Indirect N_2O emission due to atmospheric N deposition

a case study for The Netherlands

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Introduction

- Nitrous oxide (N_2O) is a potent greenhouse gas
- Formation through natural processes of nitrification/denitrification in soils and aquatic systems
- Nitrification and denitrification will occur simultaneously in many ecosystems
- Both processes are usually coupled

Introduction

- Anthropogenic release of nitrogen compounds in the environment results in increased N_2O emission to the atmosphere
- Amounts of N lost to the environment due to agr. activities are not trivial. In general:
  - 40-60 % taken up by crops
  - some may be immobilized in soil N reserves
  - 10-40 % lost to the environment

Introduction

- UNFCCC (United Nations Framework Convention on Climate Change) request reporting of both direct and indirect N_2O emissions
- IPCC (Intergovernmental Panel on Climate Change) treats the pathways separately and provides guidelines how to estimate both emission types
- Country-specific methodologies are possible, but they have to be transparent, properly documented and/or described in peer reviewed literature

Introduction

- **direct emission** - N_2O emission emitted from agricultural soils resulting from microbial (de)nitrification of N from fertilizers, animal manure and soil N (EF = 1.25%)
- **indirect emission** - N_2O from other ecosystems (forests, streams, rivers, oceans) resulting from N lost from agricultural soils (nitrate leaching, ammonia volatilization and deposition) (EF = 1%)

- Direct/indirect emission does not refer to timing, but refers to spatial allocation

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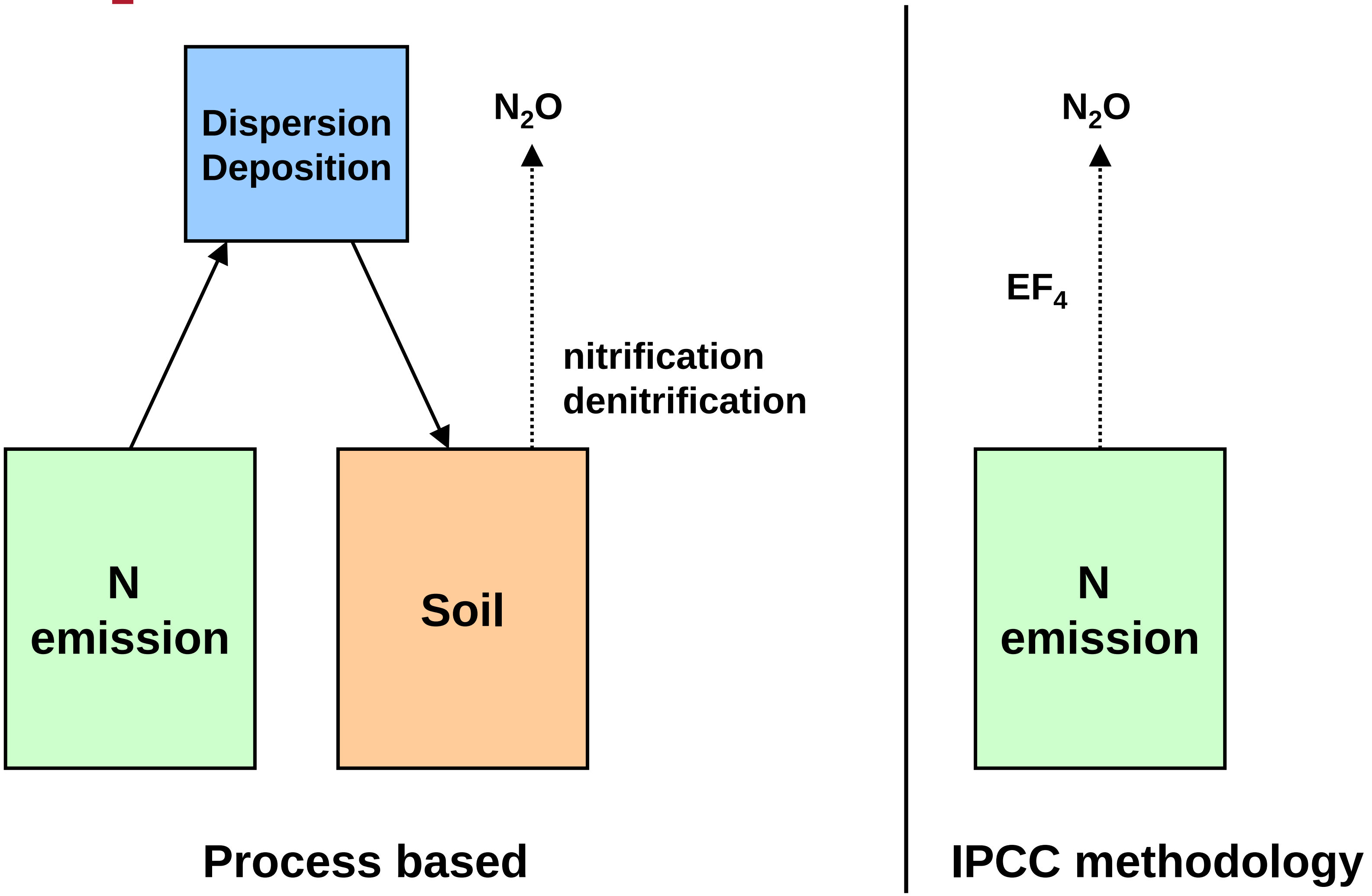
Indirect N_2O emissions

- IPCC only considers indirect N_2O emissions from nitrogen used in agriculture.
- Different pathways for synthetic fertilizer and manure input giving rise to indirect N_2O emissions are:
  - A volatilization and subsequent atm. deposition of NH_3 and NO_x
  - B nitrogen leaching and runoff
  - C human consumption of crops followed by municipal sewage treatment
  - D formation of N_2O in the atmosphere from NH_3
  - E food processing
- D and E of limited importance
- A-C estimation methodologies are proposed by IPCC
- This presentation focuses on methodologies to report and estimate indirect N_2O emissions from the Netherlands for pathway A

Indirect N_2O emissions

- Focus is on the indirect emission of N_2O due to atmospheric N deposition
- Presently this emission is not included in the National inventory report of The Netherlands
- While investigating the IPCC methodology some basic assumptions could be discussed
- The choices made can significantly influence N_2O emissions in the Netherlands, but may also change the way other countries calculate the N_2O emission due to atmospheric deposition

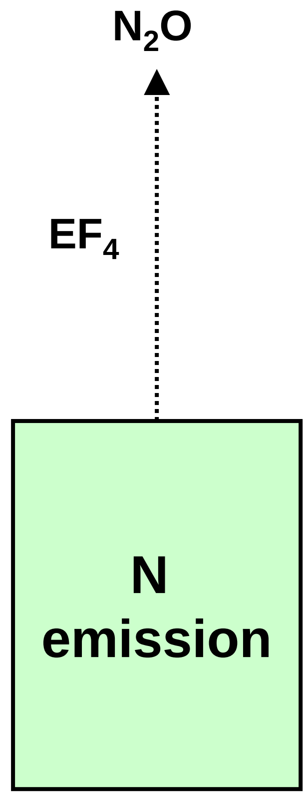
N_2O emission calculation



N_2O emission calculation

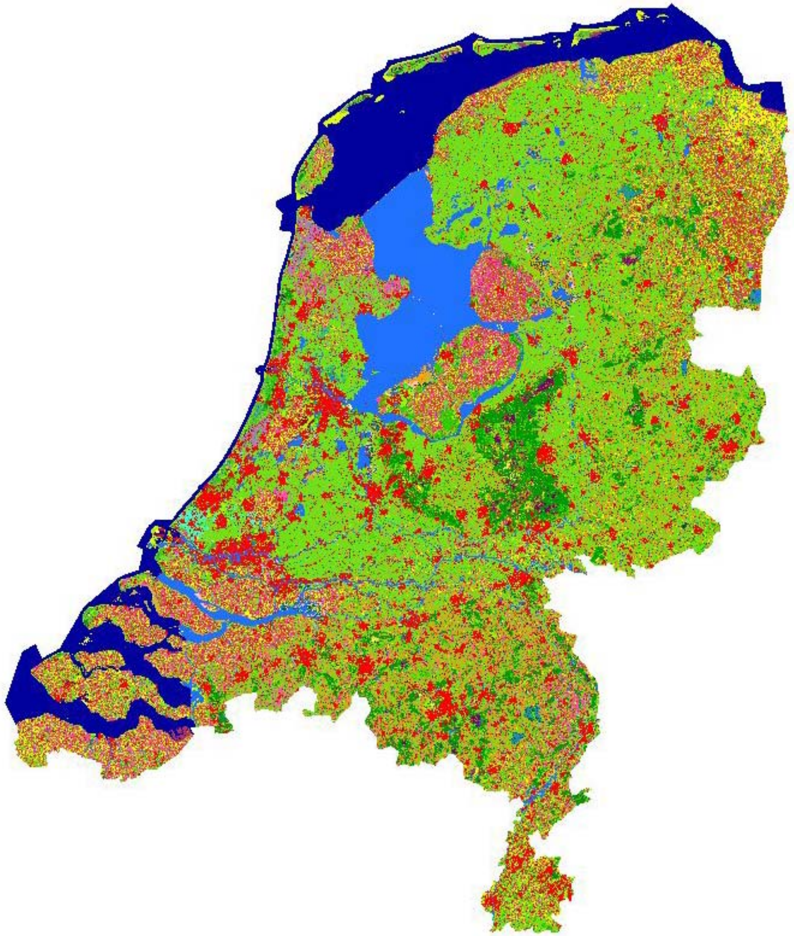
$$N_2O\text{-}N_{dep} = EF_4 \times [\text{em. agr. } NH_3\text{-}N + NO_x\text{-}N]$$

$EF_4 = 0.01$ kg N_2O-N/kg NH_4-N & NO_x-N



IPCC methodology

Agriculture in the Netherlands



- •Highly intensive
- •High N inputs for
  - •sustaining high production levels
  - •soil productivity
- •N input ranks among highest in Europe
- •70% of land used for agriculture

- •High environmental pressures
- •Difficult to meet environmental targets
  - •nitrate leaching
  - •ammonia volatilization

N_2O emissions in the Netherlands (in Gg N_2O yr^{-1})

Source	NIR	NIR	IPCC Default[b)]	IPCC CS[c)]	IPCC CS[c)]
Year	1990	1999	1990	1990	1999
Manure Management	0.7	0.6	5.0		
Agricultural Soils					
Direct soil emissions	21.5	25.0	20.0	17.2	20.5
Indirect emissions	0.0	0.0	17.0	15.3	13.5
Atm. deposition of agricultural NH_3 and NO_x	NE	NE	3.1	2.7	2.4
Agricultural N leaching and run off	RE	RE	13.9	12.6	11.1
Agriculture total (B+D)	22.2[a)]	25.7[a)]	42.1	32.5	34.0

Discussing the IPCC methodology

- review of EF_4
- land use specific N_2O emission
- including other nitrogen sources

Review of EF_4

- Standard IPCC emission factor is 1%
- Literature review of recent articles showed:
  - emission factor is land use specific
  - emission will thus depend on ultimate location of deposition
  - best estimate of EF_4 is higher than IPCC standard for each land use type
  - improved estimate of EF_4 would be 0.02 (0.005-0.04) or 2% of N deposition re-emitted as N_2O
  - using this new emission factor increases indirect N_2O emissions due to N deposition by a factor of 2

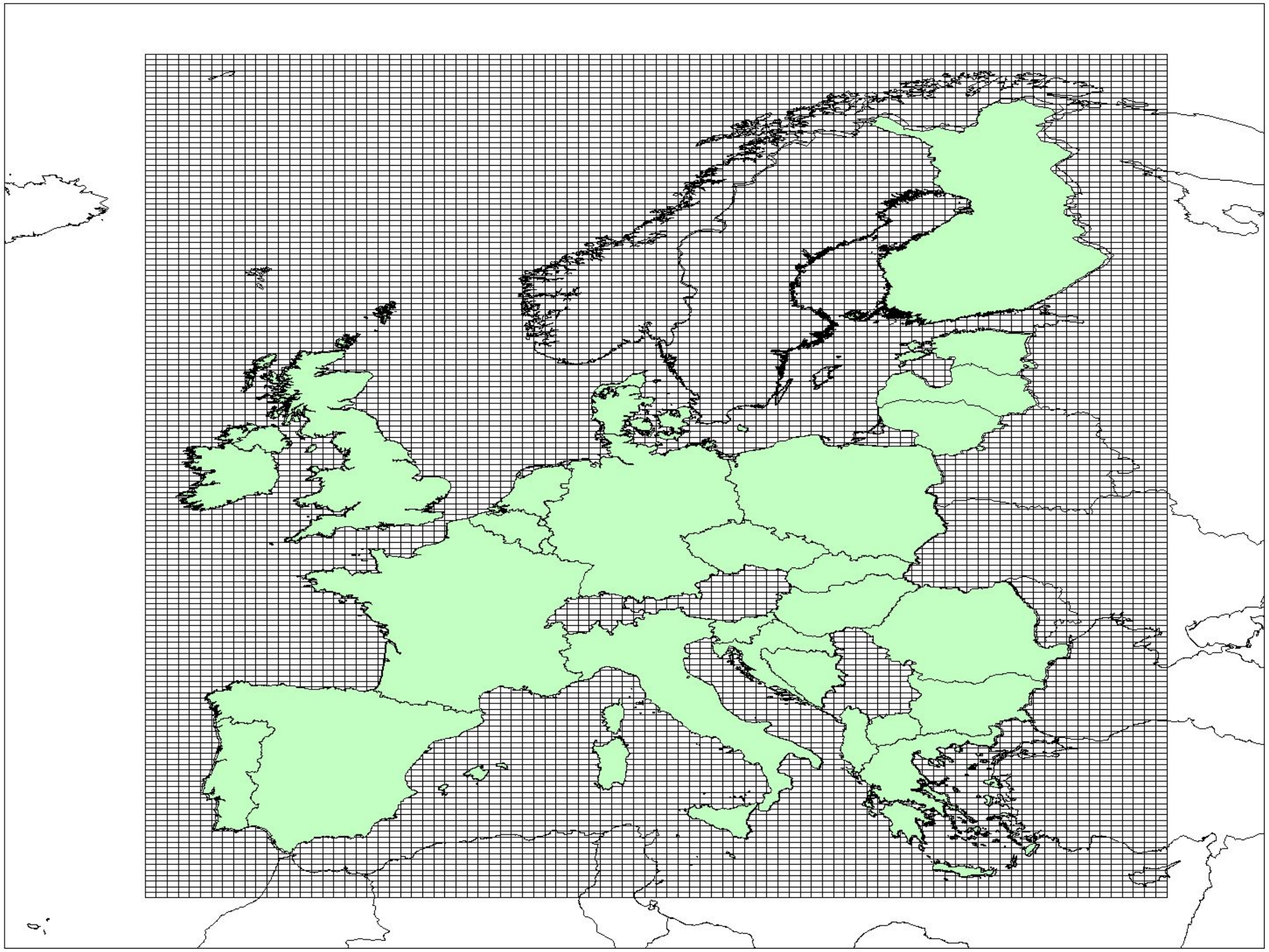
Land use	Grass, pasture	Arable land	Permanent Crops	Coniferous forest	Deciduous forest	Water	Urban area	Bare land	Unidentified
$EF_{4\_land\ use}$	1.25%[a)]	1.25% [a)]	1.25% [a)]	1.40%	6%	1%[b)]	0%	1%[b)]	1%[b)]

[a)] Derived from the IPCC emission factor for direct N_2O emission from agricultural soils
[b)] The IPCC default value for EF_4

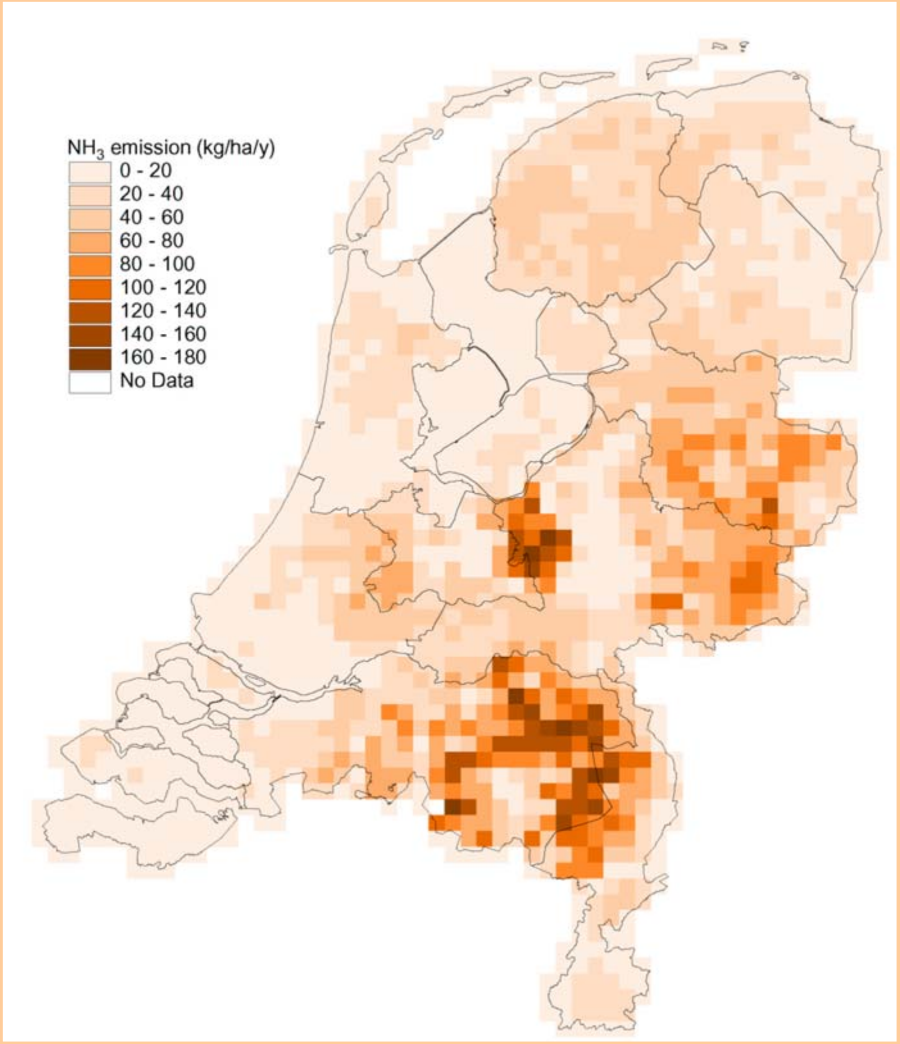
Land use specific N_2O emissions

- Use of land use specific emission factors
- Deposition calculated by means of an atmospheric dispersion and deposition model
- Input:
  - land use information for Europe (Corine)
  - emission data on agricultural NH_3 for the Netherlands
- Combining calculated deposition, land use information and specific emission factors will result in land use specific N_2O emissions

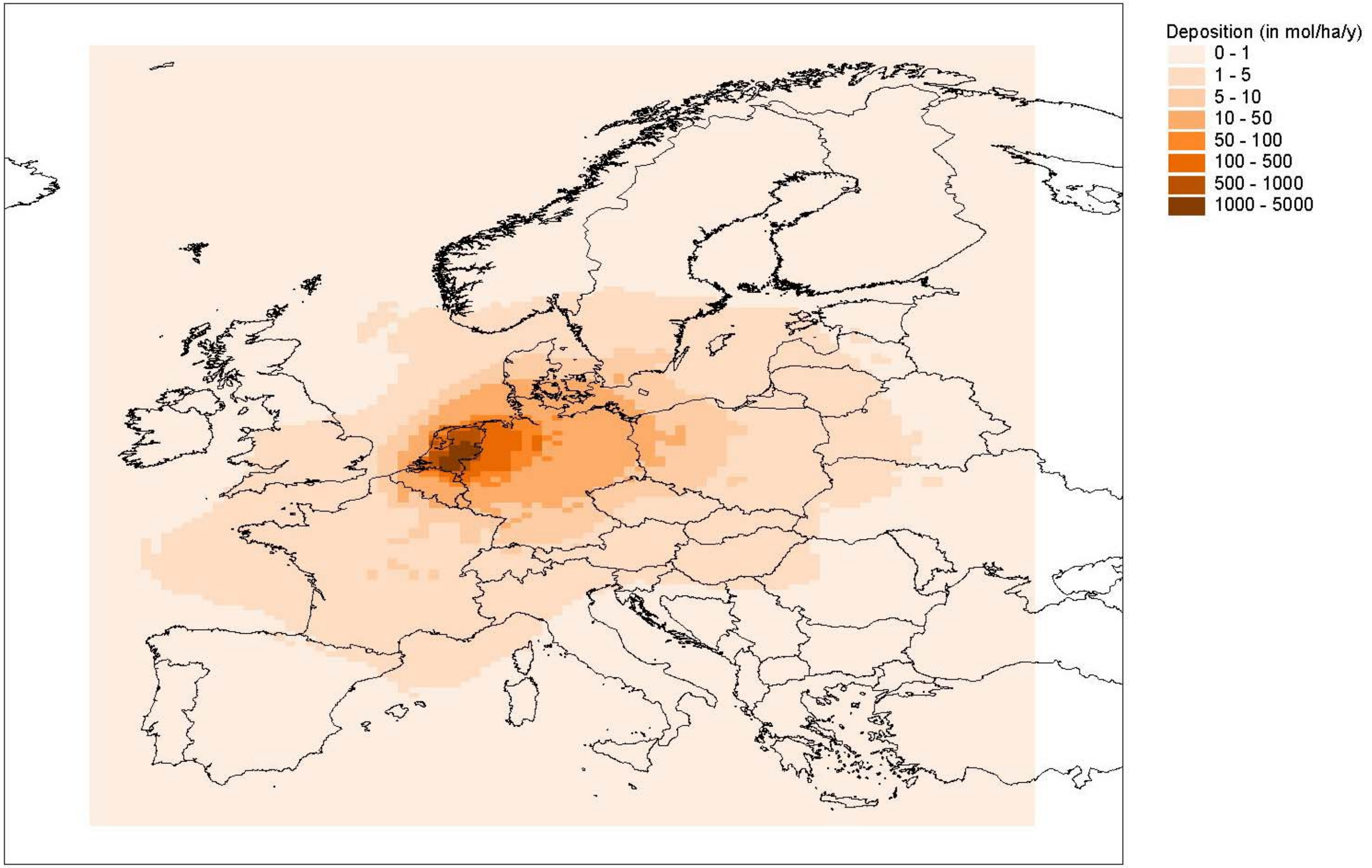
Modeling region



NH_3 emission for the Netherlands



Deposition due to NH_3 emissions from the Netherlands



Distribution of NH_3 emission from the Netherlands

Land use	N Deposition ($Gg\ N.y^{-1}$)	Fraction of agricultural N emission received (%)
Grass (pastures)	19.8	17
Arable	32.8	29
Permanent crops	3.1	3
Coniferous forest	9.1	8
Deciduous forest	2.1	2
Water_inland	1.4	1
Urban areas	5.9	5
Bare land	1.5	1
Sea	5.1	4
Sub total on identified land use		*70*
Unidentified Land [a)]	2.7	2
Missing (not allocated cells) [b)]	7.1	6
Sub total within model domain	*90.7*	*79*
Deposited outside of model domain	24.3	21
Total	**115**[c)]	**100**

[a)] Land use data were not available for all countries within the deposition domain.
[b)] Grid cells that partly contain cells from countries with land use data and partly from countries without land use data cannot be allocated to one particular land use.
[c)] Equaling the agricultural NH_3 emission according to CCDM (2003).

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Land use specific emission scenarios

scen	Land use description and associated fraction (%) of N input emitted as N_2O.								N_2O-N emission CORINE area[a)]	Fraction (%) attributed to land use not described by CORINE			N_2O-N emission deposition domain[b)]	Total[c)] indirect N_2O-N emission	Total[c)] indirect N_2O emission
	Grass[f)]	Arable land	Perm. Crops	Con. forest	Dec. forest	Water inland	Urban	Bare	(Gg N yr^{-1})	No_LU[d)]	Sea	Missing[e)]	(Gg N yr^{-1})		(Gg yr^{-1})
1	1	1	1	1	1	1	1	1	0.48	1	1	1	0.91	1.15	1.80
2	***1***	***1***	***1***	***1***	***1***	***1***	***0***	***1***	***0.44***	***1***	***1***	***1***	***0.87***	***1.11***	***1.74***
3	1.25	1.25	1.25	1	1	1	0	1	0.53	1	1	1	0.96	1.21	1.91
4	2	1.25	1.25	1	1	1	0	1	0.61	1	1	1	1.05	1.32	2.08
5	2	1.25	1.25	3.80	3.80	1	0	1	0.86	1	1	1	1.30	1.64	2.58
6	1.25	1.25	1.25	3.80	3.80	1	0	1	0.78	1	1	1	1.21	1.53	2.40
7	***2***	***1.25***	***1.25***	***1.40***	***6***	***1***	***0***	***1***	***0.73***	***1***	***1***	***1***	***1.16***	***1.47***	***2.31***
8	6	1.25	1.25	1.40	6	1	0	1	1.19	1	1	1	1.63	2.06	3.23
9	***1.25***	***1.25***	***1.25***	***1.40***	***6***	***1***	***0***	***1***	***0.64***	***1***	***1***	***1***	***1.07***	***1.36***	***2.13***
10	1.25	1.25	1.25	1.40	6	0	0	1	0.64	1	0	1	1.07	1.35	2.12
11	1.25	1.25	1.25	1.40	6	2	0	1	0.64	1	2	1	1.08	1.36	2.14

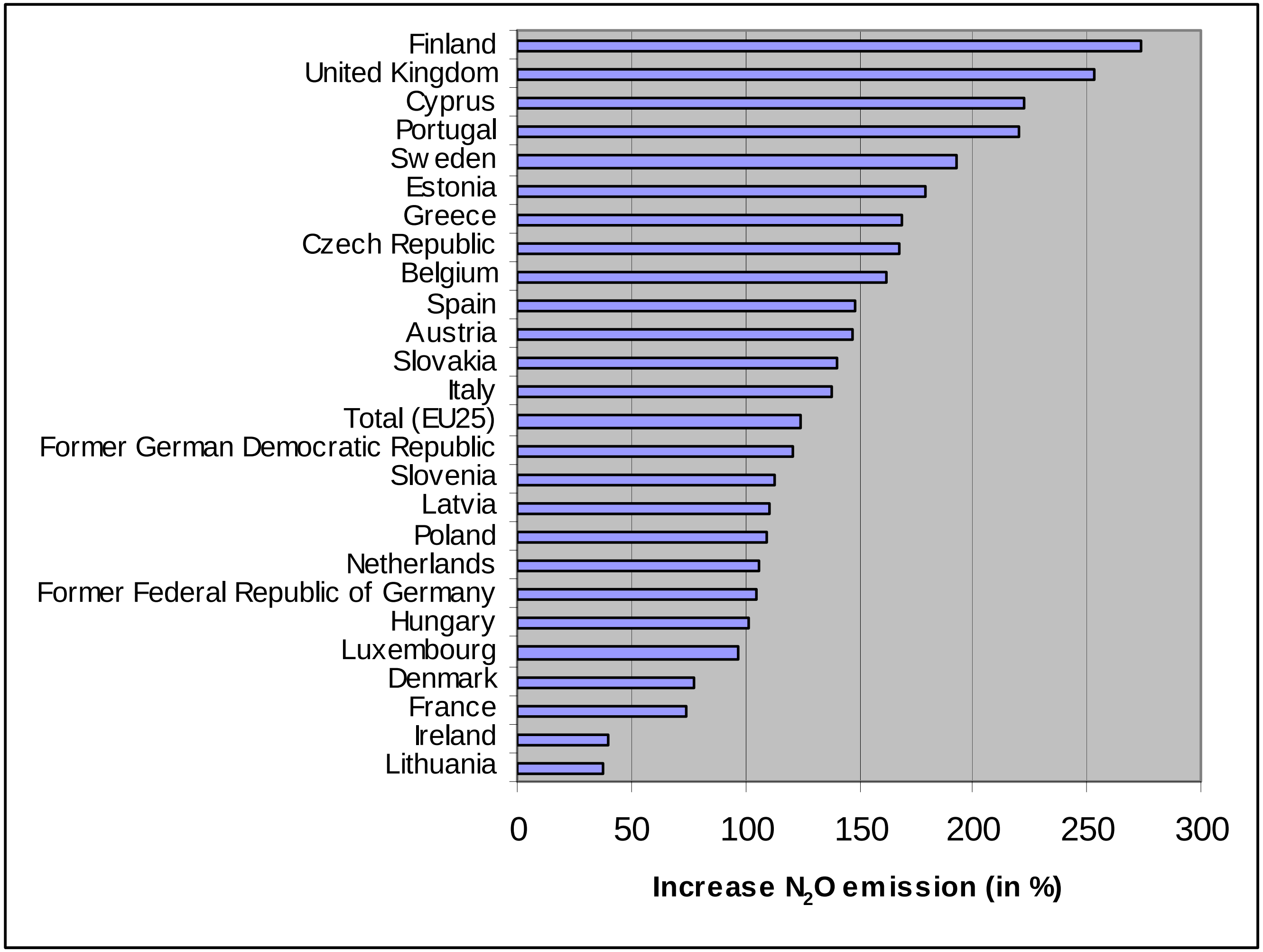
a) Total area covered by the CORINE land use map is 8.5 10^6 km^2
b) Total area covered by the modeled deposition domain is 12.7 10^6 km^2
c) Corrected for the 21 % of N emitted which is deposited outside of the modeled deposition domain
d) The No_LU class describes areas that are land but with no land use information in CORINE e.g., Norway, Sweden, Switzerland
e) The area covered by the missing class describes border cells that cannot be allocated to one particular class are partly land partly sea
f) Including unfertilized pastures and natural grass lands

Other nitrogen species

Species	N-emission (Gg N.y^{-1})	Estimated resulting indirect N_2O-N emissions (Gg N.y^{-1}) [a)]
NOx-N[a)]	136	1.36[b)]
NH_3-N_agriculture	115	1.15
NH_3-N_other	11	0.11 [b)]
Total	**262**	**2.62**

a) assuming a simple 1% default emission factor in line with IPCC for agricultural sources.
b) not taken into consideration by IPCC.

Other European countries



Conclusions

- Calculating the indirect N_2O emissions using a land use-specific approach and an atmospheric transport and deposition model, resulted in a ~30% higher indirect N_2O emission.
- Higher land use specific emission factors were applied that are higher than the IPCC default.
- 10-15% of the N emitted by The Netherlands is deposited on forests; 80% on other land use – mostly agricultural land.
- The IPCC default emission factors for indirect (1%) and direct (1.25%) N_2O emission from agricultural land should be harmonized, resulting in a more reliable and transparent emission estimation

Conclusions

- This study revealed two issues, which should be subject to discussion in the IPCC process:
  - The IPCC default value for EF_4 appears to underestimate indirect N_2O emissions due to N deposition. Literature review gave an improved estimation of 2% (0.5-4%) compared to 1% (IPCC default).
  - Omission of indirect N_2O emission resulting from non-agricultural anthropogenic N deposition in the current IPCC estimation methodology. Approximately half of the anthr. N emissions are not taken into account (i.e. estimated indirect N_2O emission may potentially increase by a factor of ~2).