Feedback from terrestrial productivity changes to the climate

Model predictions of greenhouse gas emission at a regional scale

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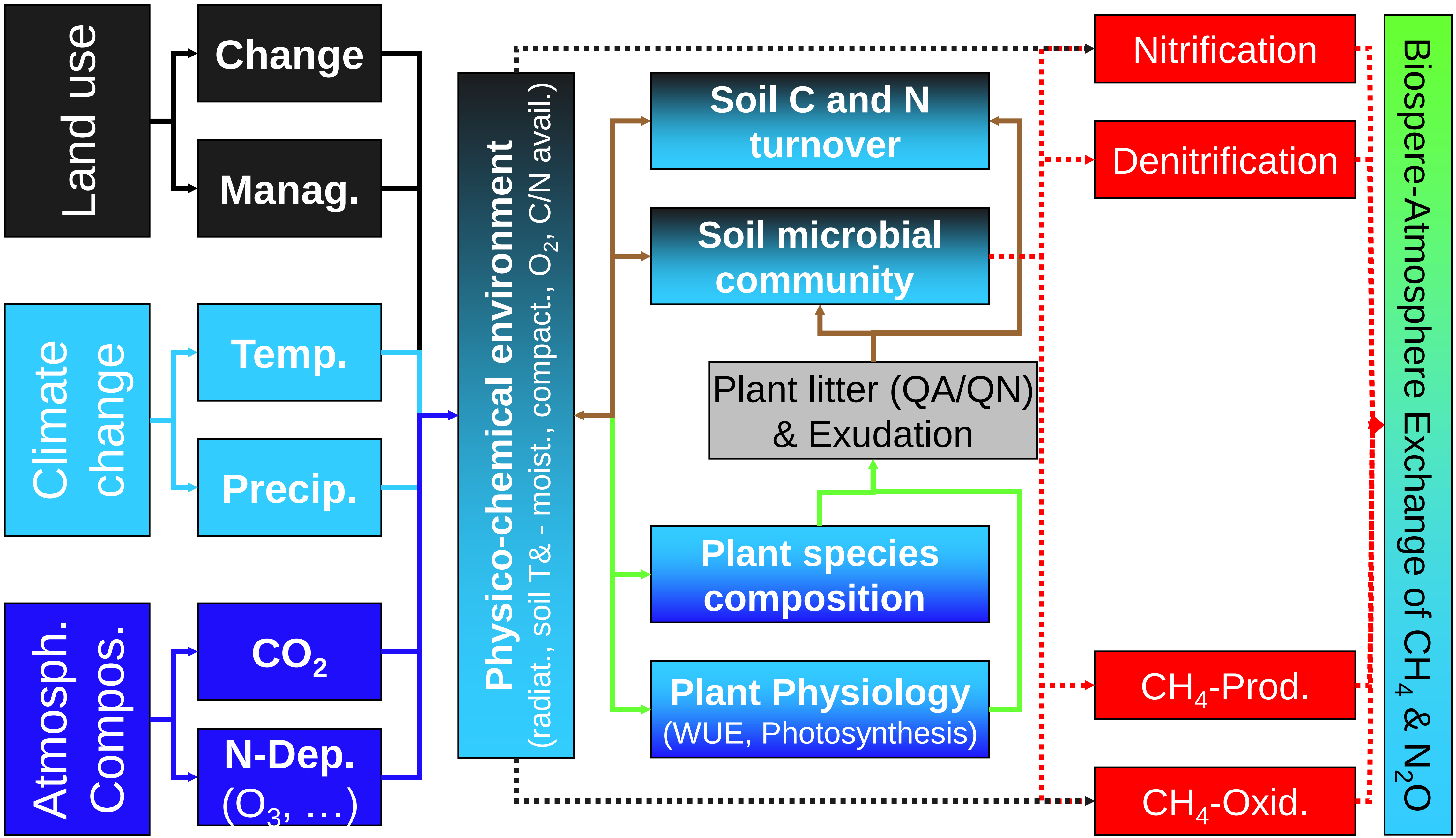
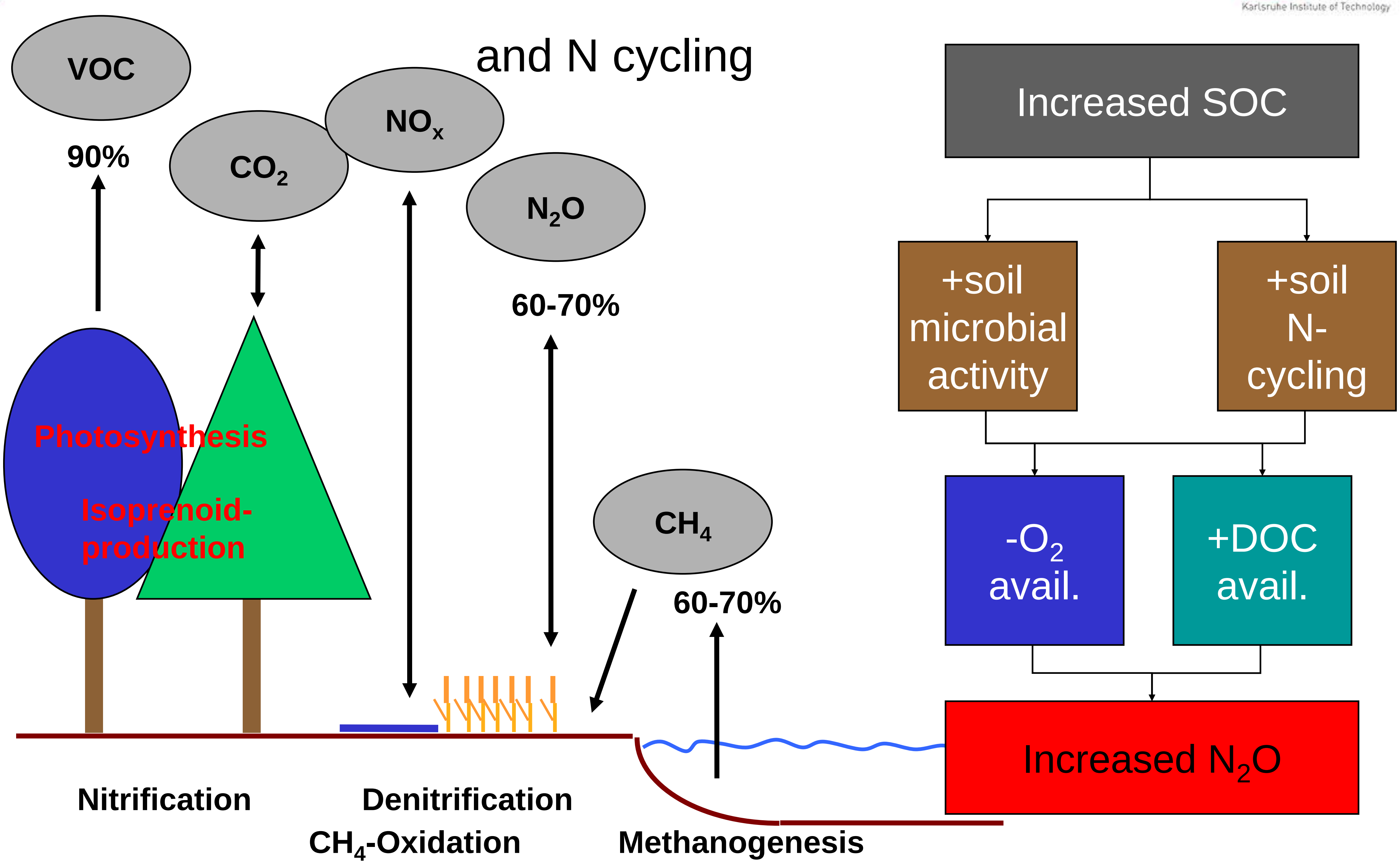
Global Changes and soil N_2O and CH_4 exchange



Understanding the environmental feedbacks between C and N cycling



The challenge: Regional fluxes

Bridging the gap: process understanding ↔ ecosystem/ regional fluxes

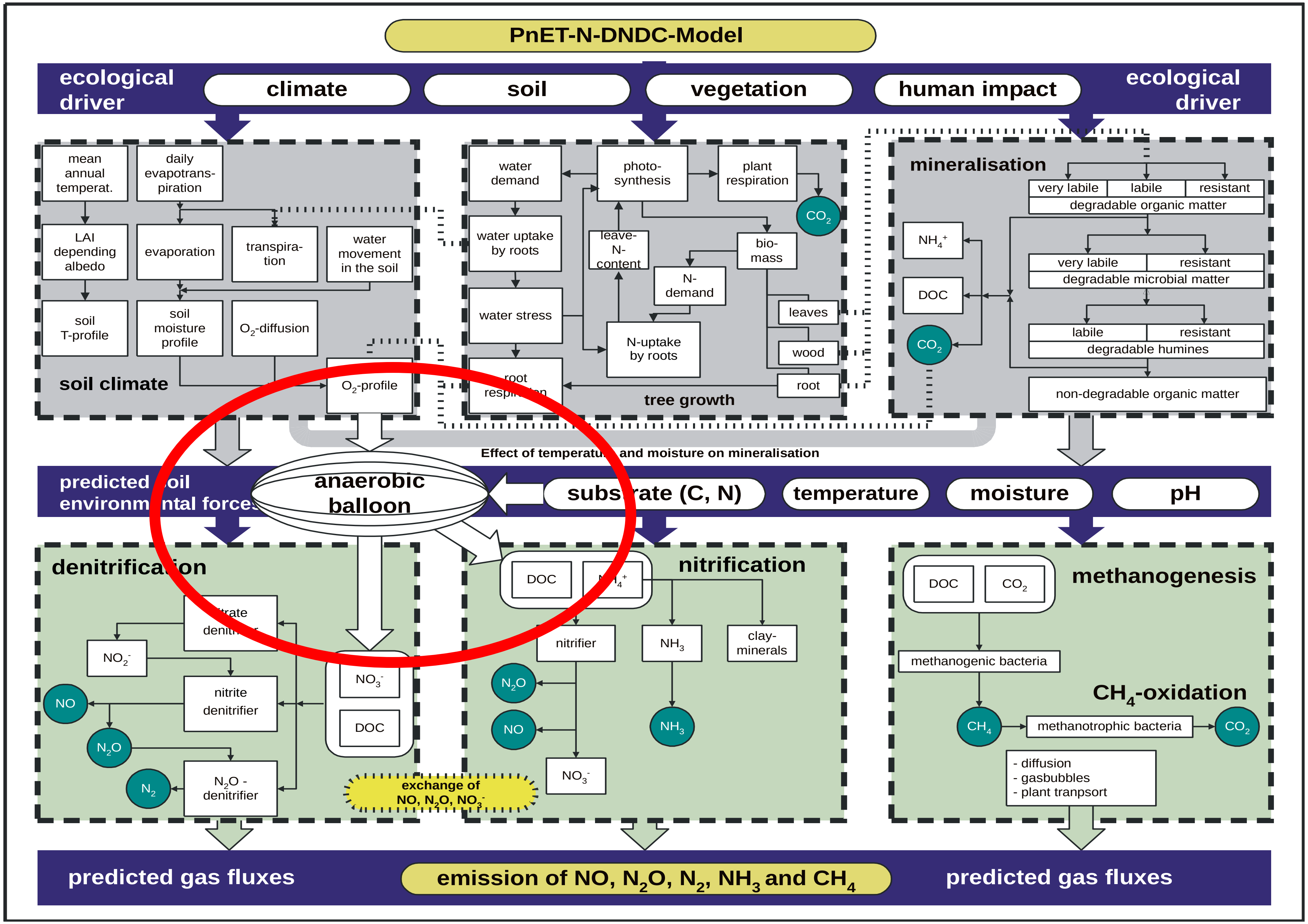
Empirical/ statistical approaches for inventories

- IPCC and emission factors
- Robust (most likely), but can hardly be used for
  - evaluating land use/ land management strategies, or
  - assessing climate-biosphere feedbacks

Process oriented modeling

- DayCent, DNDC, CERES, COUP, etc.
- Complex → processes descriptions, high parameter demand
- still need further development and UC assessment, but
  - provide realistic simulation of ecosystem processes
  - allow to test hypotheses,
  - can be used to assess global change feedbacks

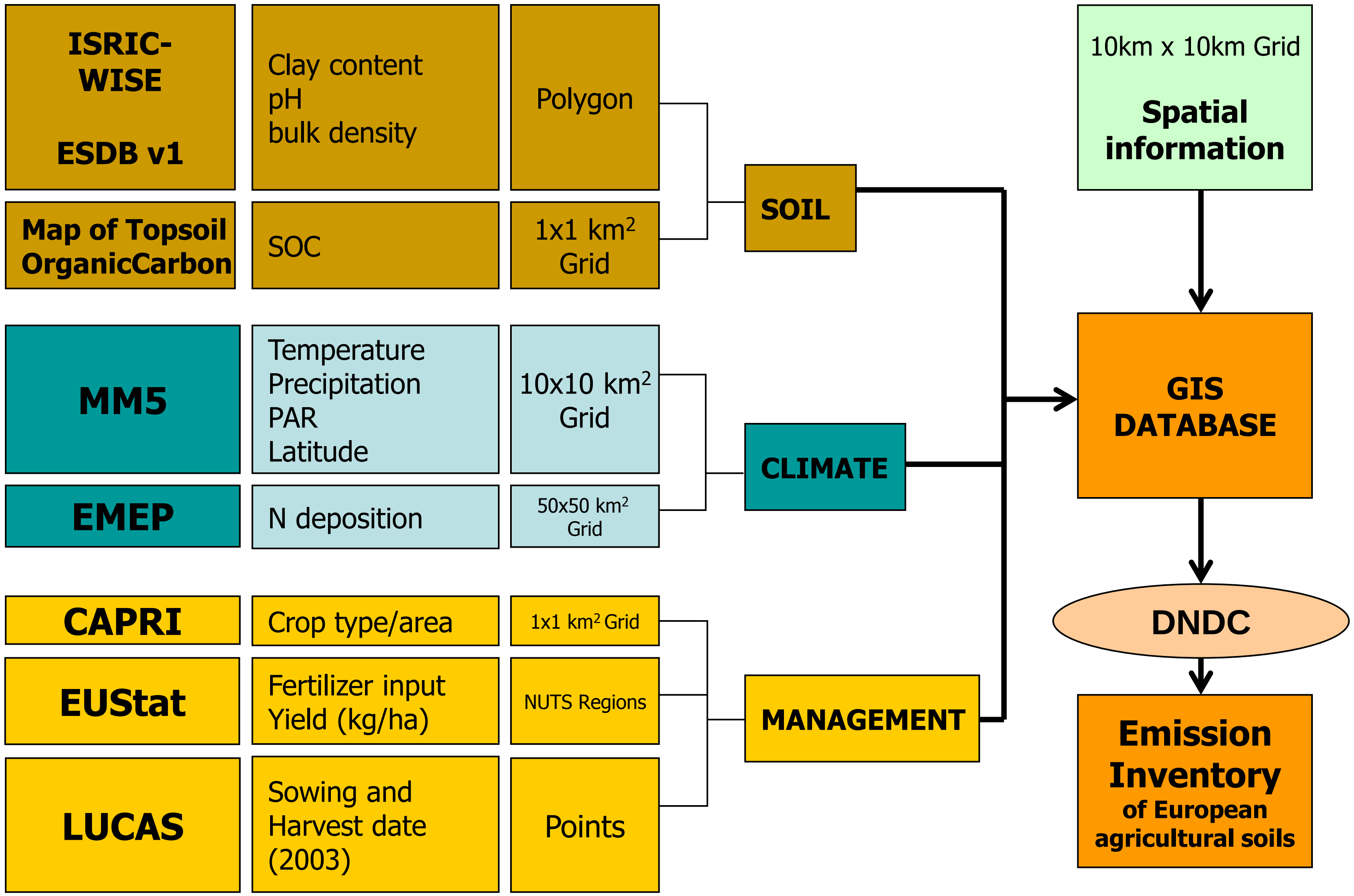
Process oriented modeling of biosphere-atmosphere exchange



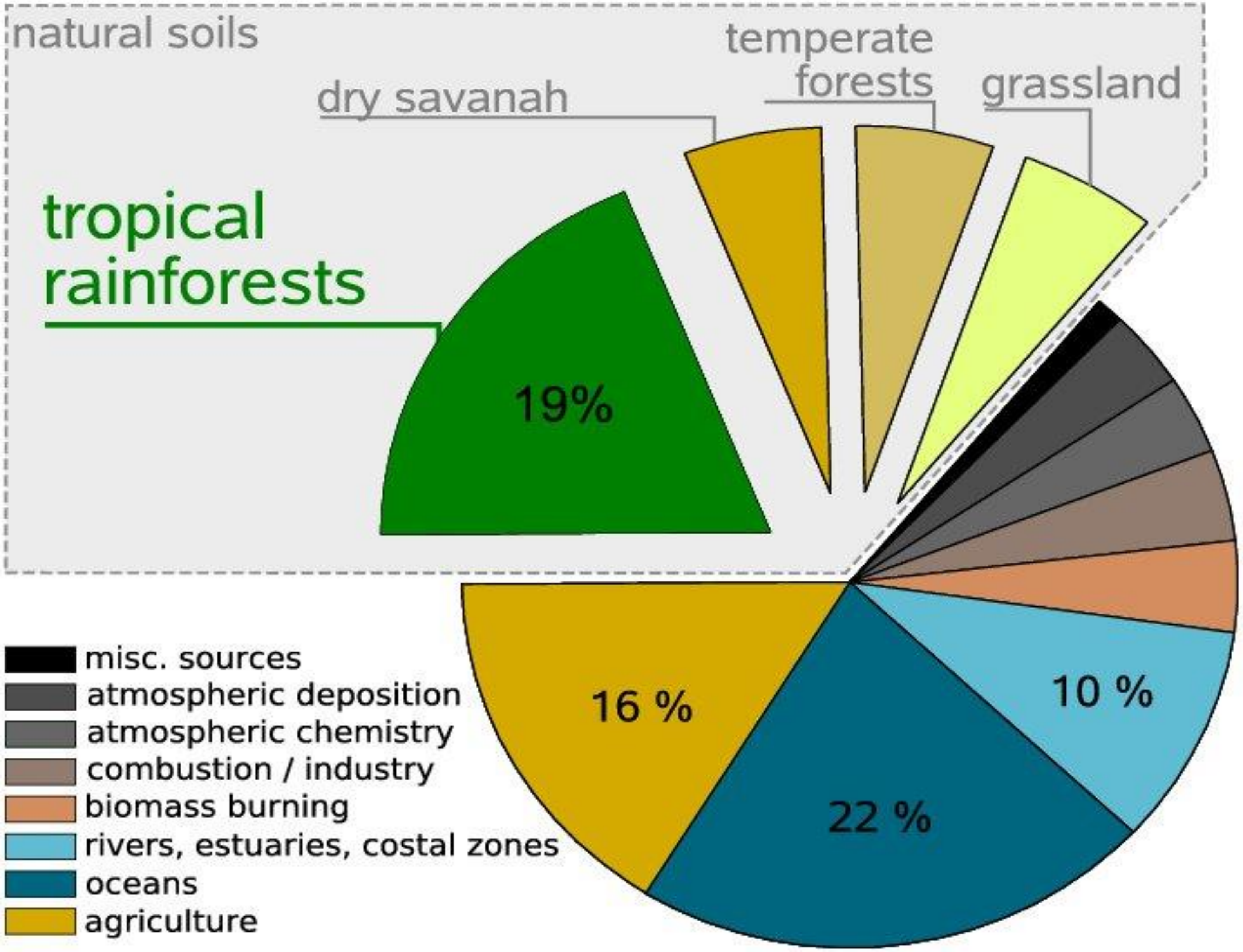
GIS coupling for GIS – the problem of data

GIS database for DNDC

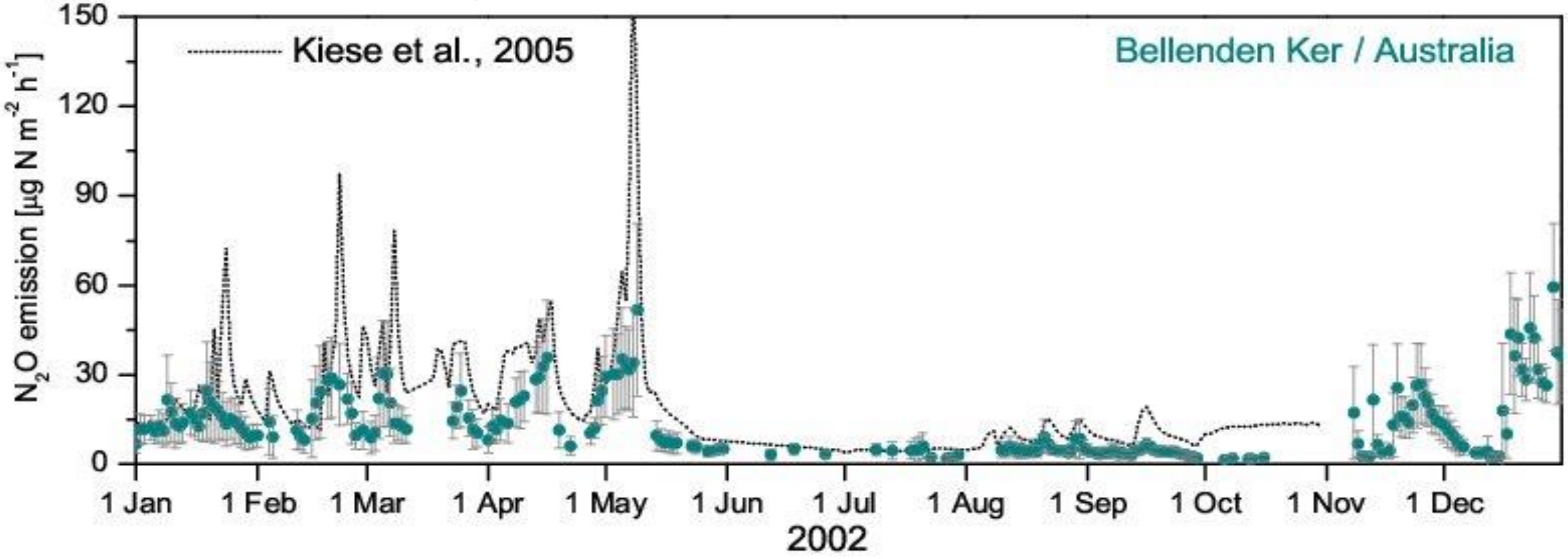
Data source **Data content** **format**



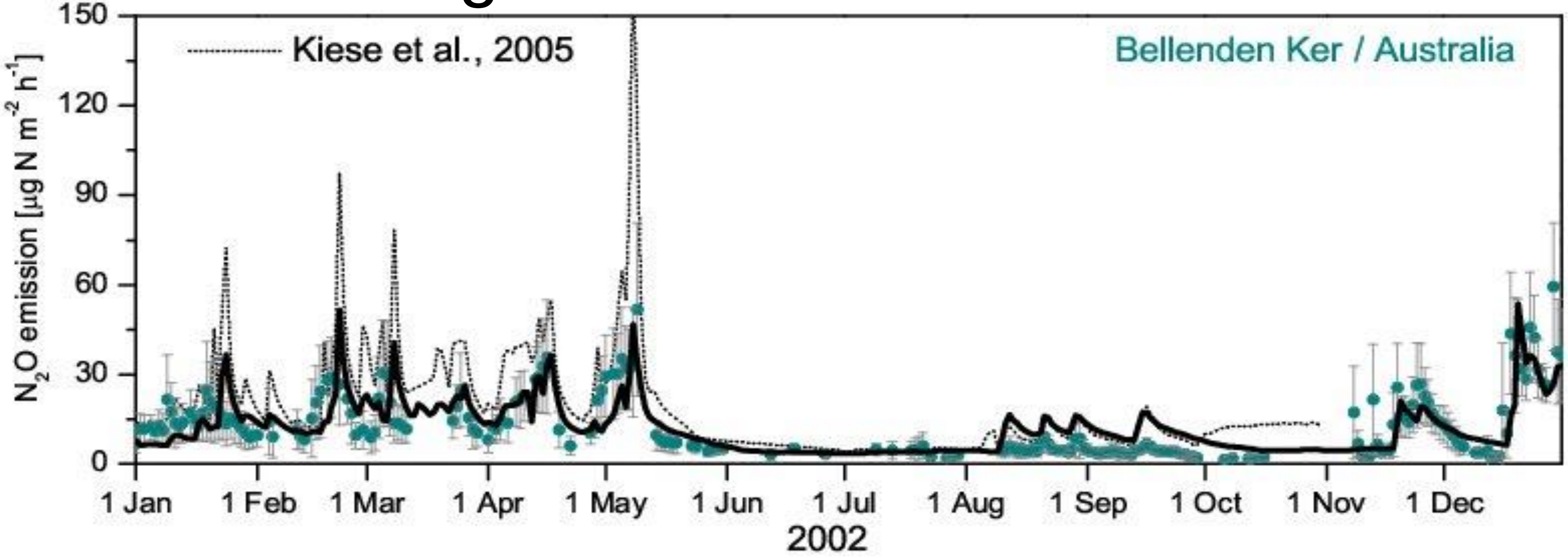
Global N_2O budget



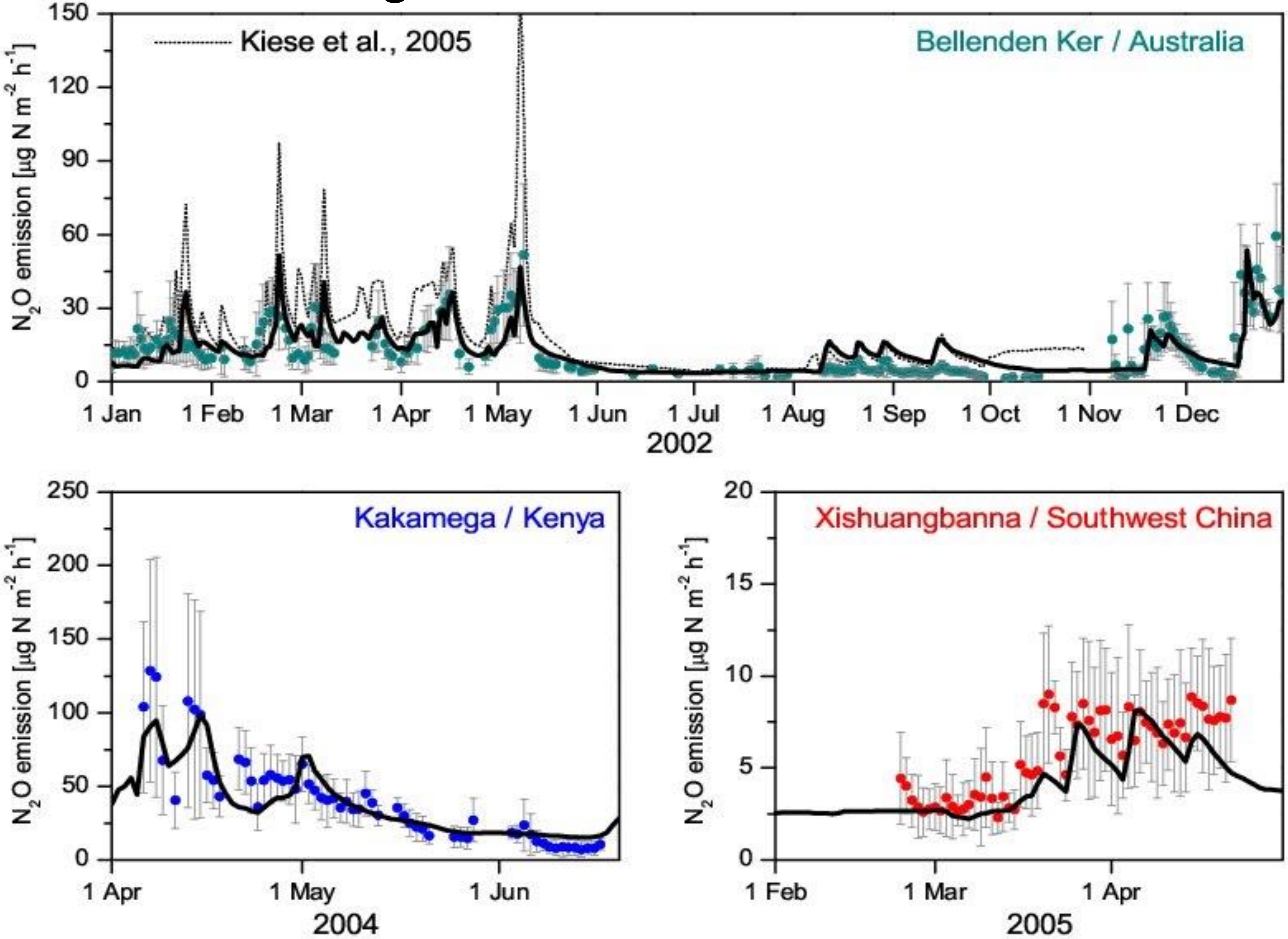
Model testing



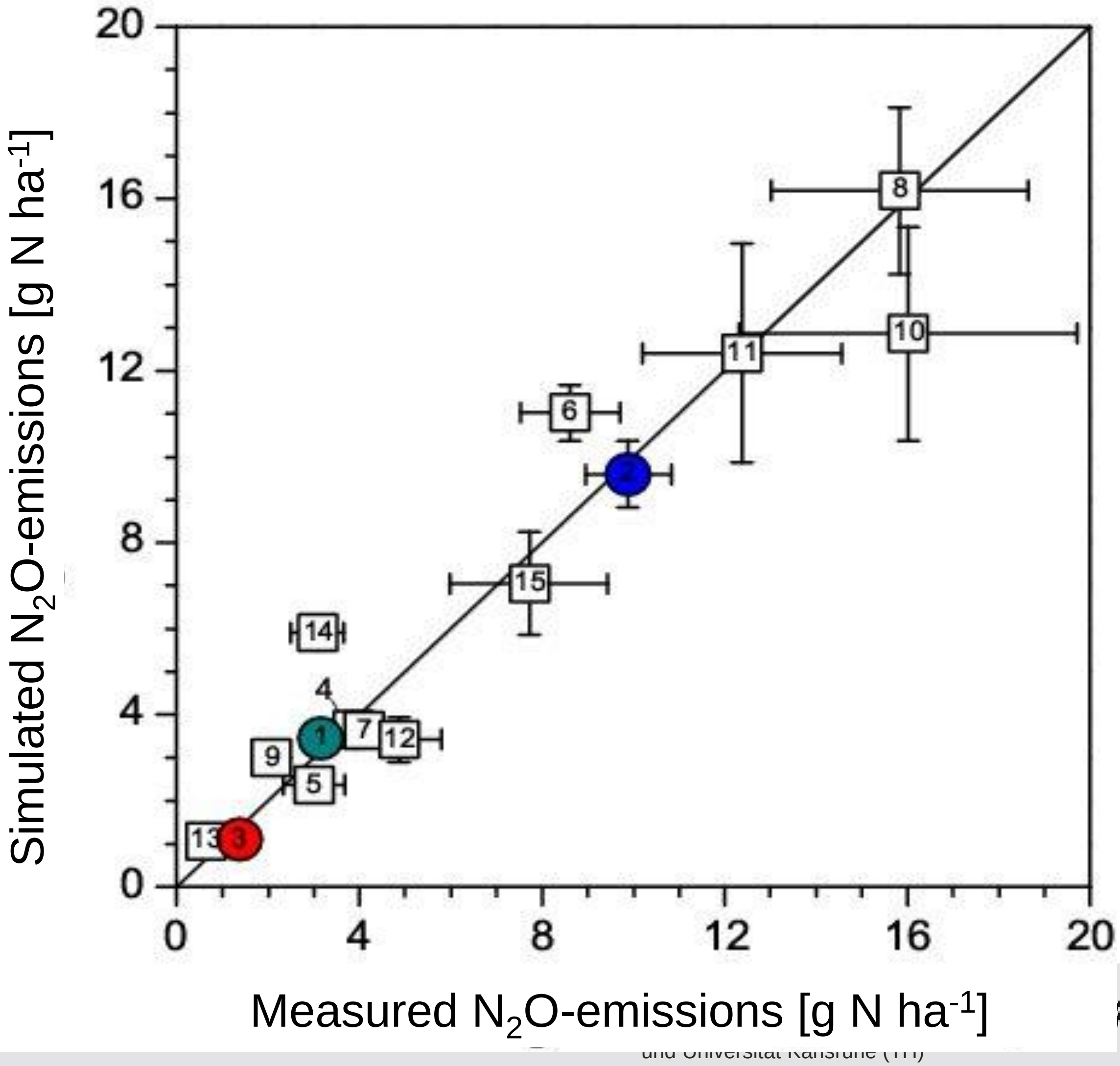
Model testing



Model testing




10, 11
15
12
Kakamega
Xishuangbanna
14
13
Bellenden Ker
4, 5, 6, 7, 8


Simulated N_2O-emissions [g N ha^{-1}]
Measured N_2O-emissions [g N ha^{-1}]
0
4
8
12
16
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Global GIS

Drivers:
integrated binary dataset:
CRU climate dataset
FAO global soil database

LPJ-DGVM

Lund-**P**otsdam-**J**ena **D**ynamic
Global **V**egetation **M**odel

[SMITH et al., 2001, SITCH et al., 2003; ZAEHLE and SITCH, 2005]

BIOMASS

wood mass, leaf mass,
litter mass

Global GIS

Drivers:
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BIOMASS

wood mass, leaf mass, litter mass

Climate

ECMWF RA-40 Forecast
0.5x0.5°; daily
(1991- 2000)

temperature (min/max); rainfall; PAR

Soil

spatial: FAO global soil map; 0.25x0.25° (rs)
profile data: ISRIC-WISE

topsoil attributes:
pH, SOC, texture, BD, ...

Forest Area

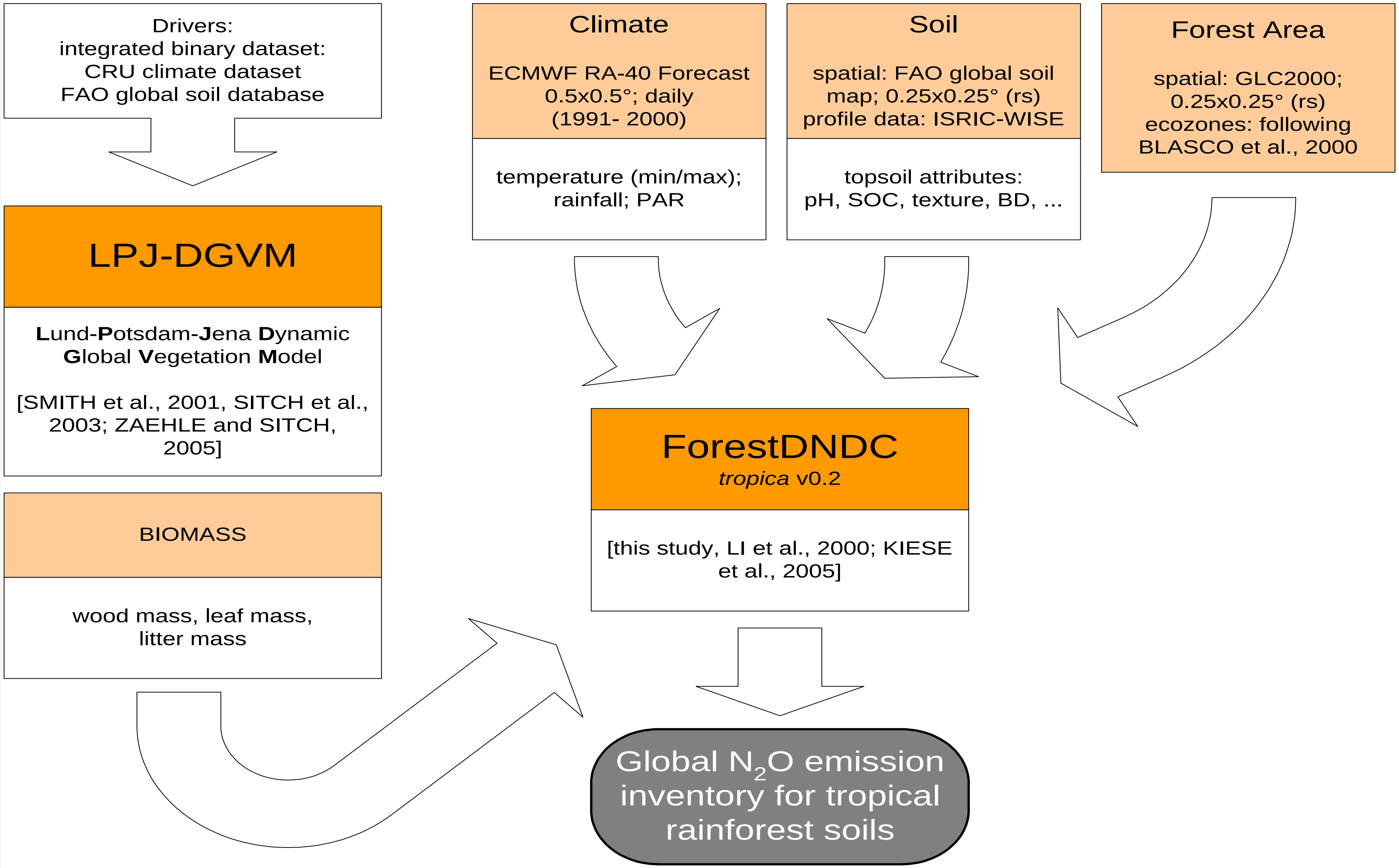
spatial: GLC2000; 0.25x0.25° (rs)
ecozones: following BLASCO et al., 2000

ForestDNDC

tropica v0.2

[this study, LI et al., 2000; KIESE et al., 2005]

Global GIS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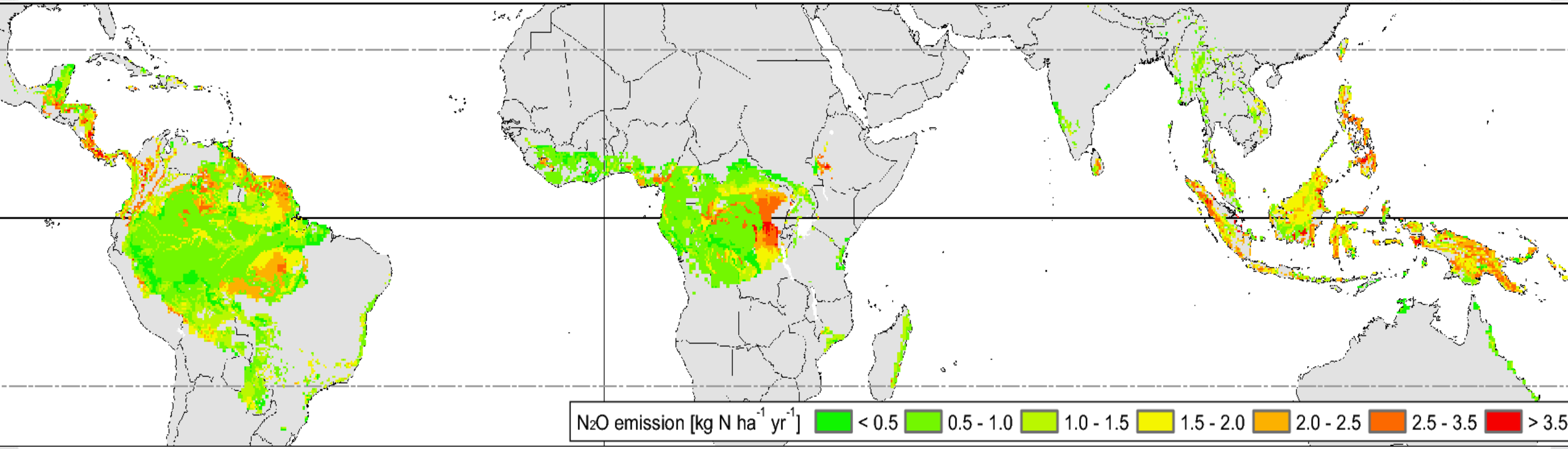
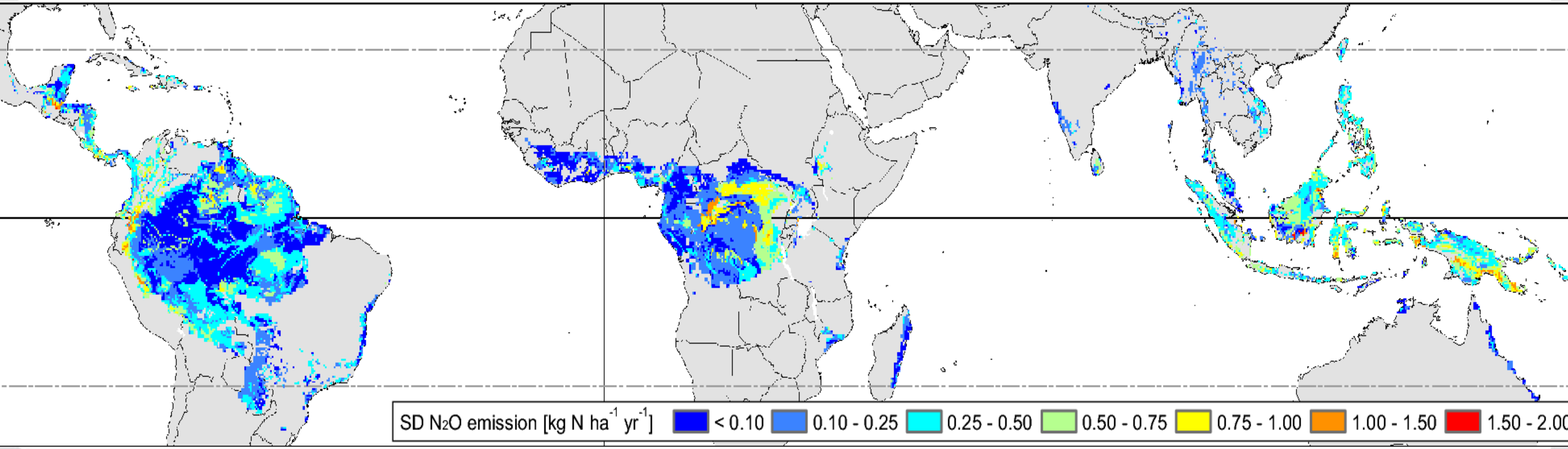
Global N_2O emission inventory for tropical rainforest soils

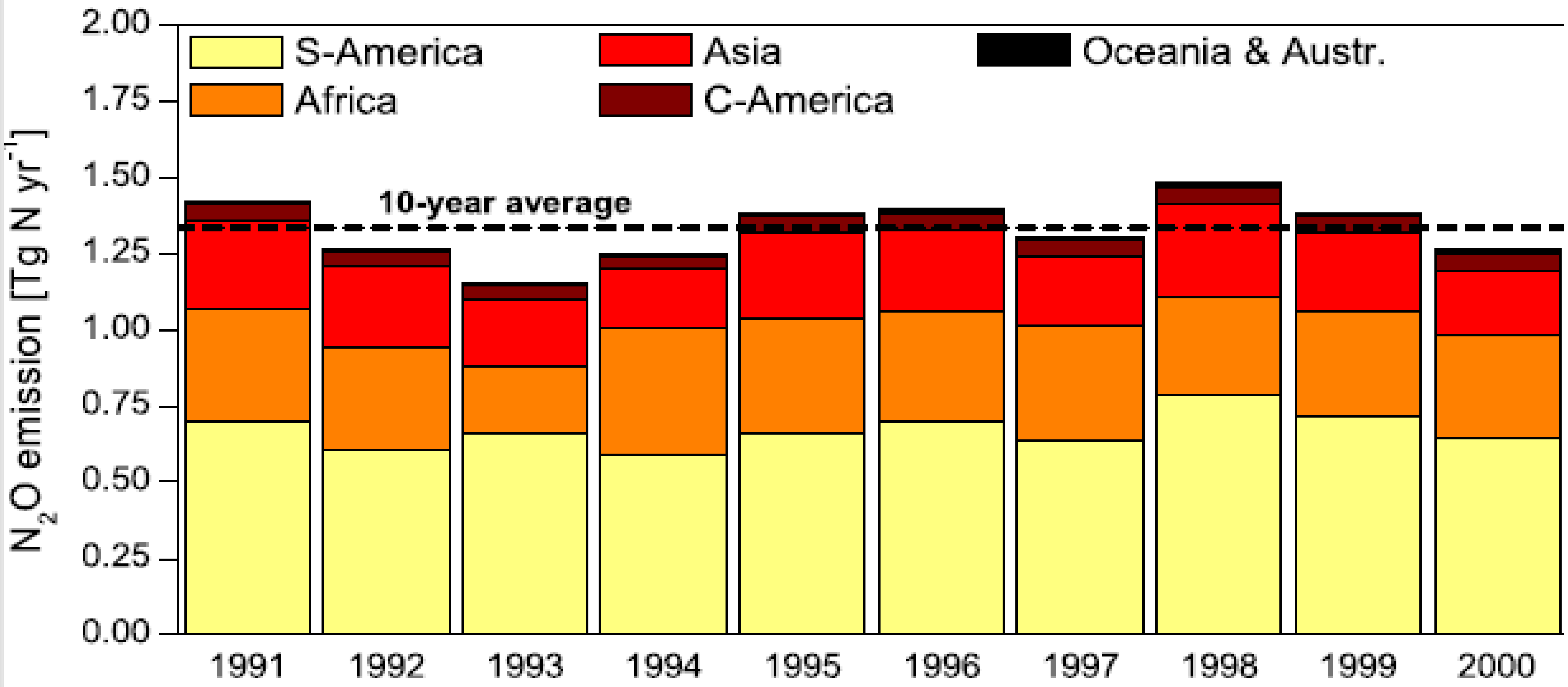
Global N_2O inventory





Werner et al., 2007, JGR – Global Biogeochem. Cycl.

Interannual variability



Werner et al., 2007, JGR – Global Biogeochem. Cycl.

Comparison with earlier estimates

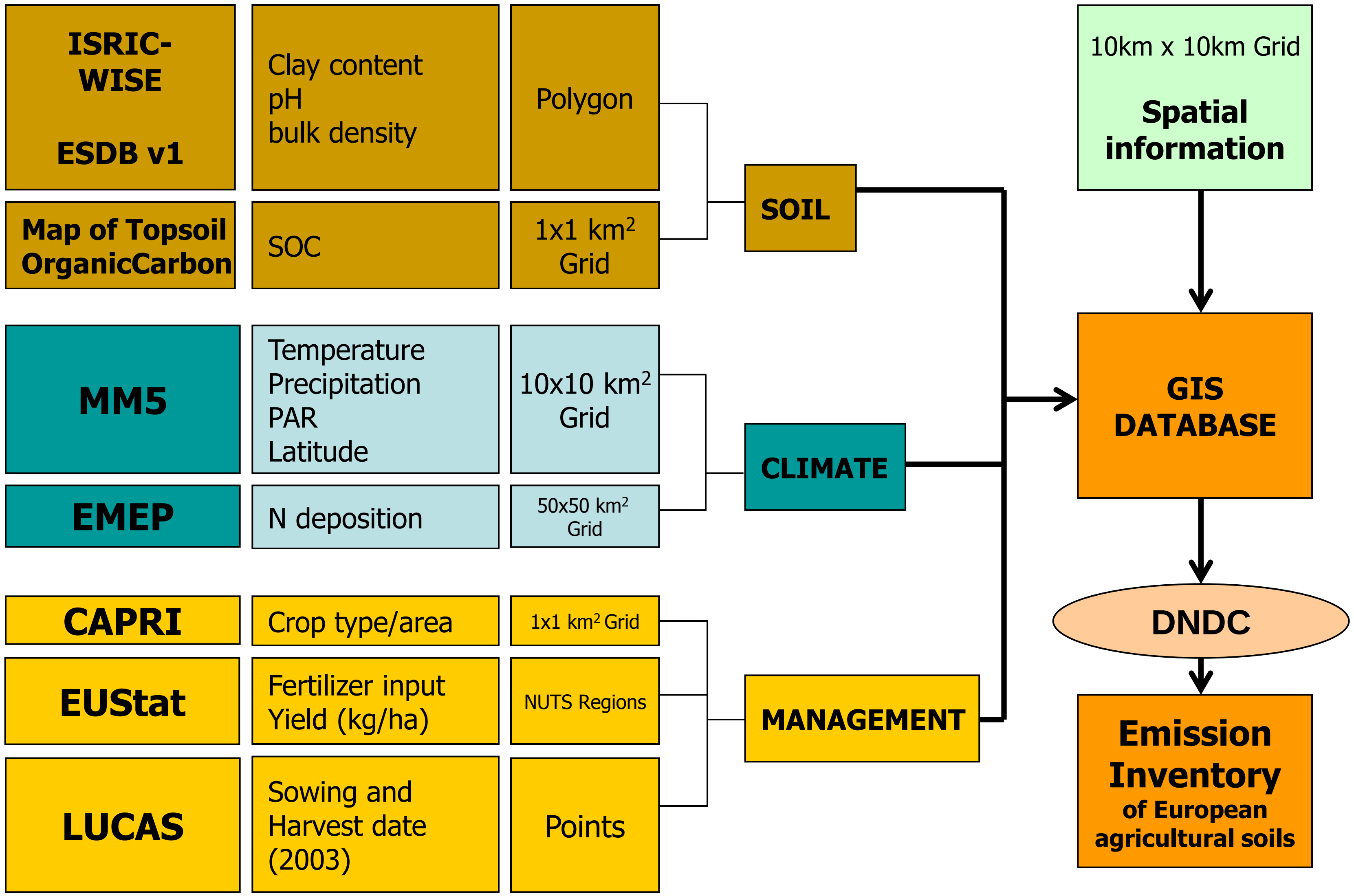
- What is the area we are talking about?
  (all N_2O emissions scaled to the area used in this study; orange: scaled / white: original)
- Matson and Vitousek 1990: 1.8 Tg N yr^{-1} (2.4 Tg N yr^{-1})
- Bouwman et al. 1995: 1.5 Tg N yr^{-1} (2.3 Tg N yr^{-1})
- Potter 1998: 1.3 Tg N yr^{-1}
- Breuer et al. 2000: 2.6 Tg N yr^{-1} (3.55 Tg N yr^{-1})
- Stehfest and Bouwman 2006: 1.5 Tg N yr^{-1} (1.17 Tg N yr^{-1})
- This study: 1.3 Tg N yr-1 (± 0.3 SD)

Werner et al., 2007, JGR – Global Biogeochem. Cycl.

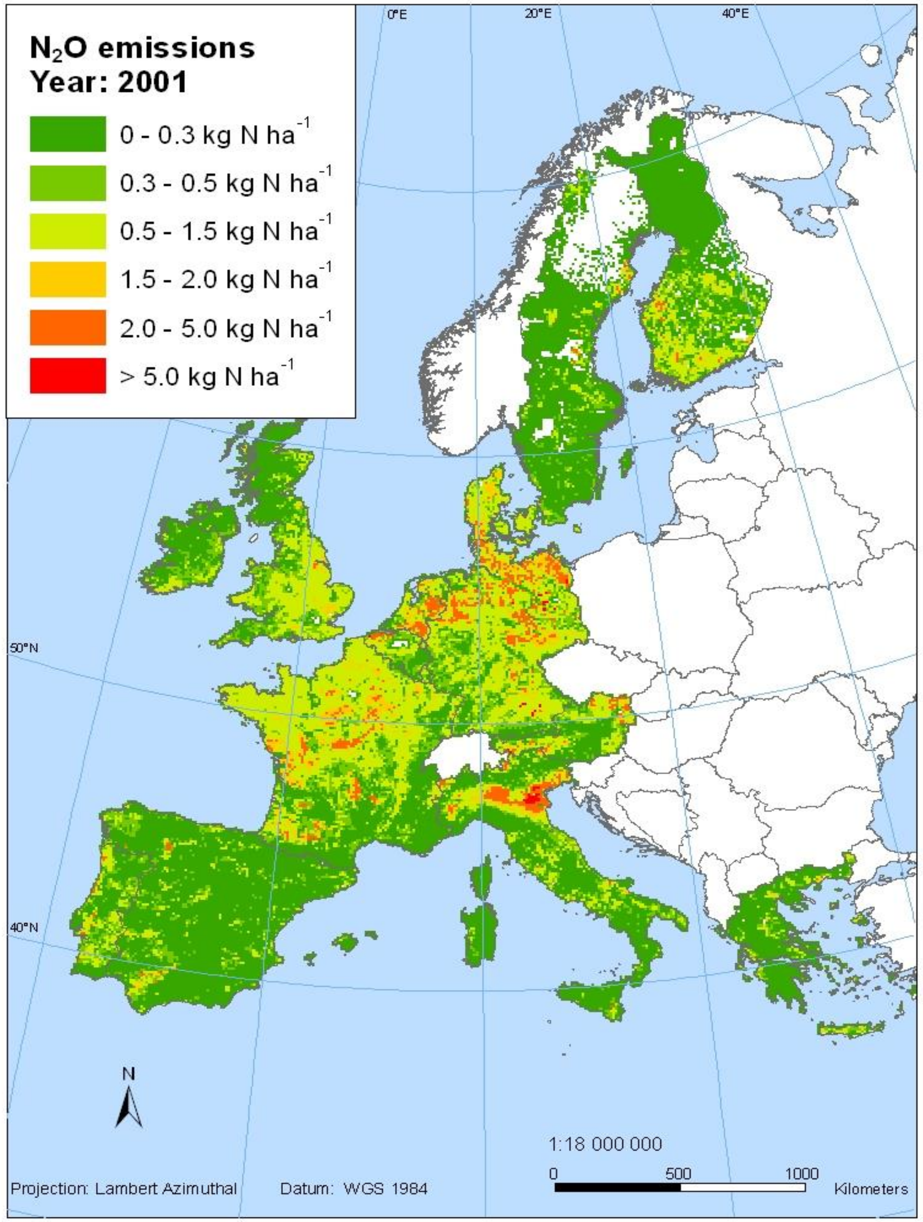
Predictions for Europe

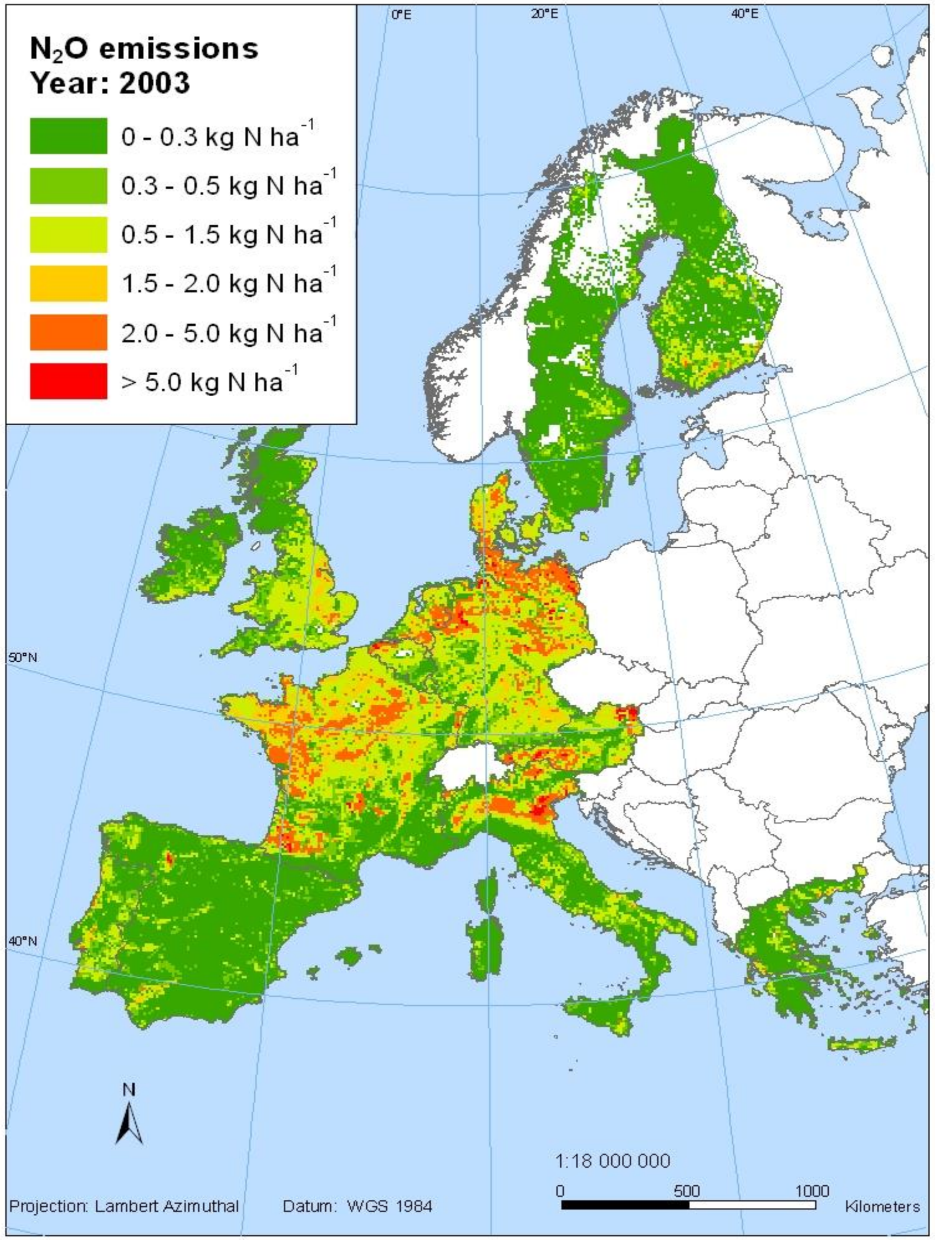
GIS database for DNDC

Data source **Data content** **format**



Identifying key regions and interannual variabilities

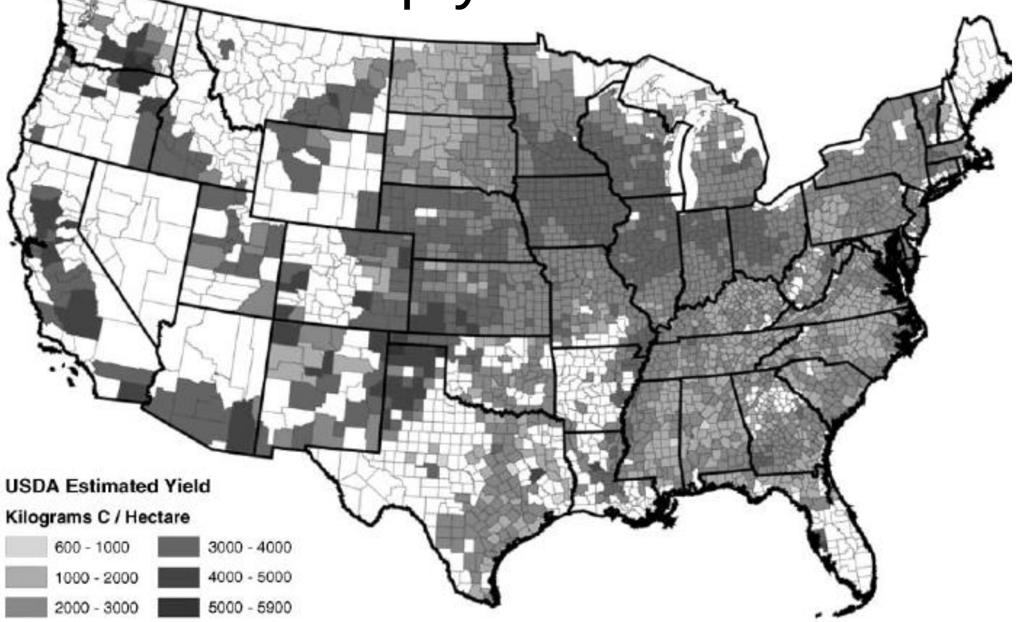




Identifying key regions

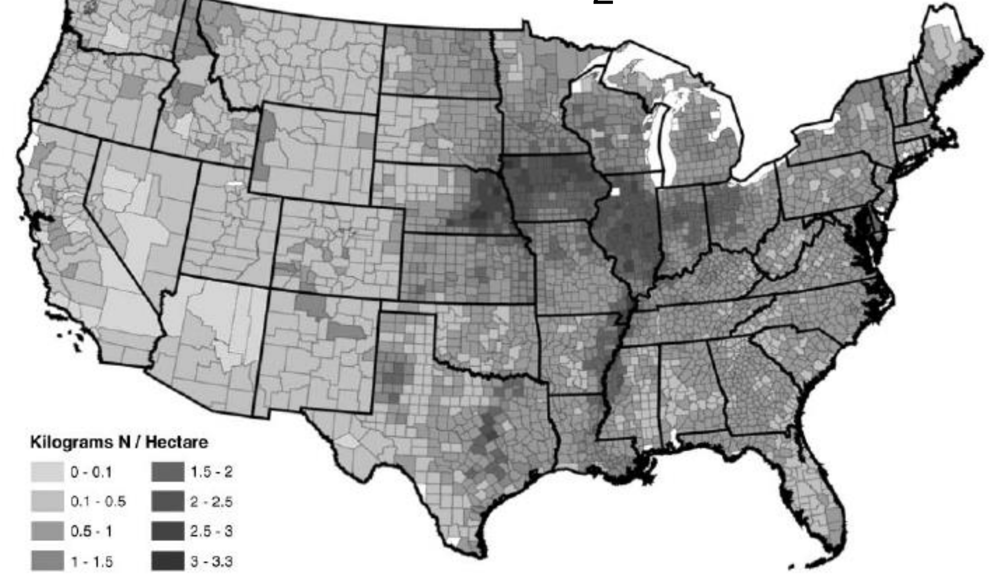
Crop yield - statistics

a)



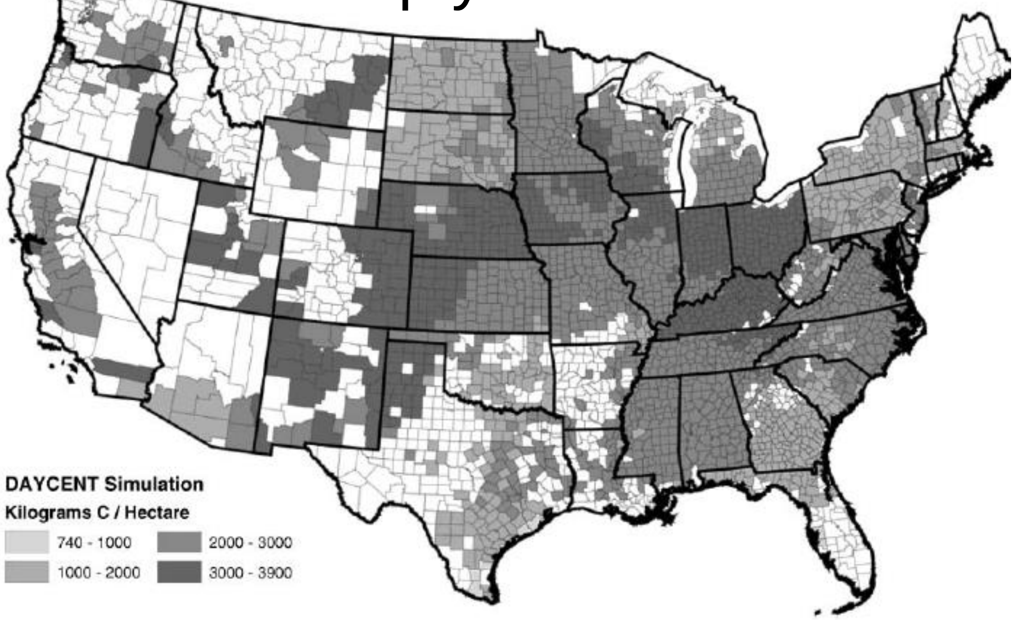
Simulated N_2O

a)



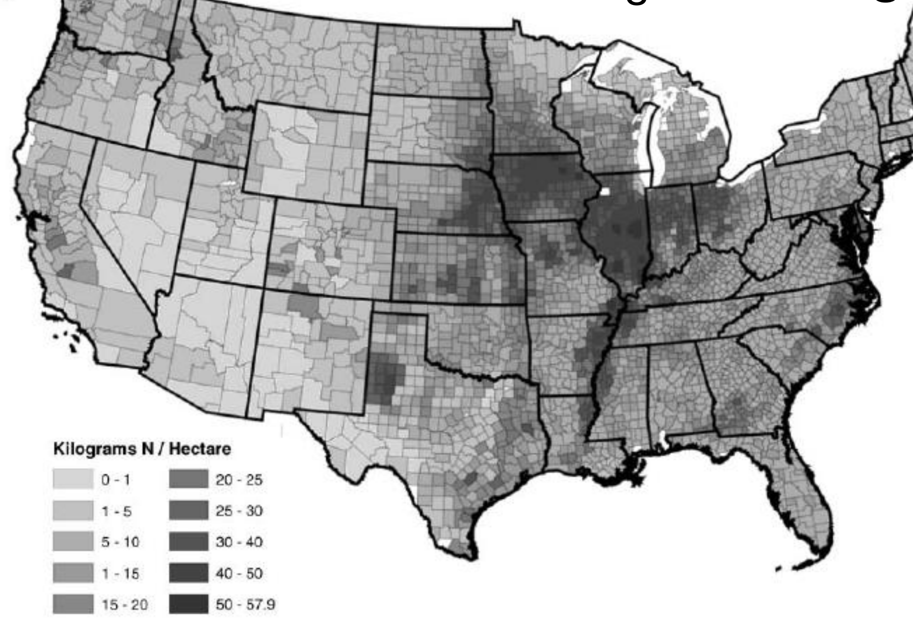
Crop yield - DAYCENT

b)



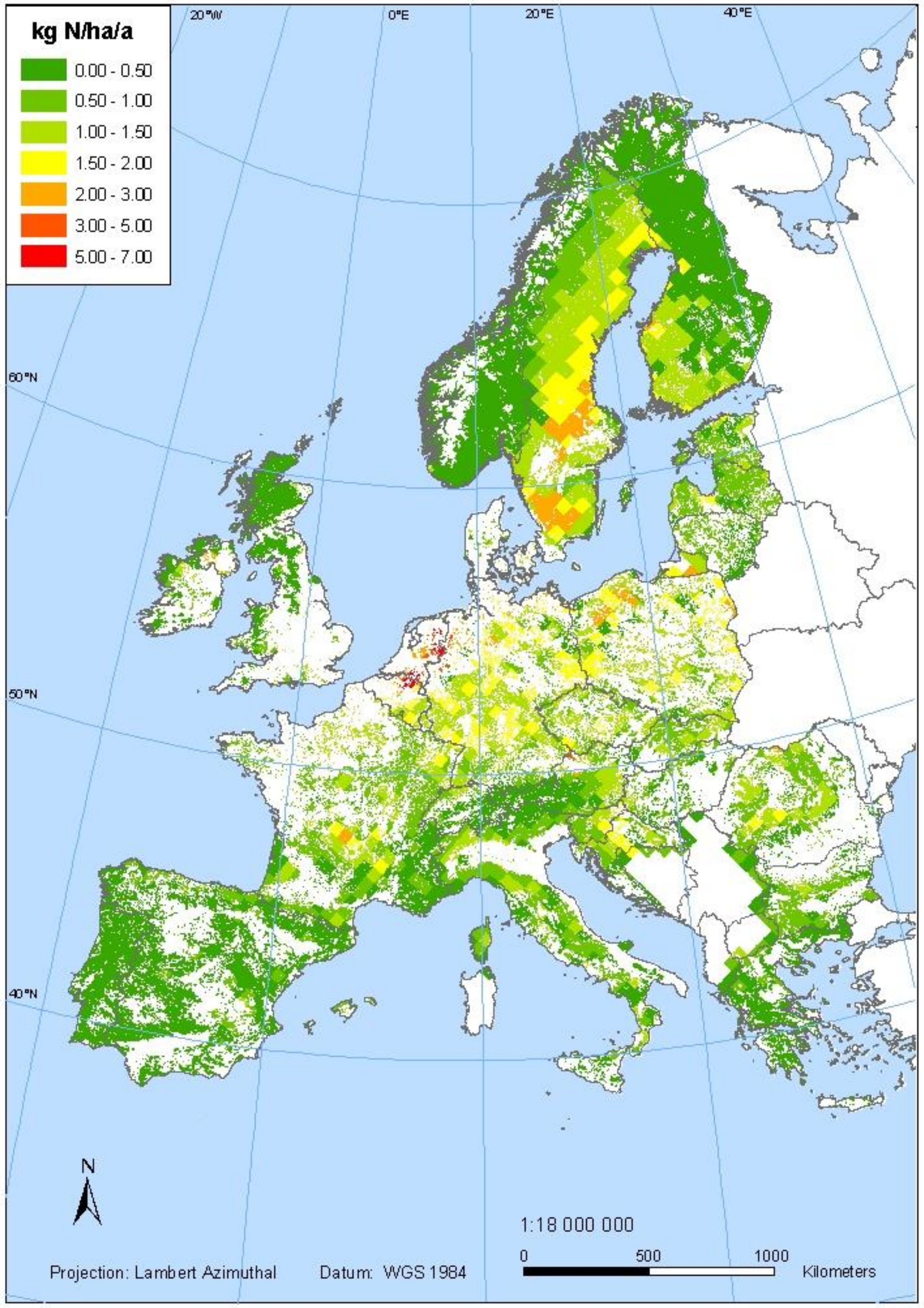
Simulated NO_3 leaching

b)



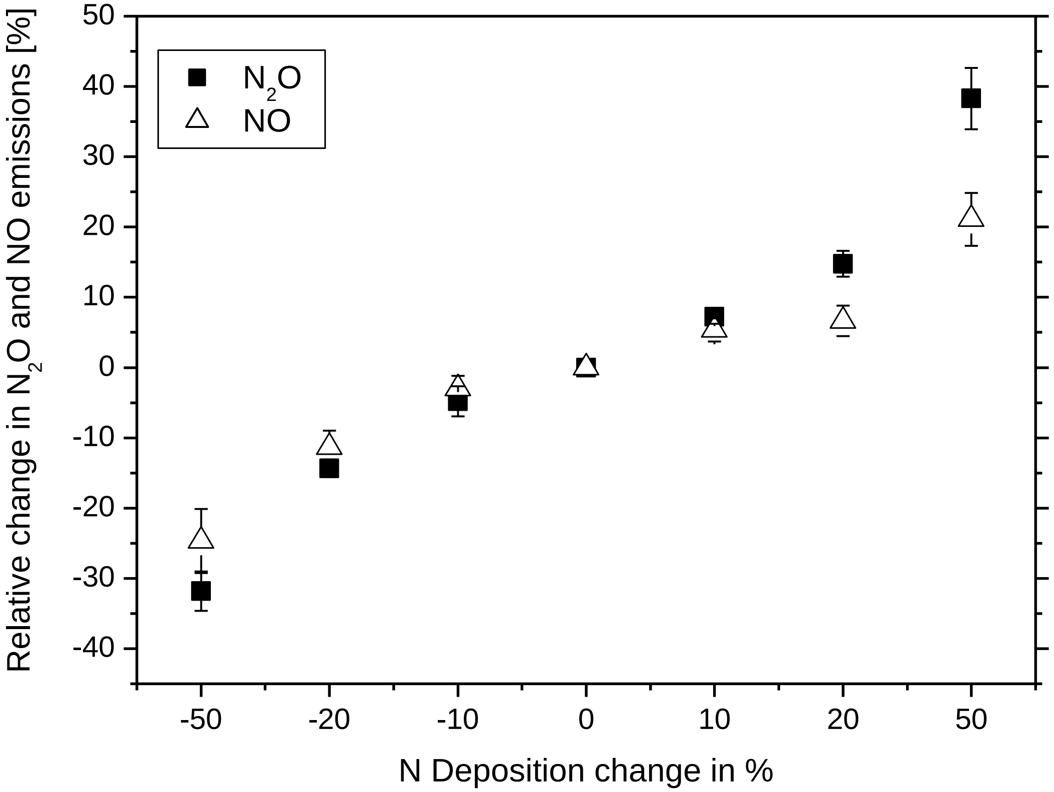
Del Grosso et al., 2006, J. Env. Qual.

Inventorying soil N trace gas fluxes and identifying feedbacks



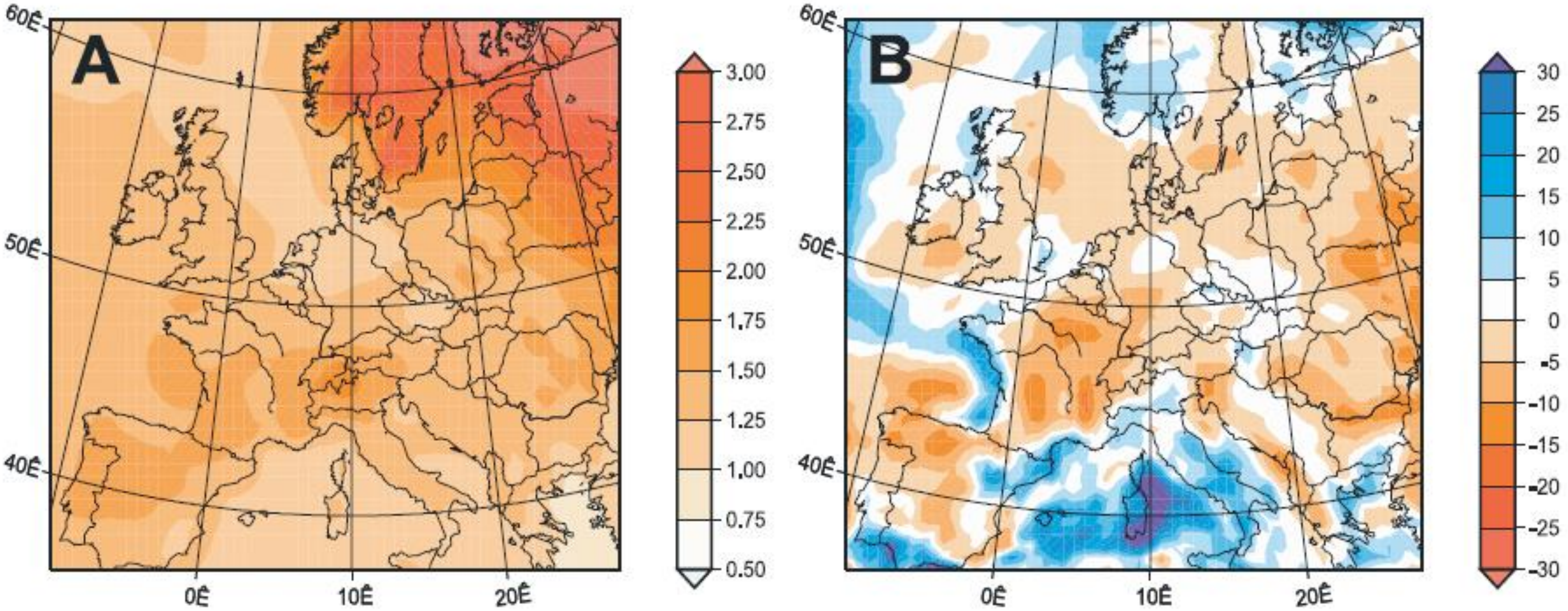
NO Emissions	Minimum Scenario kt N a^{-1}	Average Scenario kt N a^{-1}	Maximum Scenario kt N a^{-1}
1990	45	98	248
1995	38	85	220
2000	45	99	254

Simulated forest area of Europe: 1 410 477km²



Climate change feedbacks

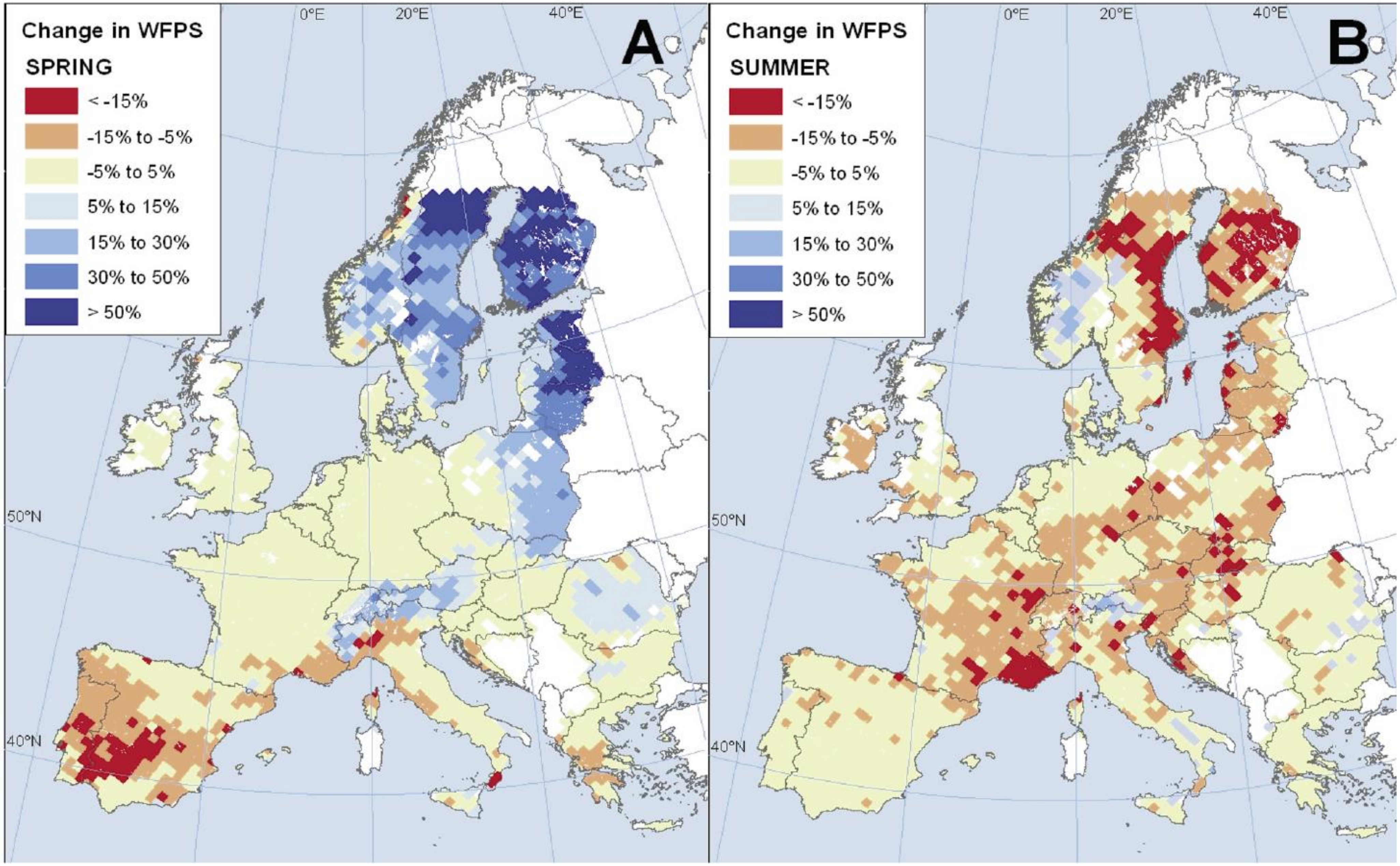
(2031-2039) - (1991-2000) [A2 scenario]



ECHAM4 → MCCM/MM5 regionalisation (60kmx60km)

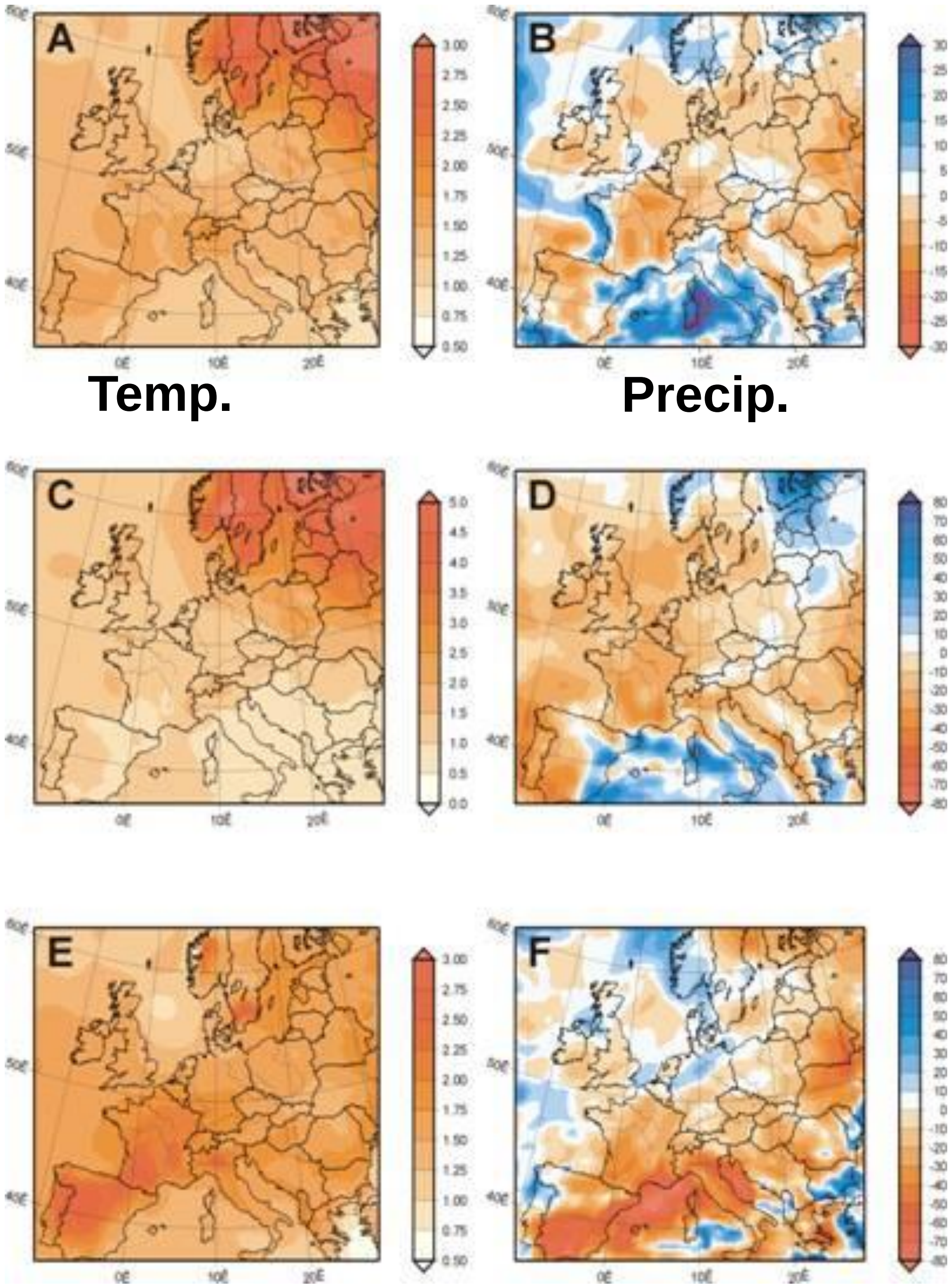
Climate change feedbacks (2031-2039) - (1991-2000)

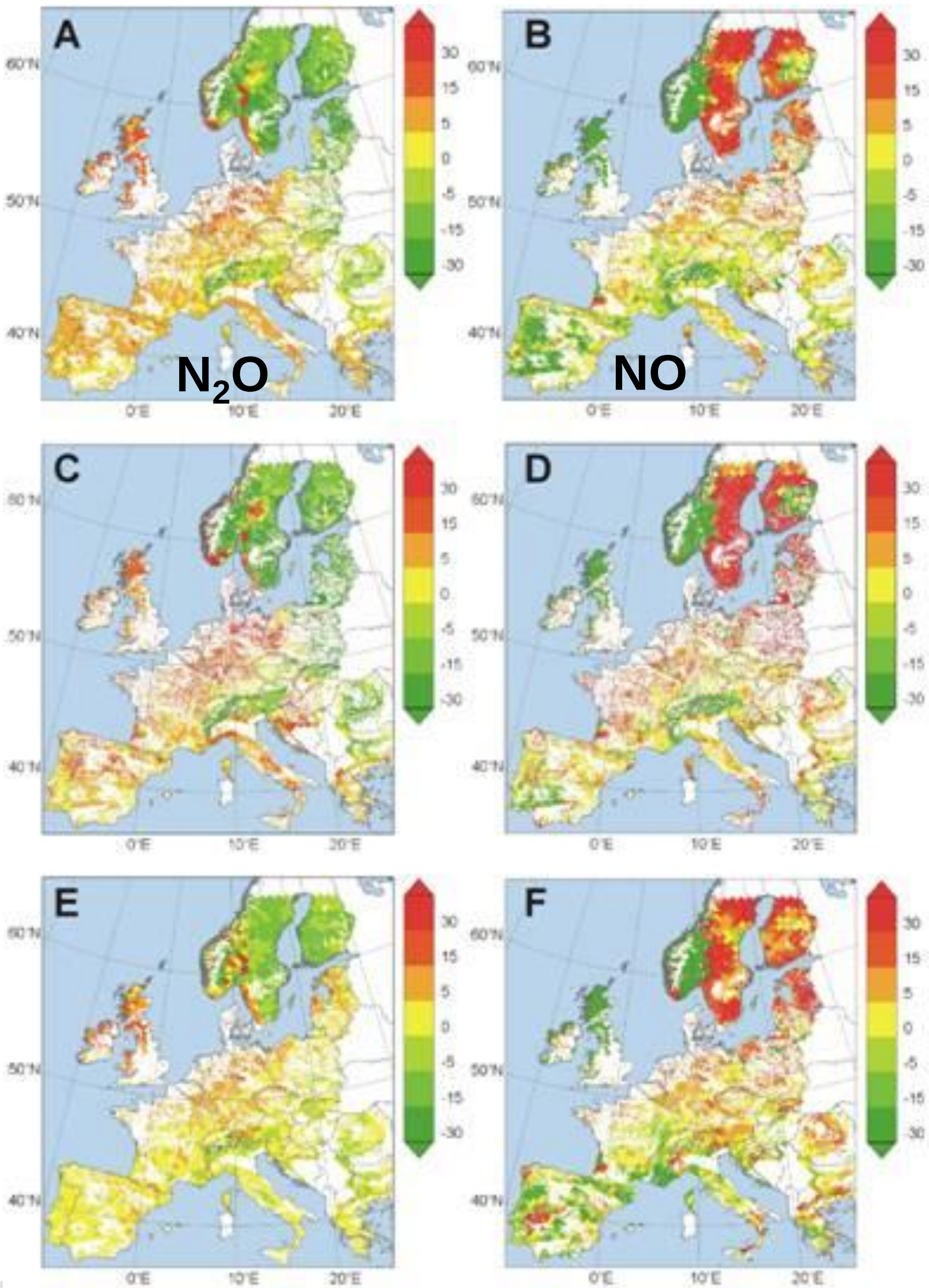
Seasonal changes in soil moisture



Kesik et al., 2006, JGR - Biogeosciences

Climate feedbacks on forest soil N_2O/NO emissions





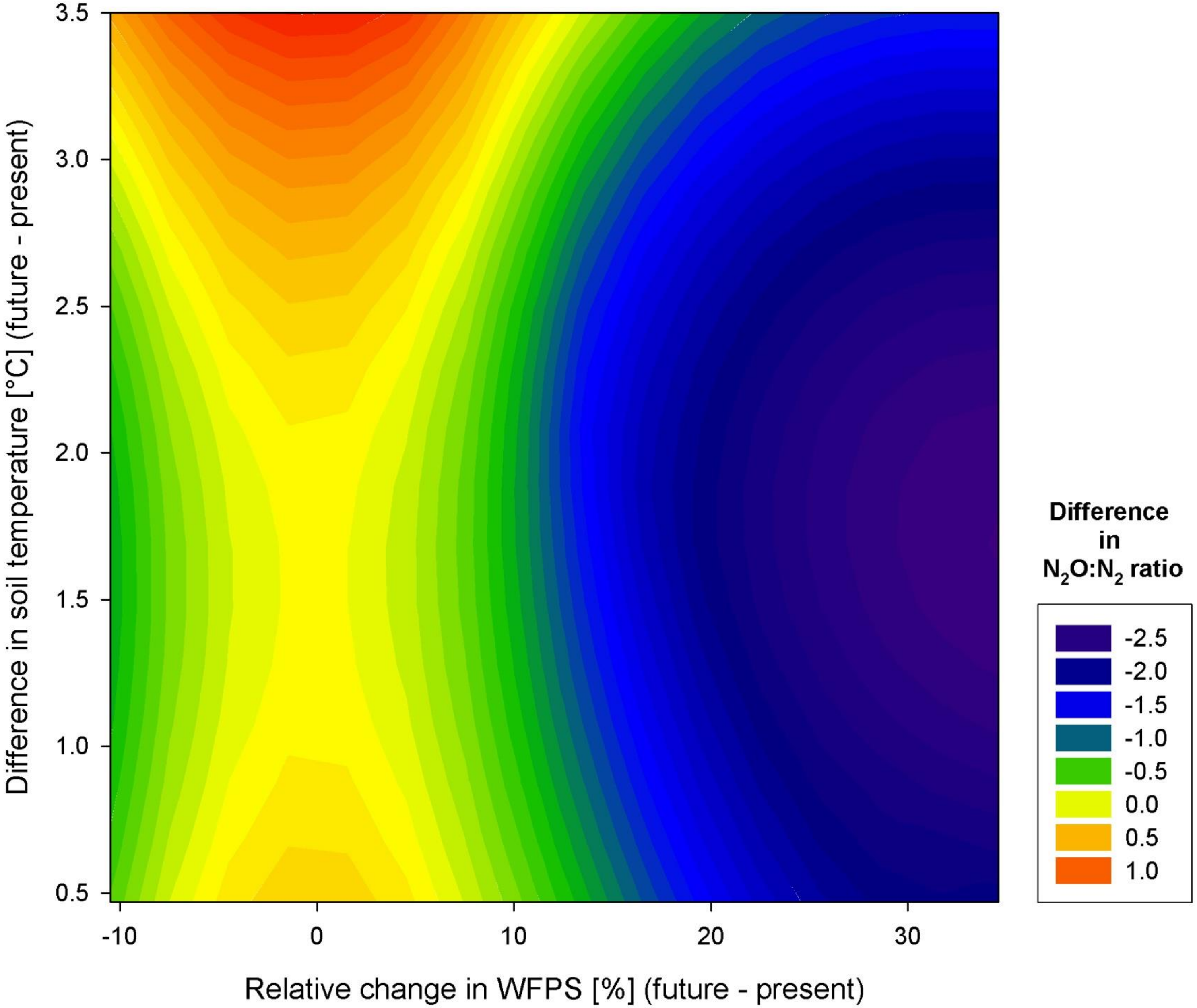
Kesik et al., 2006, JGR - Biogeosciences

Climate feedbacks on forest soil N_2O/NO emissions

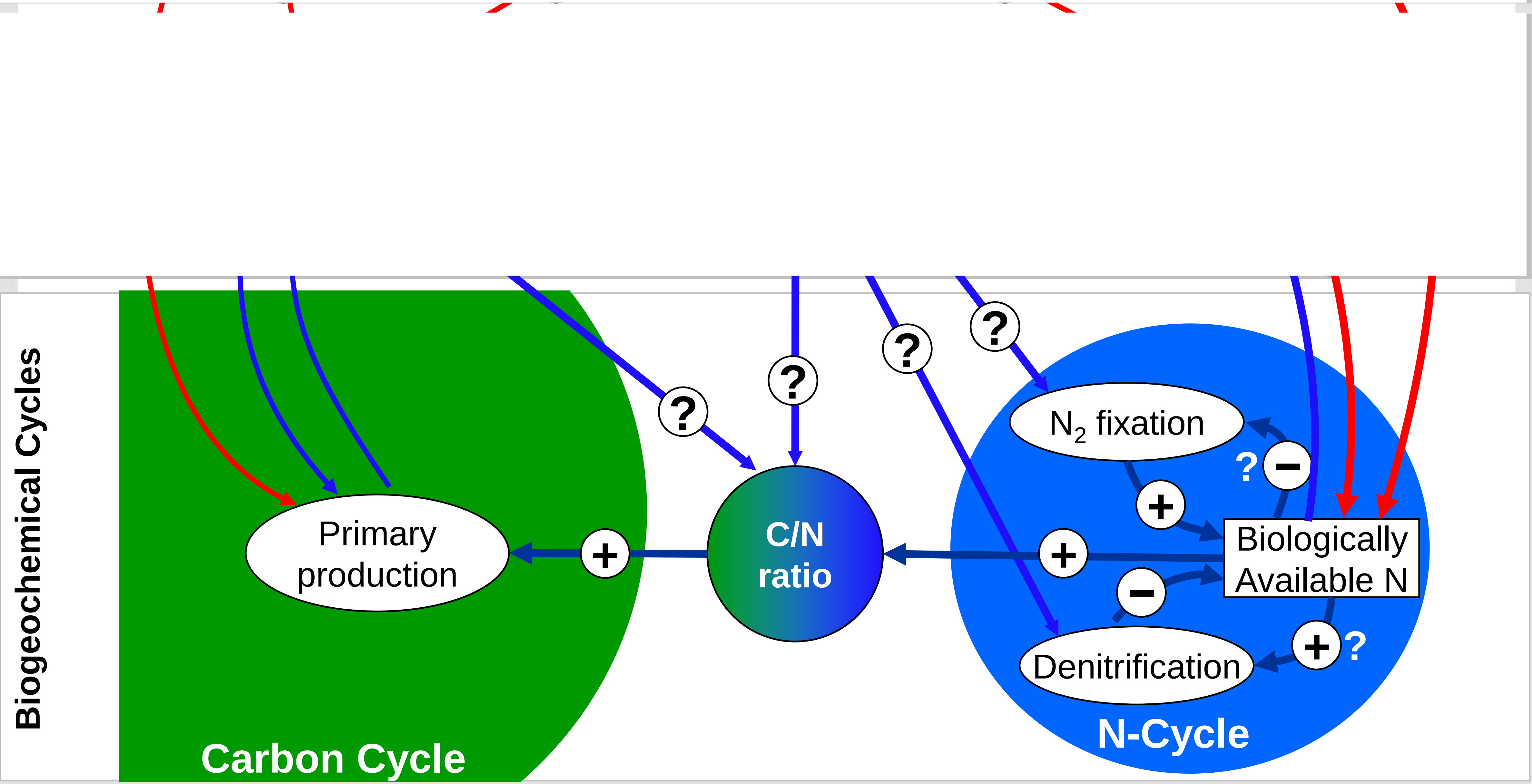
Country	Forest Area, km^2	N_2O 1991–2000 kg N ha^{-1} yr^{-1}	N_2O 1991–2000 kt N yr^{-1}	N_2O 2031–2039 kg N ha^{-1} yr^{-1}	N_2O 2031–2039 kt N yr^{-1}	Change in Emission, %	NO 1991–2000 kg N ha^{-1} yr^{-1}	NO 1991–2000 kt N yr^{-1}	NO 2031–2039 kg N ha^{-1} yr^{-1}	NO 2031–2039 kt N yr^{-1}	Change in Emission, %
Andorra	232	0.16	3.7×10^{-3}	0.17	3.9×10^{-3}	6	0.21	4.9×10^{-3}	0.12	2.8×10^{-3}	−44
Austria	24,032	0.46	1.11	0.43	1.03	−7	0.44	1.07	0.41	1.00	−6
Belgium	7699	0.77	0.59	0.87	0.67	14	1.53	1.18	1.73	1.33	13
Bulgaria	28,494	0.52	1.50	0.51	1.45	−3	0.32	0.90	0.30	0.86	−4
Croatia	12,574	0.46	0.57	0.49	0.62	8	0.46	0.58	0.46	0.58	1
Czech.	20,406	0.43	0.88	0.44	0.91	3	0.66	1.36	0.68	1.39	2
Republic	18,608	0.60	1.12	0.72	1.34	21	0.89	1.66	1.05	1.95	18
Denmark	18,341	0.60	1.10	0.40	0.73	−33	0.50	0.91	0.61	1.12	23
Estonia	116,126	0.82	9.54	0.62	7.21	−24	0.48	5.59	0.59	6.80	22
Finland	132,395	0.44	5.81	0.48	6.34	9	0.55	7.23	0.55	7.32	1
Germany	117,849	0.56	6.57	0.63	7.43	13	0.95	11.15	1.04	12.24	10
Gibraltar	0.43	0.58	2.5×10^{-5}	0.63	2.7×10^{-5}	9	0.06	2.7×10^{-6}	0.07	2.9×10^{-6}	7
Greece	30,676	0.50	1.54	0.53	1.64	7	0.28	0.87	0.29	0.88	1
Hungary	21,181	0.63	1.32	0.62	1.32	0	0.35	0.73	0.34	0.72	−2
Irish Republic	5523	0.20	0.11	0.24	0.13	20	0.50	0.28	0.49	0.27	−3
Italy	59,834	0.48	2.89	0.49	2.96	3	0.40	2.39	0.40	2.42	1
Latvia	28,229	0.66	1.86	0.46	1.29	−30	0.57	1.60	0.67	1.89	18
Liechtenstein	89	0.56	4.9×10^{-3}	0.36	3.2×10^{-3}	−35	0.42	3.8×10^{-3}	0.30	2.6×10^{-3}	−30
Lithuania	18,843	0.46	0.87	0.36	0.68	−23	0.40	0.76	0.41	0.78	2
Luxembourg	1032	0.45	0.05	0.52	0.05	15	0.81	0.08	0.82	0.08	2
Monaco	0.21	0.19	3.9×10^{-6}	0.21	4.4×10^{-6}	12	0.11	2.4×10^{-6}	0.08	1.7×10^{-6}	−28
Netherlands	8271	1.17	0.97	1.36	1.13	16	2.53	2.09	3.01	2.49	19
Norway	108,987	0.18	1.91	0.13	1.45	−24	0.16	1.74	0.06	0.67	−62
Poland	78,358	0.56	4.26	0.50	3.82	−10	0.76	5.84	0.86	6.58	13
Portugal	32,713	0.41	1.35	0.44	1.44	7	0.14	0.47	0.12	0.40	−15
Romania	41,284	0.69	2.85	0.62	2.56	−10	0.41	1.70	0.42	1.73	2
San Marino	0.35	0.23	8.2×10^{-6}	0.25	8.9×10^{-6}	8	0.24	8.4×10^{-6}	0.20	7.0×10^{-6}	−17
Slovakia	9162	0.68	0.62	0.60	0.55	−12	0.47	0.43	0.48	0.44	2
Slovenia	7881	0.48	0.3	0.49	0.39	2	0.49	0.39	0.45	0.35	−8
Spain	128,484	0.54	7.49	0.58	8.08	8	0.25	3.49	0.24	3.27	−6
Sweden	163,782	0.60	9.91	0.48	7.93	−20	0.71	11.70	0.92	15.12	29
Switzerland	12,407	0.40	0.49	0.35	0.43	−12	0.42	0.53	0.34	0.42	−21
United Kingdom	22,481	0.27	0.62	0.33	0.73	19	0.56	1.27	0.55	1.23	−3
Sum	1,283,978		68.27		64.32			67.96		74.32	
Average		0.53		0.50		−6	0.53		0.58		9

Kesik et al., 2006, JGR - Biogeosciences

Climate feedbacks on N_2O/N_2 ratio. Is this realistic?



Kesik et al., 2006, JGR - Biogeosciences

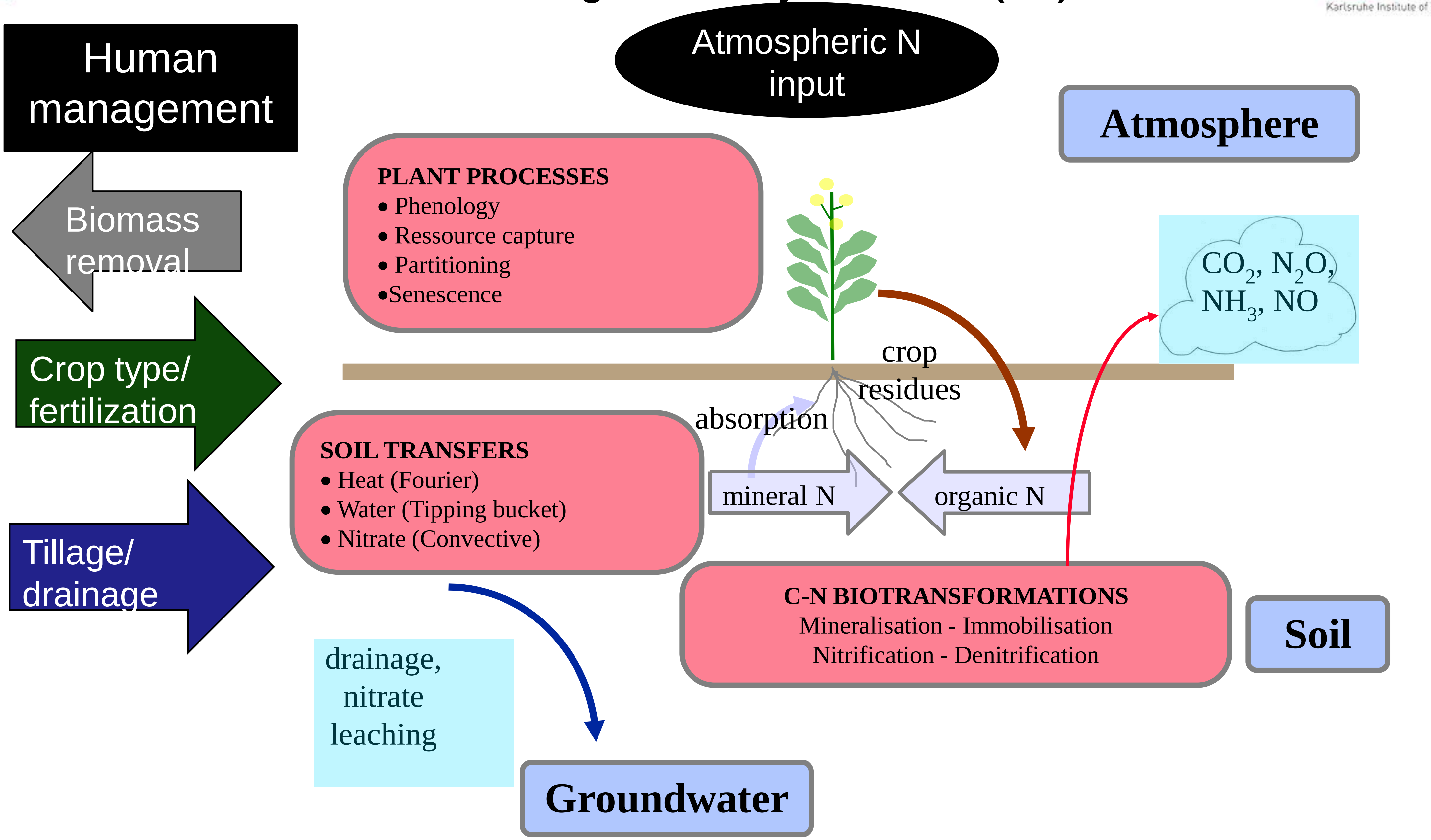


Gruber & Galloway, Nature 2008

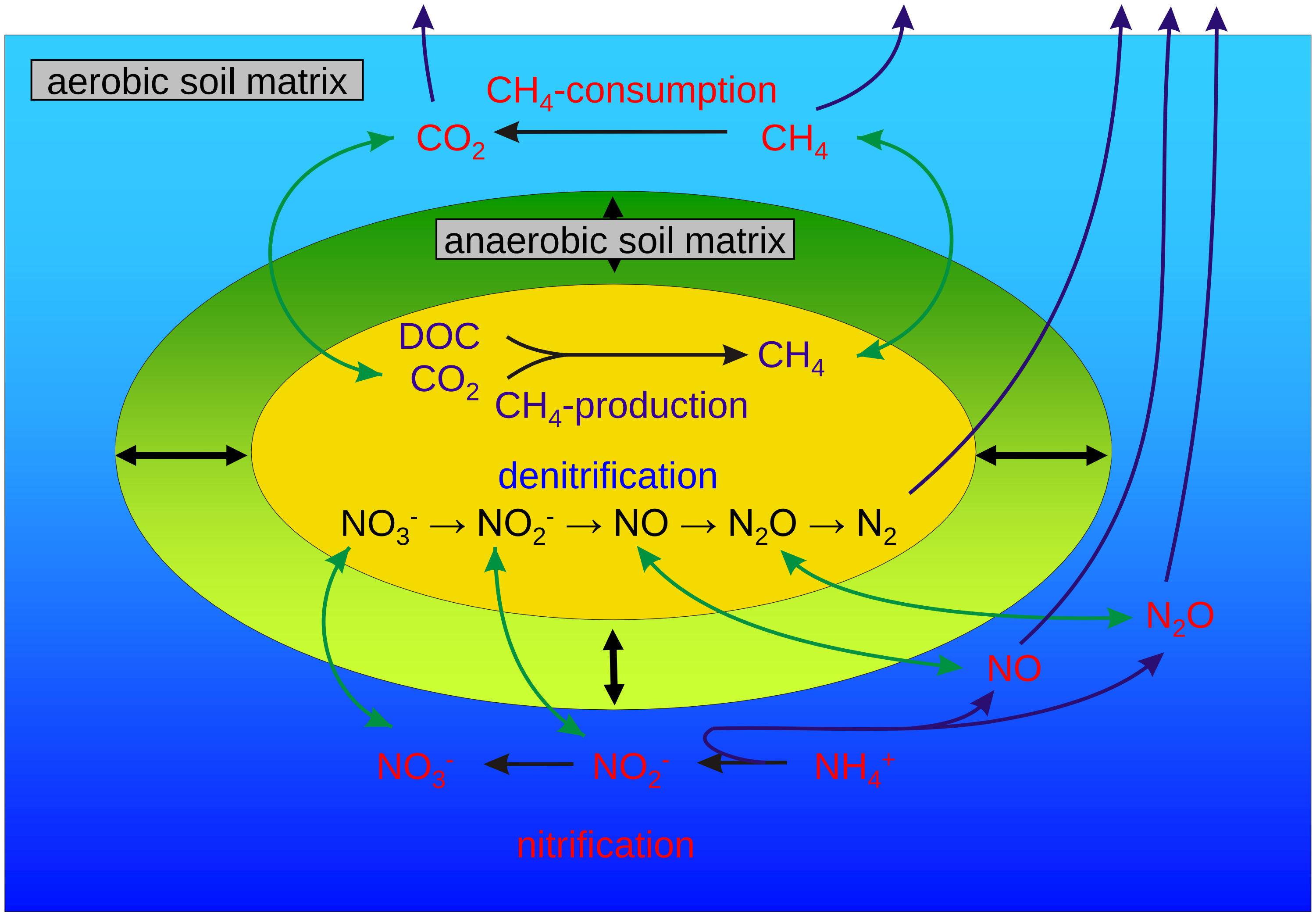
Summary

- Nr emission/ deposition processes are by far more complex as compared to e.g. CO_2-exchange processes, due to
  - Complexity of involved processes
  - Complexity of feedbacks to environmental drivers
  - N_r cascading on landscape/regional and global scales
- Understanding of microbial production and consumption processes under changing environmental conditions is still incomplete, and
  - Link between process understanding, field observations and model implementation cannot always be established
  - Closing the N cycling remains difficult due to uncertain N_2 losses
- Long-term measurements are needed [holistic approach]
- Models need to address the regional scale and linking of biogeochemical models to hydrological models is needed

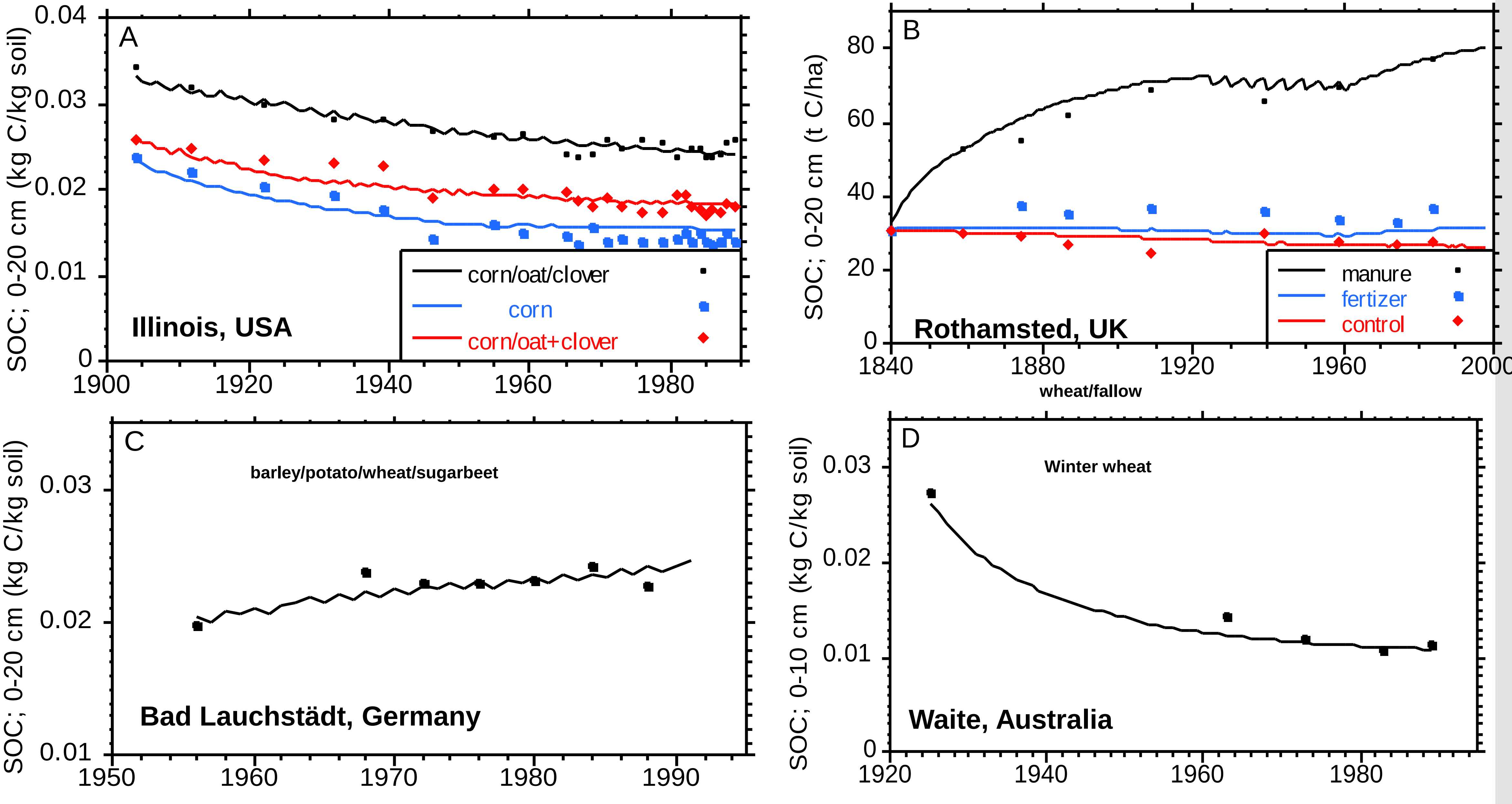
Process oriented modeling of ecosystem N- (C-) fluxes



Conceptual model of an anaerobic balloon

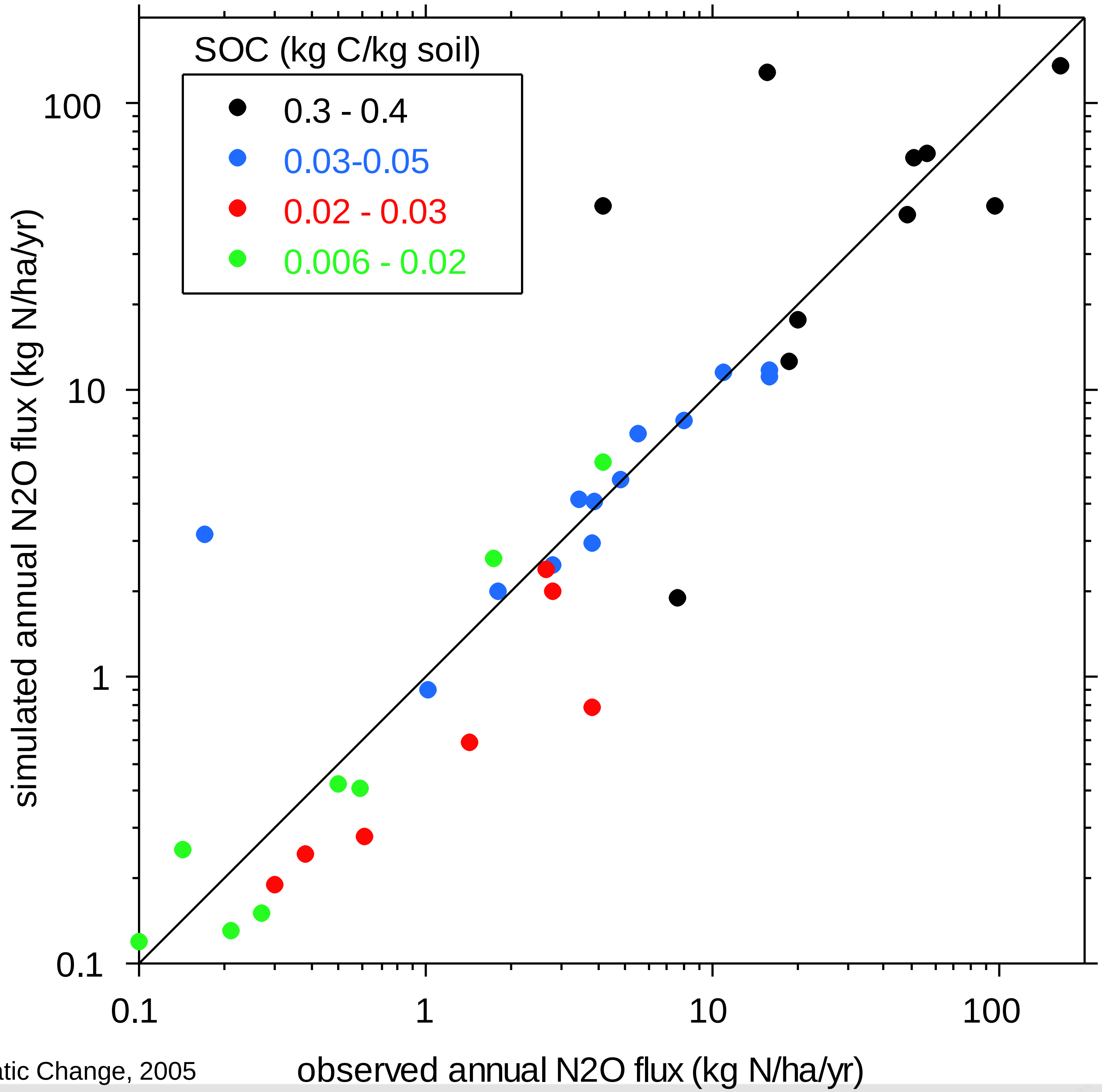


Model evaluation: SOC dynamics



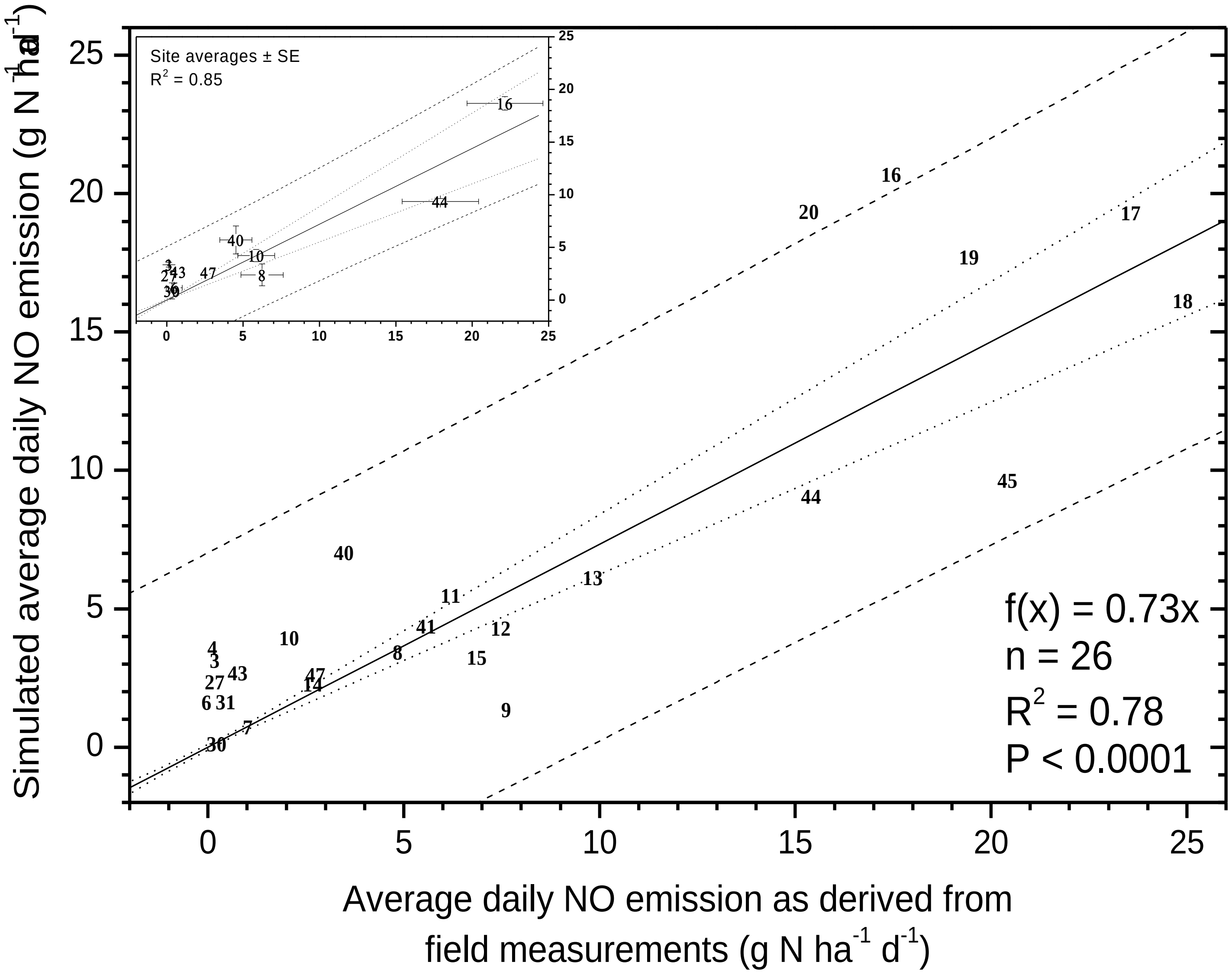
Li, Frolking, Butterbach-Bahl, Climatic Change, 2005

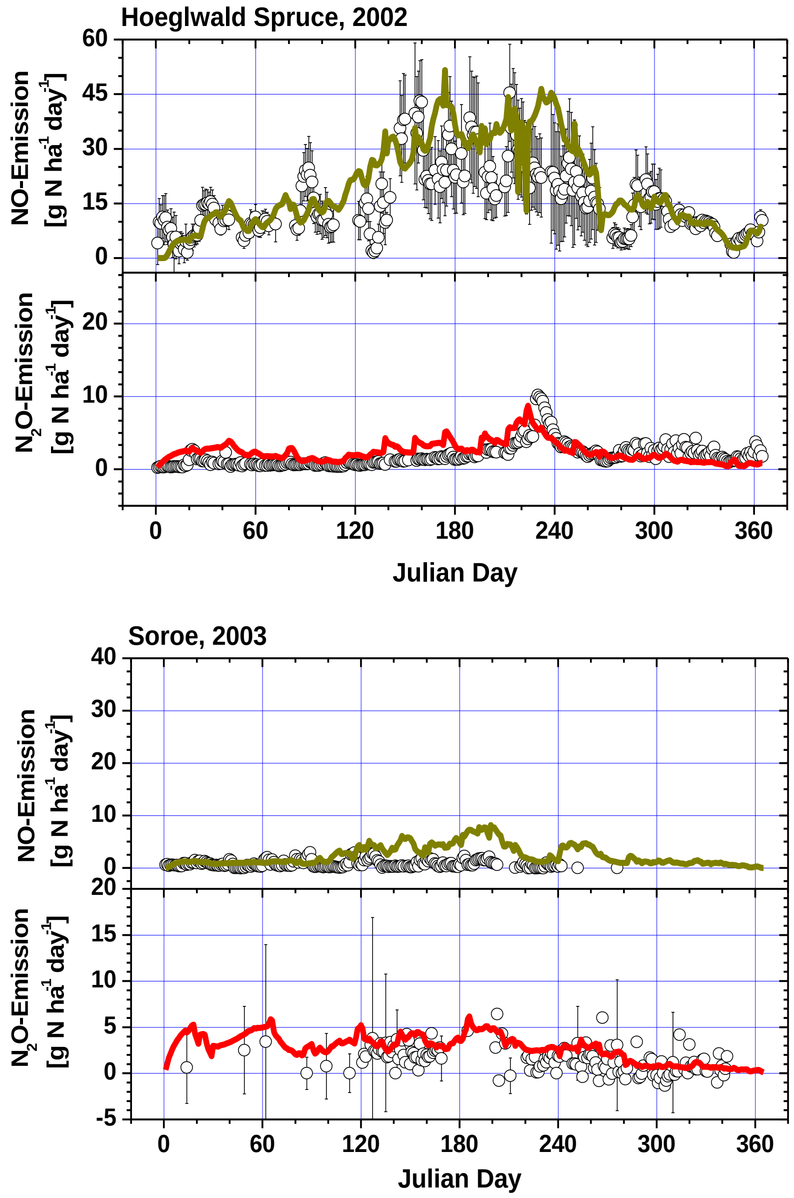
Model evaluation: N_2O fluxes



Li, Frolking, Butterbach-Bahl, Climatic Change, 2005

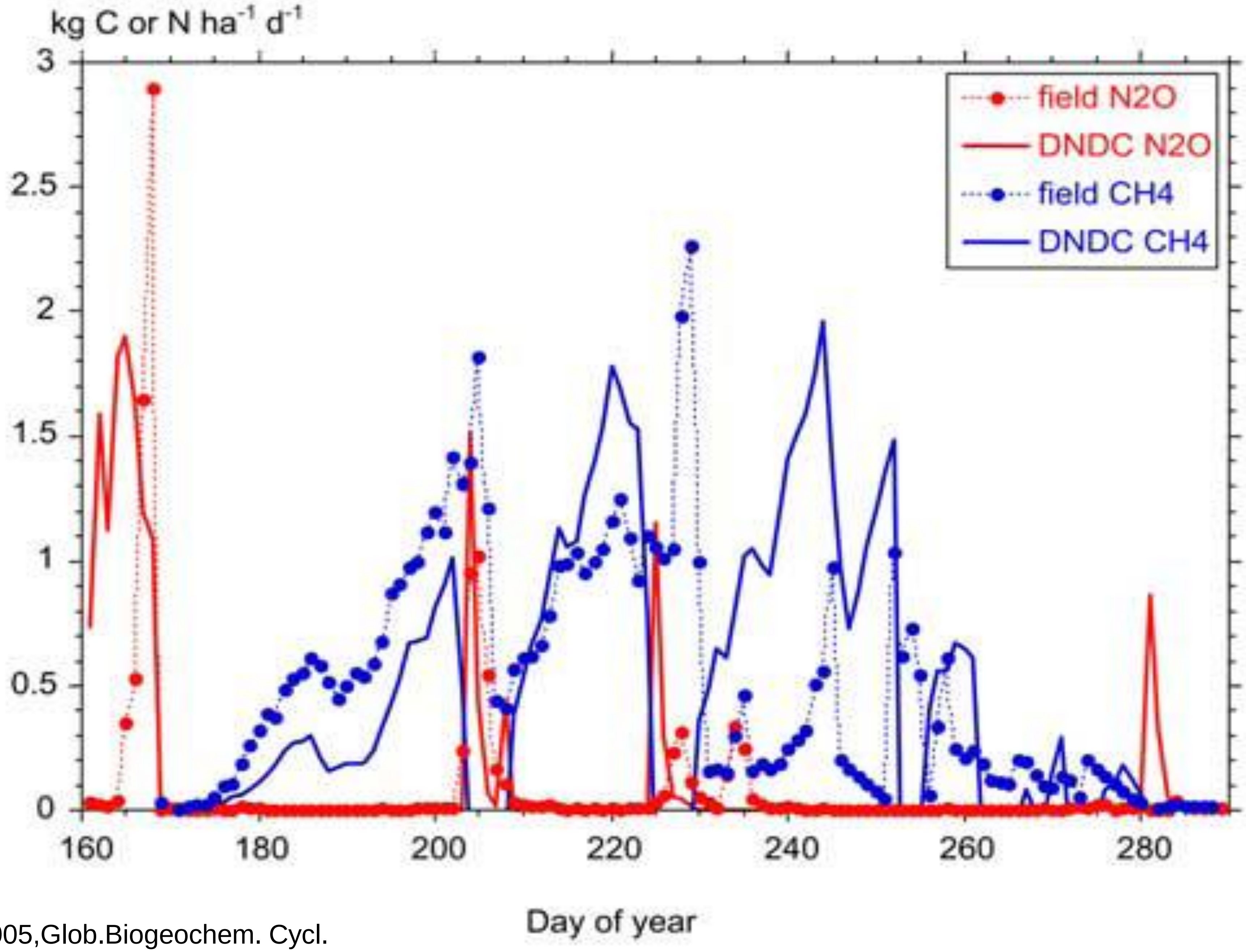
Model evaluation: NO fluxes [forests]





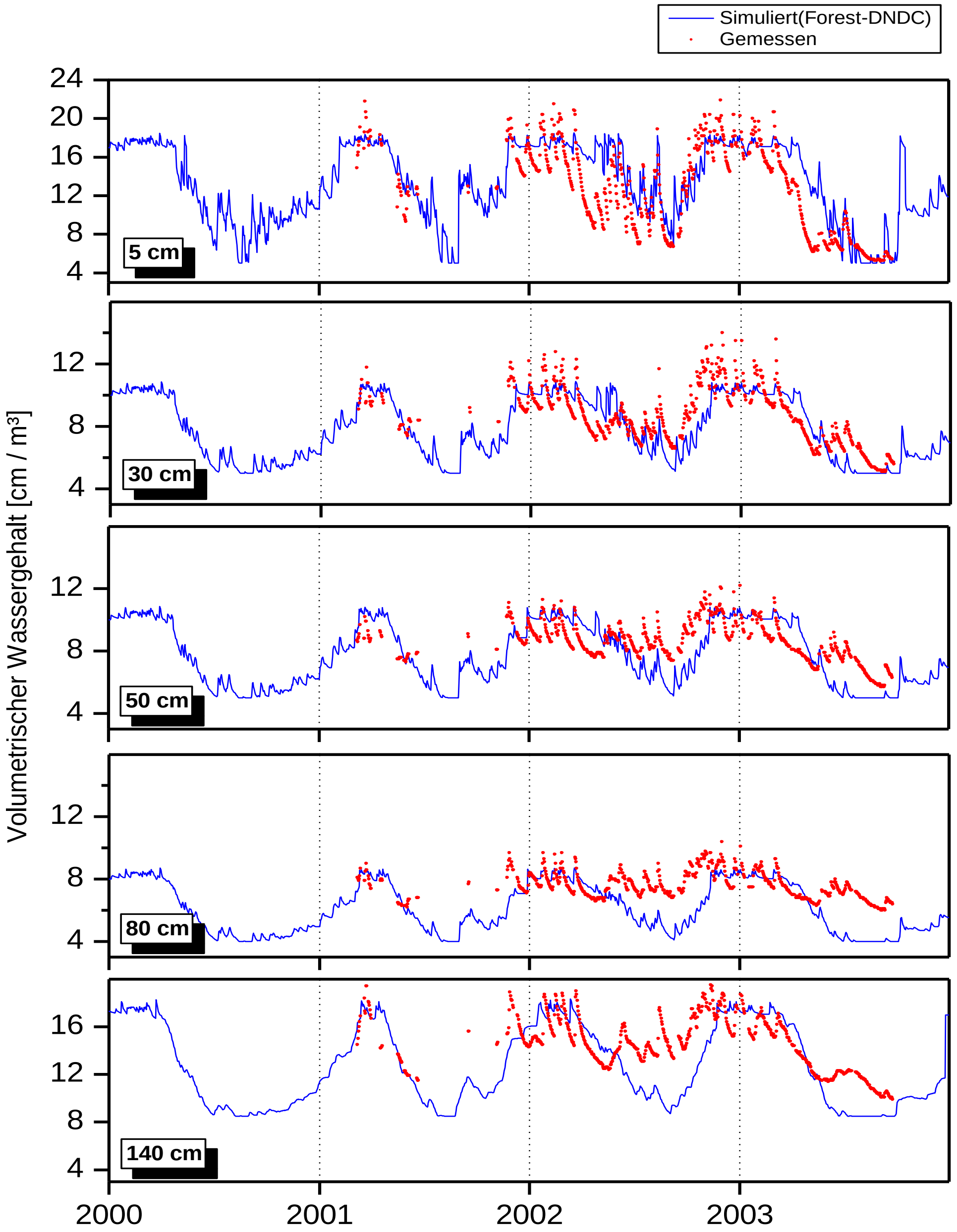
Kesik et al., 2006, Biogeosciences

Eh changes driven in CH_4/N_2O fluxes in rice paddies

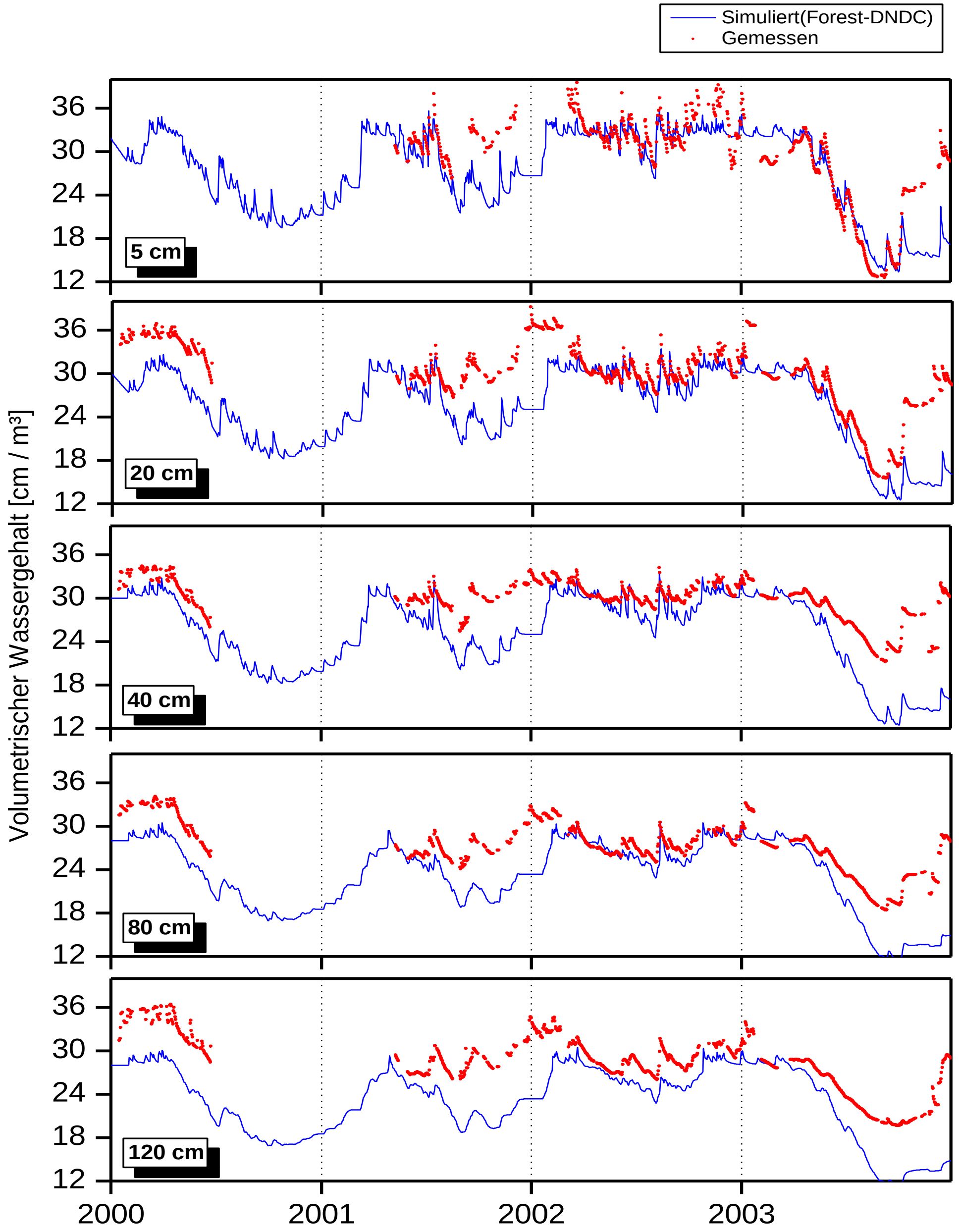


Li et al., 2005,Glob.Biogeochem. Cycl.

Model evaluation: Soil water fluxes



Altdorf



Flossenbürg