Manure management for greenhouse gas mitigation

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Manure Management for Greenhouse Gas Mitigation

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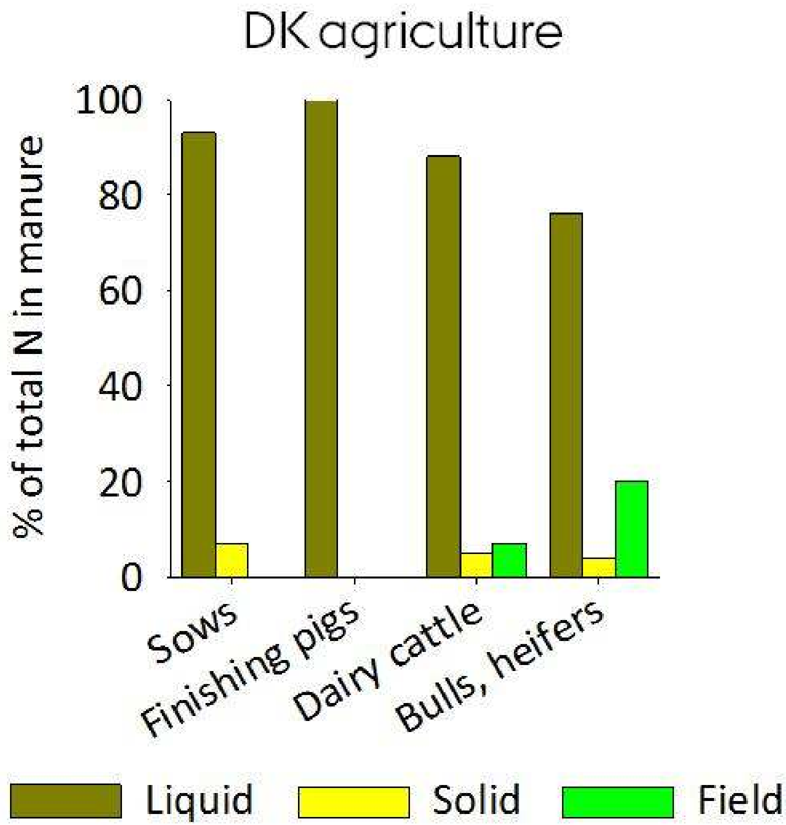

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Nadège


Julio


Melanie


Agustin


Sven


David

GHG balance, livestock production

	GHG emissions (CO_2 eq)	
	10^9 tonnes	%
Land use, land use change	2.5	36
Feed production	0.4	7
Enteric fermentation, energy	1.9	25
Manure management	2.2	31
Processing, transport	0.03	1

(Steinfeld et al., 2006)

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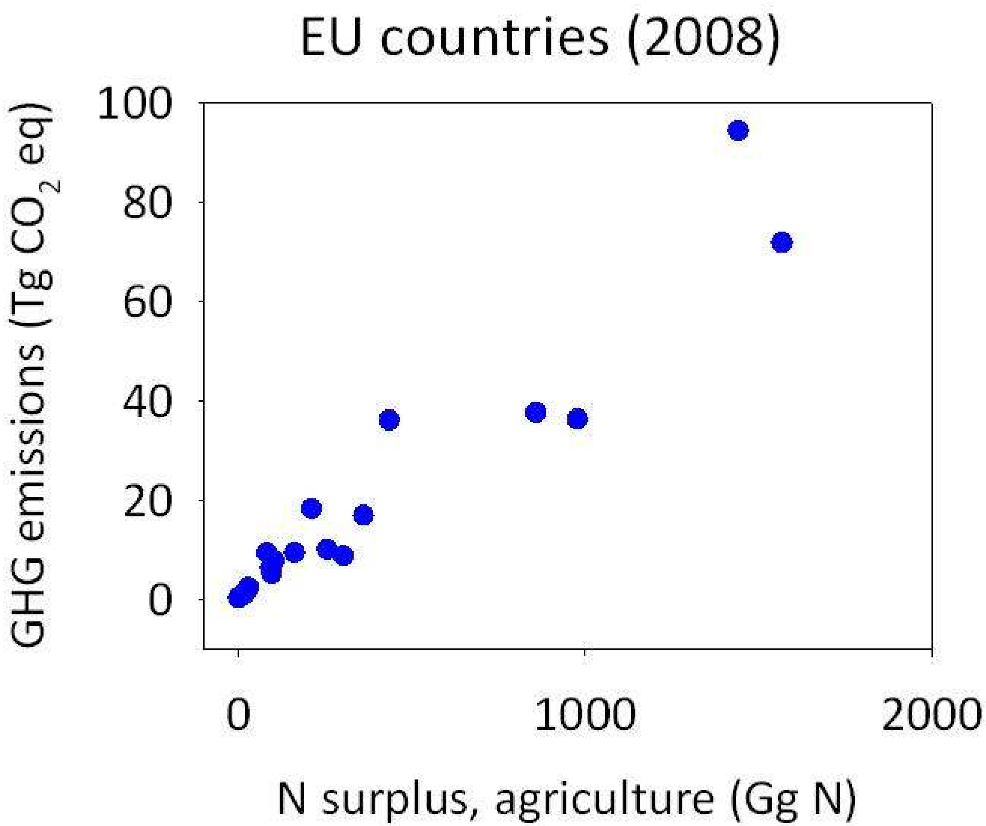
N surplus: an indicator of GHG emissions



- and therefore improving N use efficiency is a strategy for GHG mitigation

(Eurostat)

Outline

› Diversity of livestock production and manure management

› Sources of CH_4 and N_2O in manure environments

› Mitigation measures and strategies

› Quantifying effects of mitigation

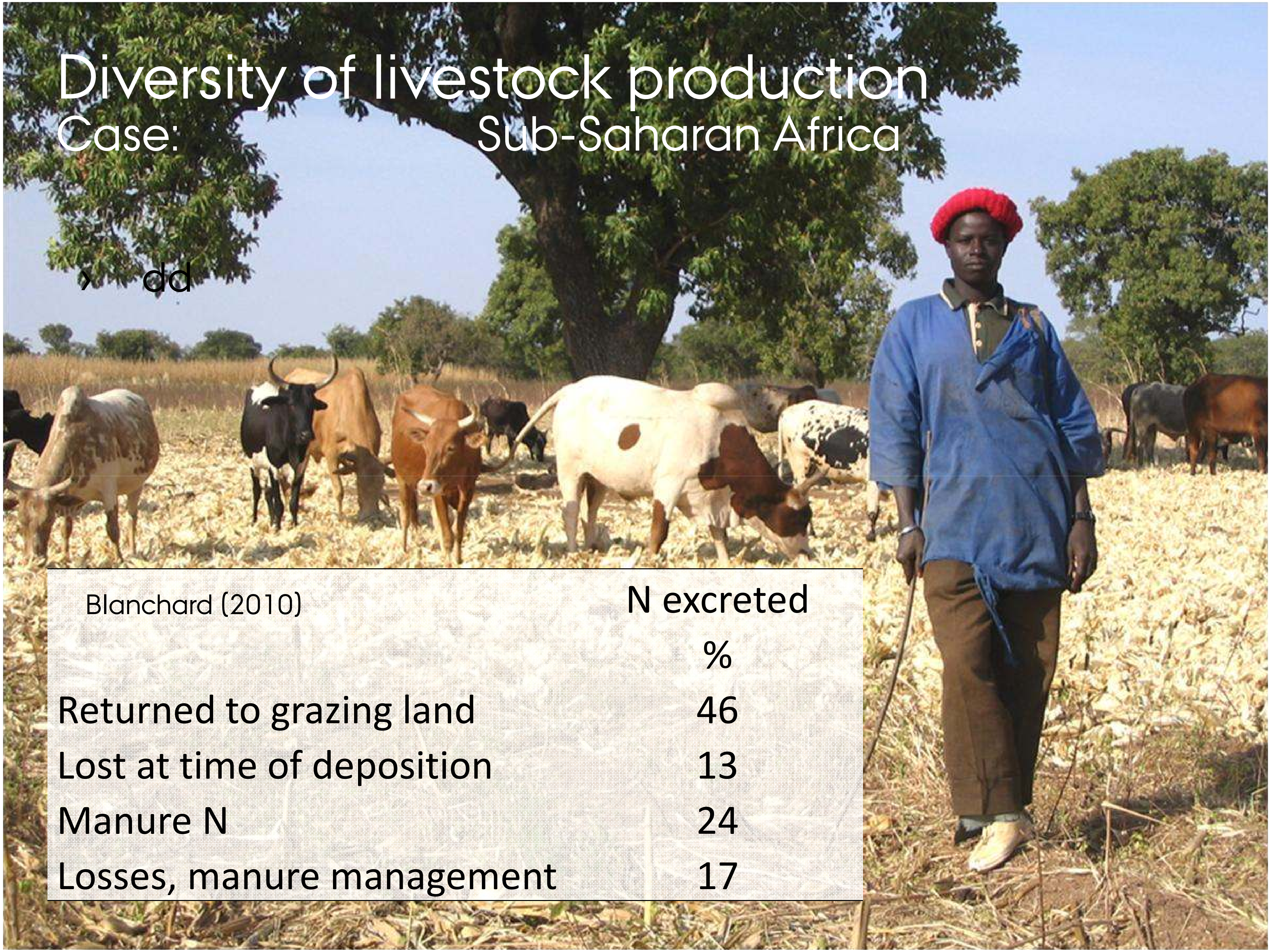
› Global trends, conclusions

Diversity of livestock production

Case: Sub-Saharan Africa

- dd

Blanchard (2010)	Area	Farms
	ha	%
Crop production w. livestock	5-11	68
Livestock, grazing	11-24	30
Specialist breeders	<1	2



Diversity of livestock production
Case: Sub-Saharan Africa

- dd

Blanchard (2010)	N excreted %
Returned to grazing land	46
Lost at time of deposition	13
Manure N	24
Losses, manure management	17

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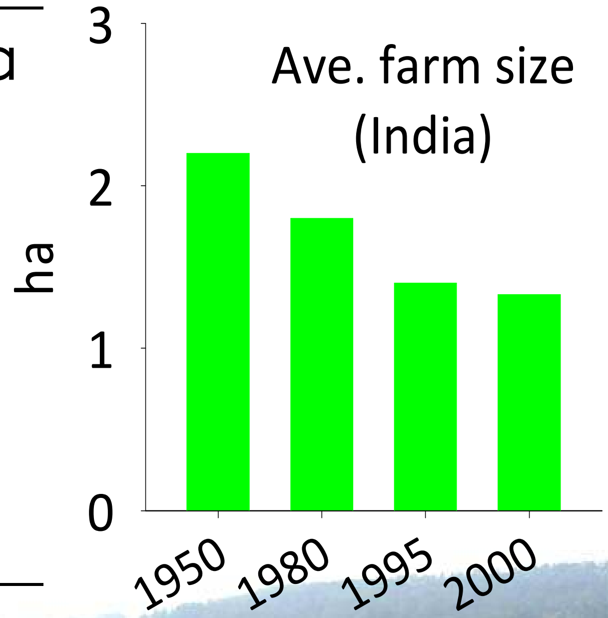
Diversity of livestock production

Case: Southeast Asia

	Ave. farm size	Farms <2 ha
	ha	%
Bangladesh	0.5	96
Nepal	0.8	93
India	1.4	81
Pakistan	3	58

Source: Thapa (2009)



Diversity of livestock production

Case: Southeast Asia

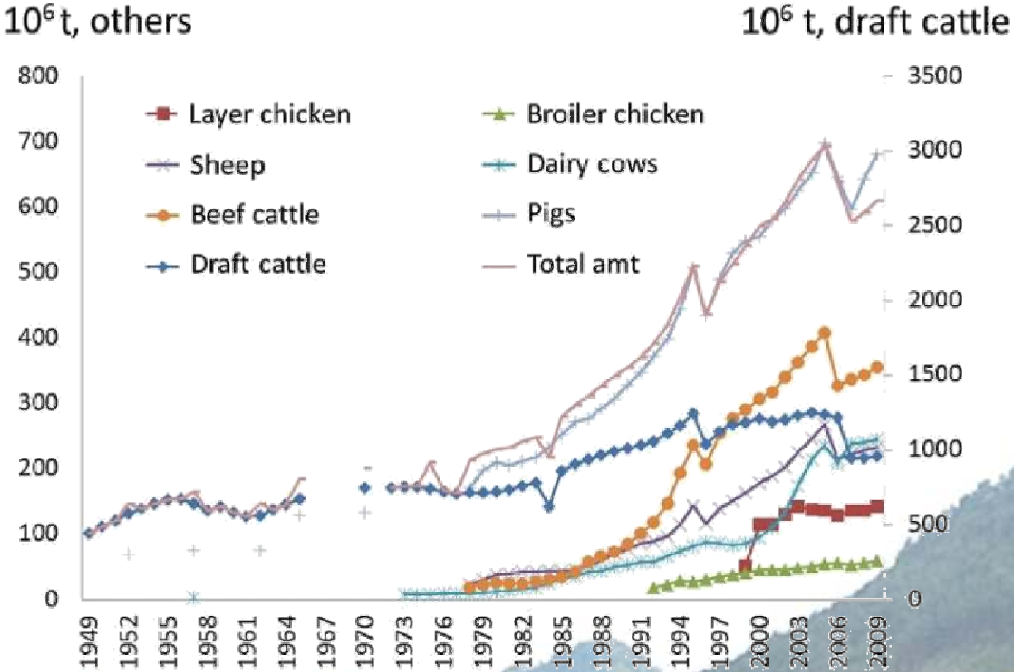
Vietnam:
23,000,000
pigs (2004)

Vietnam 110,000 digesters
China 30,000,000 digesters

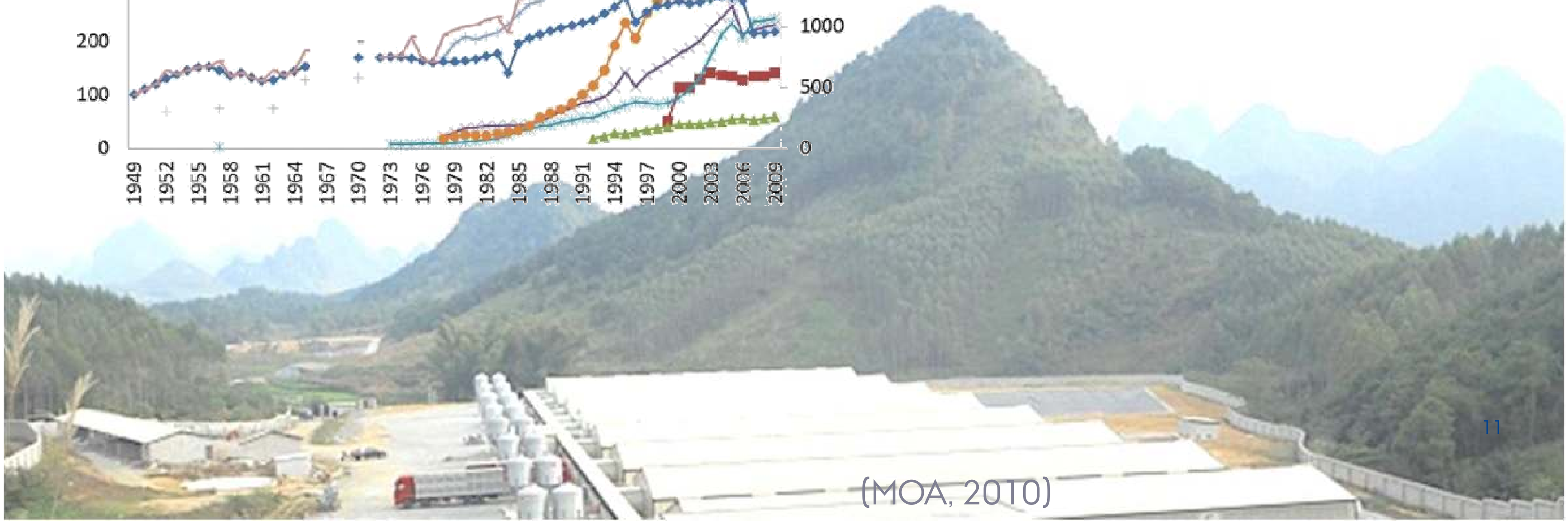
Discharge 9-15% of N intake

Leakage losses of CH_4?

Diversity of livestock production
Case: China



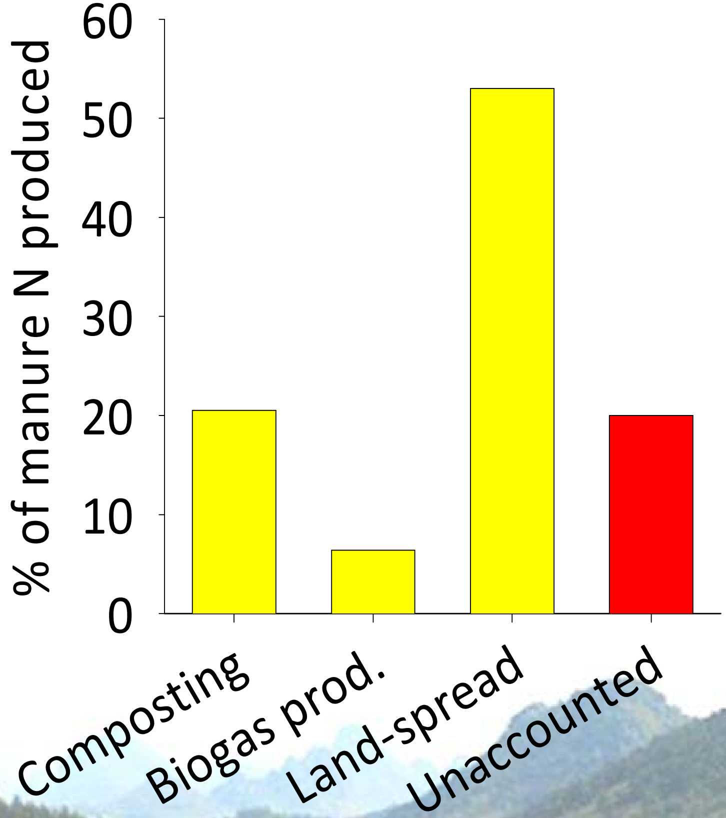
Proportion of confined animal feeding operations is increasing



(MOA, 2010)

Diversity of livestock production

Case: China



- Increase manure treatment to stabilise nutrients
- Account for manure N fertiliser value
- Reduce N application rates

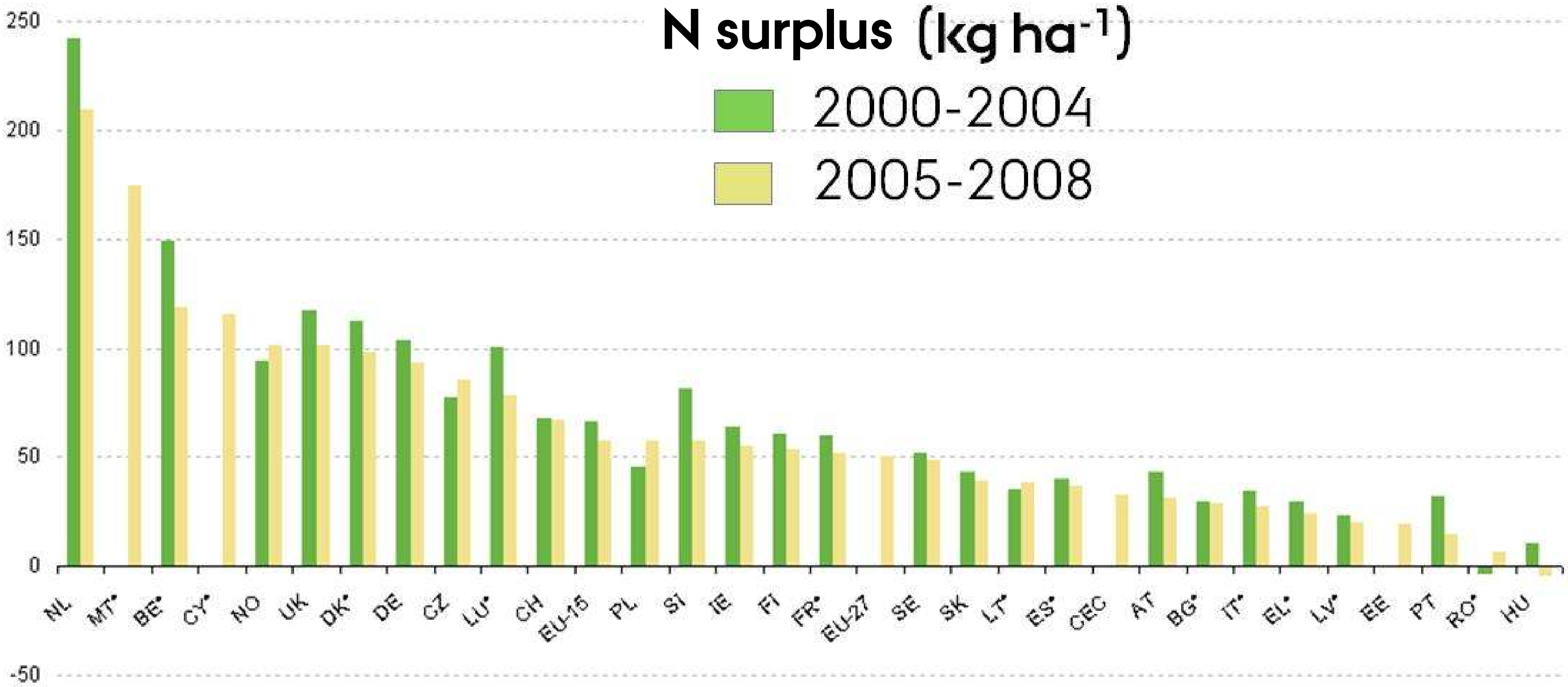
(MOA, 2010)

Diversity of livestock production
Case: European Union

Increasing adoption of regulations to reduce N surplus and GHG emissions:

› Manure storage capacity
› Manure storage conditions
› Limits to N application rates
› Assign manure N fertiliser value

Diversity of livestock production
Case: European Union

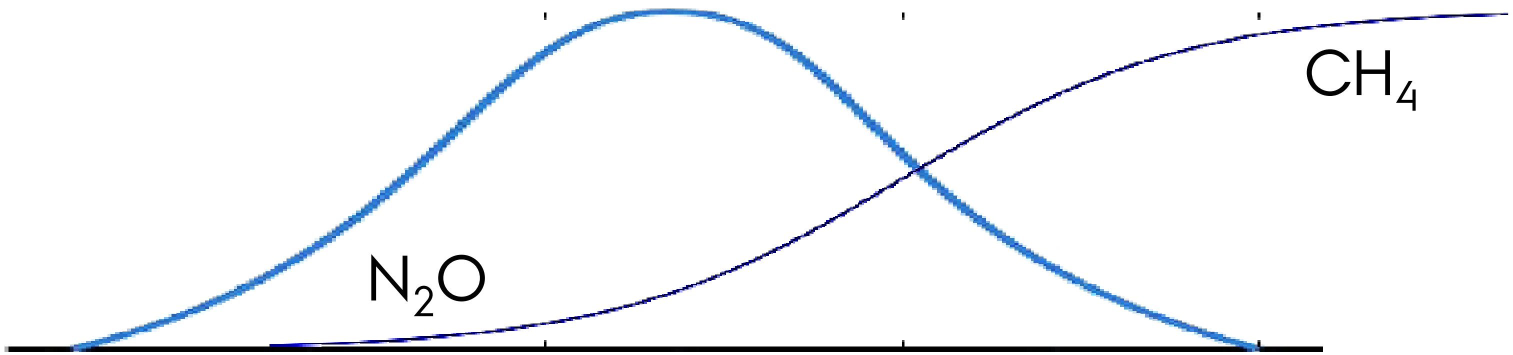


More confinement, higher productivity

(Eurostat)

Livestock production systems (solid → liquid)

Manure storage (aerobic → anaerobic)



Regulation of CH_4 and N_2O emissions in manure environments?

Methane emissions from (liquid) manure

IPCC: Temperature a key control of manure CH_4 emissions

TABLE 10.17
MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS

System[a]		MCFs by average annual temperature (°C)																		
		Cool					Temperate											Warm		
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28
Liquid/Slurry	With natural crust cover	10%	11%	13%	14%	15%	17%	18%	20%	22%	24%	26%	29%	31%	34%	37%	41%	44%	48%	50%
	Without natural crust cover	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	80%

IPCC (2006)

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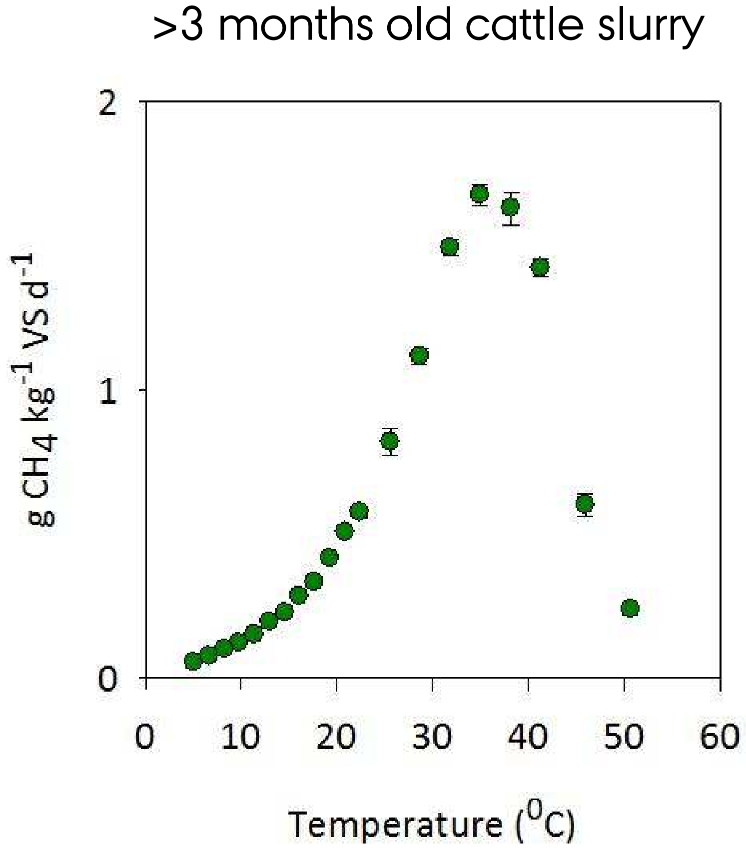
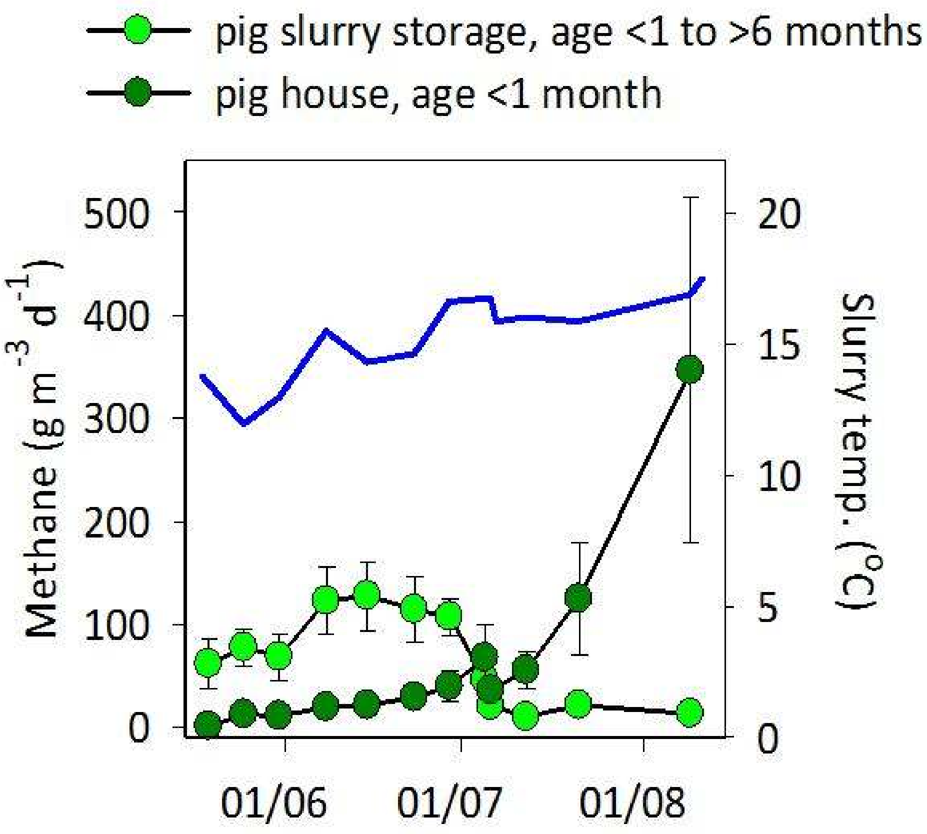
Methane emissions

Role of methanogens?



Elsgaard et al. (unpubl.)



Petersen et al. (subm.)

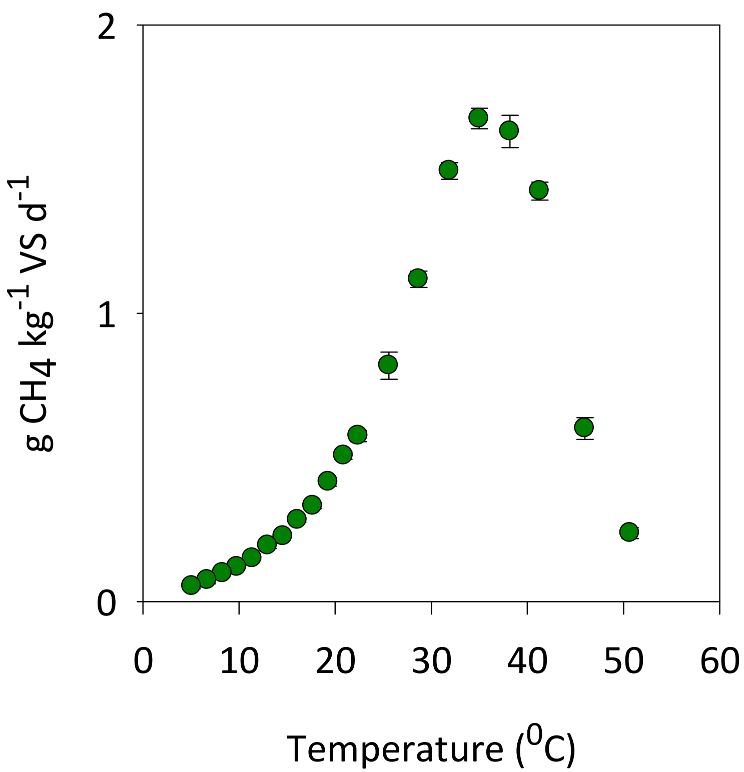
Methane emissions

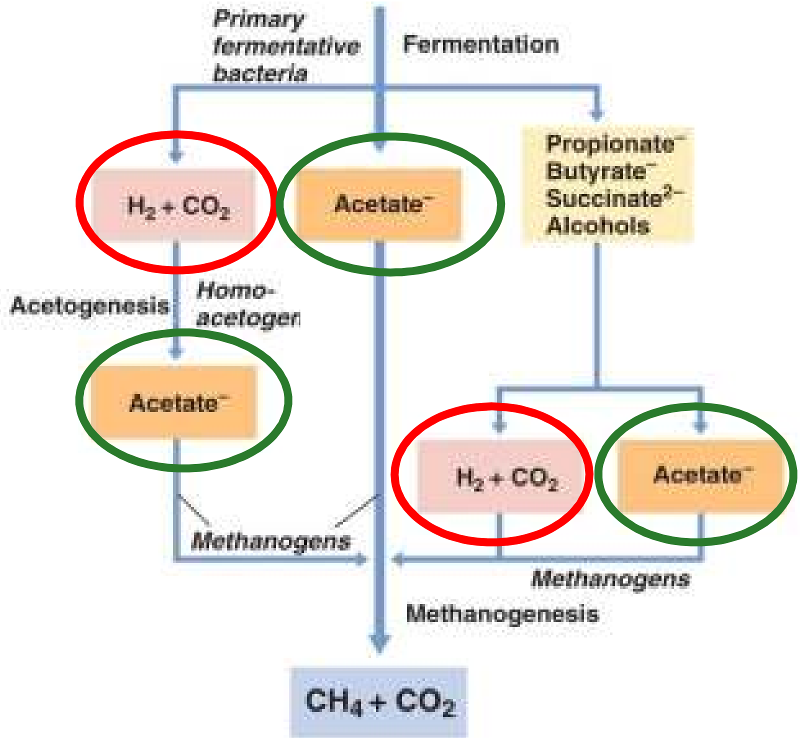
Role of methanogens?

Hydrogenotrophs

Acetotrophs, methylotrophs

>3 months old cattle slurry





Elsgaard et al. (unpubl.)

Methane emissions

Potential CH_4 mitigation strategies

Reduce CH_4 production by:

- Lower storage temperature
- Avoid mixing with adapted slurry
- Remove volatile solids
- Additives to inhibit methanogens

Nitrous oxide emissions

Via nitrification

AOB - Ammonia oxidizing bacteria

NOB - Nitrite oxidizing bacteria

$$NH_3 \xrightarrow{AOB} NO_2^- \xrightarrow{NOB} NO_3^-$$

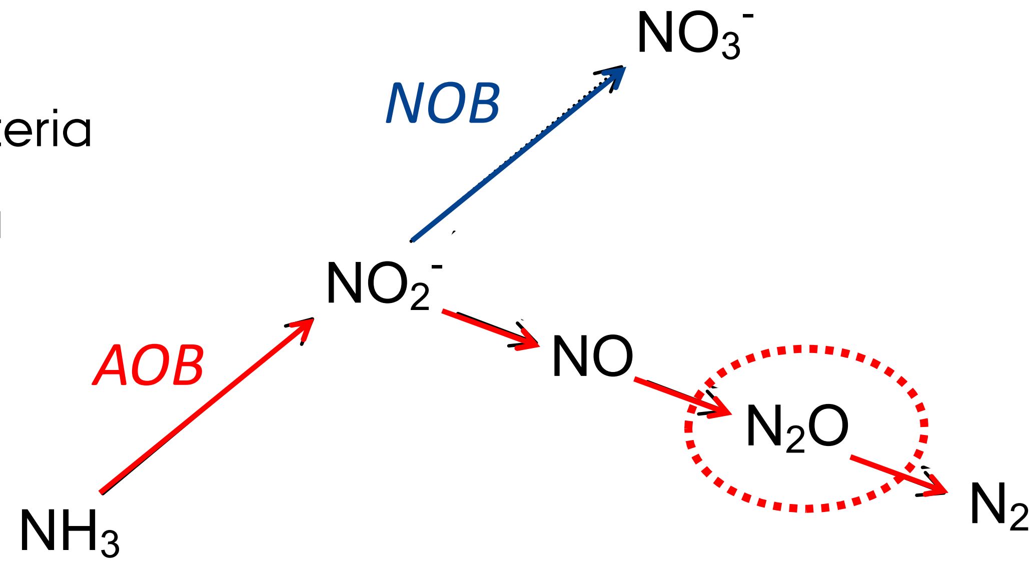
	AOB	NOB
	Nitrosomonas sp.	*Nitrobacter sp.*
Oxygen affinity , K_m (kPa)	5-15	22-108
NH_3 (free) (mg N L^{-1})	10-150	0.1-1.0
HNO_2 (free) (mg N L^{-1})	0.1-0.4	0.011-0.023

Nitrous oxide emissions

Via nitrification

AOB - Ammonia oxidizing bacteria

NOB - Nitrite oxidizing bacteria



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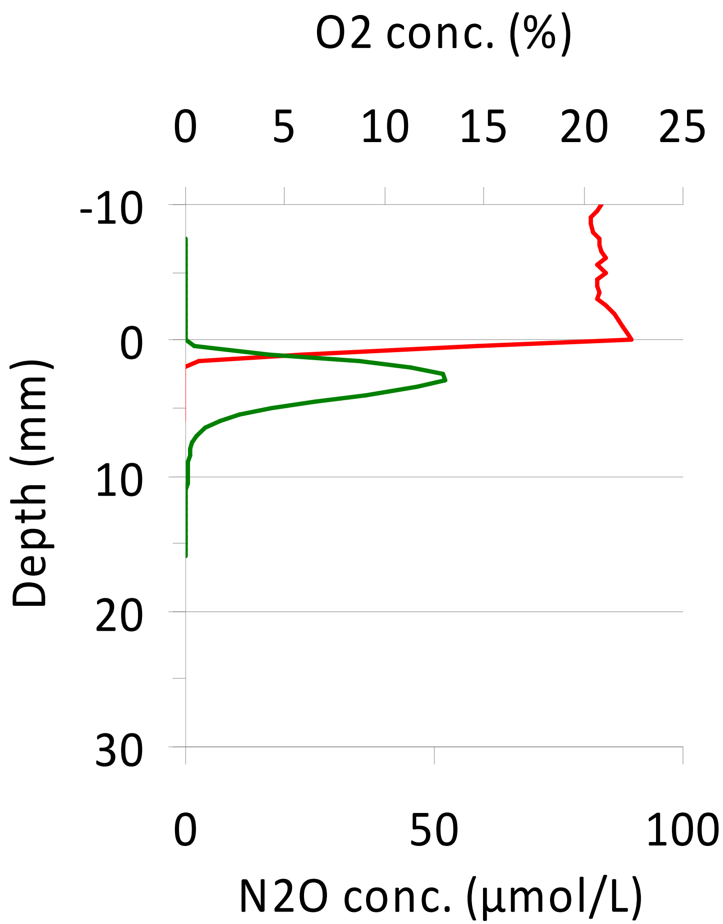
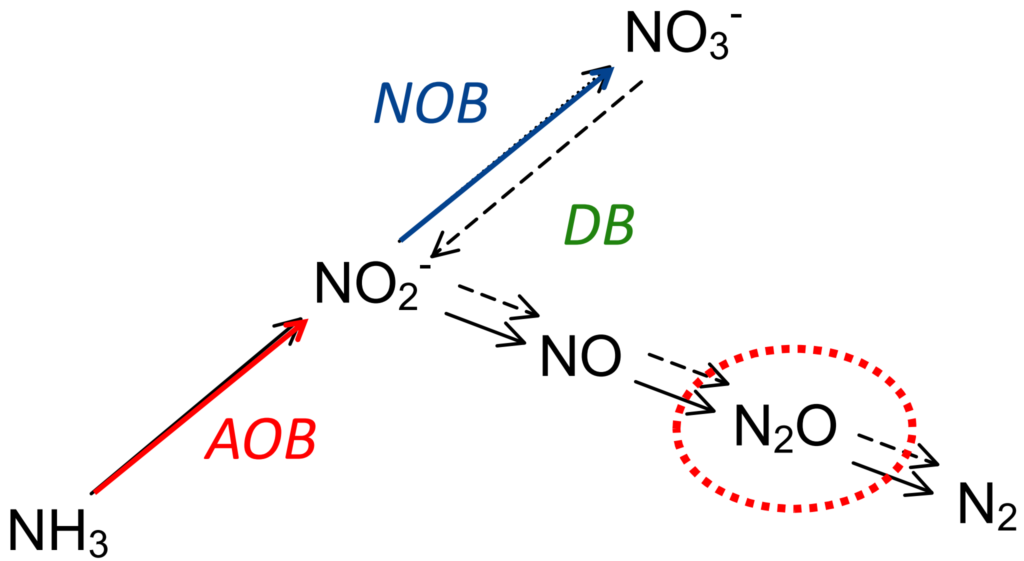
Nitrous oxide emissions
Via denitrification





Duan et al. (in prep.)

Nitrous oxide emissions

Potential N_2O mitigation strategies

Reduce N_2O emissions by:

- Minimising the extent of oxic-anoxic interfaces

  (oxic <u>or</u> anoxic)

- Uncoupling C and N turnover

  (treatment before storage)

Mitigation measures
Housing

	N_2O	CH_4
Liquid manure vs. solid management	↓	↓↑





Mitigation measures

Housing

	N_2O	CH_4
Liquid manure vs. solid management	↓	↓↑
Cooling		↓
Frequent removal	↓	↓

Mitigation measures

Storage

	N_2O	CH_4
Solid manure		
Active vs. passive composting	↓↑	↓
Extra straw	↓	↓
Plastic sheet	↓↑	↓↑
Liquid manure		
Crust	↑	↓↑
Solid cover	↓↑	↓




Mitigation measures
Treatment

	N_2O	CH_4
Manure separation	↓↑	↓↑
Anaerobic digestion	↑	↓
Dilution		↓
Additives, e.g. acidificaton	↓	↓

Methane mitigation by slurry acidification

Reduction in CH_4 emissions:

	Storage period	Fresh	Aged
Cattle slurry	95 d	67%	87%
Pig slurry	83 d	99%	94%
(compared to untreated reference)			

Petersen et al. (2012; submitted)

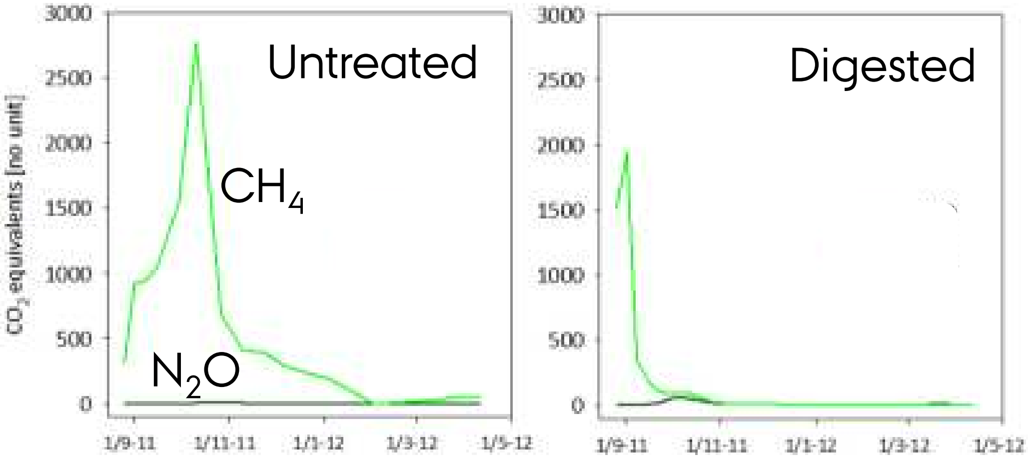
Mitigation measures
Treatment

	N_2O	CH_4
Manure separation	↓↑	↓↑
Anaerobic digestion	↑	↓
(Dilution)		↓
Additives, e.g. acidificaton	↓	↓

”Down-stream” effects

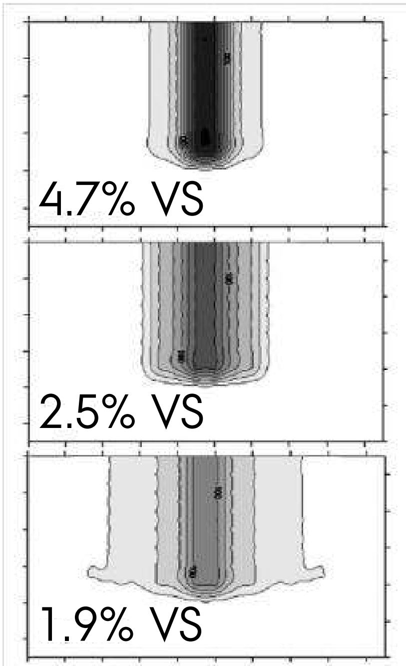
Mitigation measures

Treatment effects



Petersen et al. (in prep.)

After 24 h:



Thomsen et al. (2010)

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Mitigation measures
Field application

› Application method (soil-manure contact)

› Application rate (avoid large pools of mineral N)

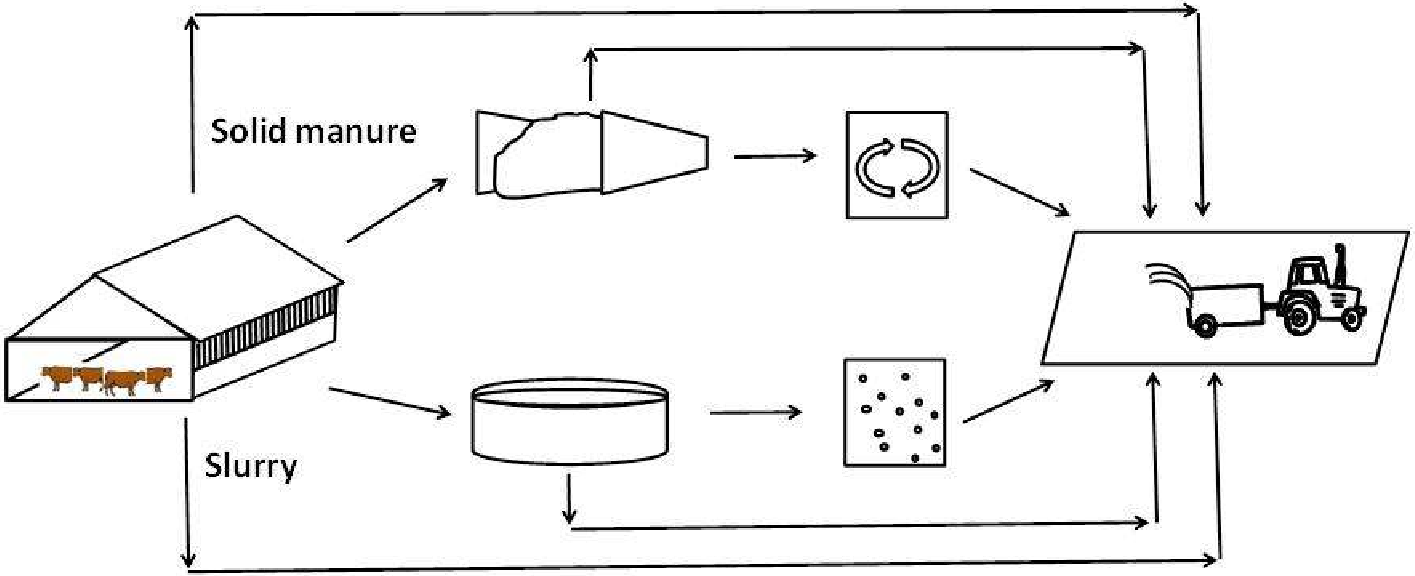
› Timing (mineral N residence time)

Soil type
Soil wetness
Tillage practice

Strategies for GHG mitigation

The “manure management continuum”

Feeding Housing | Storage | Treatment | Field application

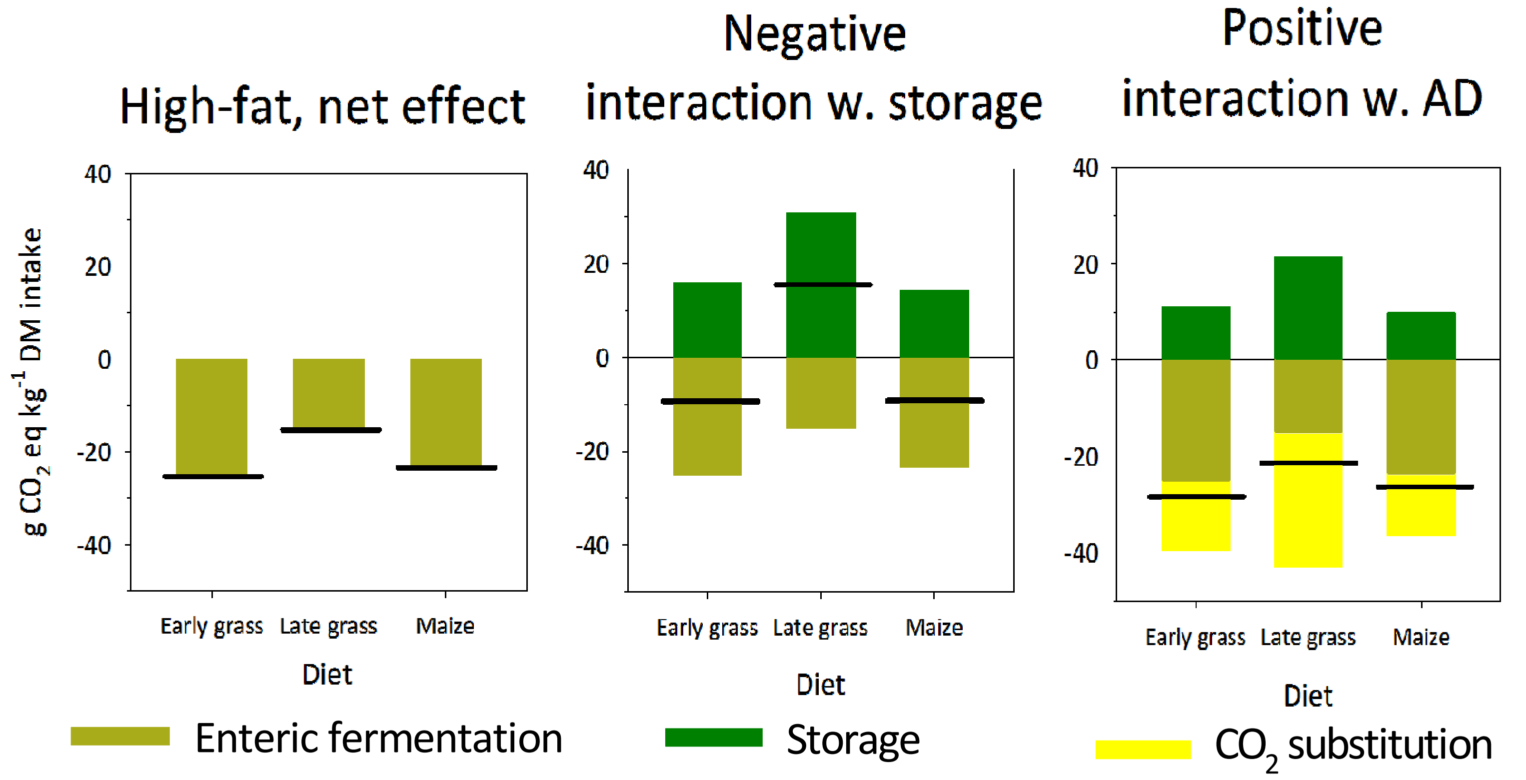


Example:
Three diets (early grass, late grass, maize) w/wo rapeseed

Chadwick et al. (2011)

Strategies for GHG mitigation

The "manure management continuum"



β_0 (faeces)
MCF = 10%

Evaluating GHG mitigation requires a whole-farm approach

GHG mitigation at farm level

Criteria for evaluating farm models

- Ability to simulate temporal, spatial, genetic variability, and farmer decision making
- Coupling of nutrient, water, energy flows
- Economy
- Uncertainties

Data availability for parameterisation

1) Temperature; 2) O_2 status; 3) Manure handling/treatment/application



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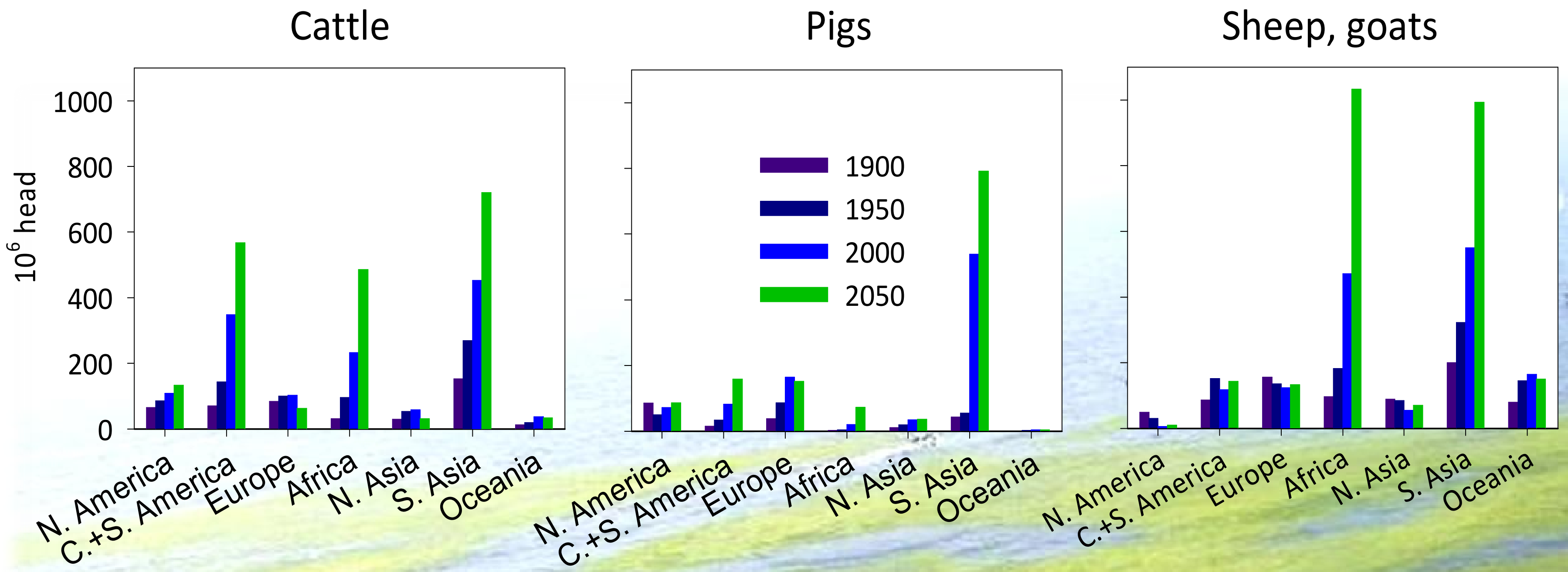
Global trends

Livestock populations, by region



Growth mainly in developing countries

At least 75% of the growth in confined systems (FAO scenario)

How to achieve sustainable intensification?

Source: Bouwman et al. (2012)

How to achieve sustainable intensification?

Subsistence agriculture

- Containment of manure nutrients during storage
- Recycling of manure nutrients for crop production
- Increasing market orientation

How to achieve sustainable intensification?

Mixed farms > farms specialised in crops or livestock

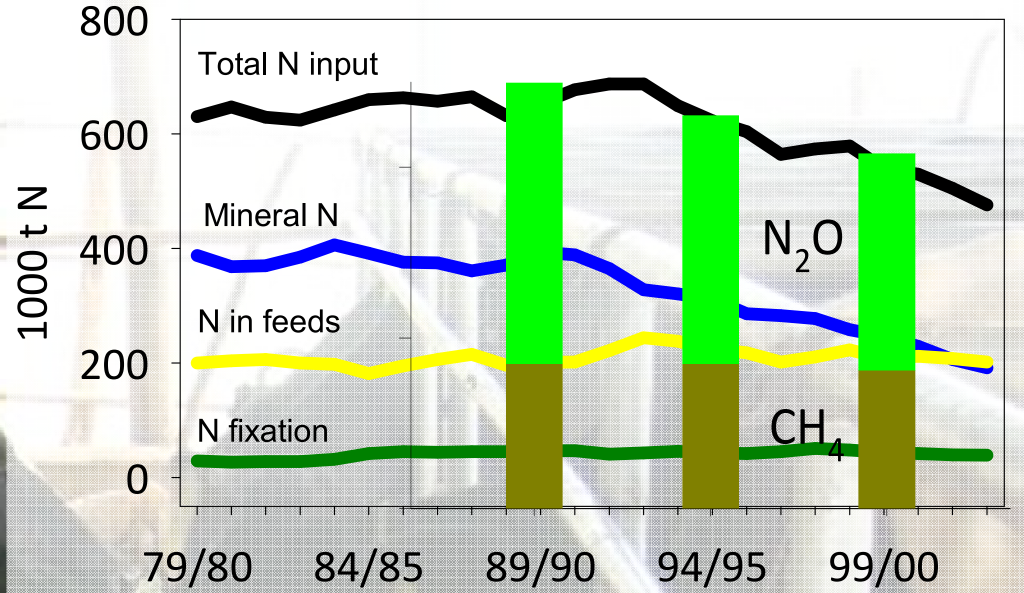
› Less external inputs (fertilisers, feed)
› Lower costs
› Diversification = less sensitivity to fluctuating prices
› Lower risk of N pollution
› Greater biodiversity

How to achieve sustainable intensification?

Industrialised production systems

- Recycling rather than discharge of manure nutrients
- Treatment technologies
- Need for regulation/incentives

DK agriculture



(Kyllingsbæk and Hansen, 2007)

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Conclusions

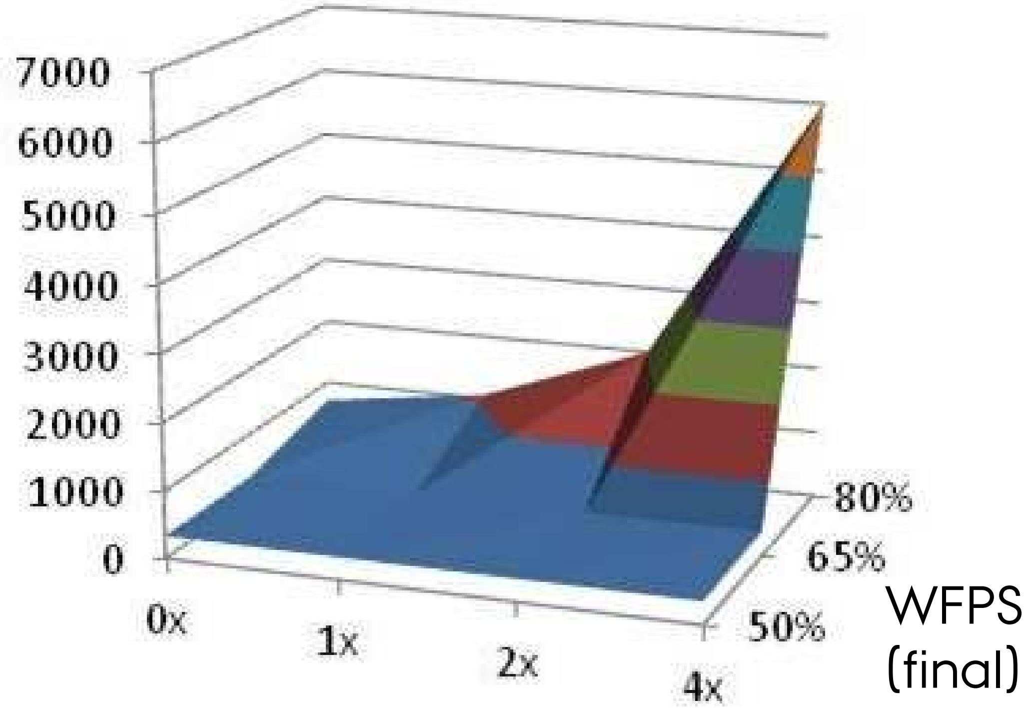
- Treatment and management to improve N use efficiency will also promote GHG mitigation
- Higher N use efficiency can improve farm profitability while also reducing GHG emissions per unit product
- Future increases in livestock production mainly in confinement systems – effective recycling of nutrients should be ensured via regulations/incentives
- A whole-farm approach is needed to identify cost-effective GHG mitigation measures

Acknowledgements

AnimalChange (FP7)
Danish Strategic Research Council
Basque Dept. Education

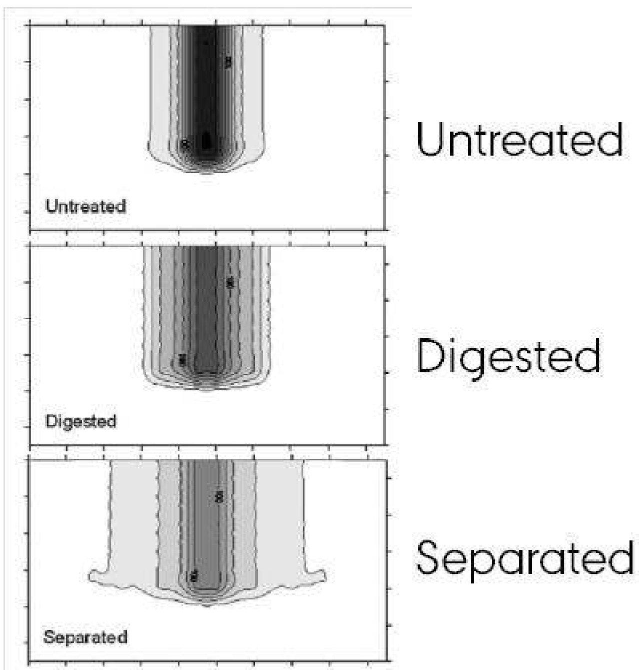
Thank you!

Nitrous oxide mitigation by separation?



Cattle slurry (0, 1, 2 or 4x)
+ 70 kg N in NH_4NO_3

After 24 h:

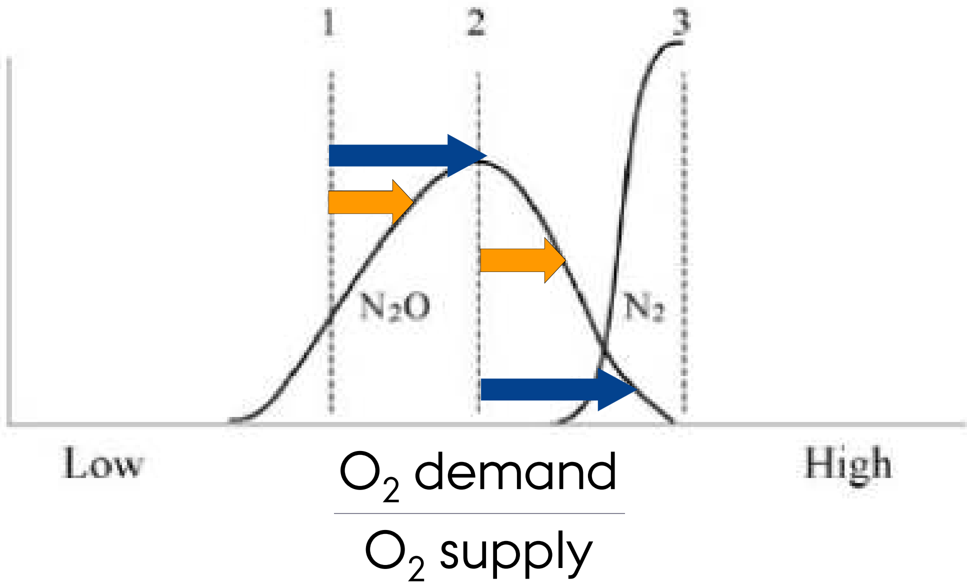


Thomsen et al. (2010)

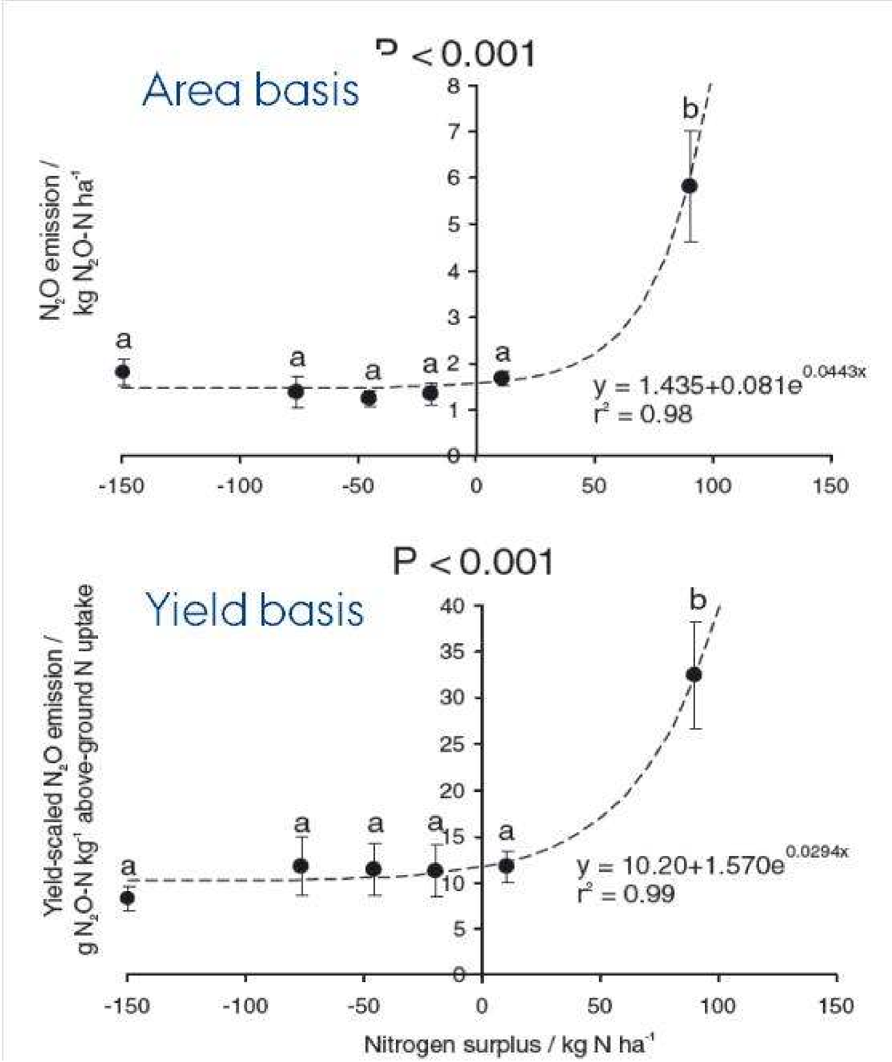
N_2O emission from soil-manure system
Interactions between manure OM and soil conditions

O_2 demand affected by:
› manure OM composition
› infiltration

O_2 supply affected by :
› texture
› compaction
› moisture

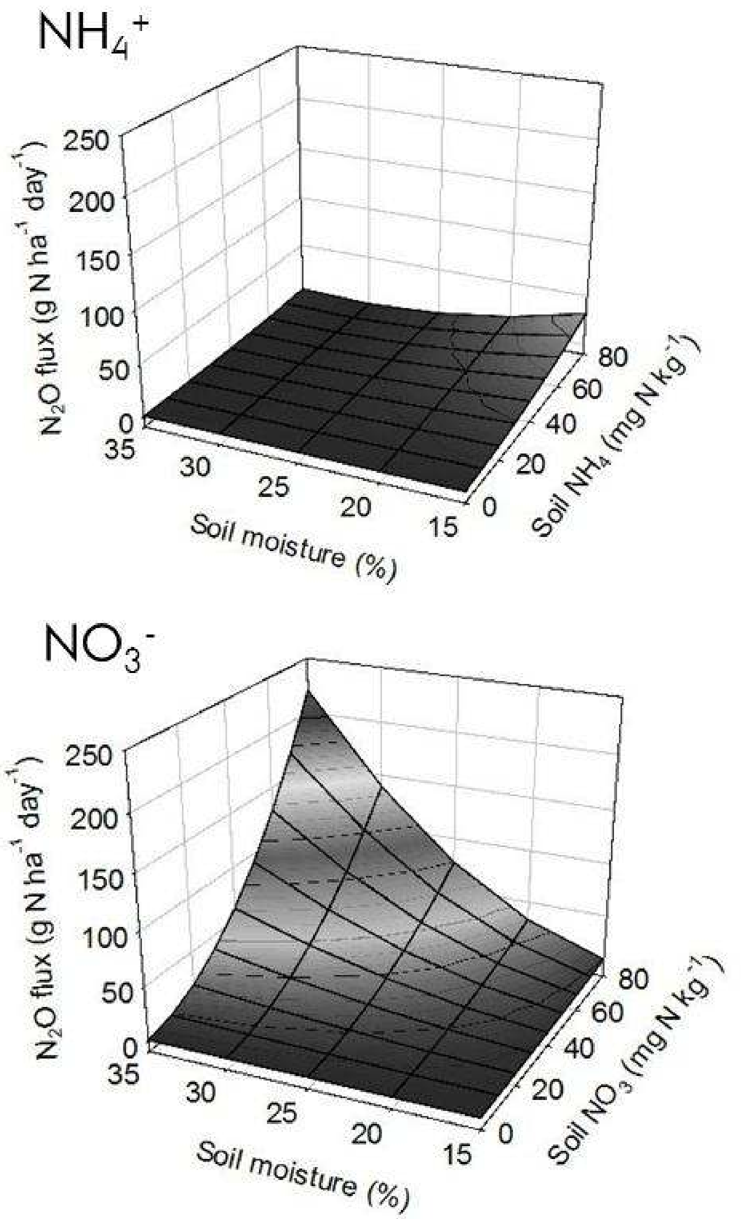


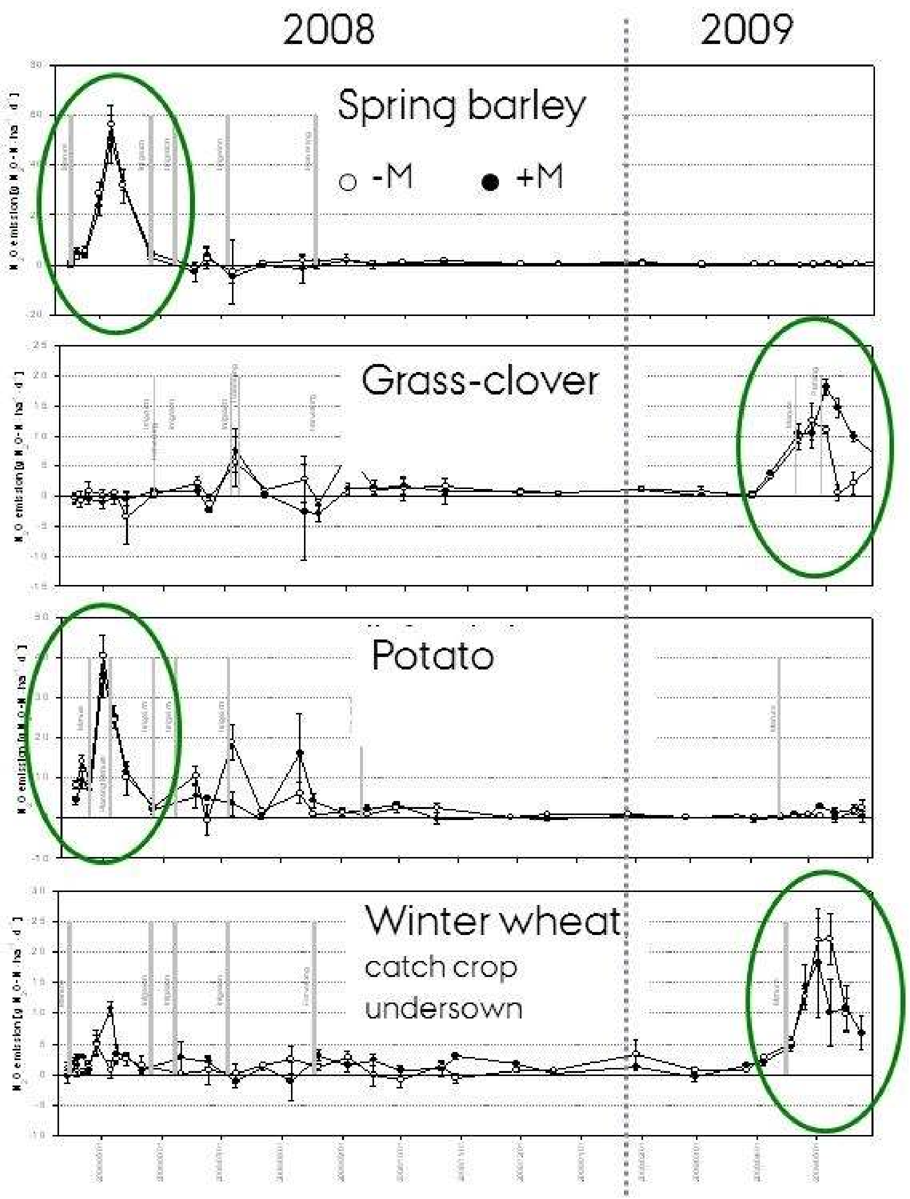
(Thomsen et al., 2010)

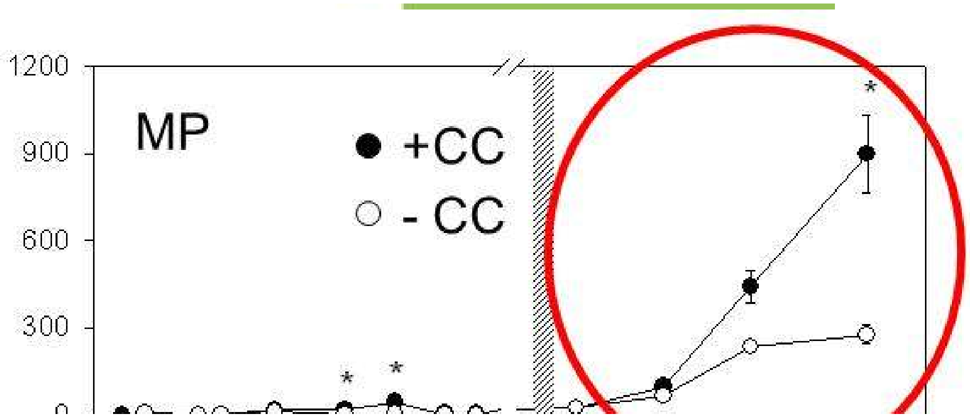


Van Groenigen et al. (2010)

(Brozyna et al., in prep.)







17-24 April:
Tillage
Slurry injection
Seeding

Direct seeding						Ploughing					
+ cover crop			- cover crop			+ cover crop			- cover crop		
0	INJ	TH	0	INJ	TH	0	INJ	TH	0	INJ	TH

0 – no slurry **INJ** – injection **TH** – trail hose application