CONSERVATION AGRICULTURE: AN EFFICIENT TOOL TO REDUCE N LOSS?

20 YEARS OF NON-INVERSION TILLAGE AND STRAW RETENTION

JORGE F. MIRANDA VÉLEZ
DEP. OF AGROECOLOGY – AARHUS UNIVERSITY

Overview:

1. Our approach to Conservation Agriculture (5 min)

2. The CENTS experiment (5 min)

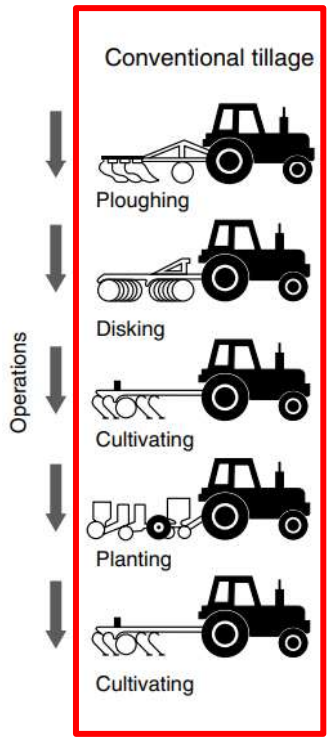
3. Effects of no-till and straw retention on Yield and N-leaching (5 min)

    a) Average effects after 10 years and onwards

    b) Trend of effects throughout 20 years of the experiment

Intensive agriculture is hard on soils

Mechanized tillage is associated with many negative effects on soils



(Modified from:
Hallet & Bengough, 2013)

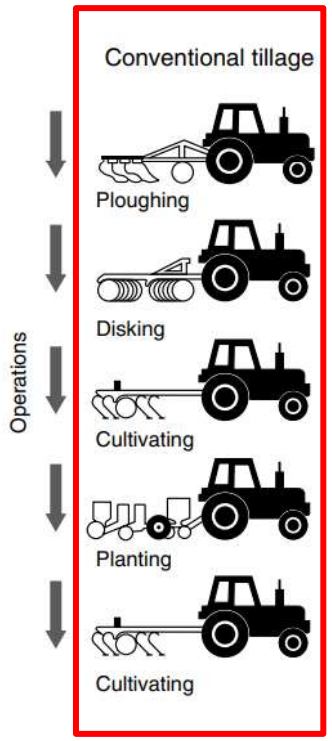
Direct erosion

Compaction

Complicated changes to soil structure

Intensive agriculture is hard on soils

Things are made worse by long periods of bare fallow, low crop diversity and low OM inputs to the soil



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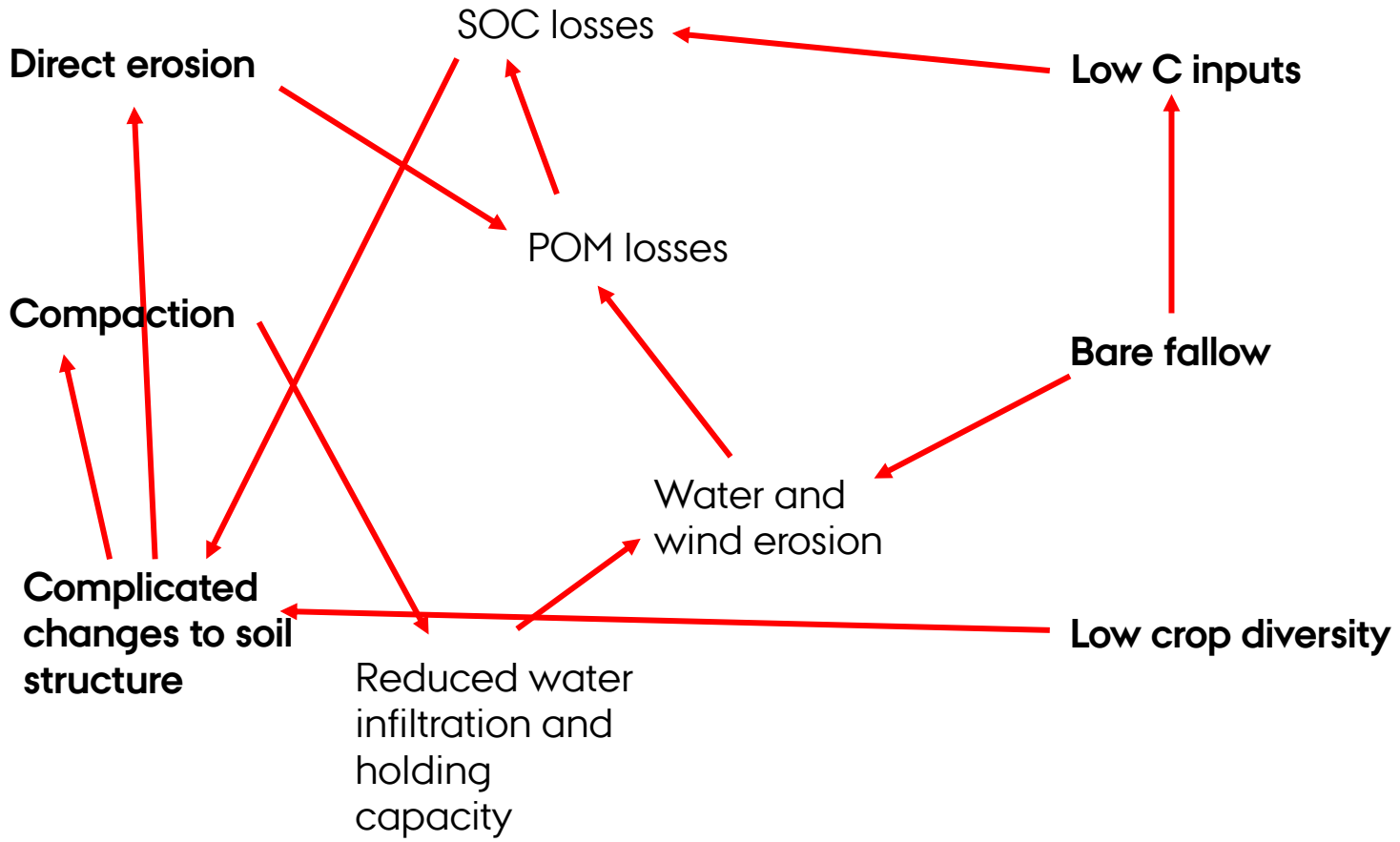
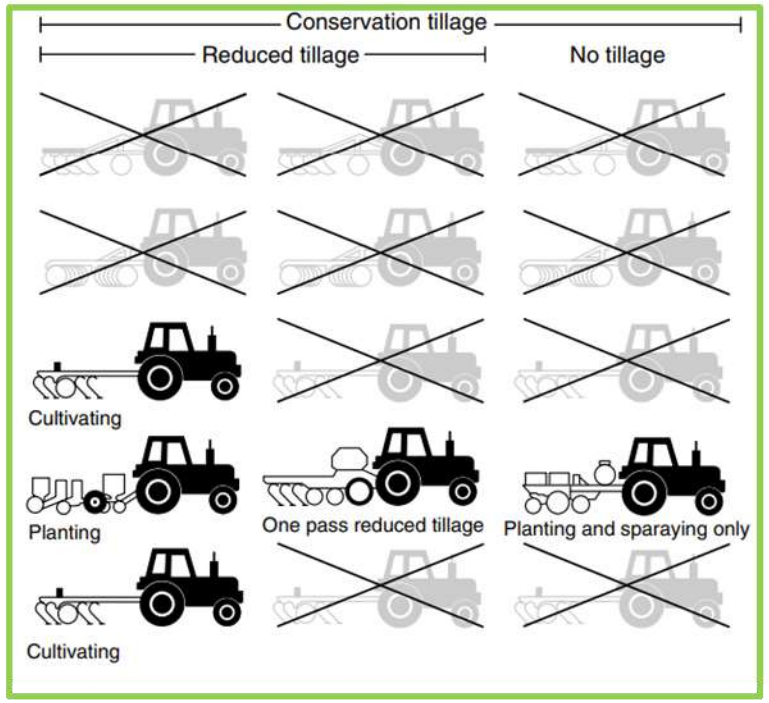


Conservation Agriculture tries to address this

Plant cover between crops (**cover crops**) and **residue retention** reduce erosion and increase SOC

Conservation tillage practices (**non-inversion, no-till**) reduce the direct effects



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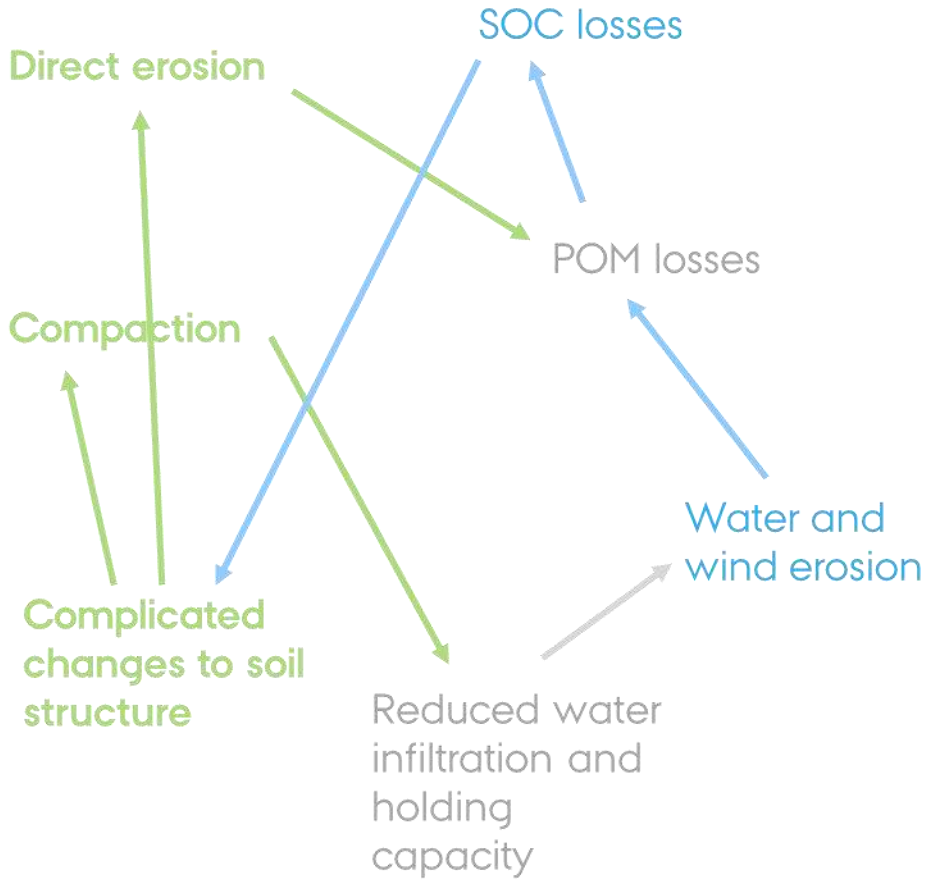


(Fodder radish in CENTS Flakkebjerg)

(Straw retention in CENTS Foulumgård)

Diverse **crop rotations** help fight weeds, improve soil microbiome and improve soil structure, requiring **fewer mechanical interventions**

But how does CA affect N losses?

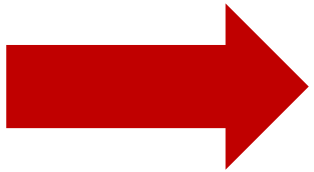
Expectation:

- Higher water holding capacity
- Slower SOM mineralization
- Slower cover crop and crop residue decomposition

Effect?

Reduced N-leaching

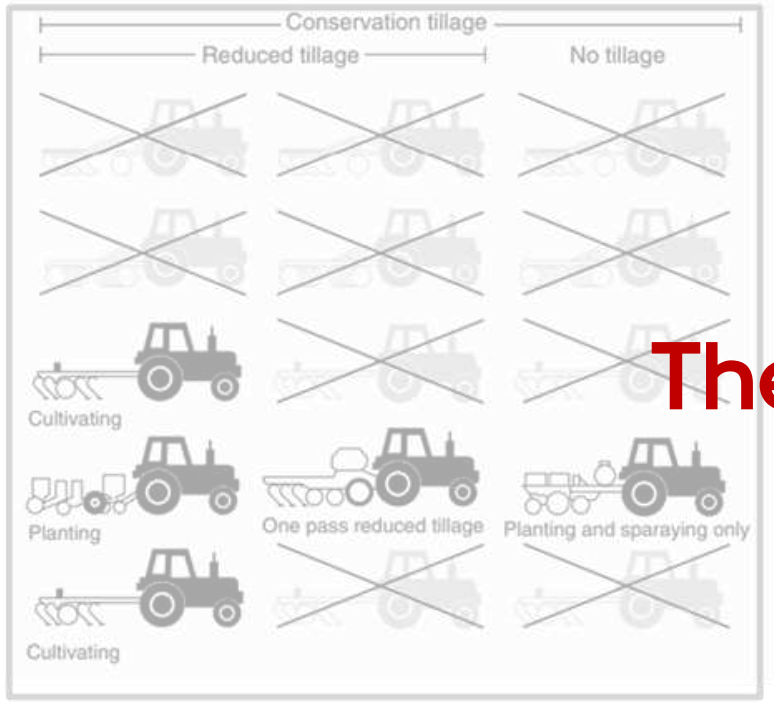
- Higher water infiltration
- Lower crop yields
- Lack of mixing of C-rich residues in the soil



Increased N-leaching

Conservation agriculture tries to address this

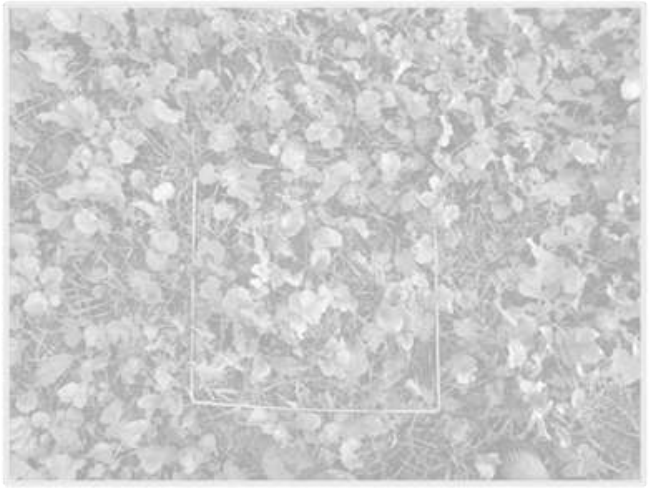
Conservation tillage practices (**non-inversion, no-till**) ameliorate the direct effects



(Modified from:
Hallet & Bengough, 2013)

Note:
These changes take years

Plant cover between crops (**cover crops**) and **residue retention** reduce erosion and increase SOC



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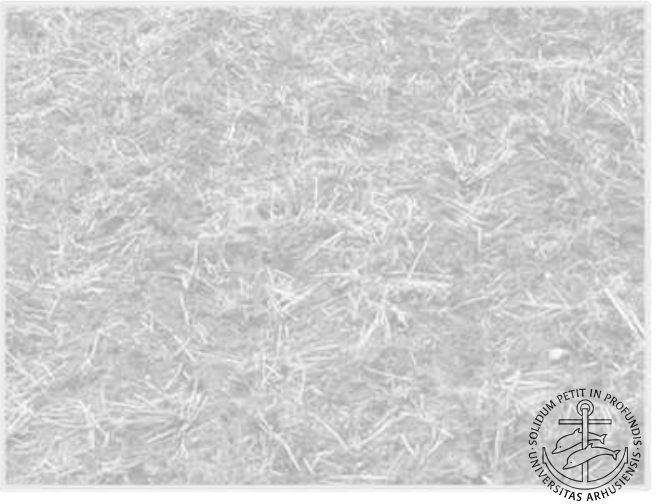


Diverse **crop rotations** help fight weeds, improve soil microbiome and improve soil structure, requiring **fewer mechanical interventions**

The CENTS experiment
(2002-present)

Weighed DM yields every year in 3 parallel rotations

Measured subsoil NO_3^- (1 m depth) every ~2 weeks and calculated N-leaching

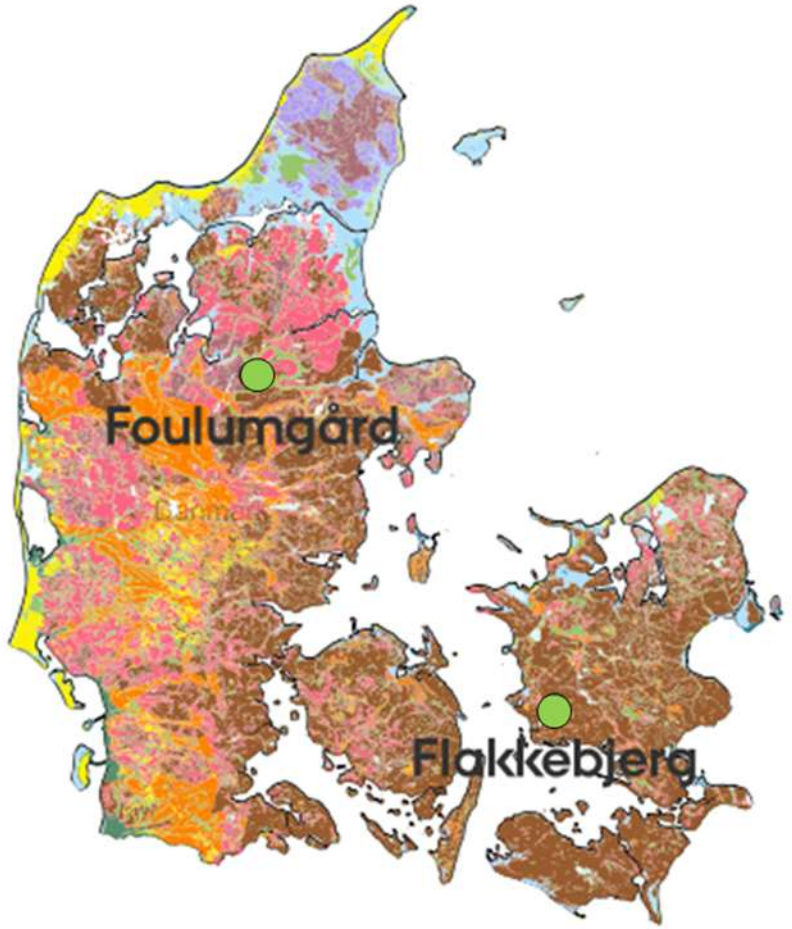
Many other measurements that we won't discuss today

(CENTS in Foulumgård, 2016)

The CENTS experiment
(2002-present)

Soil types/climates:

- AU Viborg (Foulumgård) – JB4
- AU Flakkebjerg – JB6



The CENTS experiment
(2002-present)

Soil types/climates:

- AU Viborg (Foulumgård) – JB4
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Straw management:

- **Removed after harvest (Straw-)**
- **Retained on surface (Straw+)**

(CENTS in Foulumgård, 2025)

The CENTS experiment (2002-present)

Soil types/climates:
- AU Viborg (Foulumgård) – JB4
- AU Flakkebjerg – JB6

Straw management:
- Removed after harvest
- Retained on surface

Tillage:

- **Plough (20 cm)**
- **Harrowing (8-10 cm)**
- **No-till (direct sowing)**

(Ploughing in Flakkebjerg, 2005)

(Direct sowing in Flakkebjerg, 2015)

<u>These results are not published (or peer-reviewed) yet</u>

They may change (a little) as we finish our analyses

Please contact me if you want to be updated when the results are published

Average DM yields (2012-2022)

We first calculated the average yield of each crop across all the times it was harvested in 11 years.

	Crop	Avg. yield	95% Conf. int.
	ton per ha DM		
2012 -2022	W. rape	**2.5**	1.3 – 3.6
	Fava bean	**3.6**	2.6 – 4.5
	S. barley	**4.6**	3.8 – 5.4
	W. barley	**5.6**	4.6 – 6.6
	Oat	**6.0**	5.2 – 6.8
	W. wheat	**6.7**	6.3 – 7.5
	W. rye	**8.0**	7.1 – 8.9

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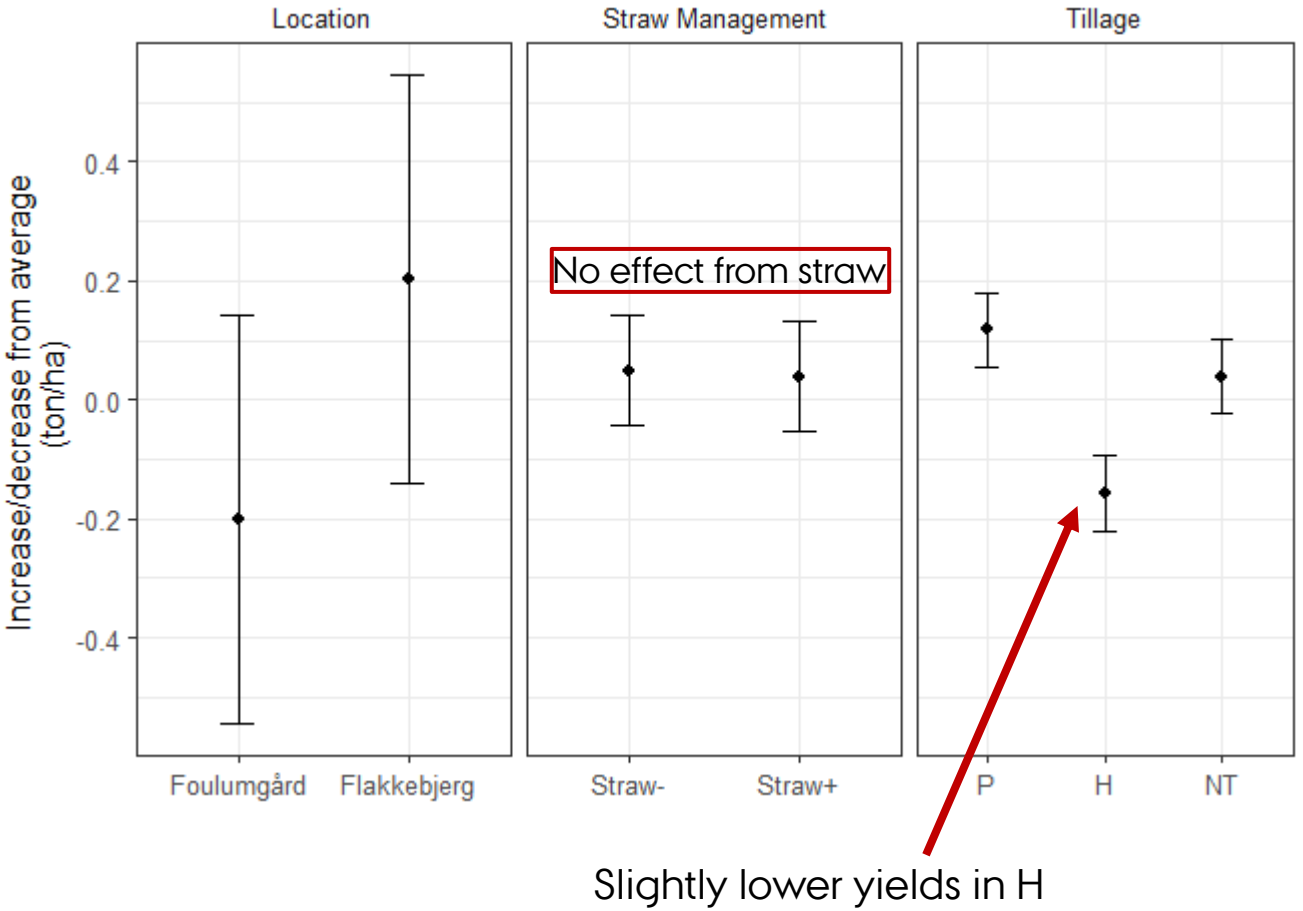
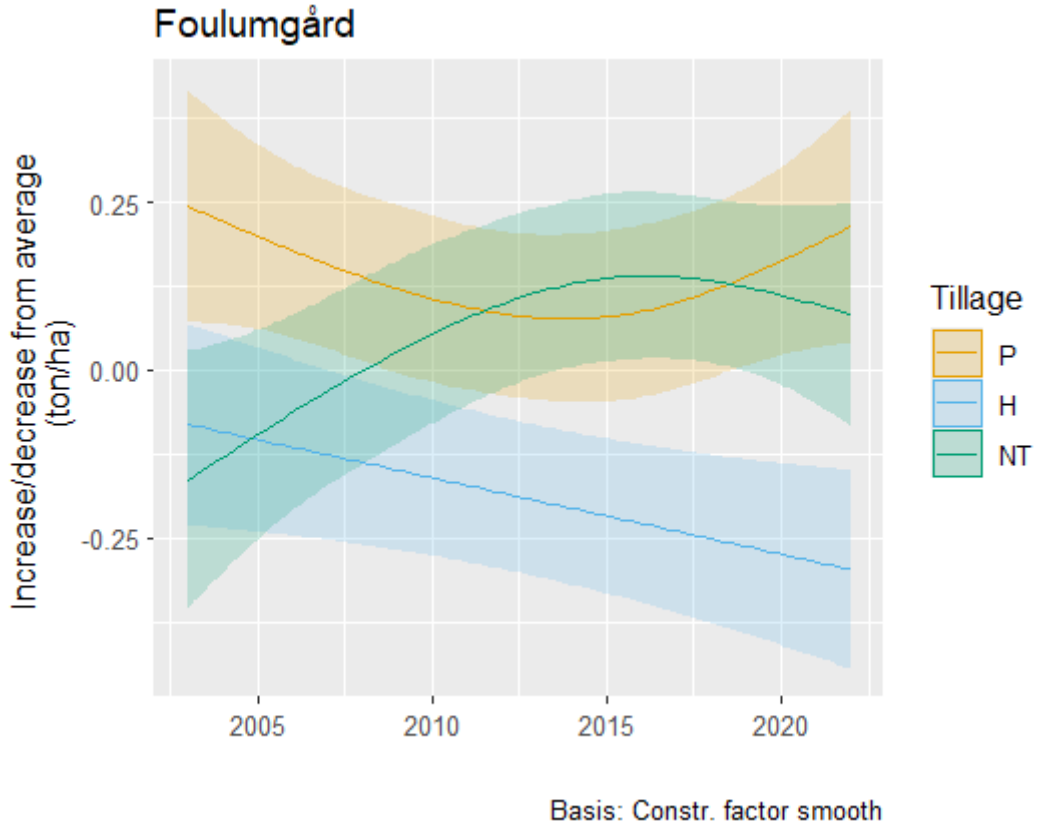
Then we calculated whether straw management or tillage would in general make all yields lower or higher.

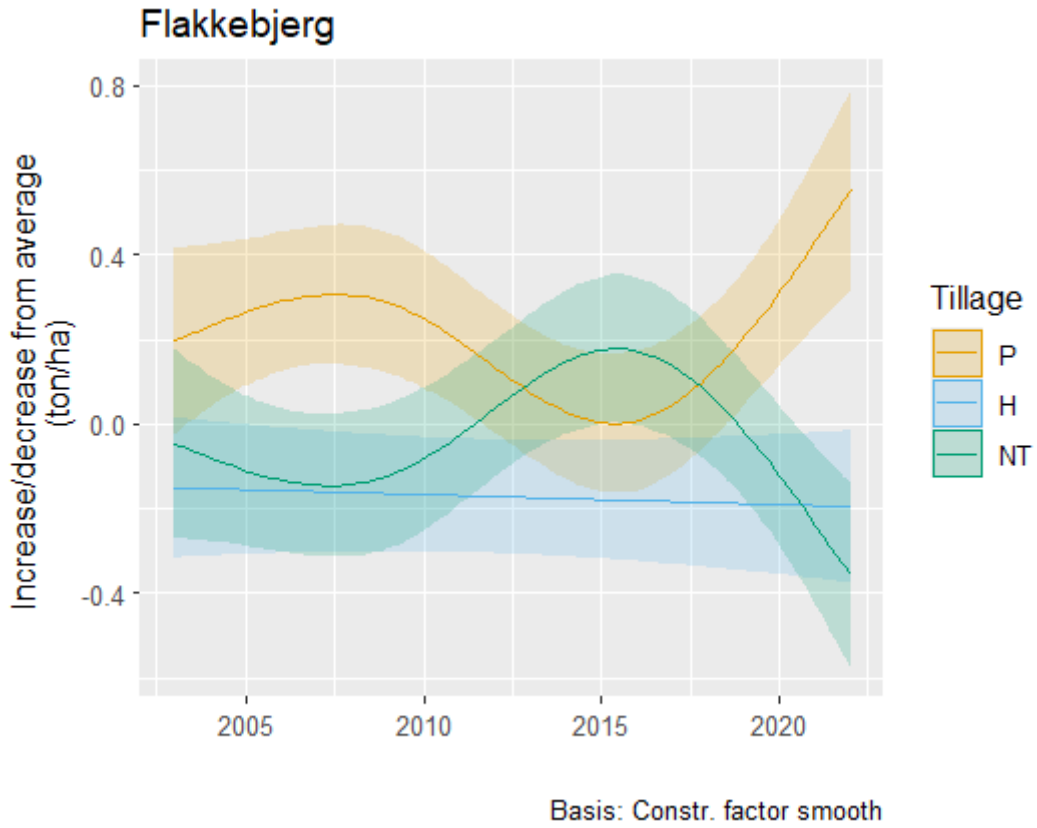


Slightly lower yields in H

Yield increase/decrease over time

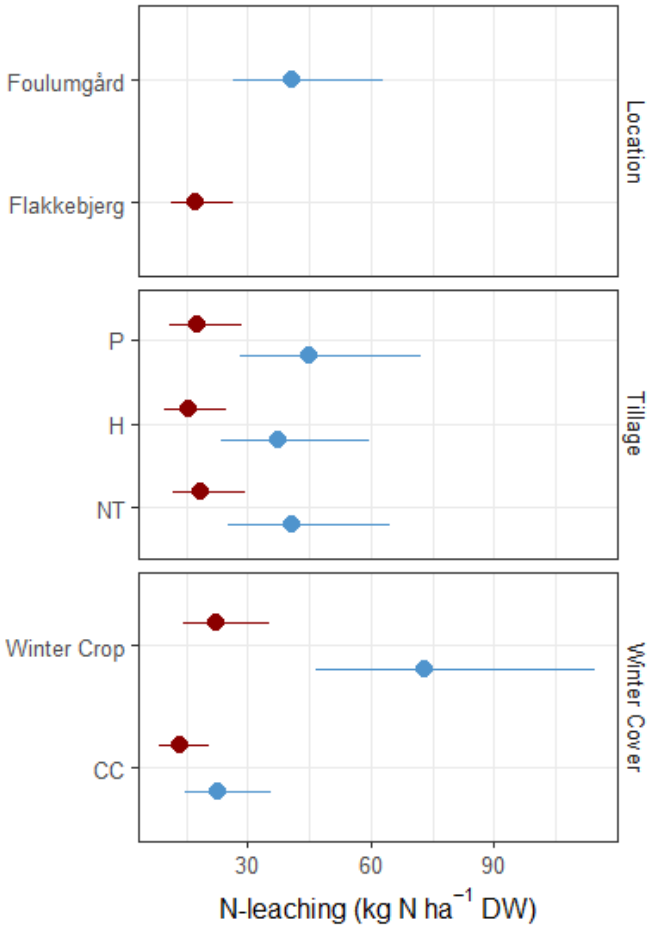
Similar approach, but treating the yields as a timeline, and seeing how the effects of straw and tillage have changed across 20 years





Yields in H and NT are reduced in the first years
BUT
Yields in NT catch up to P in the long term

Average N-leaching 2012-2020



Higher N leaching in Foulumgård (Jutland, JB4)

<u>Slightly</u> lower N-leaching in H in both locations.
<u>Slightly</u> lower N-leaching in NT in Foulumgård.

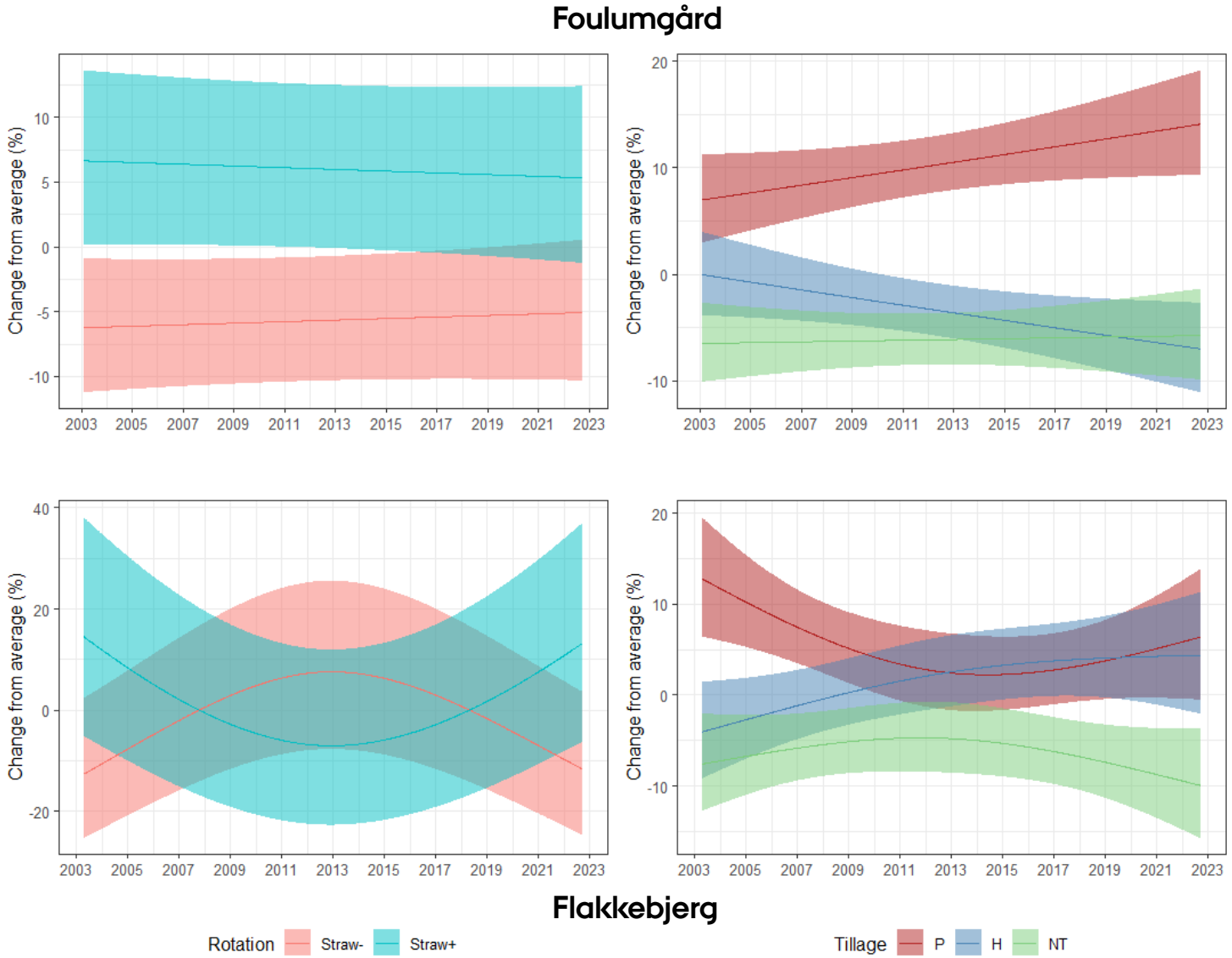
N-leaching is roughly halved with CC's compared to winter crops
(The net difference is smaller in Flakkebjerg)

And no effect from straw management

Nitrate in the subsoil (1 m depth) over time

Slightly lower soil NO3- at 1 m depth <u>without</u> straw

No clear effect from straw



Lower soil NO3- in H and NT, the difference has increased through time

Lower soil NO3- in NT, but H lost its effect after a few years

Take-home messages:

- The effects of tillage continue to develop after 20 years
- Harrowing reduced yields (a little) but No-Till matched ploughing after ~10 years
- Ploughing leads to slightly higher subsoil NO_3^- and N-leaching
- Straw management had little to no effect on yields and N-leaching

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PlanteKongres 2026

Tillage and residue management influence on N_2O emissions in three Danish Fields

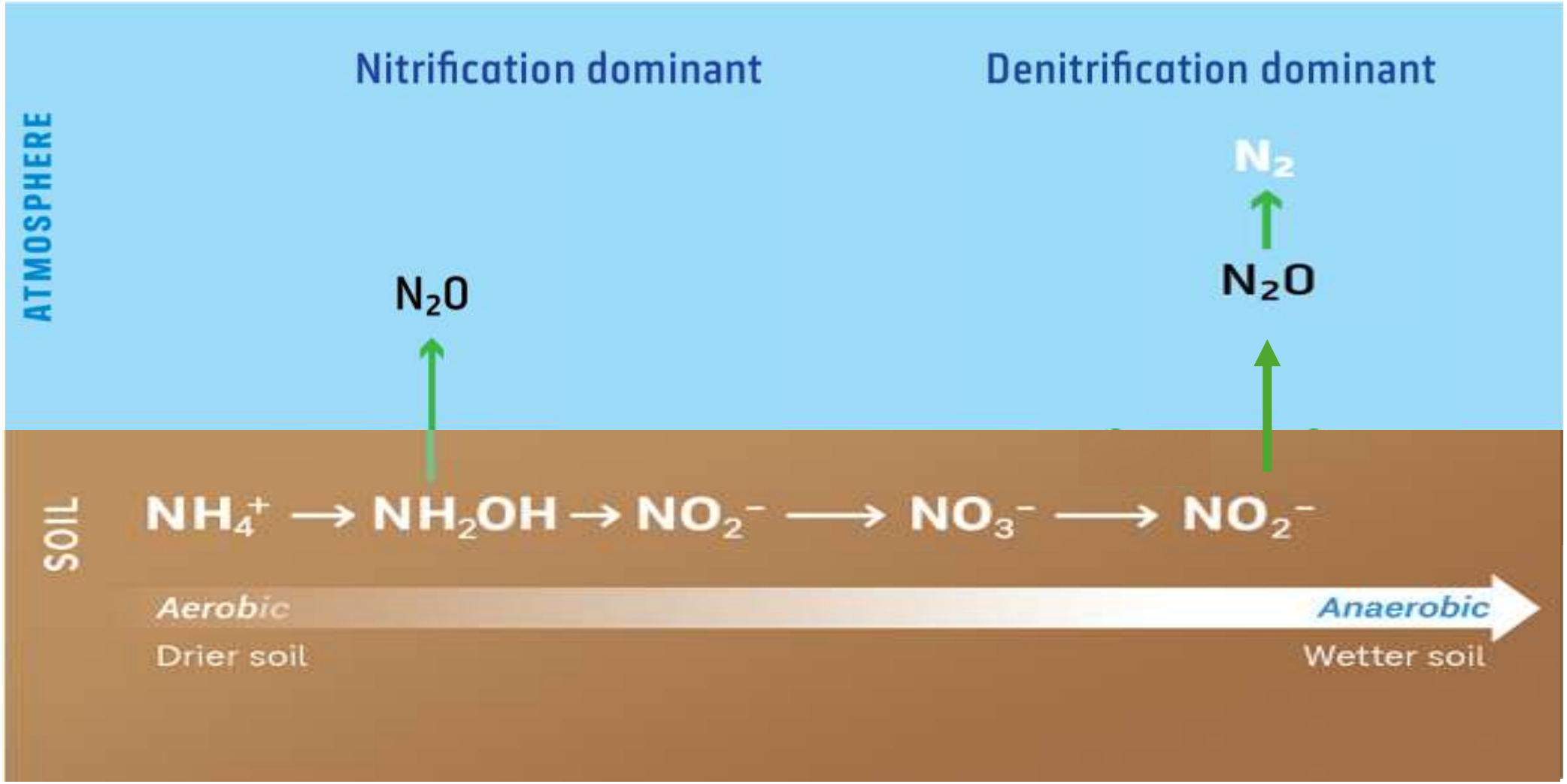
Harika Bommisetty, PhD student

Department of Agroecology

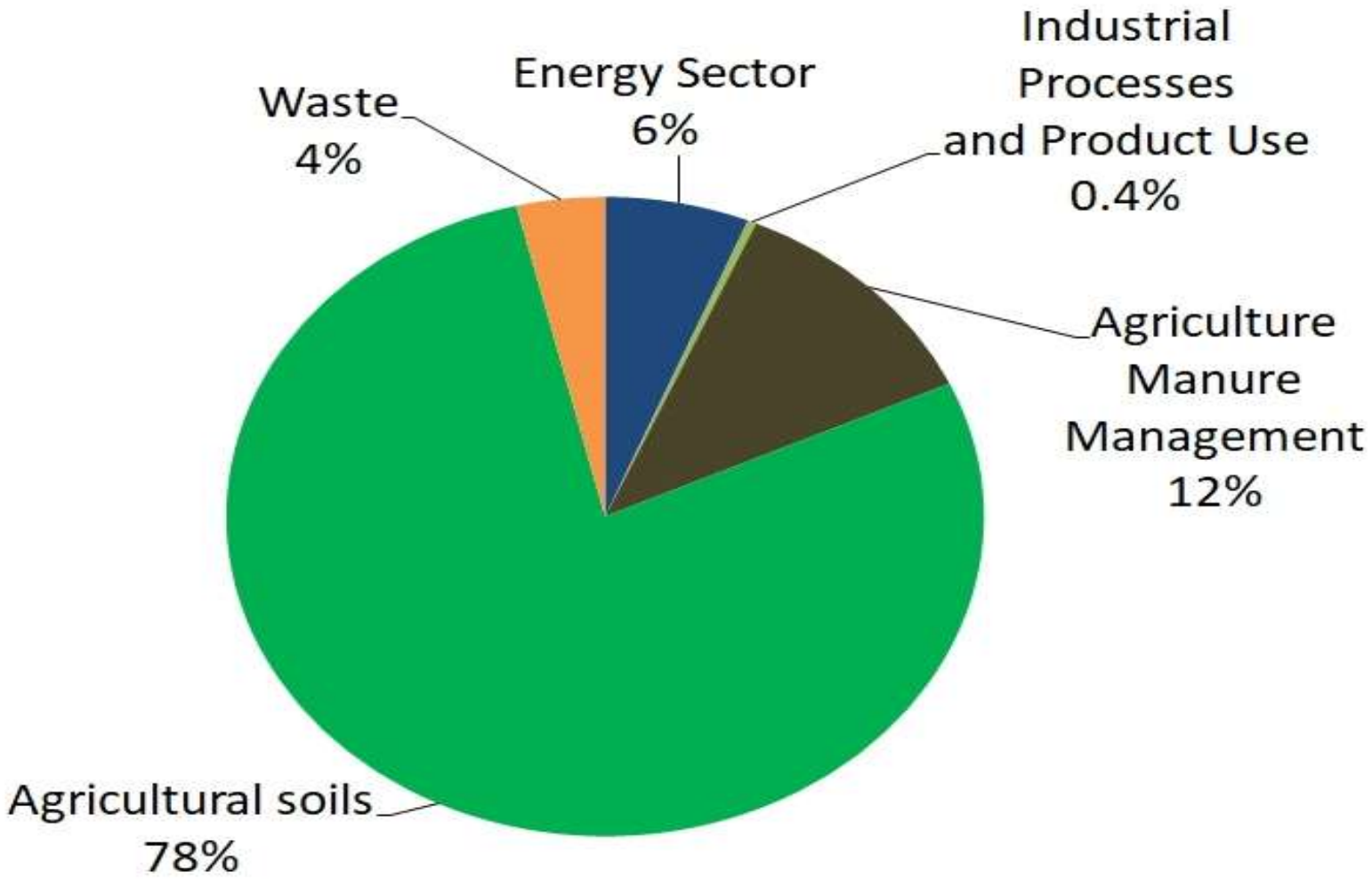
Aarhus University

AARHUS UNIVERSITY

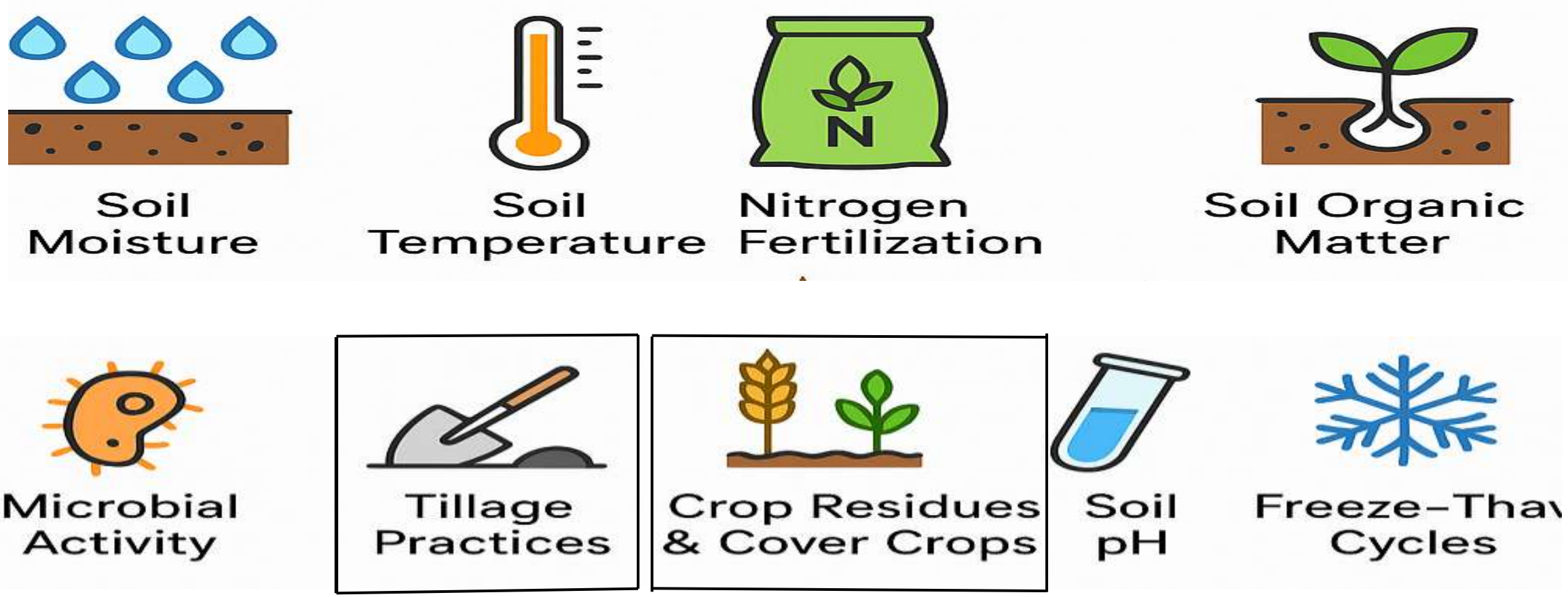
N_2O is a powerful greenhouse gas produced by microbes during nitrogen (N) cycle processes



Soils are the most important N_2O emission source contributing with **78 %** from **agriculture**



Factors and management practices responsible for N_2O emission from agricultural soils



The impact of **tillage intensity** on N_2O emissions studied under field conditions at GRObund trails of Holstebro and Slagelse

(coarse sand- JB3)

Holstebro

Slagelse

(sandy loam- JB6)

Treatments: Ploughing (PL)

Reduced Tillage (RT)

Direct seeding (DS)

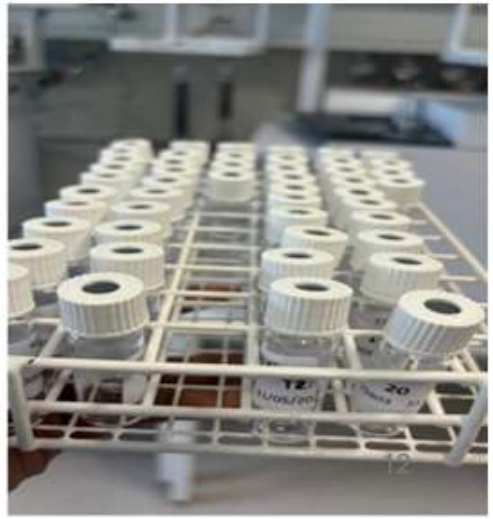
Crop: Holstebro - Winter rape (2023)

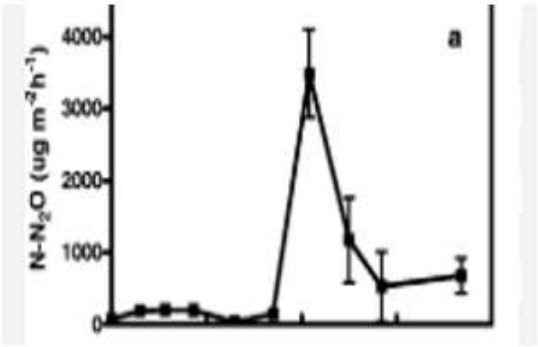
Winter wheat (2024)

Slagelse - Winter wheat (2023)

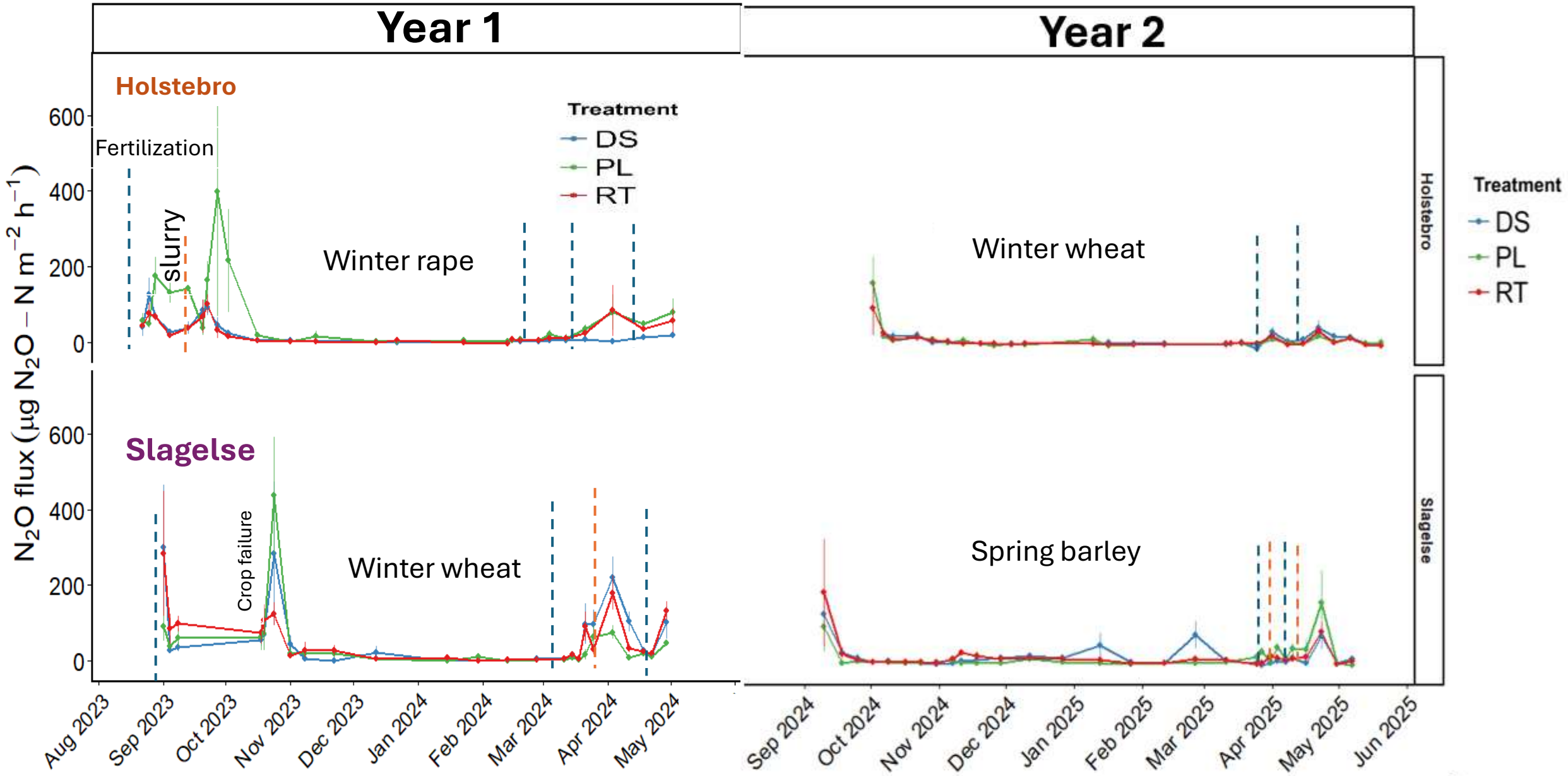
Spring barley (2024)

Methodology

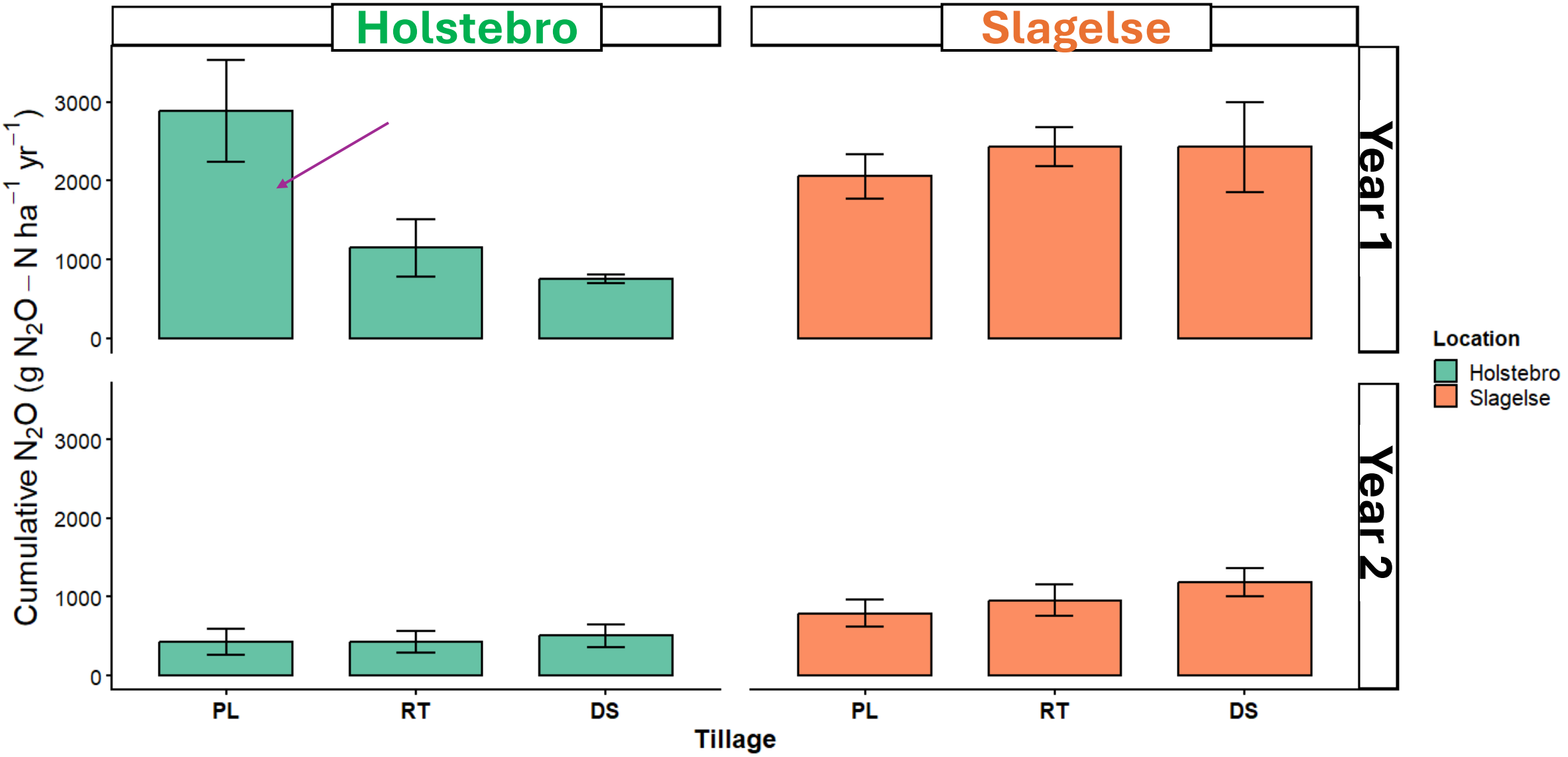




Temporal dynamics of N_2O emissions



Higher N_2O emissions in Year 1 at both the locations



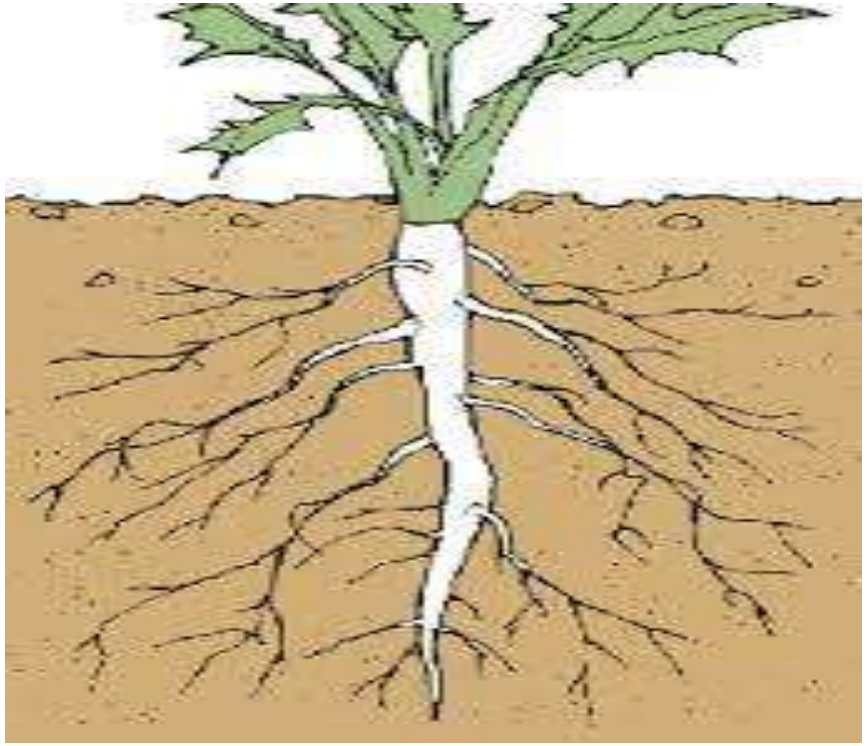
Conclusion

- Year 1 showed significantly higher N_2O emissions at both Holstebro and Slagelse compared to Year 2.
- Emission peaks occurred shortly after N application and tillage operations due to mineralization, highlighting critical risk periods.
- Ploughing (PL) at Holstebro resulted in the highest cumulative emissions (>2500 g N_2O-N ha^{-1} yr^{-1}), while Slagelse had consistently high emissions across all tillage treatments in Year 1.
- These results emphasize the strong influence of seasonal conditions on N_2O fluxes, whereas management effects can be more variable.

As a part of Conservation Agriculture, Fodder radish as a cover crop has been used widely in Denmark

Benefits of fodder radish as cover crop:

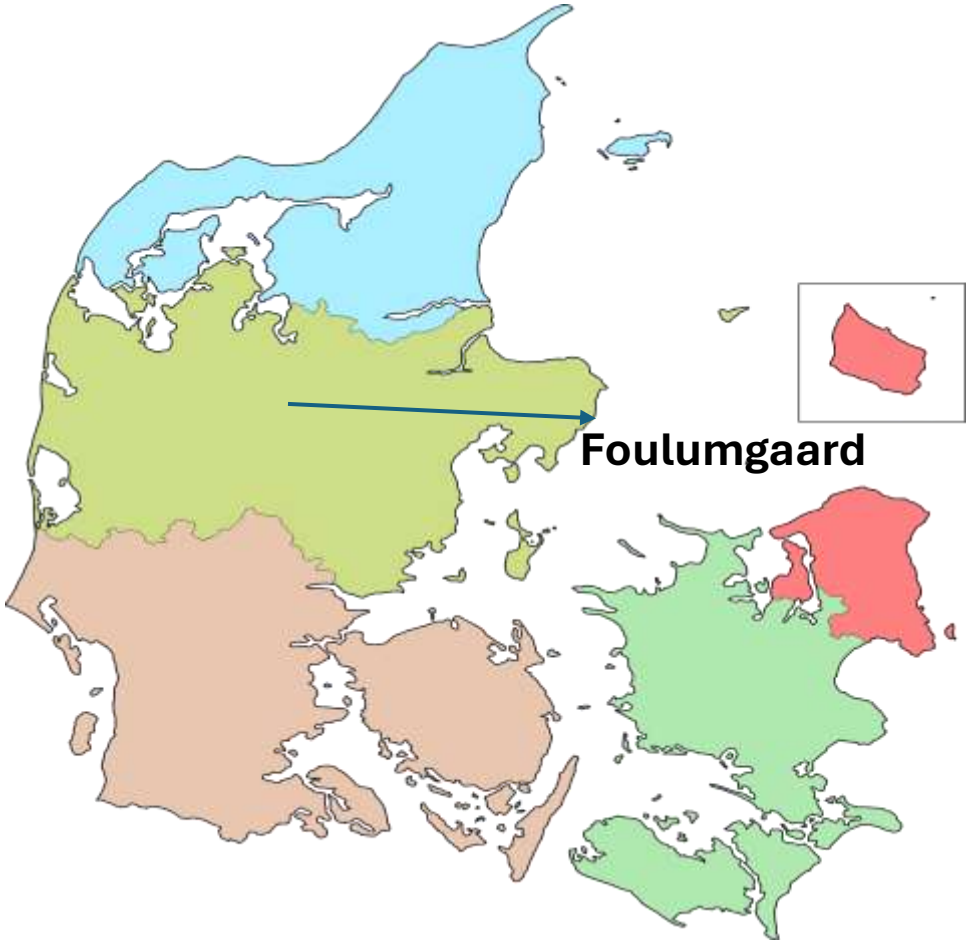
- Effective Nitrate Catch Crop
- Improve soil structure
- Supress weeds
- Reduces soil erosion
- Carbon sequestration



The effect of post-harvest cover crop residue management and tillage on N_2O emissions

Experimental site :

- Location: CENTS trail, Foulumgaard (AU Viborg)
- Duration: 2 years
- Main Crop : Spring barley (2023),
  Spring oat (2024)
- Cover crop: Fodder radish



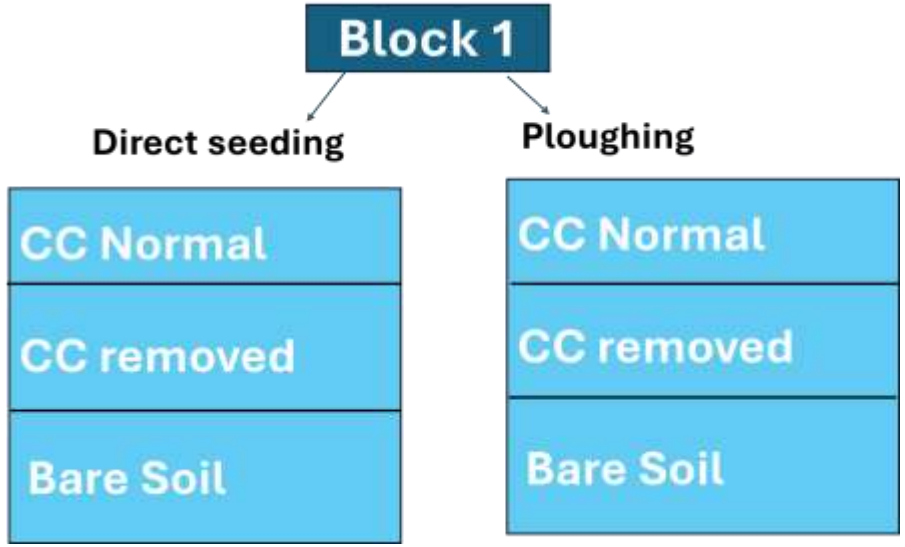
Cover crop management interactions with Direct seeding and Ploughing

Cover crop:

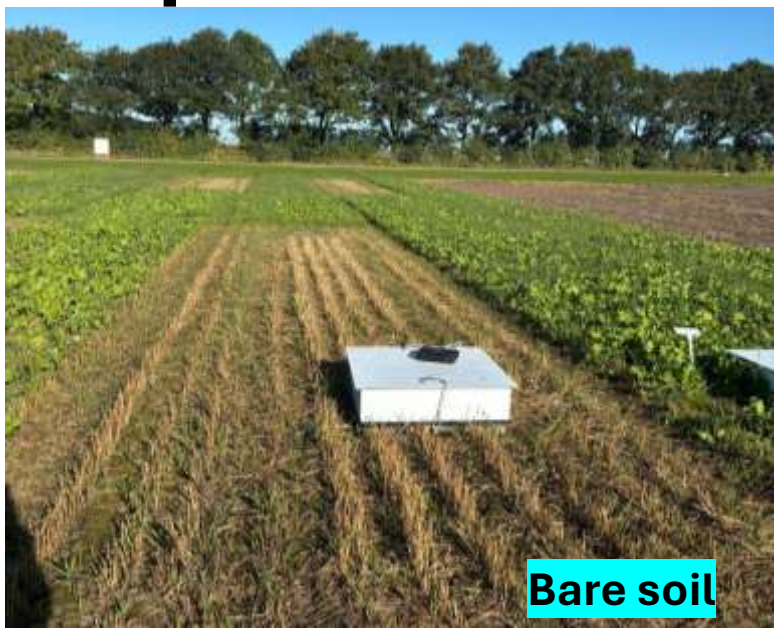
CC normal: Cover crop residues were killed by the frost and left to decay naturally in the field.

CC removed: Cover crop residues were terminated, and aboveground residues were removed biomass at late autumn.

Bare soil: Reference (No cover crop)

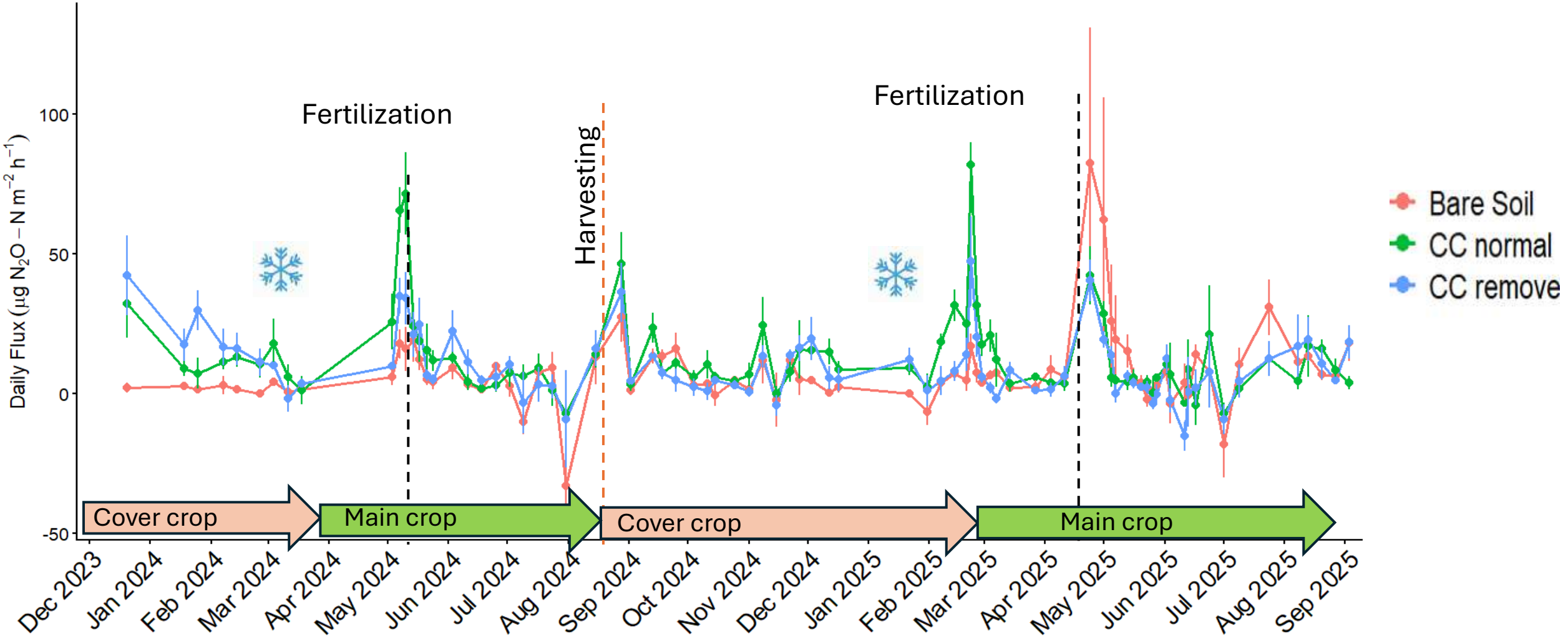


Before removing aboveground cover crop biomass

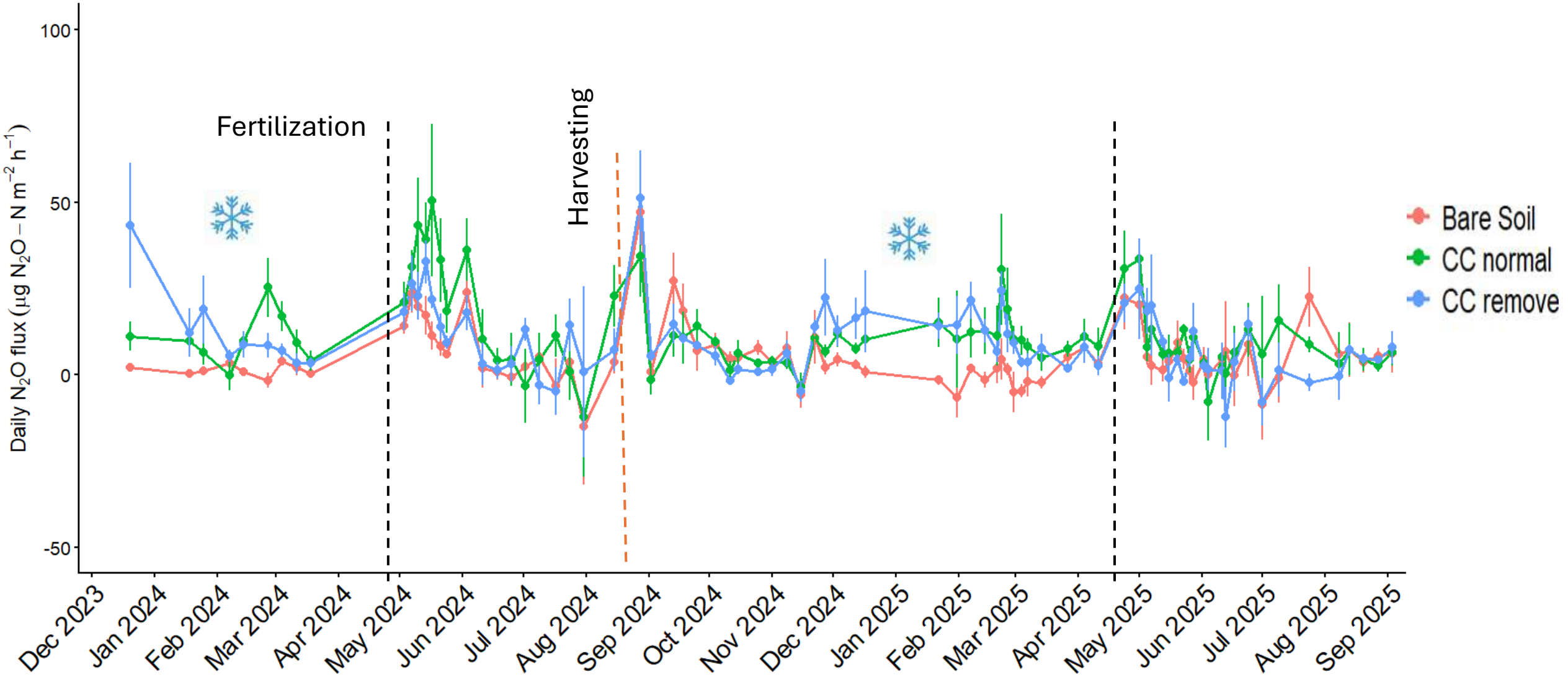


After removing aboveground cover crop biomass

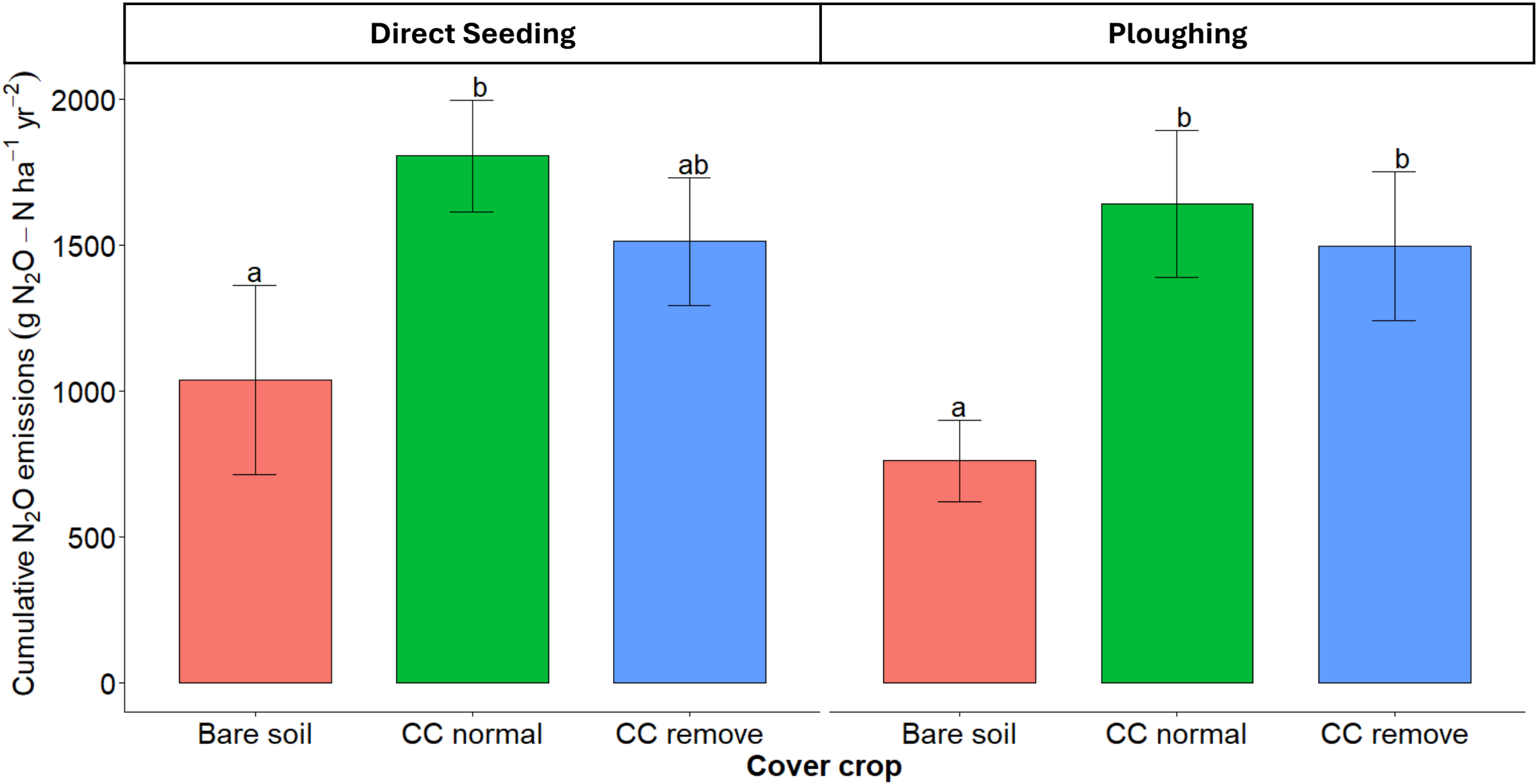
Temporal dynamics of N_2O emissions in Direct seeding



Temporal dynamics of N_2O emissions in Ploughing



Cover crop treatment increased N_2O emissions compared to bare soil in both tillage practices



Conclusion

- The presence of cover crops is the dominant factor driving higher **N_2O** fluxes, regardless of whether you use direct seeding or ploughing.
- Even when cover crop biomass is removed, cumulative emissions remain significantly higher than bare soil, as decaying roots and residues continue to fuel nitrogen loss.
- Emission peaks are highest during cover crop decomposition and immediately following fertilization events.
- High emissions are more likely, when soil becomes anaerobic (wetter soil), which accelerates the denitrification process that releases **N_2O** into the atmosphere.

Take home message

- Fertilizer application right after ploughing can lead to short spike of N_2O emissions.
- Cover crop as a fodder raddish increase N_2O emissions compared to bare soil, regardless of CC removed or CC normal how residues are managed.
- Fodder radish breaks down quickly because of its low carbon-to-nitrogen ratio and deep roots, which can boost N_2O emissions.

Thank you!

The present work was supported by funding from the Ministry of Food, Agriculture and Fisheries of Denmark through the project “Klimaeffekter og nitratudvaskning ved forskellige typer af jordbearbejdning og plantedække (KLIMON)” (Grant No. 33010-NIFA-22-792). We thank all project collaborators from Aarhus University, the University of Copenhagen, and SEGES.

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