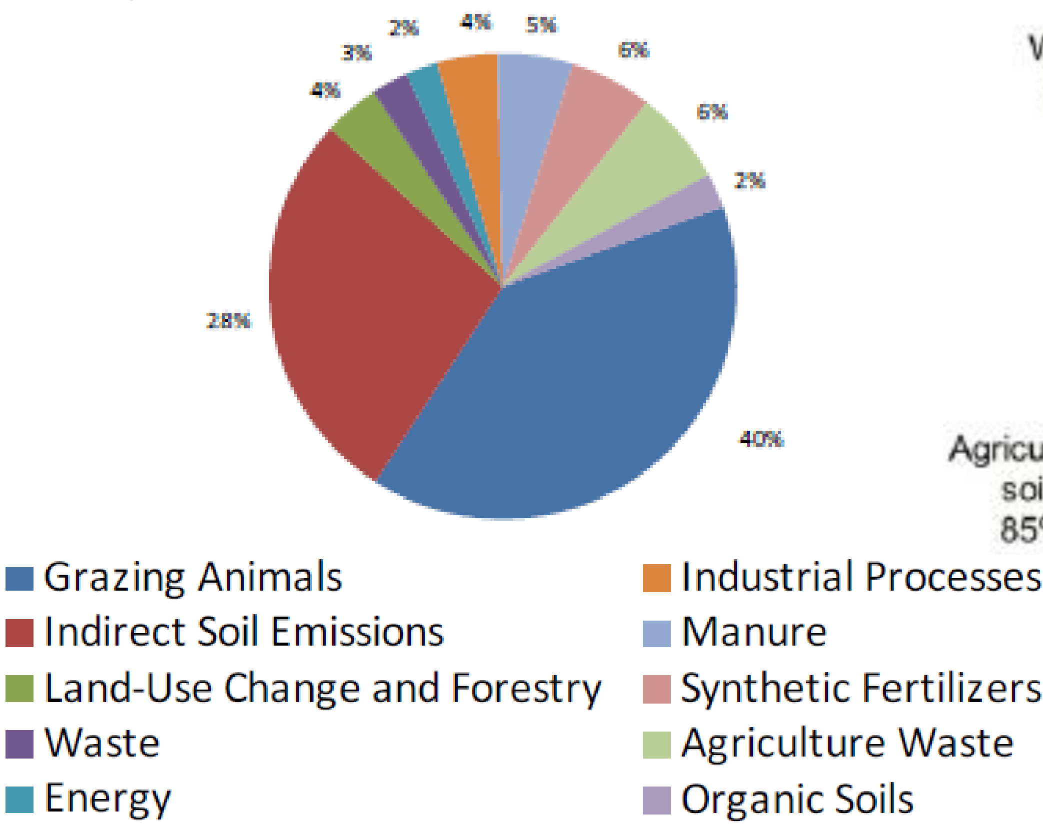
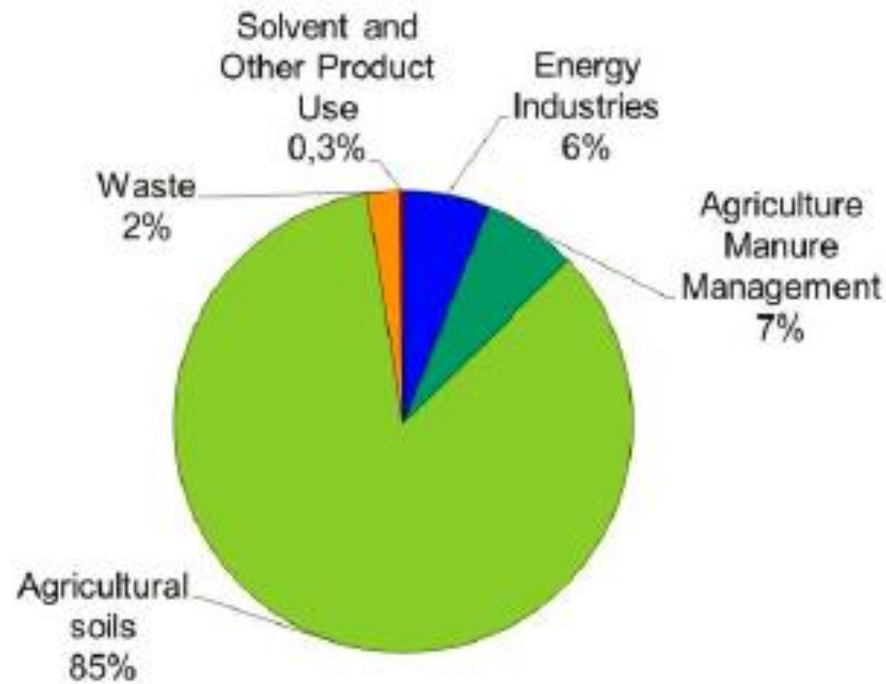
Nitrous oxide emissions from biowaste applied to soil

Søren O. Petersen, Aarhus University, DK

Sources of N_2O

Brazil



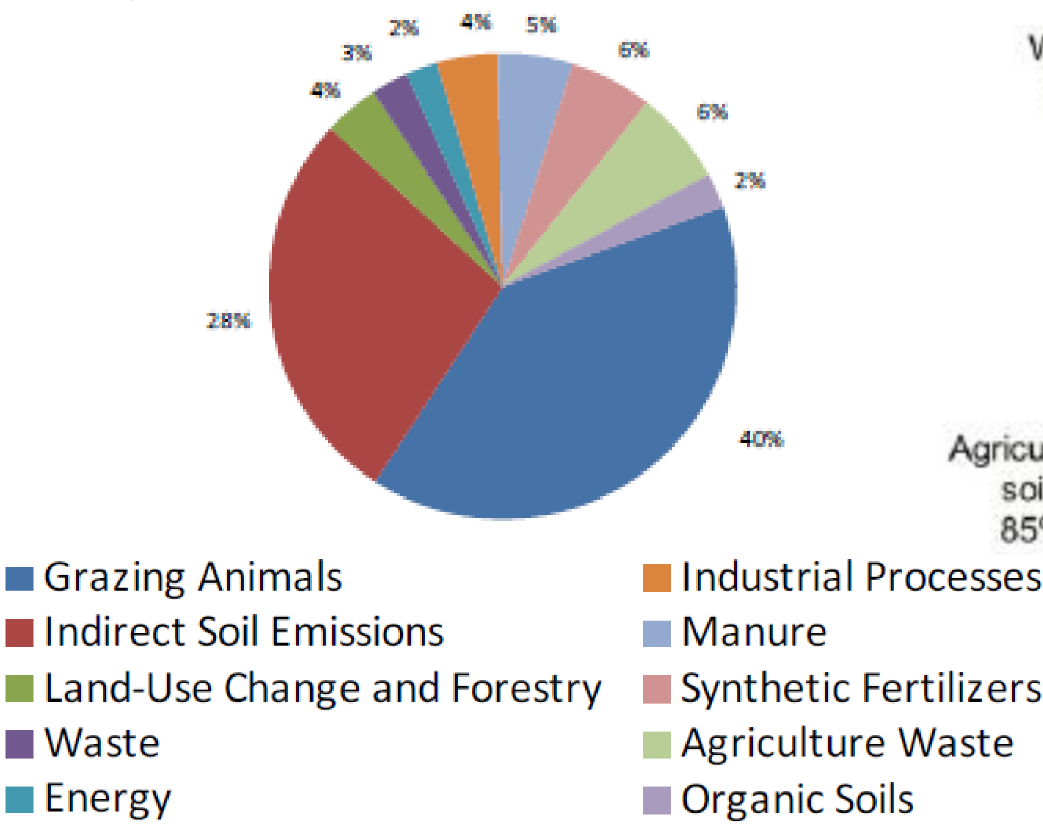


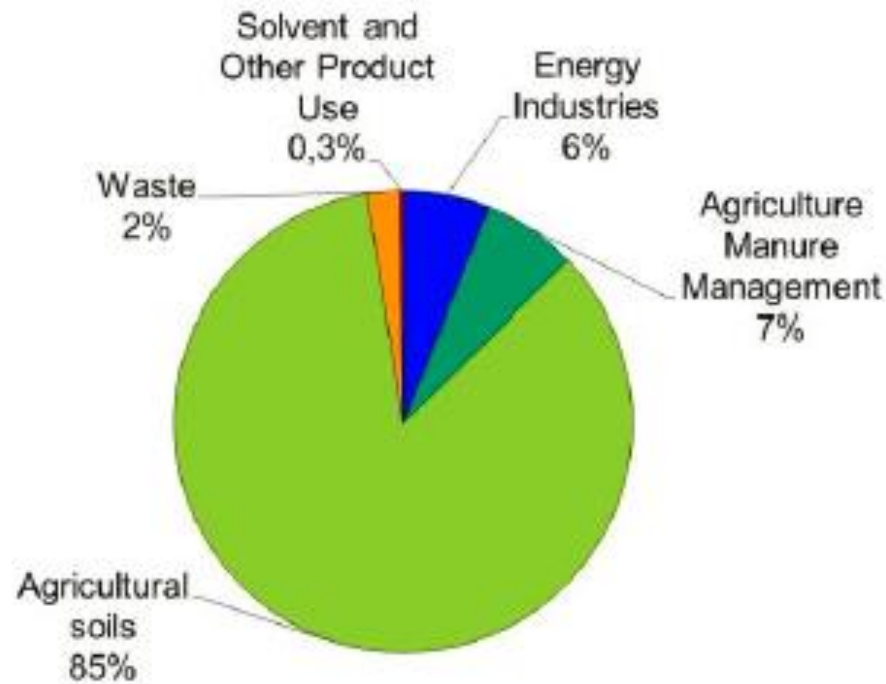
Denmark

- 546 Gg N_2O in 2005
- Agriculture 87% of N_2O emissions
- 43% increase since 1990

- 19.5 Gg N_2O in 2011
- Agriculture 92% of total
- 33% decline since 1990

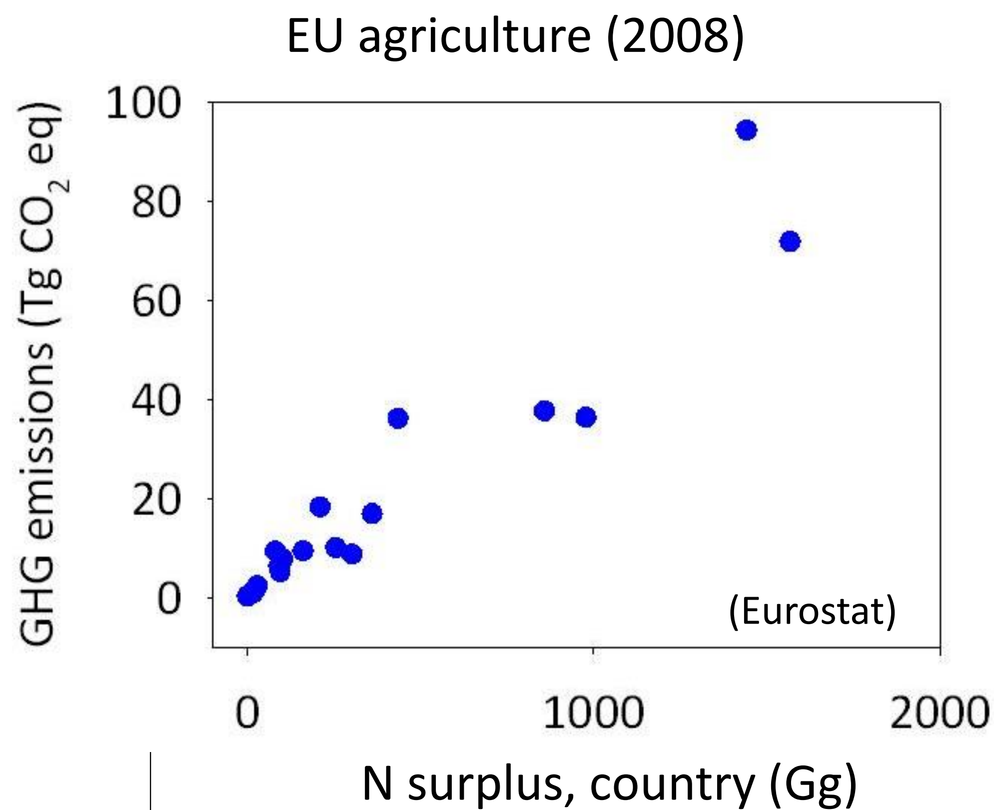
Brazil

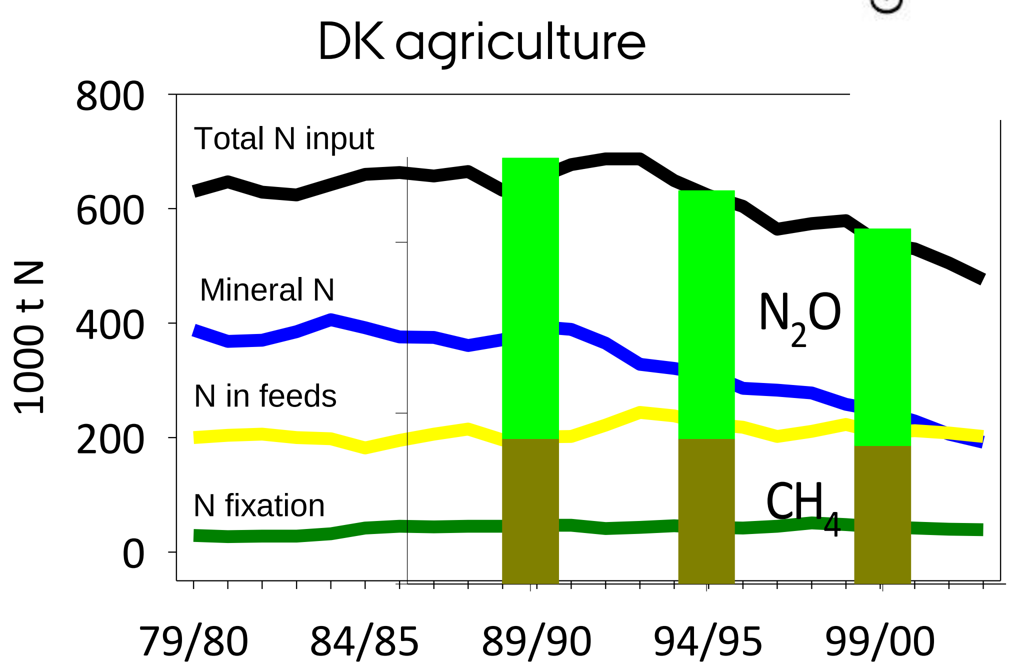




Denmark

GHG emissions and N surplus





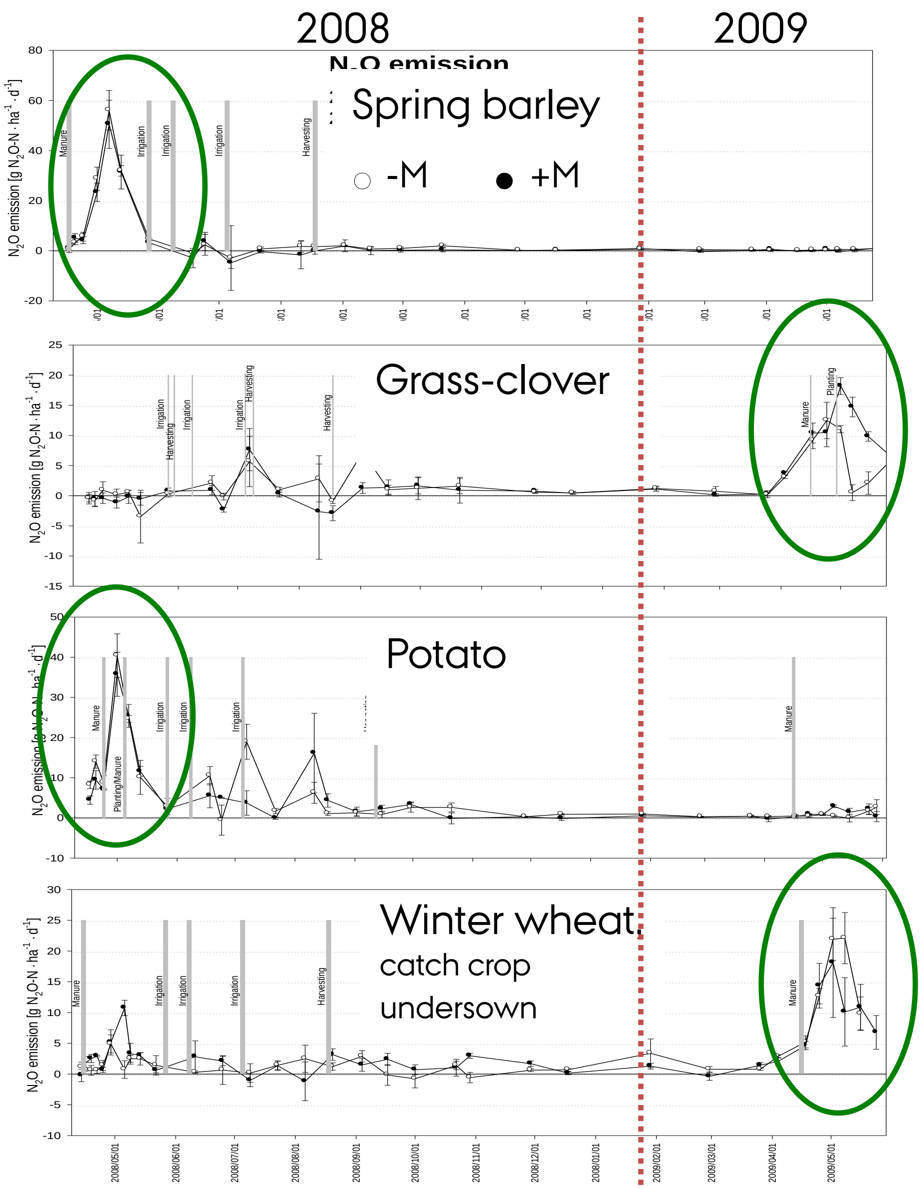
(Kyllingsbæk and Hansen, 2007)

Is nitrogen the only important driver for N_2O emissions?

Uncertainty of N_2O emission factors

Pollutant	CRF category	Emission	Activity data,%	Emission factor, %
N_2O, Gg CO_2 eqv.	4.B Manure management	403	22	100
	4.D.1.1 Synthetic fertiliser	1180	25	100
	4.D.1.2 Animal waste applied to soils	1169	22	100
	4.D.1.3 N-fixing crops	259	20	100
	4.D.1.4 Crop residue	315	20	100
	4.D.1.5 Cultivation of histosols	205	20	100
	4.D.1.6 Sewage sludge/industrial waste	39	20	100
	4.D.2 Animal production (grazing)	208	25	100
	4.D.3.1 Atmospheric deposition	286	19	100
	4.d.3.2 N-leaching and runoff	1456	20	100
	4.F Field burning	1	25	50

Patterns in N_2O emissions



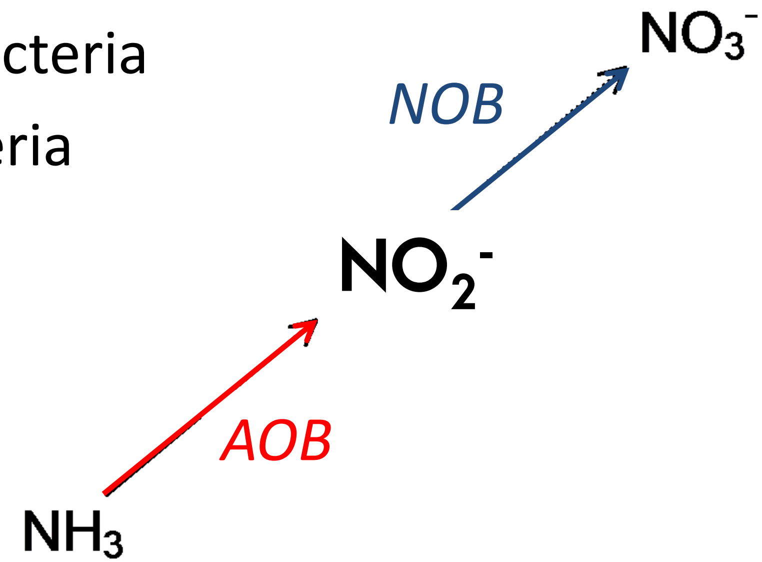
Outline of presentation

- Sources of nitrous oxide (N_2O)
- Distribution of biowaste in soil
- Oxygen supply and demand
- Empirical model, experimental validation
- Role of vinasse for N_2O emission
- Conclusions

Sources of nitrous oxide

AOB - Ammonia oxidizing bacteria

NOB - Nitrite oxidizing bacteria



	AOB	NOB
	Nitrosomonas sp.	*Nitrobacter sp.*
Oxygen affinity , K_m (kPa)	5-15	22-108
NH_3 (free) (mg N L^{-1})	10-150	0.1-1.0
HNO_2 (free) (mg N L^{-1})	0.1-0.4	0.011-0.023

Sources of nitrous oxide

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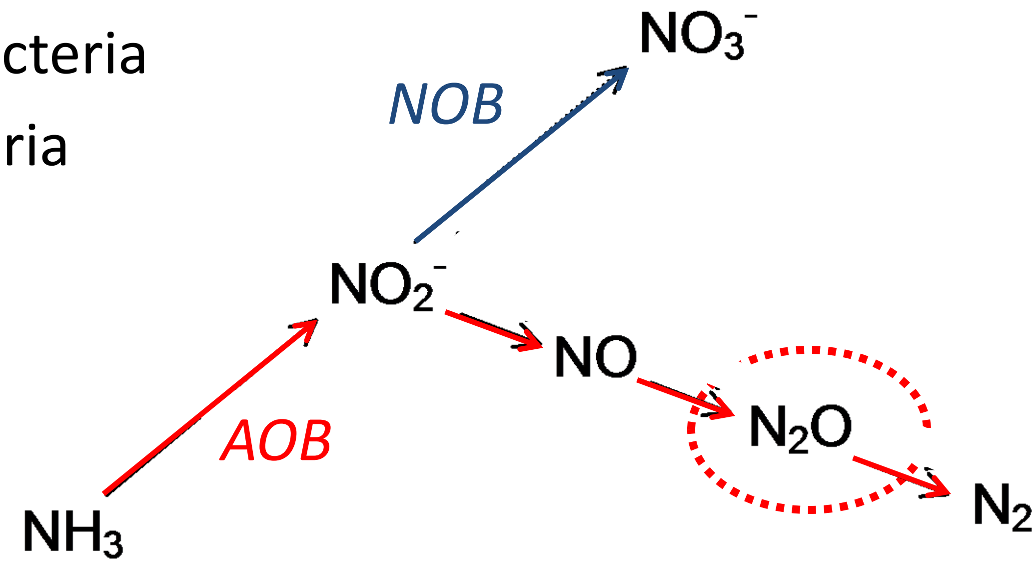

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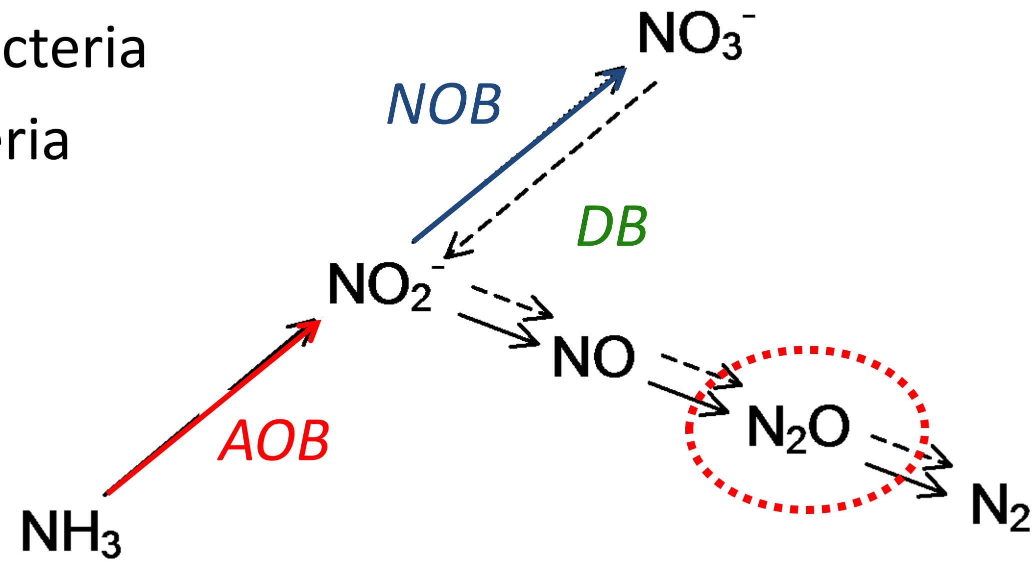
Sources of nitrous oxide

AOB - Ammonia oxidizing bacteria

NOB - Nitrite oxidizing bacteria

DB - Denitrifying bacteria



	AOB	NOB
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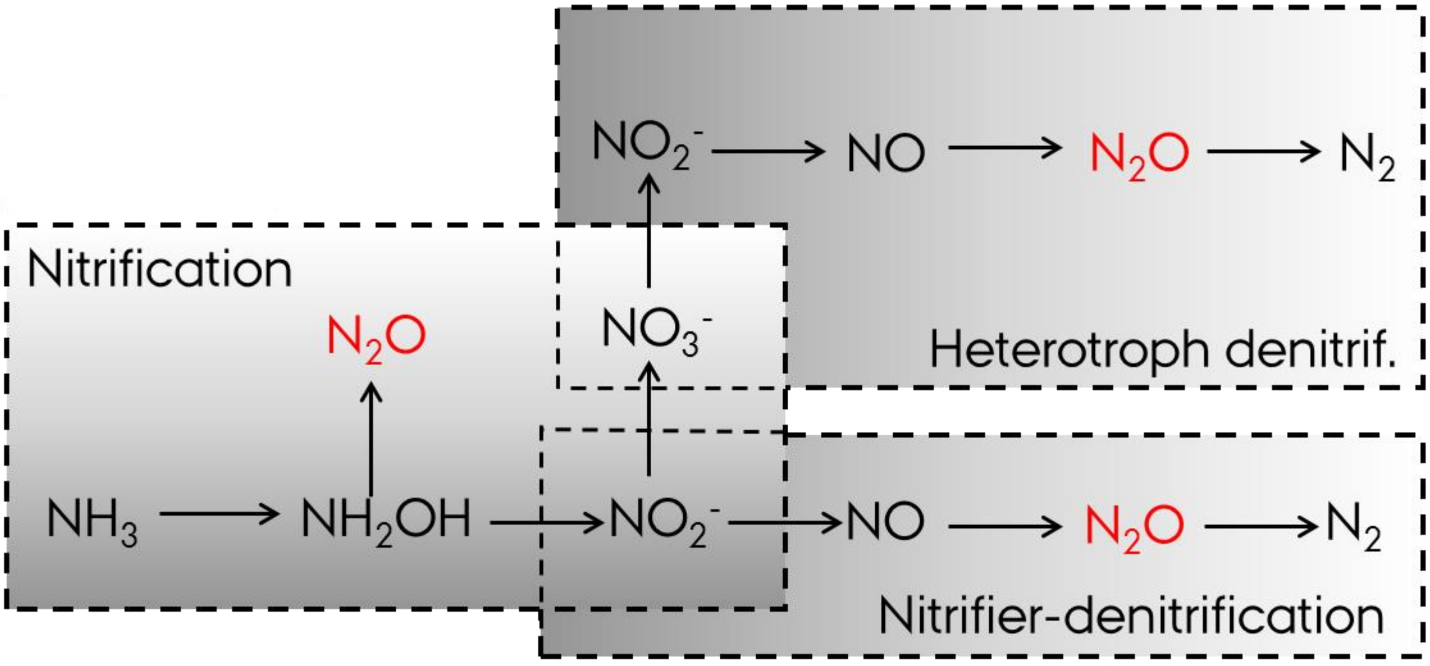
Sources of nitrous oxide



Oxygen limitation stimulates N_2O emission from all sources

Outline of presentation

- Sources of nitrous oxide (N_2O)
- **Distribution of biowaste in soil**
- Oxygen supply and demand
- Empirical model, N_2O emission from biowaste
- Role of vinasse for N_2O emission
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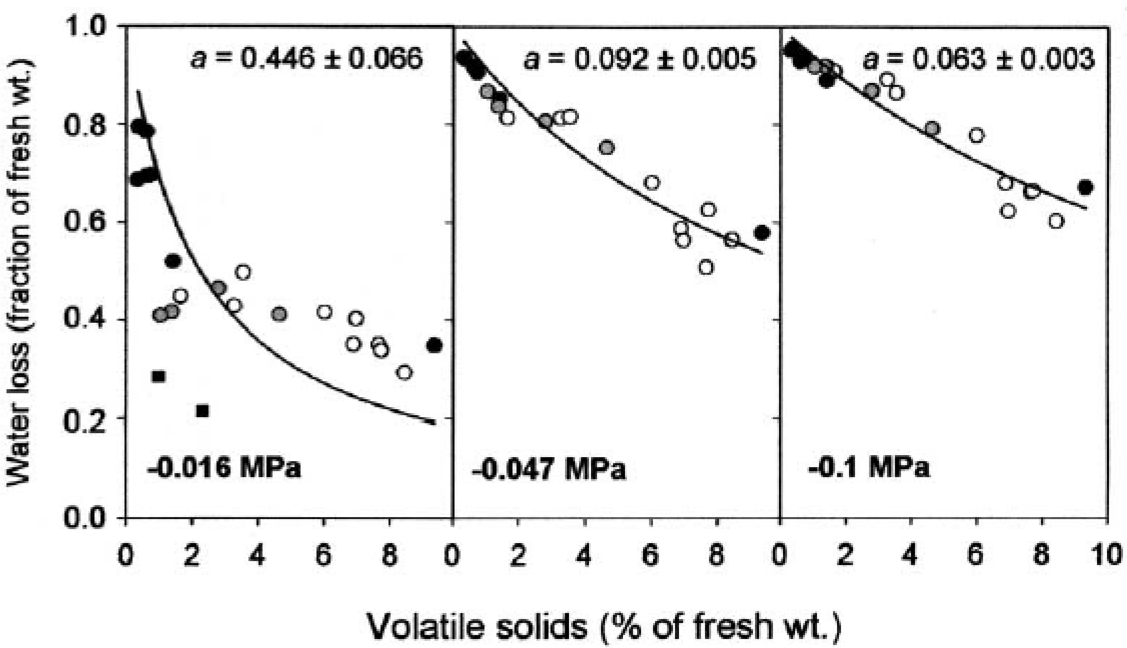
Redistribution of biowaste



9 cattle slurries
9 pig slurries
4 digestates

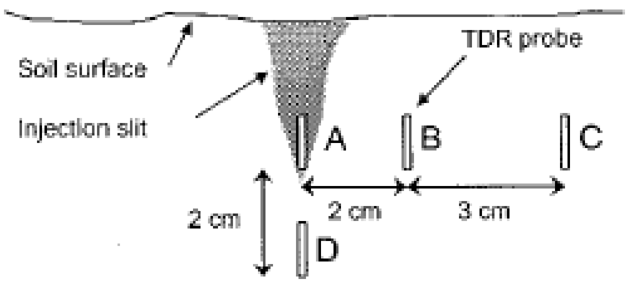
Slurry water retained:

$$f_R = 1 - (1 + aVS)^{-1}$$
$$a = 0.063 + 1.33\exp(77.8\psi)$$

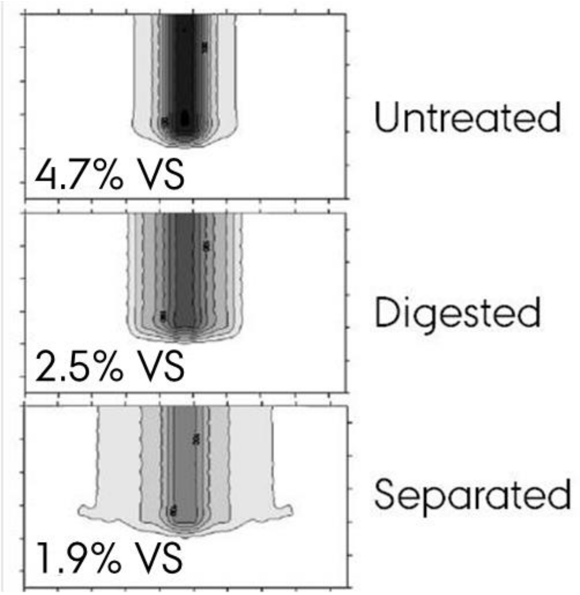
f_R : fraction of water retained
VS : volatile solids
ψ : water potential

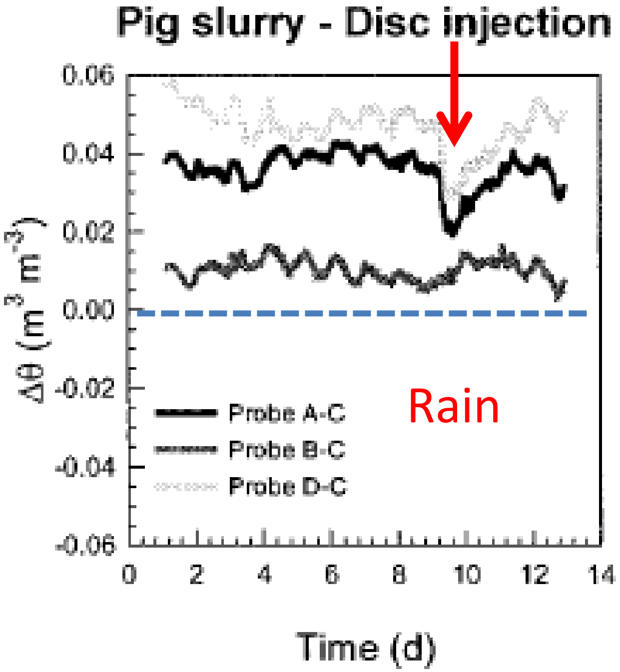
(Petersen et al., 2003)

Redistribution of biowaste liquid



Ammoniacal N after 24 h:





(Petersen et al., 2003)

Outline of presentation

- Sources of nitrous oxide (N_2O)
- Distribution of biowaste in soil
- **Oxygen supply and demand**
- Empirical model, N_2O emission from biowaste
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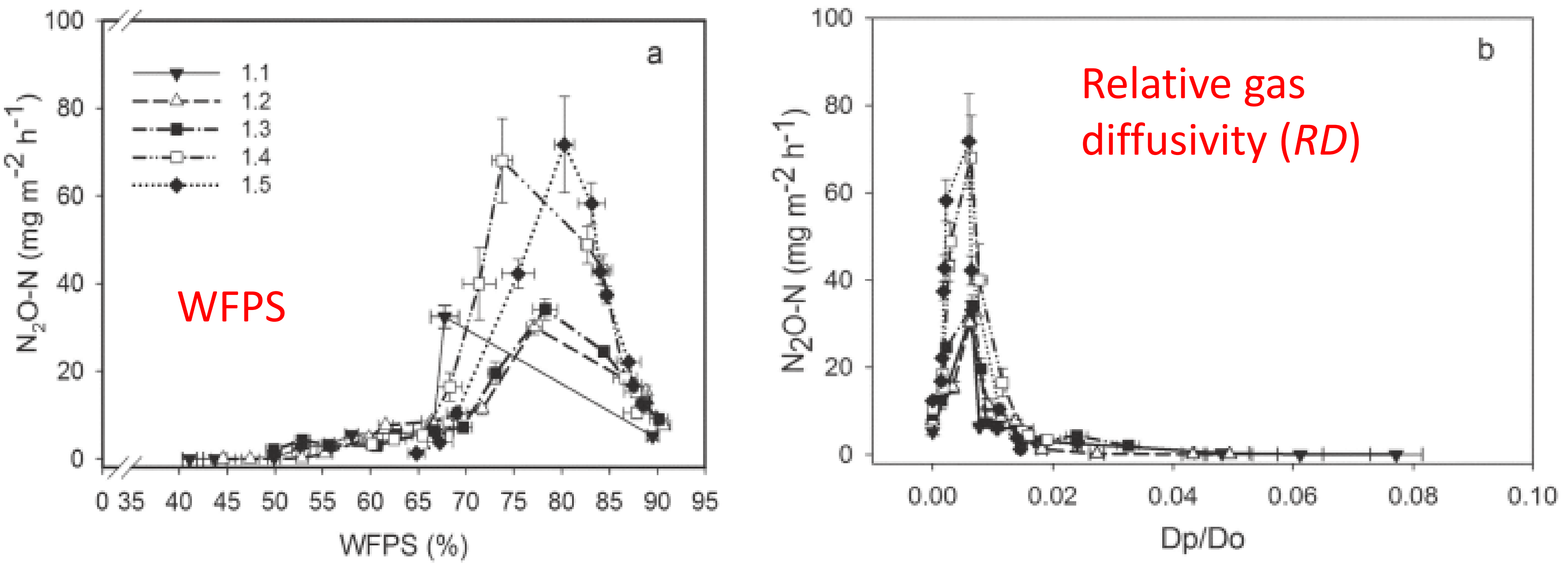
Oxygen supply and demand

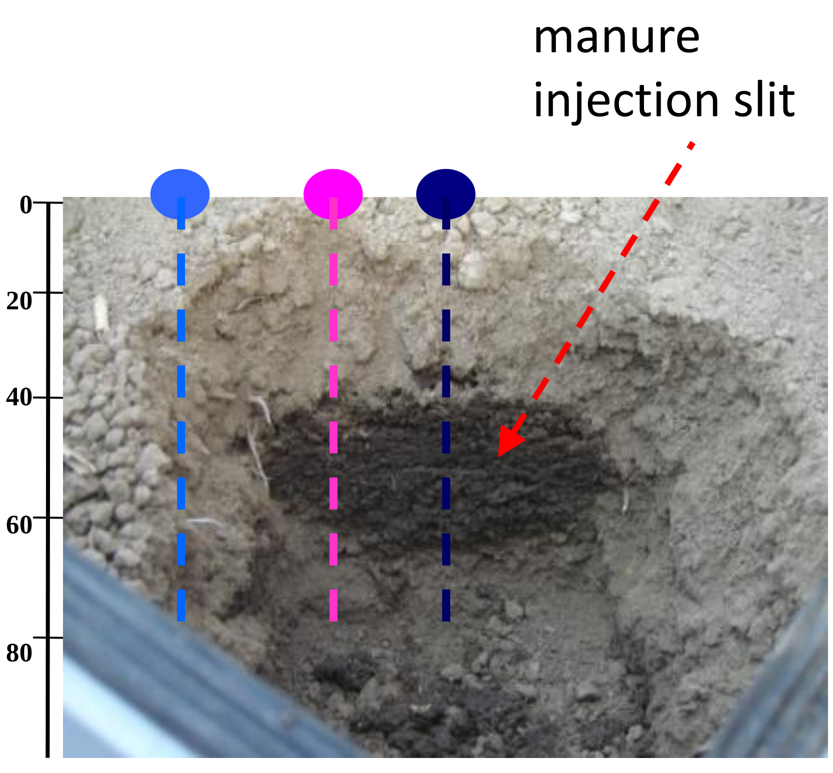
- N_2O monitored at five bulk densities
- How to express effect of soil water content on N_2O?

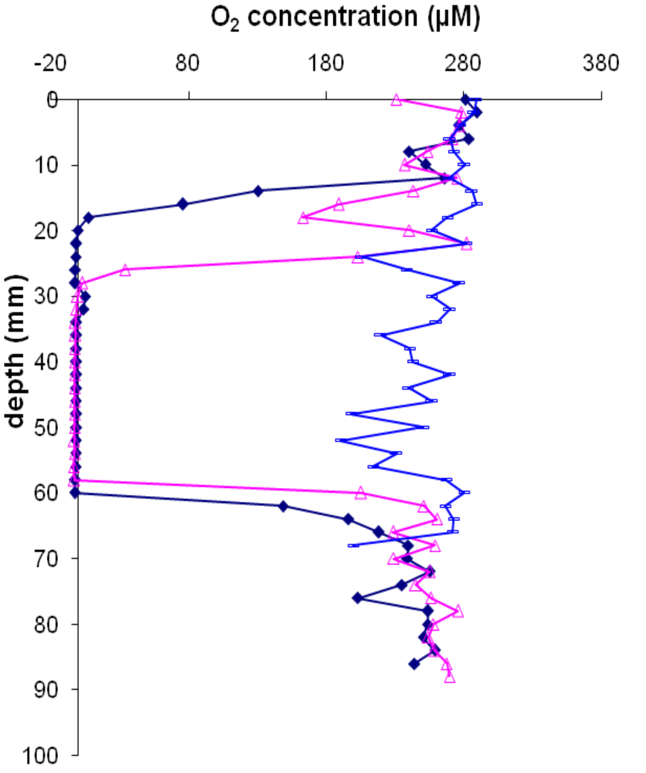


Balaine et al. (2013)

Oxygen supply and demand

- Simulate slurry injection
- Measure oxygen profiles in different positions





(Markfoged et al., 2012)

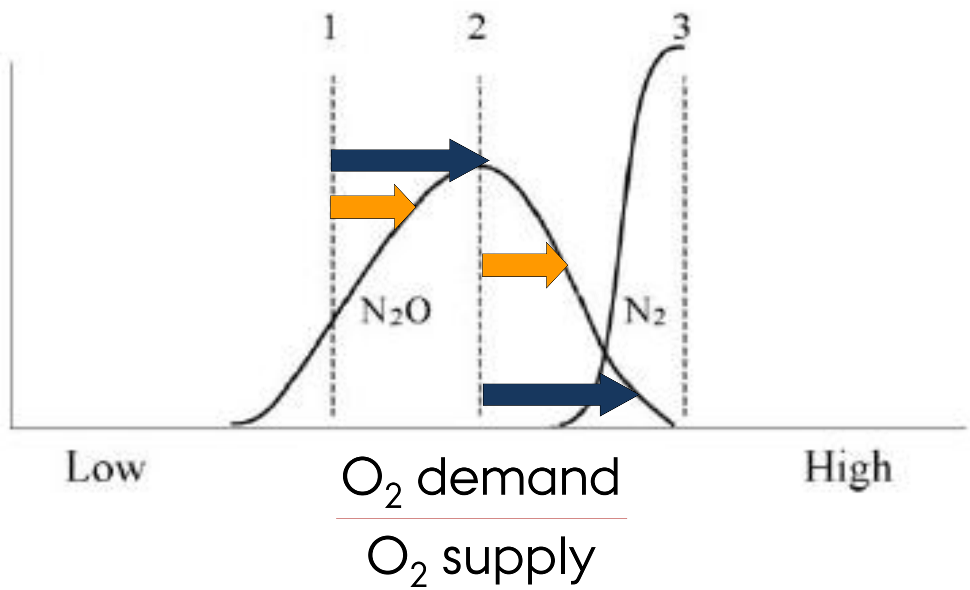
Oxygen supply and demand

O_2 demand:

› manure VS composition
› slurry redistribution

O_2 supply:

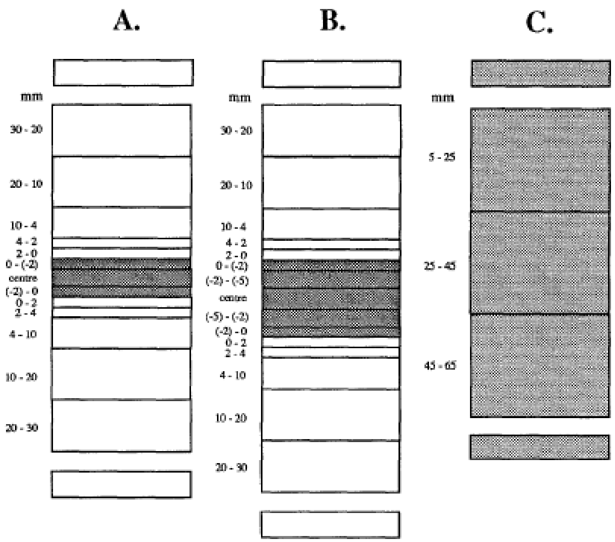
› texture
› compaction
› moisture

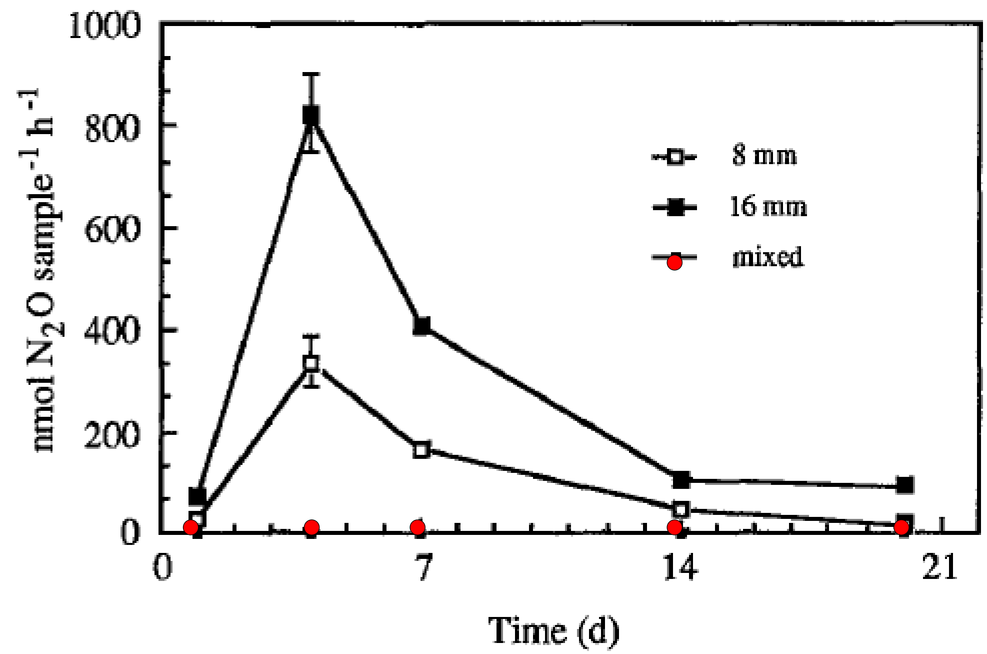


(Thomsen et al., 2010)

Oxygen supply and demand

- Simulate slurry application, different degrees of mixing
- Measure denitrification rates



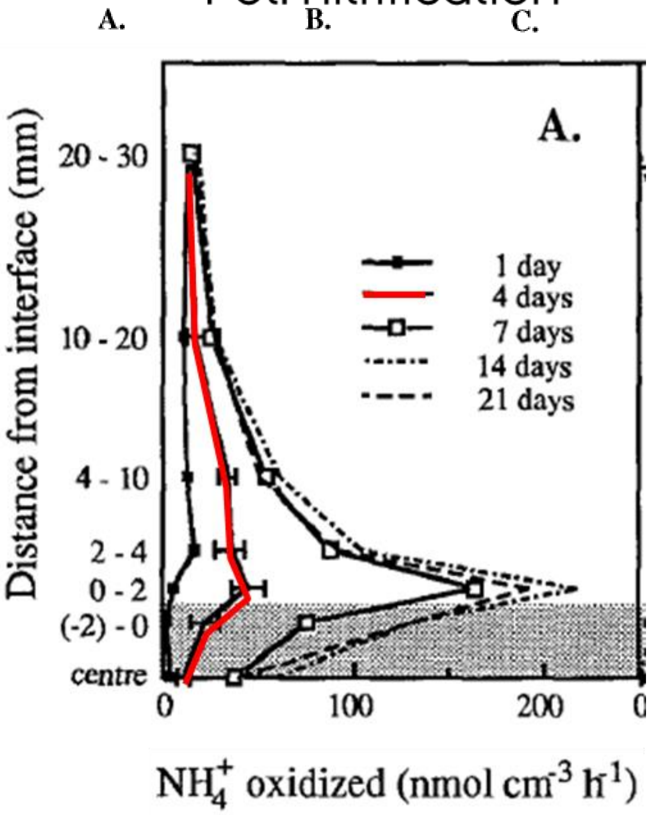


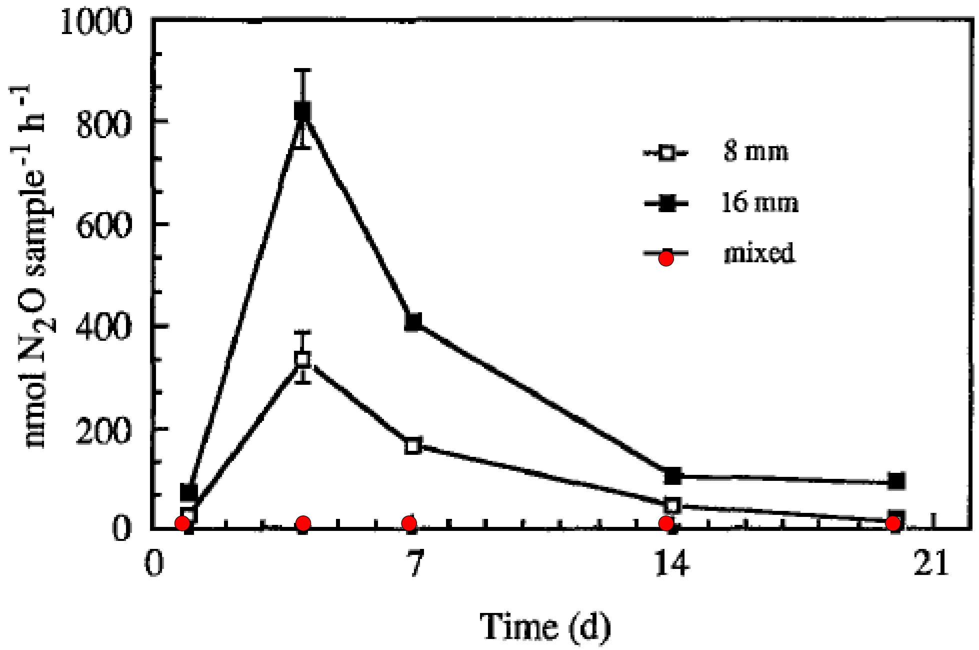
(Petersen et al., 1992)

Oxygen supply and demand

- Simulate slurry application, different degrees of mixing
- Measure denitrification rates

Pot. nitrification





Heterogeneity = potential for coupling between nitrification and denitrification

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- **Empirical model, N_2O emission from biowaste**
- Role of vinasse for N_2O emission
- Conclusions

Empirical model, N_2O from biowaste

Volatile solids (VS) =

Degradable VS (VS_d) and non-degradable VS (VS_{nd})

- VS_d and TAN is soluble = mobile

  VS_{nd} is particulate = immobile

$$VS_{clump} = VS_{nd} + f_R \times VS_d$$

- Three main sources of N_2O:

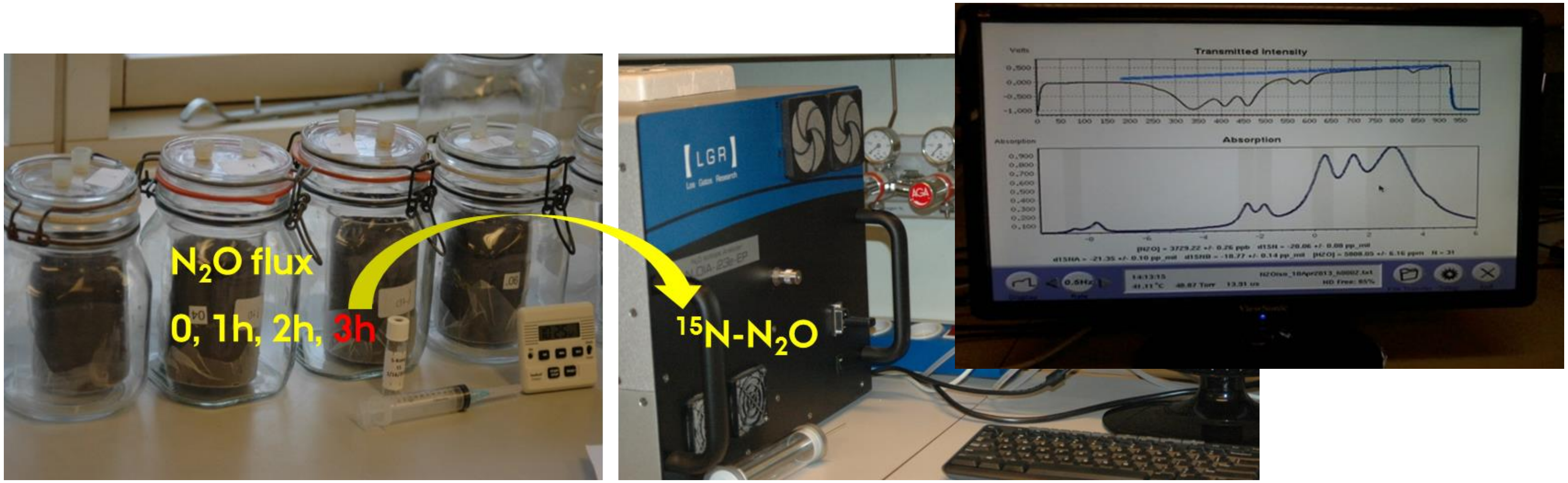
Slurry clumps (oxygen limited)

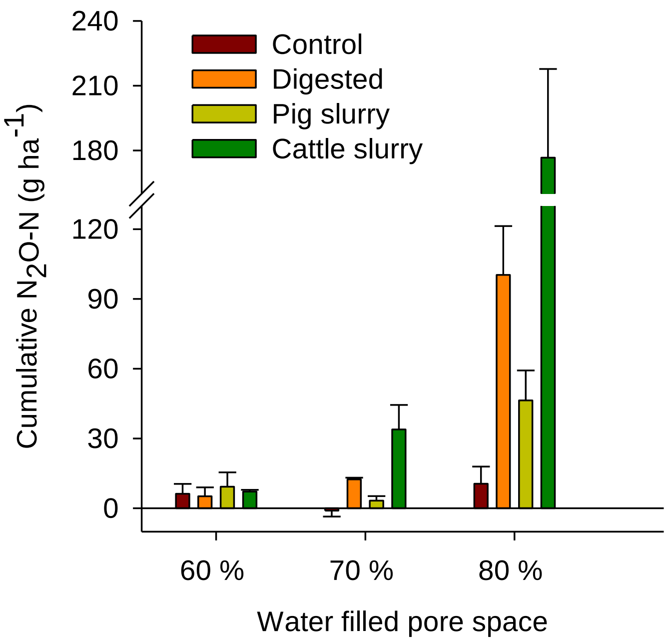
- Nitrification (N_{cl})
- Denitrification (D_{cl})

Bulk soil (well-aerated)

- Nitrification (N_s)

- Degradable VS is the only driver of denitrification





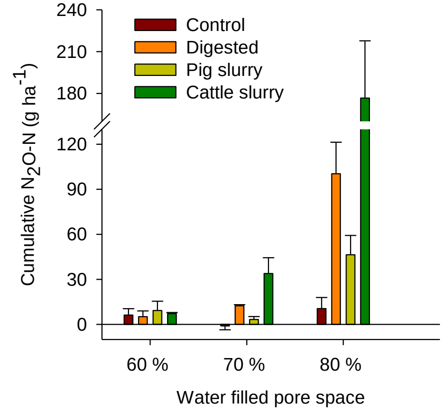
Factorial experiment with:

- 3 moisture levels
- 3 slurry treatments + control
- ^{15}N labelling of soil nitrate for source identification

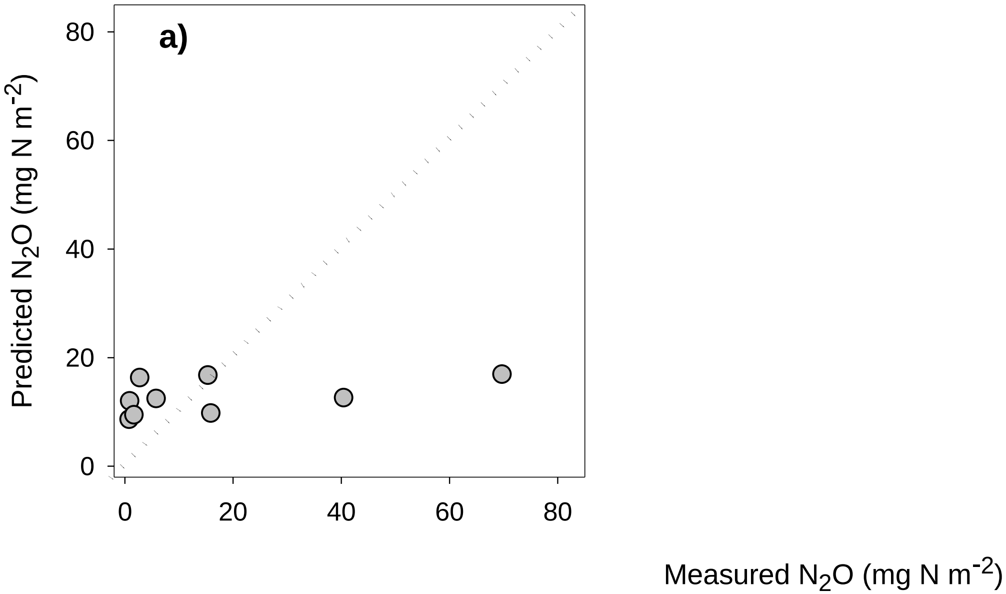
- Determine EF by multiple regression:

$$F_{N2O} = \alpha D_{cl} + \beta N_{cl} + \gamma N_s$$

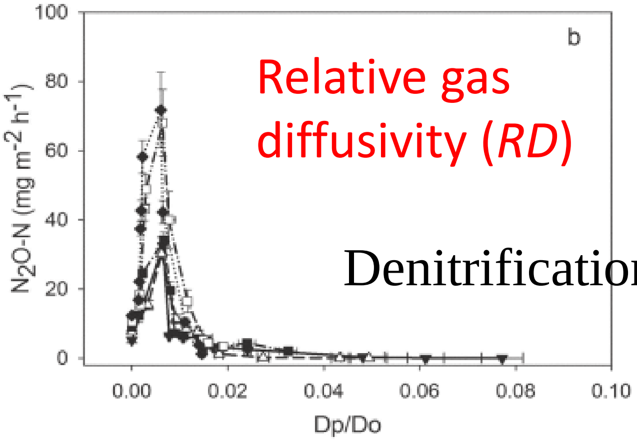
Empirical model, N_2O from biowaste



Parameters:
Sommer et al. (2004)



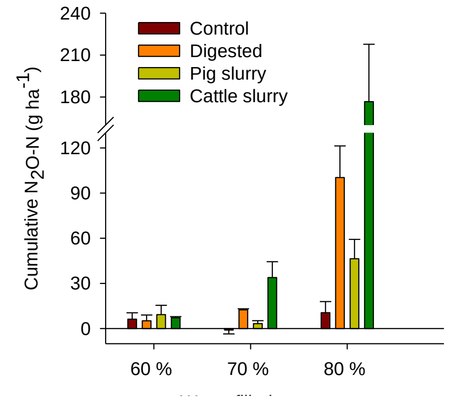
Empirical model, N_2O from biowaste



Relative gas diffusivity (*RD*)

$$f_D \sim \frac{1}{RD^2}$$

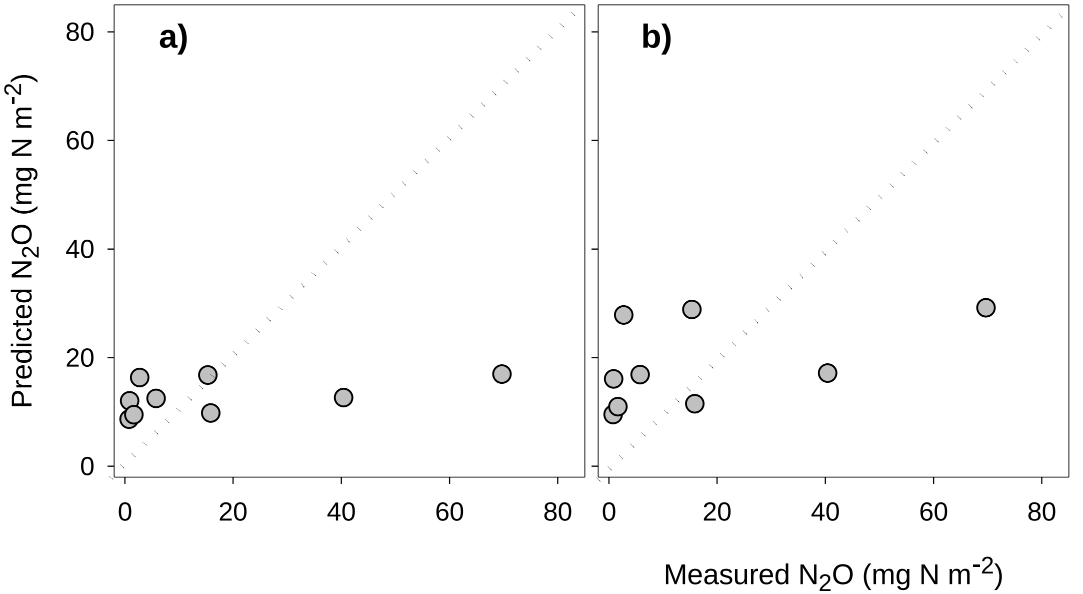
$$\text{Denitrification} \sim \frac{1}{RD}\ ?$$



Parameters:

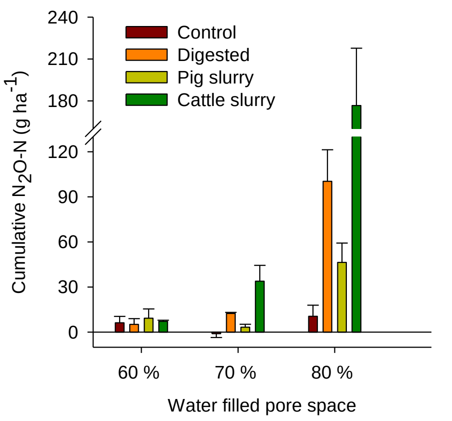
Literature data

$$\alpha D_{cl} + \beta N_{cl} + \gamma N_s$$



Empirical model, N_2O from biowaste

- ~~Degradable VS is the only driver of denitrification~~



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$\alpha D_{cl}+\beta N_{cl}+\gamma N_s$

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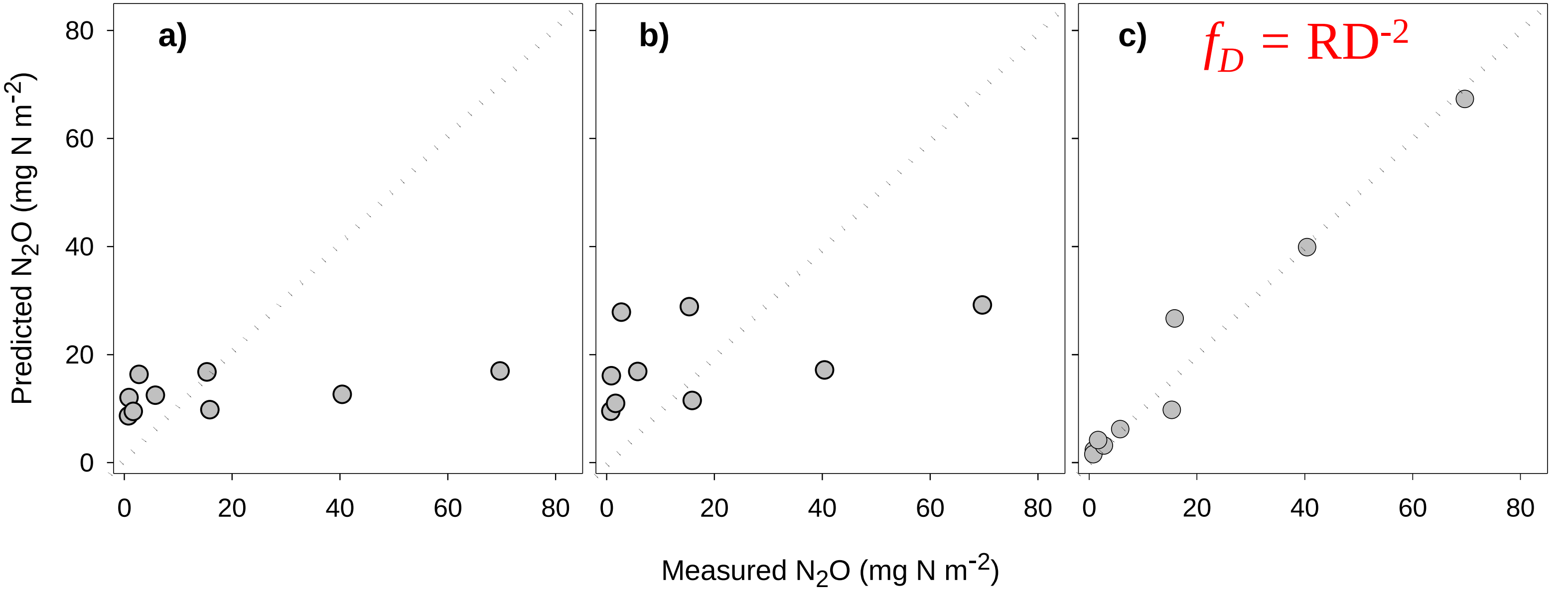
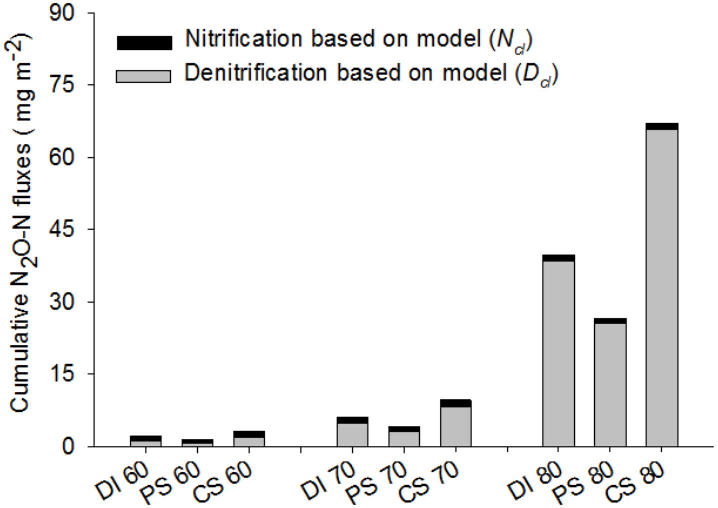
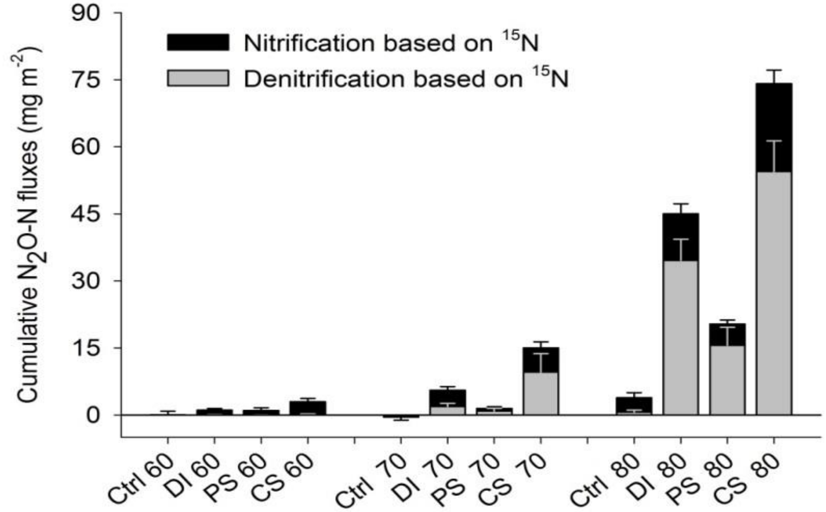


Sources of N_2O from slurry-amended soil?

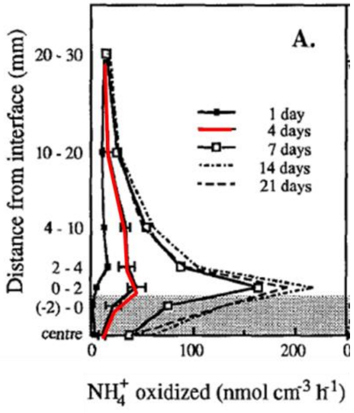
Based on model



Based on ^{15}N



Assumption of uniform labelling of $^{15}NO_3^-$ pool probably not true near the surface applied manure



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- **Role of vinasse for N_2O emission**
- Conclusions

Effects of vinasse on N_2O emission

- 100 t ha^{-1} (10 mm water) limiting oxygen supply
- Soluble C increasing oxygen demand

Carmo et al. (2013)

Treatments (crop trash level) (Mg ha^{-1})	*Vinasse*	†Added N (kg ha^{-1})	*Emission factor (%)
0	With	142	0.59 ± 0.29
	Without	120	0.68 ± 0.41
7	With	142	1.19 ± 0.84
	Without	120	0.96 ± 0.46
14	With	142	1.89 ± 1.00
	Without	120	0.76 ± 0.30
21	With	142	3.03 ± 1.22
	Without	120	2.03 ± 1.15

Effects of vinasse on N_2O emission

- Limited N input (<20 kg N ha^{-1})
- Interaction with crop residues

Carmo et al. (2013)

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	Without	120	0.76 ± 0.30
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Is VS decomposition (oxygen demand) also a main driver of N_2O emissions in the field?

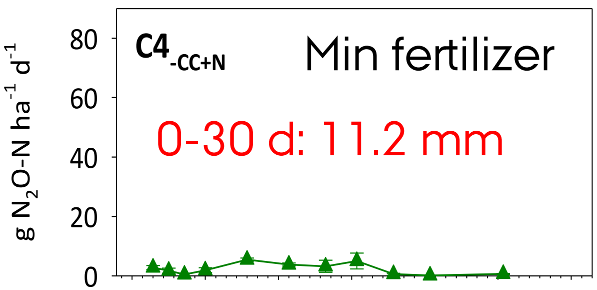
+ slurry + cover crop residues
+ slurry - cover crop residues
- slurry + cover crop residues
- slurry - cover crop residues

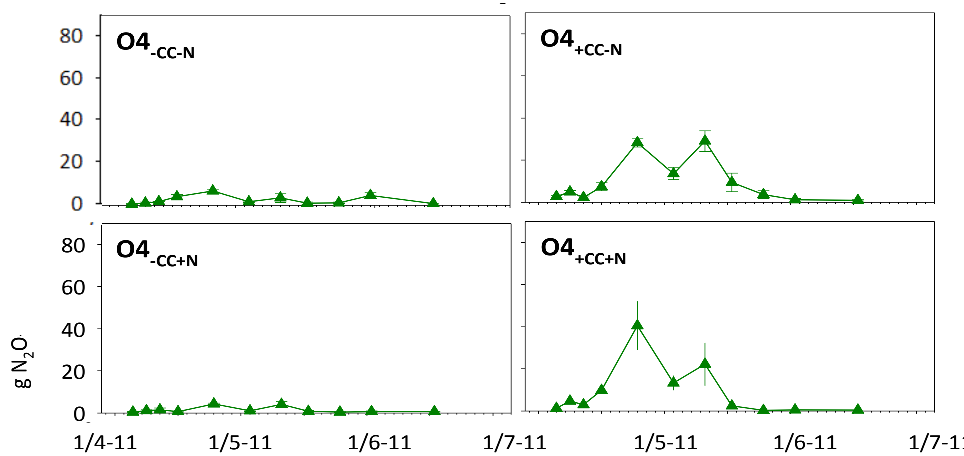
Spring barley
N2O monitored April–June

	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
	3	Potato	Potato	Potato	Potato
	4	Winter wheat[CC]	Winter wheat[CC]	Winter wheat	Winter wheat

[CC]Catch crop

- cover crop + cover crop **2011**



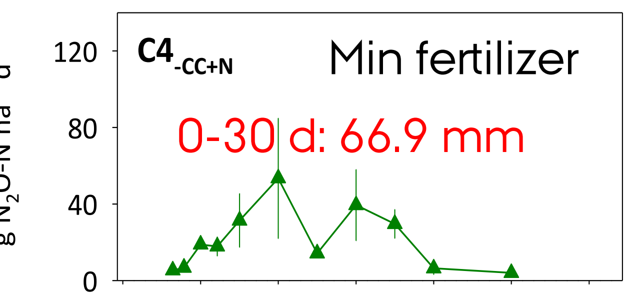


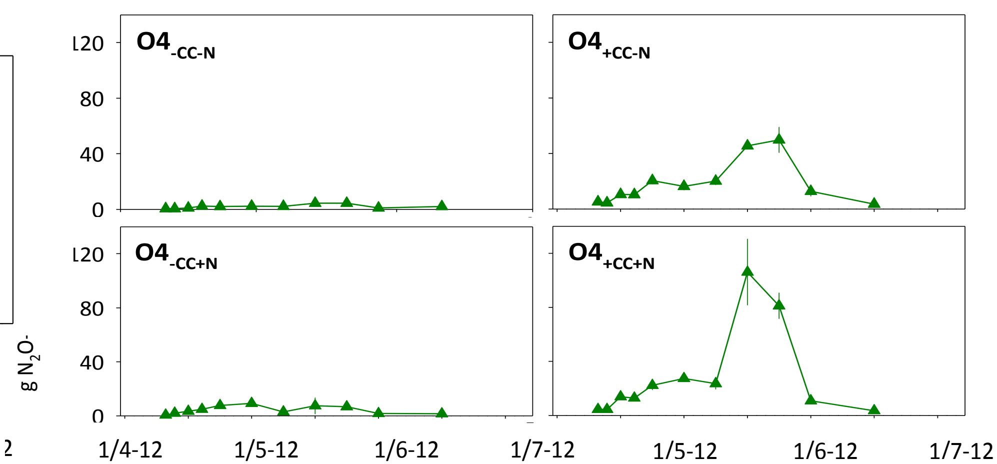
- pig slurry

+ pig slurry

Dry spring:
oxygen main driver?

- cover crop + cover crop **2012**





- pig slurry

+ pig slurry

Wet spring:
Both oxygen demand and supply important?

Duan et al., in prep.

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Conclusions

- N_2O emissions from soil are a major source of agricultural GHG emissions
- Inventory methods based on N input can not account for observed variability
- Balance between oxygen supply and demand is important for the N_2O emission potential
- An empirical model distinguishing two compartments predicted observed N_2O
- Effects of vinasse on N_2O emission should be related to residue management

- Michal A. Brozyna
- Khagendra R. Baral

+ collaborators at Aarhus University

Thank you!