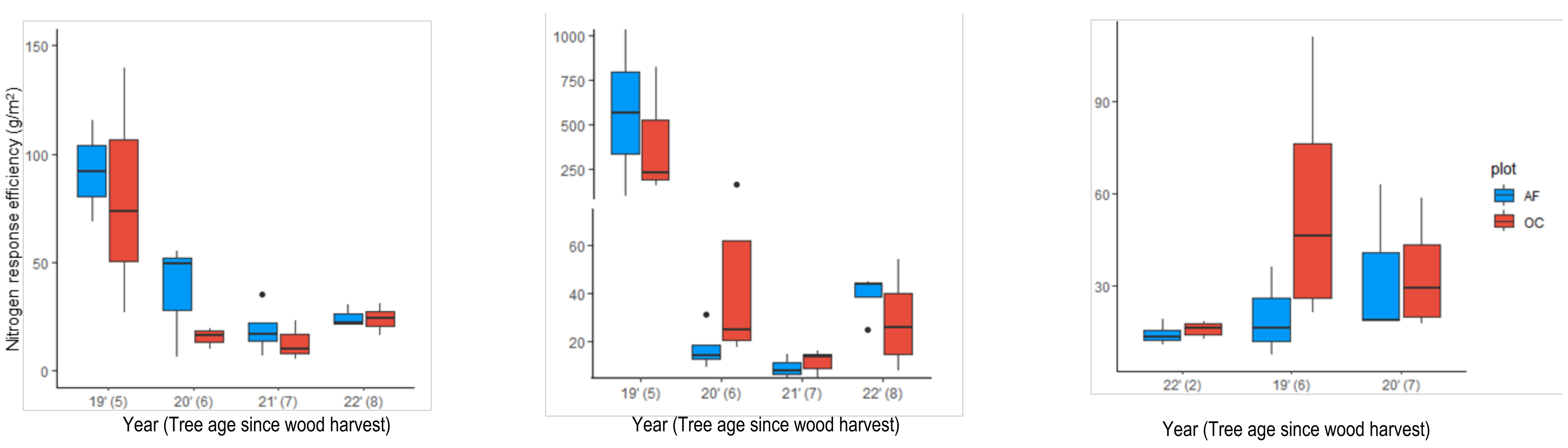
Study sites in Germany (Result from Vechta is not included in this poster)



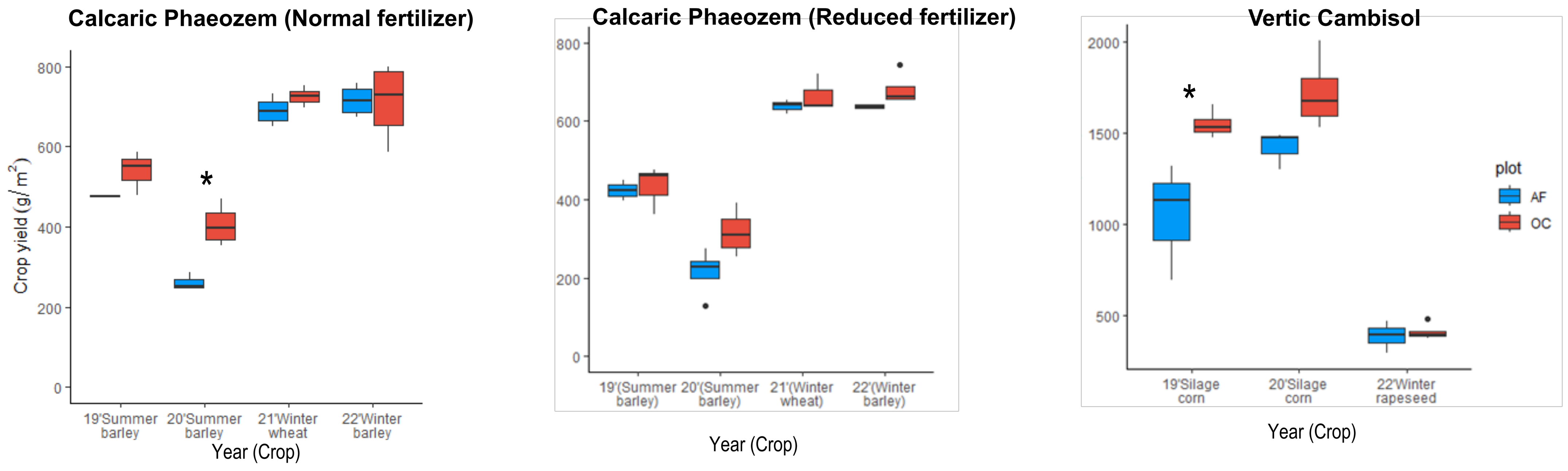
Sampling design of the SIGNAL agroforestry system and open croplands. Measurements are taken in the tree row, at 1 m, 4 m, 7 m, and 24 m away from the tree row, and from the open croplands, which is at least 50m away from agroforestry site.

Results

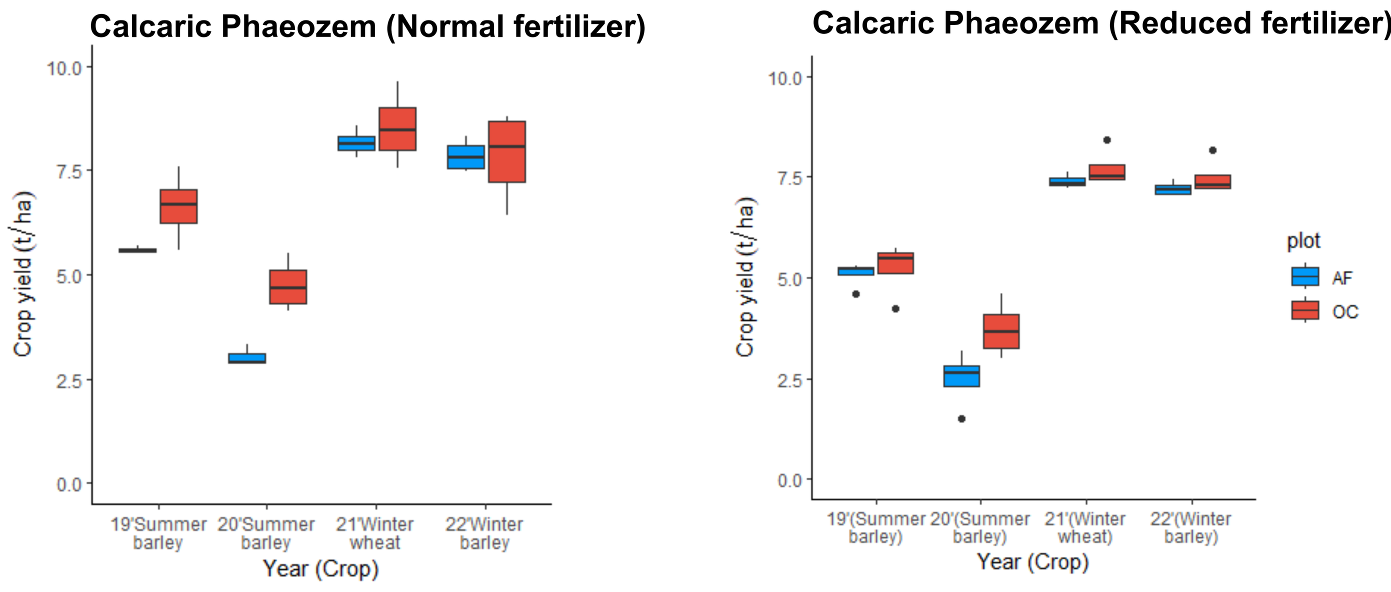
Nitrogen response efficiency (g/m²)



Crop yield (dry matter) (g/m²)



Crop yield (adjusted to standard moisture content) (t/ha)



Top row: Nitrogen response efficiencies (NRE) of crops at two sites, which indices were measured in the top 0.05-m depth during the growing season of 2019, 2020, 2021, and 2022. NRE did not significantly differ between crops in alley-cropping agroforestry (blue) and open croplands (red). Middle row: Dry matter of crop yield was measured and did not significantly differ between crops in alley-cropping agroforestry (blue) and open croplands (red) except in Calcaric Phaeozem (Normal fertilizer) in 2020 and Vertic Cambisol in 2019. Bottom row: Dry matter of crop yield was adjusted to standard moisture content in Calcaric Phaeozem at 86% moisture content.

- The same crop, summer barley, was grown in 2019 and 2020 at Calcaric Phaeozem. However, only in 2020, crop yield from open croplands was significantly higher than the agroforestry system. This might be due to older tree age since wood harvest.
- The opposite trend was observed in 2019 and 2020 at Vertic Cambisol. In 2019, at younger tree age since wood harvest, silage corn yield from open croplands was significantly higher than the agroforestry system than in 2020. Thus, tree rotation age might not be the main factor that affects the crop yield or plant available nutrient in agroforestry system.
- In general, productivity and nutrient recycling efficiency are not significantly different between alley-cropping agroforestry and open croplands.
- Between normal and reduced fertilizer sites in Calcaric Phaeozem (Dornburg), both crop yields and NRE did not differ at a significant level, which displays nutrient saturation at normal fertilizer sites.

Field descriptions

Site	Wendhausen	Dornburg
Soil type	Vertic Cambisol	Calcaric Phaeozem
Mean annual precipitation (mm)		
Long-term (2010-2021)	585 ± 34	580 ± 28
2019	578	485
2020	526	595
2021	628	692
Year of agroforestry establishment	2008	2007
First harvest of trees in agroforestry	Winter 2014	Winter 2015
Second harvest of trees in agroforestry	Winter 2021	-

Dornburg 8-year-old tree (in 2nd rotation) April 29, 2022

Dornburg 8-year-old tree (in 2nd rotation) September 27, 2022

Future research plan

- Assess the effect of tree age since wood harvest and inter-annual climatic differences on the NRE of different crops, crop yield, and the plant available nutrient between ACA and OC across 2016 to 2023
  - 4 sites from SIGNAL project
- Compare NRE of crops in ACA and other innovative crop management systems with conventional management from 2022 to 2023
  - 6 sites from SIGNAL project and 6 sites from BonaRes project

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