# Five years of cover cropping and its effects on soil carbon and nitrogen losses and characteristics of organic matter associated with fractions of different ecological meaning

Christopher Anuo, PhD student

Department of Agronomy and Horticulture

University of Nebraska Lincoln

# Background and Significance

- Soil management strategies that promote soil productivity while at the same time enhancing soil organic matter (SOM) sequestration are important for sustainable & resource efficient agro-ecosystems.

- The integration of **winter cover crops** in crop rotations primarily for soil protection against erosion has gained huge attention due to its additional potential to enhance soil organic carbon (SOC).

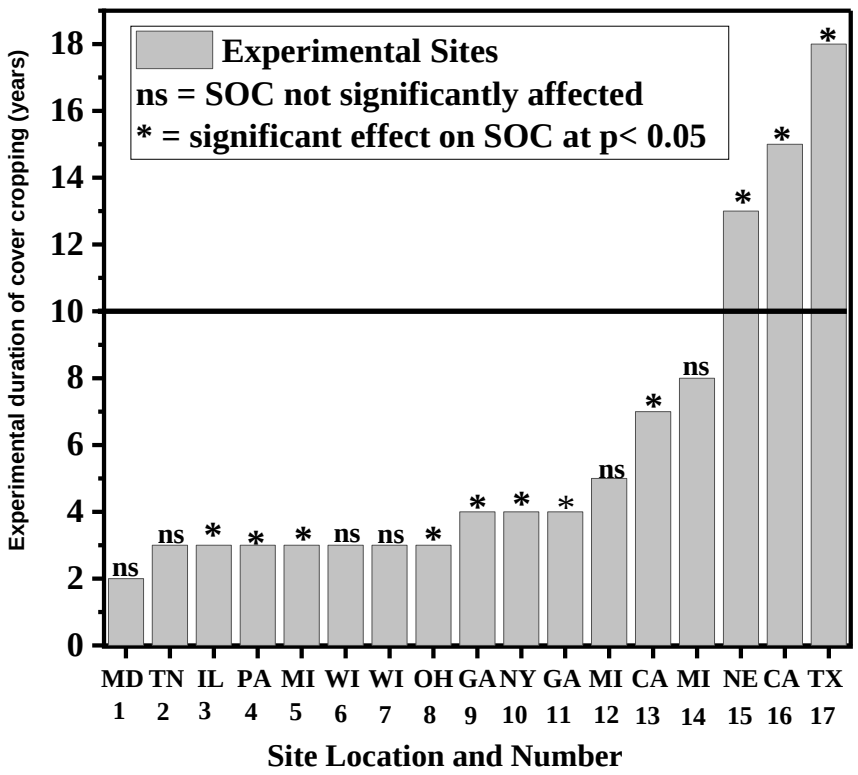
- Studies have shown that this management option could be more effective under **no till**.

*Bai et al. (2019); Bender et al. (2016);Plaza et al. (2013)*

*Photo credit: Jen Cooper*

# Literature Review

a)




b)

Soil characteristics, biomass production, and tillage intensity for study sites <u>with < 10 years</u> experimental duration : mean values ± standard error (n). n represents number of sites. Data were almost normally distributed and were tested using two sample t-test at p = 0.05

| | Study sites with a significant effect on SOC | Study sites with no significant effect on SOC |
|---|---|---|
| Initial SOC (g kg $^{-1}$) | 14.9 ± 3 (n = 8) | 13.7 ± 3 (n = 6) |
| Silt (%) | 42.1 ± 6 (n = 8) | 52.8 ± 4 (n = 6) |
| Clay (%) | 19.1 ± 3 (n = 8) | 17.8 ± 2 (n = 6) |
| Silt+Clay (%) | 61 ± 8 (n = 8) | 71 ± 5 (n = 6) |
| Sampling depth (cm) | 11.6 ± 3 (n = 8) | 19 ± 3 (n = 6) |
| Biomass production | 2.9 ± 0.9 (n = 3) | 2.8 ± 0.5 (n = 6) |
| Conventional tillage | n = 0 | n = 1 |
| Reduced tillage | n = 5 | n = 3 |
| No tillage | n = 3 | n = 4 |

a) Experimental duration of cover cropping and its effect on soil organic carbon (SOC) for 17 study sites (1: Wang et al., 2017; 2: Chu et al., 2017; 3-5: Jilling et al., 2020; 6: Cates et al., 2019; 7: Cates and Jackson, 2018; 8: Stavi et al., 2012; 9: Sainju et al., 2015; 10: Nunes et al., 2018; 11: Hubbard et al., 2013; 12: Ladoni et al., 2016; 13: Wolff et al., 2018; 14: Snapp and Surapur, 2018; 15: Sharma et al., 2018; 16: Mitchell et al., 2017; 17: Lewis et al., 2018) within the US (MD: Maryland, TN: Tennessee, IL: Illinois, PA: Pennsylvania, MI: Michigan, WI: Wisconsin, OH: Ohio, GA: Georgia, NY: New York, CA: California, NE: Nebraska, TX: Texas) and 1 b) information about differences in soil characteristics, biomass production, and tillage intensity for study sites with < 10 years of cover cropping that show a significant effect on soil organic carbon (SOC) and for those that do not show a significant effect on SOC.

*Anuo et al., (submittedd to SSSAJ)*

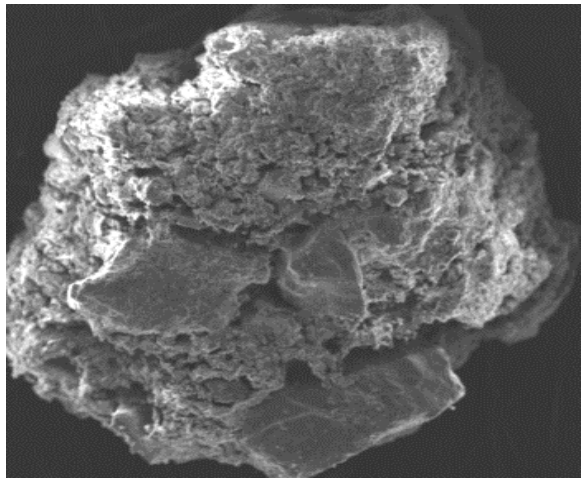
# Review - Take Home Messages

- The inconsistent positive effect highlights the need for a more detailed understanding of the interaction between cover crop and soil organic carbon dynamics within the **first ten years** after introduction of cover crop into crop rotations.

- Furthermore, majority of the studies only investigated cover crop effect on bulk soil organic matter but did not investigate soil organic matter fractions.

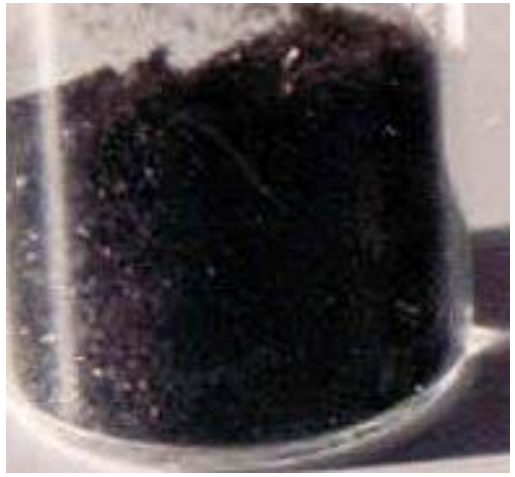
- These fractions show highly contrasting physical & chemical properties, mean residence time in soils, and respond differently to management.

free-POM



o-POM

WEOM



MAOM

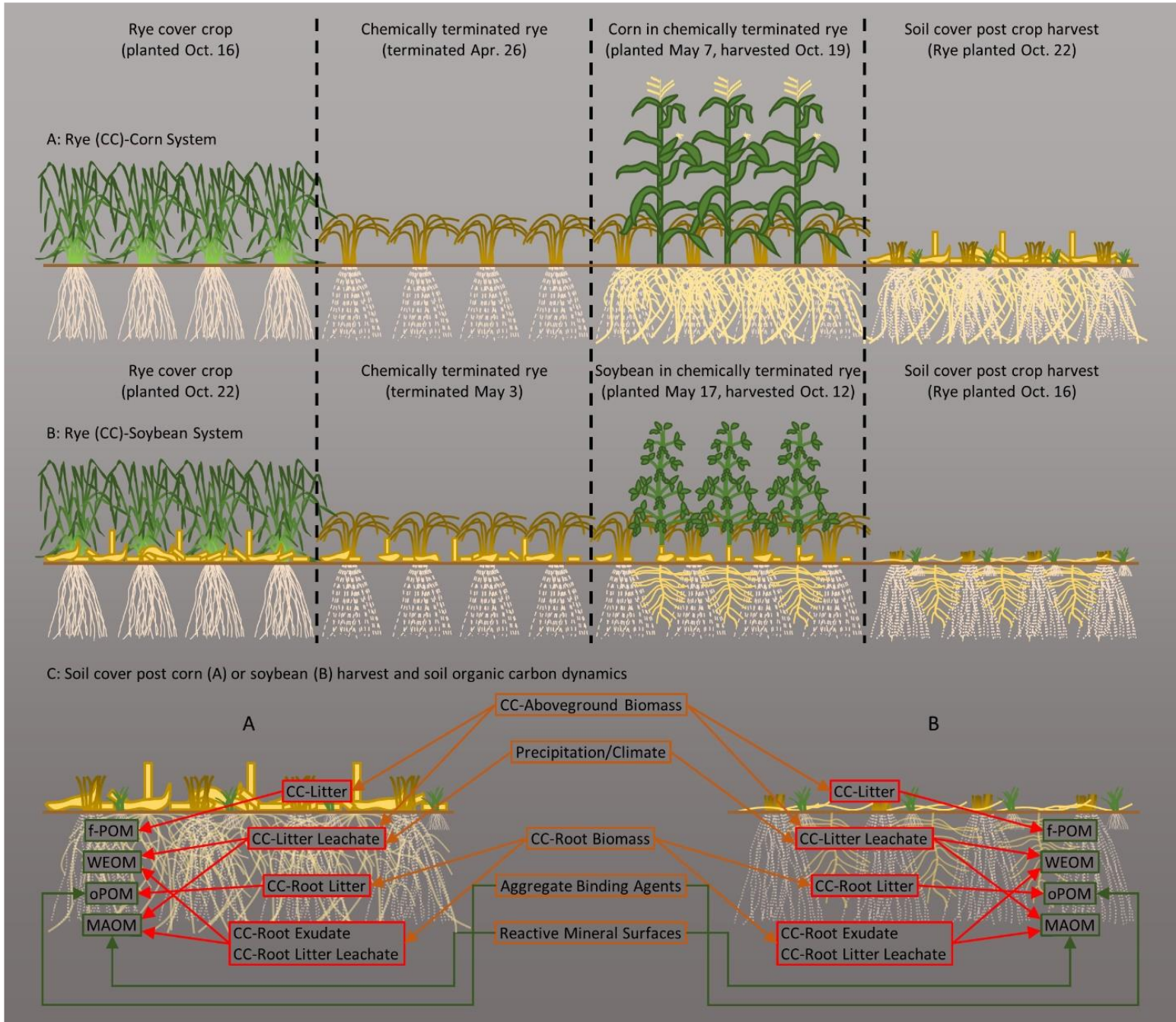
- Soil organic matter fractions includes; free particulate organic matter (f-POM), occluded particulate organic matter (o-POM), water extractable organic matter (WEOM), & the mineral associated organic matter (MAOM).

- Information from soil organic matter fractions are important to define soil ecological boundaries that are most promising for short-term (i.e., < 10 years) significant improvement of soil organic carbon storage due to cover cropping.

# How do cover crops affect soil organic matter fractions?

- The litter pathway
- The dissolved organic carbon (DOC) pathway
- The root pathway

- All three pathways and their quantitative contribution to soil organic matter over time are controlled by various sets of:
- **Management** (e.g., tillage intensity, crop rotation, fertilization)
- **Environmental** factors (e.g., climate, soil texture).
- Implying their relative importance is highly site specific.




*Anuo et al., (submittedd to SSSAJ)*

# Objectives

**The objectives of this study were to clarify and quantify short-term (i.e., <10 years) cover crop effects on:**

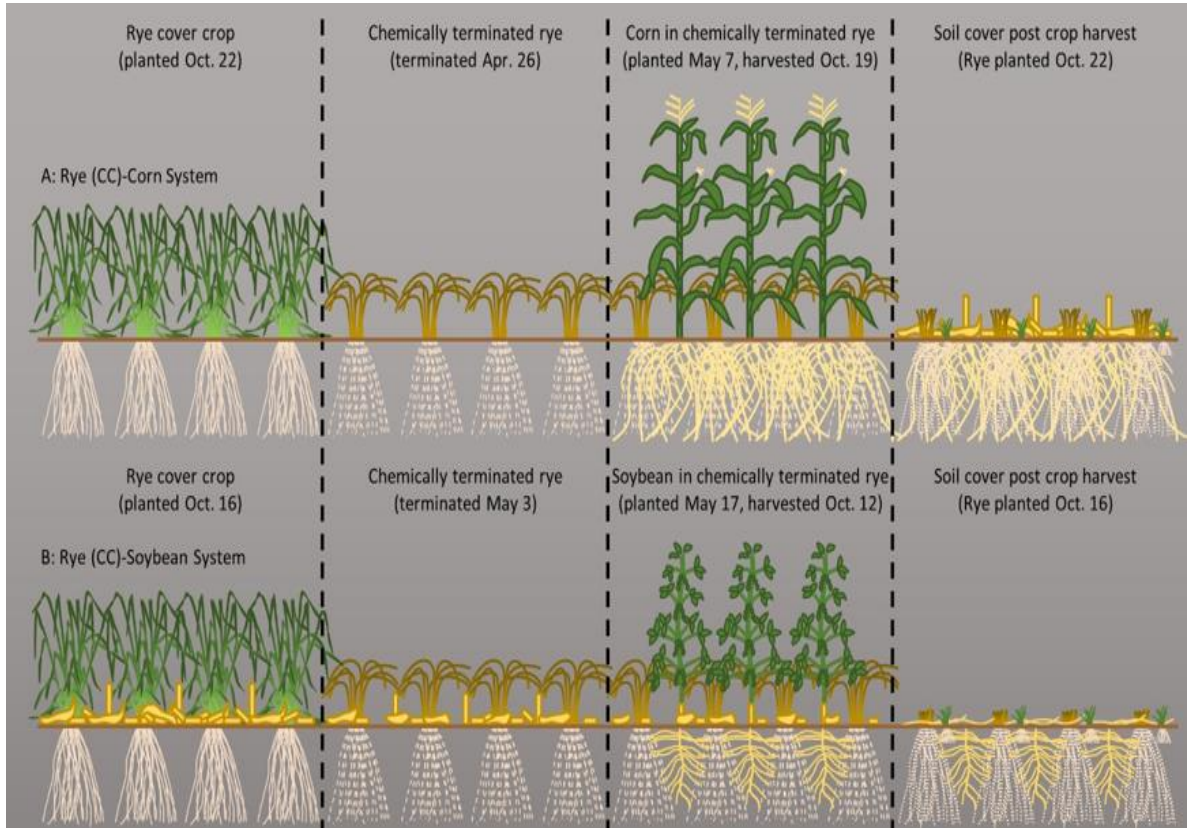
**(i) soil organic carbon(OC) and total nitrogen(N) in the bulk soil organic matter and fractions of different soil ecological relevance,**

**(ii) and on potential losses of OC and total N via leaching and decomposition.**

# Materials and Methods

## Field experiment: University of Nebraska Research and Extension Center near Clay Center, NE

- **Corn-soybean systems (one field was in corn, the other in soybean).**
- **Treatments: Rye cover crop and no rye as control**
- **Duration of cover cropping: 5 years**
- **Soil samples were collected before planting and after harvesting**
- Silt loam
- No-till, irrigated
- Cover crop was terminated with Glyphosate




| SOC ( g $kg^{-1}$) | Total N (g $kg^{-1}$) | Depth (cm) | pH | % Sand | % Clay | % Silt |
|---|---|---|---|---|---|---|
| 18.3 | 2.0 | 0 - 10 | 6.7 | 10 | 30 | 60 |

# Greenhouse gas and leachate measurements

- Soil columns (20 cm diameter x 20 cm tall, PVC) were collected from each field plot at a depth of 0-10 cm at the same time as pre-planting soil samples were collected (April 2019).
- Soil columns were transferred to the greenhouse were the incubation study lasted for 20 weeks.
- The temperature and humidity of the greenhouse was kept at 20 $^{o}$C and ~ 60 % respectively.
- We measured organic carbon (OC) and N losses from topsoil via decomposition using gas chromatography.
- Dissolved OC and N losses via leaching was measured using total organic carbon analyzer

# Soil Organic Matter Fractionation

- Samples were fractionated using a combined physical and chemical fractionation method based on size, density, and solubility.

**10 g bulk soil sample**

↓

**Electrostatic attraction** → **free POM (f-POM)**

↓

**Mixing with $H_2O$**

Skimming floating particle ↑

Shaking for 12 h, filtration → **Water-extractable OM (WEOM)**

↓

**Sonication I**
**Dispersion Macro-Aggregates**

Ultrasonication @ 60 J $cm^{-3}$

Pipetting organic particles >53 µm and sieving mineral particles >250 µm → **Macro-Aggregate occluded POM (MA-oPOM)**

↓

**Sonication II: Residue <250 µm**
**Dispersion Micro-Aggregates**

Ultrasonication @ 440 J $cm^{-3}$

Sieving mineral particles >53 µm

↓

**Sonication III: Residue <53 µm**
**Dispersion small Micro-Aggregates**

Ultrasonication @ 500 J $cm^{-3}$

Sieving mineral particles >20 µm → **Mineral Particles + small Micro-Aggregates <20 µm**

↓

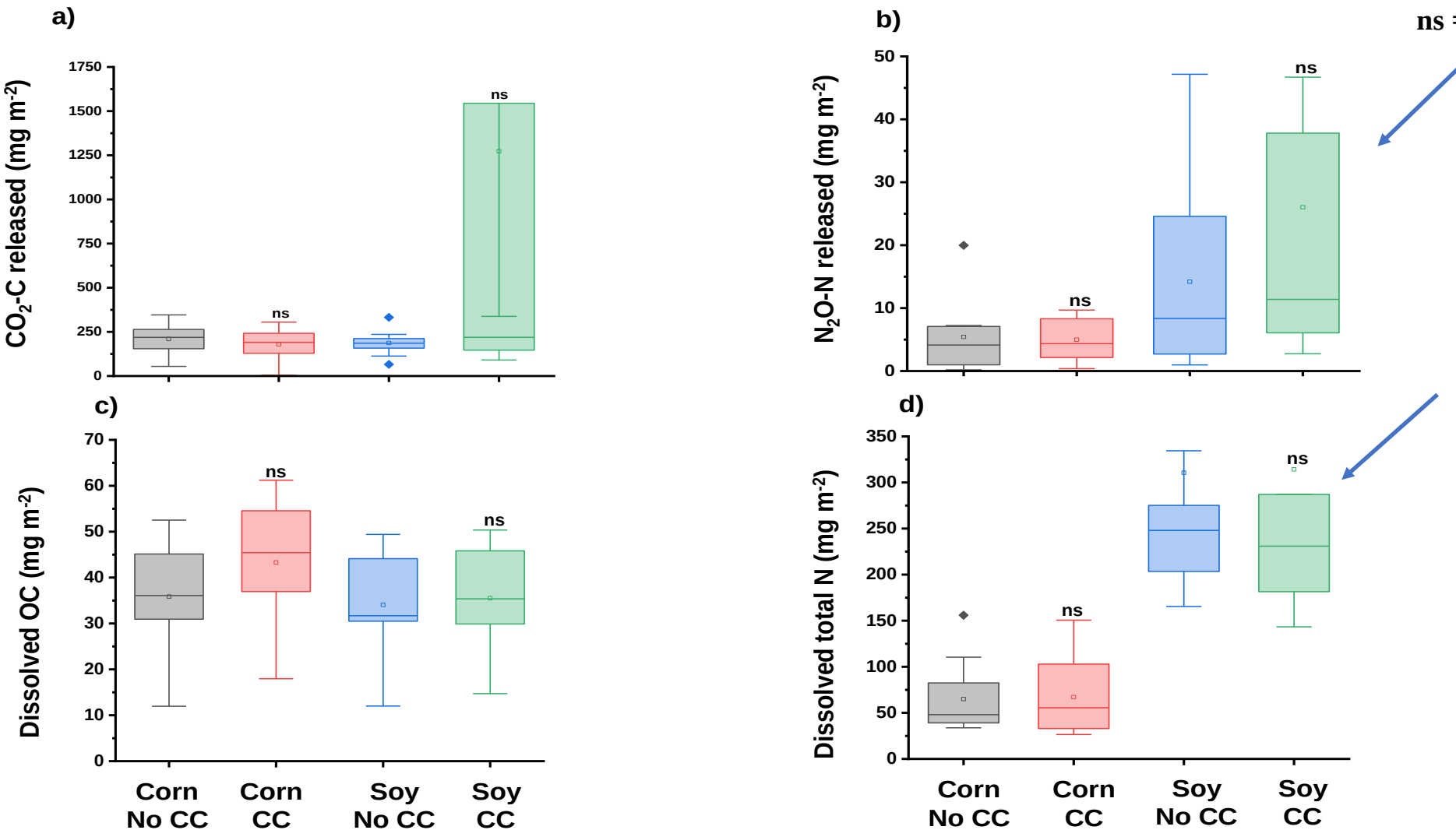
**Mineral-Associated OM (MAOM)**

*Remus et al (2018); Kaiser & Berhe (2014)*

# Results

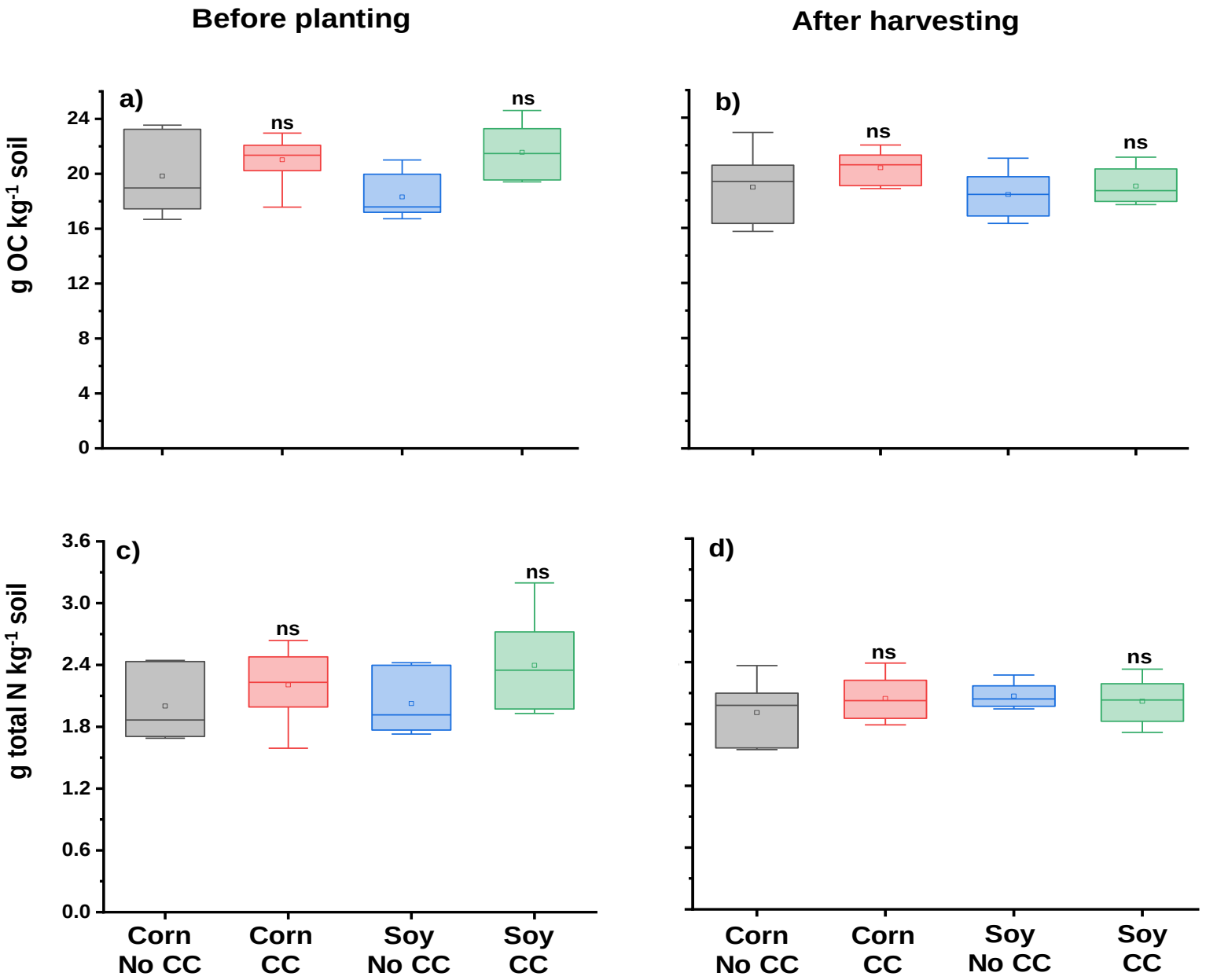
## C and N losses via Decomposition and Leaching

P = 0.05
ns =not significant



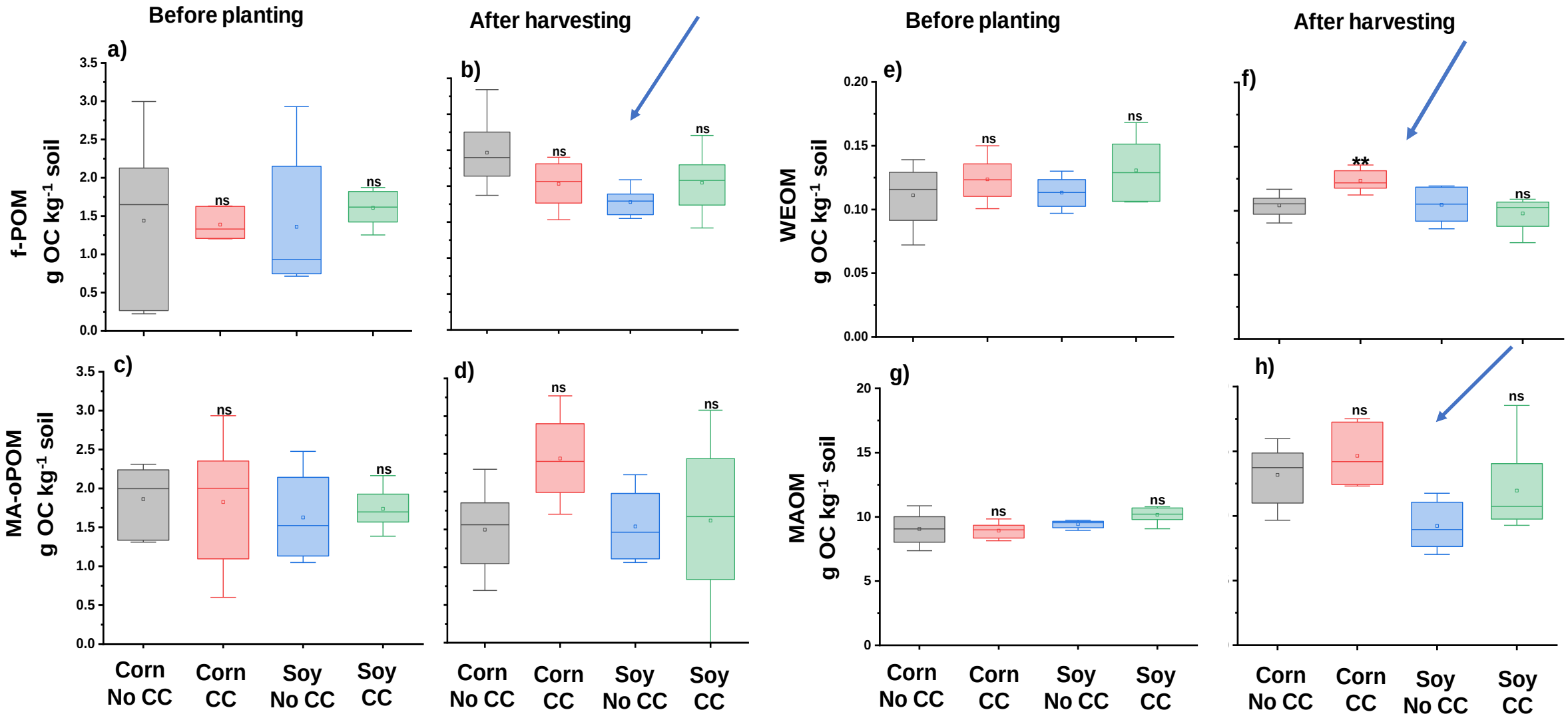
# OC and N in Bulk Soil

P = 0.05
ns = not significant

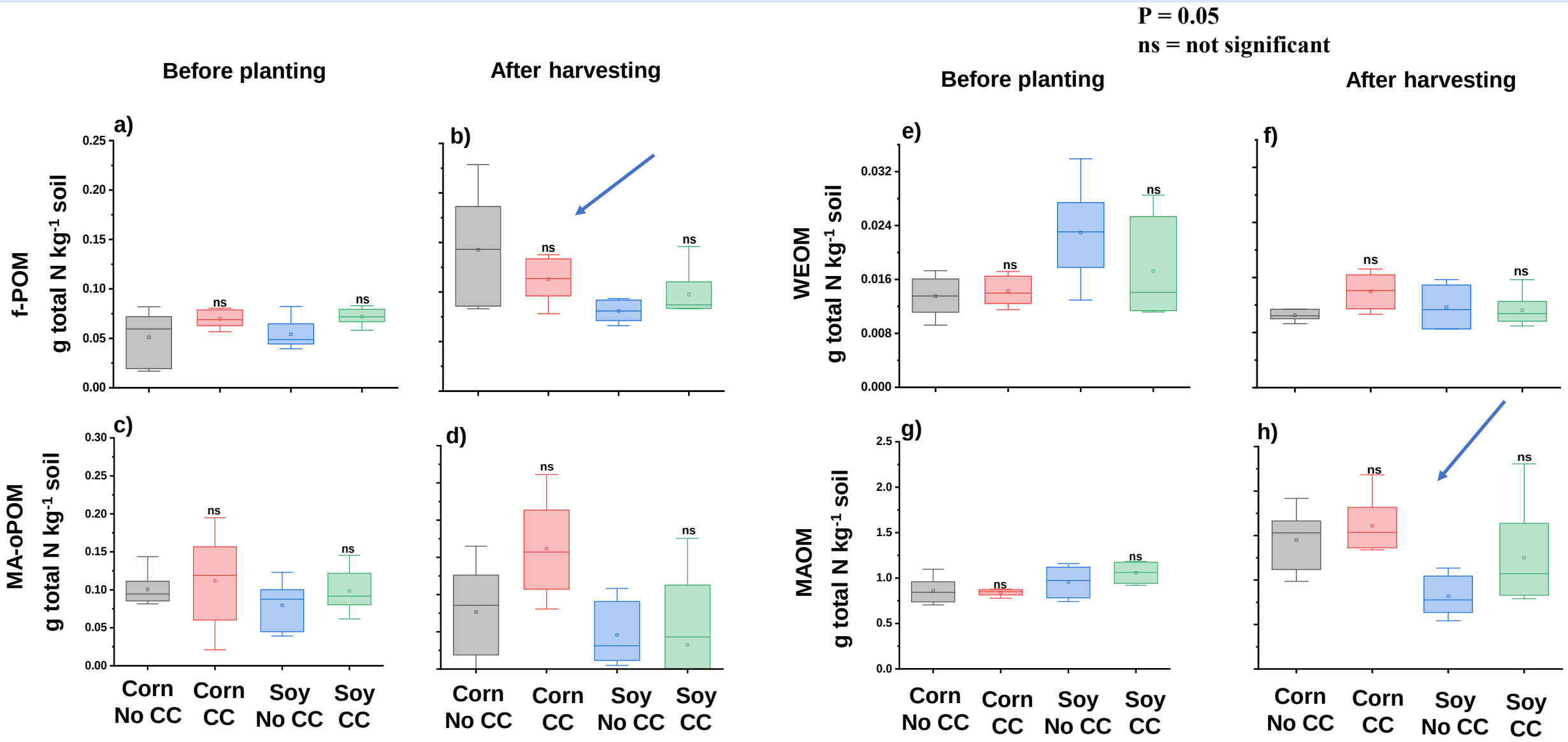


# OC in soil organic matter (SOM) fractions

P = 0.05
** = significant
ns = not significant



# N in soil organic matter fractions



# Summary

- Our data showed no effects of CC on soil OC and N losses (gaseous and leaching) and on bulk soil OC and N storage.
- Differences were found among SOM fractions with more pronounced CC effect detected in the WEOM fraction.
- To significantly increase the OC and N storage in 0-10 cm depth under the given site conditions, more than five years of cover cropping seem to be necessary.
- Increasing the relatively low aboveground and belowground CC biomass in the systems analyzed should be considered as a strategy to accelerate soil OC accumulation.