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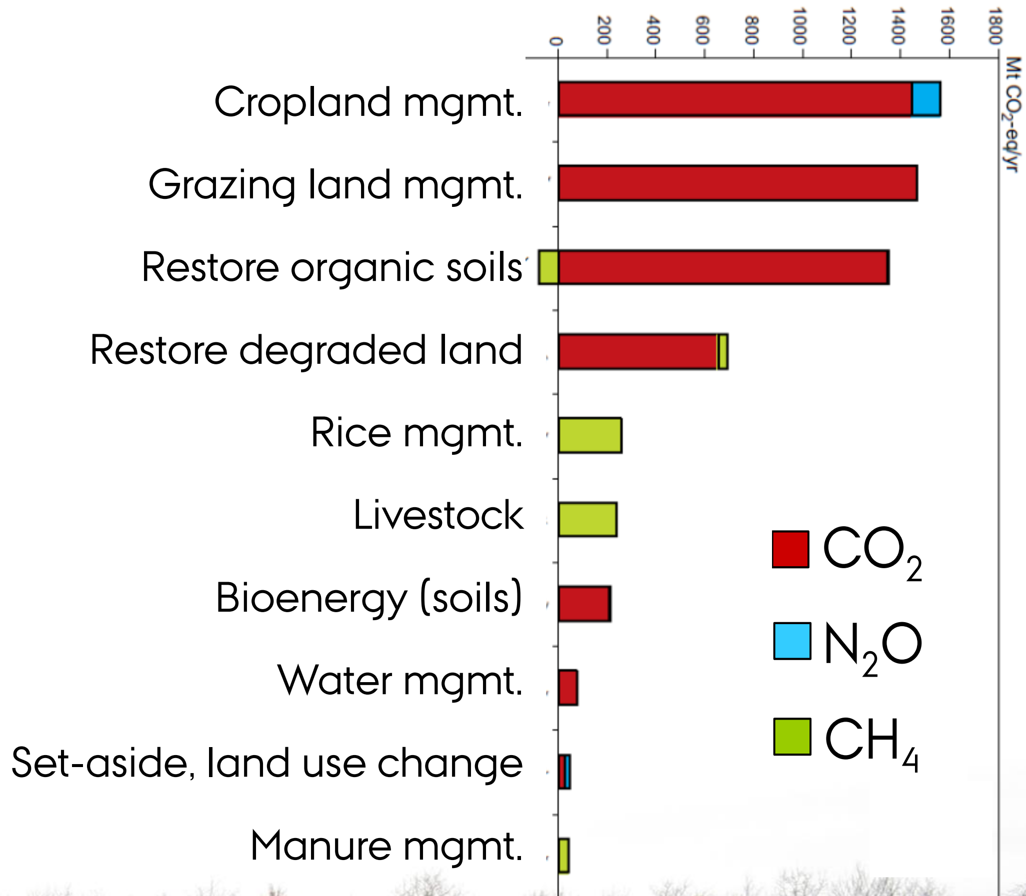
17 Oct 2011

Nitrous oxide emissions from arable soil: Effects of crop rotation, tillage and manure management

Søren O. Petersen

Aarhus University, Dept. Agroecology

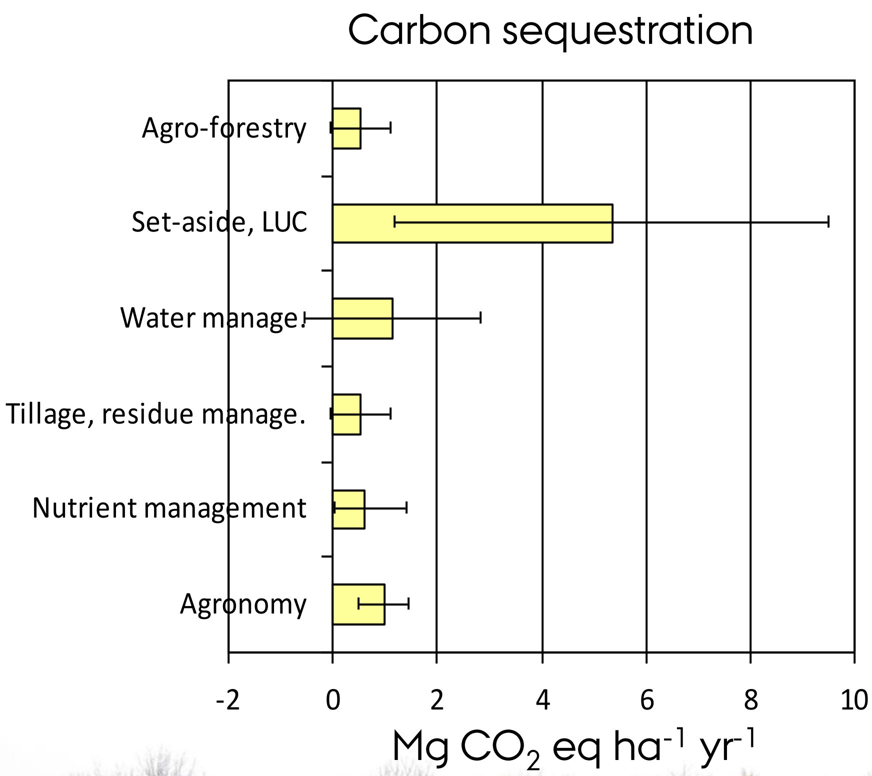
Global GHG mitigation potentials



(Smith et al., 2007)

GHG mitigation, cropland

C storage potentials high – but uncertain



(Smith et al., 2007; cool-moist climate)

GHG mitigation, cropland

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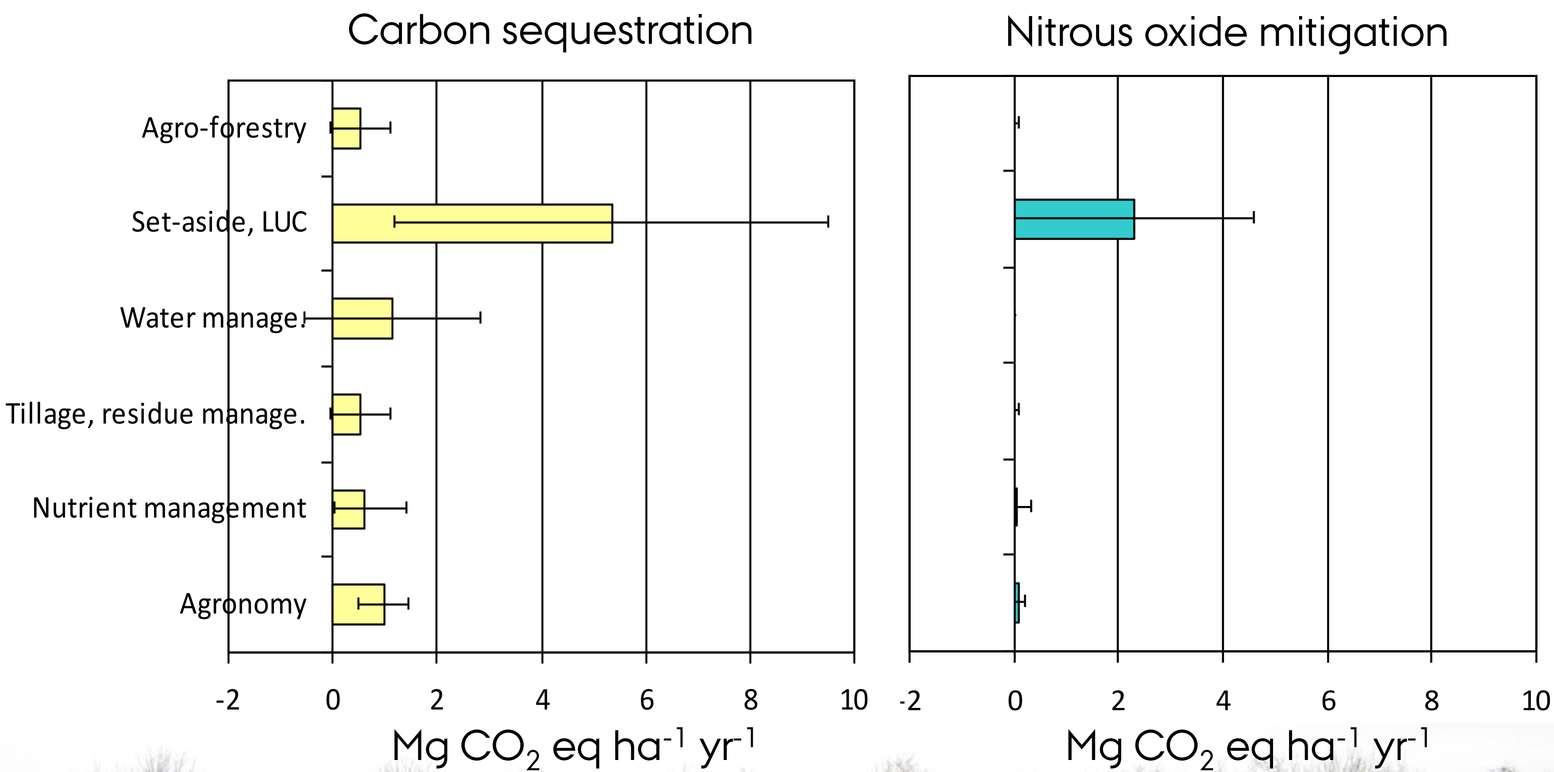

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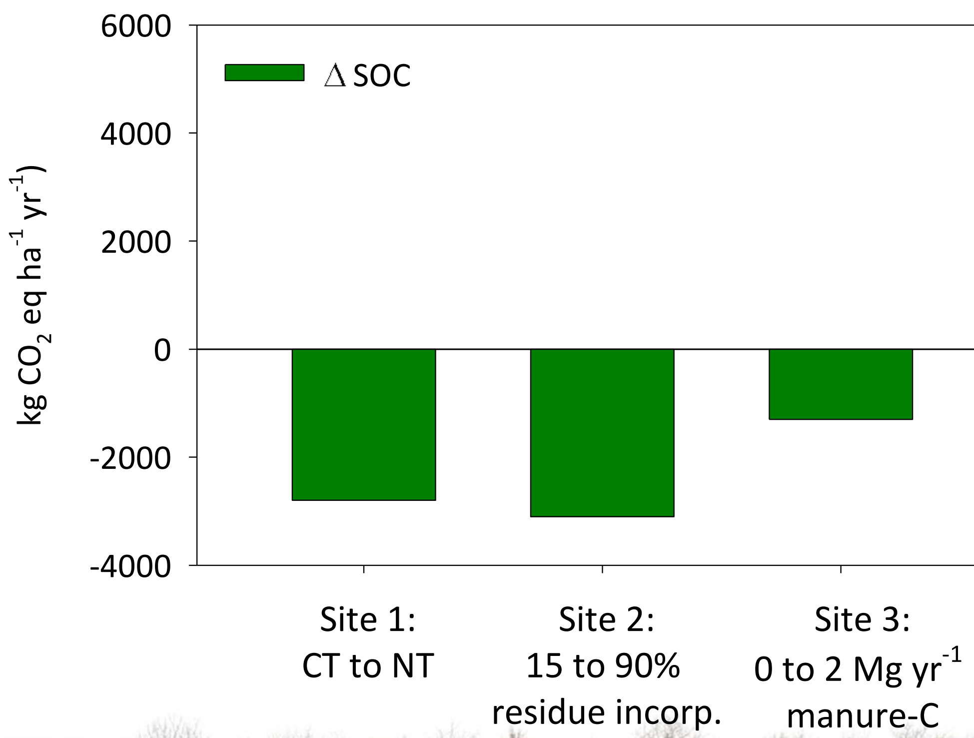
GHG mitigation, cropland

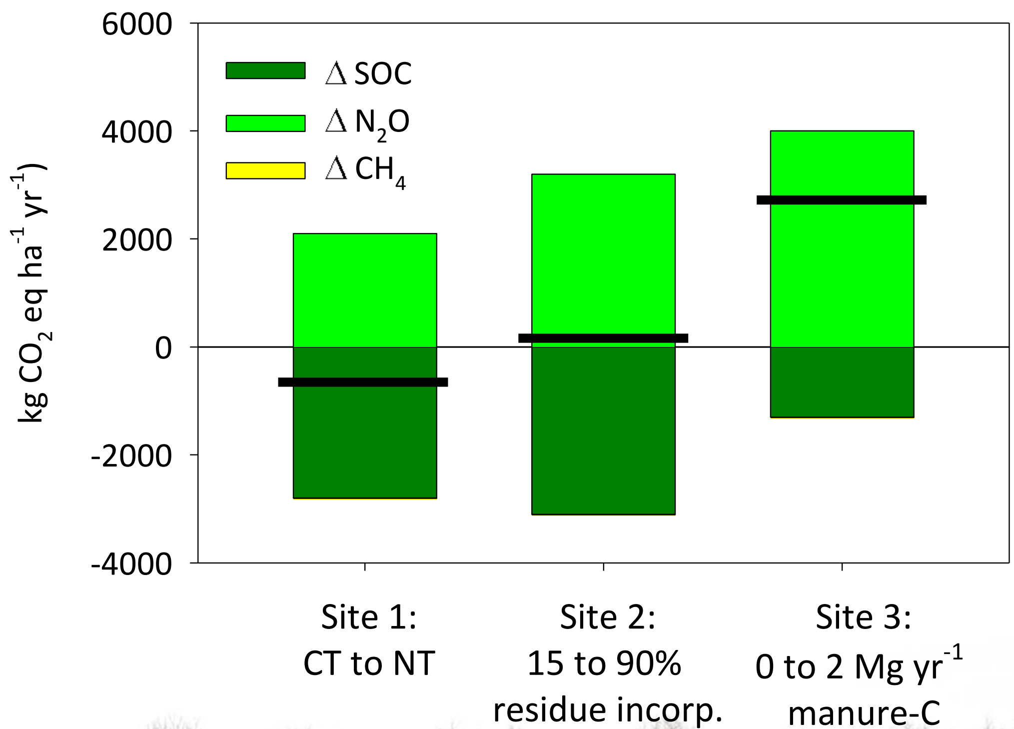
C and N interactions



(Li et al., 2005)

GHG mitigation, cropland

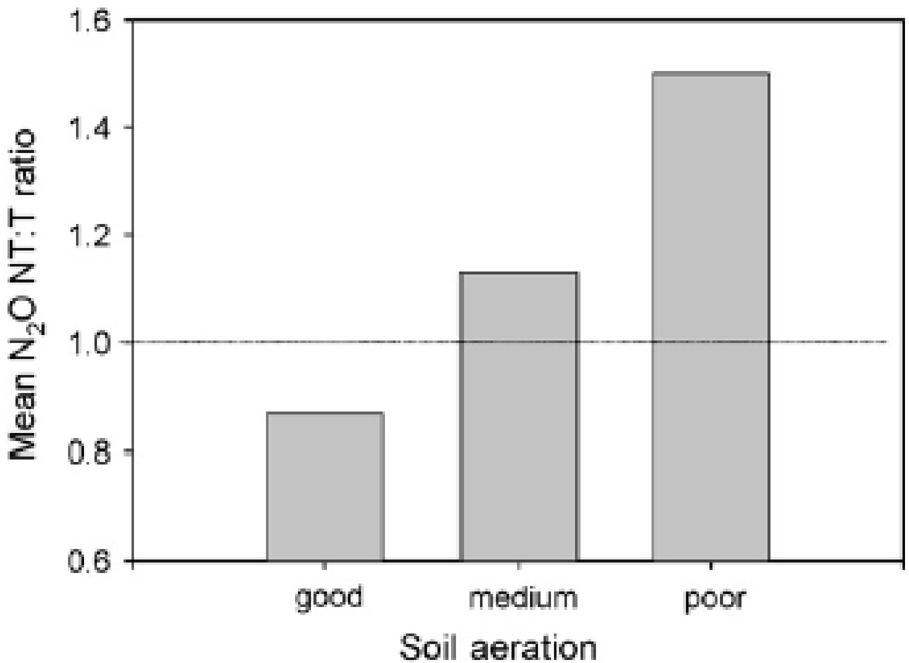
C and N interactions



(Li et al., 2005)

GHG mitigation, cropland

No-till and N_2O



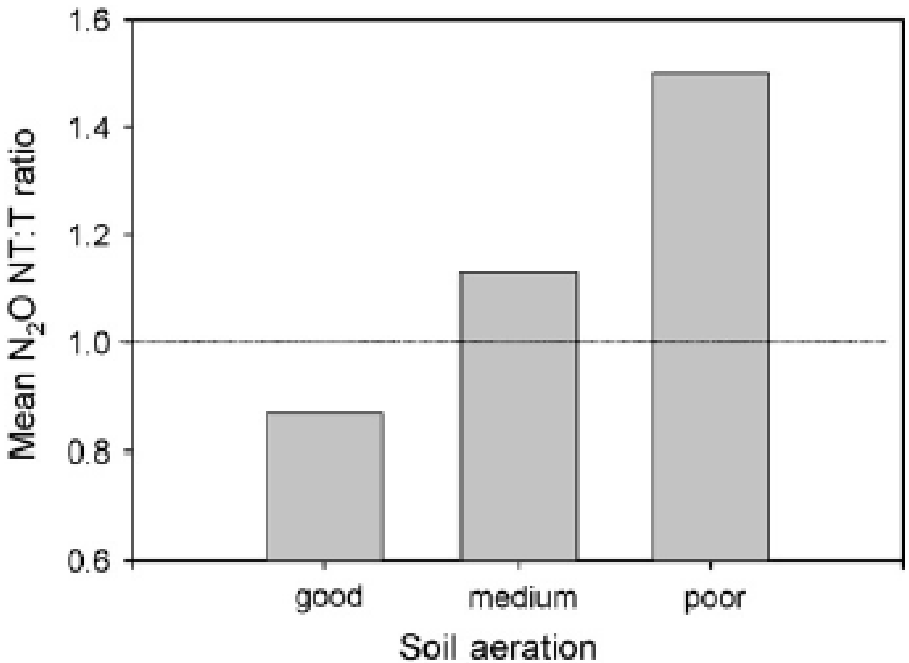
- 45 site-years
- Tillage: Mostly ploughing

(Rochette, 2008)

GHG mitigation, cropland

No-till and N_2O

Max: 1.65 4.28 3.42
Min: 0.48 0.48 0.87



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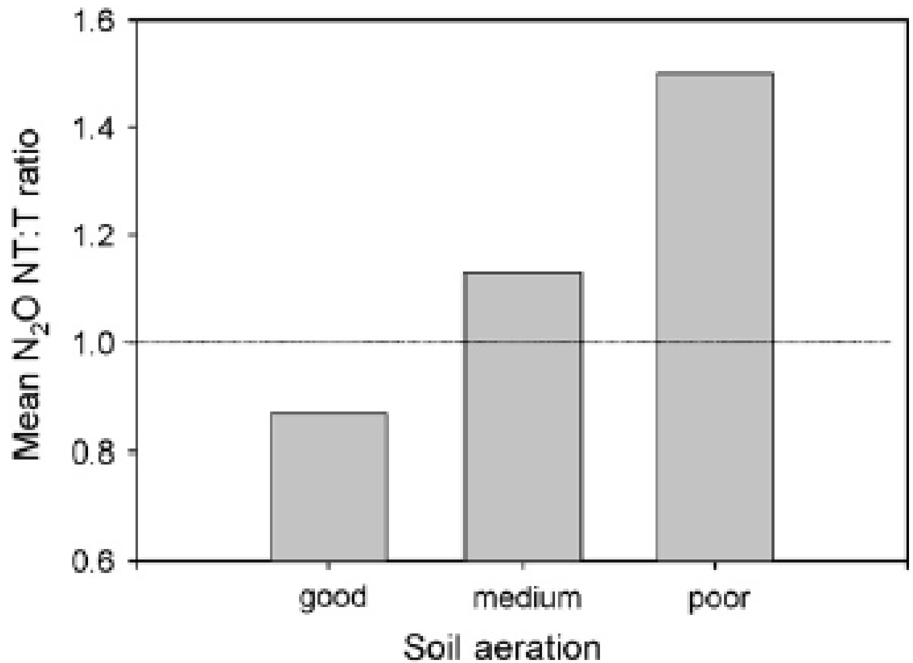


- 45 site-years
- Tillage: Mostly ploughing

- Residue management?
- Fertilization?

(Rochette, 2008)

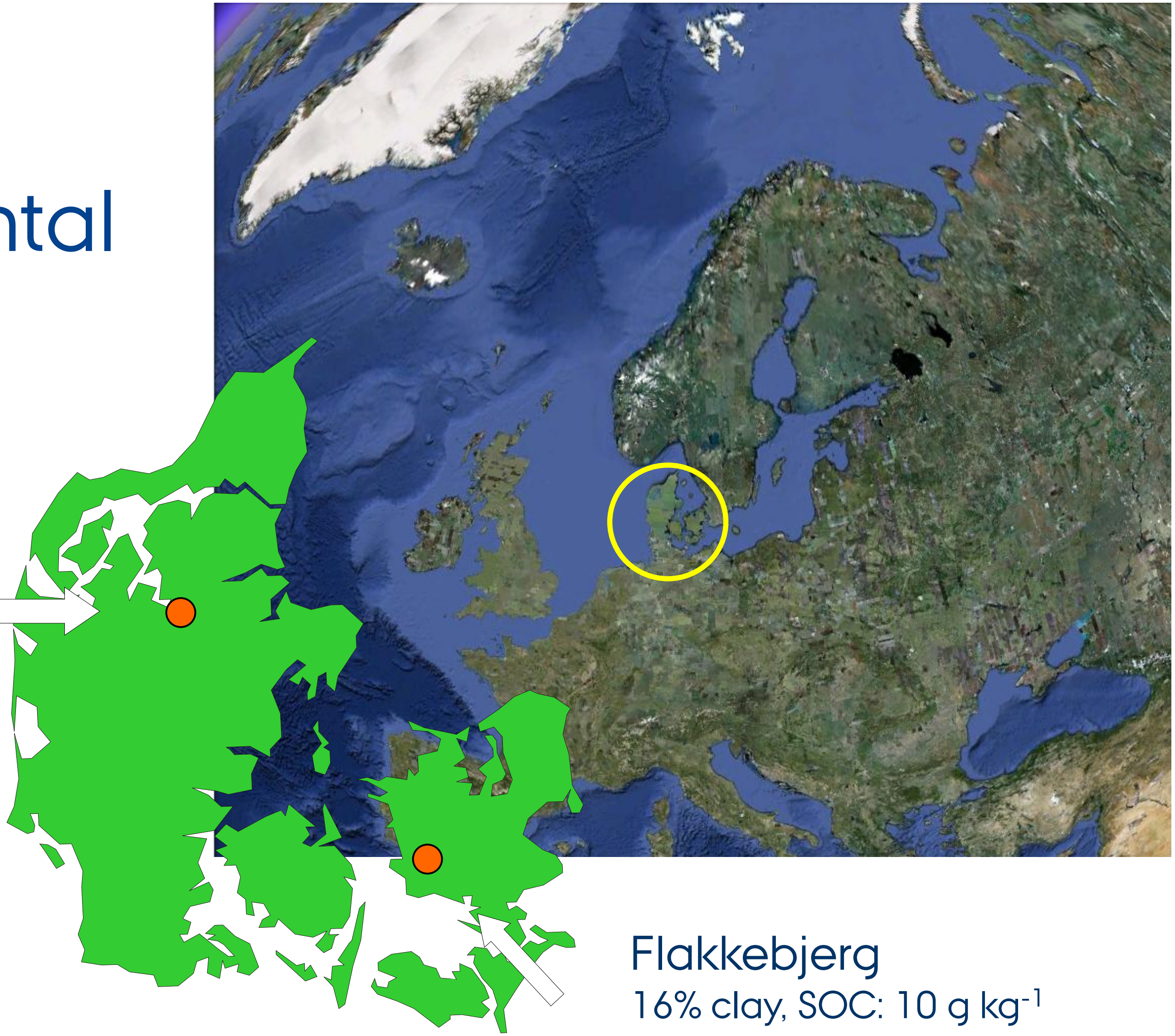
Management effects on N_2O

Experiences from experimental crop rotations

- Tillage × residue management
- Green manure management
- Effects of crop rotation
- Control of N_2O emission

Experimental locations

Experimental locations



Foulum
9% clay
SOC: 23 g kg^{-1}
7.3°C
626 mm

Flakkebjerg
16% clay, SOC: 10 g kg^{-1}
7.7°C
558 mm

Long-term crop rotation experiments
Foulum + Flakkebjerg

Organic rotations (1997-)

Tillage practices (2002-)

Tillage × residue management I

N_2O emissions from winter barley – and from a cover crop

		Straw retention	
Moldboard ploughing	MP	+	-
Reduced tillage (harrowing 8-10 cm)	RT	+	-
Direct drilling (”no-till”)	DD	+	-

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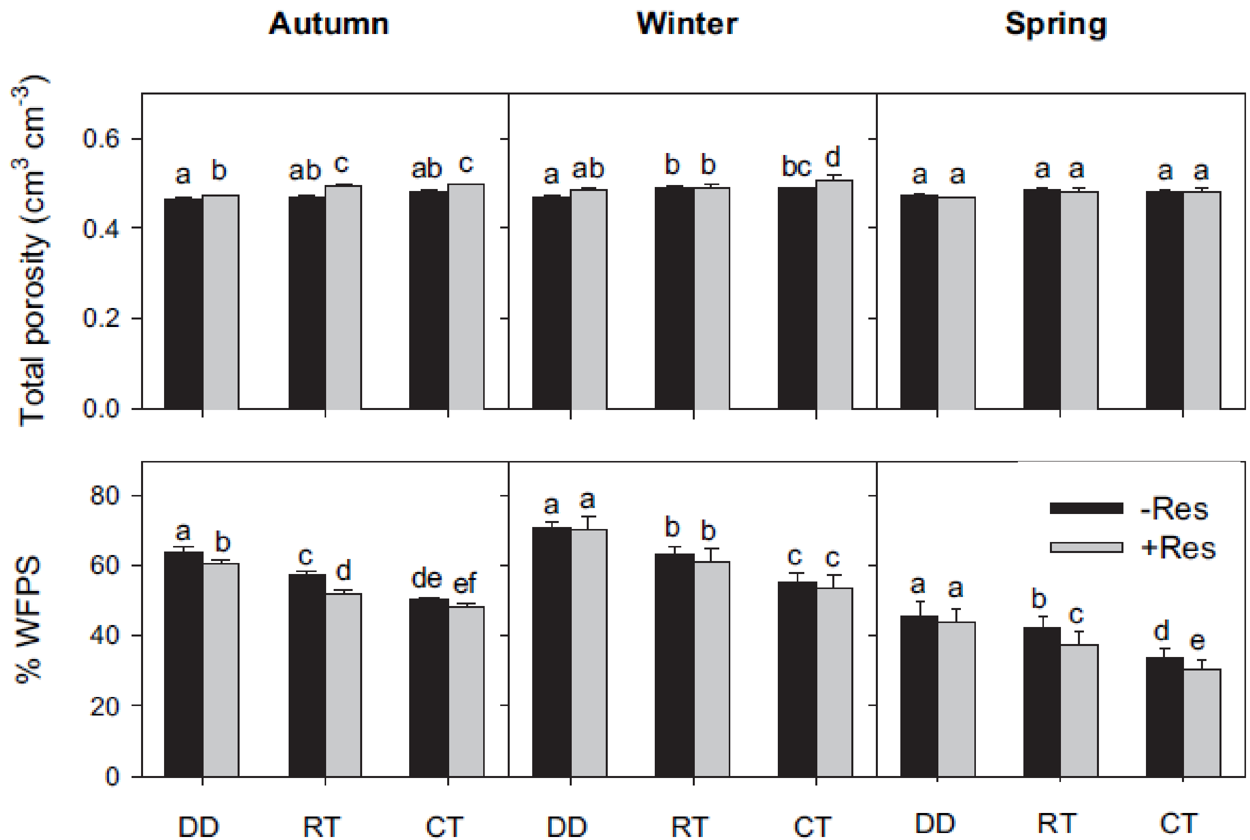
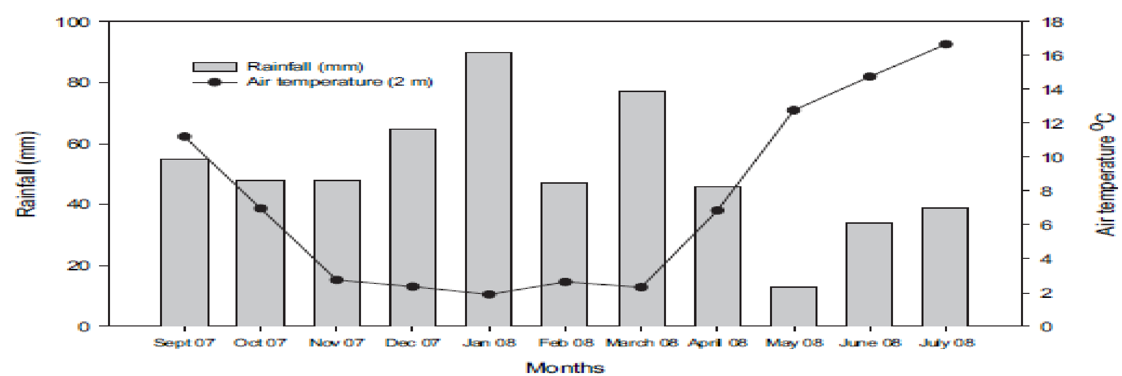
(Mutegi et al., 2010)

Total porosity

Water-filled pore space



Temperature
Precipitation



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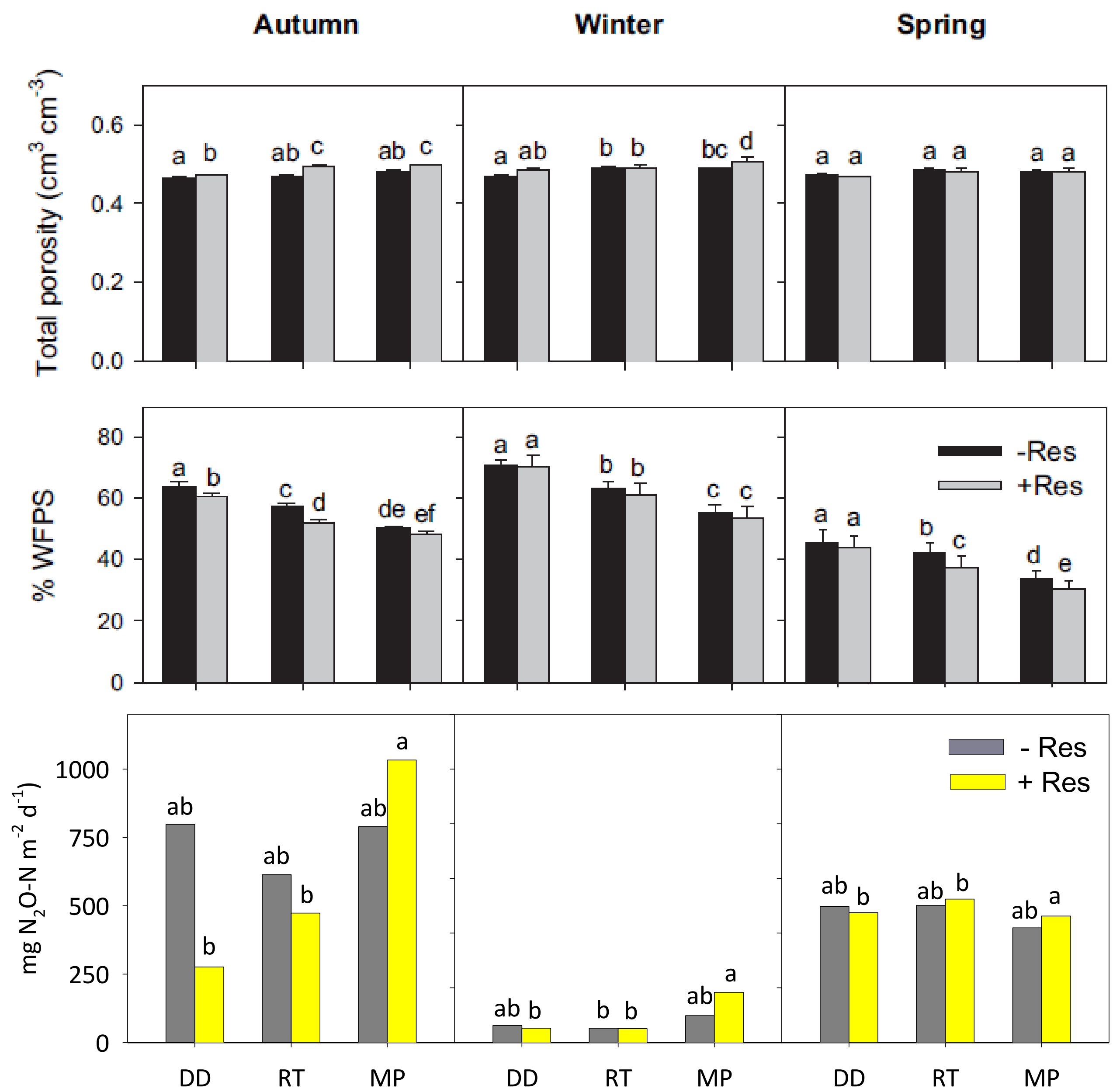
Nitrous oxide



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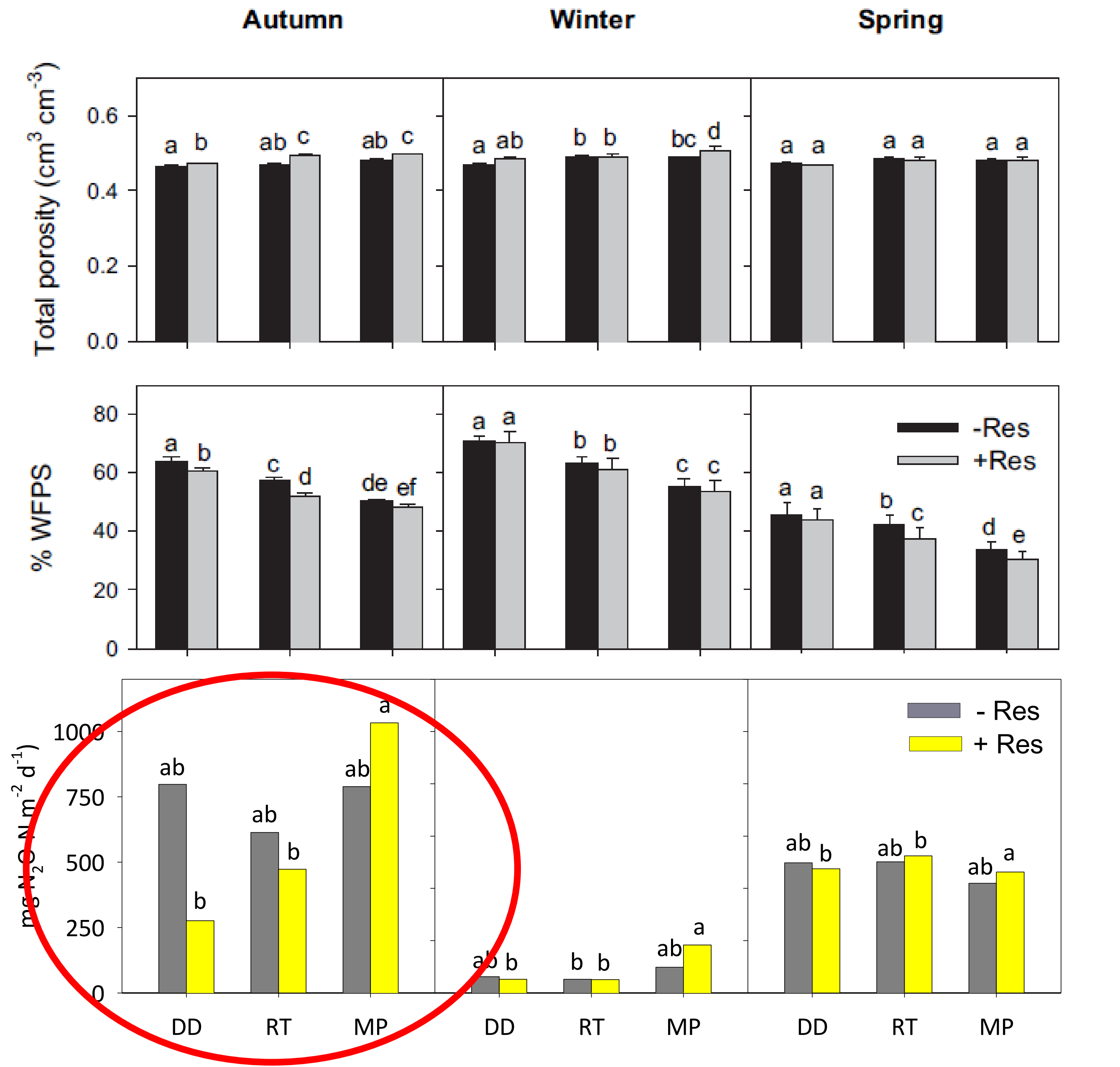

Tillage × residue management II

N_2O emissions during and after growth of a winter cover crop

		Straw retention	Cover crop	
Moldboard ploughing	MP	+	+	-
Reduced tillage (harrowing 8-10 cm)	RT	+	+	-
Direct drilling (”no-till”)	DD	+	+	-

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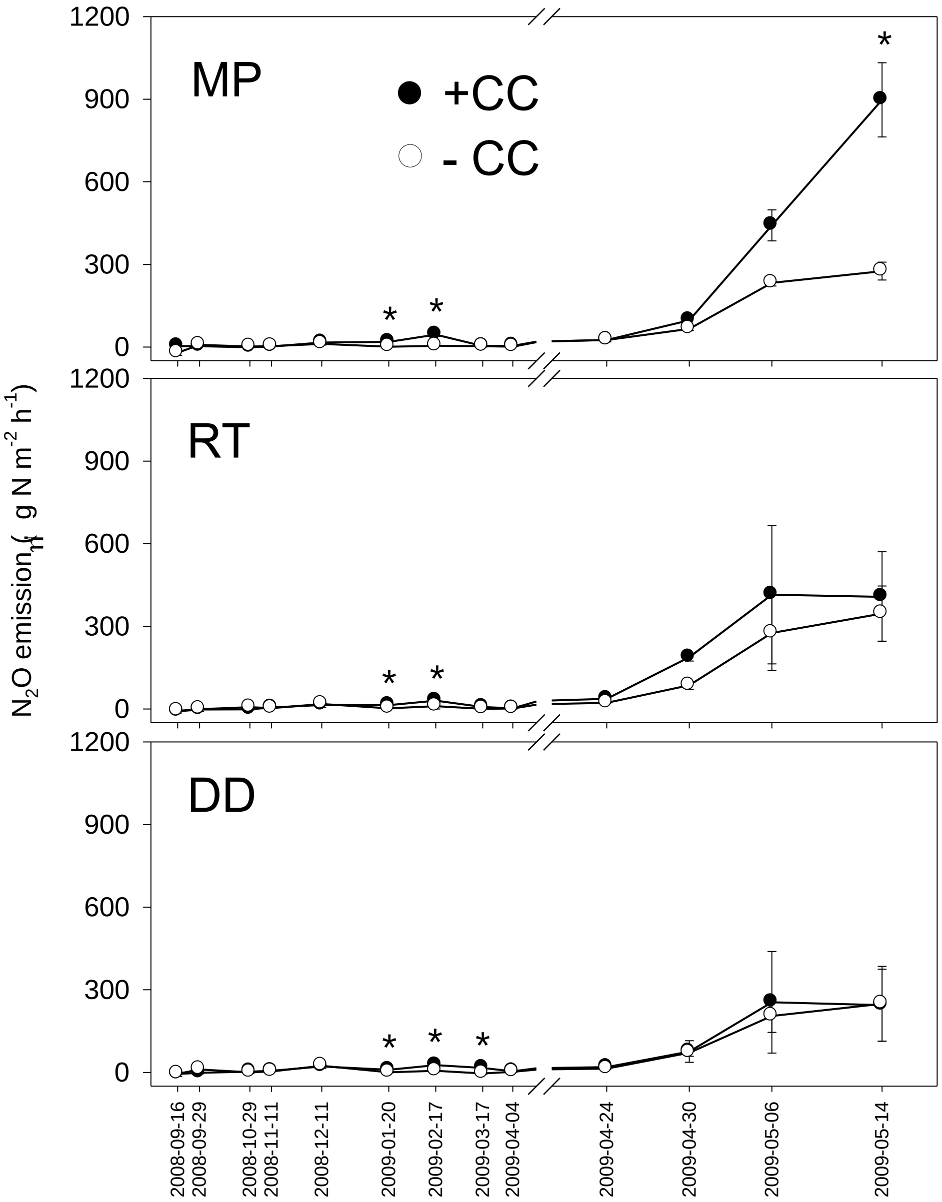
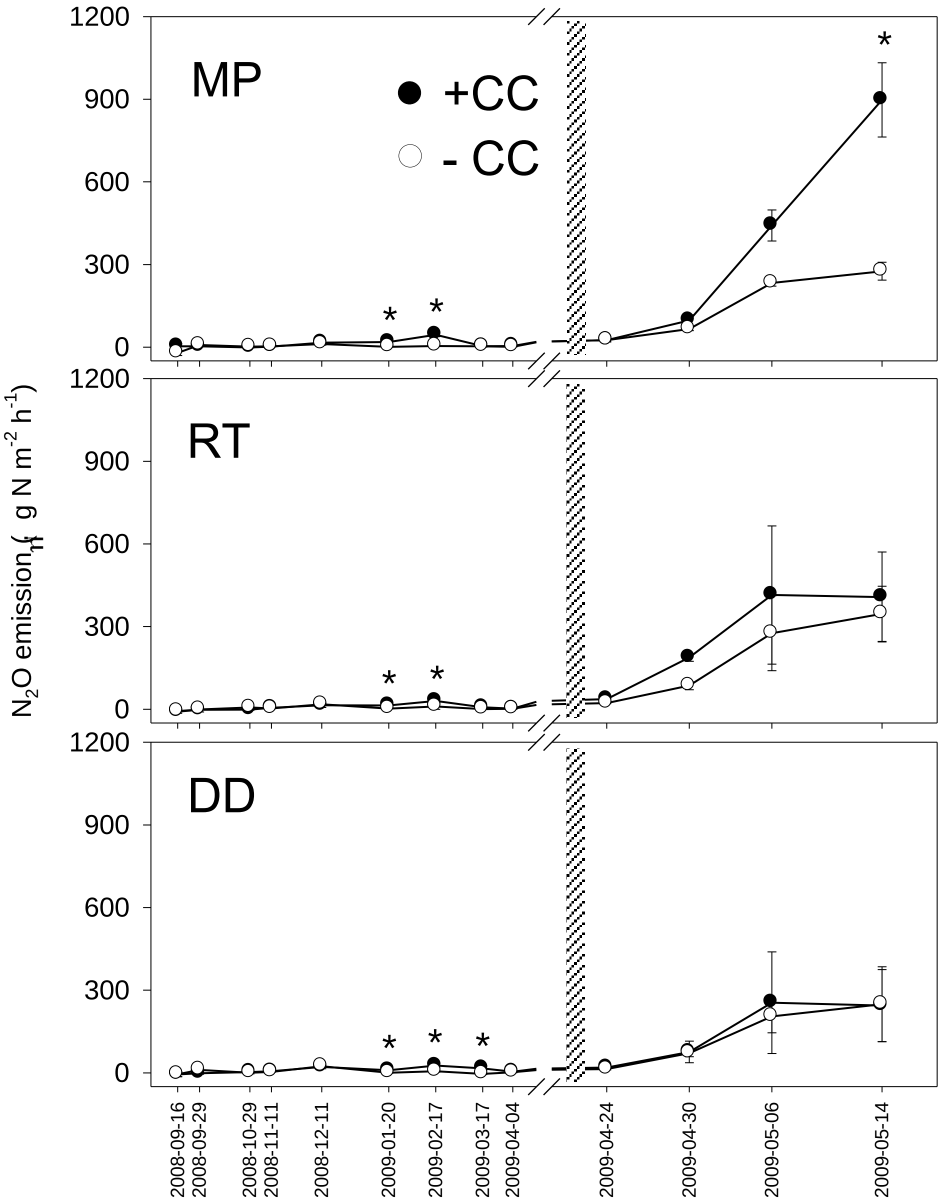
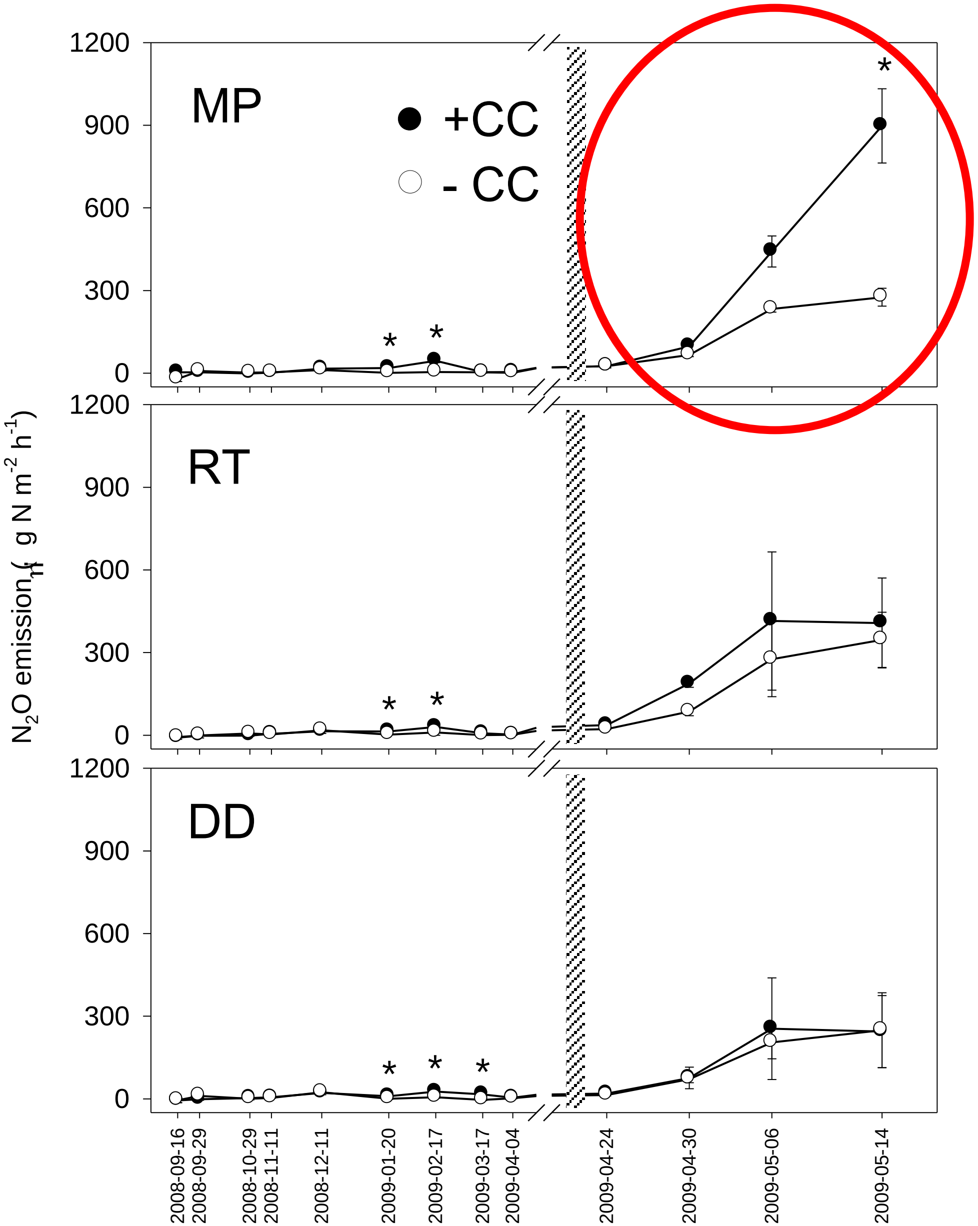
(Petersen et al., 2011)





17-24 April:
Tillage
Slurry injection
Seeding



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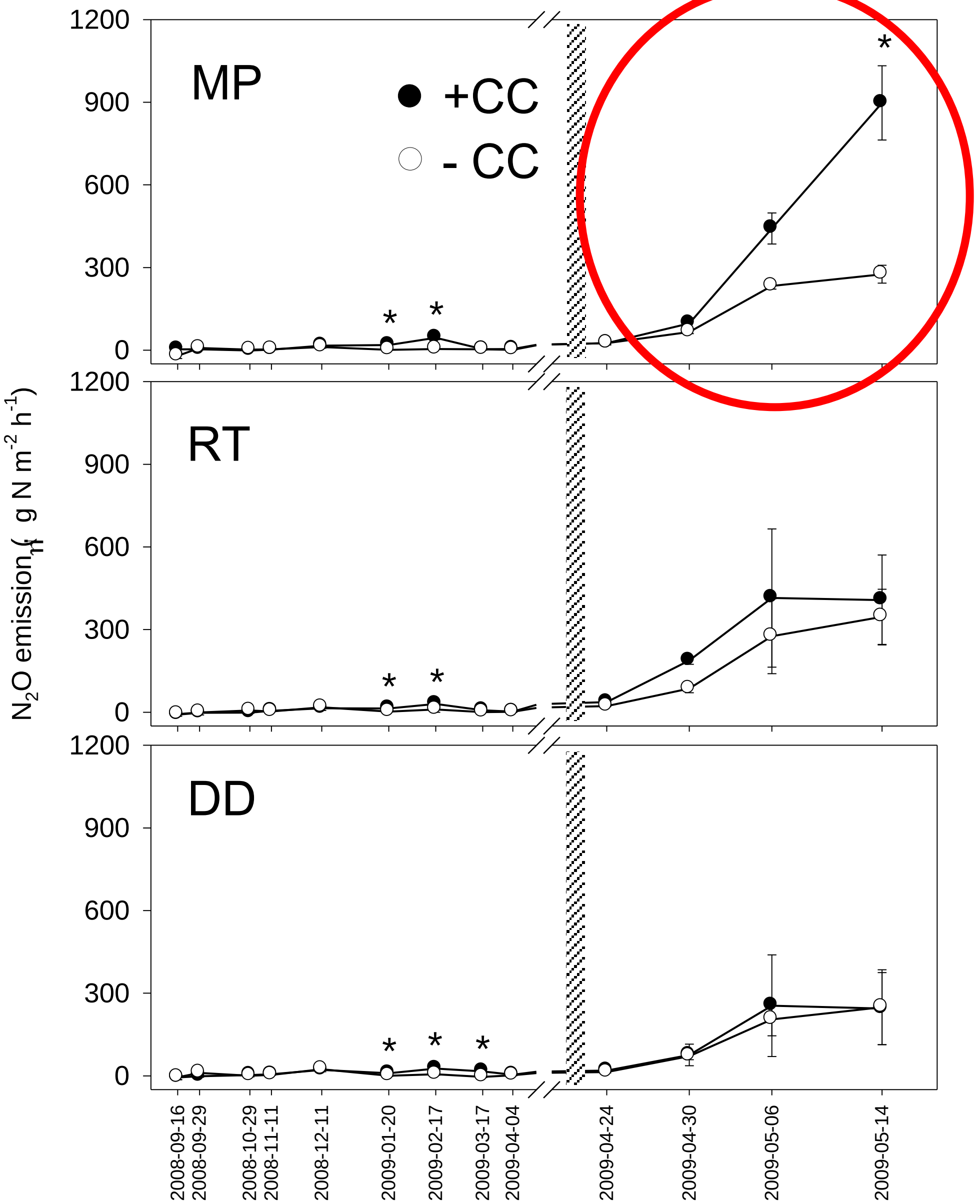

17-24 April:
Tillage
Slurry injection
Seeding

Soil N_2O concentrations:
5, 10, 20 and 30 cm depth

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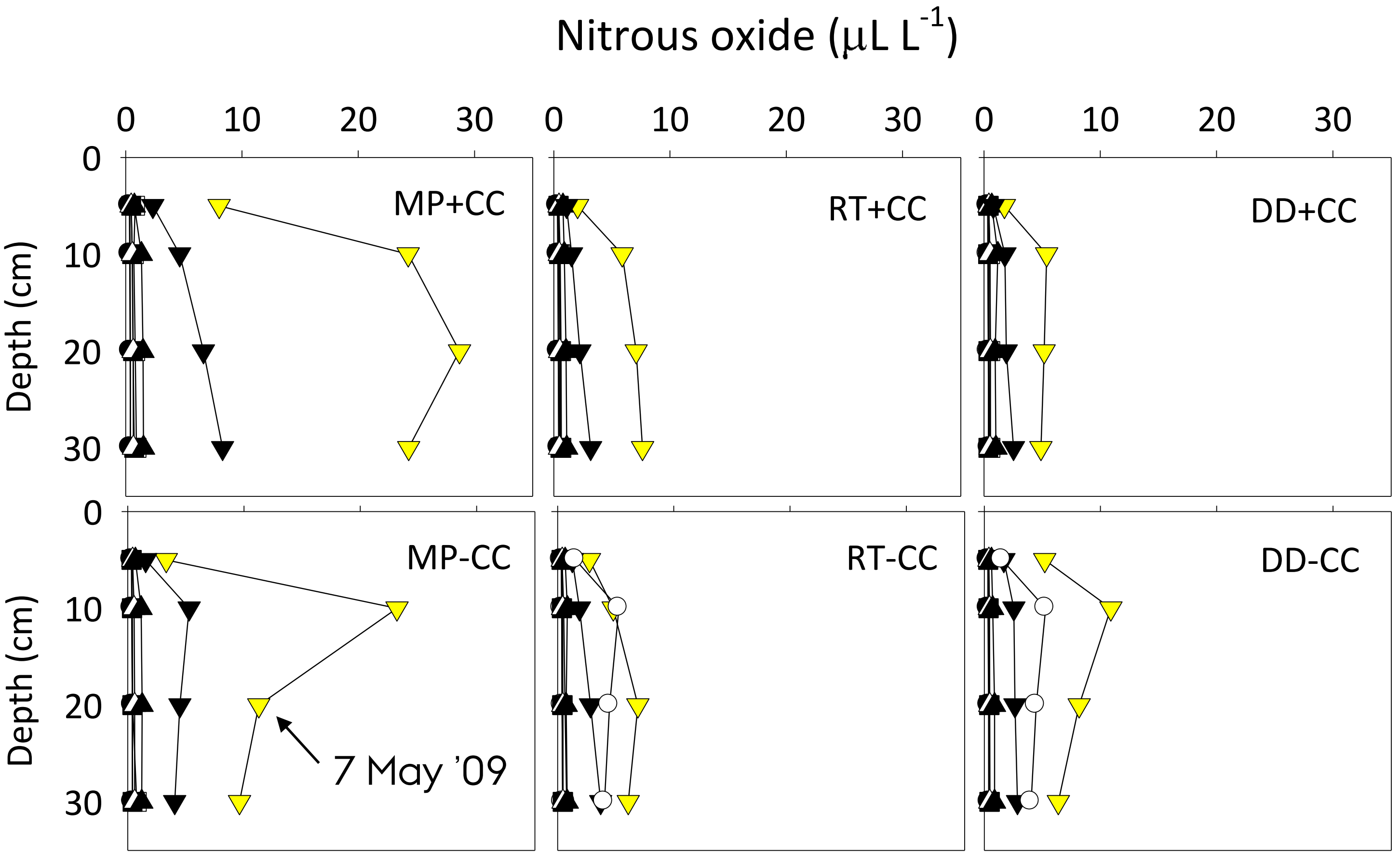
(Petersen et al., 2011)

Tillage × residue management II

Soil N_2O concentrations 31 Oct '08 – 19 May '09



Tillage × residue management II

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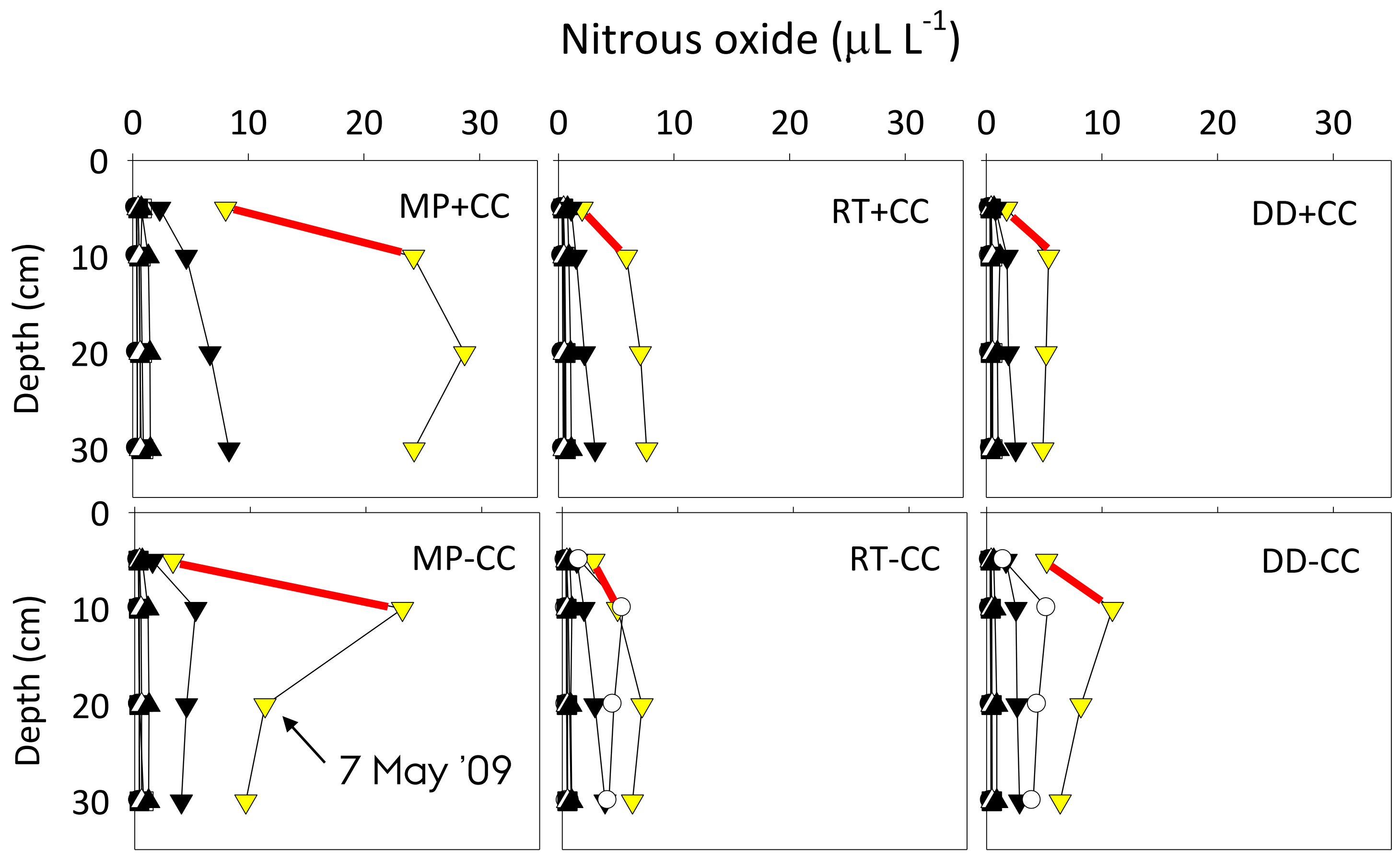

Treatment	Static chambers	Conc. gradient	Ratio
	$\mu g\ m^{-2}\ h^{-1}$		
CT-CC[1]	232 (11)	128 (97)	1.8
CT+CC	442 (56)	105 (9)	4.2
RT-CC	276 (136)	16 (11)	17.3
RT+CC	414 (251)	31 (20)	13.4
DD-CC	205 (60)	43 (25)	4.8
DD+CC	254 (185)	27 (14)	9.4

[1] CT – Conventional tillage; DD – Direct drilling; RT – Reduced tillage;
-CC – Without cover crop; +CC – with fodder radish as cover crop.

(Petersen et al., 2011)

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Summary

Tillage × residue management

Sandy loam soil, well-structured:

› Organic inputs were a major source (driver?) of N_2O emissions

› Deep incorporation stimulated emissions compared to more shallow distribution

Green manure management

	Field	O2 organic	O4 organic	O4 organic	C4 conventional
3rd course	1	S. barley:ley	S. barley^{CC}	S. barley	S. barley
2005-2008	2	Grass-clover	Pea/barley^{CC}	Pea/barley	Pea/barley
	3	Potato	Potato	Potato	Potato
	4	Winter wheat^{CC}	Winter wheat^{CC}	Winter wheat	Winter wheat

^{CC}Catch crop

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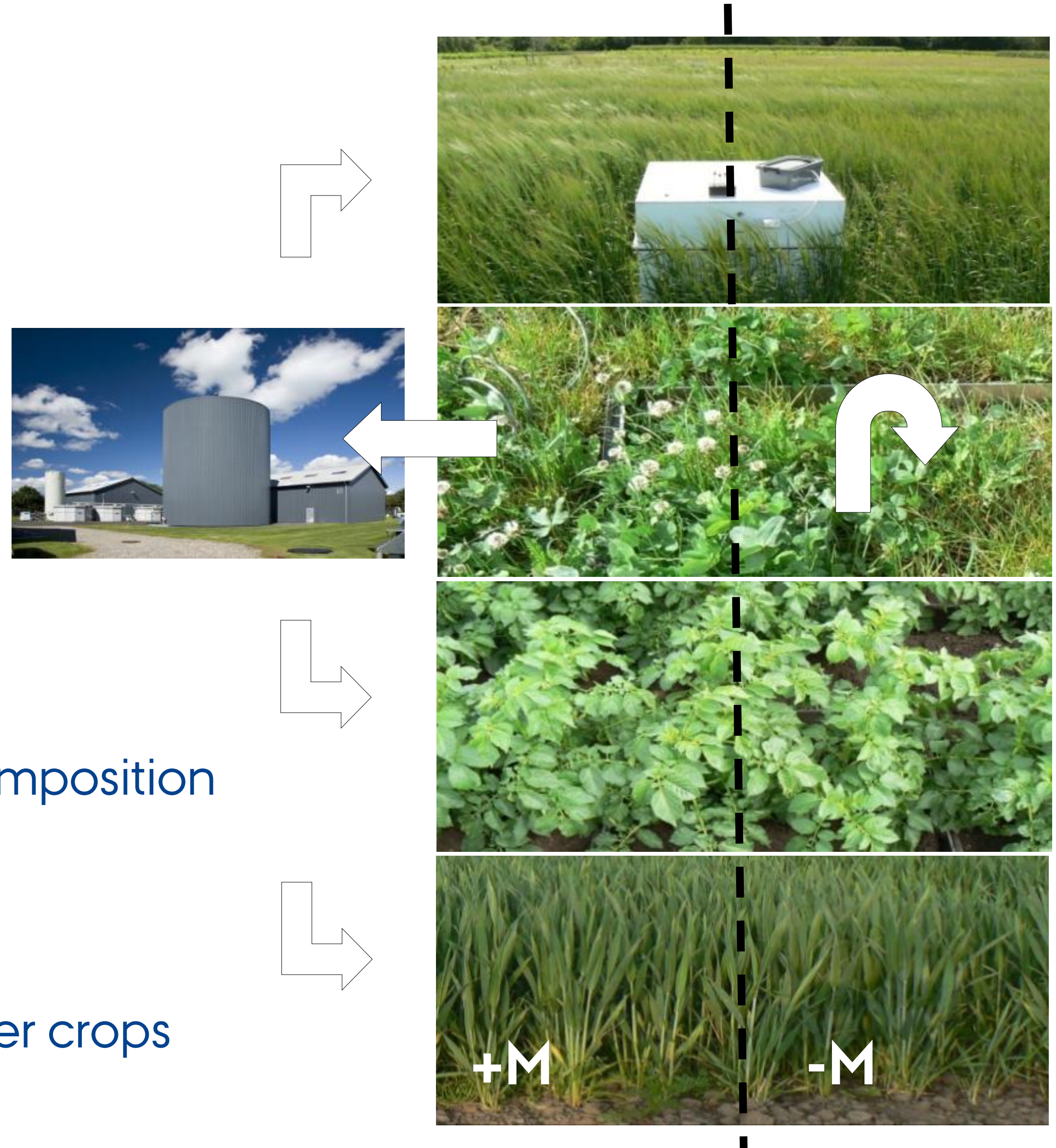

- **Treatment 1 (-M)**:
- Cuts left for in-field decomposition

- **Treatment 2 (+M)**:
- Cuts exported for biogas treatment and use in other crops

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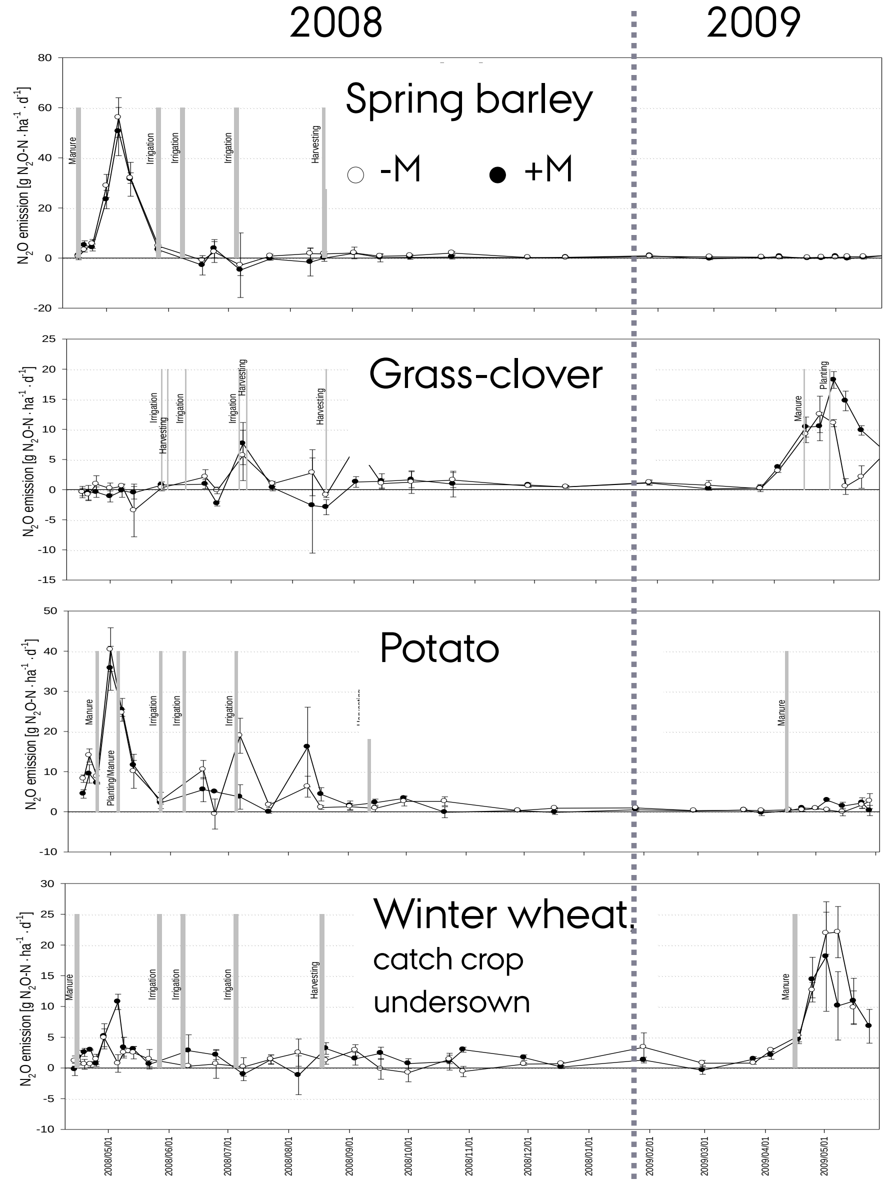
(Brozyna et al., in prep.)

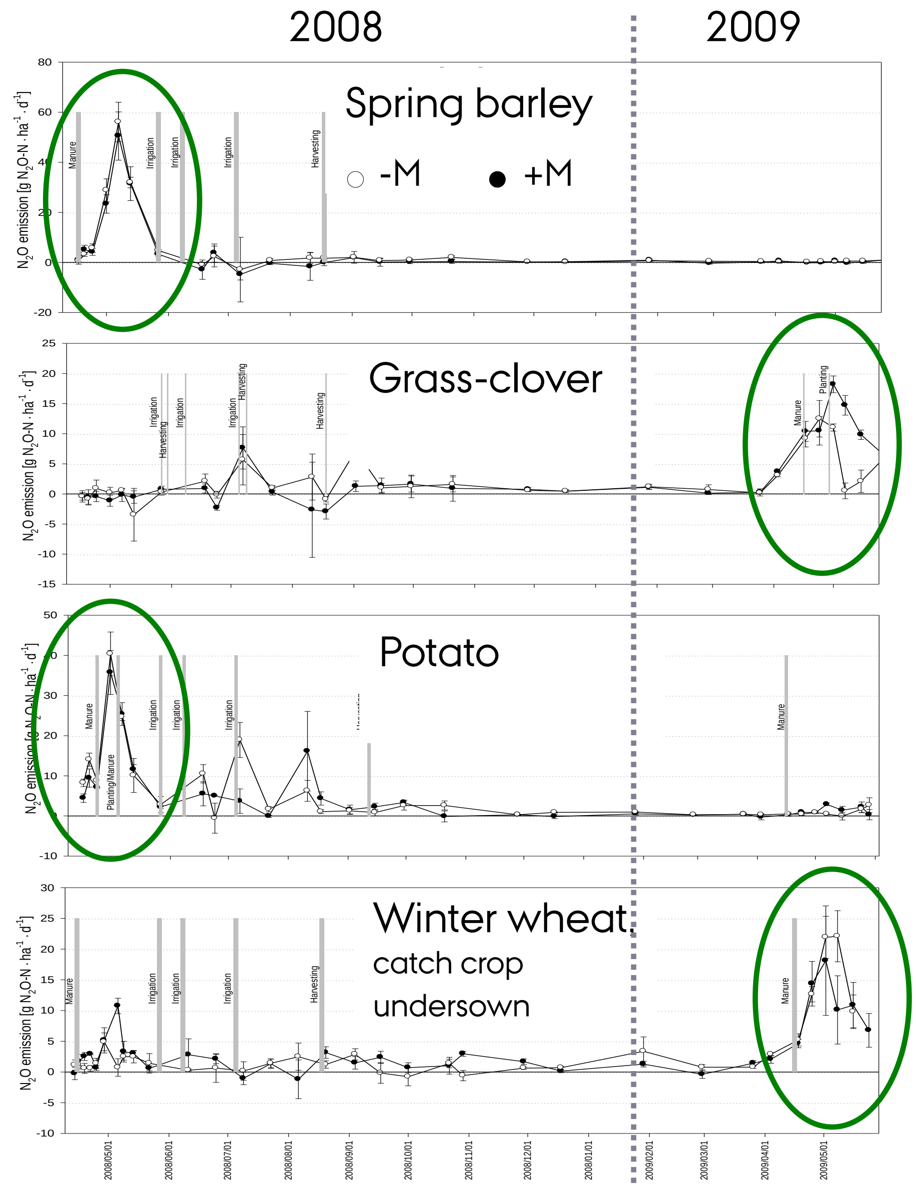
Green manure management

N_2O emissions



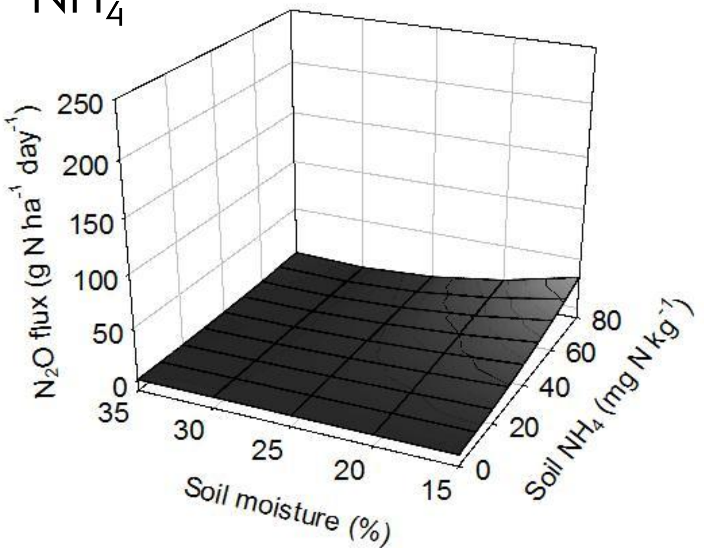
Grass-clover management

N_2O emissions

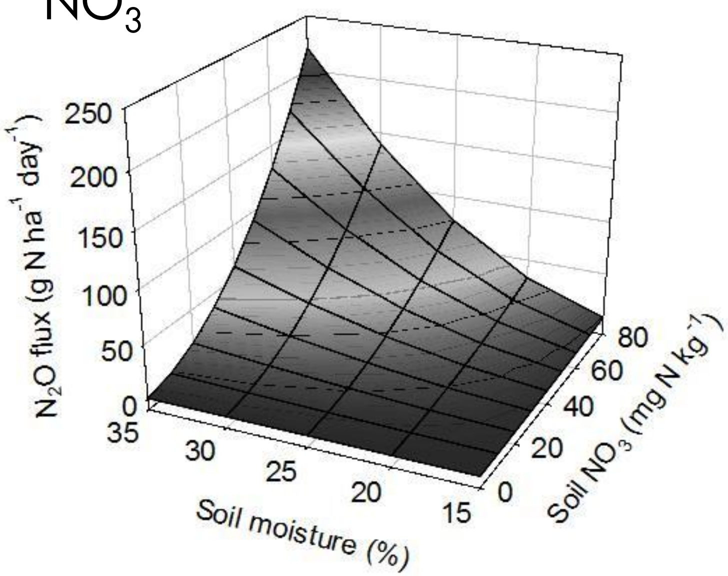


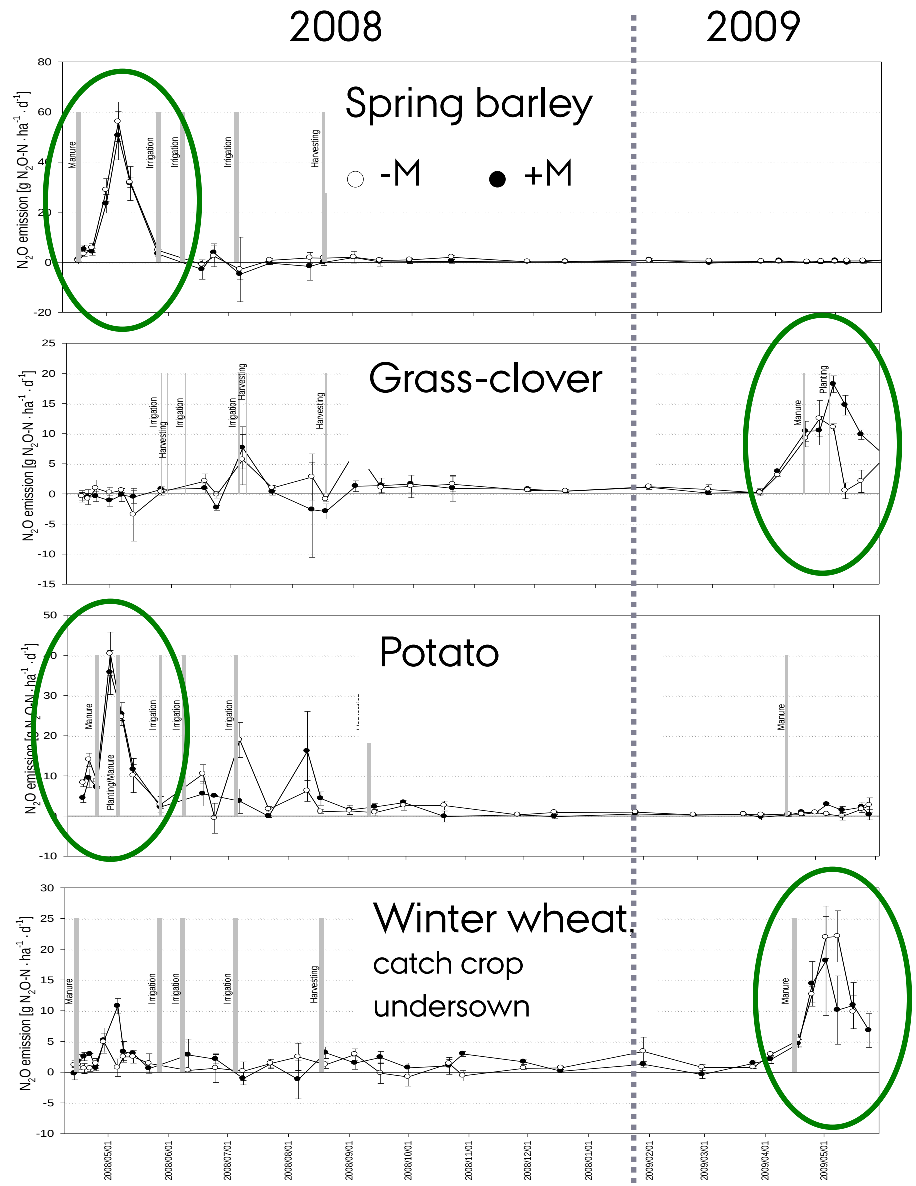
(Brozyna et al., in prep.)

NH$_4^+$



NO$_3^-$





(Brozyna et al., in prep.)

Green manure management

Nitrogen input, crop yield, and N_2O

		Treatment	
		-M	+M
Manure	kg N ha^{-1}	0	70
Residues, main crops	kg N ha^{-1}	122	54
Residues, catch crop	kg N ha^{-1}	20	16
Total input	kg N ha^{-1}	141a	139a
N_2O emissions	kg N ha^{-1}	0.9a	0.8a
Cash crop yield	Mg DM ha^{-1}	4.2b	4.8a
N_2O per crop yield	kg N_2O-N Mg DM^{-1}	0.22a	0.16b

Summary

Green manure management

Sandy loam soil, well-structured:

- Anaerobic digestion of grass-clover a mobile source of N
- Higher cash crop yields, and similar emissions of N_2O resulted in less emission per unit product

Effects of crop rotation

N_2O emission potential after freeze-thaw event

	Field	O2 organic	O4 organic	O4 organic	C4 conventional
3rd course 2005-2008	1	S. barley:ley	S. barley^{CC}	S. barley	S. barley
	2	Grass-clover	Pea/barley^{CC}	Pea/barley	Pea/barley
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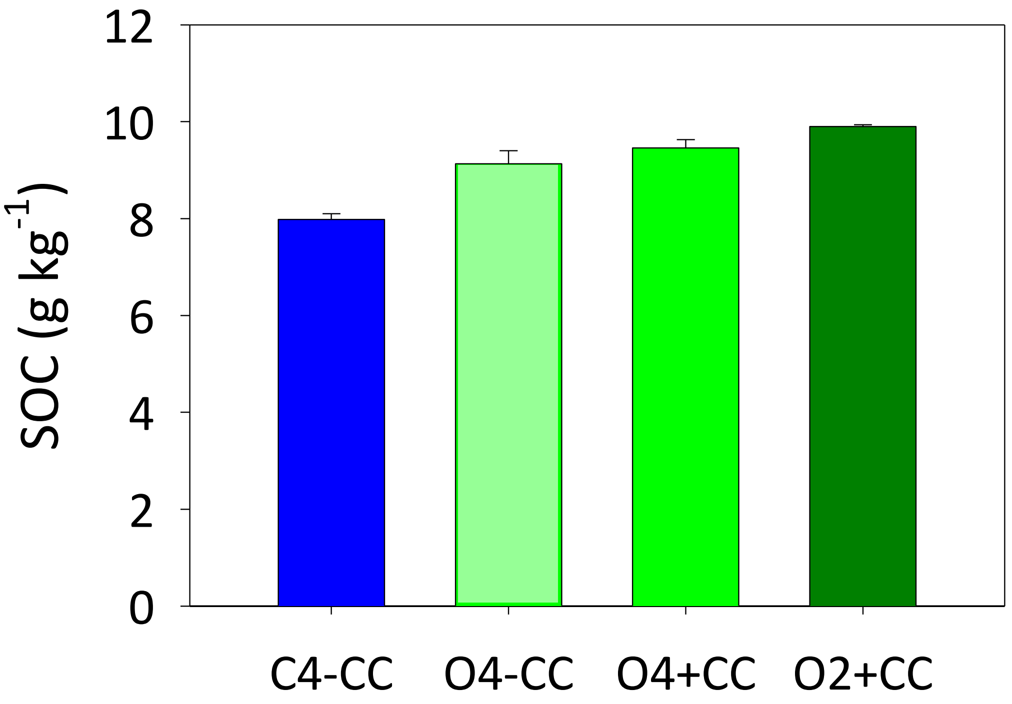
Effects of crop rotation

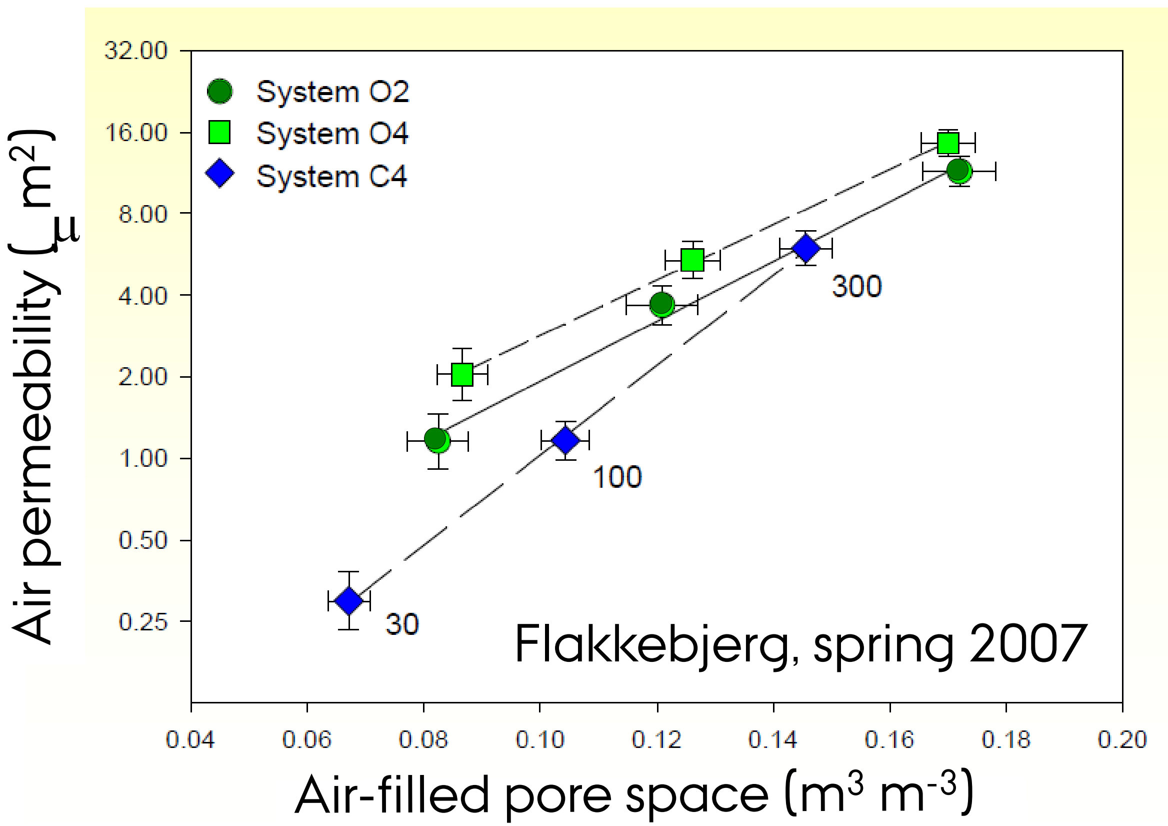
Soil organic carbon



(data: P. Schjønning)

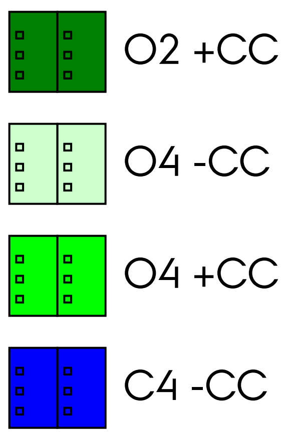
Effects of crop rotation

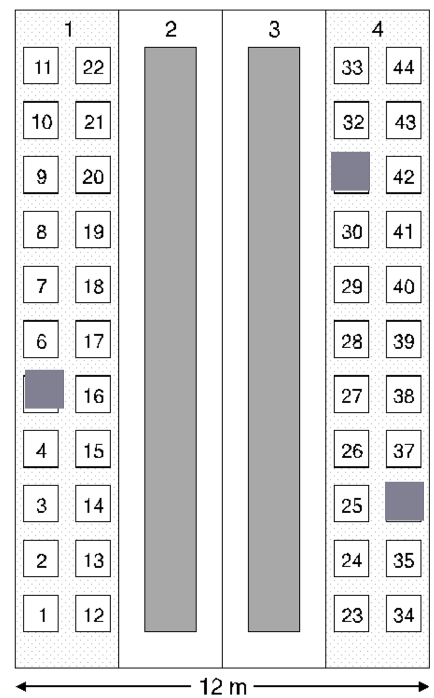
Soil structure



Effects of crop rotation

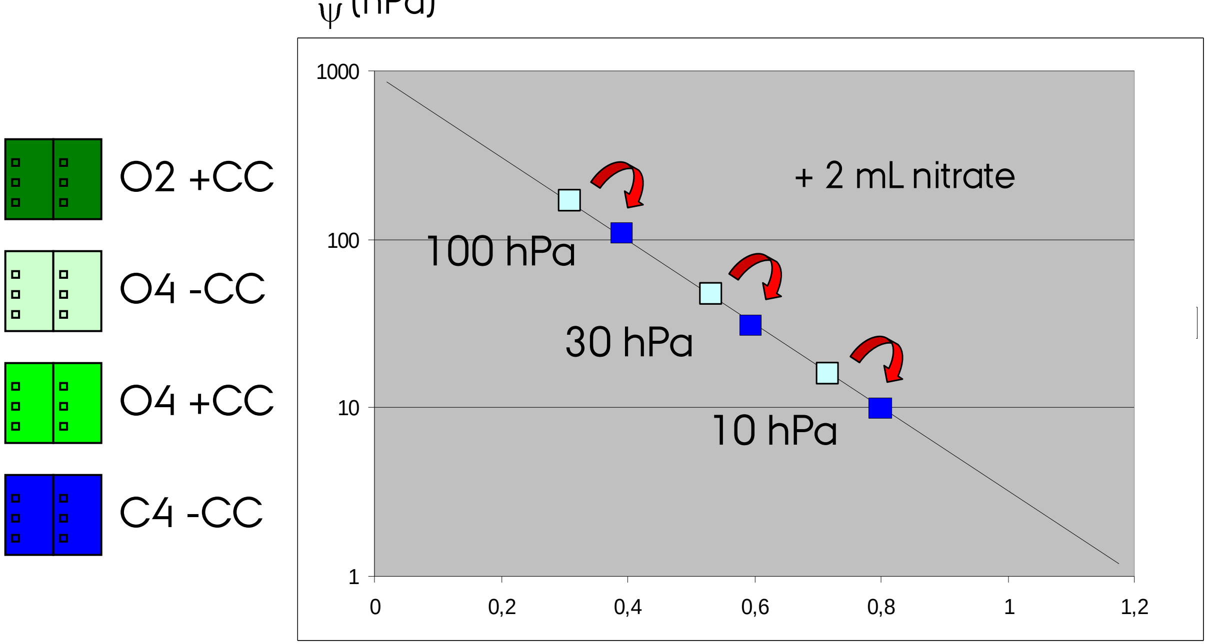
Intact samples collected in WW, early spring

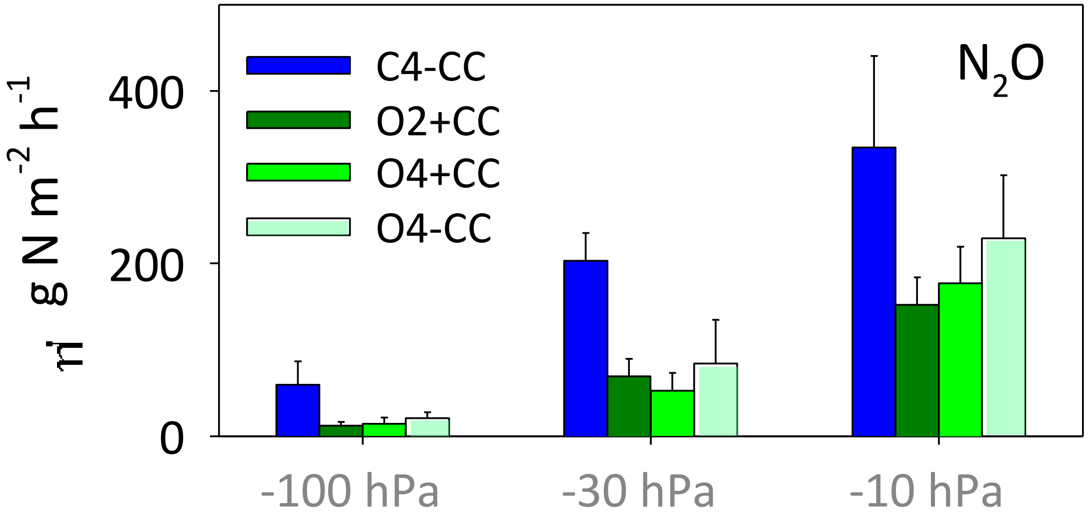




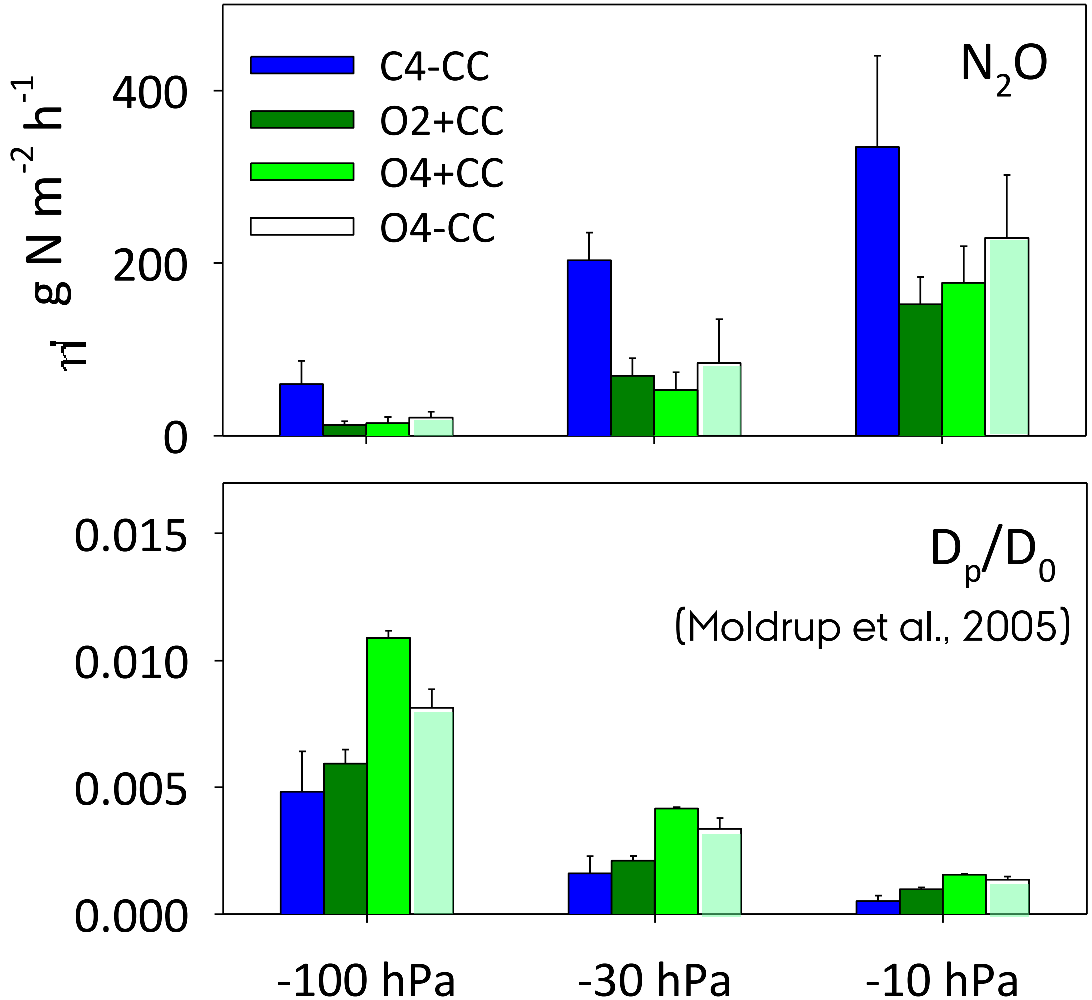
Effects of crop rotation

3 matric potentials, NO_3^- added, -10°C overnight





N2O
C4-CC
O2+CC
O4+CC
O4-CC
0
200
400
-100 hPa
-30 hPa
-10 hPa



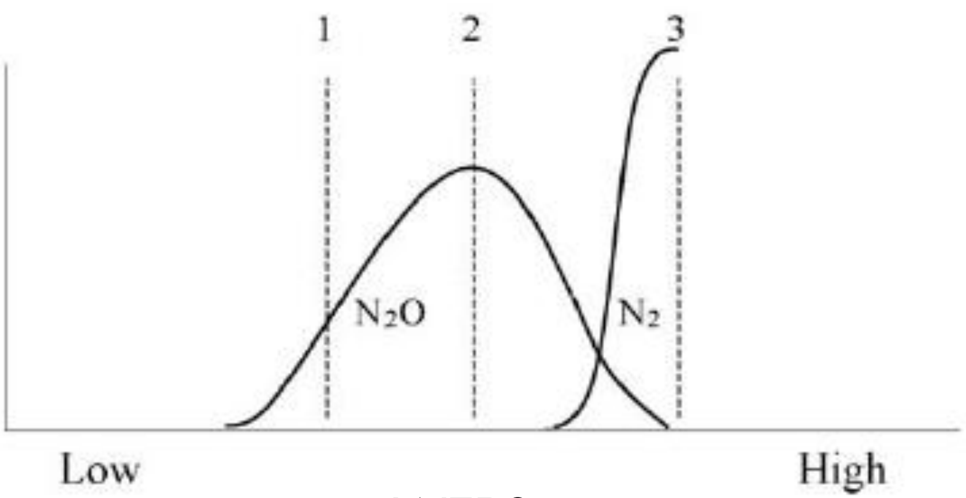
µg N m-2 h-1
400
200
0
C4-CC
O2+CC
O4+CC
O4-CC
N2O
0.015
0.010
0.005
0.000
Dp/D0
(Moldrup et al., 2005)
-100 hPa
-30 hPa
-10 hPa

Summary
Effects of crop rotation

Sandy loam soil, poorly-structured:
› Long-term effects of crop rotation on soil physical properties
› Oxygen supply appeared to be the main driver of N_2O emissions

Control of N_2O emission

The significance of oxygen availability



WFPS

Control of N_2O emission

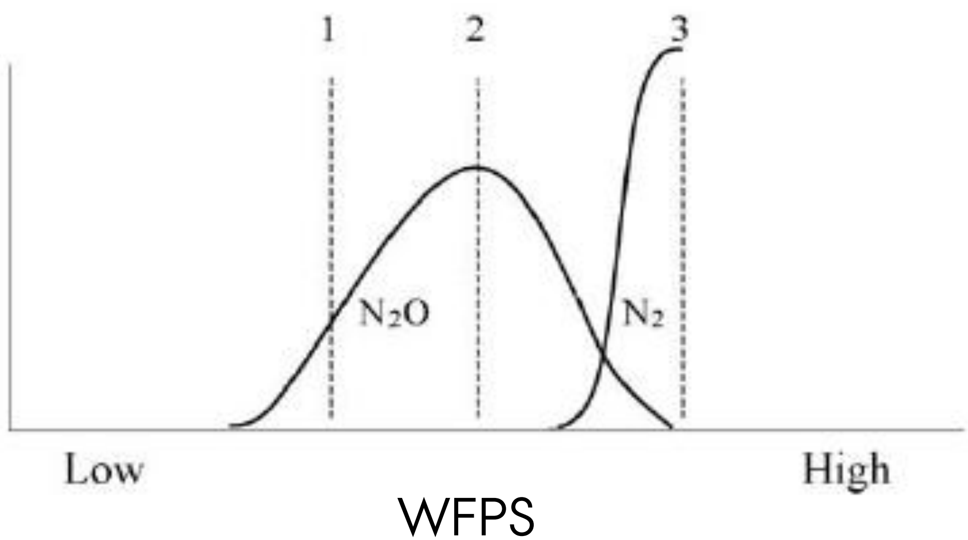
The significance of oxygen availability

O_2 demand

› OM quantity
› OM quality
› OM-soil contact

O_2 supply

› texture
› structure
› moisture



Control of N_2O emission
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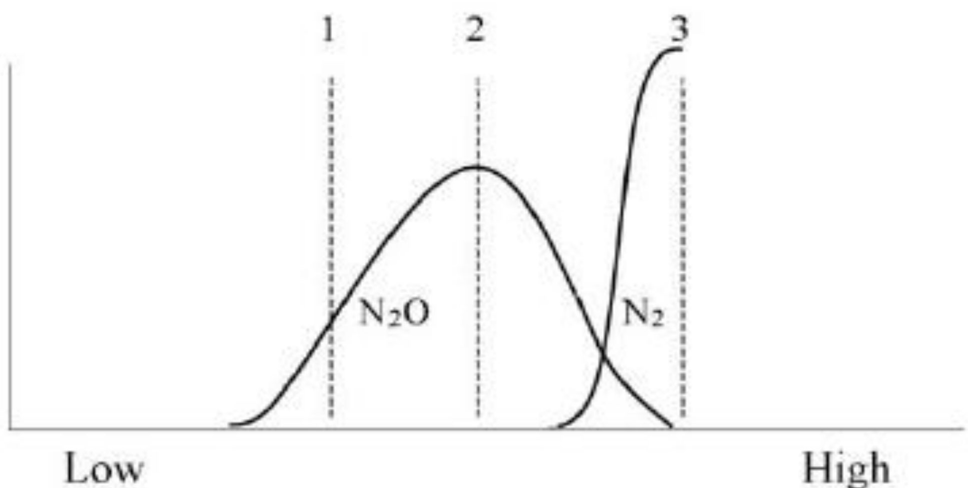

$$\frac{O_2 \text{ demand}}{O_2 \text{ supply}}$$

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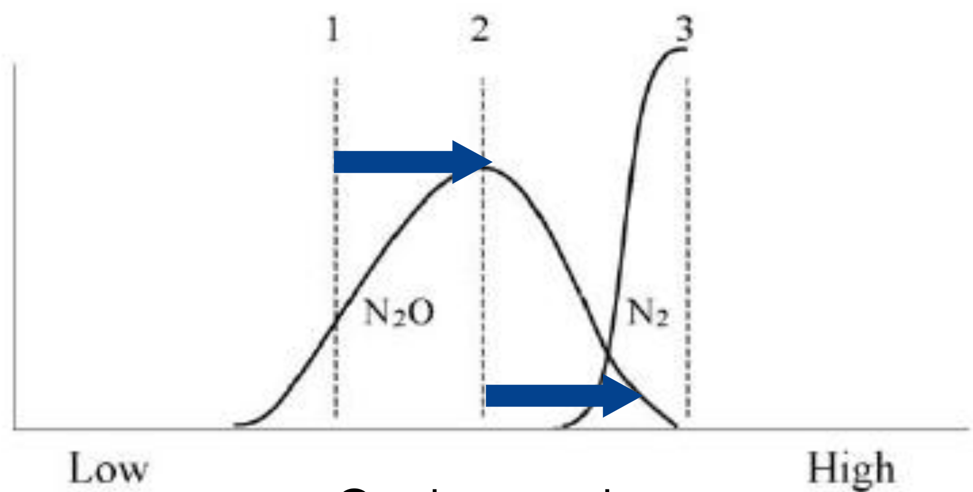

$$\frac{O_2 \text{ demand}}{O_2 \text{ supply}}$$

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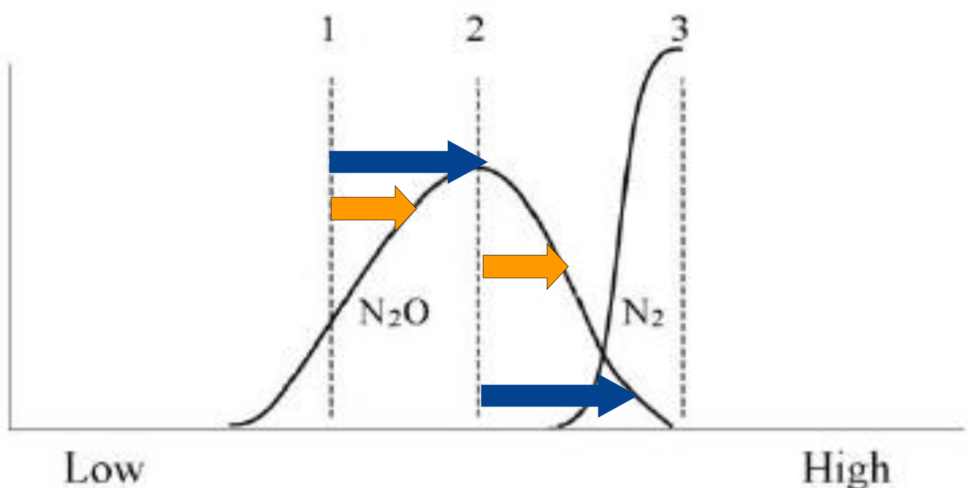

$$\frac{O_2 \text{ demand}}{O_2 \text{ supply}}$$

Conclusions

- In well-aerated cropland soil N_2O emissions are mainly driven by inputs of manure and crop residues. On such soils reduced tillage appeared to be a mitigation option

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› Anaerobic digestion of green manure crops could be a strategy to improve crop yields without additional N_2O

Conclusions

- In well-aerated cropland soil N_2O emissions are mainly driven by inputs of manure and crop residues. On such soils reduced tillage appeared to be a mitigation option
- Anaerobic digestion of green manure crops could be a strategy to improve crop yields without additional N_2O
- Long-term effects of rotation on soil properties can affect the potential for N_2O emissions

Conclusions

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- Anaerobic digestion of green manure crops could be a strategy to improve crop yields without additional N_2O
- Long-term effects of rotation on soil properties can affect the potential for N_2O emissions
- Estimates of N_2O emissions, and of management effects, could be improved by an approach that takes oxygen demand and oxygen supply into account

Acknowledgements

› PhD students James Mutegi, Michal Brozyna and Ngoni Chirinda,

› Field staff at Foulumgaard and Flakkebjerg

› Jørgen E. Olesen, Lars J. Munkholm, Per Schjønning, Elly Møller Hansen,

Thank you!