Impacts of management measures on N_2O emissions from agricultural soils in Europe using different model approaches

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Presentation Outline

- Introduction: previous work
- Methods used for deriving N_2O emissions (IPCC)
  - Inference scheme
  - Statistical model
  - Fuzzy set model
- Mitigation measures
- Results: comparison of four methods
  - Current situation: year 2000
  - Impacts of measures
- Conclusions

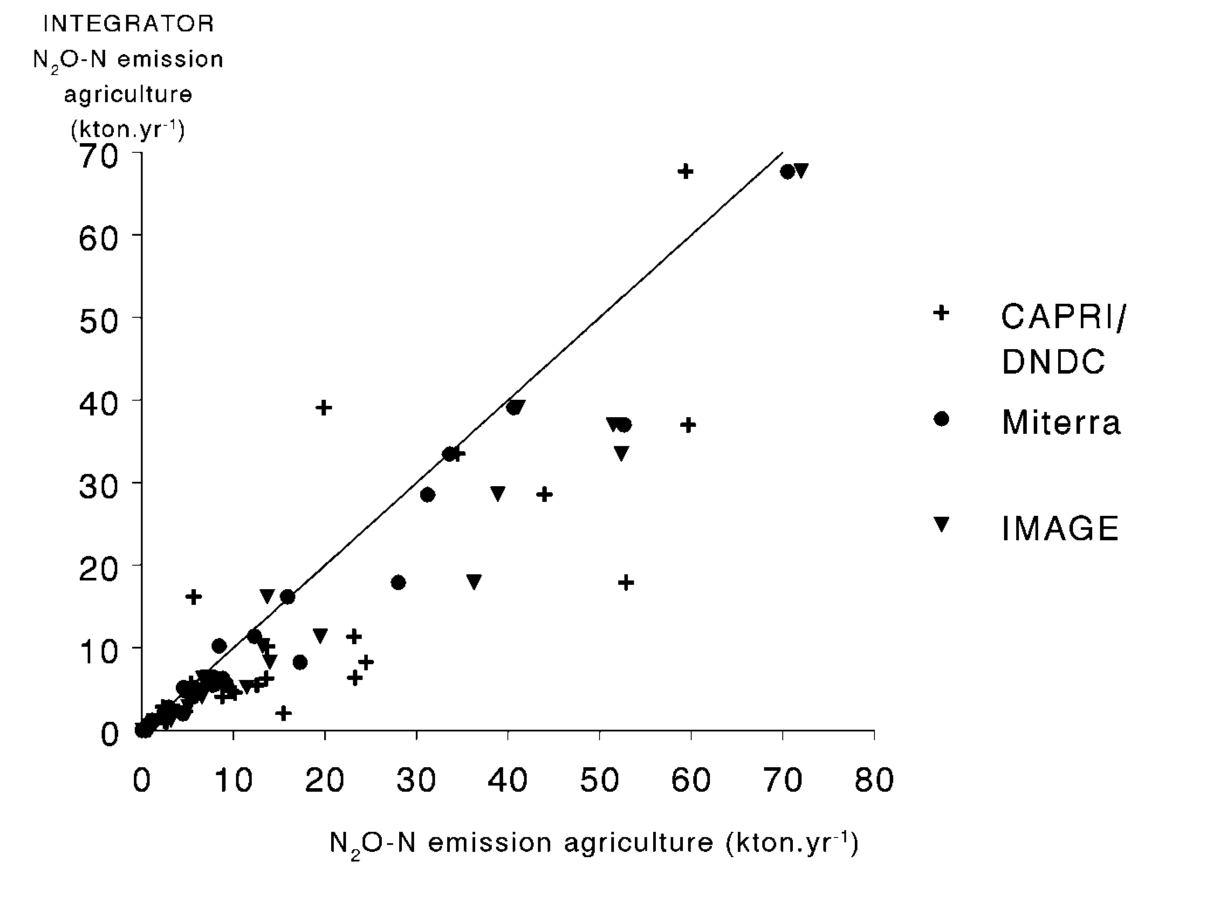
Introduction

- N_2O emissions are highly variable in space and time and large scale estimates vary relatively strongly.
- N_2O emissions from European agriculture have been derived with many model approaches using different schematizations/spatial resolutions and input data
- Examples are study De Vries et al (2011), presented at previous NCGG5 conference and study Leip et al (2011) presented at this NCGG6 conference.

N_2O emissions with different models/ schematizations

Model inputs	INTEGRATOR	CAPRI –DNDC	MITERRA	IMAGE
Resolution	NCU (ca. 40.000)	HSMU (ca. 180.000)	NUTS2 (ca. 300)	Country (27)
Animal livestock numbers	FAO database	EUROSTAT production statistics.	RAINS data (country) and CAPRI data (level)	FAO database
Nitrogen excretion factors	N excretion model scaled to GAINS data in 2000	Calculated as N input (feed, fodder) minus N output (products sold).	Country-specific N excretion rates for 8 animal categories based on GAINS model	Continental specific N excretion rates (2 in Europe) for 9 animal categories
N_2O emission factors	Inference scheme: Function of N source, application technique, soil type, pH, land use, precipitation	IPCC	IPCC	Statistical model: Function of crop type, fertilizer type, application technique. climate, soil pH, and CEC.

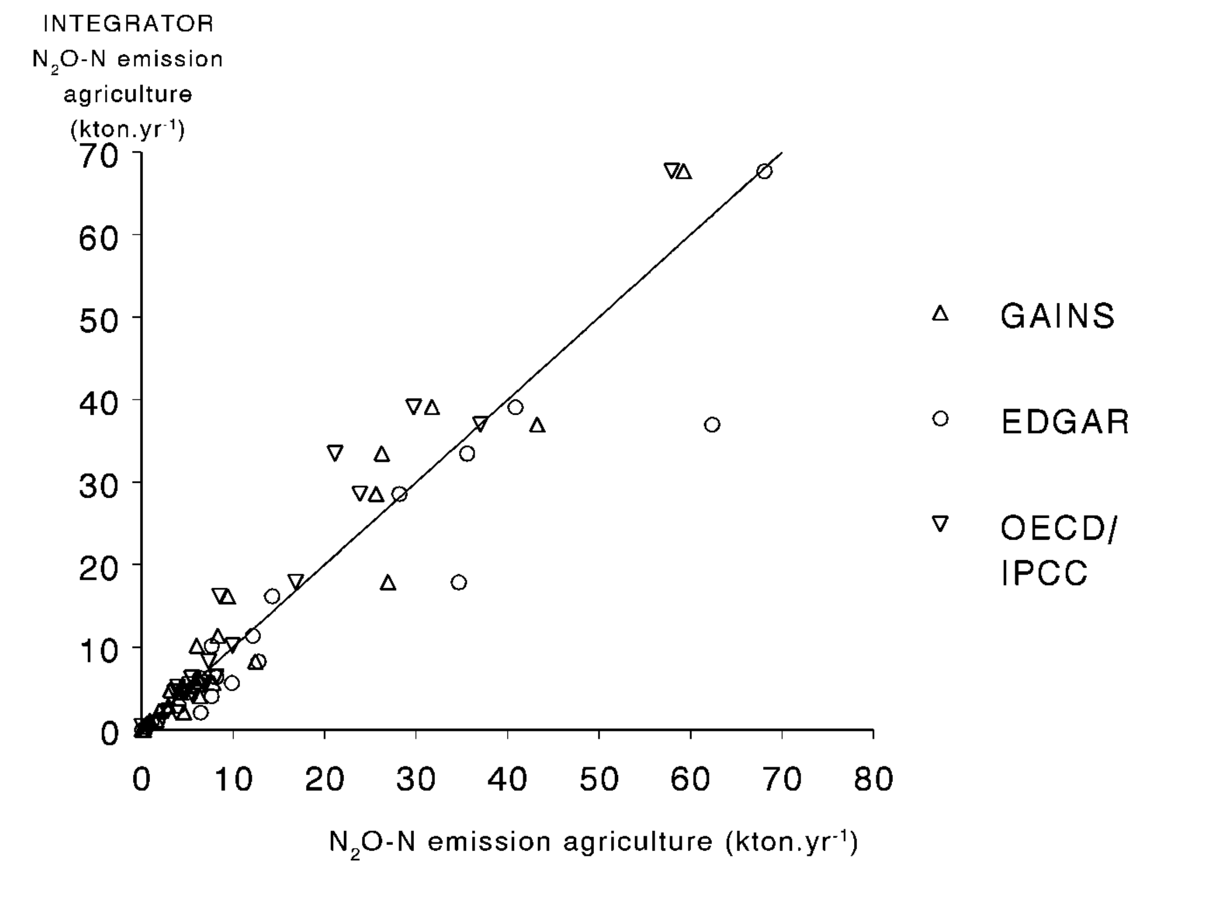
Comparison INTEGRATOR with other model approaches (CAPRI-DNDC, MITERRA and IMAGE)



Country emissions for N_2O derived with INTEGRATOR and other models for the year 2000 using different inputs and schematizations

De Vries et al. (2011)

Comparison N_2O emissions INTEGRATOR with emission factor approaches (GAINS, EDGAR and OECD/IPCC)



Country emissions for N_2O derived with INTEGRATOR compared with inventory methods for the year 2000 using different inputs and schematizations

De Vries et al. (2011)

Aim of this study

- European wide N_2O emissions from agriculture, using four different approaches in INTEGRATOR model with similar schematization/spatial resolutions and input data (ca. 40.000 NCUs)

- Estimate the plausibility: Comparison with country level estimates by inverse models

- Demonstrate the difference in effect of agricultural mitigation options

Four methods for large scale N_2O estimates

- Methods for deriving N_2O emission fractions:
  - Inference scheme: fractions that depend on environment, land use and management (default INTEGRATOR approach).
  - Statistical model: emissions related to environmental and management factors; fractions derived from it.
  - Fuzzy set method: fractions management data, vegetation- soil properties and seasonal variations of climatic drivers.
  - IPCC Tier 1 method: constant default emission fractions.

Inference scheme: INTEGRATOR approach

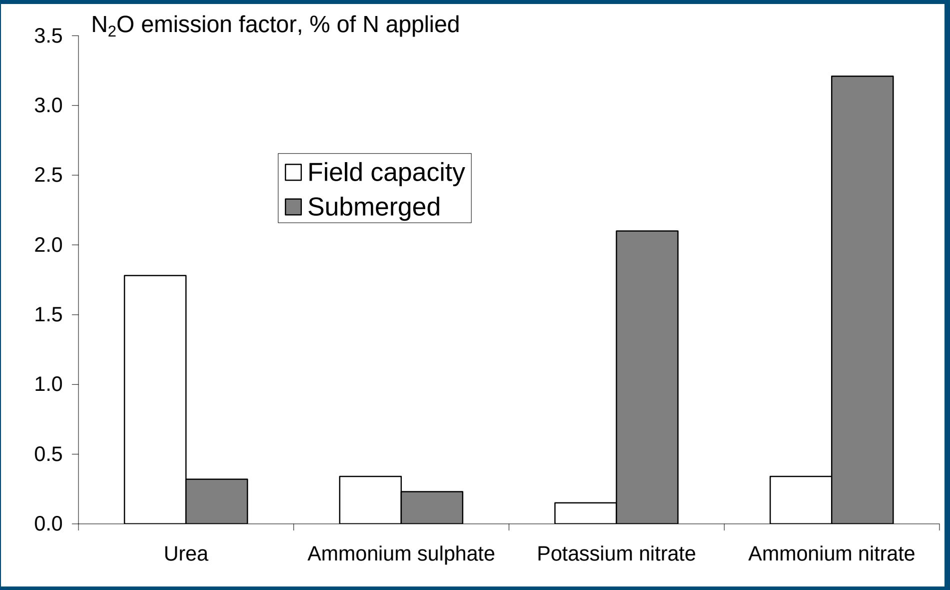
- Starting point is EF for fertilizer of 1% of applied N
- Two-year monitoring study in Netherlands (Velthof et al., 1996) with the following conditions:
  - Fertilized with calcium ammonium nitrate fertilizer
  - Grassland
  - Well-drained sandy soil
  - Neutral pH (> 5)
  - Average precipitation (600-900 mm/year)

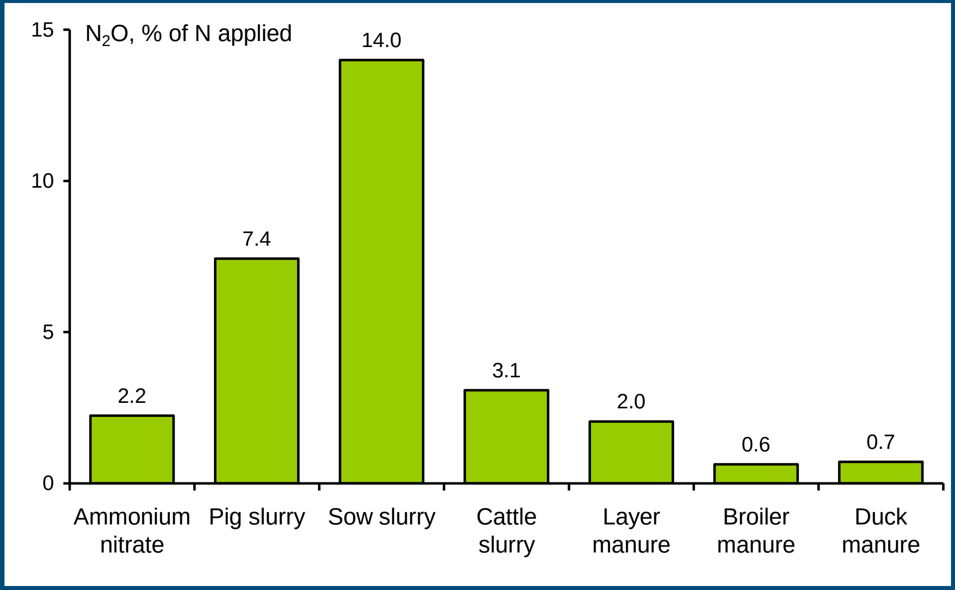
Effects of nitrogen input

Sources of nitrogen:

- Mineral fertilizer: NO_3 fertilizer, NH_4 fertilizer and urea
- Manure:
  - cattle, pig and poultry
  - Manure type: solid or slurry
  - Application technique: surface or injection
- Grazing
- Biological N fixation
- Crop residues: cereals, vegetables and other crops
- Atmospheric N deposition
- Net mineralization of soil organic N

Example: effects of fertilizer and manure types





(Pathak and Nedwell, 2001)

(Velthof et al., BFS, 2003)

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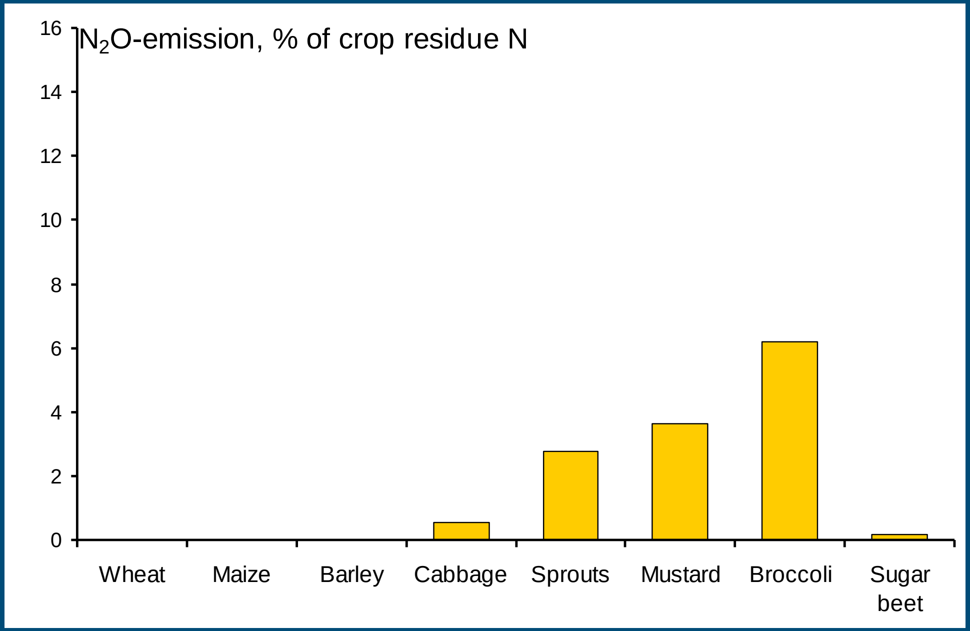
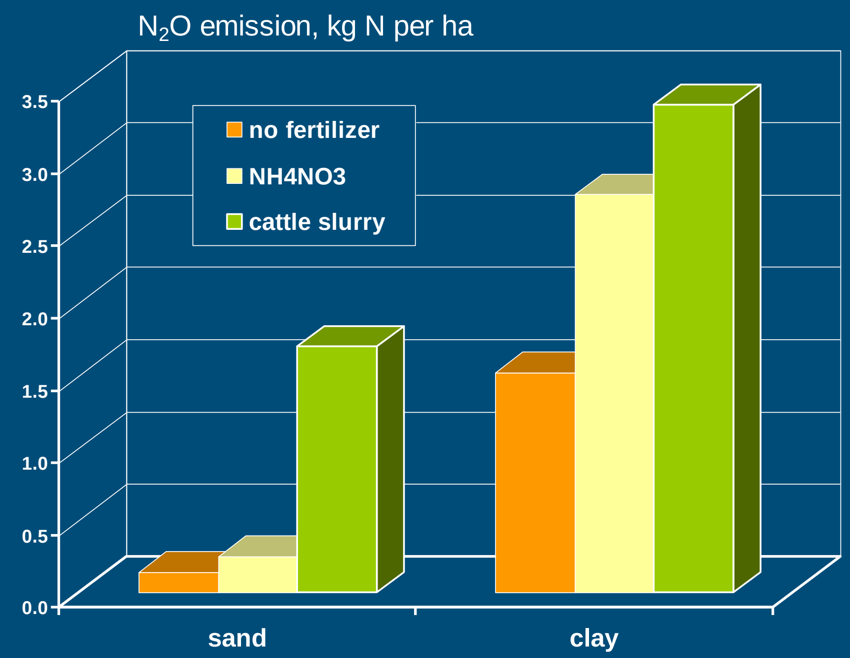
Example: effect of crop residues and of soil type and manure type





Velthof et al. (2002) (Van Groenigen et al., Plant & Soil. 2004)

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Emission factors inference scheme

Source N input	Sand		Clay		Peat	
	Grass	Arable	Grass	Arable	Grass	Arable
Nitrate based fertilizer	1.00	0.50	1.50	0.75	2.00	1.00
Urea based fertilizer	0.50	0.40	0.75	0.60	1.00	0.80
Pig slurry low NH_3 application	0.75	1.13	1.13	1.69	1.50	2.25
Pig slurry surface-applied	0.50	0.75	0.75	1.13	1.00	1.50
Cattle slurry low NH_3 application	0.50	0.75	0.75	1.13	1.00	1.50
Cattle slurry surface-applied	0.33	0.50	0.50	0.75	0.67	1.00
Solid manure, poultry manure	0.17	0.25	0.25	0.38	0.33	0.50
Atmospheric deposition	0.38	0.30	0.56	0.45	0.75	0.60
Mineralization	0.38	0.30	0.56	0.45	2.60	2.60

Lesschen et al. (2011)

IMAGE approach: emiss

- N_2O emissions in IMAGE are based on derived by Stehfest and Bouwman (20(
  - log $N_2O_{emission}$ = sum $E_i + A$
  - agriculture in temperate zones (n = 1137)
  - E accounts for impacts of soil properties (climate, crop type and length of experimer

Constant	−1.5160
N Application rate per kg N ha^{-1}	0.0038
Soil organic C content	
< 1	0
1–3	0.0526
> 3	0.6334
Soil pH	
< 5.5	0
5.5–7.3	−0.0693
> 7.3	−0.4836
Texture	
Coarse	0
Medium	−0.1528
Fine	0.4312
Climate	
Temp_C	0
Temp_O	0.0226
S-Trop.	0.6117
Trop.	−0.3022
Crop type	
Cereals	0
Grass	−0.3502
Legume	0.3783
Other	0.4420
W-Rice	−0.8850
None	0.5870
Length of experiment	
Per year (> 300 days)	1.9910

Stehfest and Bouwman (2006)

Fuzzy logic approach: Fuzzy set method

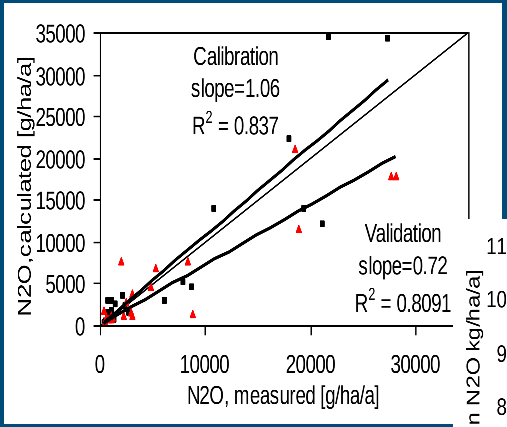
- N_2O emissions are based on the annual Fuzzy logic model from Dechow and Freibauer (2011)
- Predicts annual emissions with factors of annual resolution
- Training data set consisted of 162 (cropland) and 88 (grassland) extracted from the Stehfest & Bouwman data base.

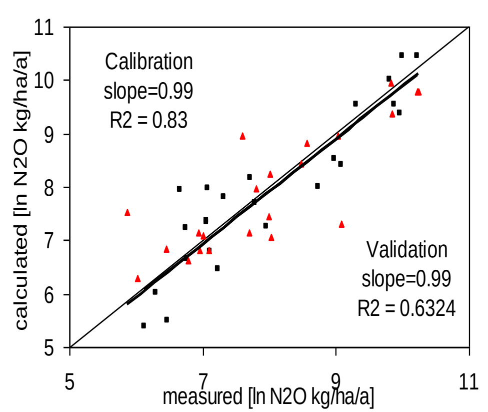
Fuzzy set method

Grassland

Factors:

- Fertilisation amount
- pH, SOM
- Precipitation, summer
- Temperature, summer

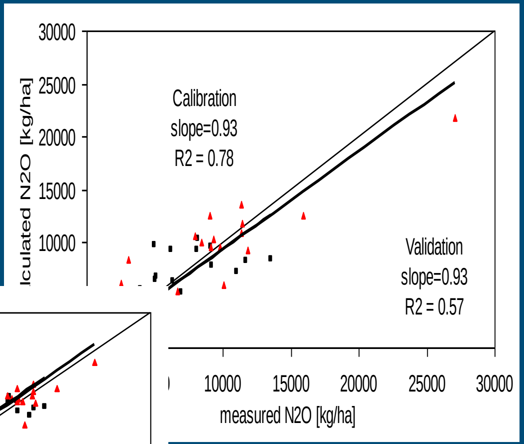


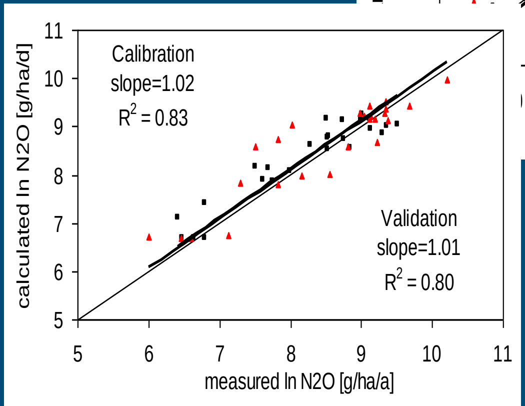


Cropland

Factors:

- Fertilisation amount and type
- pH, SOM
- Mean number of frost days
- Precipitation, autumn
- Clay





Dechow and Freibauer (2011)

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Comparison of models on large data set

- Stehfest and Bouwman (2006) data set
  - Total of 1372 N_2O measurements
  - 1137 measurements for agriculture in temperate zones
  - 352 measurements including N_2O emission from control plot without N input (INTEGRATOR and IPCC approach of corrected N_2O EF).
  - Limiting dataset to 133 sites for which factors in the inference framework were available

- Comparison observed EF with calculated N_2O emission factor for each sites based on:
  - INTEGRATOR inference approach
  - IMAGE empirical relation by Stehfest and Bouwman (2006)
  - IPCC 1% EF

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Validation of N_2O emission factors

Approach	Average difference	RMSE	Pearson correlation
Inference scheme	0.76	1.46	0.243
Statistical model	0.91	1.59	0.093
IPCC tier 1 method	0.87	1.49	-
Fuzzy set model	-	-	(0.67-0.85)

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Lesschen et al. (2011)

Evaluated Measures

- 1 Balanced fertilization
- 2 Maximum amount of animal manure
- 3 Change fertilizer type (urea substitution)
- 4 Manure incorporation
- 5 Reduced protein content feed
- 6 Restoration peat soils (histosols)
- 7 All 6 measures

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Soil nutrient management

- 1. Balanced fertilization
  - → Lower N input
- 2. Maximum amount of animal manure
  - → Lower manure N input
  - → Sometimes compensated by higher fertilizer N input
- 3. Urea substitution by NO_3 fertilizers
  - → Lower NH_3 emissions
  - → Higher N_2O emission in inference scheme and fuzzy set.
- 4. Manure incorporation
  - → Lower NH_3 emissions
  - → Higher N_2O emission in inference scheme

Livestock and land management

- 5. Reduced protein content of feed
  - Reduction in N excretion:
    - 15% for cattle
    - 20% for pigs
    - 20% for laying hens and 10% for other poultry
  - → Lower N input

- 6. Restoration histosols
  - Mean groundwater level → 10 cm

    → Lower C and N mineralization (EF for N min. only included in INTEGRATOR inference scheme)
  - No fertilizer application

    → Lower N input

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Results

Comparison N_2O emissions at EU 27 scale for the year 2000 for four model approaches

Model	N_2O_{em} (kton N_2O-N)	N_2O_{em} (kg N_2O-N ha^{-1})
Inference scheme	350	1.80
Statistical model	541	2.78
Fuzzy set model	495	2.55
IPCC tier 1 method	247	1.27

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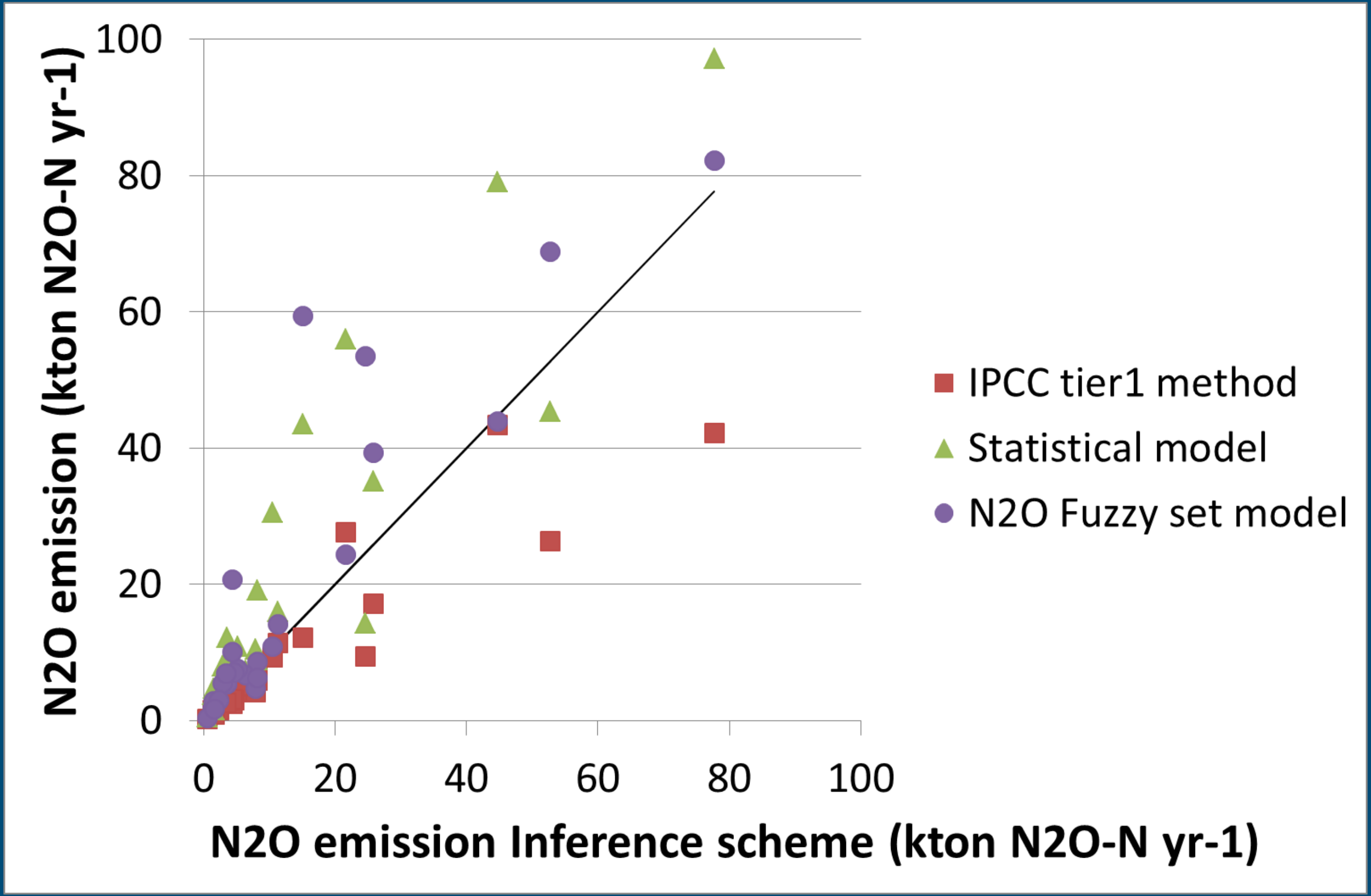
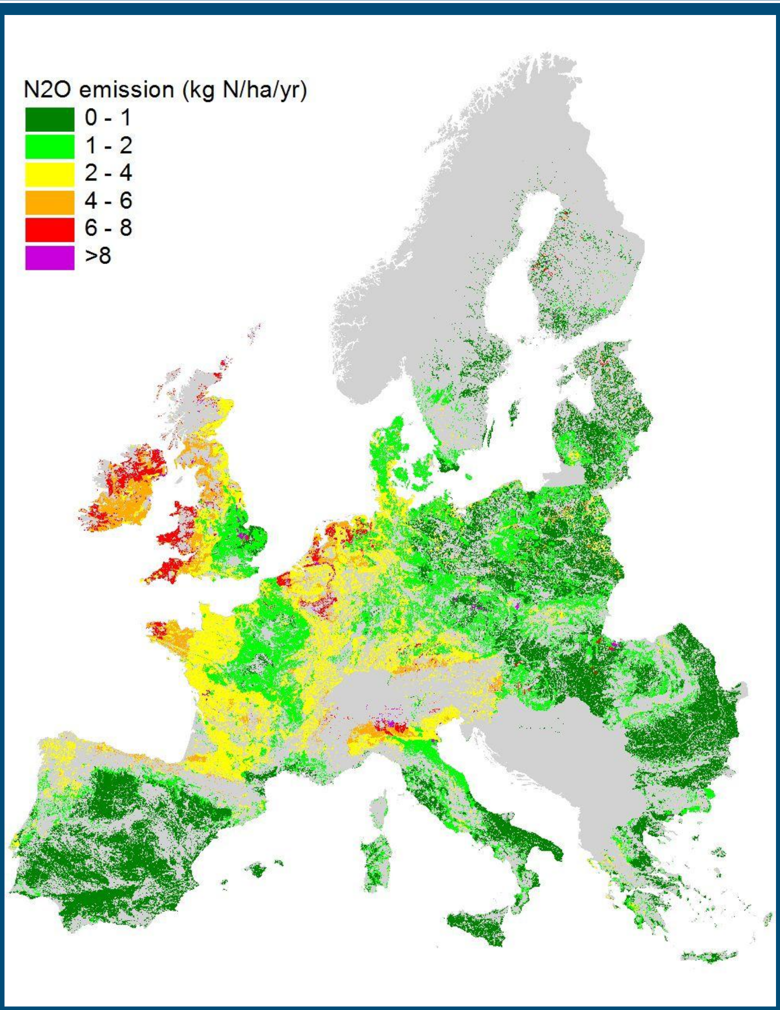
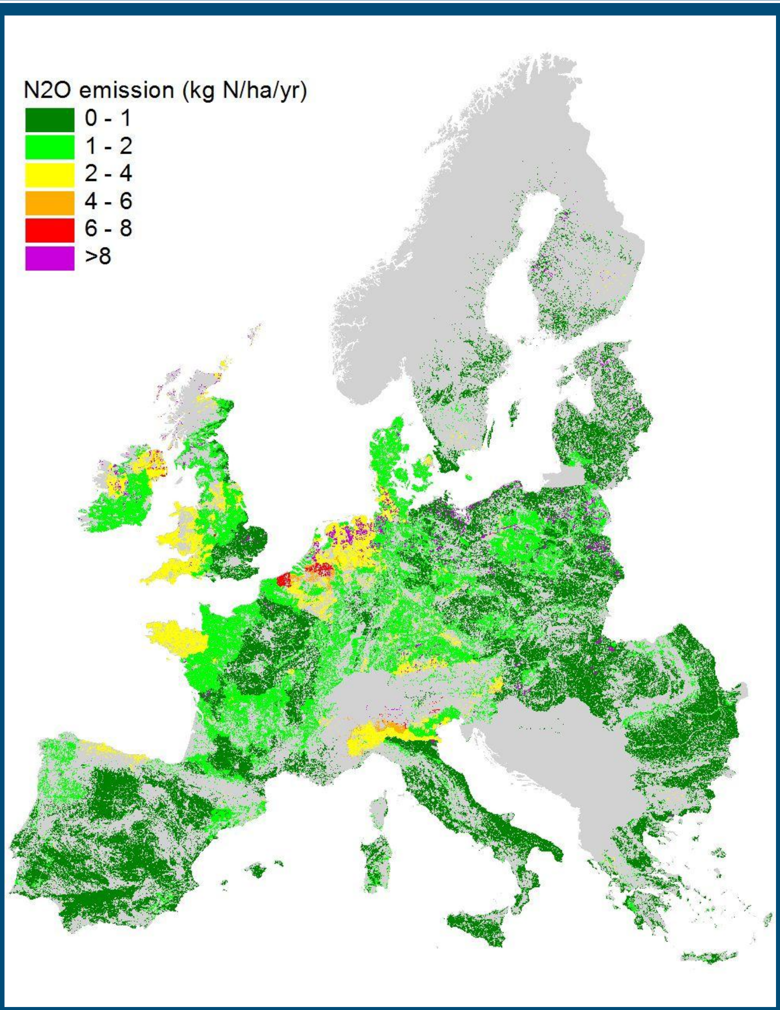
Comparison N_2O emissions per country for the four model approaches for the year 2000



Calculated N_2O emission with inference and IPCC method



Inference scheme



IPCC tier 1 method

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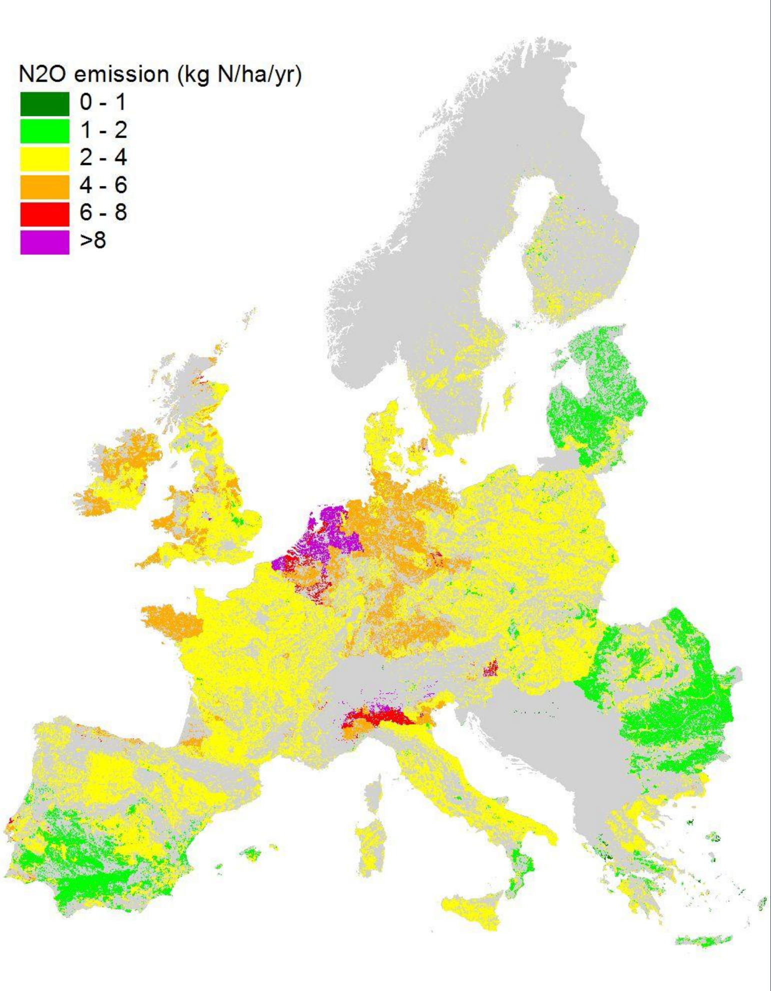
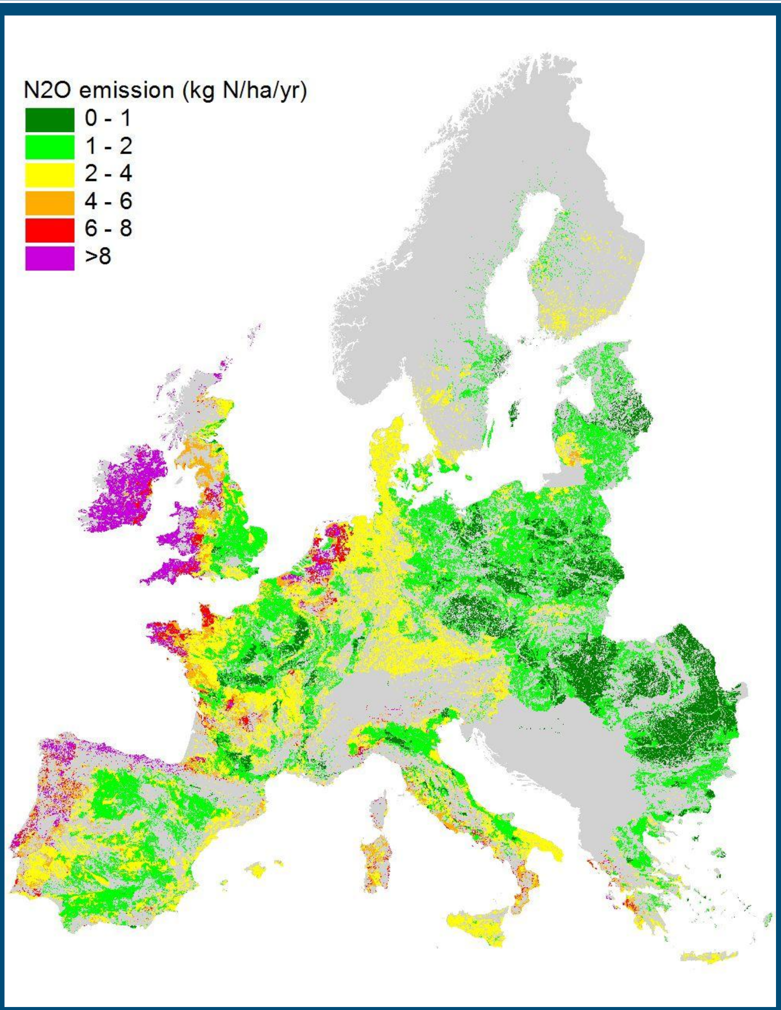
Calculated N_2O emission with statistical and fuzzy model



Statistical model



Fuzzy set model

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Comparison different model approaches with inverse model results

- Results 5 regions in year 2000: (kton N_2O-N)

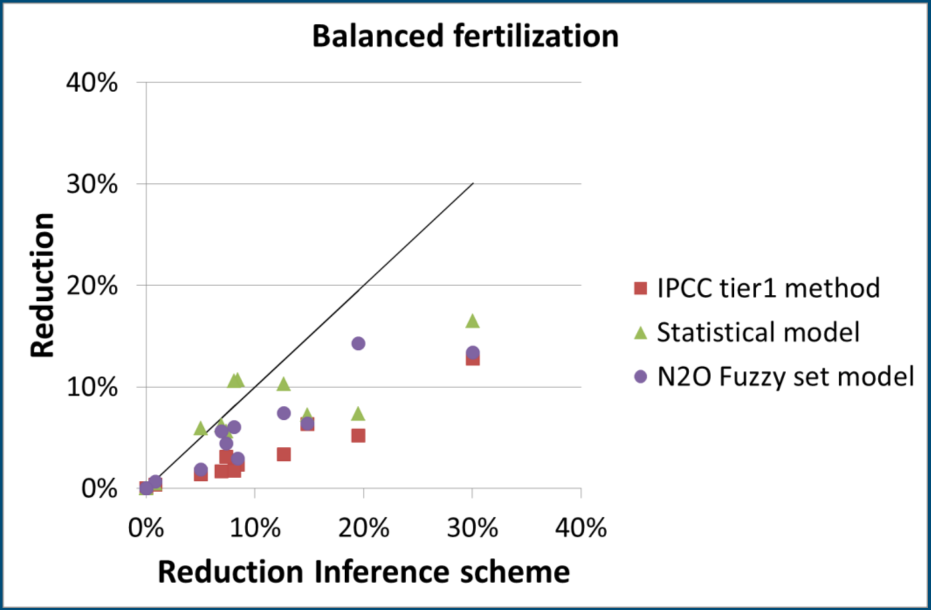
Model	Germany	Poland	France	Benelux	UK+IRE
Inference scheme	45	22	78	20	77
Statistical model	79	56	97	25	60
Fuzzy set model	44	24	82	23	122
IPCC tier 1 method	43	28	42	17	36
Inverse modelling	**55**	**29**	**61**	**13**	**37**

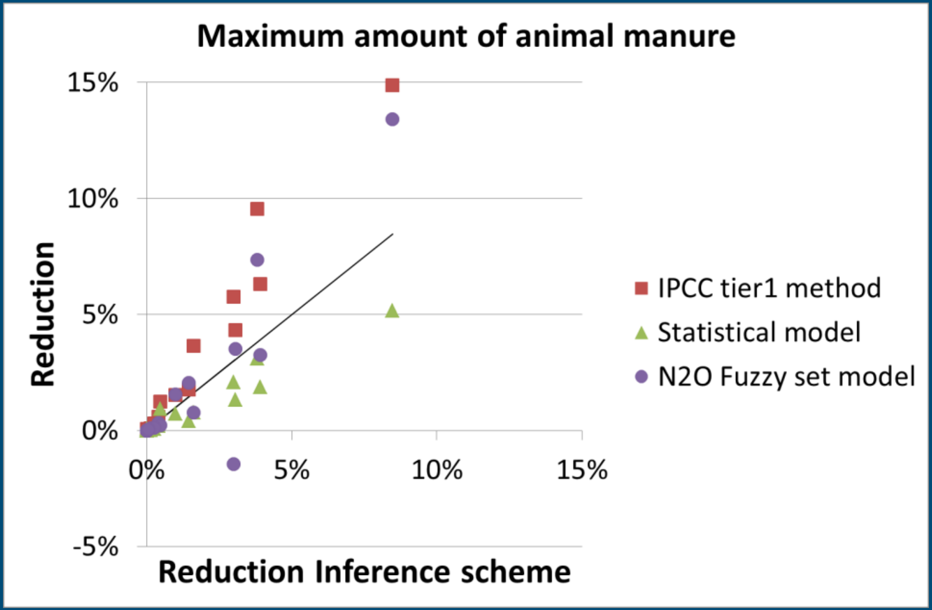
Response to various mitigation measures

- Relative reduction in N_2O emission (%) for EU27: 4 methods

Measure	Inference scheme	Statistical model	Fuzzy scheme	IPCC Tier 1
1. Balanced fertilization	3.60	3.51	2.90	1.29
2. Max amount animal manure	1.17	0.57	1.21	2.13
3. Manure incorporation	-1.12	0.0	0.0	0.0
4. Urea substitution	-1.37	0.0	-0.55	0.0
5. Reduced protein content feed	1.12	0.72	0.19	2.94
6. Restoration histosols	6.75	1.13	0.48	0.62
All measures	10.58	5.08	5.34	6.34

Comparison measures different model approaches





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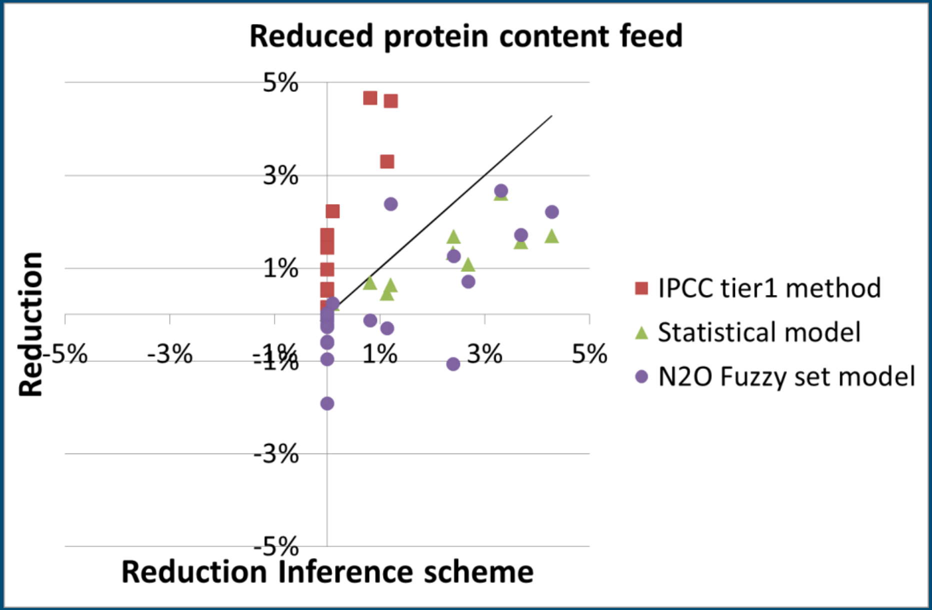
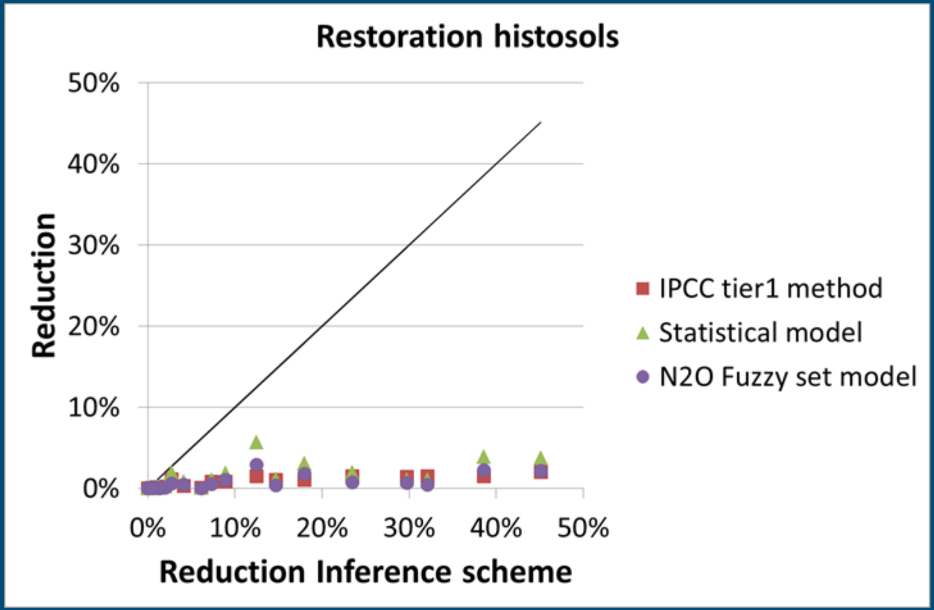
Comparison measures different model approaches





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Conclusions

- N_2O emissions derived with different approaches in one model, using same schematization and input data, are more deviating than using them in different models with different schematization and input data. Coarse resolution levels out differences.
- IPCC tier 1 method gives closest results to inverse model results followed by INTEGRATOR inference scheme. Other models give too high results
- Model approach largely affects calculated effectiveness of emission reduction approaches.

Questions?