Agriculture, Climate Change: can we produce food without greenhouse gases?

Peter Kuikman

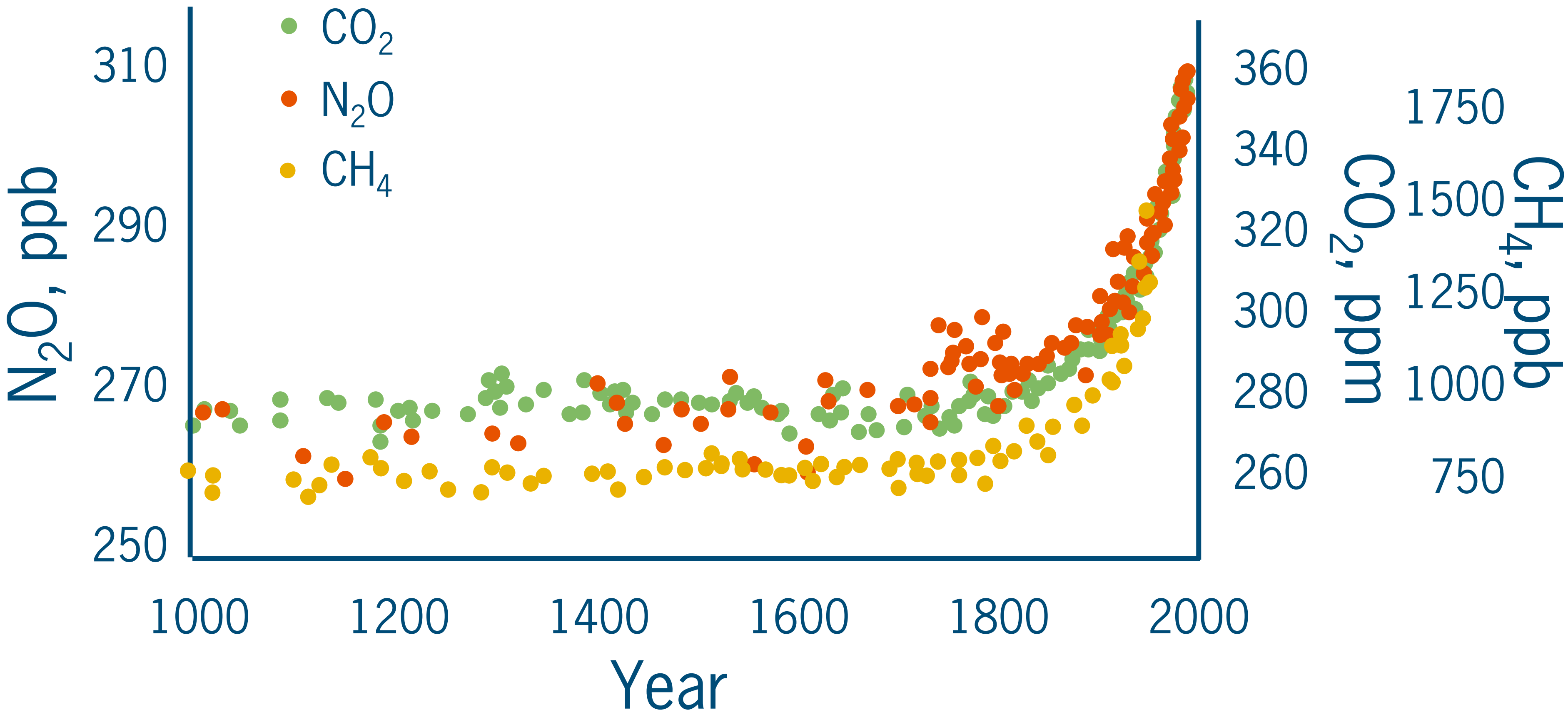
ALTERRA
WAGENINGEN UR

In short …

- Public and scientific awareness
- Trends in agriculture and emissions – why care?
- Emissions of greenhouse gases and mitigation options
- Assessment of effect & regions
- Conclusions

Climate Change and agriculture

Climate Change and agriculture

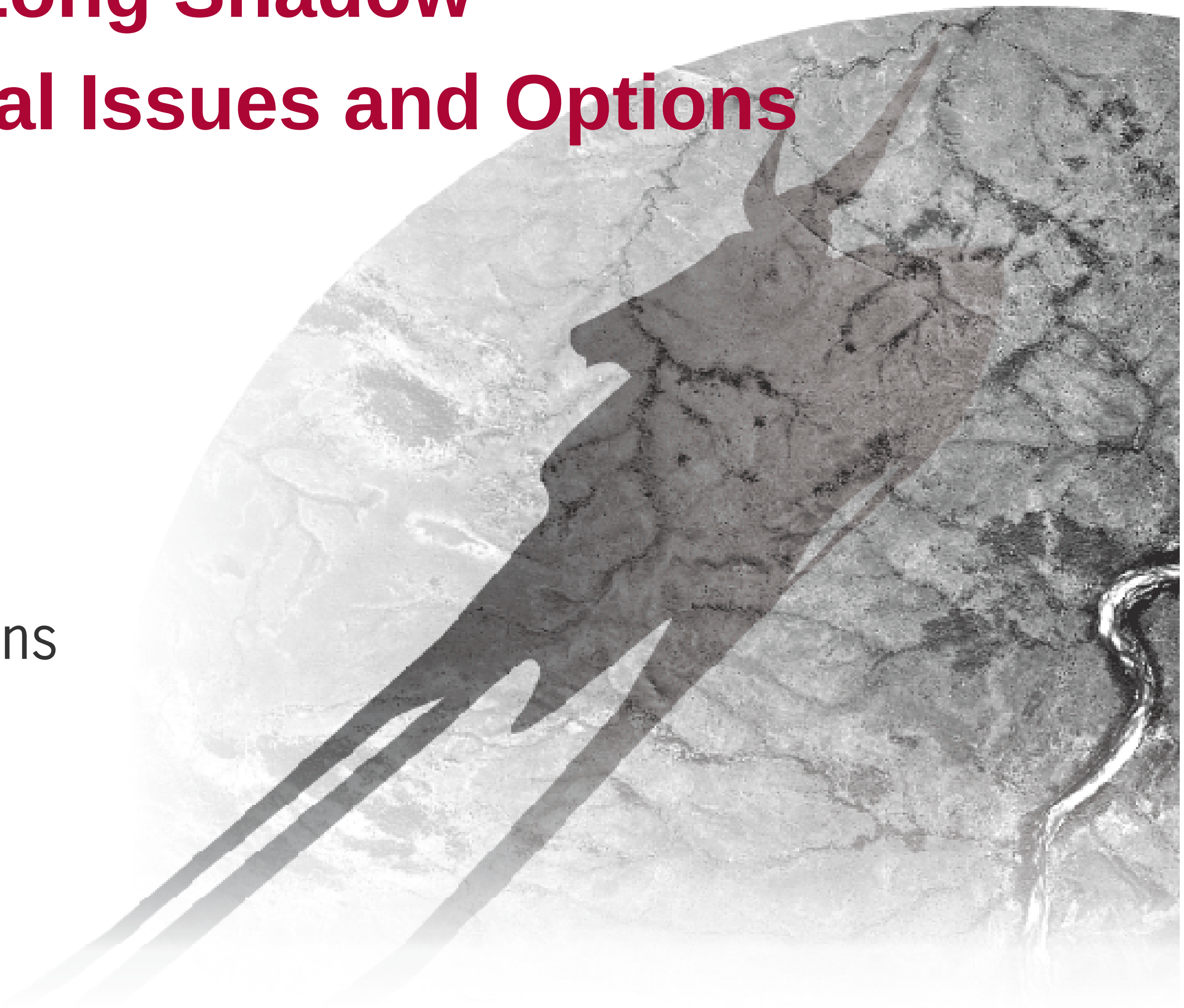


5 statements

- Global livestock doubles in 50 years
- Livestock uses scarce resources (land, water, energy)
- Livestock has major impact on climate change
- Replace consumption of meat with vegetarian diet and reduce emissions GHG
- Consumers and consumption patterns count

ALTERRA
WAGENINGEN UR

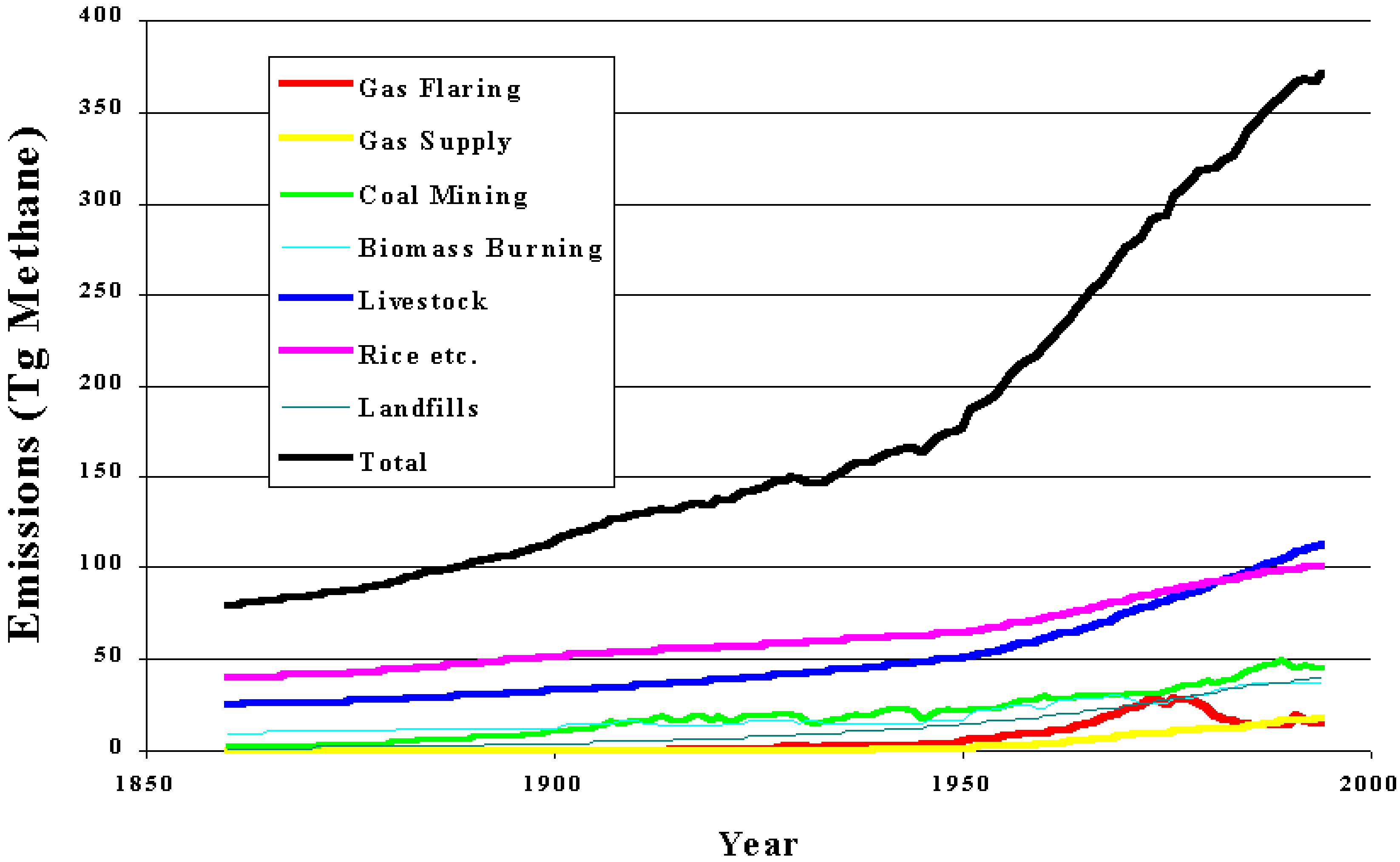
Livestock's Long Shadow
Environmental Issues and Options



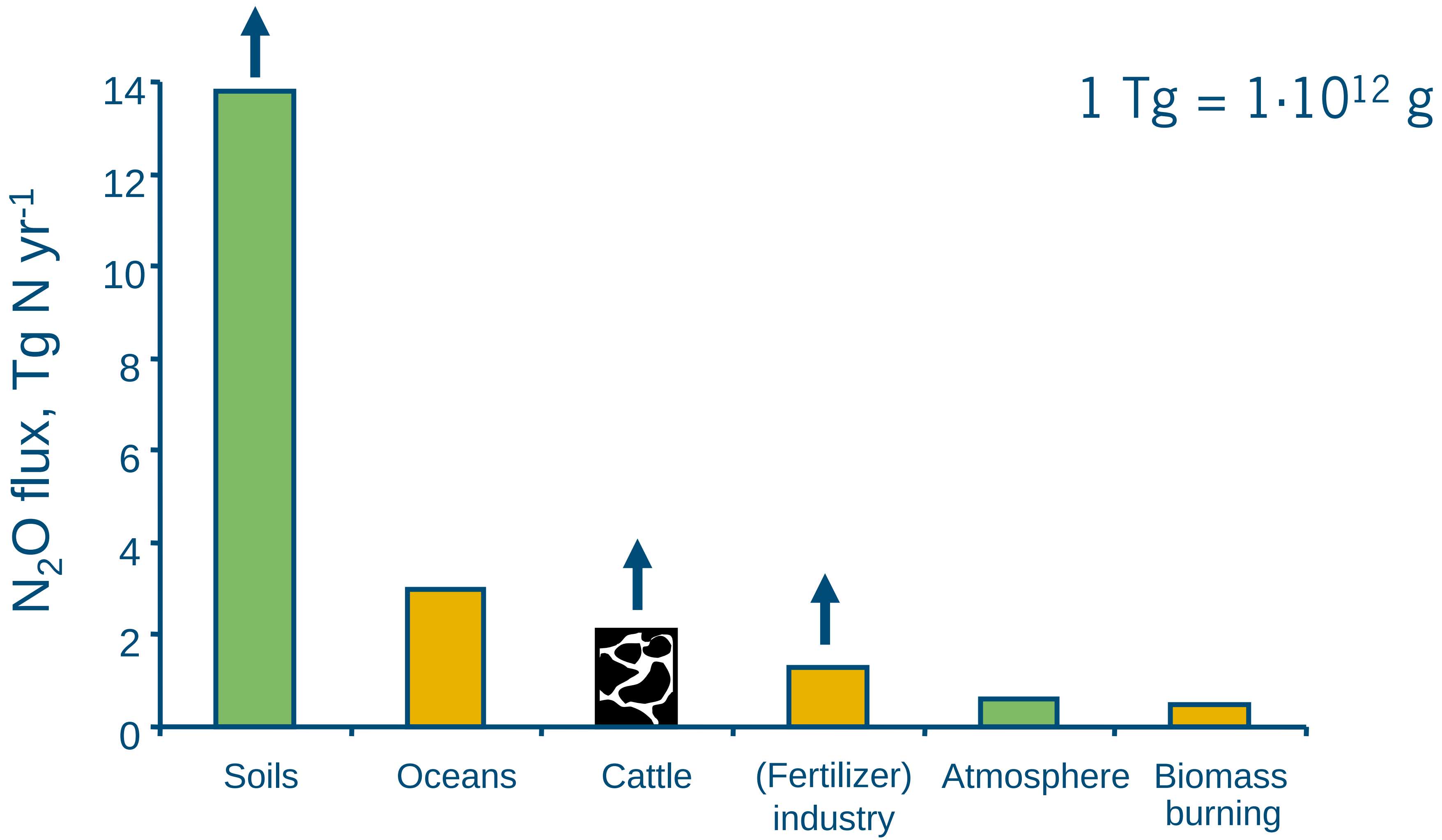
- Awareness
- Diagnoses
- Hypotheses
- Design of solutions

FAO, Steinfeld et al. (2006)

Global Anthropogenic Methane Emissions: 1860-1994
(Stern & Kaufmann)



Global sources of N_2O emissions



[IPCC, 2001]

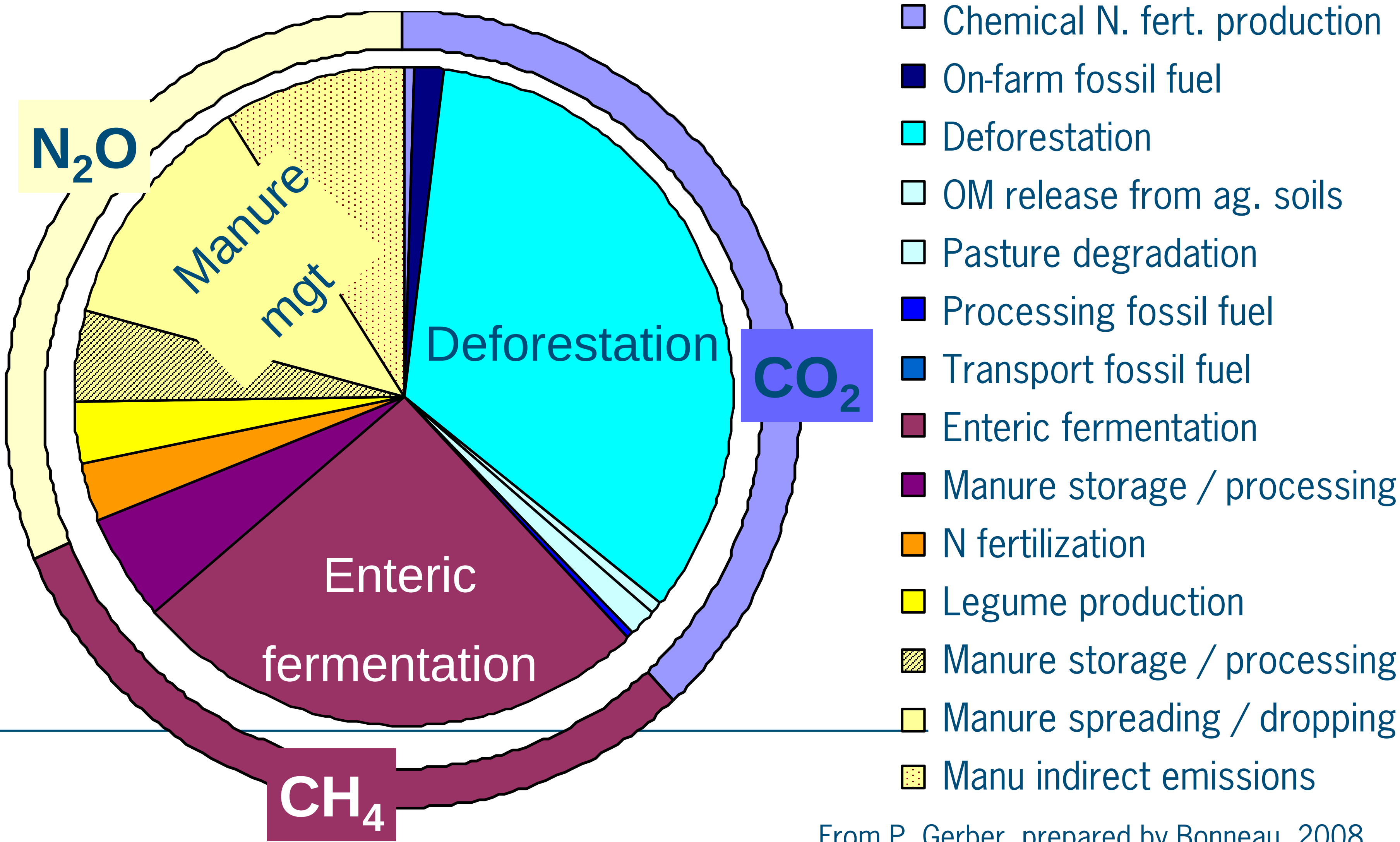
Contribution of livestock sector to GHG emissions

(Source: FAO, 2006. Emissions per year in 10^9 ton CO_2 eq.)

- CO_2 ….. Total 24.0 -> Livestock 0.16 (< 1%)
- CH_4 ….. Total 5.9 -> Livestock 2.2 (37%)
- N_2O ….. Total 3.4 -> Livestock 2.2 (65%)

- And …. 4.5 CO_2-eq land-use with major uncertainties and difficult to attribute to sectors and activities

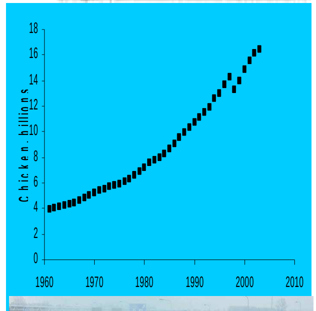
Many contributions in the food chain

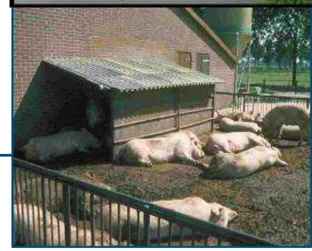


From P. Gerber, prepared by Bonneau, 2008

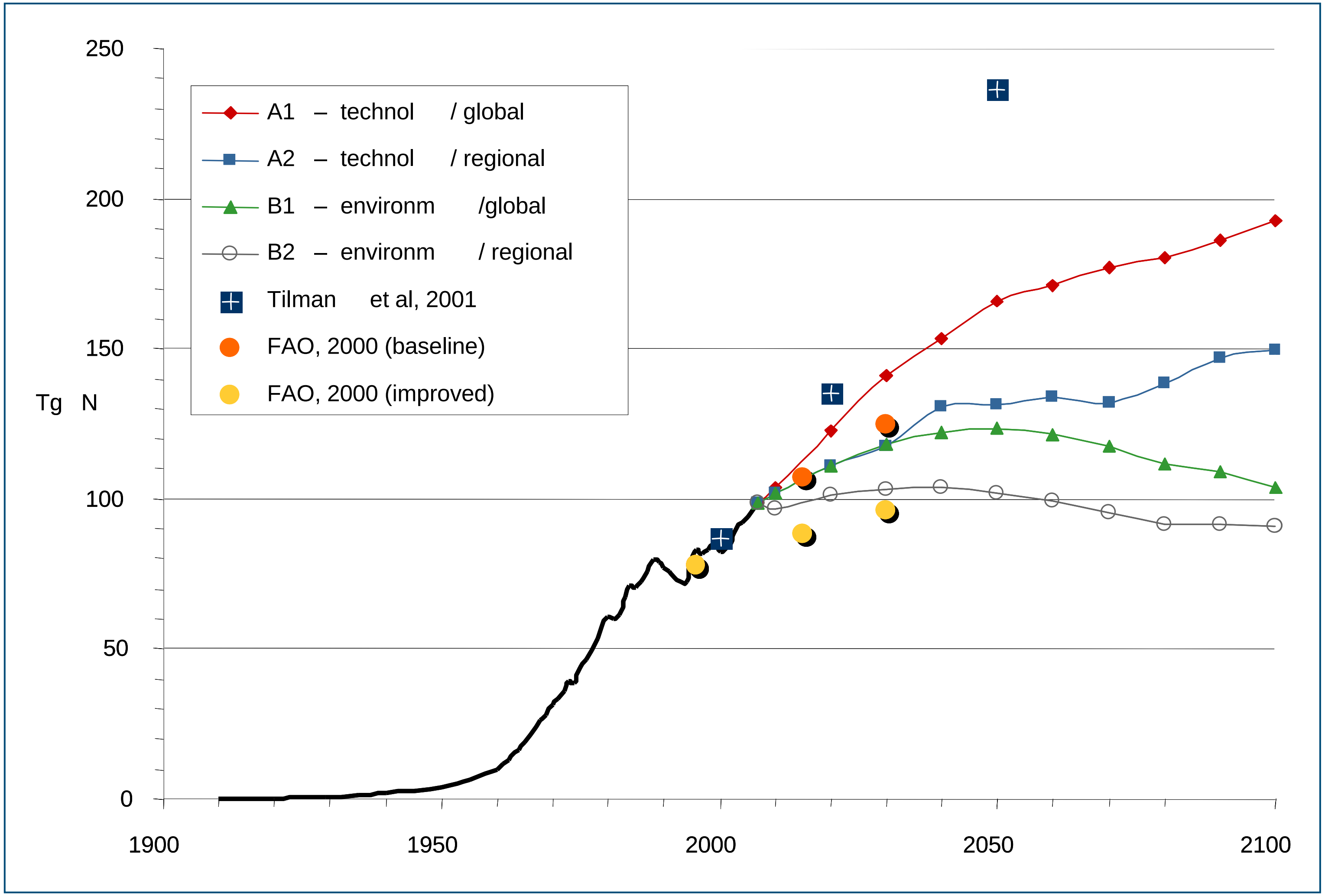
Why care?

- Human population keeps growing
- Welfare of human society increases and diets change
- Fossil fuel is non-infinite and expensive source and causes climate change requiring more biomass for bioenergy and biorefinery
- Area for agriculture declines (soil degradation, erosion, industry)
- Food security deminishes attention (political, scientific) for primary production





Global production of fertilizer (1900 – 2100)



ALTERRA WAGENINGEN UR

Erisman et al., 2008

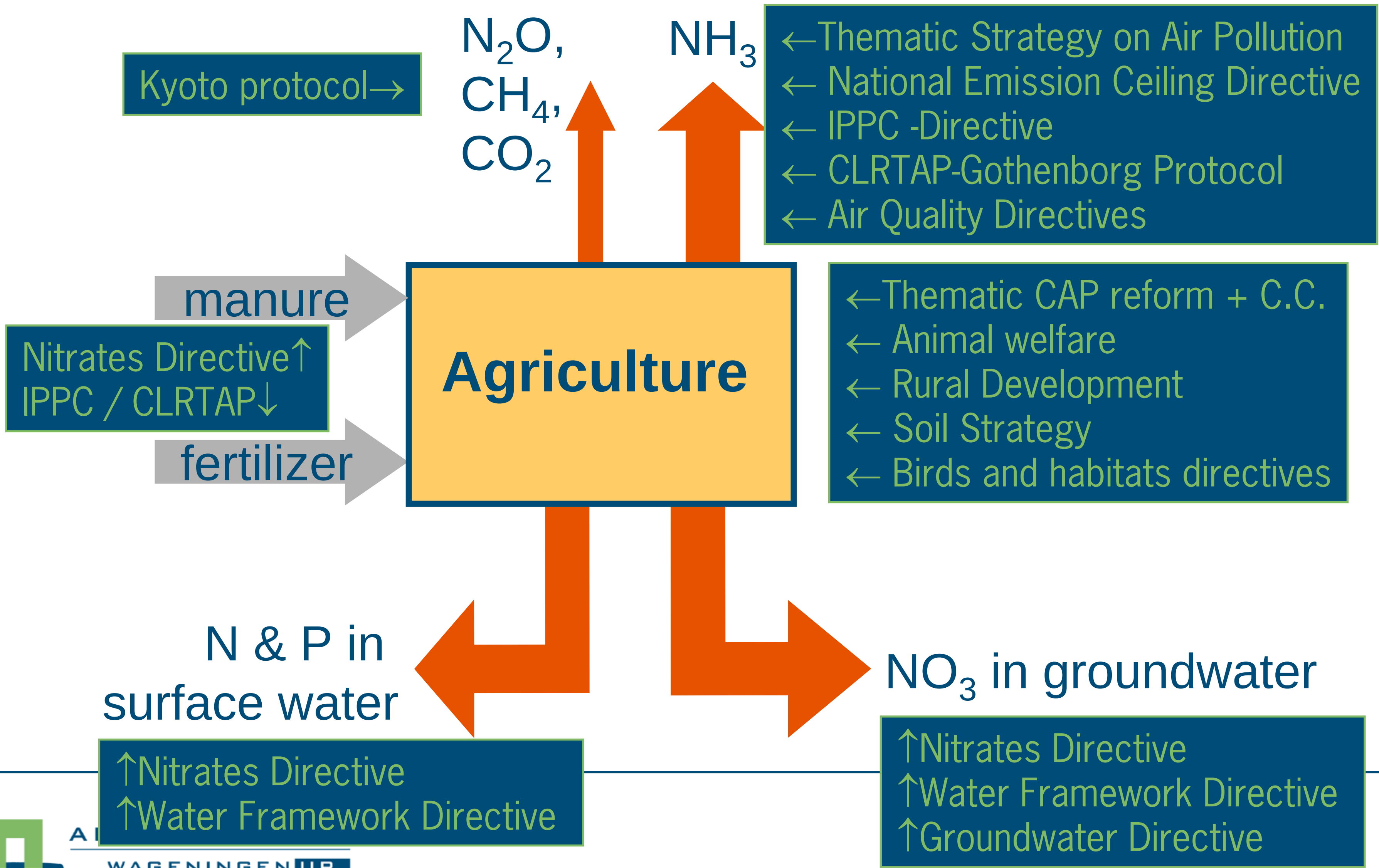
What ‘can’ or really what ‘need’ agriculture do?

- Agricultural production still growing
- No decoupling of growth and emissions
- Interventions required for effective mitigation

EU policy agenda

- Challenges from many objectives and societal needs
  - Food security
  - Public health
  - Biodiversity
  - Environment

EU: environmental legislation



EU policy agenda

- Post Kyoto agreements:
  - carbon-constrained industrial and agricultural developments?
  - emission reduction targets (also for agriculture)?
  - cap and trade policies with new (energy) markets for agriculture?
  - energy production and climate neutral agricultural and livestock production?

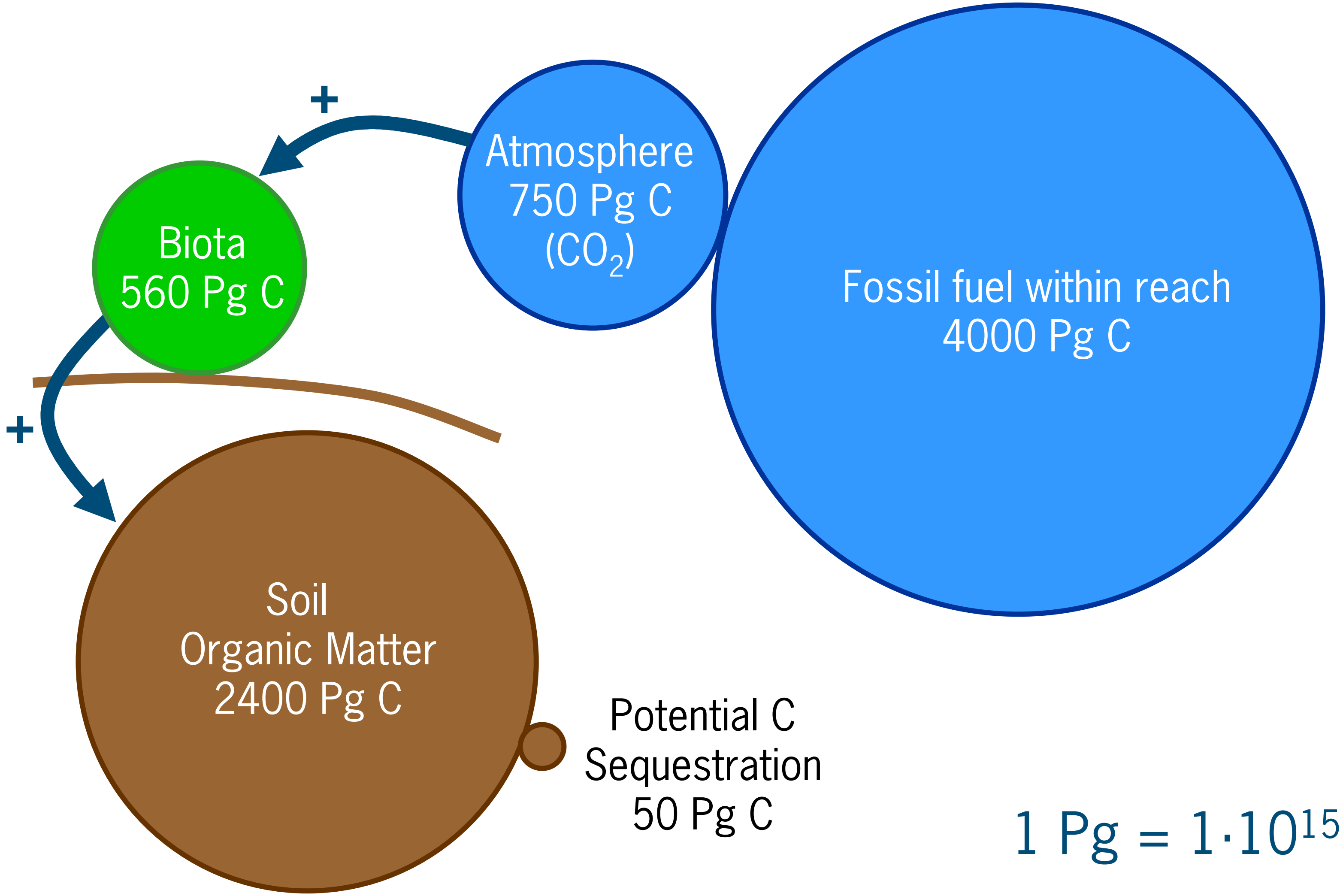
Mitigation options

- Control Land Use change
  - Avoid deforestation & use organic soils and keep permanent grass
  - Intensification of animal production and pasture management
- Conservation and sequestration of C and N in cultivated soils
  - increase tree cover
  - pasture rotation and improved pasture species
- Enteric fermentation
  - productivity gains live stock
  - feed formulation & rumen control
- Manure management
  - balanced feeding, less methane and lowering N content
  - anaerobic digestion (methane production)
  - Balanced fertilization, manure and waste application (dosing, injection)

Mitigation options – outsite sector agriculture

- ….
- Bio-energy and biobased materials (not agriculture perse)

Carbon sequestration in soils

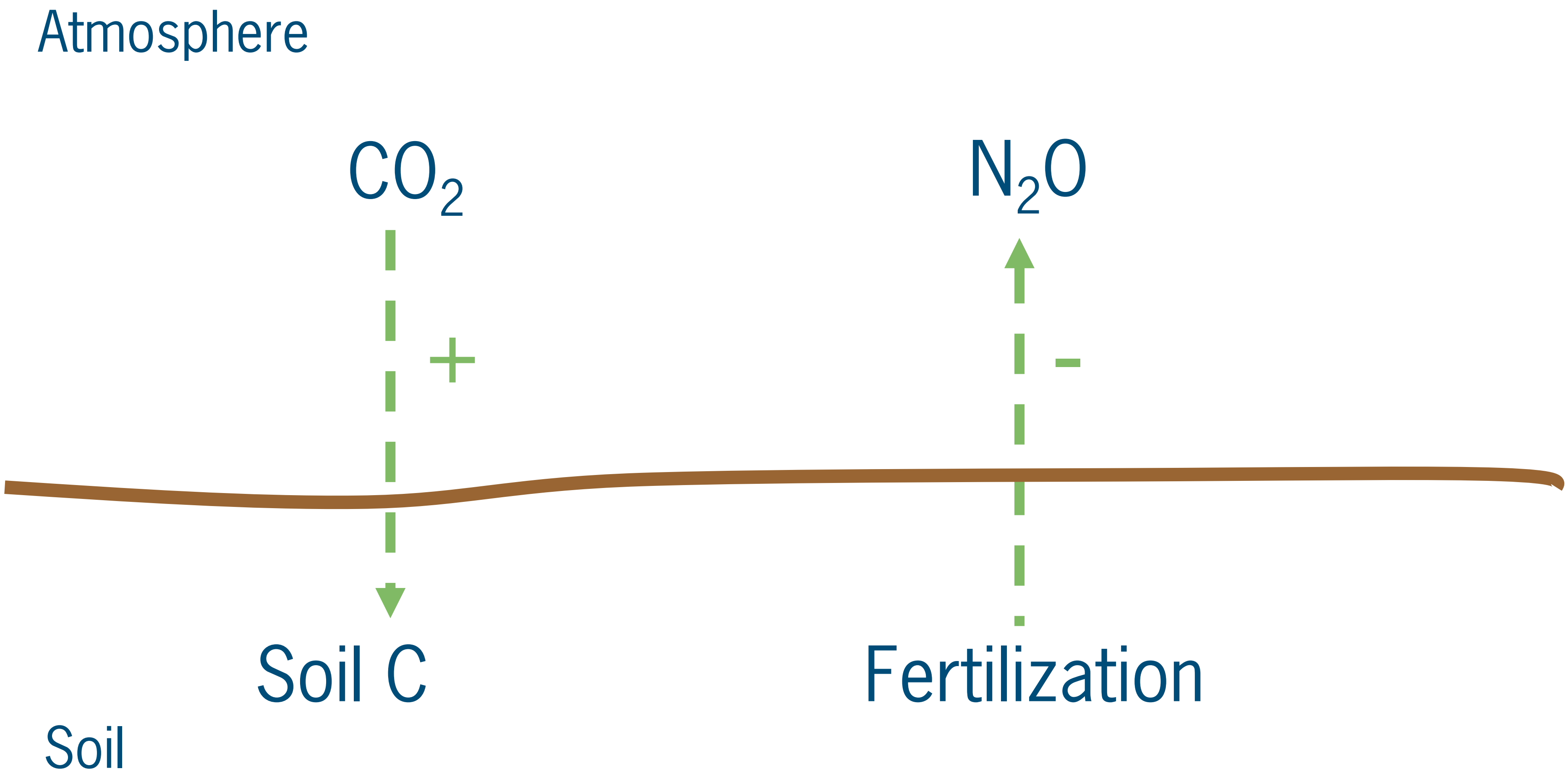


$1\ \text{Pg} = 1{\cdot}10^{15}\ \text{g}$

ALTERRA
WAGENINGEN UR

[IPCC, 2005]

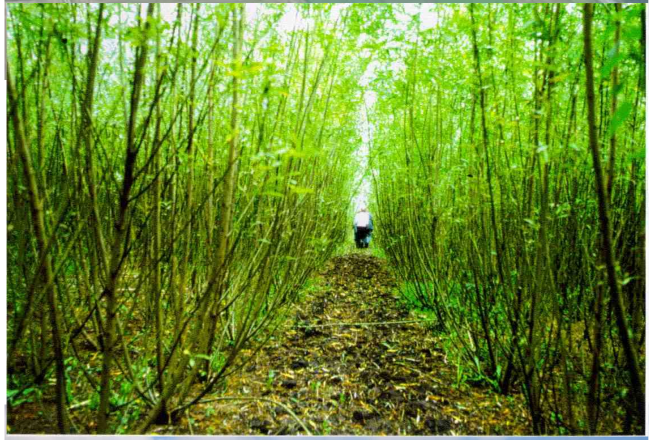
Mitigation CO_2 through soil management



Combined food, fodder and energy system: future ecosystem service?

- Biomass hedges and crops
- Crop rotation
- Organic management
- Energy neutral

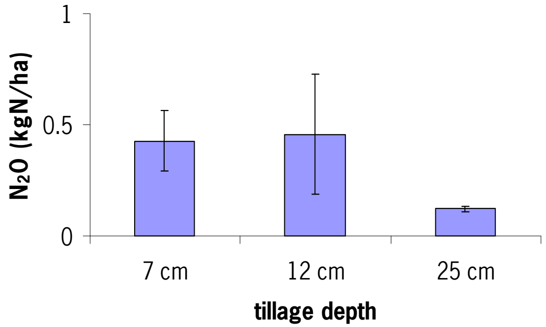
	Arable crops	SRC plot	Set-aside
Inputs on farm	5.7	2.6	0.7
Inputs, external	4.1	1.5	0.6
Outputs		116.9	
Net	9.9	*-112.8*	1.4



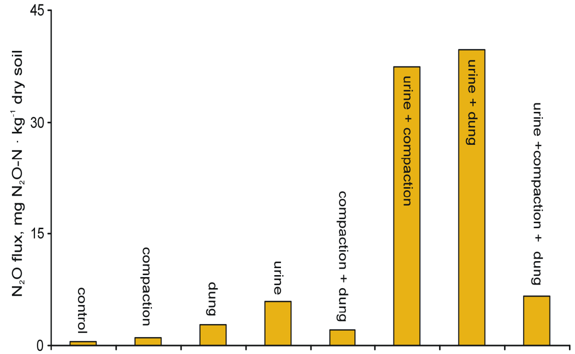
Kuemmel & Porter, 1999

Effects of soil management of N_2O emissions

Effects of plough regimes



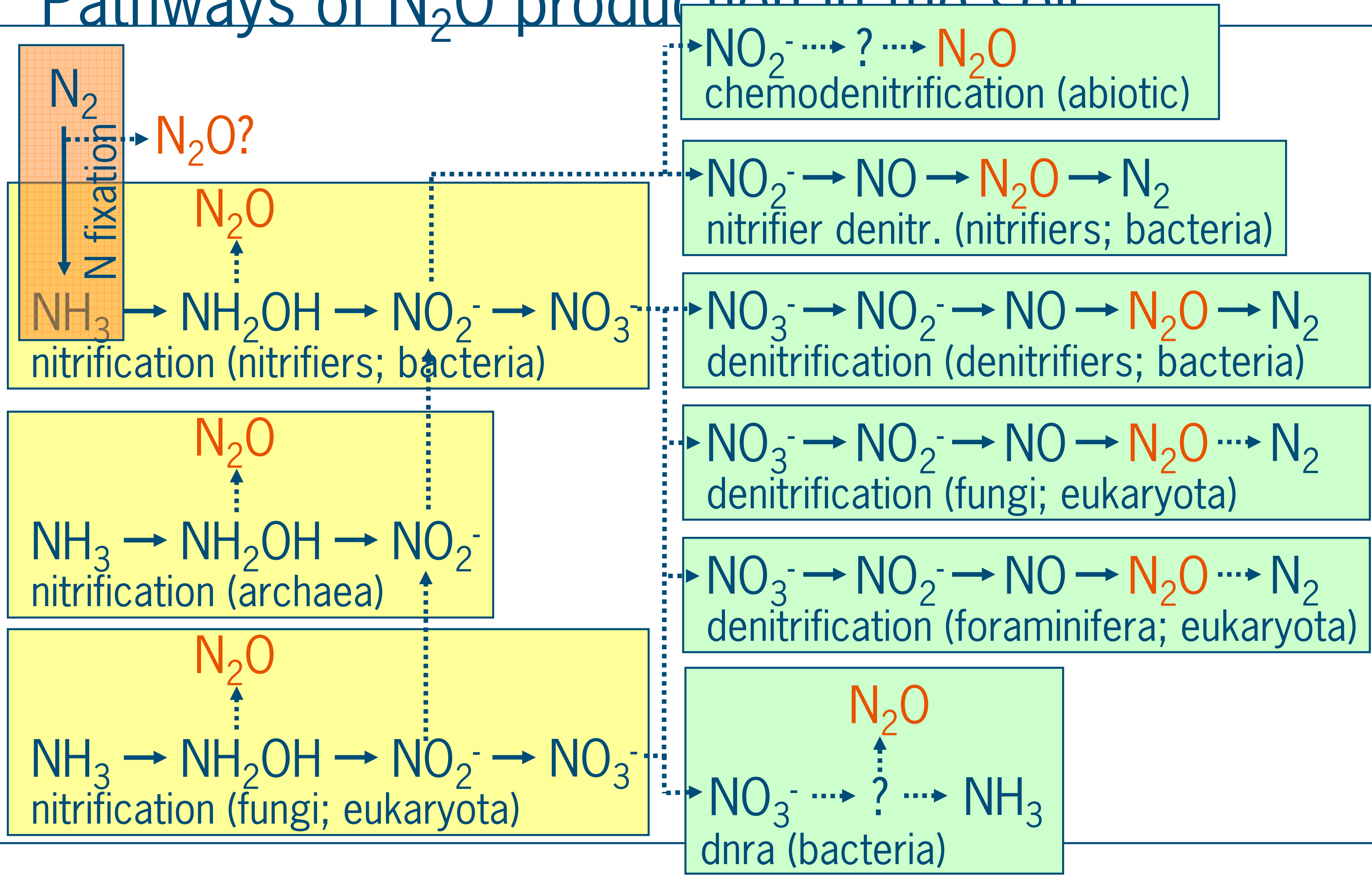
Effects of dung, urine and compaction



Oenema, de Vries, Kuikman

ALTERRA
WAGENINGEN UR

Pathways of N_2O production in the soil



The case for urine composition

- Diet affects urine and dung composition
- Dung composition affects NH_3 and N_2O emission
- Urine composition affects NH_3 volatilization

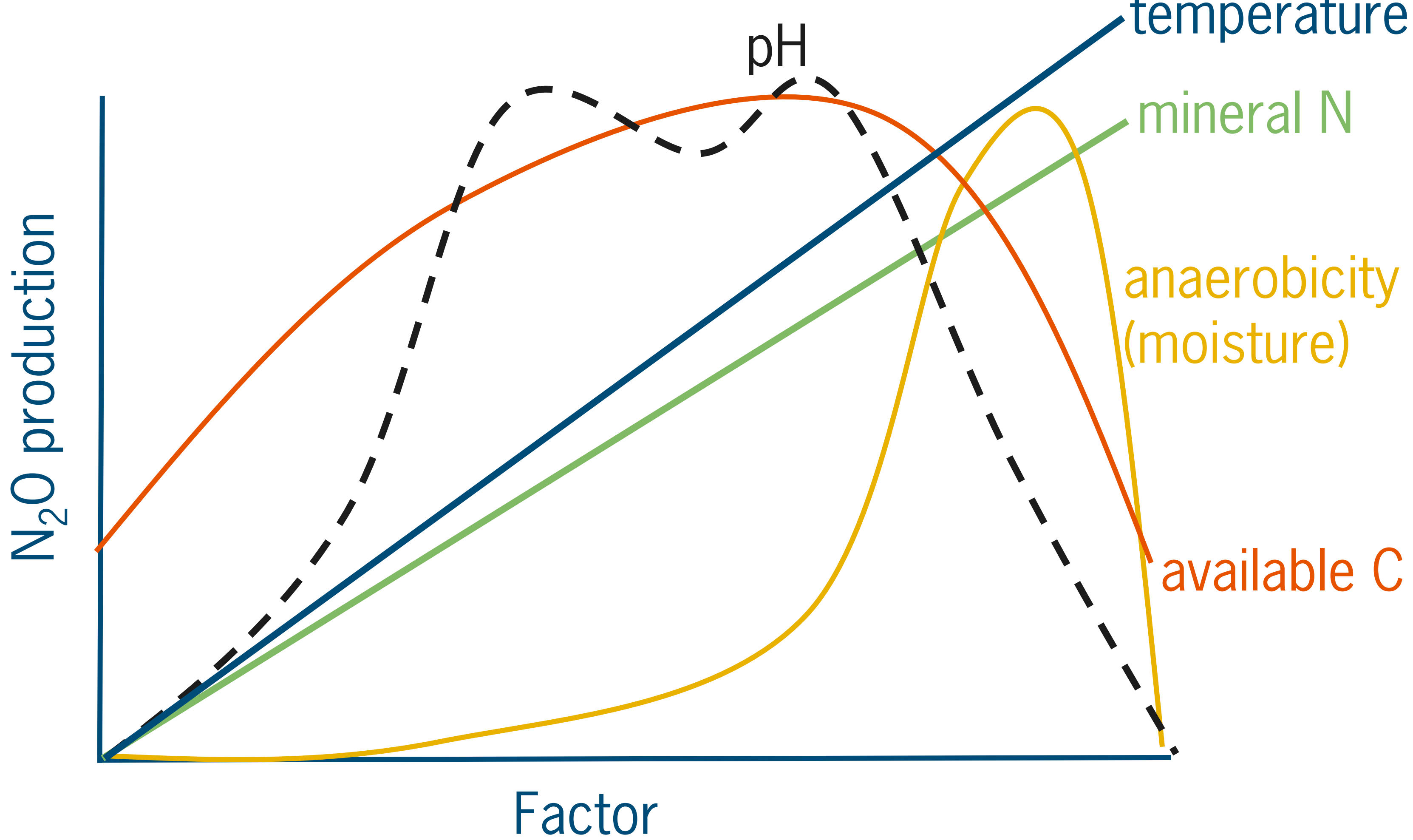
- Does urine composition affect N_2O emissions?
- Is mitigation possible by manipulating urine composition through rationing?

Controlling factors: urine patches

Effect of urine patches on soil-produced N_2O:

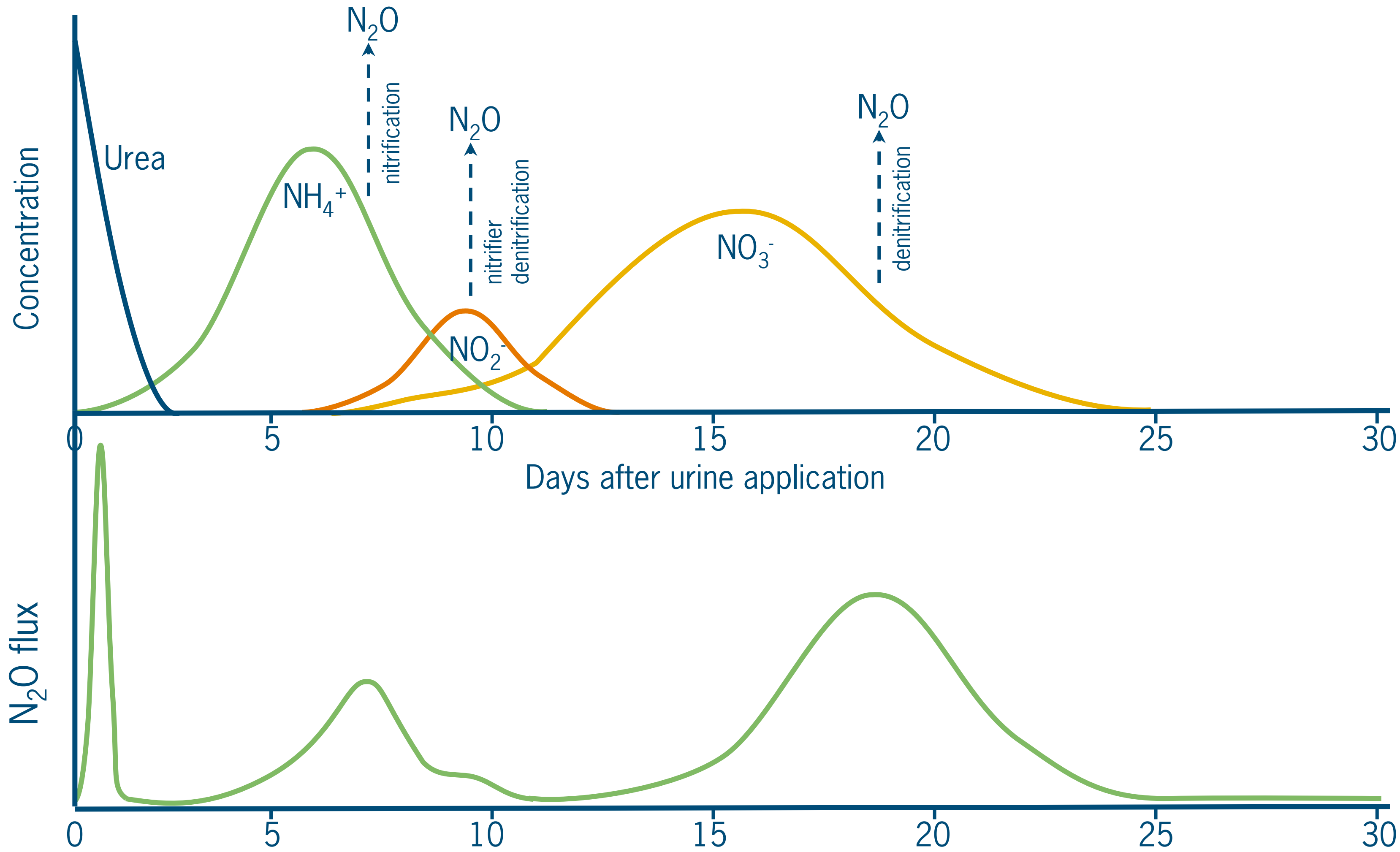
- up to 1000 kg available-N ha^{-1} ← mineral N
- up to 20 mm moisture ← anaerobicity
- up to 2 pH units increase (urea hydrolysis) ← pH
- C from urine and soil organic matter ← available C

Controlling factors for N_2O production



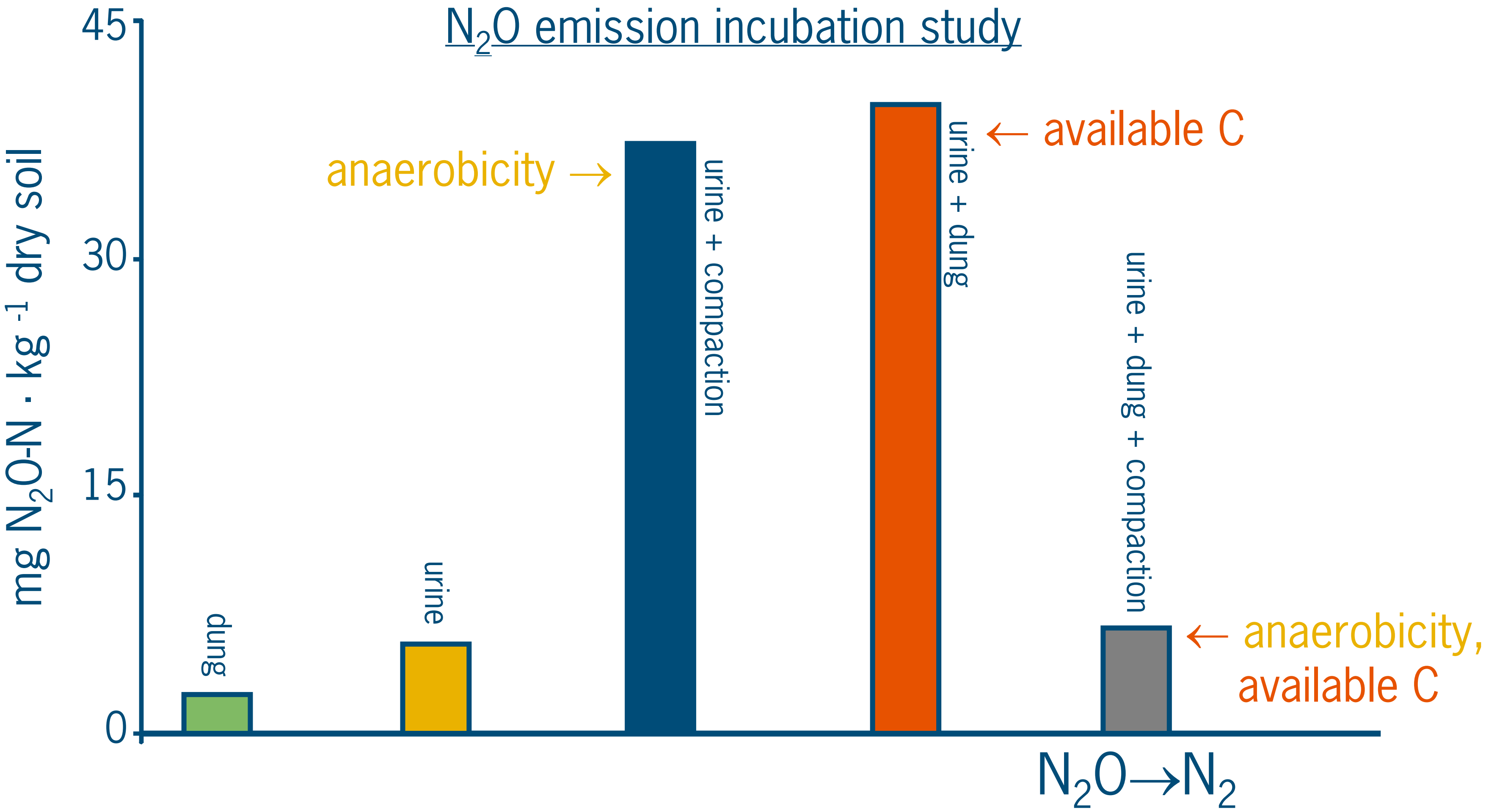
ALTERRA
WAGENINGEN UR

N_2O from urine patches in an 'ideal' world



ALTERRA
WAGENINGEN UR

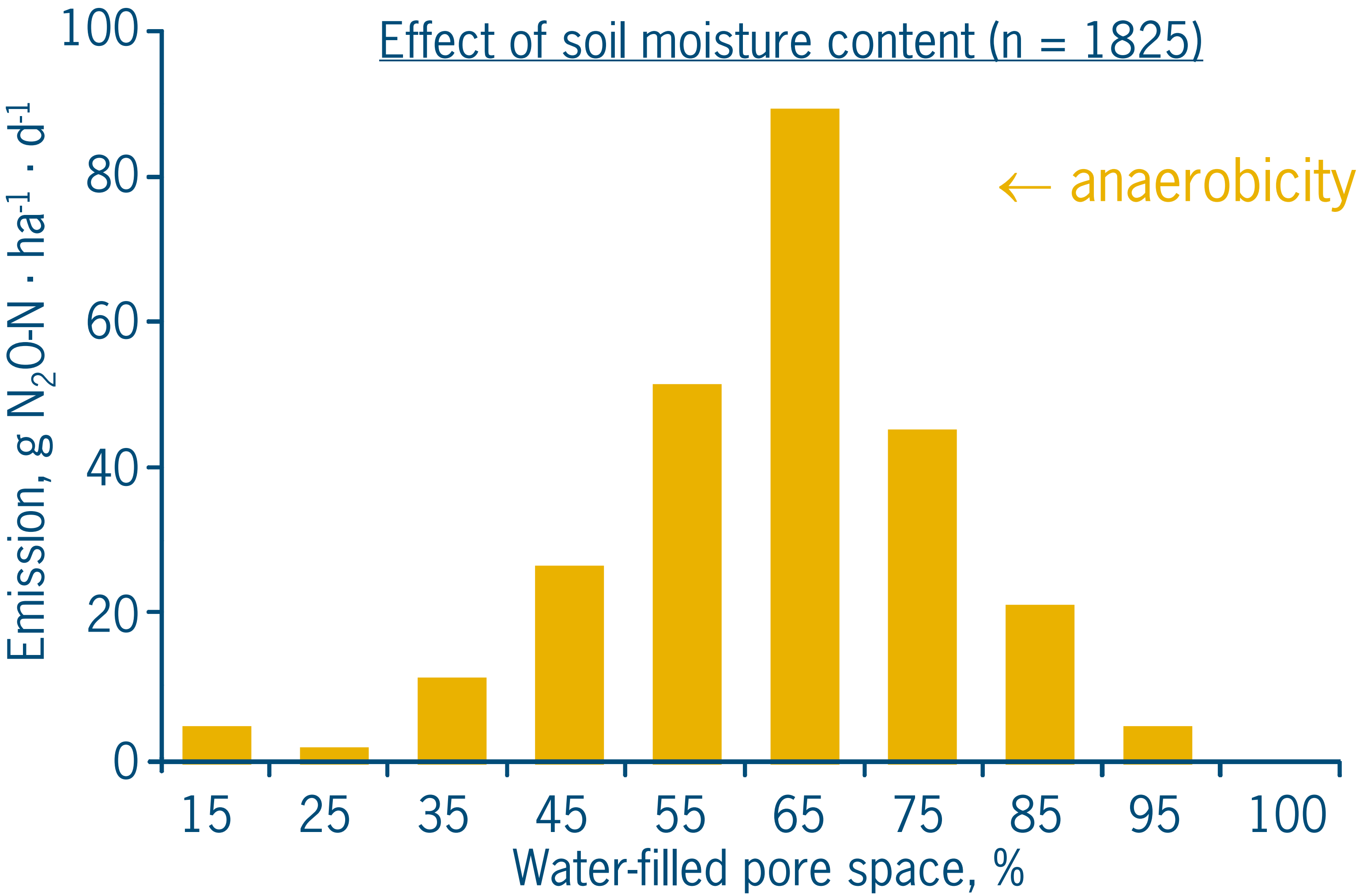
Controlling factors: urine patches



[Van Groenigen, Kuikman, De Groot & Velthof, 2005, Soil Biol. Biochem. 37, 463-473]

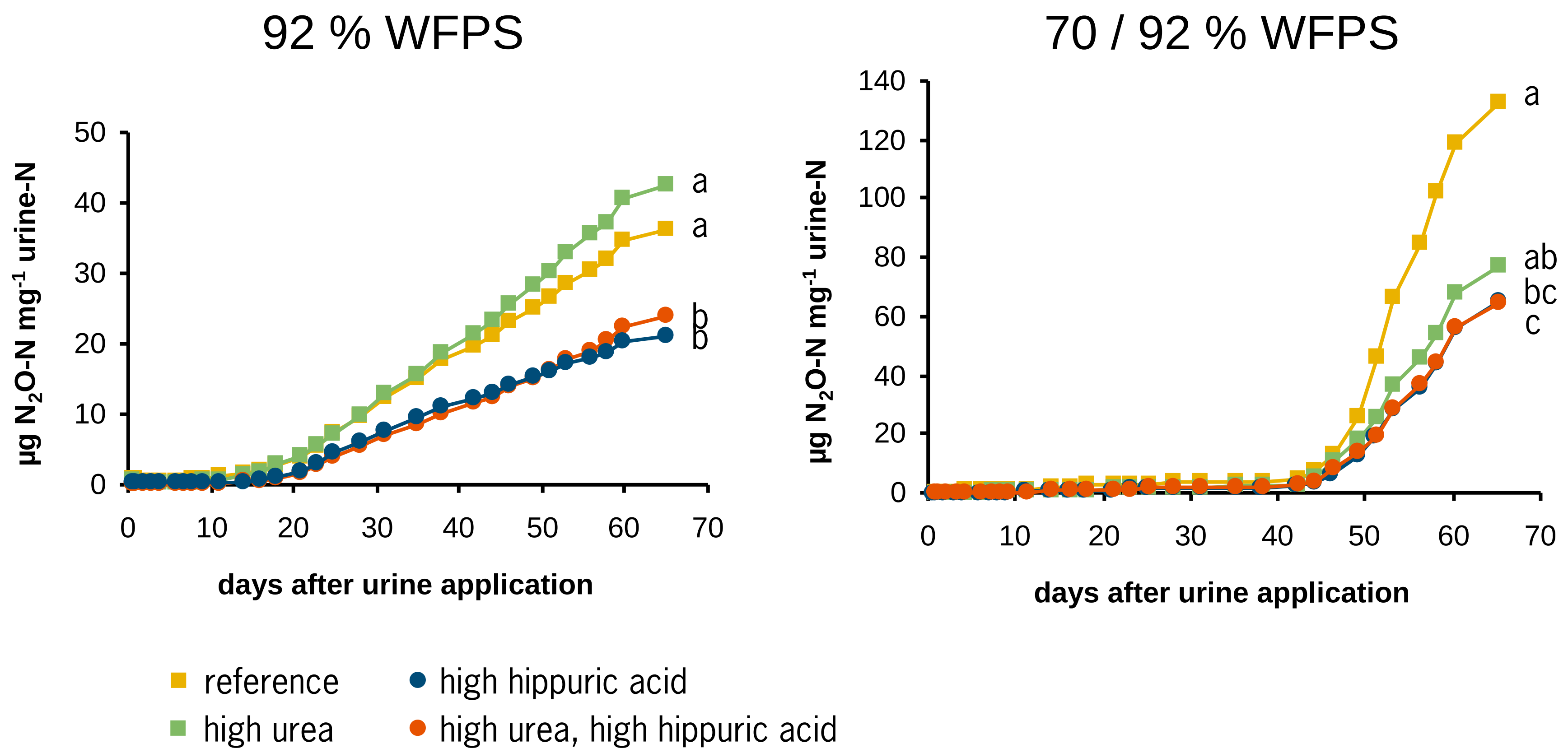
ALTERRA
WAGENINGEN UR

Controlling factors: urine patches



[Van Groenigen et al., 2005, Plant & Soil 273, 15-27]

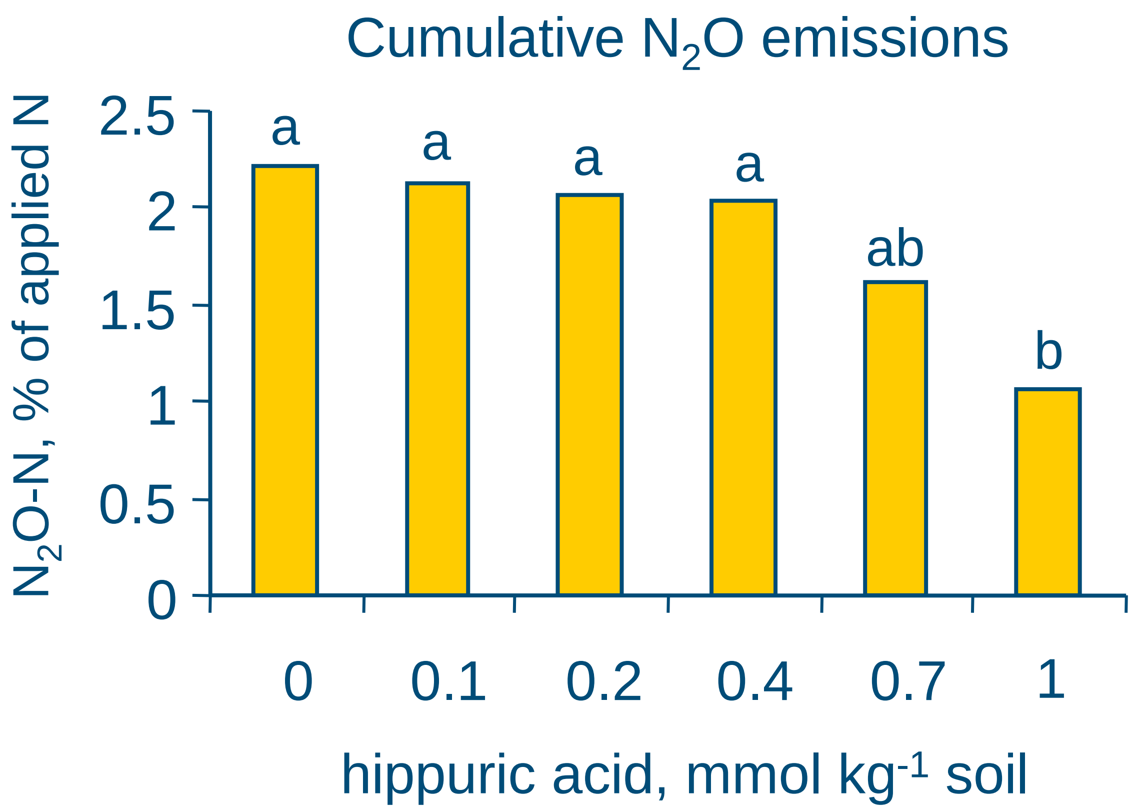
Urine composition - results



[Kool et al., 2006, Soil Biol. Biochem. 38, 1021-1027]

ALTERRA
WAGENINGEN UR

Urine composition - results



[Van Groenigen et al., 2006]

ALTERRA
WAGENINGEN UR

Controlling N_2O – is it the soil or the urine?

Most promising options:

- Avoiding dung patches
- Avoiding compaction
- No grazing after August?

it's the soil

- Increasing hippuric acid
  - feasible?
  - other aromatic compounds?

and the urine....

Integrated approaches

- Integrated assessment
  - At policy, measure as well as process level
  - Likely more effective if regionally explicit to account for range of agricultural systems and traditions
  - Can we produce net energy and operate for climate neutral agricultural and livestock production?

Integrated assessment tool MITERRA-EUROPE

Based on:

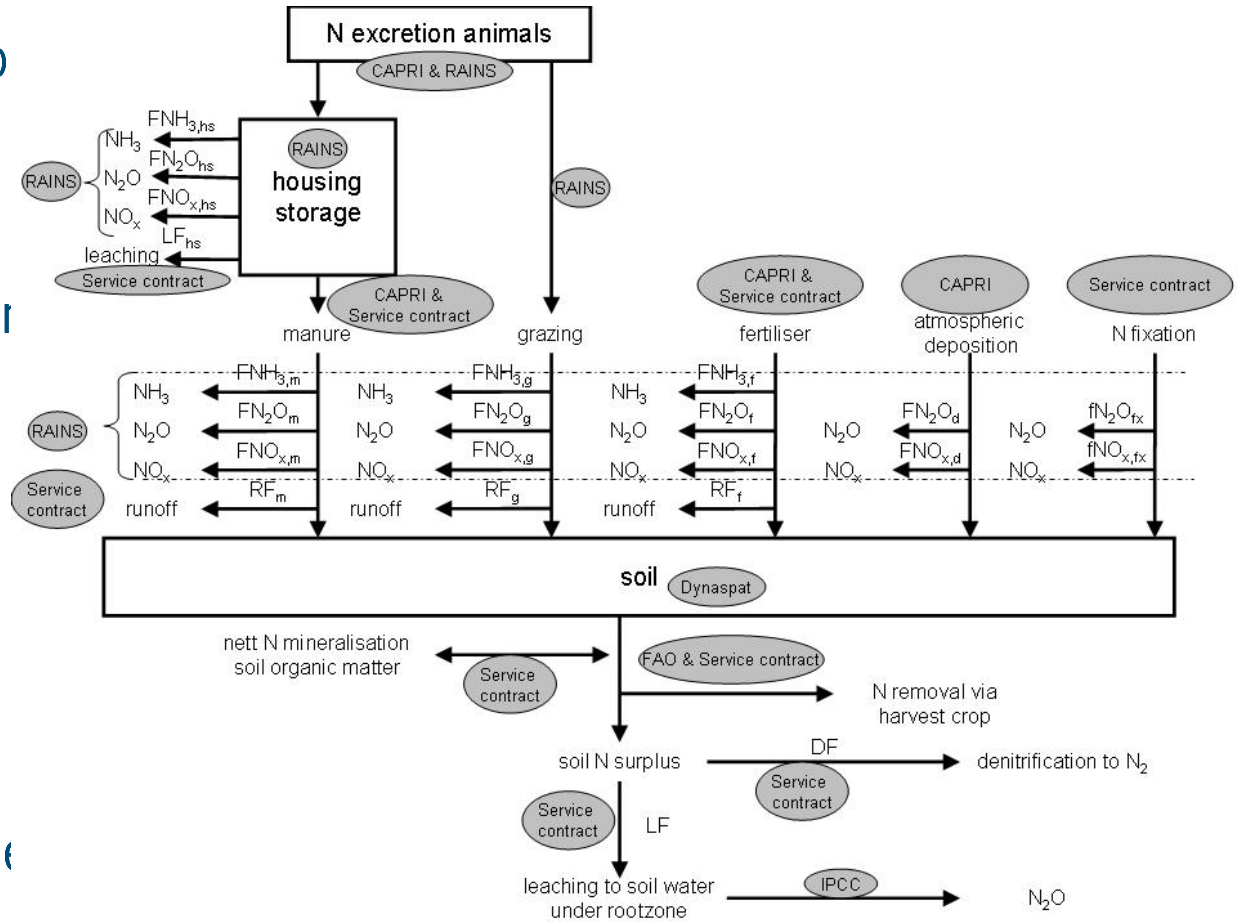
- RAINS: gaseous emissio abatement techniques
- CAPRI: activity data
- Databases: activity data
- Newly developed: leachi and soil carbon

Three scales:

- EU-27
- Member states
- Regional (NUTS-2)

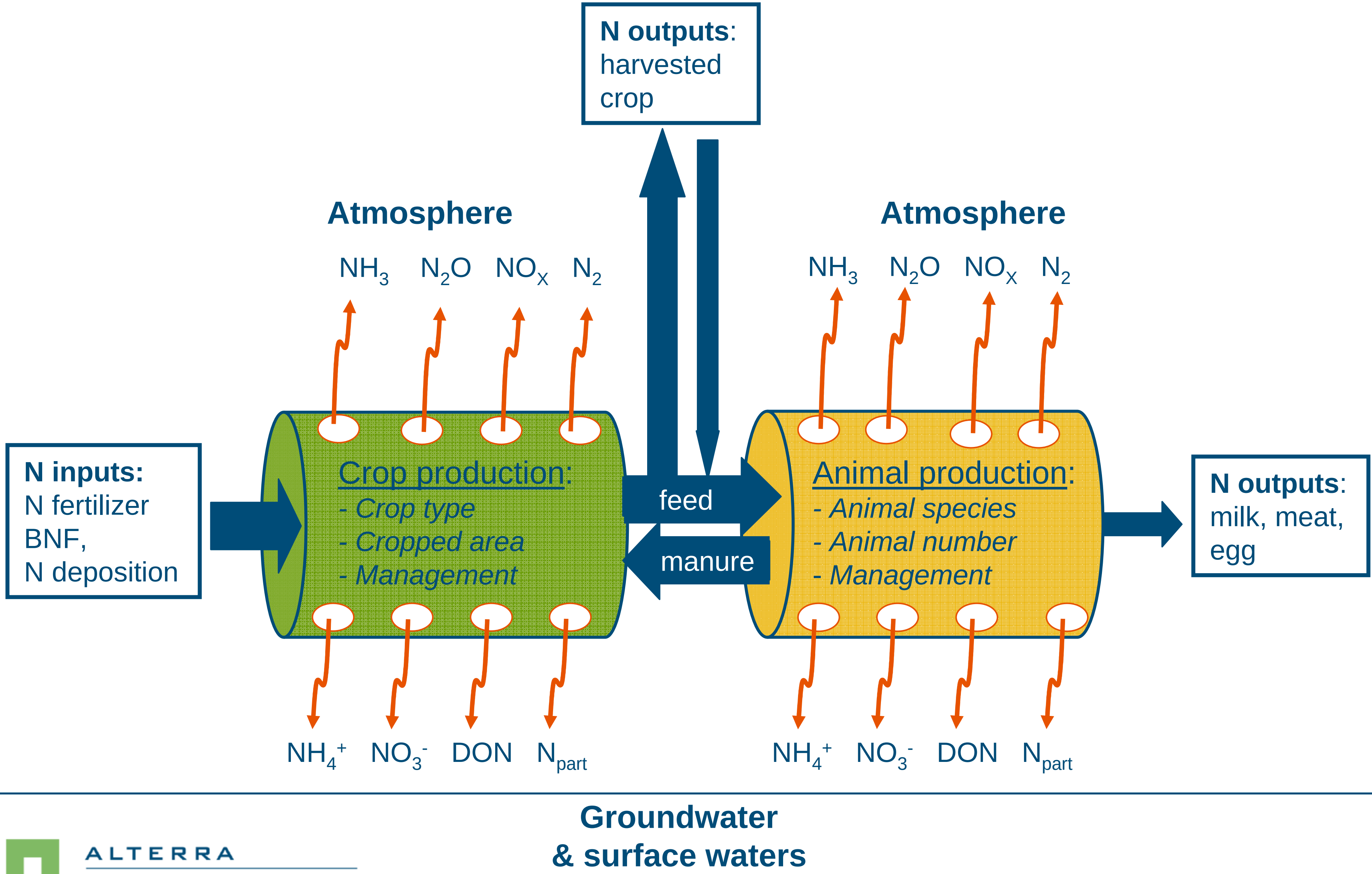
Emissions:

- NH_3, N_2O, CH_4 ,NO_3 leaching, N and P balanc and change in SOC



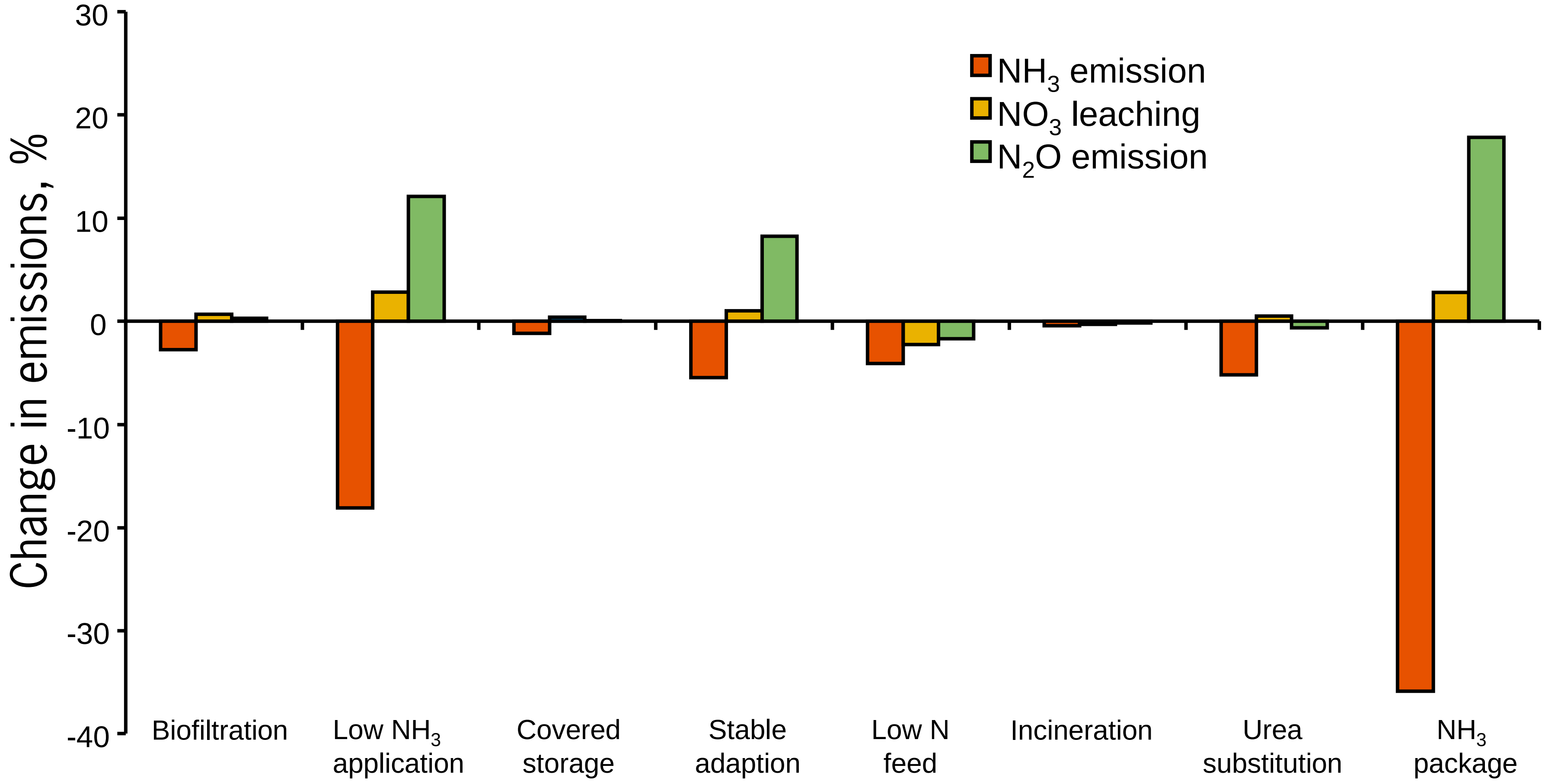
Velthof et al., 2008

Risk at pollution swapping?



ALTERRA
WAGENINGEN UR

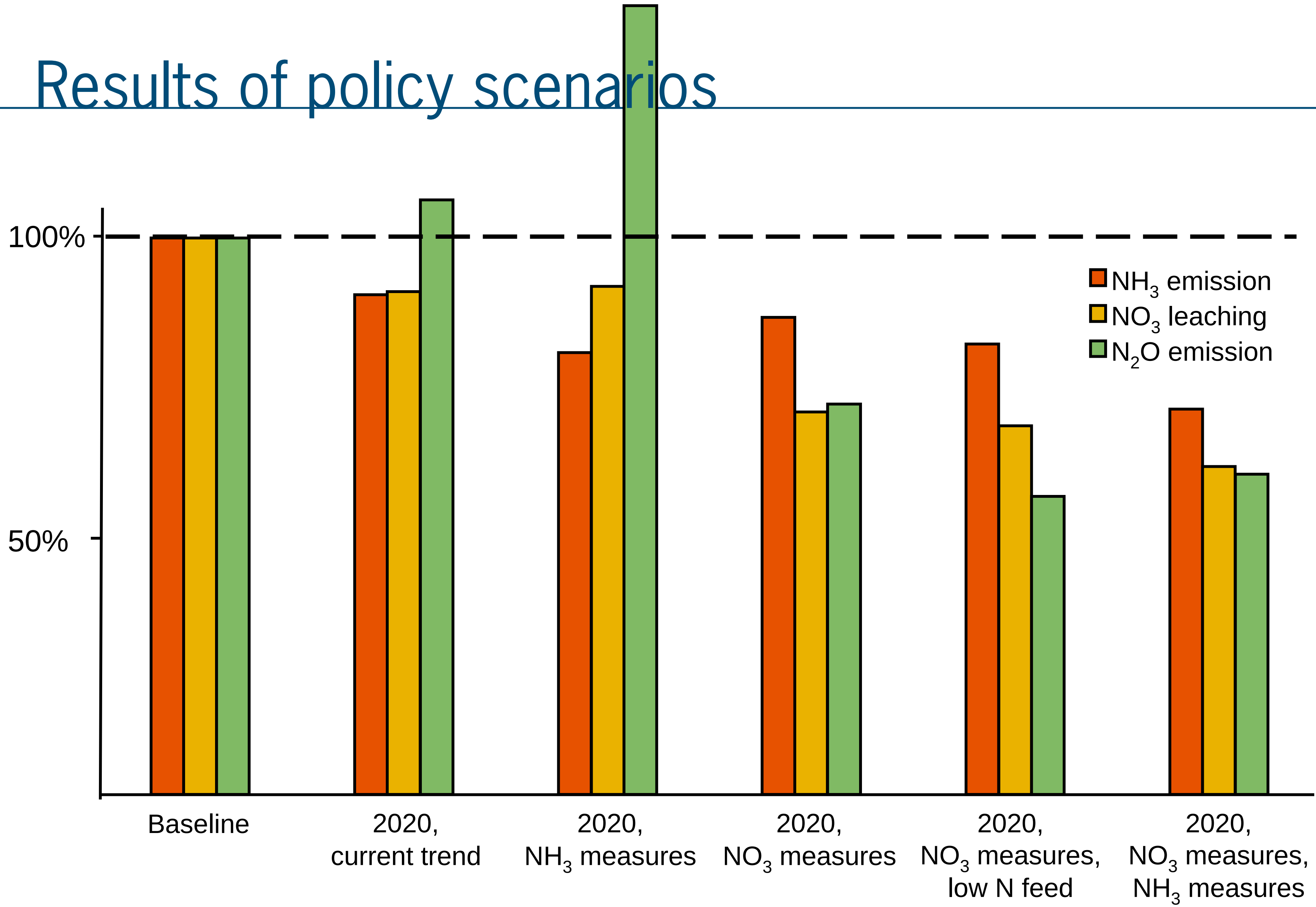
Effects of ammonia mitigation measures



Scenarios in MITERRA-EUROPE

1. Baseline, 2000
2. Mitigation measures - current trend, 2020
3. Ammonia mitigation - full implementation, 2020
4. Nitrate leaching mitigation - full implementation, 2020
5. Ammonia + nitrate mitigation - full implementation, 2020

Results of policy scenarios

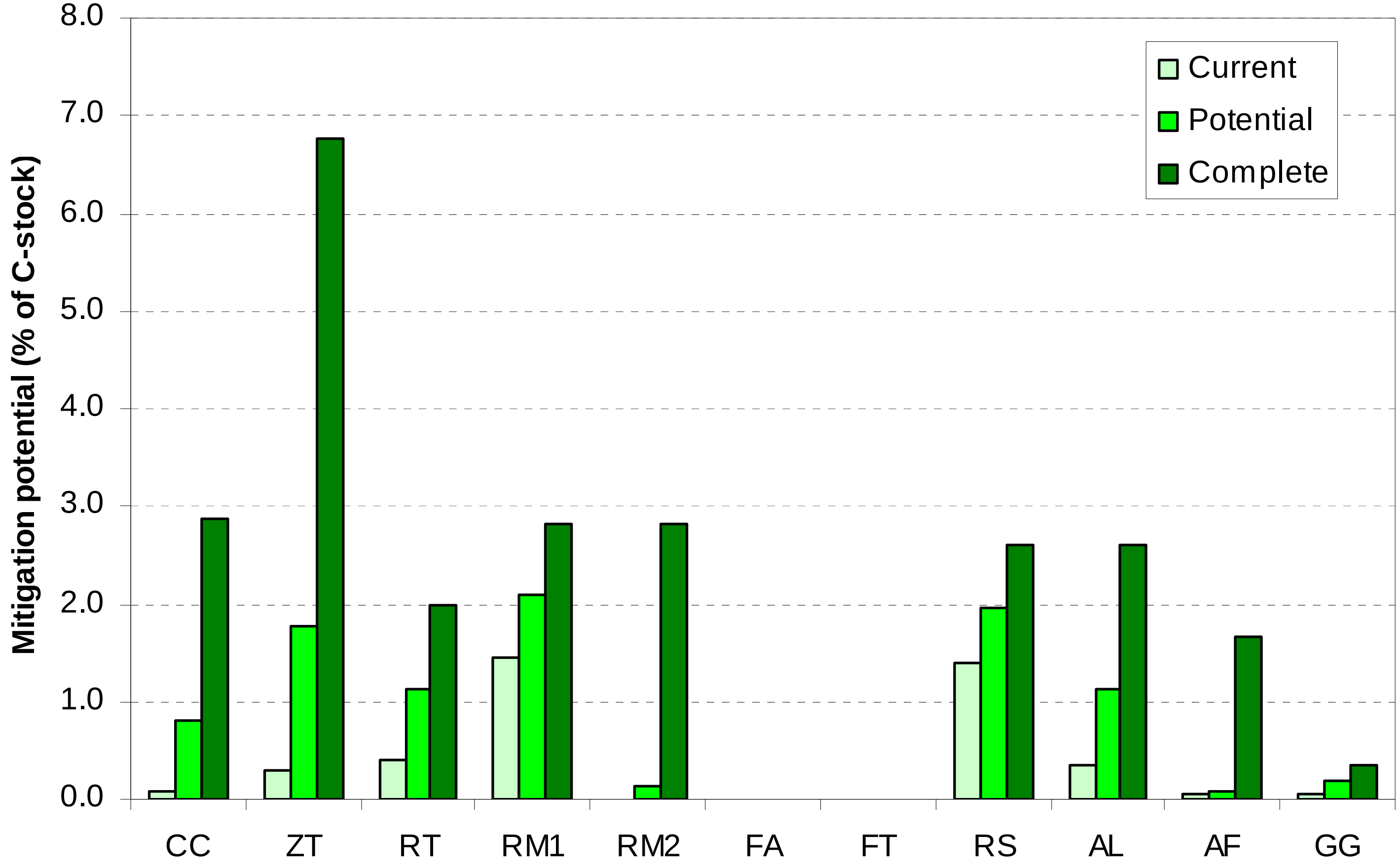


[MITERRA-EUROPE]

Selected mitigation measures in EU-PICCMAT

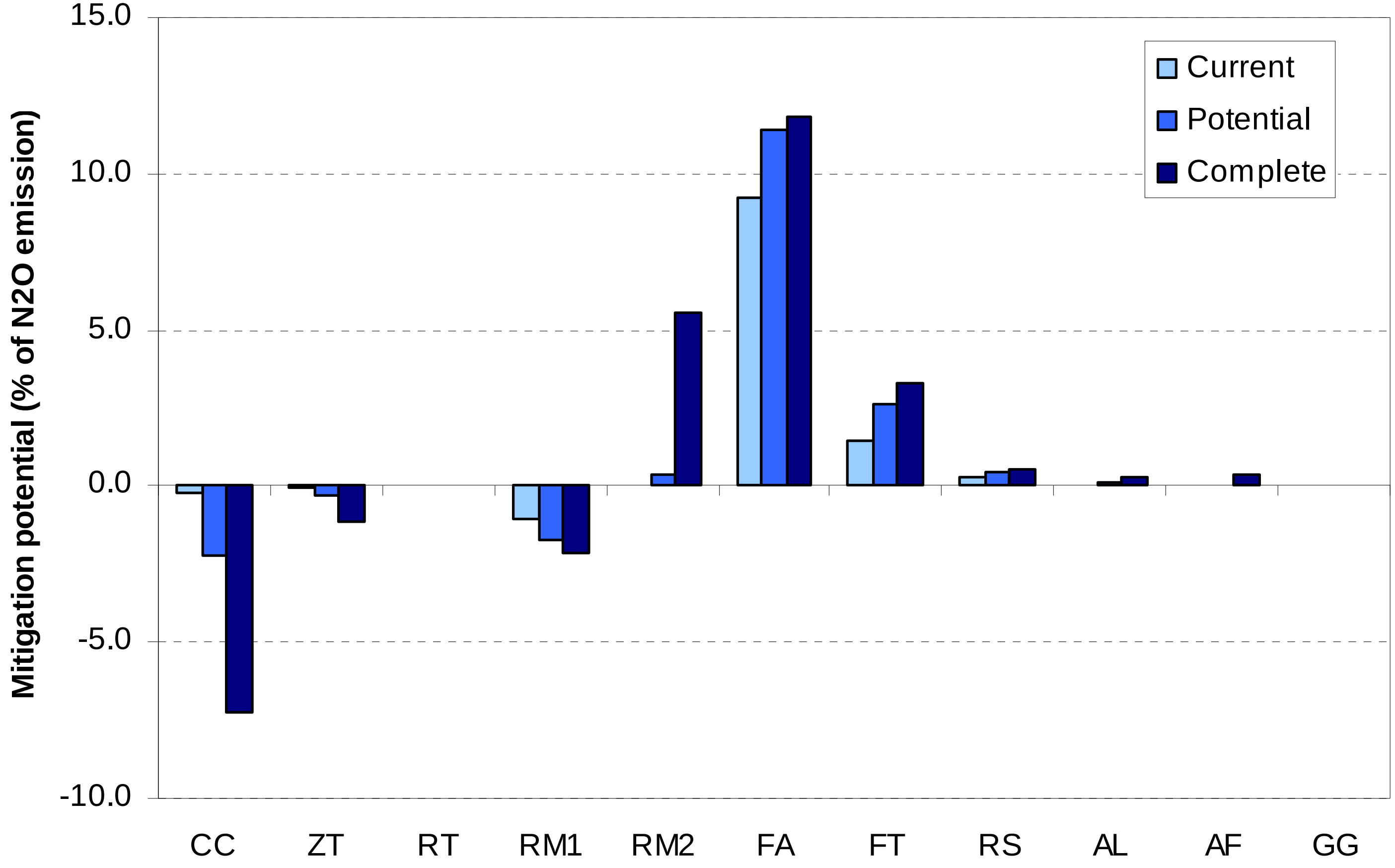
- Catch crops
- Zero tillage
- Reduced tillage
- Residue management
- Optimising fertilizer application
- Fertilizer type
- Rotation species
- Adding legumes
- Agroforestry
- Grass in orchards and vineyards

Mitigation potential for Carbon

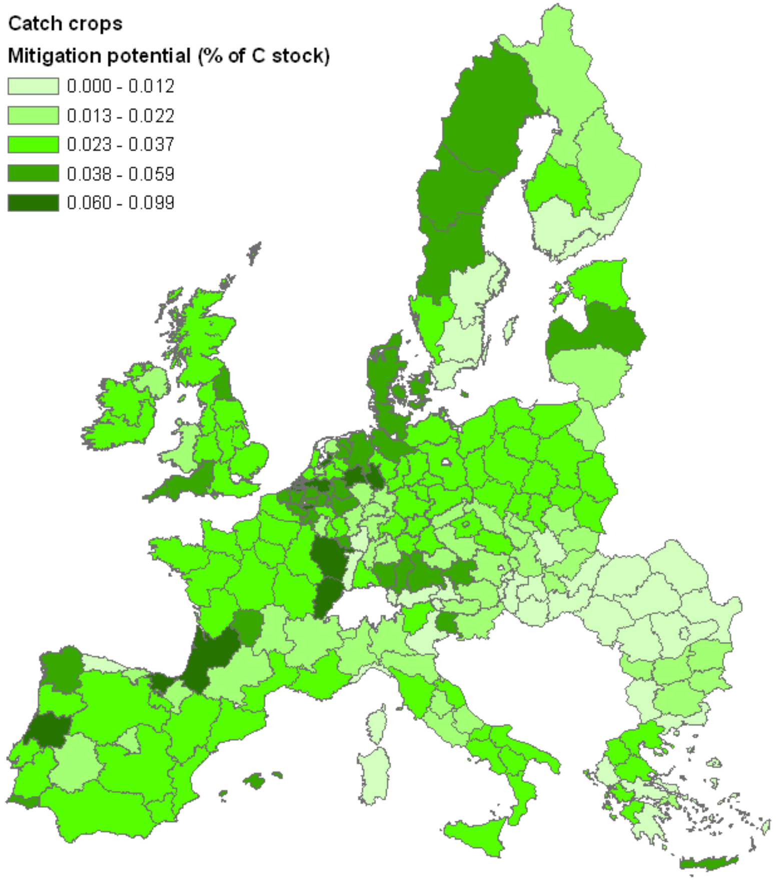


ALTERRA
WAGENINGEN UR

Mitigation potential for Nitrogen (N_2O)

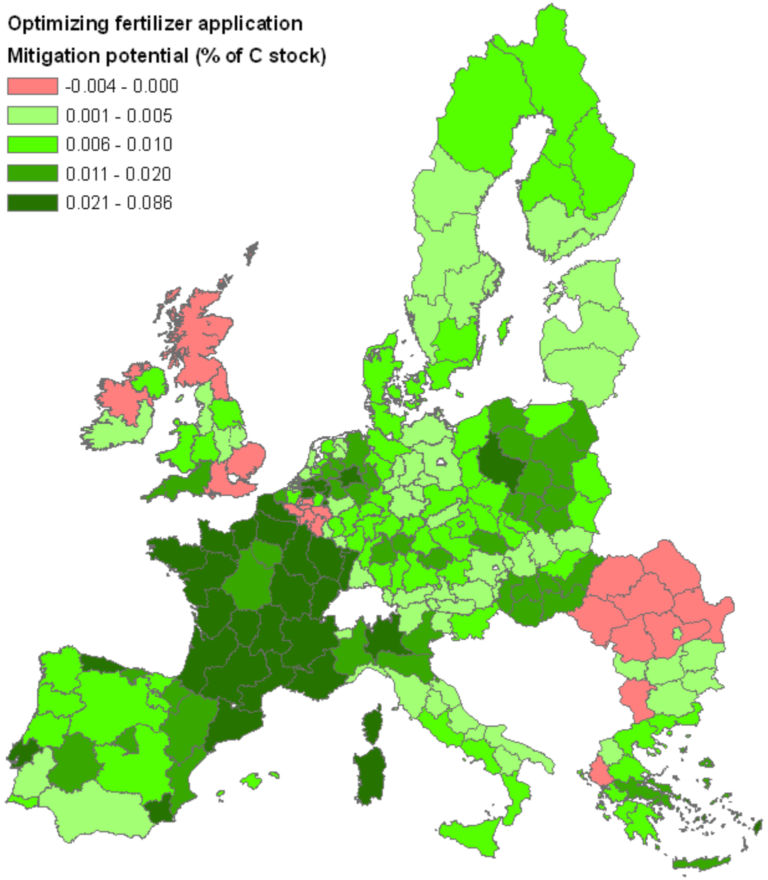


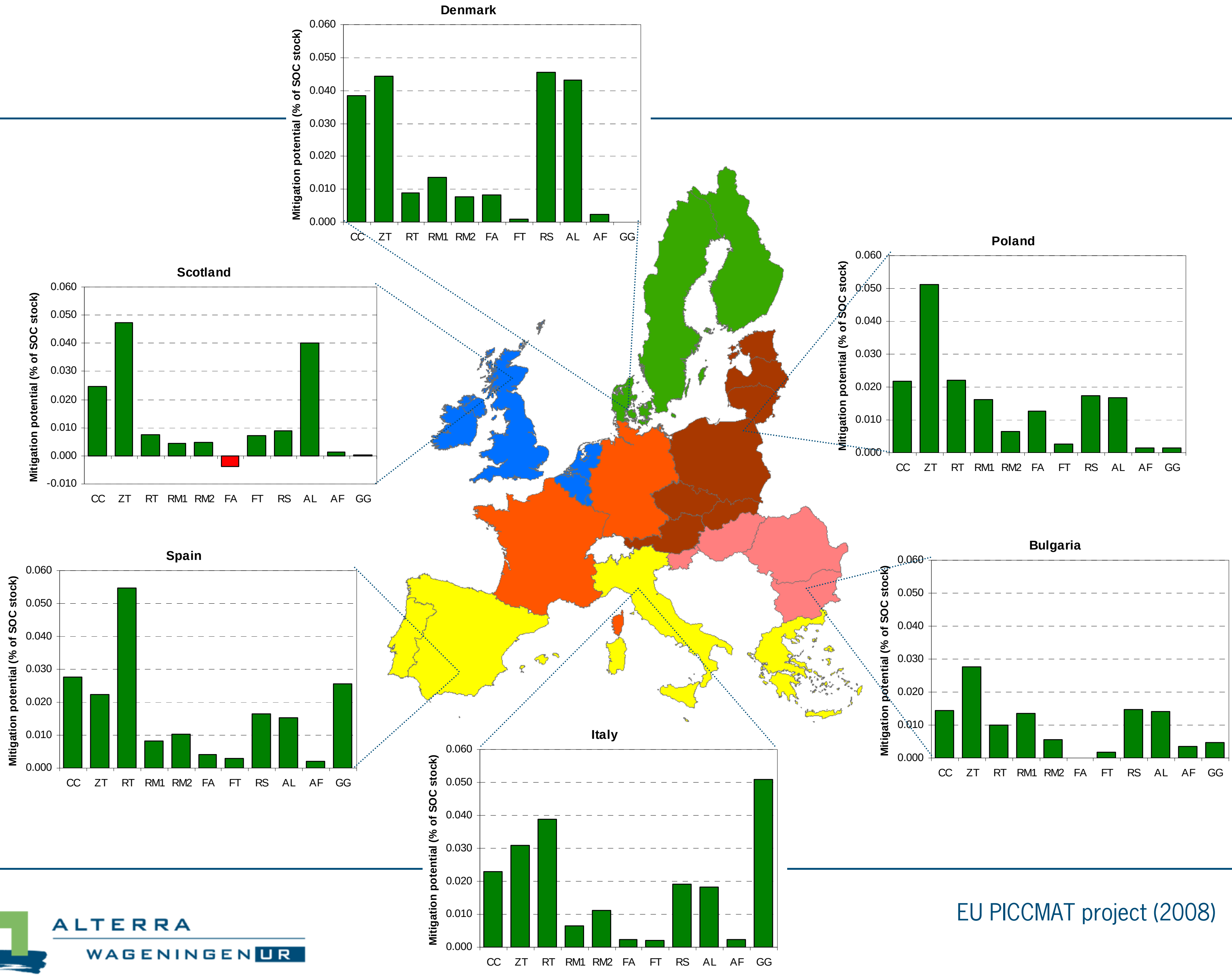
Cover crops (Miterra Europe)



ALTERRA
WAGENINGEN UR

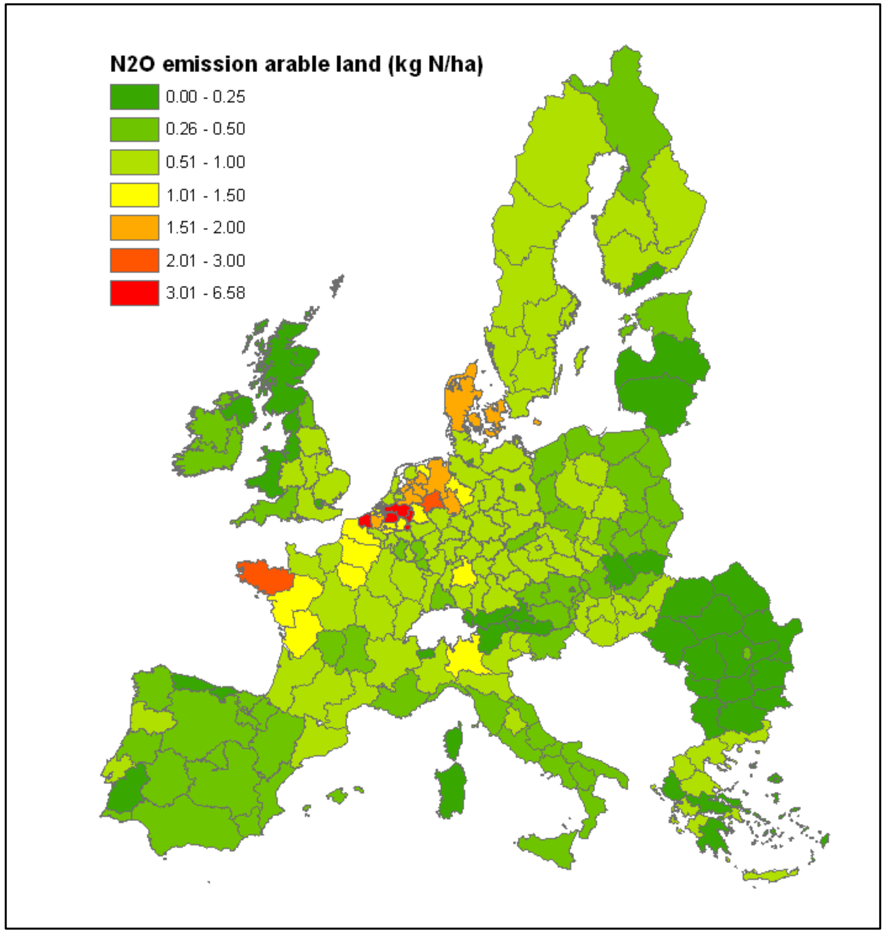
Optimizing fertilizer application (Miterra Europe)

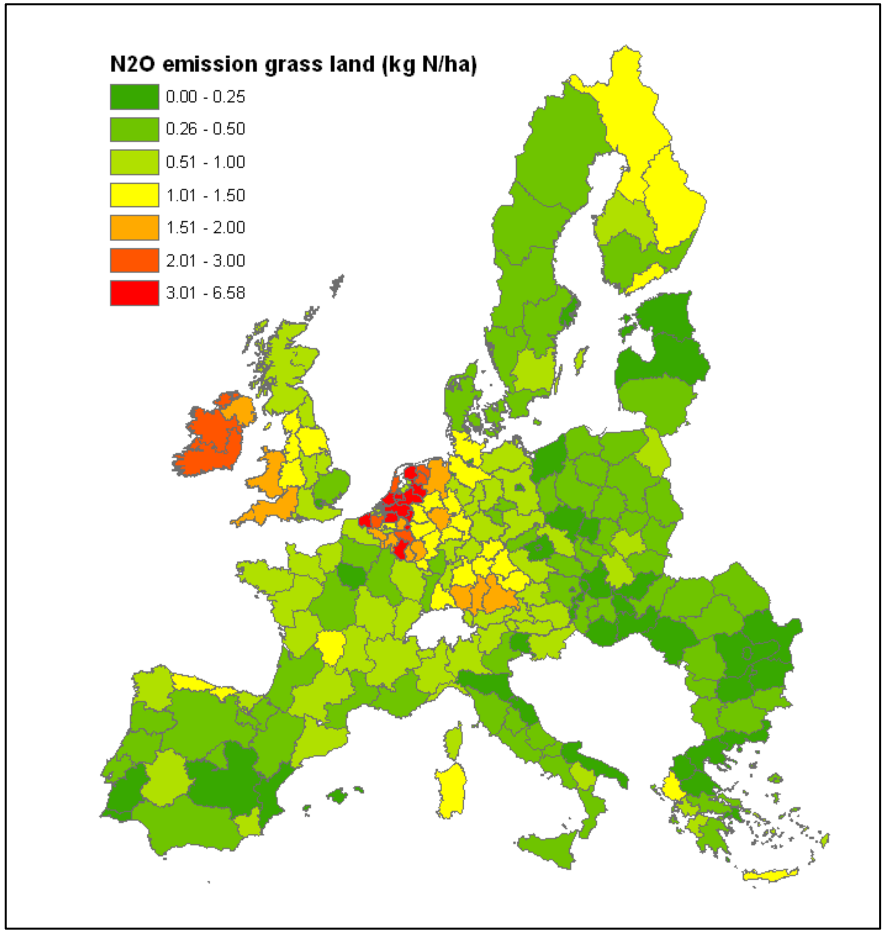




EU PICCMAT project (2008)

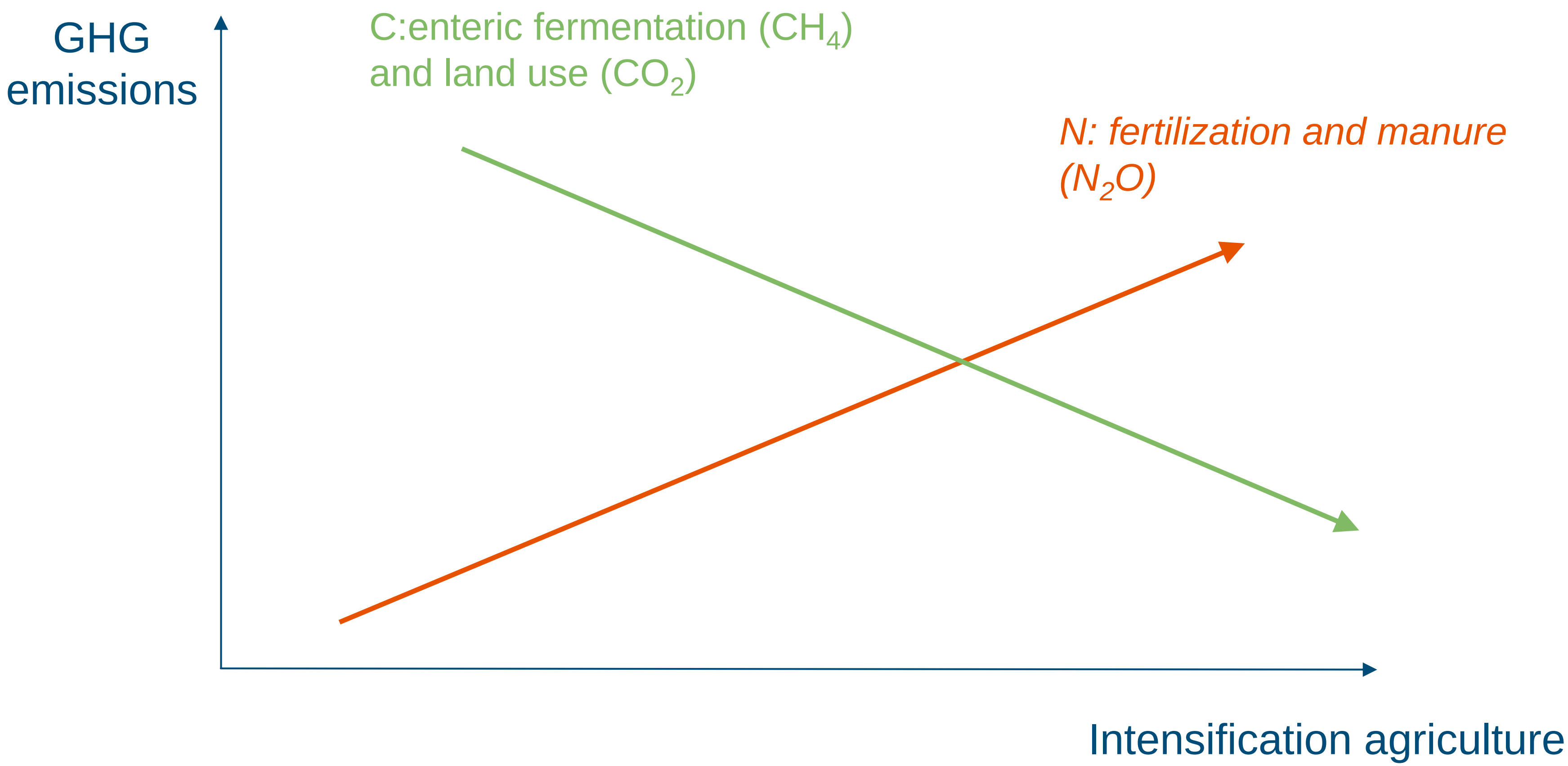
N_2O emissions from arable and grass land





ALTERRA
WAGENINGEN UR

Hypothesis: optimization for C and N emissions required to avoid trade off and greenhouse gas swapping

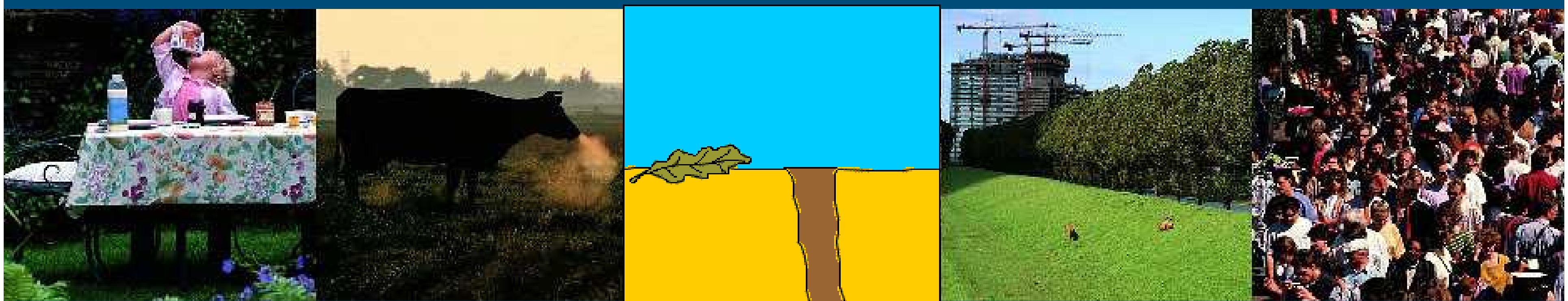


Conclusions

- Reducing GHG emissions is only one of many environmental constraints of farming (in the EU)
- Assessment is complex and effects not been tested in fields and await experimental work
- Measures that reduce N surpluses offer by far the best potential for reaching all environmental aims and prevent pollutions swapping
- Ultimately, all measures need to be feasible at the farm scale
- Awareness among farmers communities
- Agri complex may well be net energy producer
- Zero emission or ‘climate neutral’ agriculture is utopia

Thank you!

And colleagues: Jan Willem van Groenigen, Oene Oenema, Gerard Velthof, Jan Peter Lesschen, Rene Schils, John Porter and the PICCMAT team



ALTERRA
WAGENINGEN UR