# GREENHOUSE GAS MITIGATION FOR AGRICULTURE: OPPORTUNITIES AND BARRIERS

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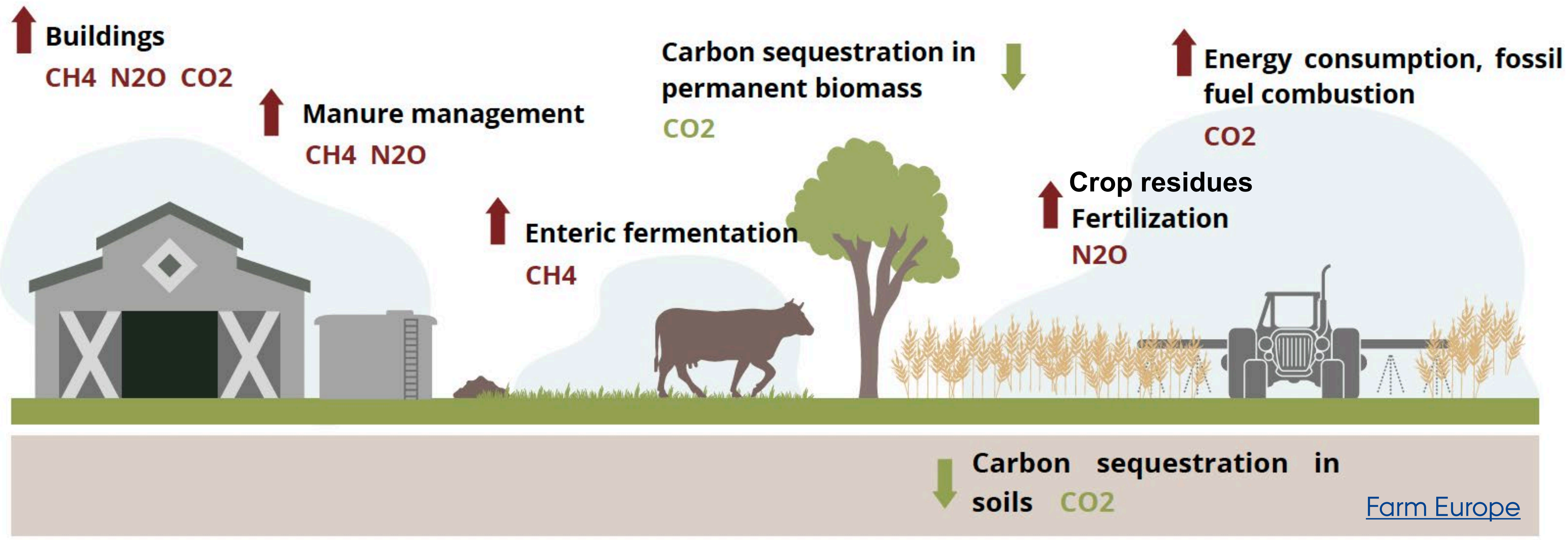
# Denmark: Arable and animal agriculture

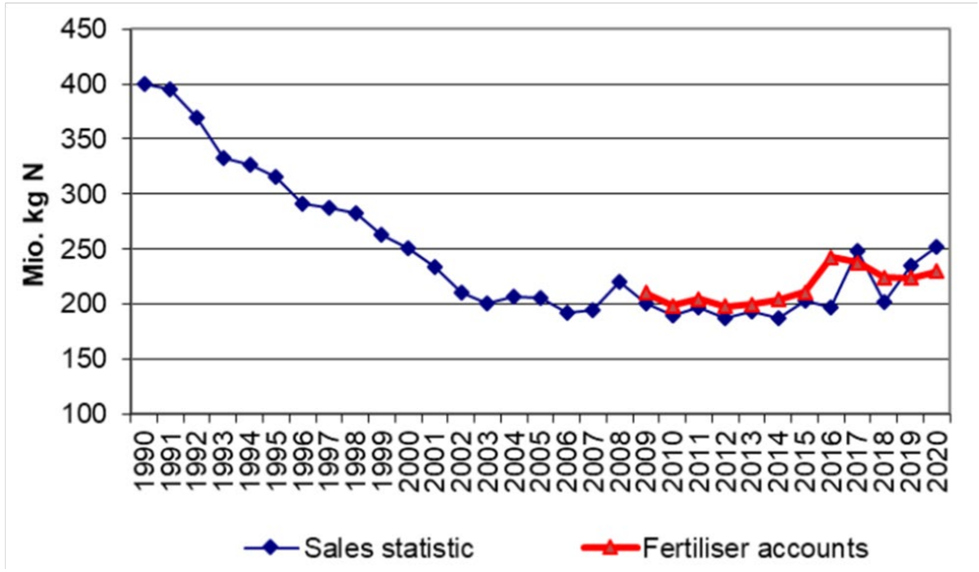



- ➔ Land use shaped by feed production
- ➔ On-farm GHG emissions a part of land use

# Challenge

- How to manage agroecosystems with minimum environmental impact?
  - Nutrient leaching
  - Soil organic carbon loss
  - GHG emissions

Synthetic N fertiliser




Regulations have enforced recycling of nitrogen in manure to reduce N surplus

➔ Higher relative importance of livestock manure as source of nitrogen

# Challenge

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  - Soil organic carbon losses
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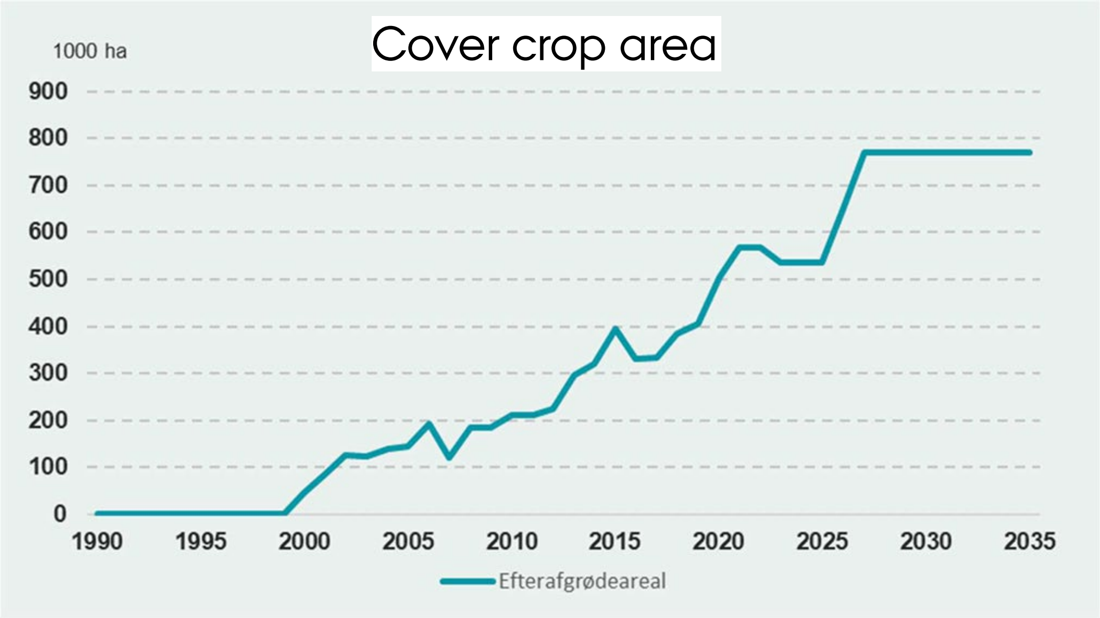


Several regulations require farmers to introduce cover crops in rotations

➔ Increasing amounts of nutrients in cover crop residues returned to soil

# Challenge

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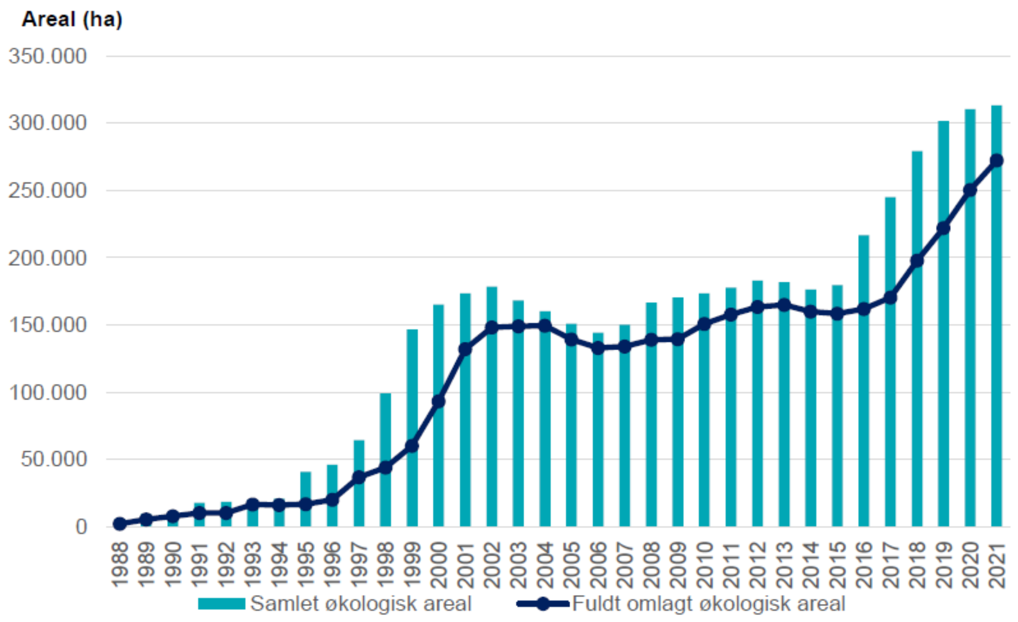
  - Nutrient leaching
  - Soil organic carbon losses
  - GHG emissions




**”Ny strategi skal understøtte fordobling af økologi”**

Ministry of Food, Agriculture and Fisheries, 2023

➔ Increasing the area dependent on organic N fertilisers only

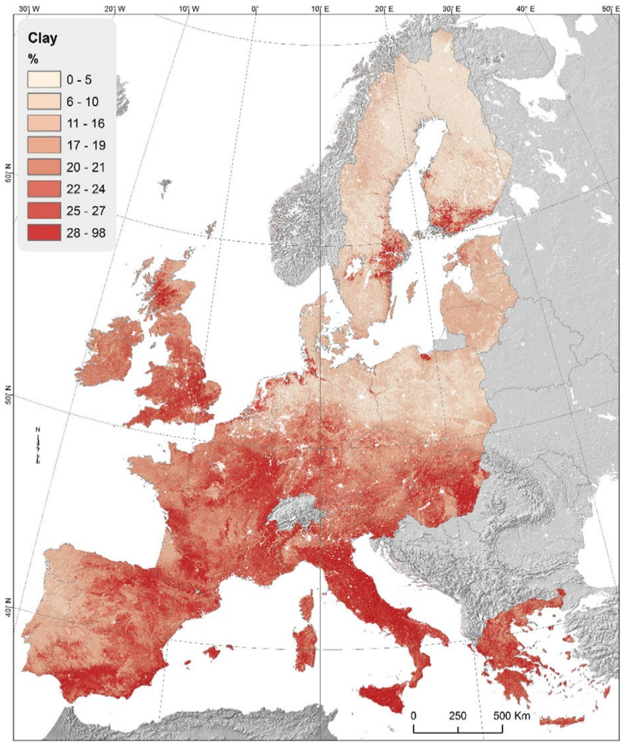
# Challenge

- How to manage agroecosystems with minimum environmental impact?
  - Nutrient leaching
  - Soil organic carbon losses
  - GHG emissions

➔ Do these trends in organic matter management contribute to GHG mitigation?

# Organic input and $N_2O$

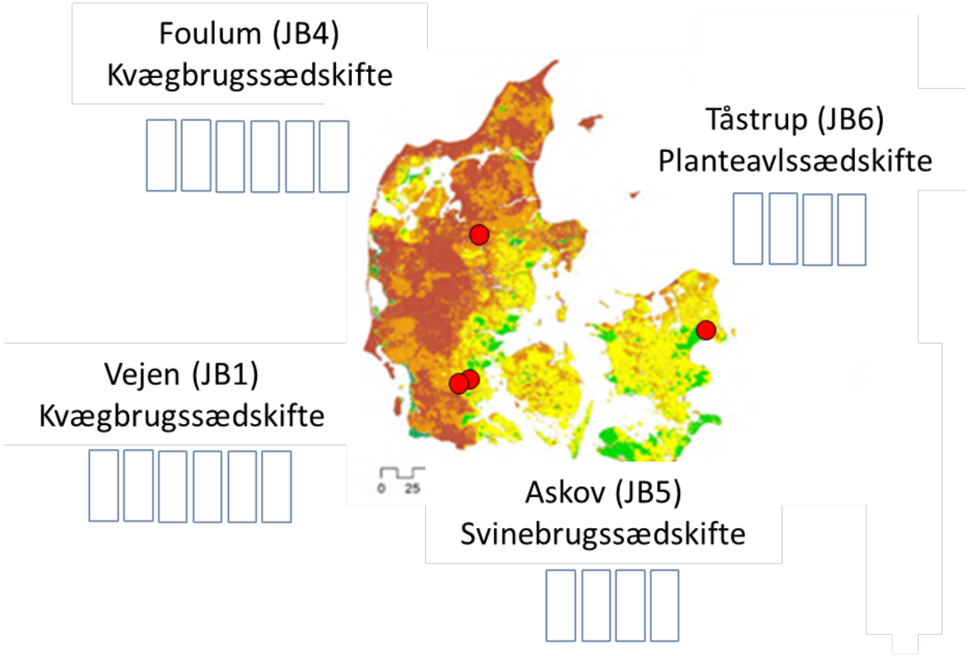
- Carbon input in crop residues a better predictor of $N_2O$ than N input for crop rotations
  (Pugesgaard et al. 2017 )
- Denitrification the main source of $N_2O$ from crop residues at 40, 50 and 60% WFPS
  (Li et al. 2016)
- Higher $N_2O$ emissions from organic compared to synthetic N fertilisers
  (Petersen et al. 2023)




Ballabio et al., 2016

**Hypothesis** Manure and crop residues constitute organic hotspots which are the main source of $N_2O$ emissions from agricultural soils in Northern Europe

# $N_2O$ emission factors, spring campaigns and annual




- All crops present every year
- Three randomised blocks

# Screening of synthetic and organic fertilisers

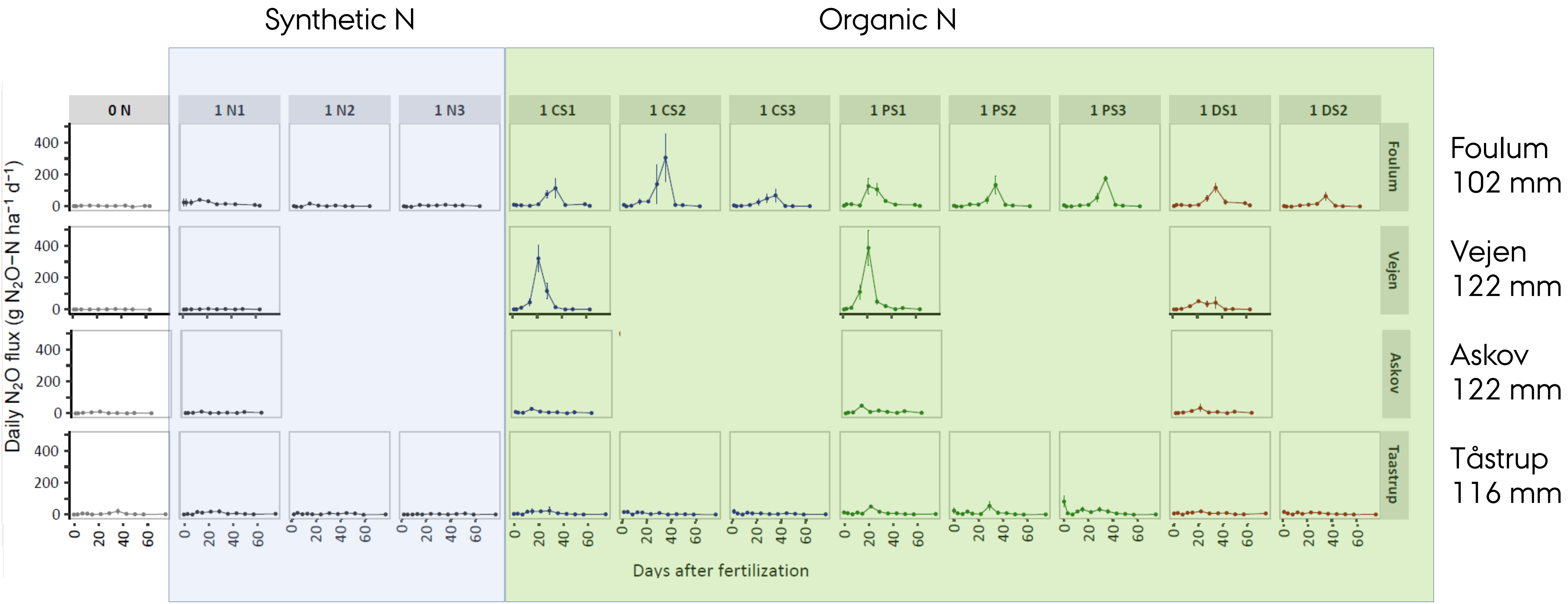
| L1 | L2 | L3 | L4 |
|---|---|---|---|
| $SN_{11}$ | $SN_{21}$ | $SN_{31}$ | $SN_{41}$ |
| $SN_{12}$ | $SN_{22}$ | | |
| $SN_{13}$ | $SN_{23}$ | | |

$$EF_{SN}\ (w.\ 95\%\ CI, n = 16)$$
$$\times \text{ Activity data}$$

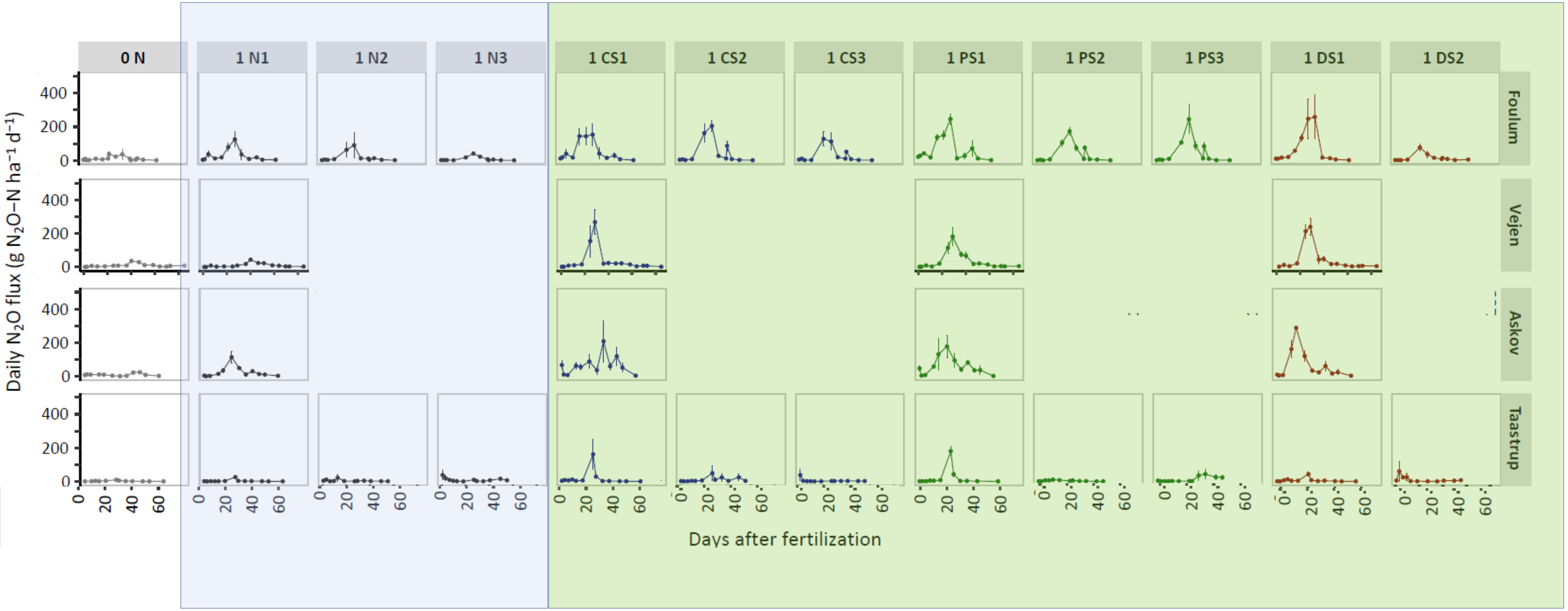
| L1 | L2 | L3 | L4 |
|---|---|---|---|
| $CS_{11}$ | $CS_{21}$ | $CS_{31}$ | $CS_{41}$ |
| $CS_{12}$ | $CS_{22}$ | | |
| $CS_{13}$ | $CS_{23}$ | | |
| $PS_{11}$ | $PS_{21}$ | $PS_{31}$ | $PS_{41}$ |
| $PS_{12}$ | $PS_{22}$ | | |
| $PS_{13}$ | $PS_{23}$ | | |
| $DS_{11}$ | $DS_{21}$ | $DS_{31}$ | $DS_{41}$ |
| $DS_{12}$ | $DS_{22}$ | | |

$$EF_{Man\ N}(w.\ 95\%\ CI, n = 44)$$
$$\times \text{ Activity data}$$

# $N_2O$ emissions during spring 2020



# $N_2O$ emissions during spring 2021




Foulum 196 mm

Vejen 309 mm

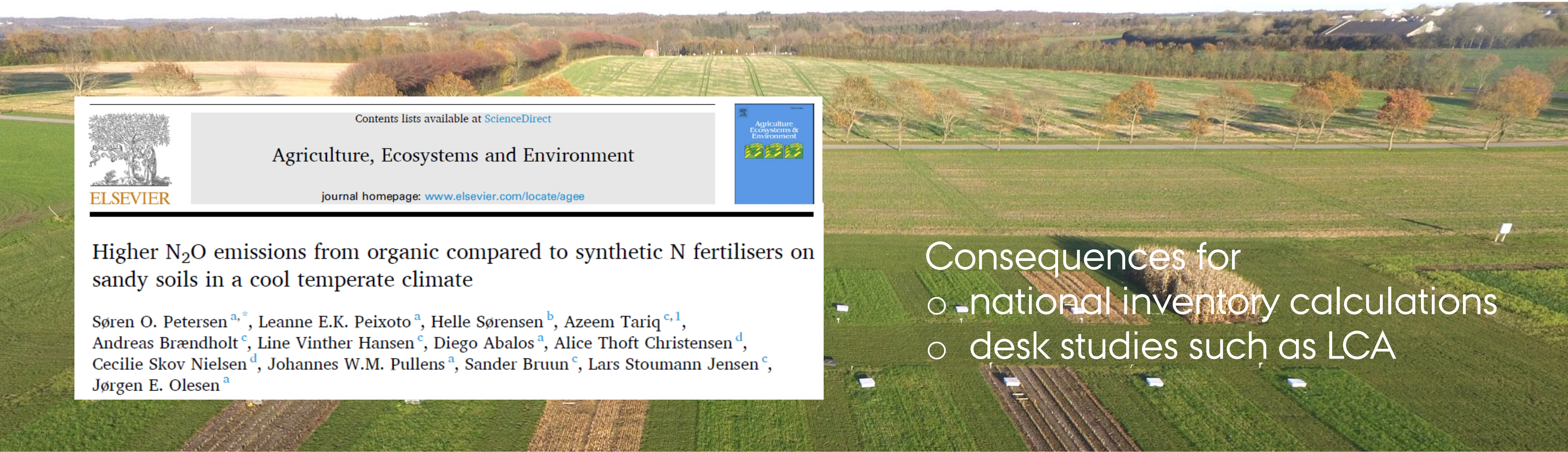
Askov 268 mm

Tåstrup 95 mm

# $N_2O$ from synthetic and organic N fertilisers

| EF, % (2020+2021) | Organic fertilisers | | | Synthetic fertilisers | | |
|---|---|---|---|---|---|---|
| | Mean | 95% C.I. | *n* | Mean | 95% C.I. | *n* |
| L1-L4 (country) | 1.02 | 0.72 - 1.33 | 44 | 0.15 | -0.08 - 0.23 | 16 |

Petersen et al. 2023


Contents lists available at ScienceDirect
Agriculture, Ecosystems and Environment
journal homepage: www.elsevier.com/locate/agee
ELSEVIER

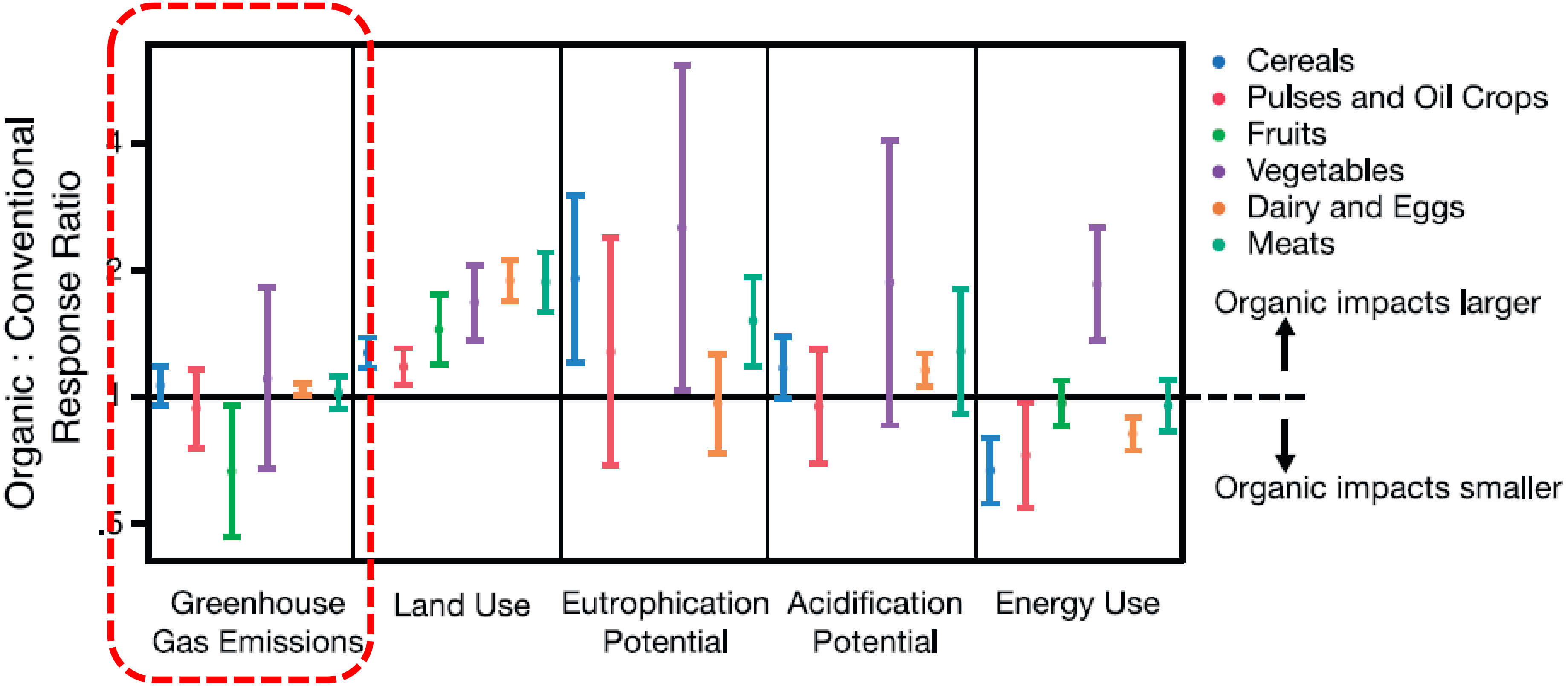
Higher $N_2O$ emissions from organic compared to synthetic N fertilisers on sandy soils in a cool temperate climate

Søren O. Petersen[a,*], Leanne E.K. Peixoto[a], Helle Sørensen[b], Azeem Tariq[c,1], Andreas Brændholt[c], Line Vinther Hansen[c], Diego Abalos[a], Alice Thoft Christensen[d], Cecilie Skov Nielsen[d], Johannes W.M. Pullens[a], Sander Bruun[c], Lars Stoumann Jensen[c], Jørgen E. Olesen[a]

Consequences for

- national inventory calculations
- desk studies such as LCA

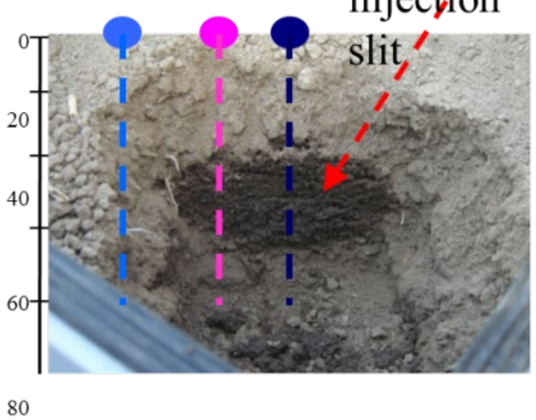
# Organic vs. conventional farming: Meta-analysis of LCA's



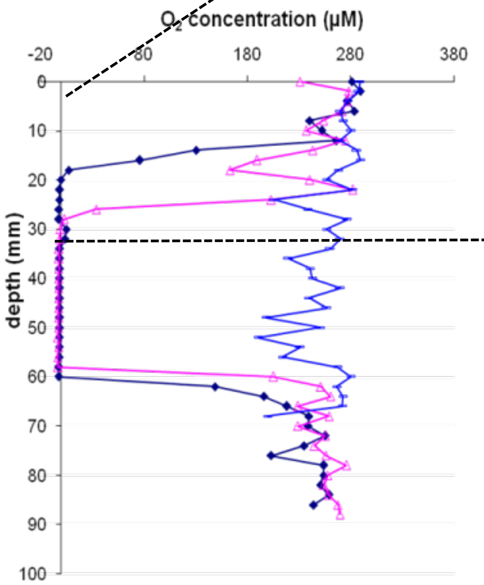

➔ Are IPCC default emission factors reliable?

Clark and Tilman, Environ. Res. Lett., 2017

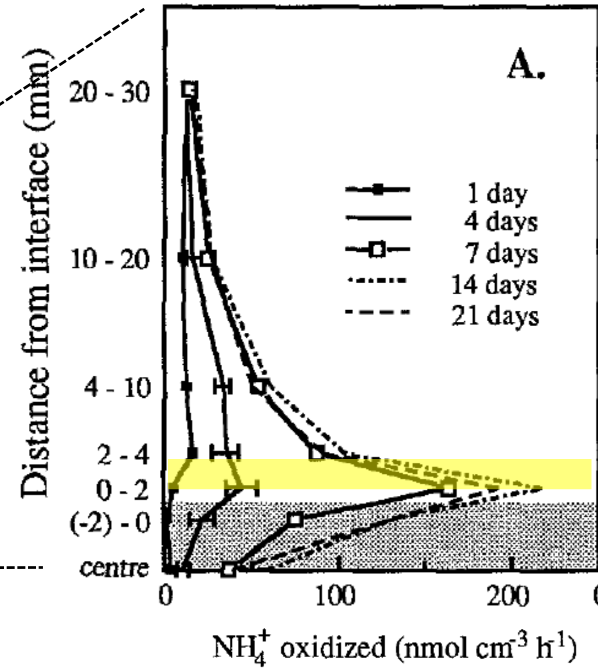
# Manure ”hotspots” – a gradient environment




Oxygen a. 24 h:




Potentiel nitrifikation



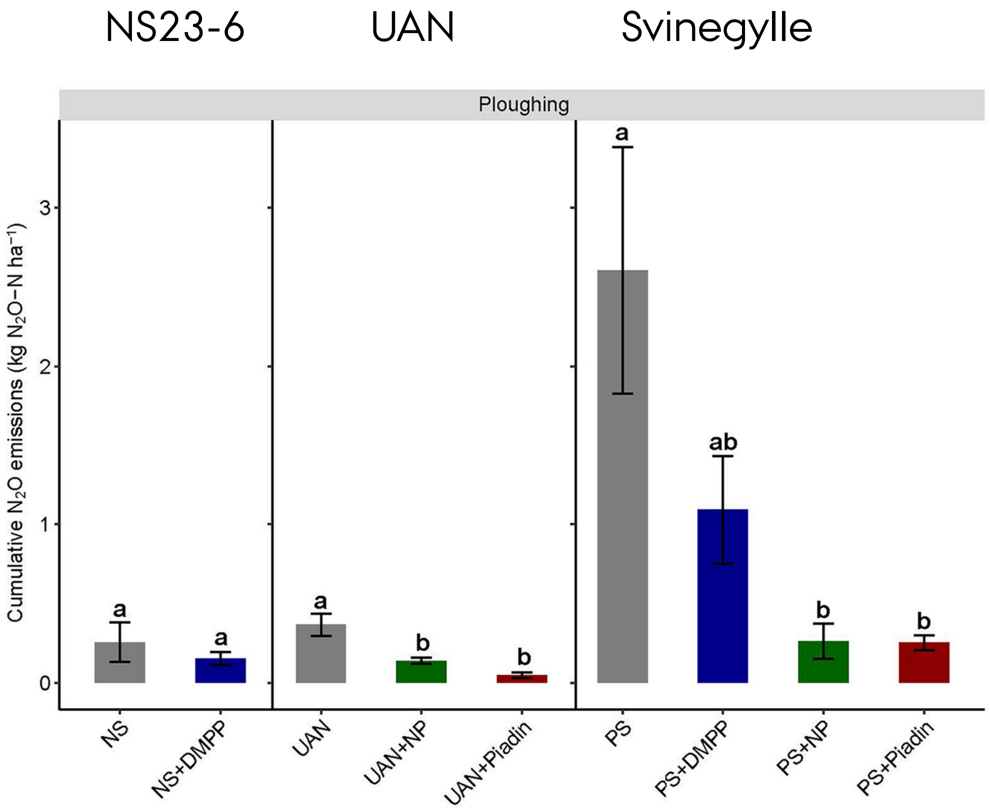

A 20-fold increase in nitrification potential within 2 weeks

➔ Coupled nitrification-denitrification (and $N_2O$ emissions) over a wide range of soil conditions

Markfoged et al., 2011

Petersen et al., 1992

# Opportunity! Prevent nitrification around org. hotspots


➔ Greater potential for $N_2O$ mitigation with manure compared to synthetic N

# Barrier? Side-effects of nitrification inhibitors

Significant effects on soil fauna and microorganisms of:

- Location and soil type
- Fertiliser type (synthetic or organic)
- Crop
- Weather conditions
- Tillage

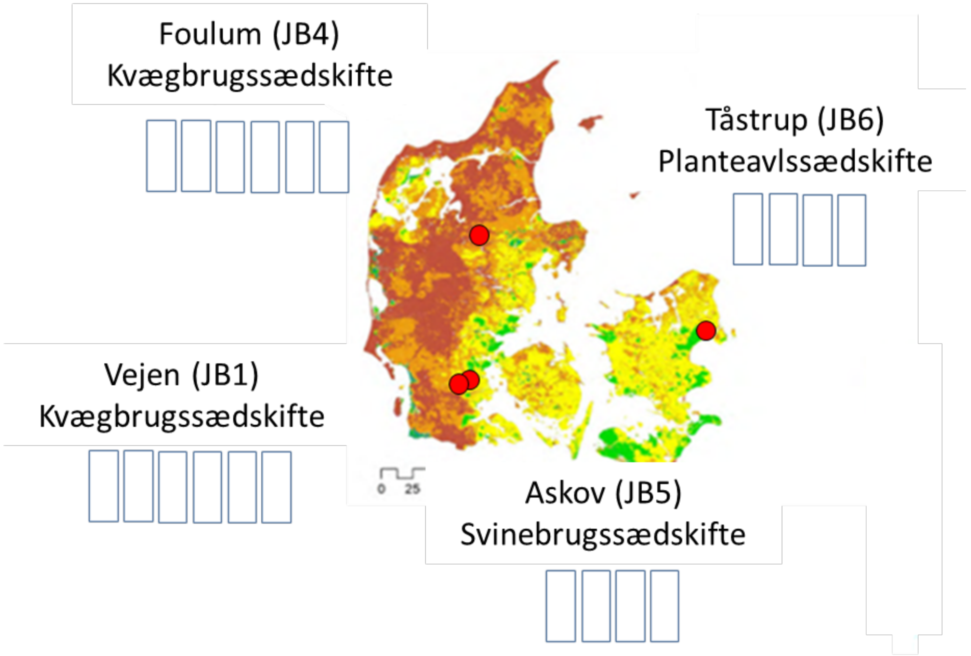
➔ Much less effect of nitrification inhibitors on soil biota compared to factors above, but accumulating over several years?

➔ Some NI measured in soil after 4 months

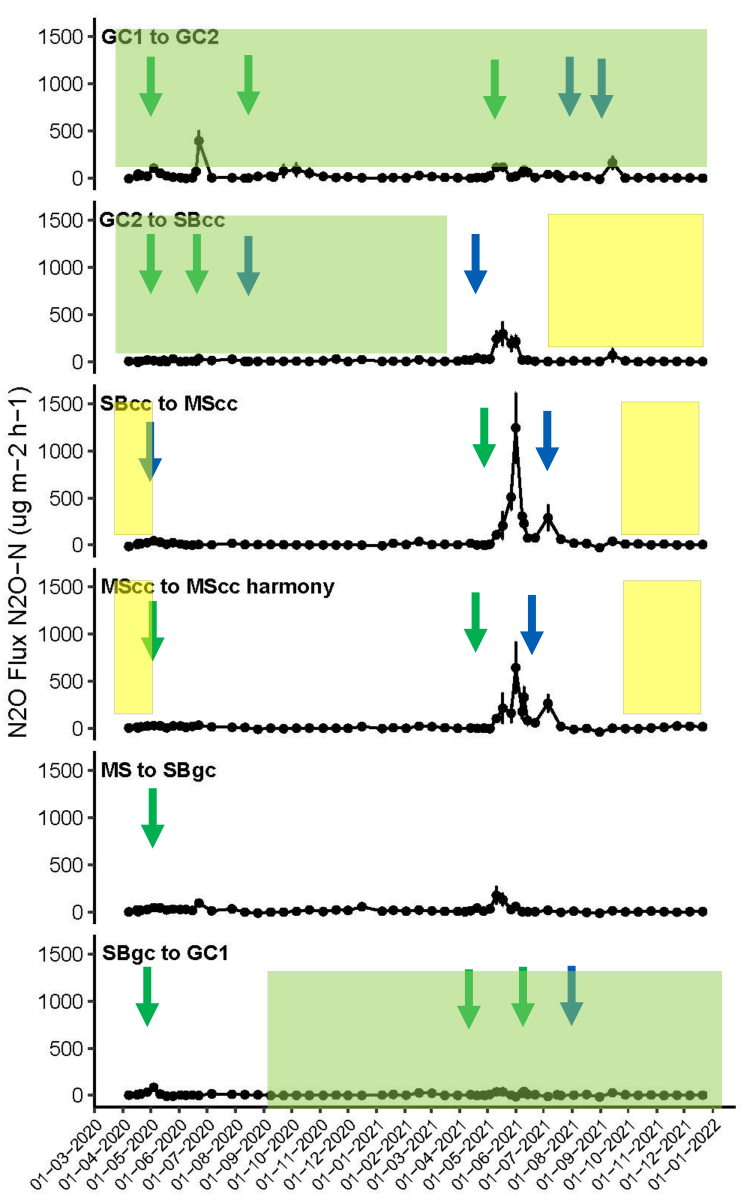
➔ Recovery of NI and metabolites influenced by rainfall

Source: A. Winding (Plantekongressen 2024)

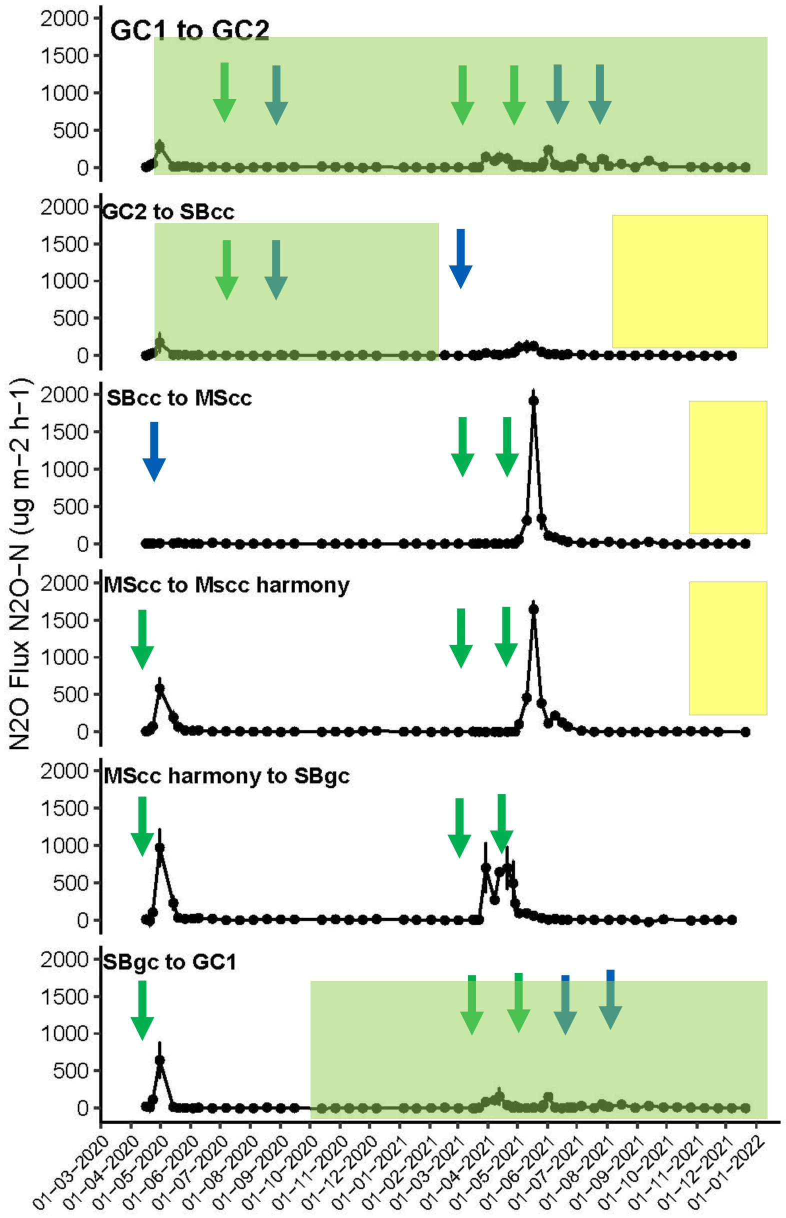
# $N_2O$ emission factors, spring campaigns and annual

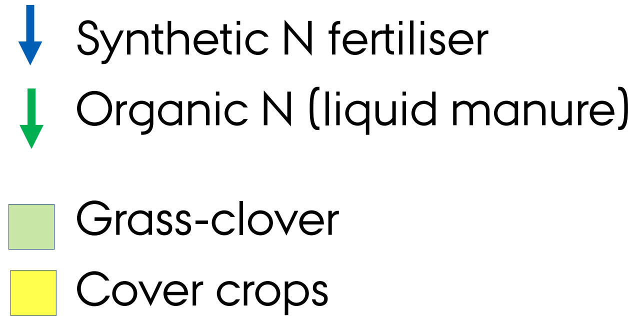



## Foulum (JB4)




## Vejen (JB1)

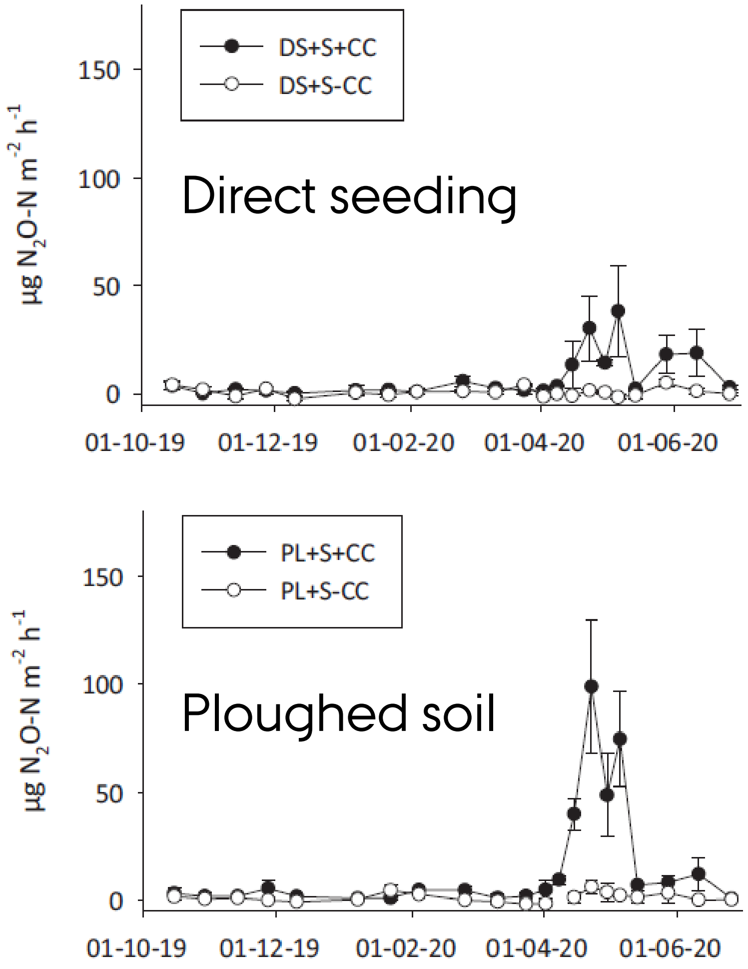


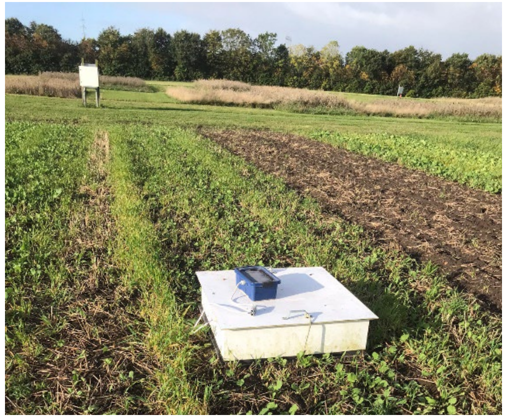




➔ Highly variable, but not random!

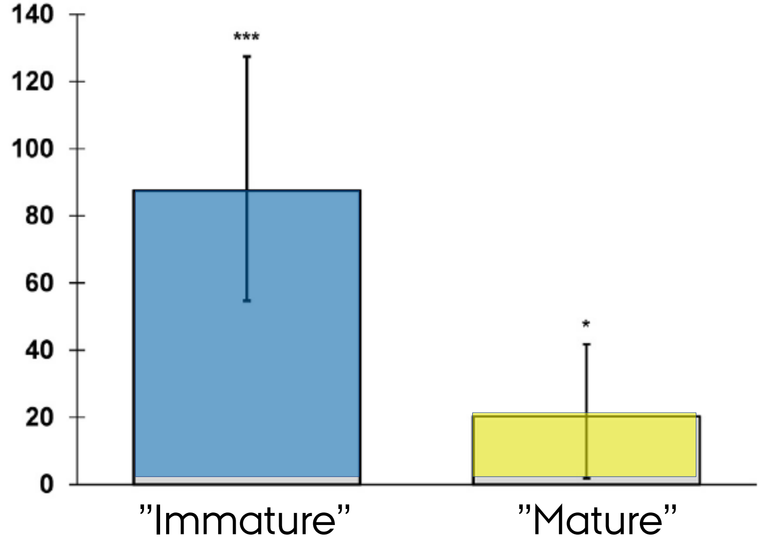
➔ Opportunity! Less $N_2O$ emission with plant cover

# Barrier? Termination of perennial crops, cover crops



Relative increase of $N_2O$ emissions, %

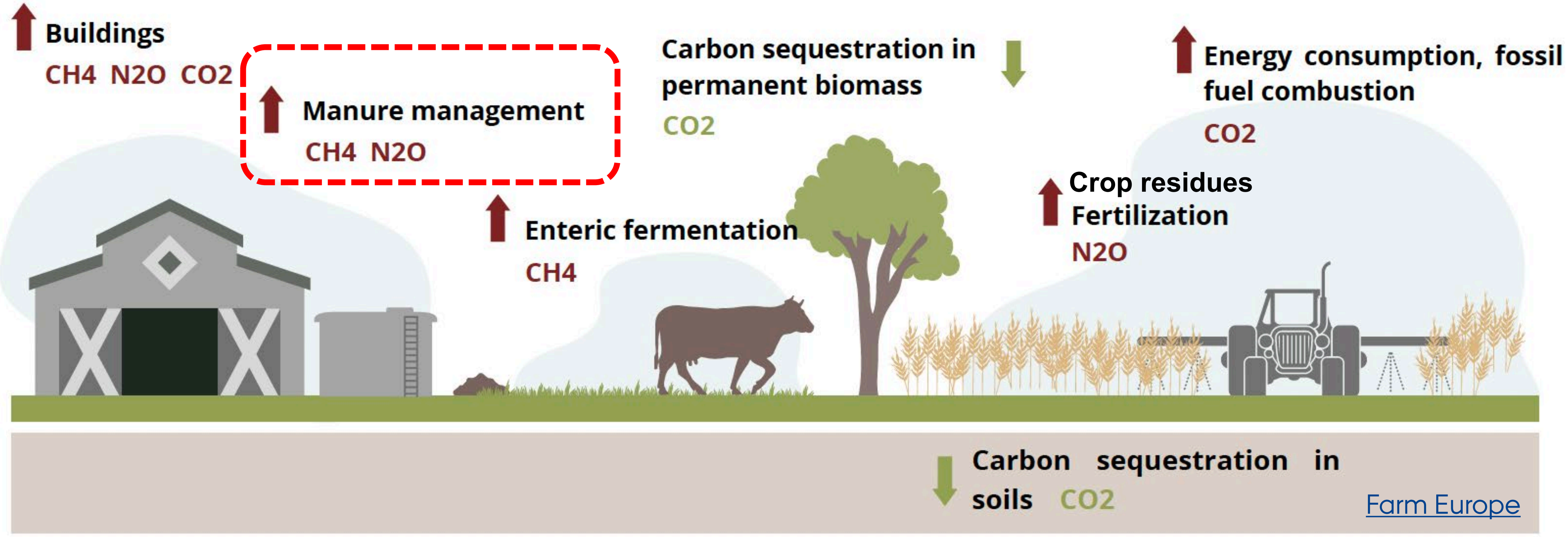



➔ Immature residues with higher risk of $N_2O$ emissions

Taghizadeh-Toosi et al., 2022

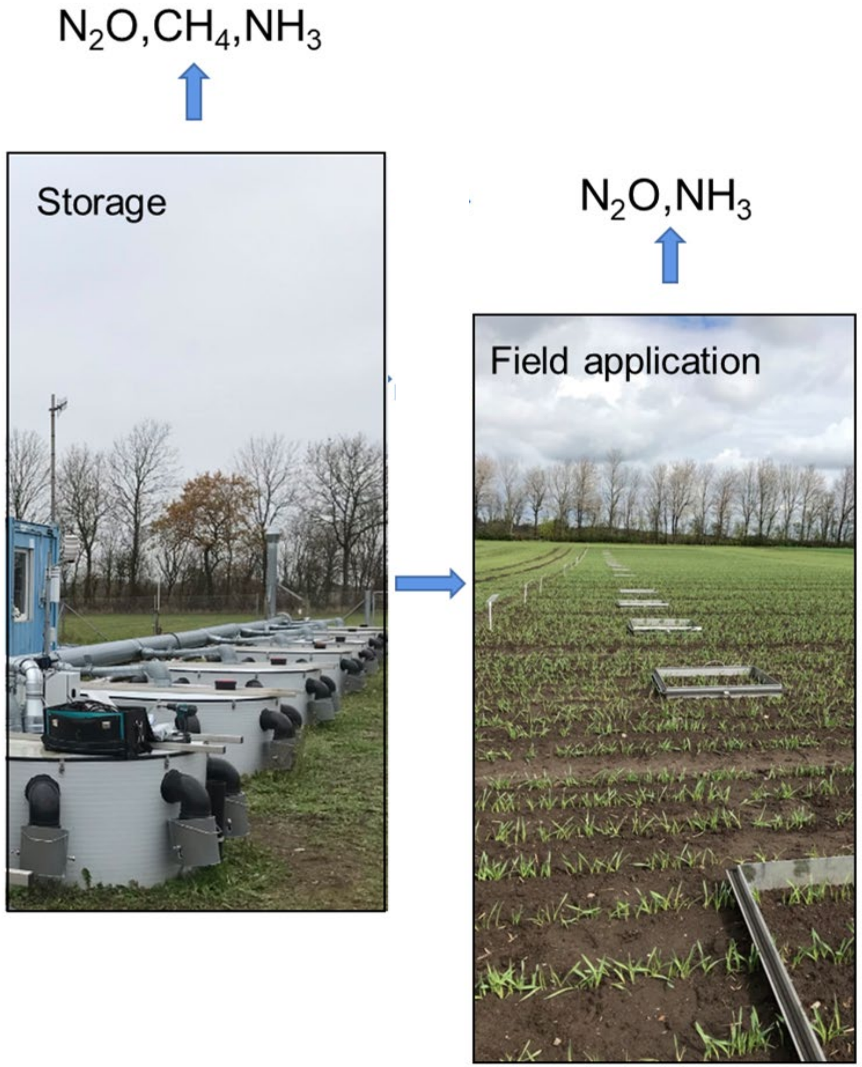
Abalos et al., 2022

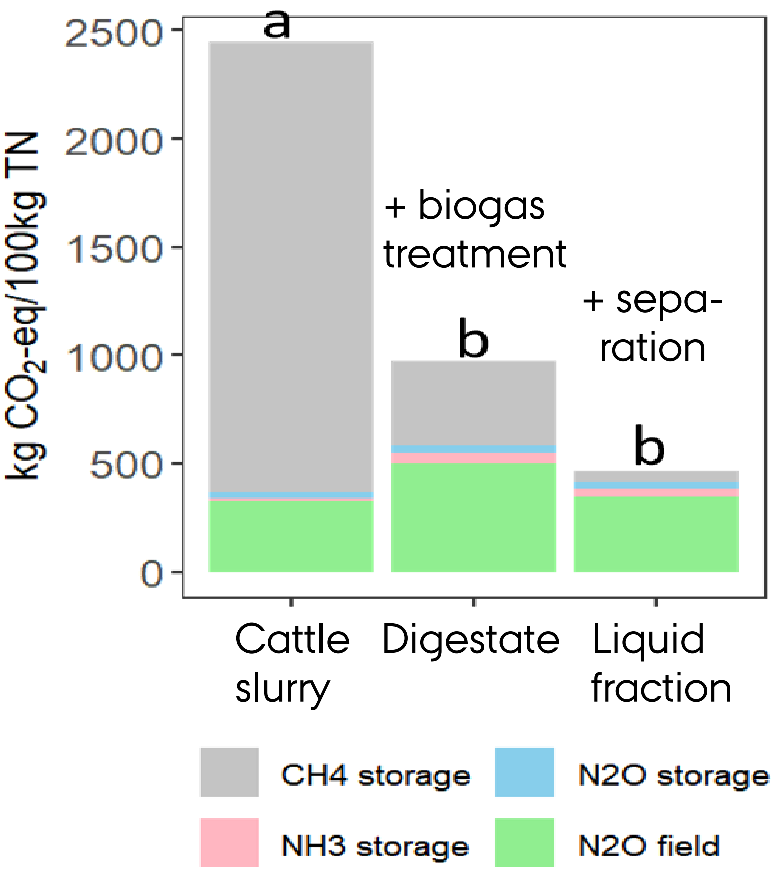
# Denmark: Arable and animal agriculture




- ➔ Land use shaped by feed production
- ➔ On-farm GHG emissions a part of land use

# Methane lost during storage dominate GHG emissions




➔ Anaerobic digestion (+separation) powerful mitigation strategy

Meng et al., 2023

# Opportunity! Manure treatment and management

- Anaerobic digestion
- Low-dose acidification
- Methane oxidation in crusts of tanks with a cover

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Letter

# Low-Dose Acidification as a Methane Mitigation Strategy for Manure Management

Chun Ma,* Frederik R. Dalby, Anders Feilberg, Brian H. Jacobsen, and Søren O. Petersen

Cite This: https://doi.org/10.1021/acsagscitech.2c00034

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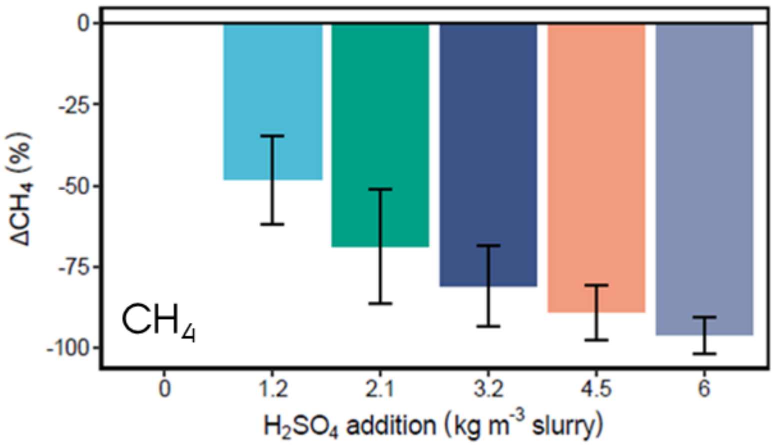
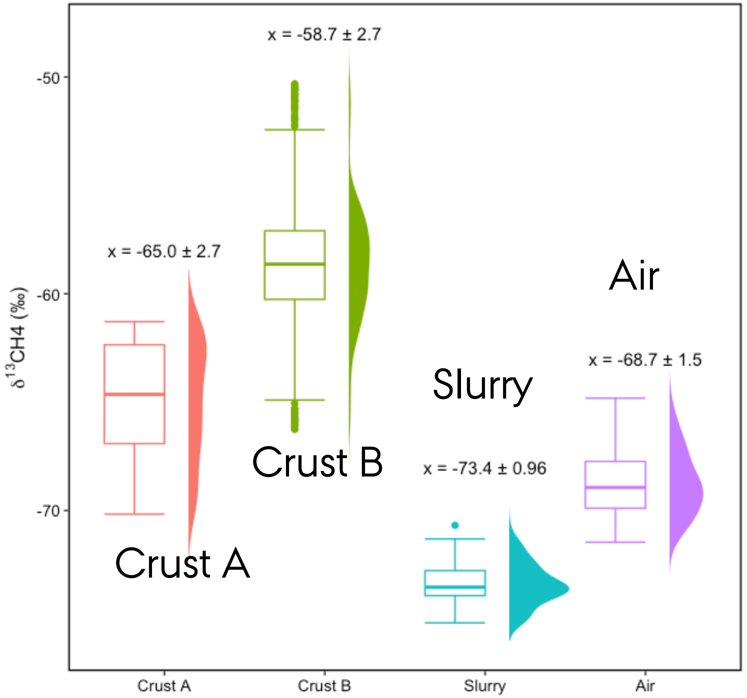



# Methane oxidation in surface crusts

- Dynamic ventilation control
- Flux measurement
- IRMS analysis of $CH_4$

$^{13}CH_4$ enrichment is evidence for $CH_4$ oxidation




Ma et al., in prep.

# Perspectives

- Land use is part of farming systems that include on-farm activities
- Several trends promote recycling of nutrients to soil in organic form with a high N2O emission risk
- There are technical ”fixes” to mitigate GHG emissions, but are they in conflict with agroecological principles?
- Is there an optimal path between sustainable intensification (land sparing?) and organic farming practices (land sharing?)
- Short-term vs. long-term mitigation targets

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