Denitrification and nitrous oxide emission in agricultural soils – common ground?

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Outline of presentation

- Introduction – Nitrate and nitrous oxide
- Experimental research
    - Nitrate leaching on sand, clay and peat soils
    - N_2O emission and denitrification
- Conclusions

Introduction

Importance of denitrification in agriculture:

- N loss from agriculture
- Effect on nitrate leaching to
  - groundwater: EU Nitrate Directive
  - surface waters: EU Water Frame Work Directive
- Source of N_2O: Kyoto protocol Climate Convention

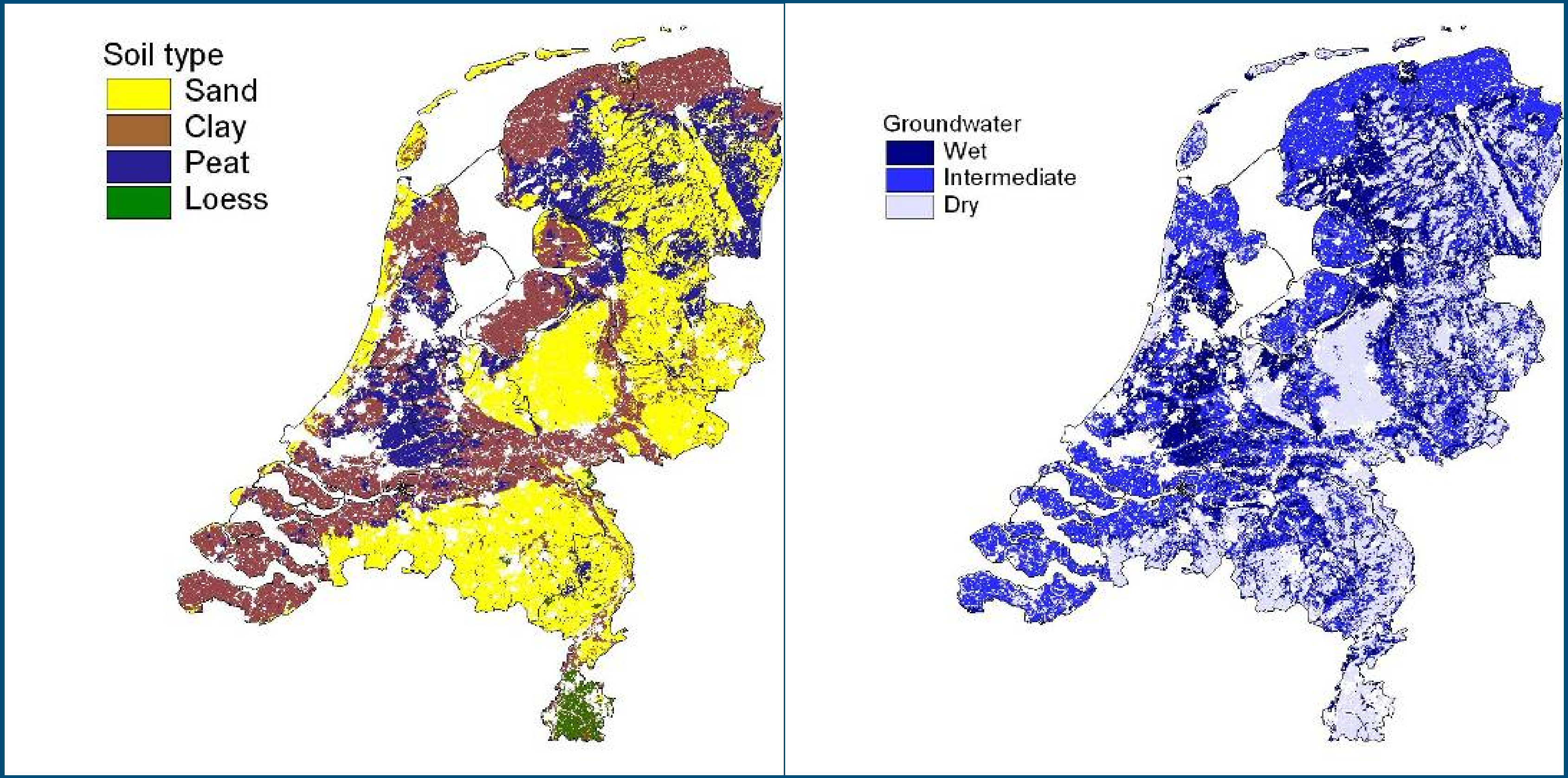
Controlling factors

	denitrification	N_2O/N_2 ratio
Increasing nitrate content	+	+
Increasing oxygen content	-	+
Increasing available organic carbon	+	-
Increasing temperature	+	-
Decreasing pH	-	+

The Netherlands: high denitrification losses?

- Shallow groundwater levels

Soil types and groundwater levels



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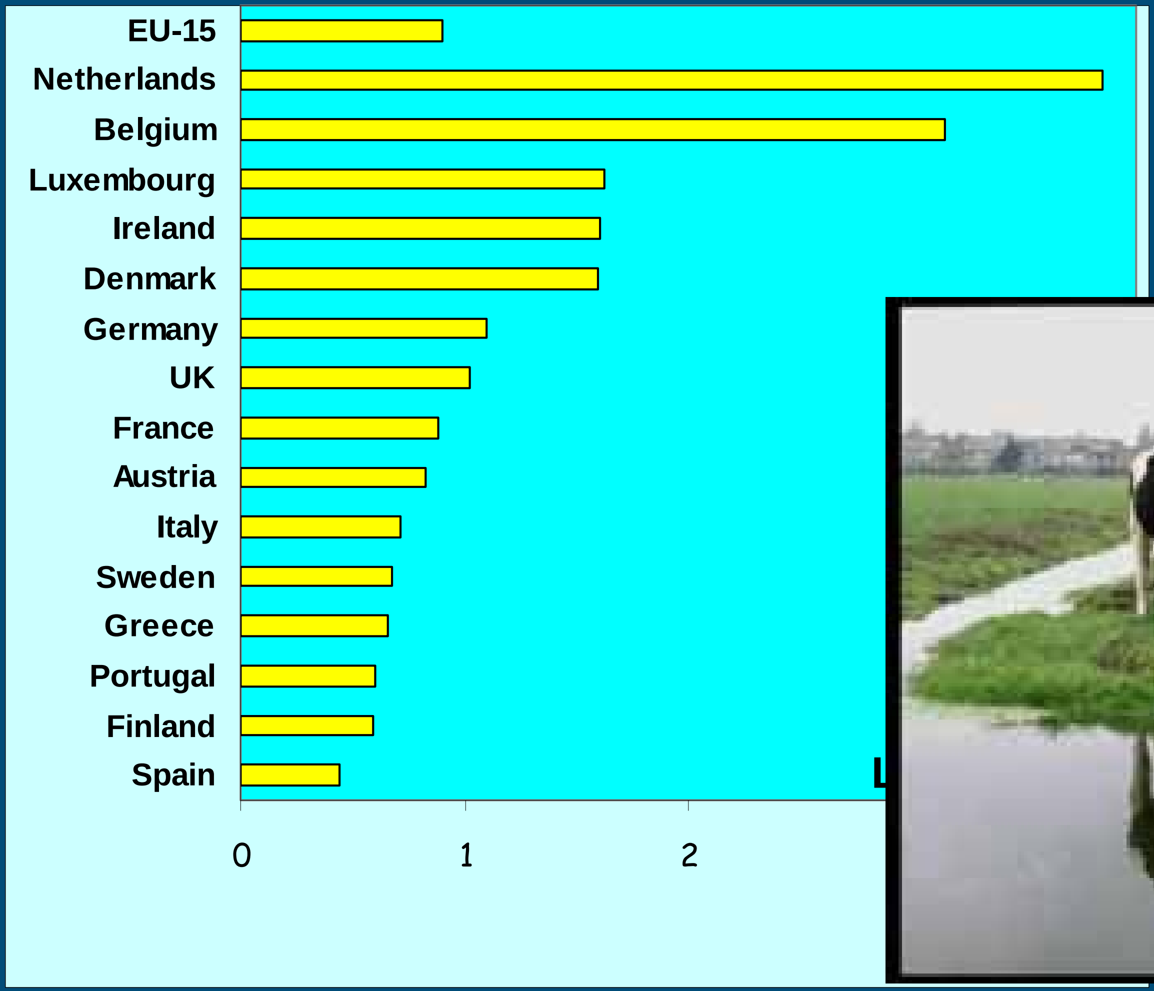
The Netherlands: high denitrification losses?

- Shallow groundwater levels
- High N input via fertilizers and manures
- Managed grasslands on drained peat soils

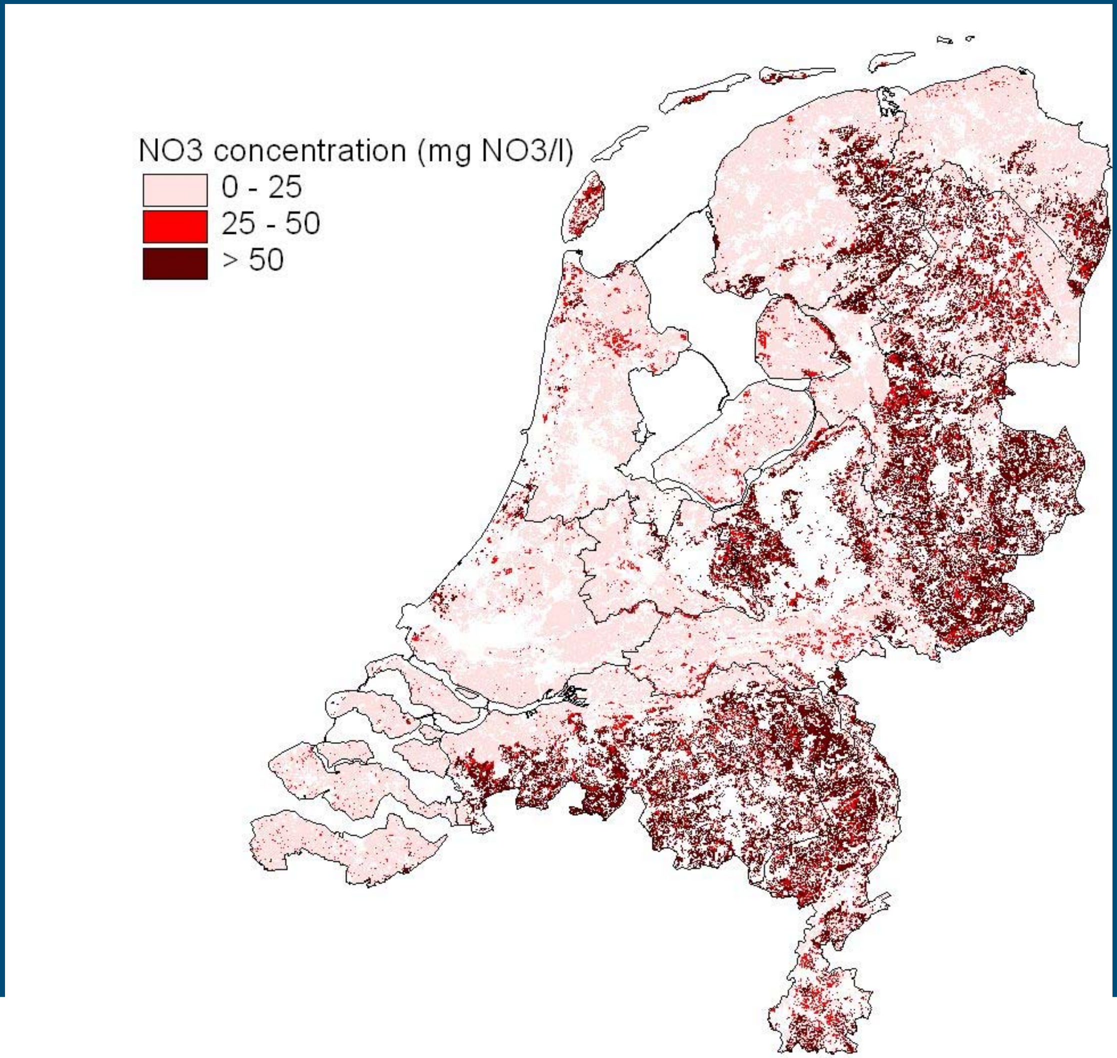
High intensive agriculture



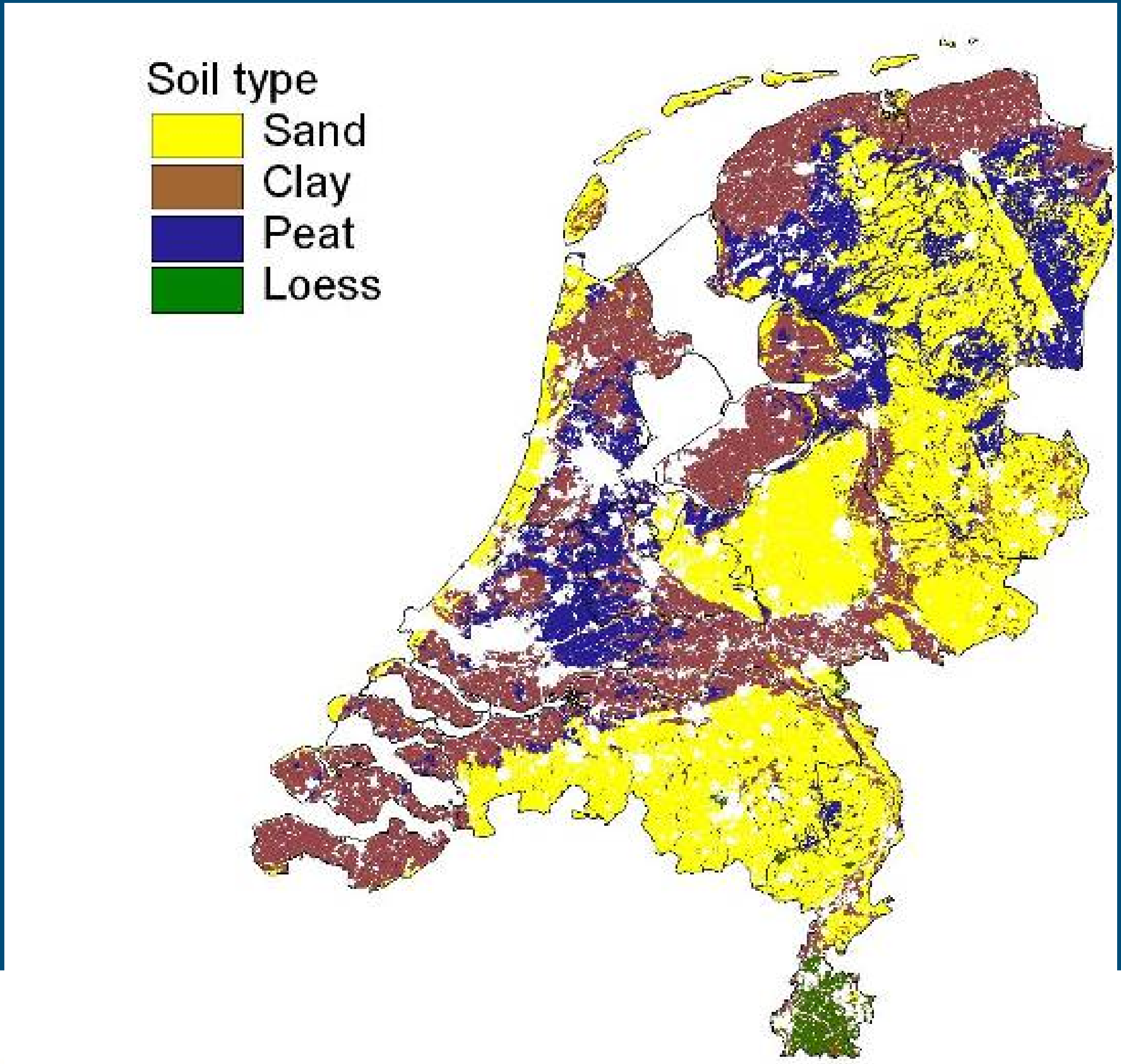
The Netherlands: high denitrification losses?

- Shallow groundwater levels
- High N input via fertilizers and manures
- Managed grasslands on drained peat soils
- High C input via crop residues and manures

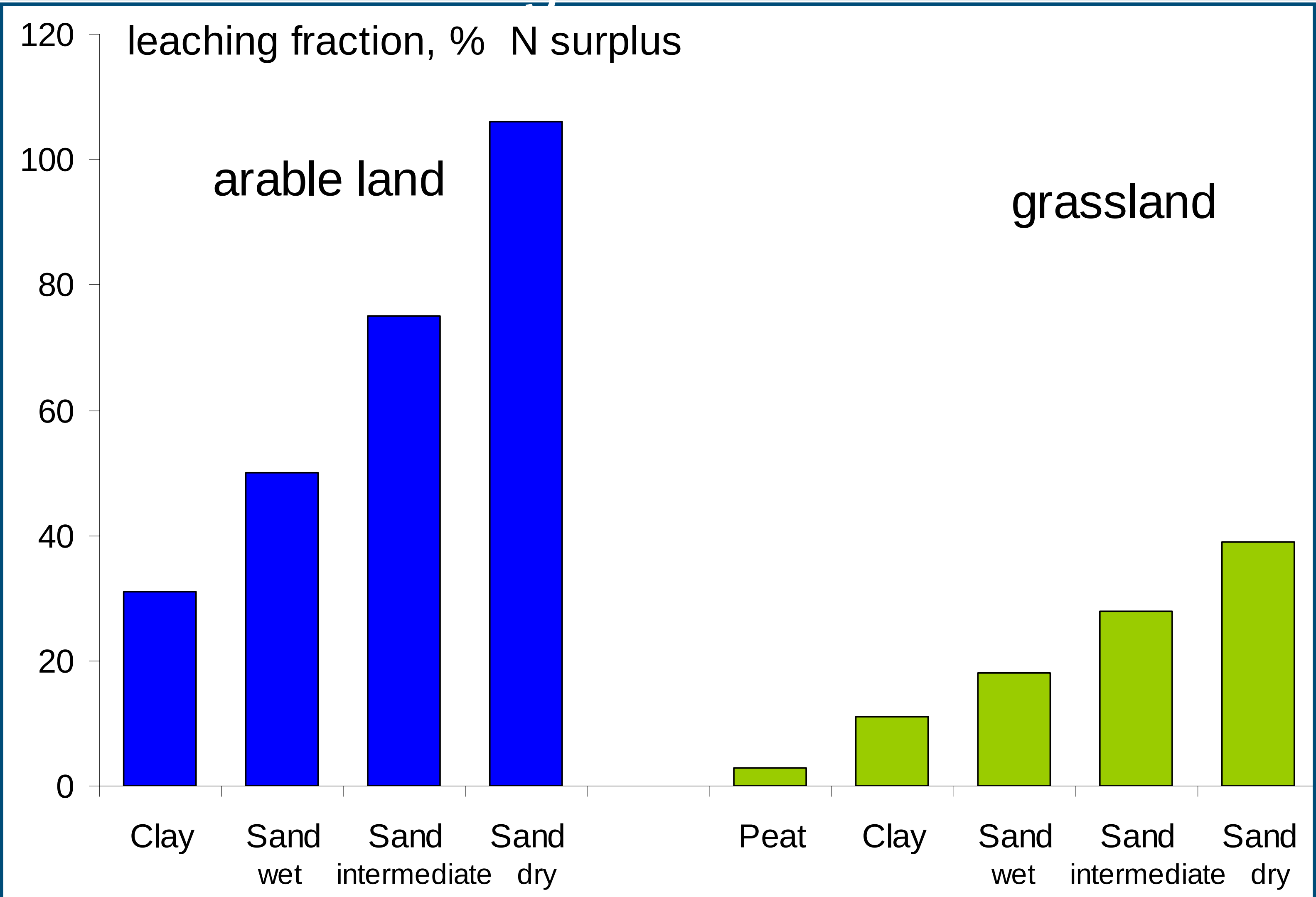
Modeling NO_3 on a national scale



Modeling N_2 on a national scale



Calculated leaching fractions



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Methods to quantify denitrification

- Potential denitrification
- Actual denitrification (acetylene inhibition)
- Fate of ^{15}N-labeled nitrogen
- N budgets using nitrate measurements in groundwater and surface waters

Potential denitrification

- Soil samples
- 200 mg NO_3 kg^{-1}
- No C added
- Anaerobic incubation
- 20 ^oC
- Acetylene inhibition

Potential denitrification

	Average potential denitrification, mg N kg^{-1} d^{-1}					
	Grassland				Maize land	
Layer, cm	Peat	Clay	Loam	Sand	Loam	Sand
0 – 20	267	151	65	26	20	11
20 - 40	317	125	30	4	9	4
40 - 60	116	5	1	0.1	1	0.1
60 - 80	61	0.9	0.3	0.5	0.3	0
80 - 100	39	0.6	0.2	0.2	0.1	0

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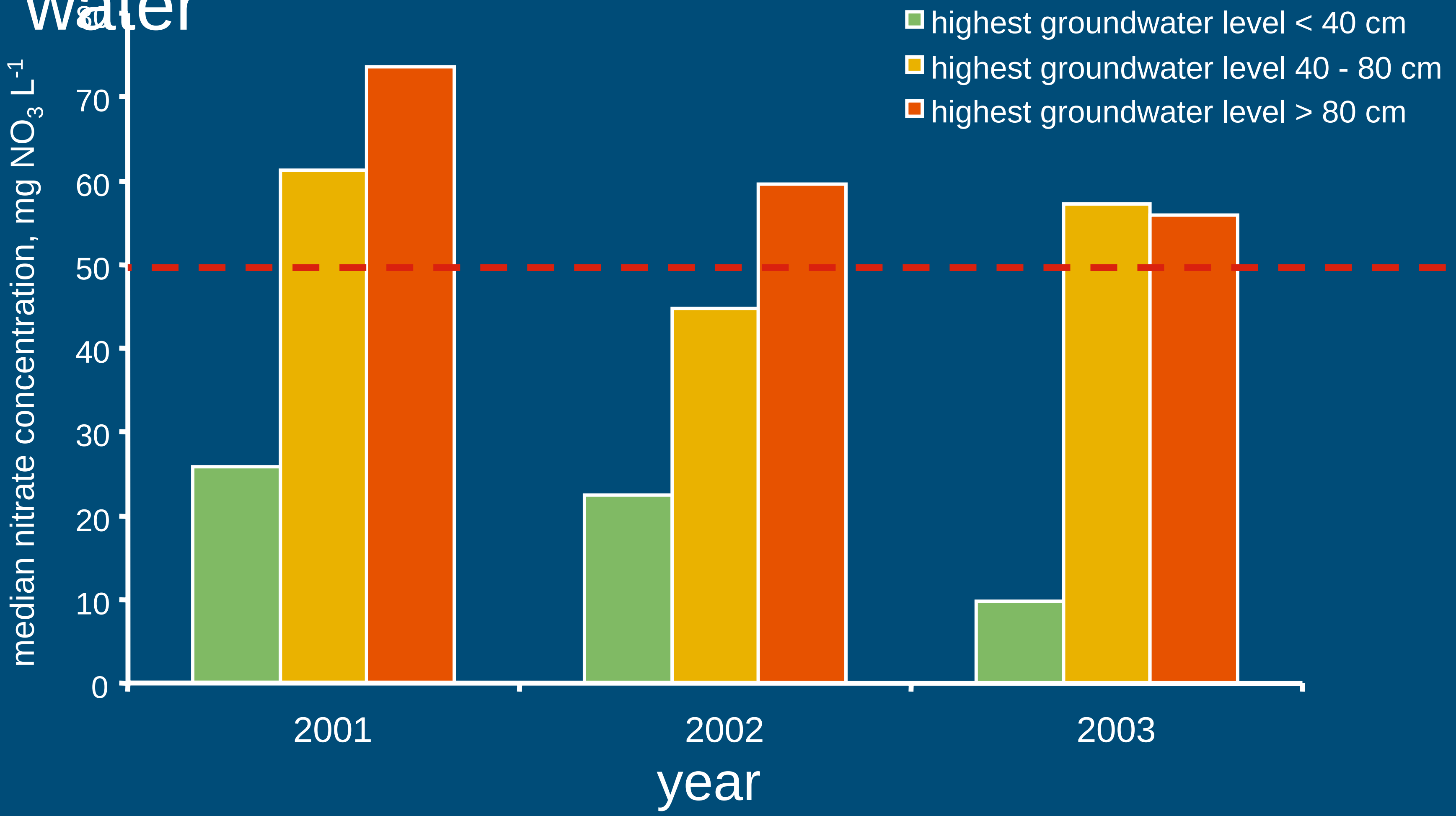
Assinck, unpublished

Measurements of leaching in sandy soils

Groundwater

Nitrate in groundwater of sand relates to water



Project 'Focus on Nitrate'

Fate of ^{15}N labelled fertiliser in a sandy soil

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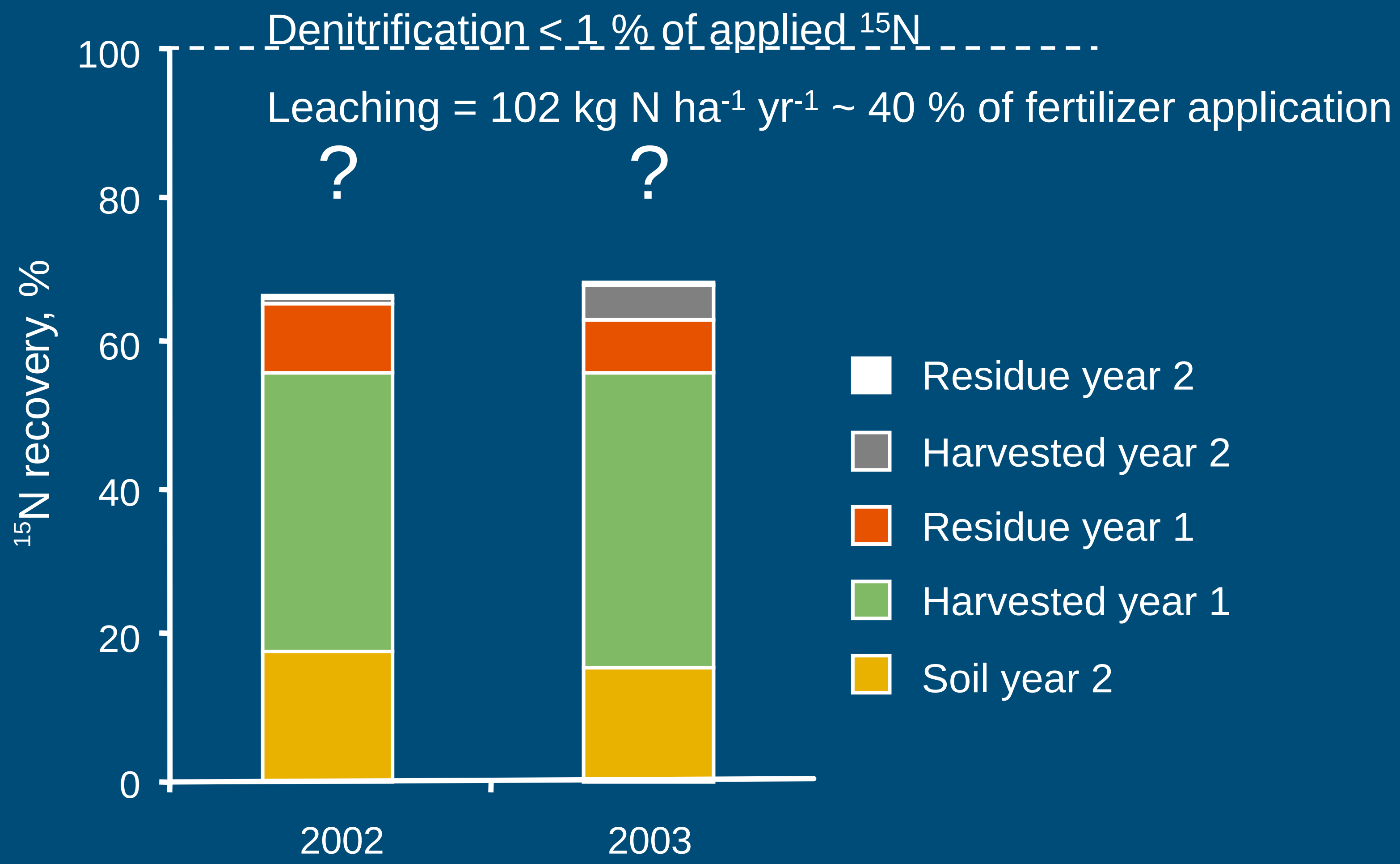
Measurement of leaching/runoff

Surface water

Fate of ^{15}N labelled fertilizer in a **sandy** soil



van Groenigen et al. (2005)

Managed grassland on clay soil

- Field balances of nitrogen
- Two years monitoring:
  - Denitrification (acetylene inhibition)
  - Leaching to surface water:
    - Trenches
    - Tile drains

Van der Salm et al. (in prep.)

N budget of grassland on a **clay** soil, kg N ha^{-1} yr^{-1}

		2003	2004
Input	Slurry (after NH_3 emission)	321	206
	Fertilizer	139	189
	Grazing	44	21
	Deposition	34	34
Output	Uptake cattle	96	32
	Cutting	285	388
	Drainage; trenches	**4**	**19**
	Drainage; tile drains	**2**	**7**
	Leaching groundwater	**0**	**0**
	Denitrification	**127**	**143**
Input - Output		24	-139

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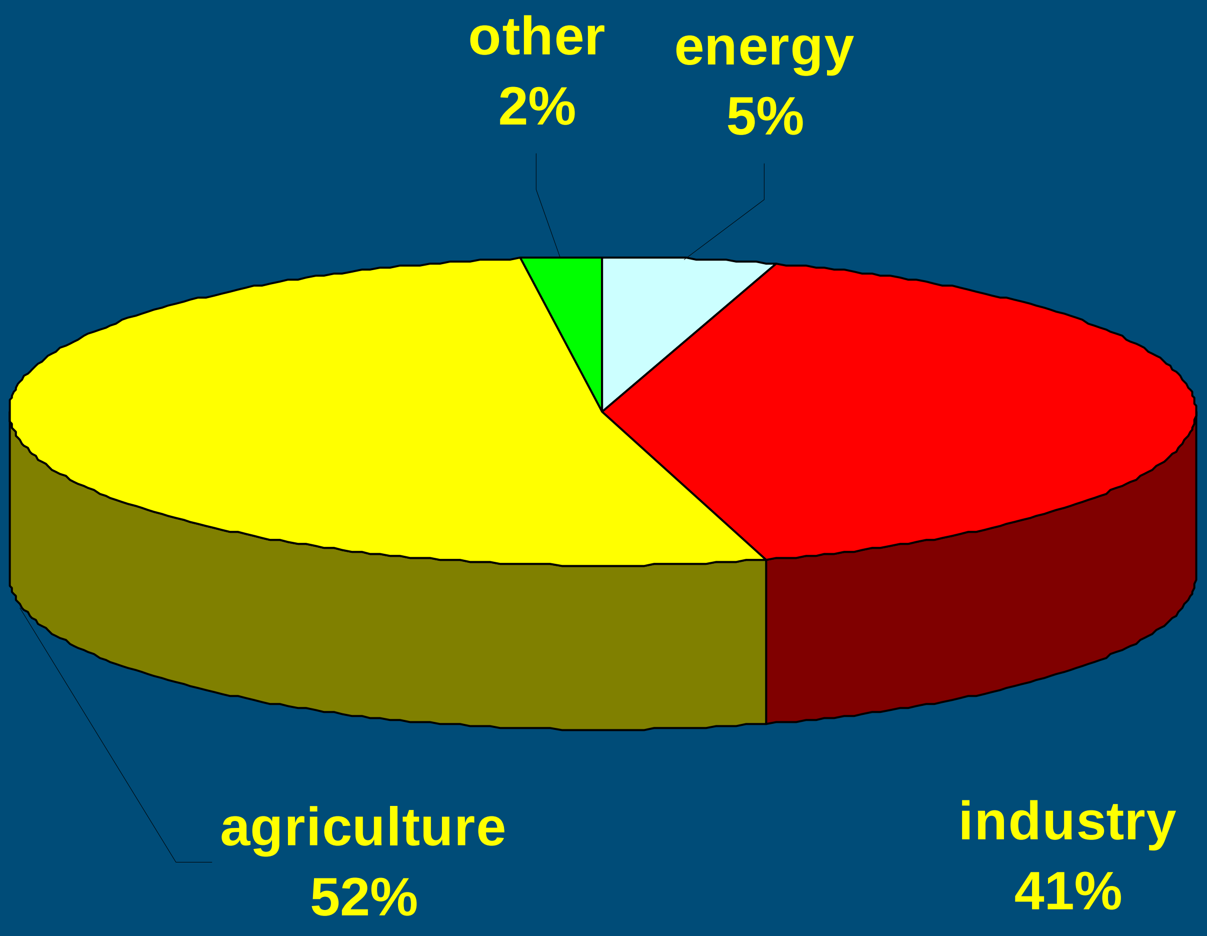
Van der Salm et al. (in prep.)

Sand versus clayey soils

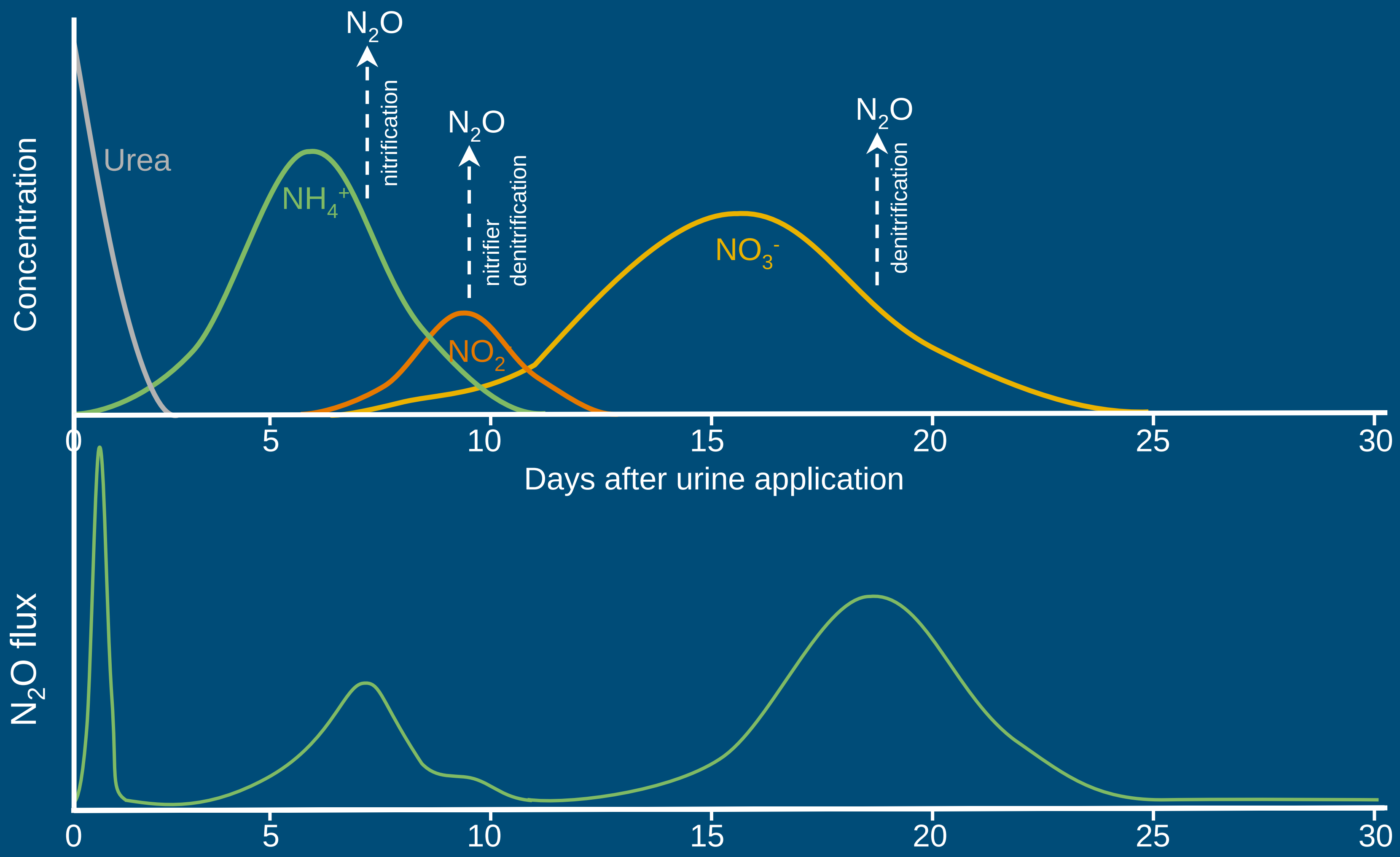
- In sand
  - potential denitrification low > 50 cm but higher in deeper layers?
  - low nitrate concentration in groundwater where groundwater high < 40 cm or in presence of peat layers in soil profile
  - low denitrification -> high NO_3 concentration in drainage water

- In clay
  - high denitrification losses (> 100 kg N ha^{-1} yr^{-1})
  - N leached to surface water < 20 kg N ha-1 yr-1
  - leaching of NH_4 and organic N lileky more important
  - Yet, total N concentration ditch water exceeds 2.2 mg N l^{-1}

N_2O emission in the Netherlands in 2002



Introduction



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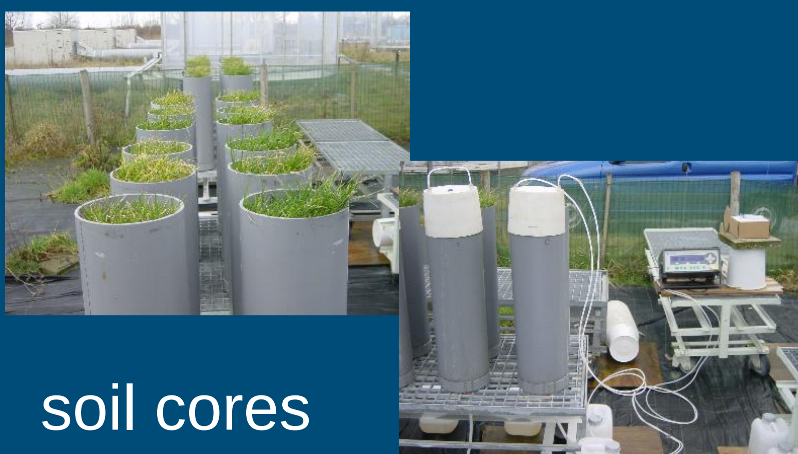
Effects fertilizer and manures on N_2O emission

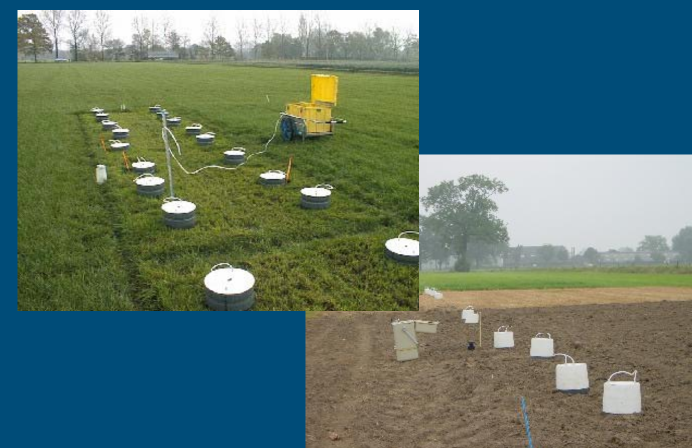
- Application of nitrogen
  - Nitrate
  - Ammonium
  - Organic N
- Application of carbon
  - Energy source for denitrifiers
  - Oxygen consumption
- Other effects:
  - pH, moisture content, EC, ….

Methods

Incubation studies



soil cores



field experiments

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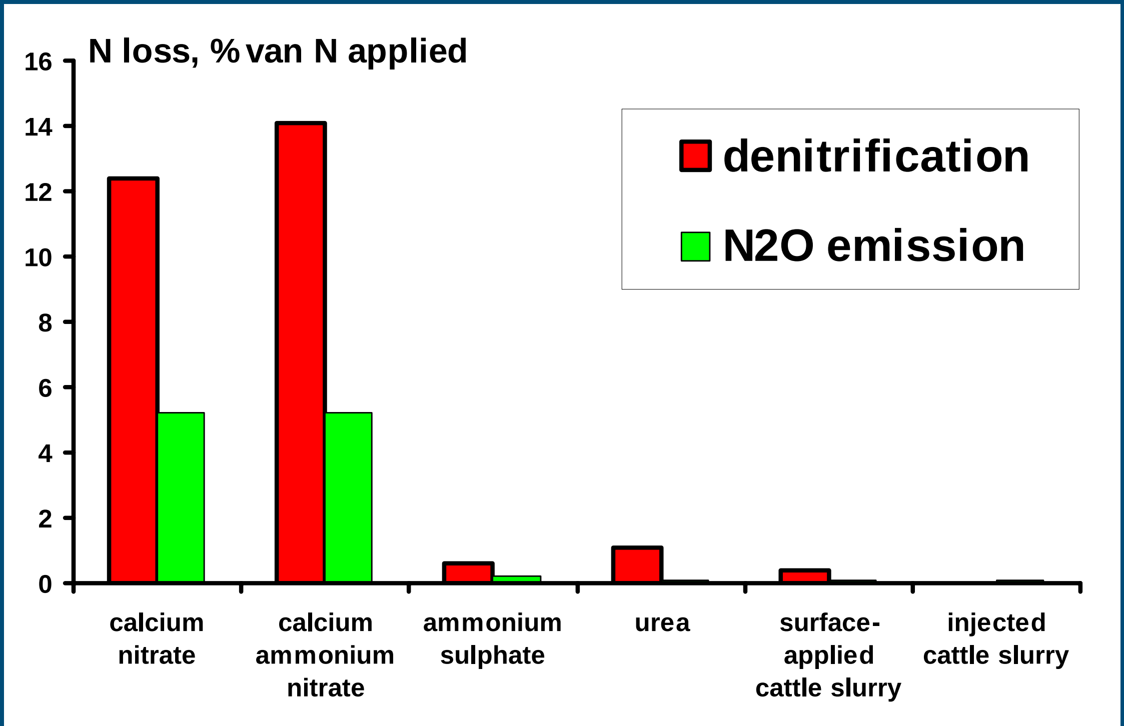
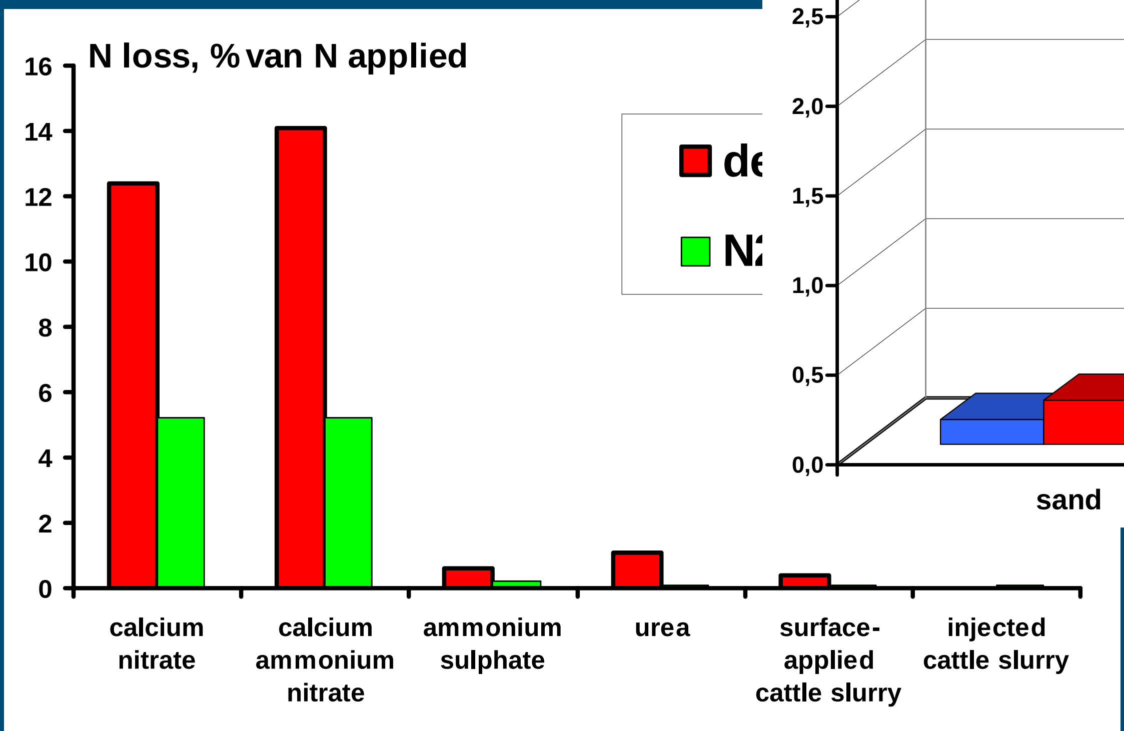
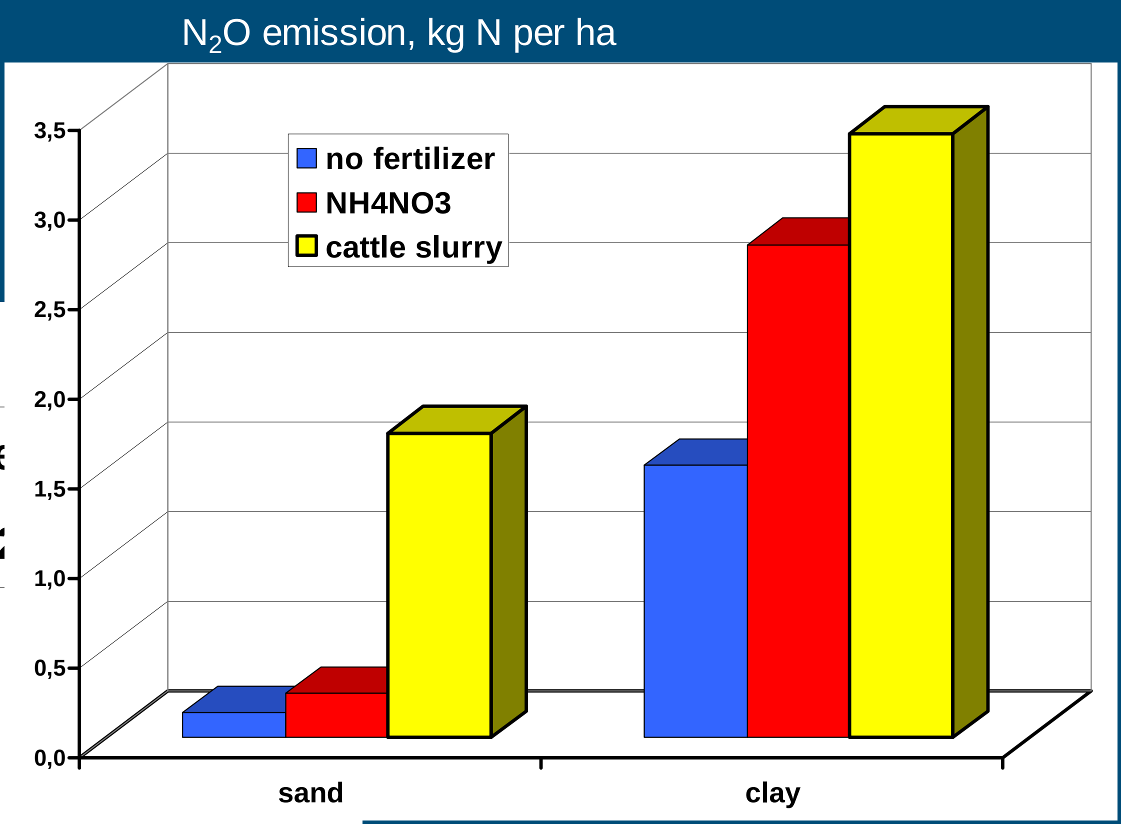
Grassland with wet conditions



Velthof et al. (1997)

Grassland versus arable land





Velthof et al. (1997)

Risk on N_2O emission

- Nitrate fertilizer: grassland > arable land
- Animal manure: arable land > grassland

because

- more available carbon in grassland
- rapid N uptake in grassland

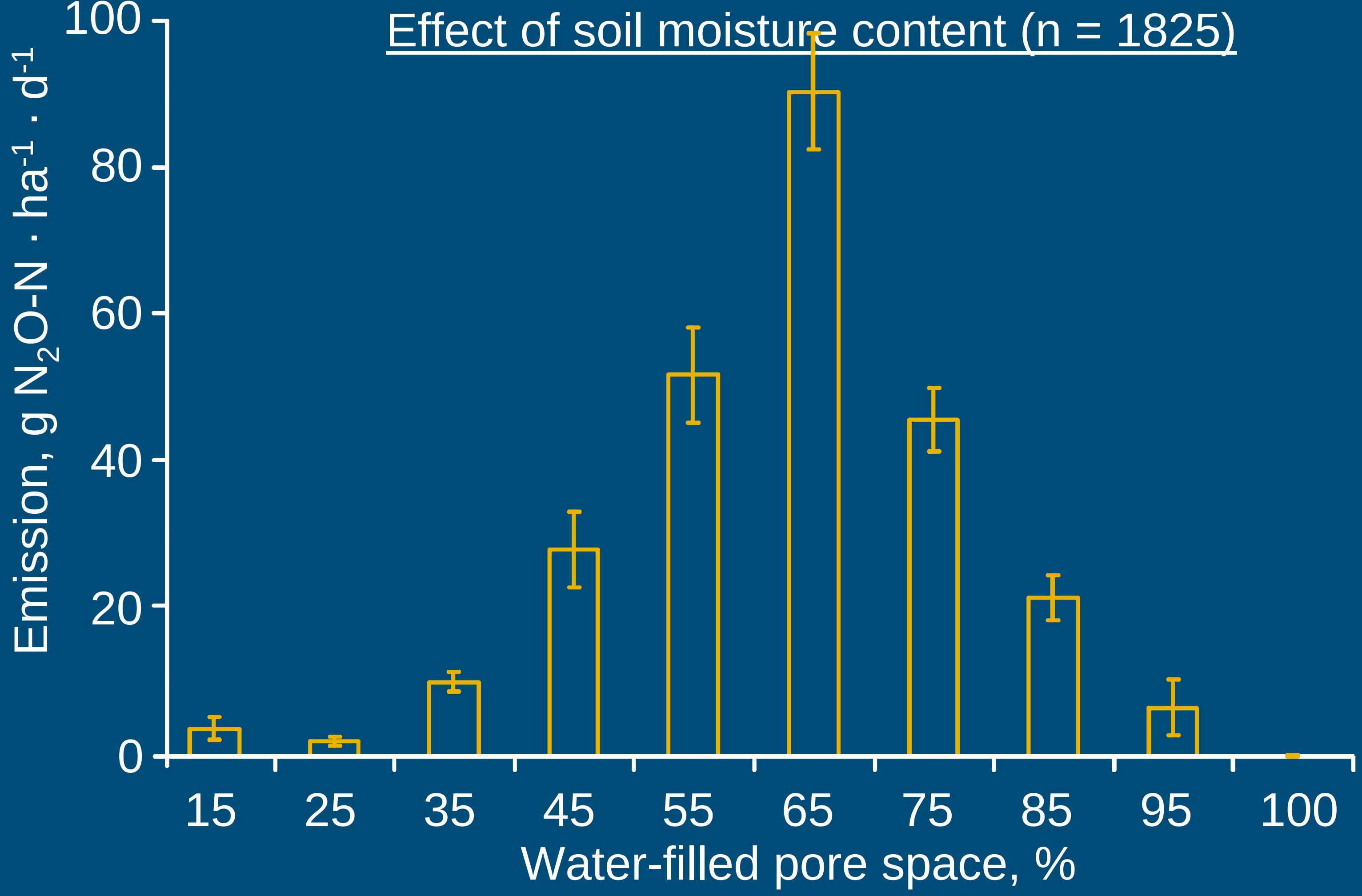
Mitigation options: fertilizer and manure use

- No use of nitrate fertilizer during wet conditions
- Animal manures to grassland
- Manipulation of manure composition
  - changes in feed
  - digestion
  - housing, manure storage (e.g. bedding material)

Effects of grazing on N_2O emission

- Urine patches: high N concentrations
- Urine patches: increased water content
- Dung pats: high carbon contents
- Trampling: compaction (low oxygen)

Urine concentration, compaction, dung



[Van Groenigen et al., 2005a]

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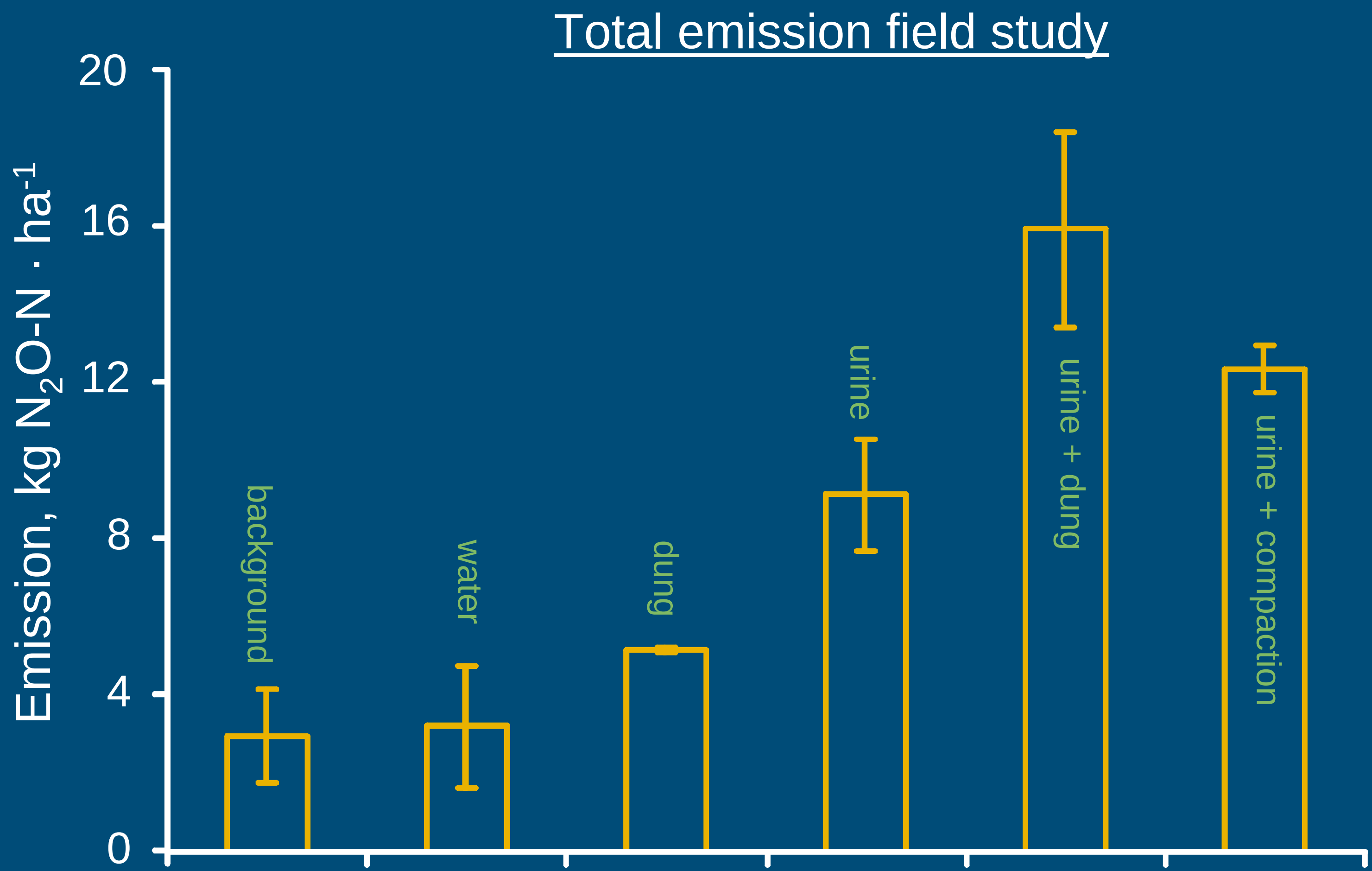
Urine concentration, compaction, dung



[Van Groenigen et al., 2005b]

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Mitigation options: grazing

- Restricted grazing
- Decrease stocking density
- Avoid grazing during wet conditions
- Avoid camping areas
- Manipulation of N and C excretions
  - feeding
- Adjust fertilizer application

Results on nitrous oxide emission

- Options available to mitigate N_2O emissions from fertilzers, manures, crop residues and grazing
- Focus not only on N, but also on C and “water/O_2”
- Uncertainties:
  - Changes in N_2O/N_2
  - Interactions with soil properties

Conclusions

- Denitrification:
  - Significant and large effect on NO_3 concentration in groundwater of sandy soils
  - High in peat and clay soils, but still total N concentrations in surface waters frequently exceed standards

- Maintaining or increasing denitrification capacity in soils may help to decrease nitrate leaching
  - But may enhance nitrous oxide emission!
  - Thus focus on preventing N leaching

Thank you!