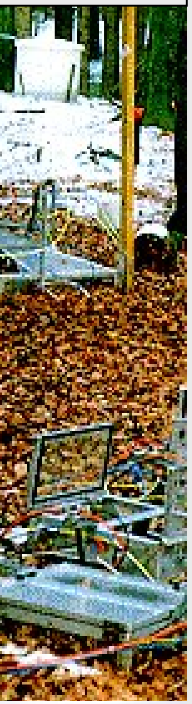


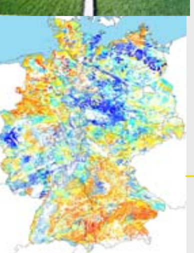

Consequences of N deposition on biosphere-atmosphere exchange of N and C trace gases in forests: results and modelling studies

Klaus Butterbach-Bahl

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Atmospheric Environmental Reseaerch (IMK-IFU)

Forschungszentrum Karlsruhe

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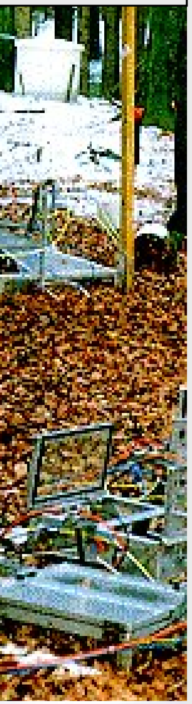
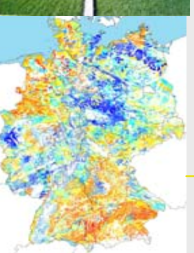
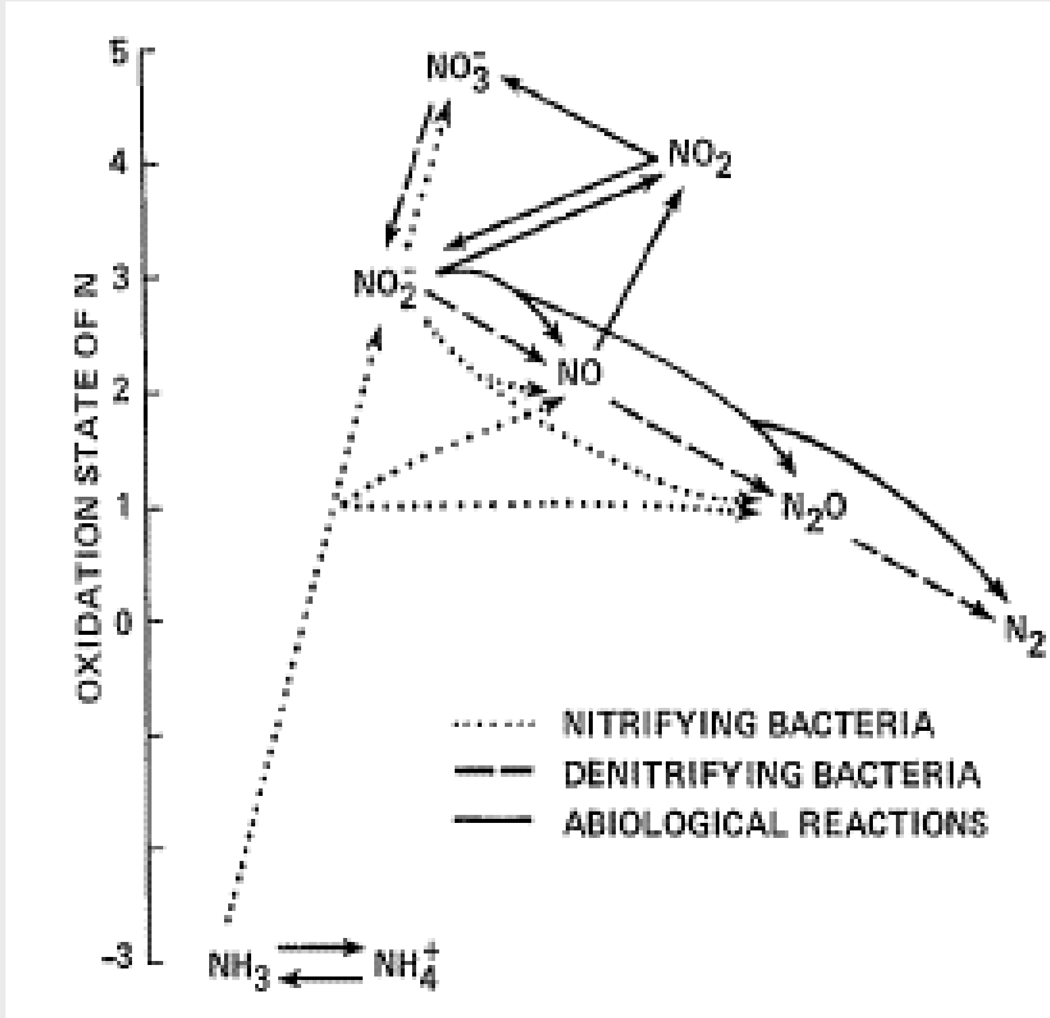






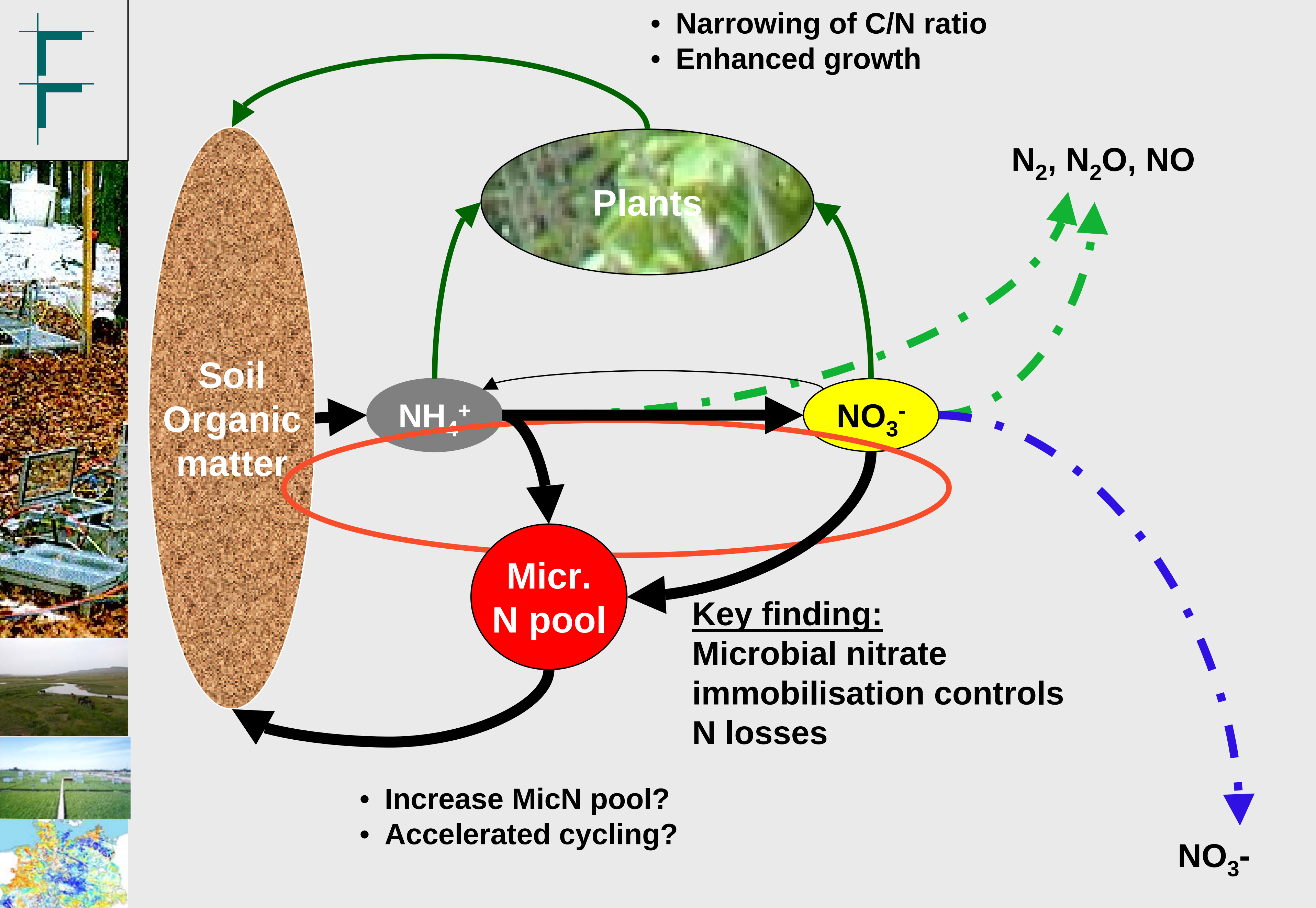
Microbial and abiological processes leading to N trace gas production

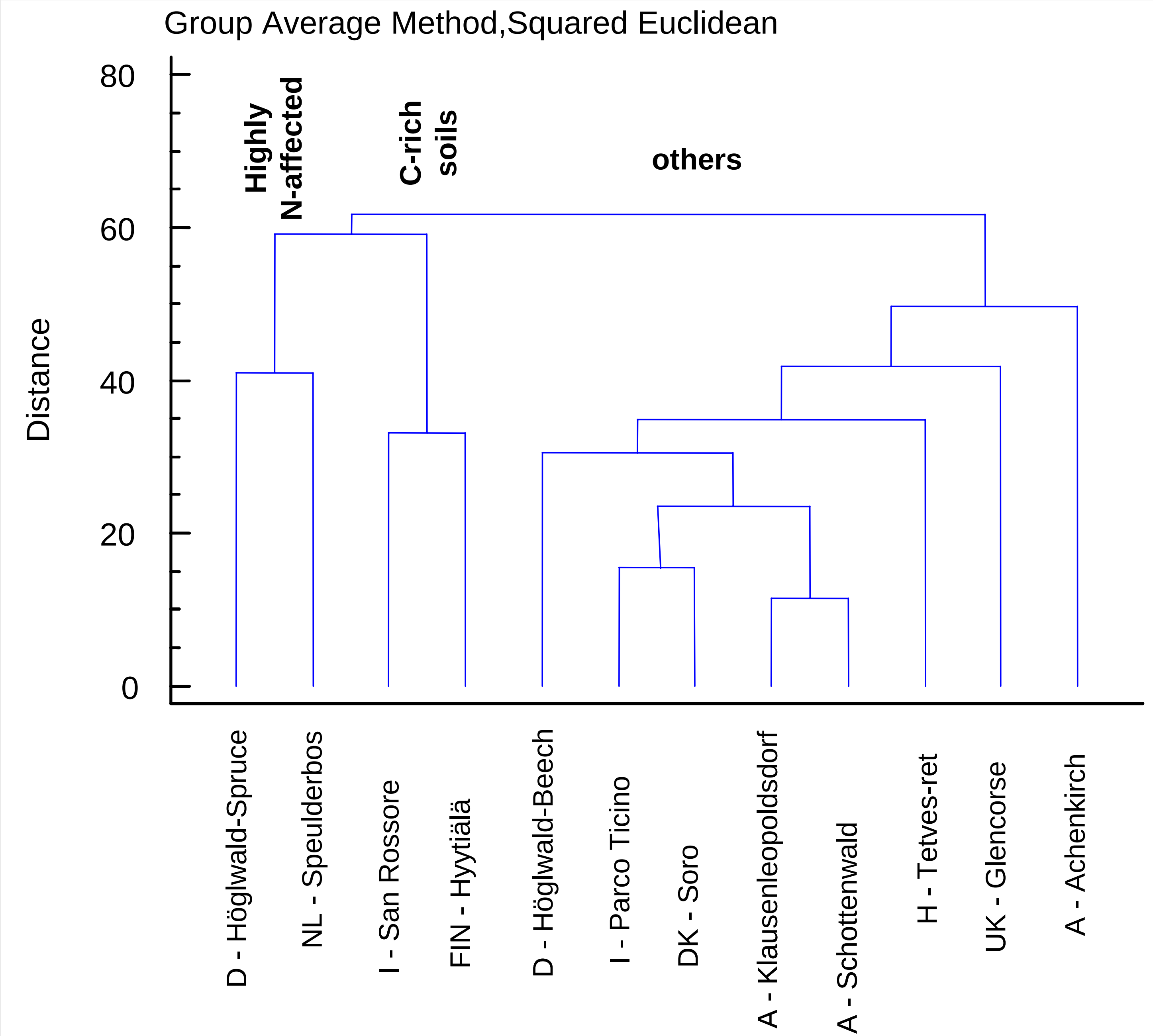
Davidson et al., 2000, BioSciences

Reported impacts of N deposition on mcirobial communities in forest soils

- Changes in microbial community composition and function
  - Decrease in active fungal biomass
  - Changes in the fungal to microbial biomass (decreas of fungi/ increase of bacteria)
  - Reduction ectomycorrhizal fungal diversity
  - Reduction of lignin degrading activity

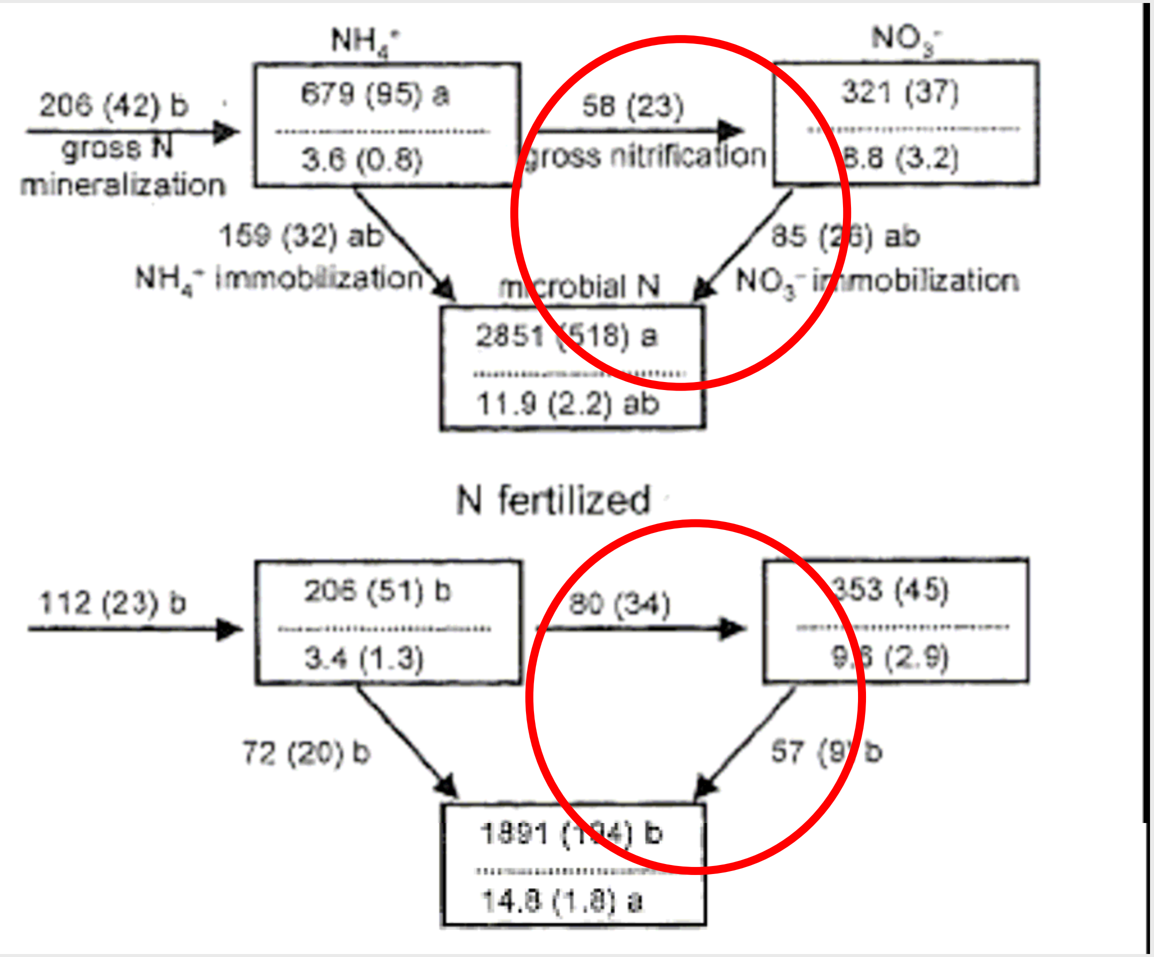
However, these findings are difficult to translate into biogeochemical models. And what does this means for N trace gas emissions?


• Narrowing of C/N ratio
• Enhanced growth
Plants
N_2, N_2O, NO
Soil Organic matter
NH_4^+
NO_3^-
Micr. N pool
Key finding:
Microbial nitrate immobilisation controls N losses
• Increase MicN pool?
• Accelerated cycling?
NO_3-


Group Average Method,Squared Euclidean
Distance
80
60
40
20
0
Highly
N-affected
C-rich
soils
others
D - Höglwald-Spruce
NL - Speulderbos
I - San Rossore
FIN - Hyytiälä
D - Höglwald-Beech
I - Parco Ticino
DK - Soro
A - Klausenleopoldsdorf
A - Schottenwald
H - Tetves-ret
UK - Glencorse
A - Achenkirch

Control

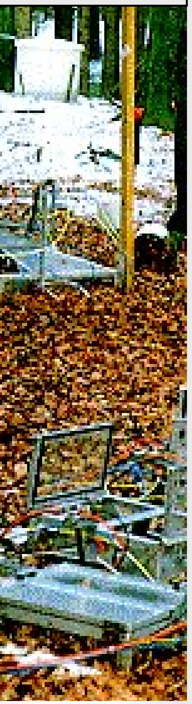
N-fertilized

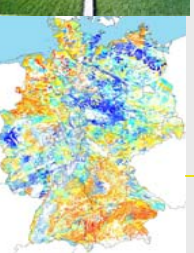


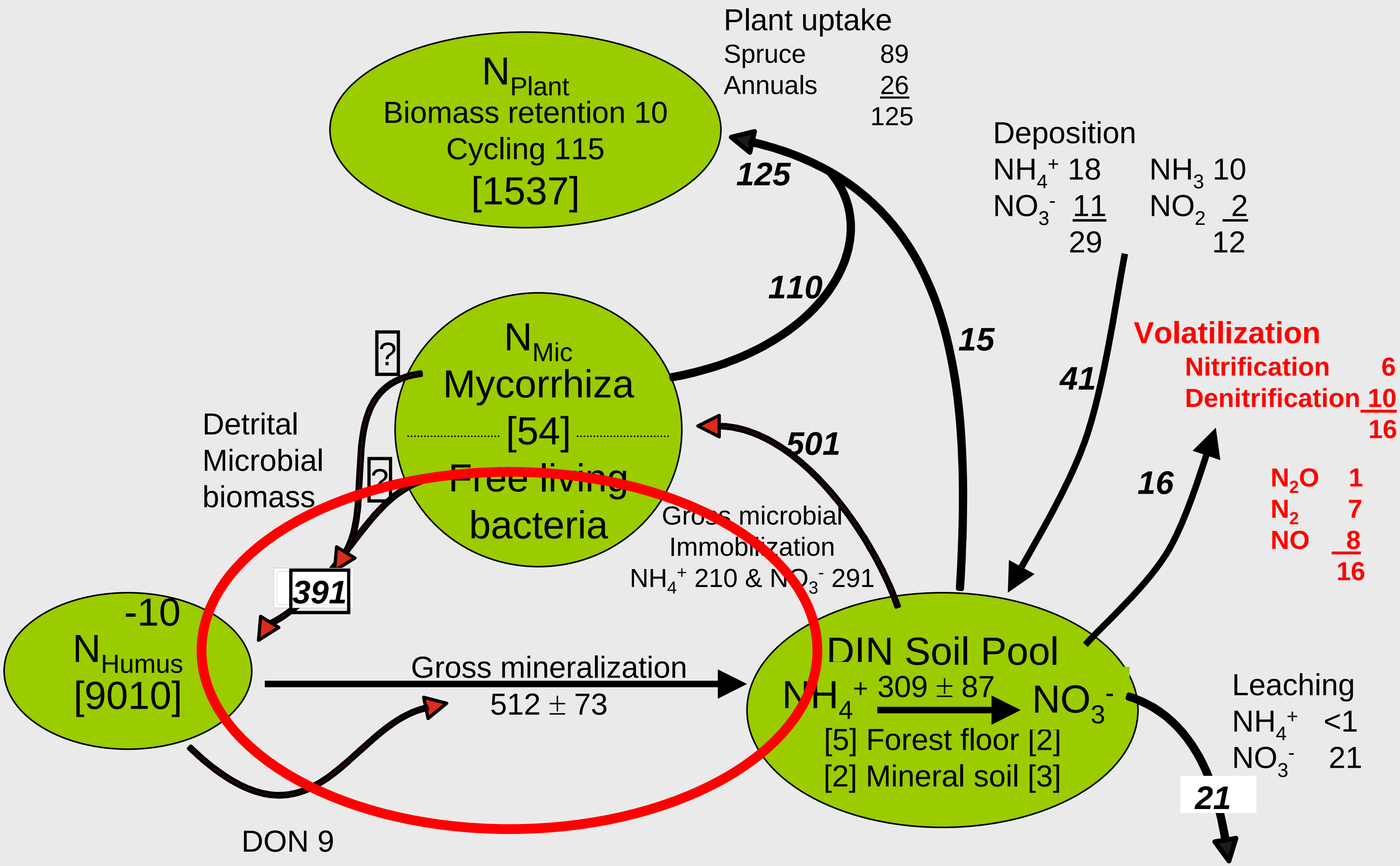
Gross rates of microbial N cycling at the Solling (control and N-fertilized)

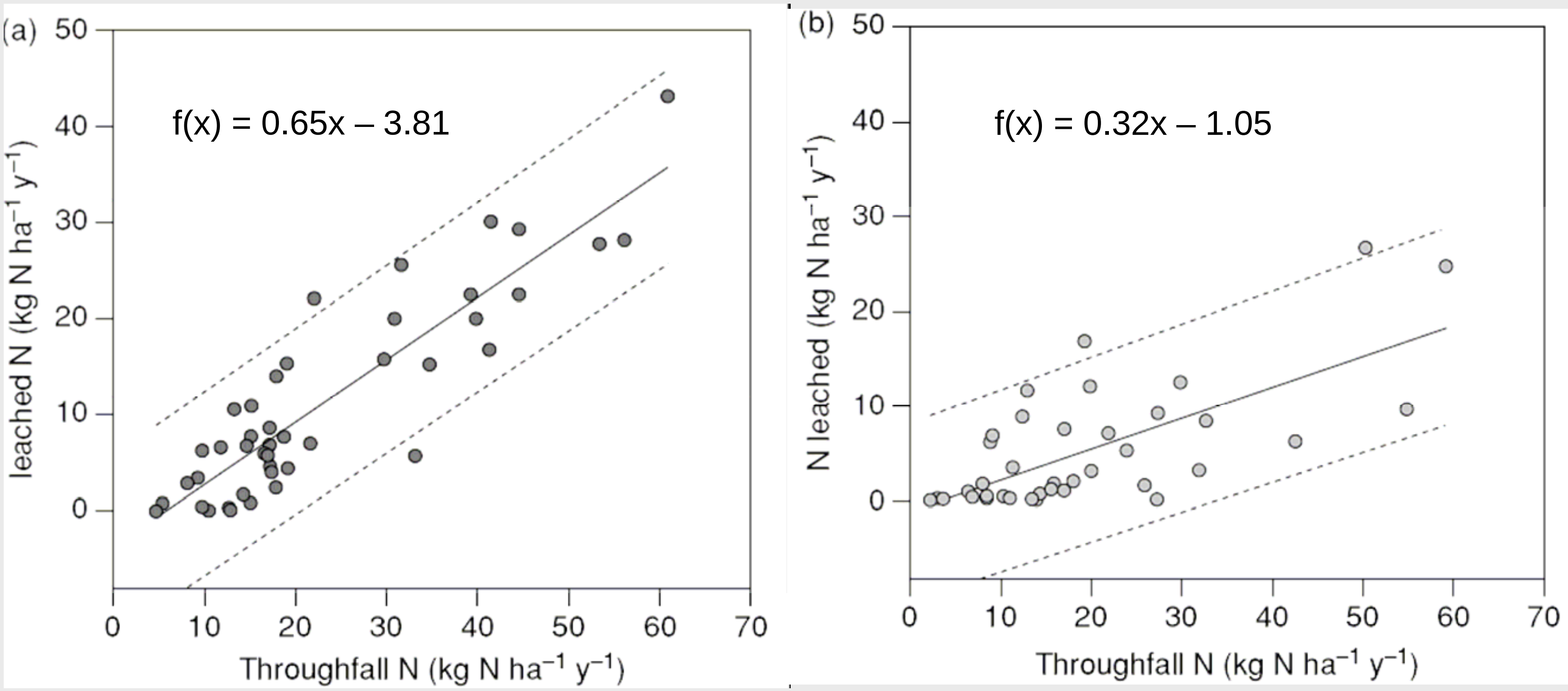
Corré et al., 2003, Ecol. Applic.

N-cycling and gaseous N-losses at the Höglwald spruce site



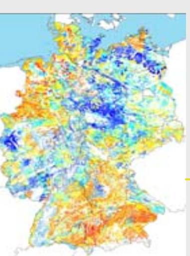


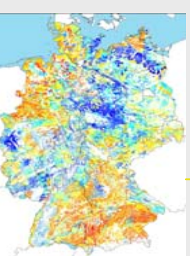


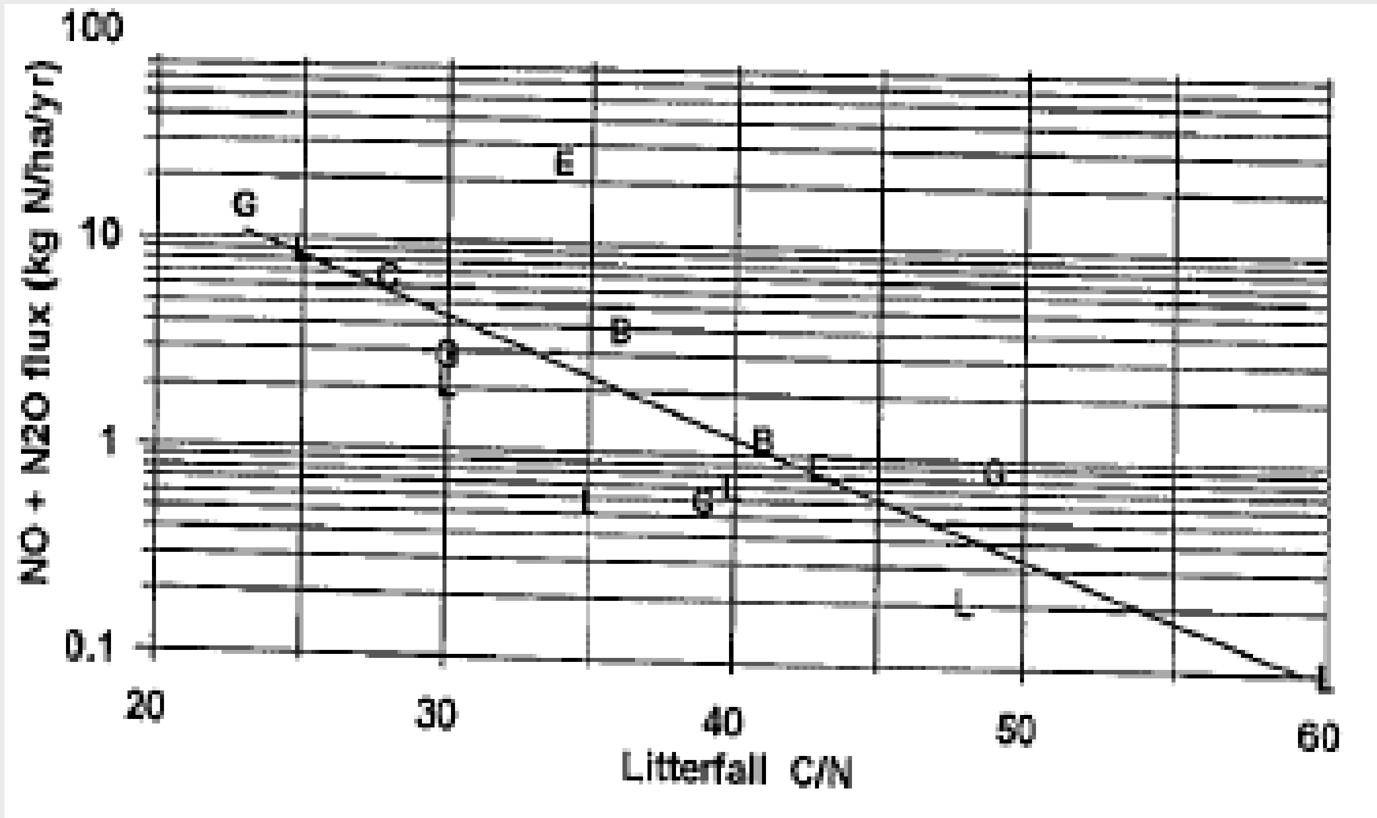


N input vs. Nitrate leaching at (a) sites with the organic layer C/N ratio <25 and (b) sites where the organic layer C/N ratio is >25.

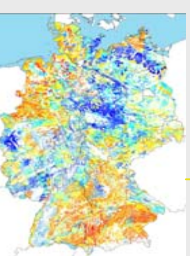
MacDonald et al., 2002, Global Change Biol.

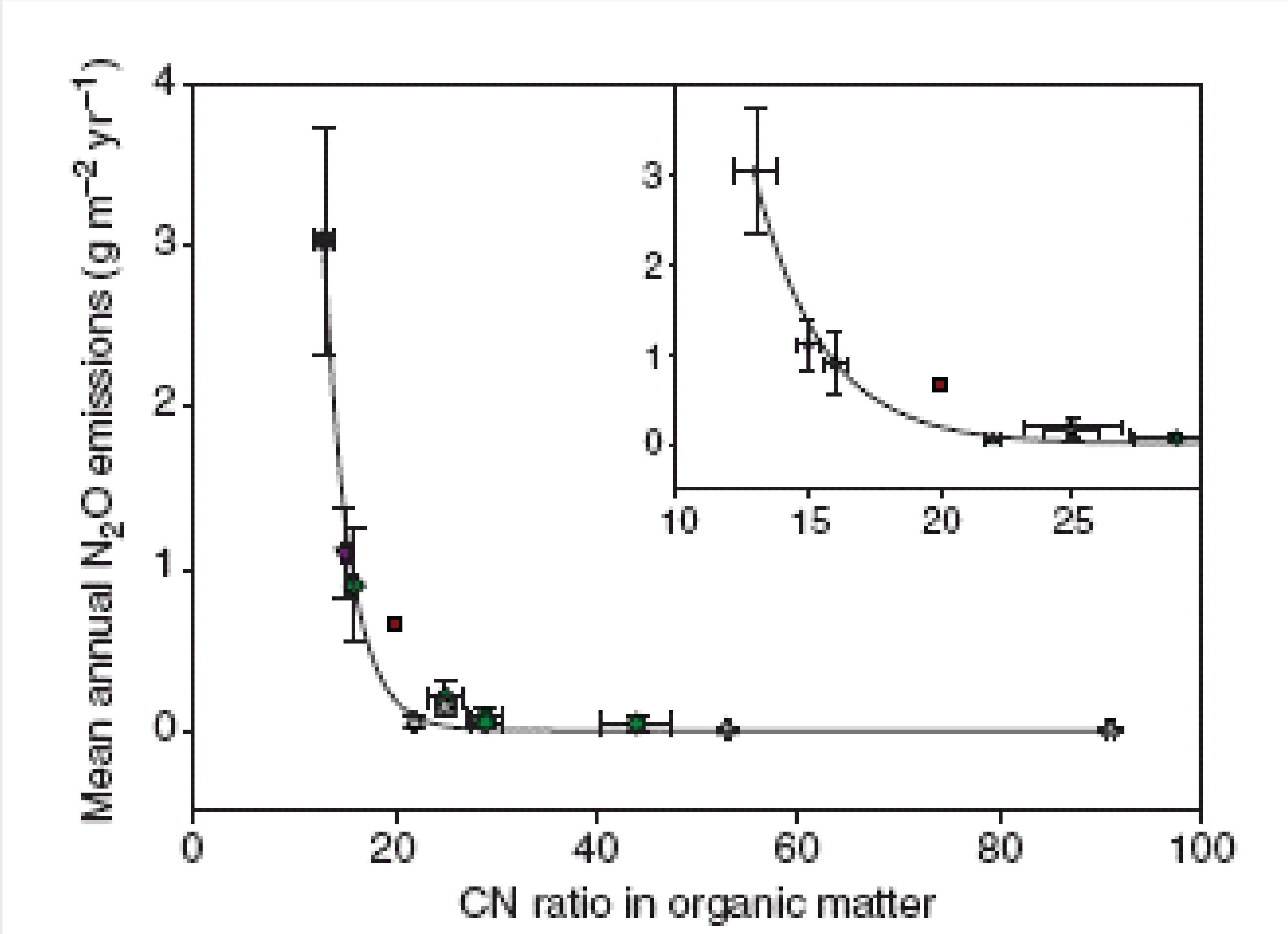






Sum of annual estimates of NO+N2O emissions as a function of litterfall charasteristics. Davidson et al., 2000, BioSciences

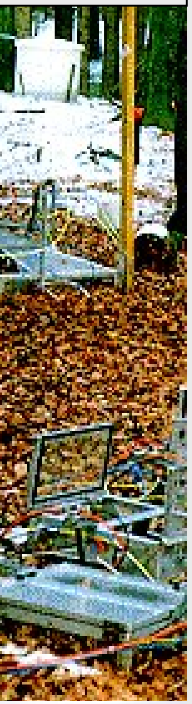


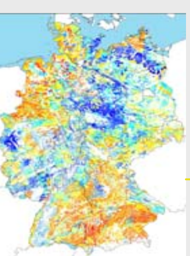


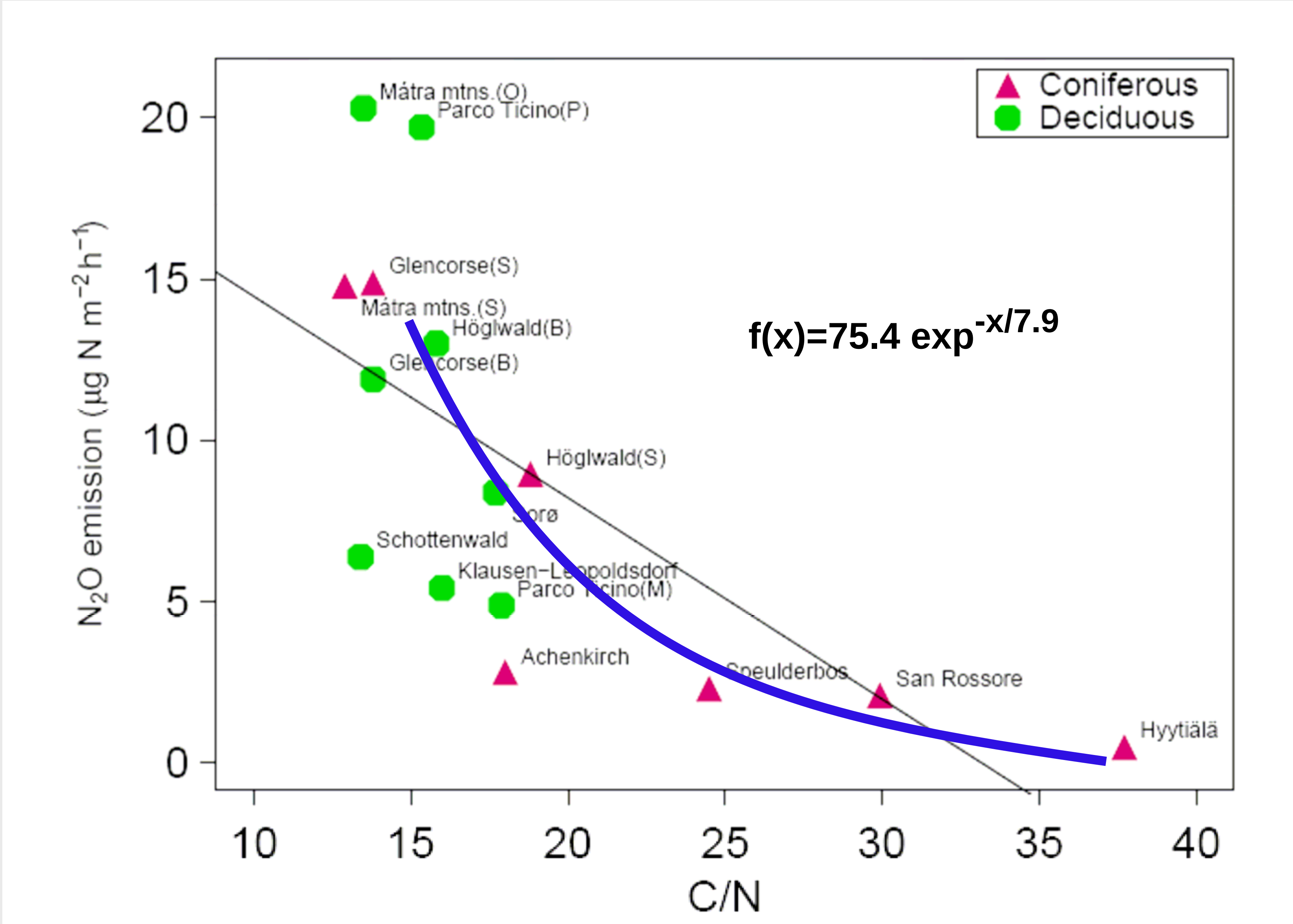
Correlation between the C/N ratio of the soil in the uppermost layer and mean annual N_2O emissions for forests on drained peatland sites

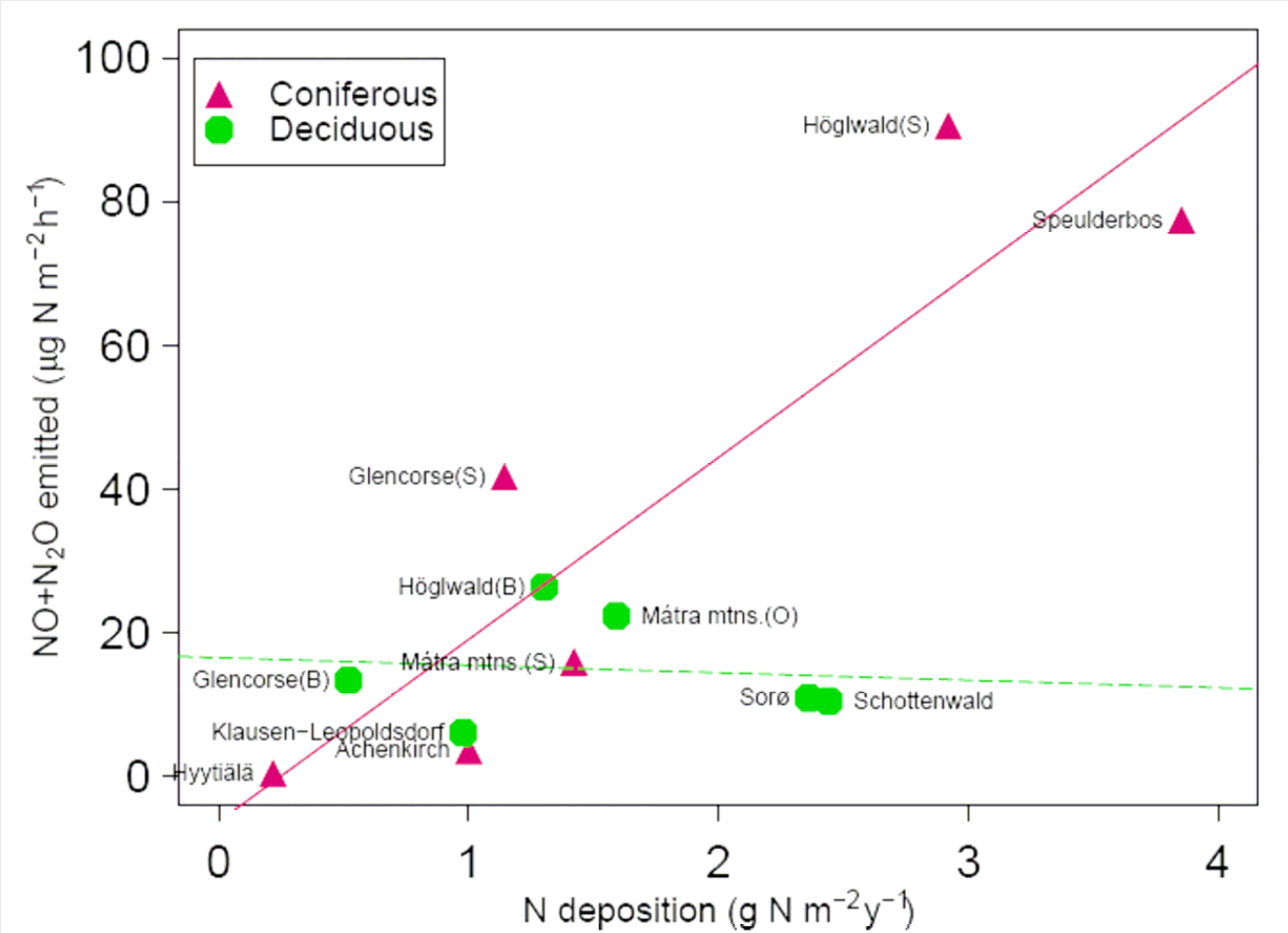
Klemedtsson et al., 2005, Global Change Biol.

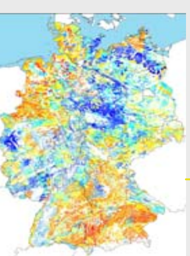

Hyytiälä
Glencorse
Sorø
Speulderbos
Schottenwald
Mátra mtns.
Höglwald
Achenkirch
Klausen−Leopoldsdorf
Parco Ticino
San Rossore

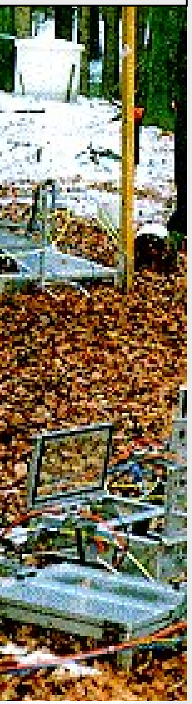


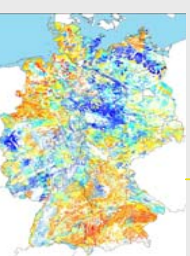


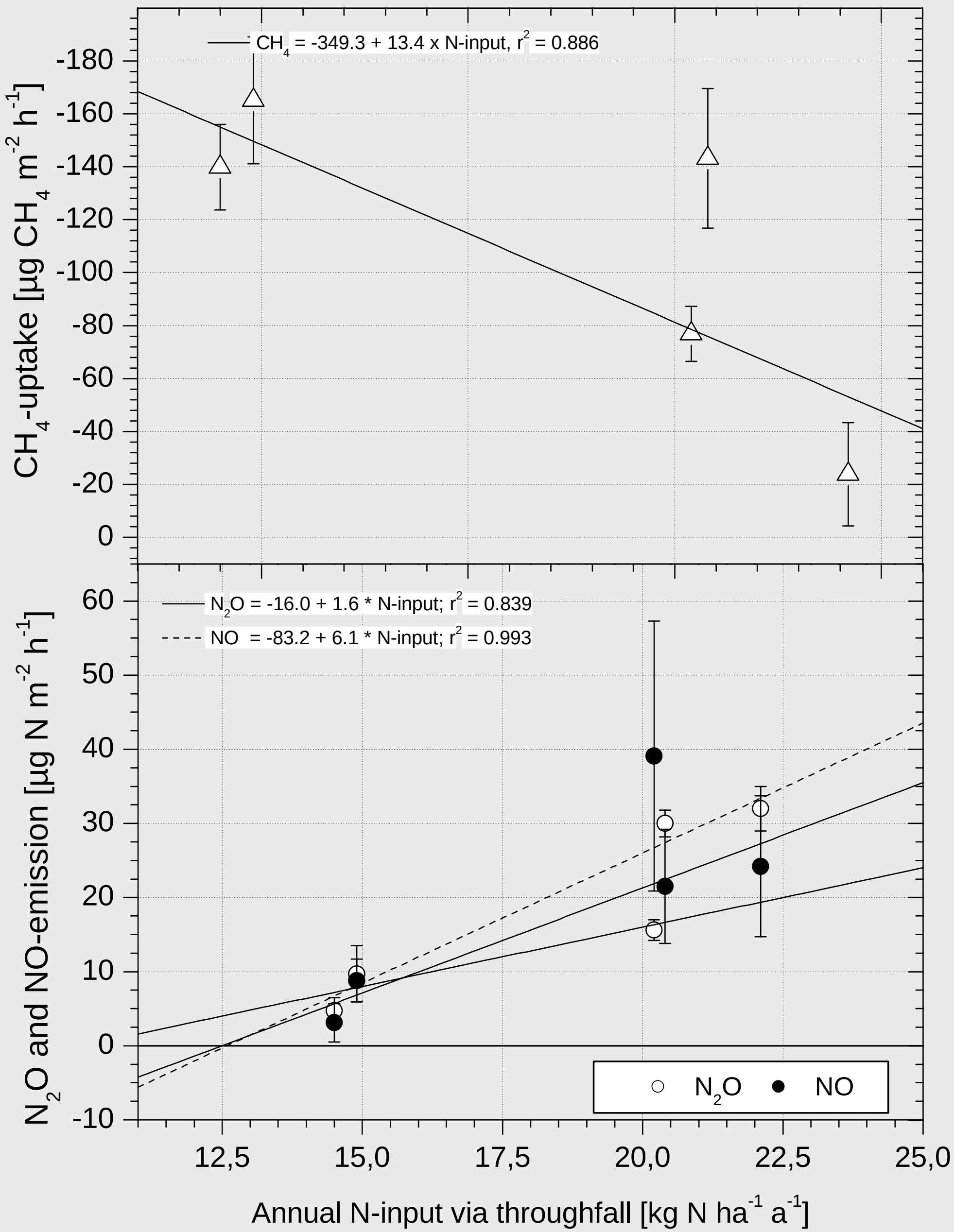

Coniferous
Deciduous
Mátra mtns.(O)
Parco Ticino(P)
Glencorse(S)
Mátra mtns.(S)
Höglwald(B)
Glencorse(B)
Höglwald(S)
Sorø
Schottenwald
Klausen−Leopoldsdorf
Parco Ticino(M)
Achenkirch
Speulderbos
San Rossore
Hyytiälä
f(x)=75.4 exp$^{-x/7.9}$
N$_2$O emission (µg N m^{-2}h^{-1})
C/N
0
5
10
15
20
10
15
20
25
30
35
40


Coniferous
Deciduous
NO+N$_2$O emitted (µg N m^{-2}h^{-1})
N deposition (g N m^{-2}y^{-1})
100
80
60
40
20
0
0
1
2
3
4
Höglwald(S)
Speulderbos
Glencorse(S)
Höglwald(B)
Mátra mtns.(O)
Mátra mtns.(S)
Glencorse(B)
Sorø
Schottenwald
Klausen−Leopoldsdorf
Achenkirch
Hyytiälä





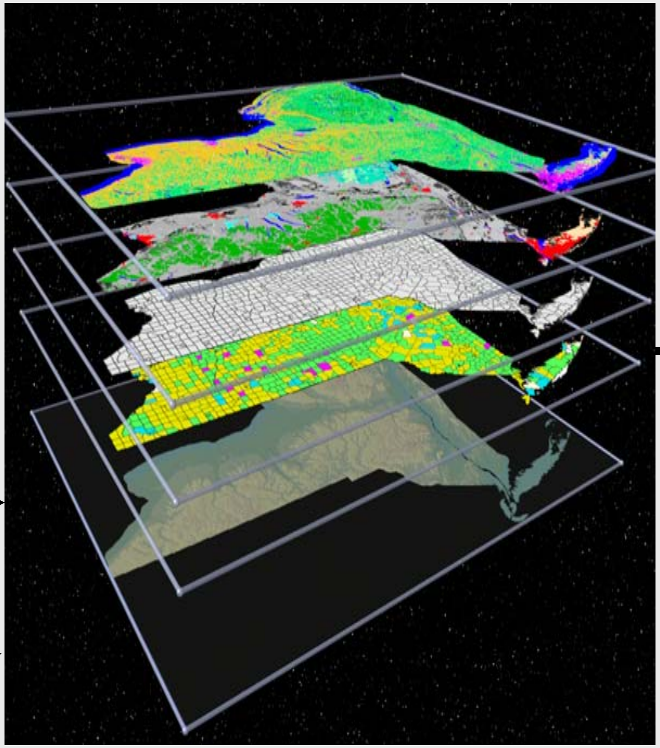


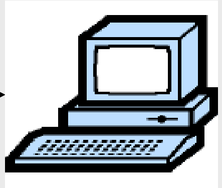


CH4 = -349.3 + 13.4 x N-input, r2 = 0.886
CH4-uptake [µg CH4 m-2 h-1]
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
N2O = -16.0 + 1.6 * N-input; r2 = 0.839
NO = -83.2 + 6.1 * N-input; r2 = 0.993
N2O and NO-emission [µg N m-2 h-1]
60
50
40
30
20
10
0
-10
N2O
NO
12,5
15,0
17,5
20,0
22,5
25,0
Annual N-input via throughfall [kg N ha-1 a-1]

Upscaling strategy

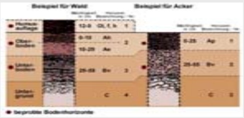
DNDC





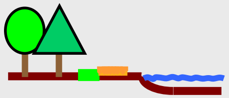
<u>Initialisation Parameters</u>

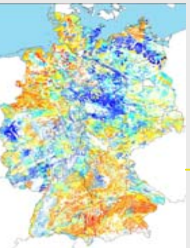
Vegetation



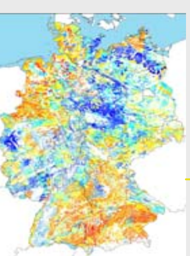
Soil

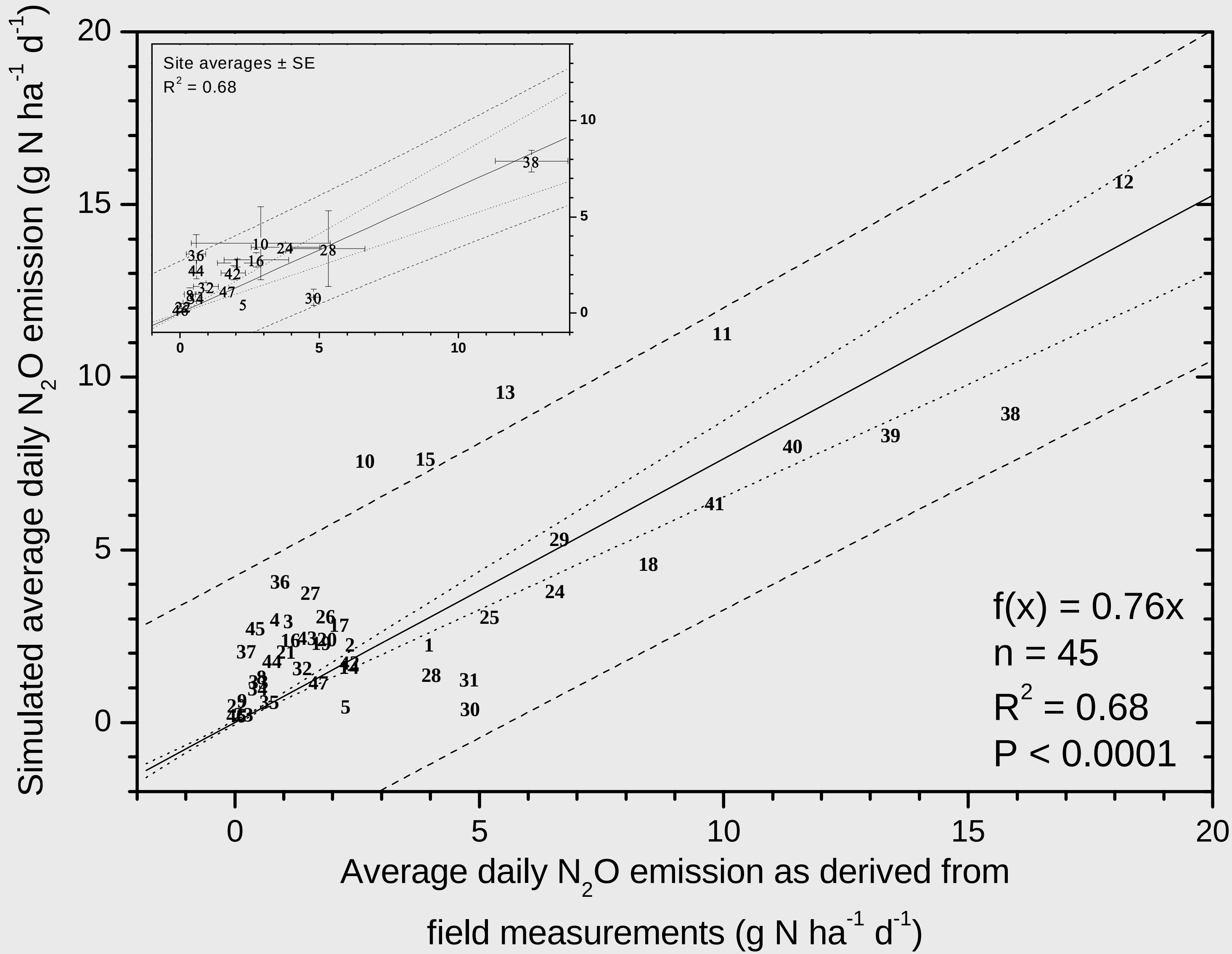
Landuse

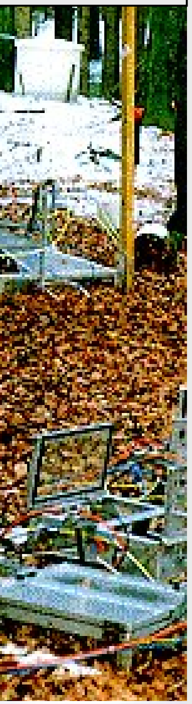


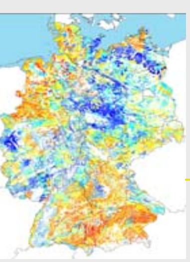


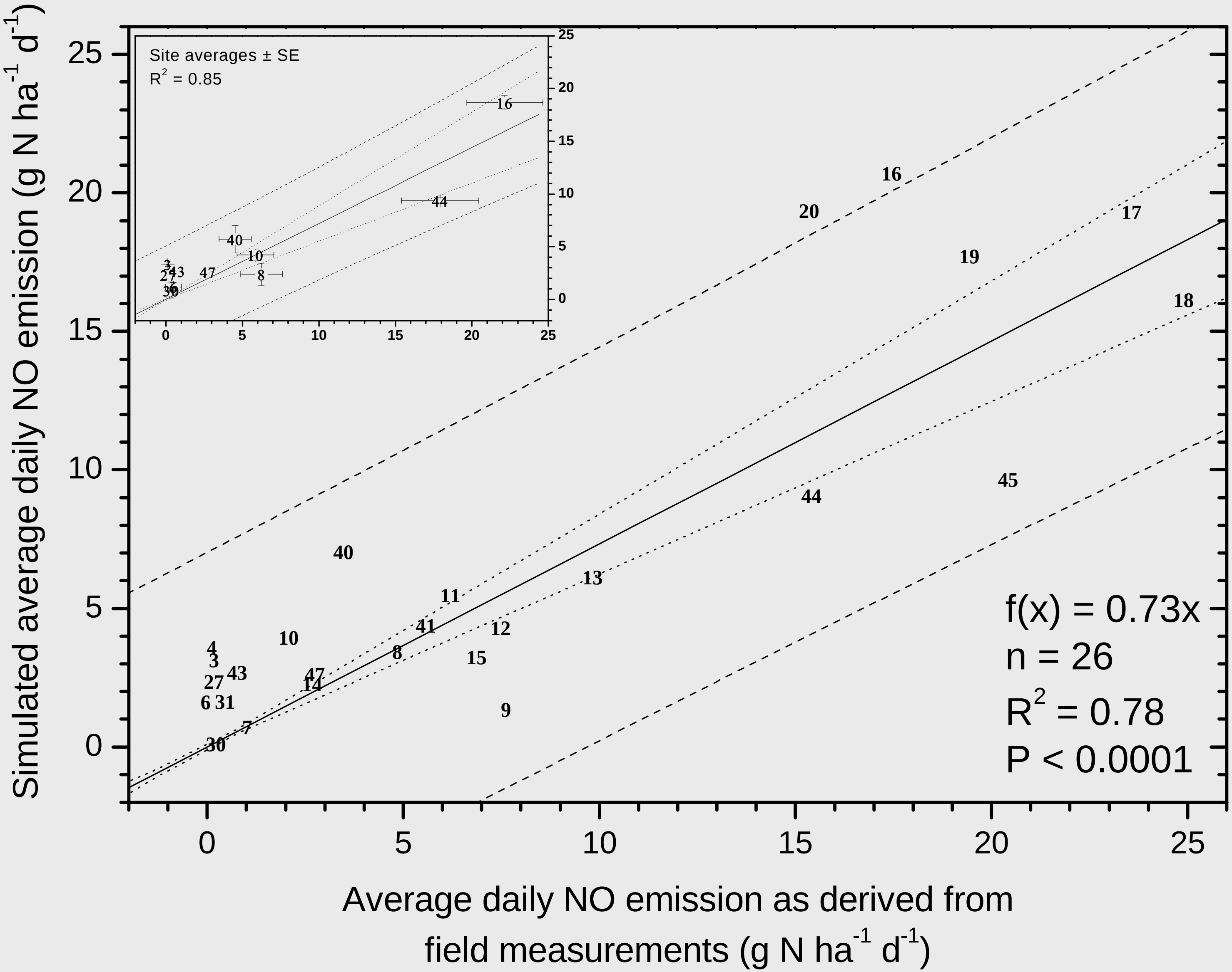
Regional NO emissions from soils

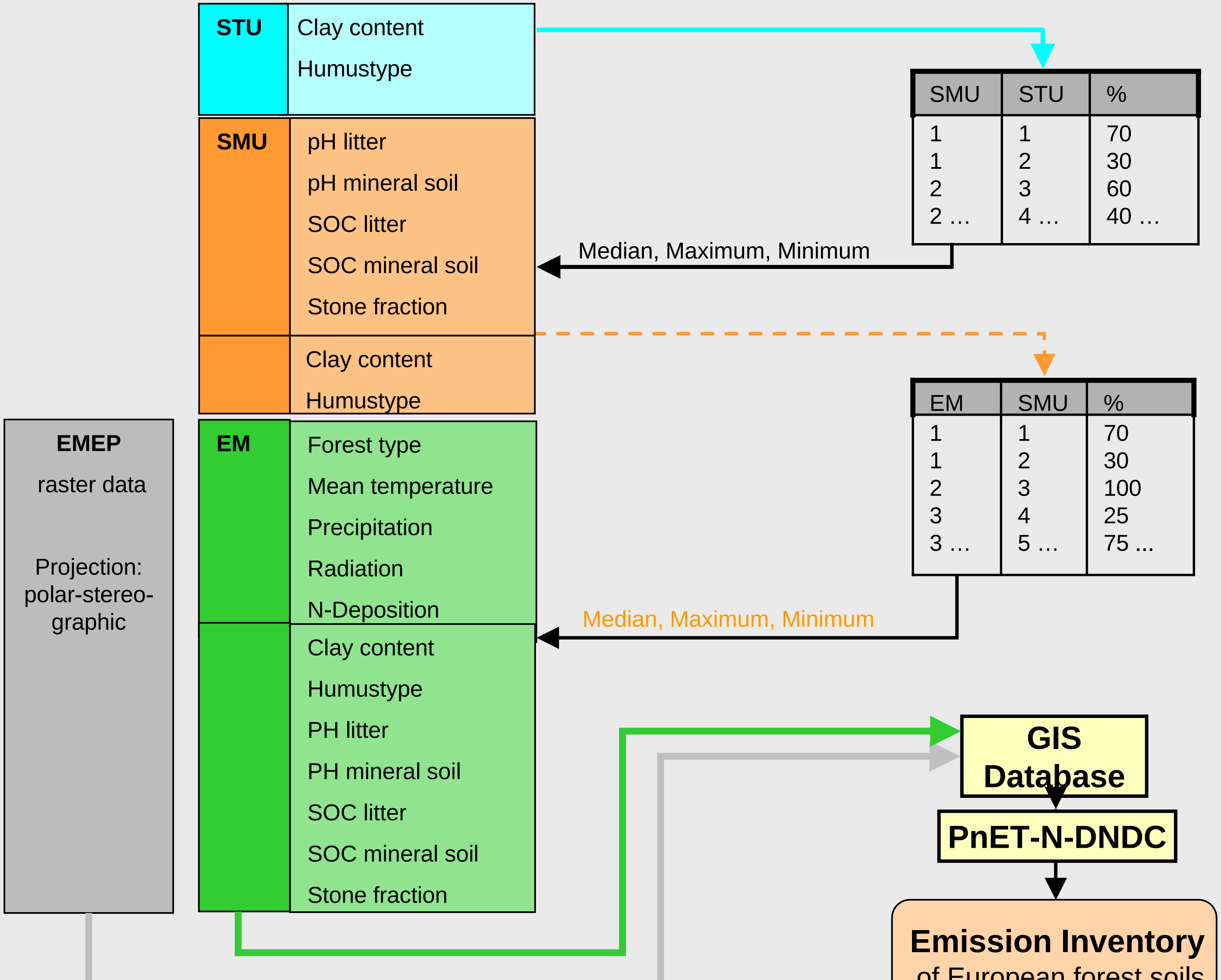


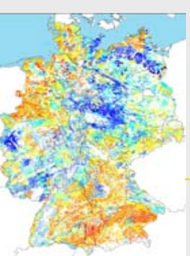

Simulated average daily N2O emission (g N ha-1 d-1)
Average daily N2O emission as derived from
field measurements (g N ha-1 d-1)
Site averages ± SE
R2 = 0.68
f(x) = 0.76x
n = 45
R2 = 0.68
P < 0.0001
0
5
10
15
20

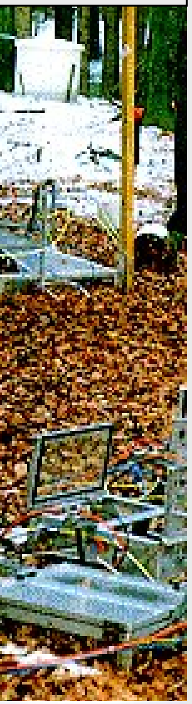


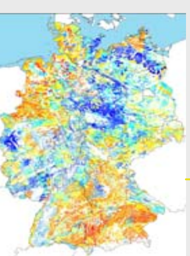


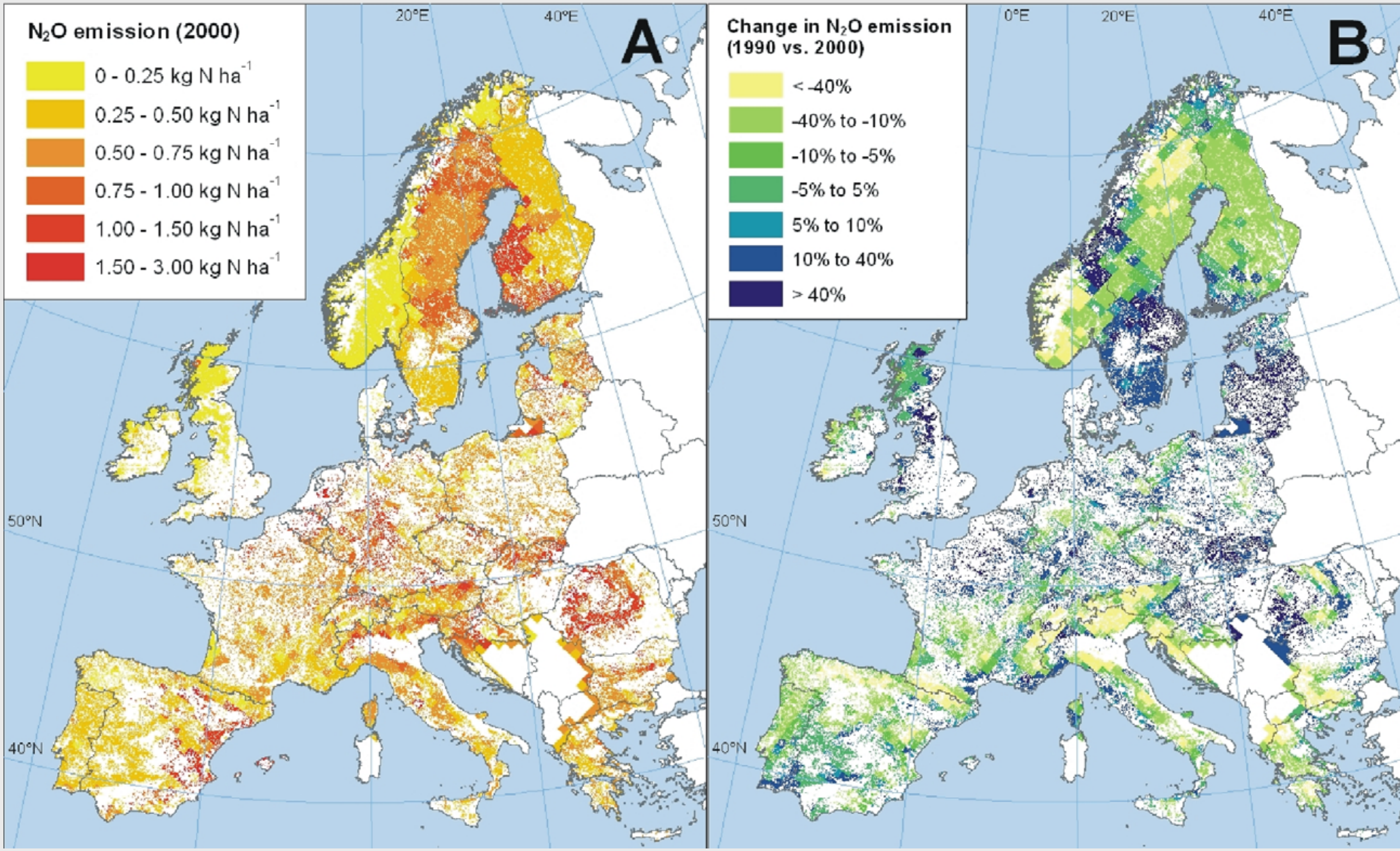

Site averages ± SE
R2 = 0.85
Simulated average daily NO emission (g N ha-1 d-1)
Average daily NO emission as derived from
field measurements (g N ha-1 d-1)
f(x) = 0.73x
n = 26
R2 = 0.78
P < 0.0001
0
5
10
15
20
25


STU
Clay content
Humustype
SMU
pH litter
pH mineral soil
SOC litter
SOC mineral soil
Stone fraction
Clay content
Humustype
EMEP
raster data
Projection:
polar-stereo-
graphic
EM
Forest type
Mean temperature
Precipitation
Radiation
N-Deposition
Clay content
Humustype
PH litter
PH mineral soil
SOC litter
SOC mineral soil
Stone fraction
SMU STU %
1 1 70
1 2 30
2 3 60
2 … 4 … 40 …
Median, Maximum, Minimum
EM SMU %
1 1 70
1 2 30
2 3 100
3 4 25
3 … 5 … 75 ...
Median, Maximum, Minimum
GIS Database
PnET-N-DNDC
Emission Inventory
of European forest soils

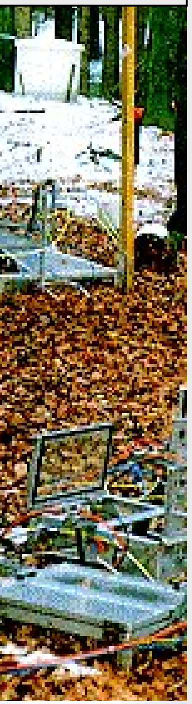


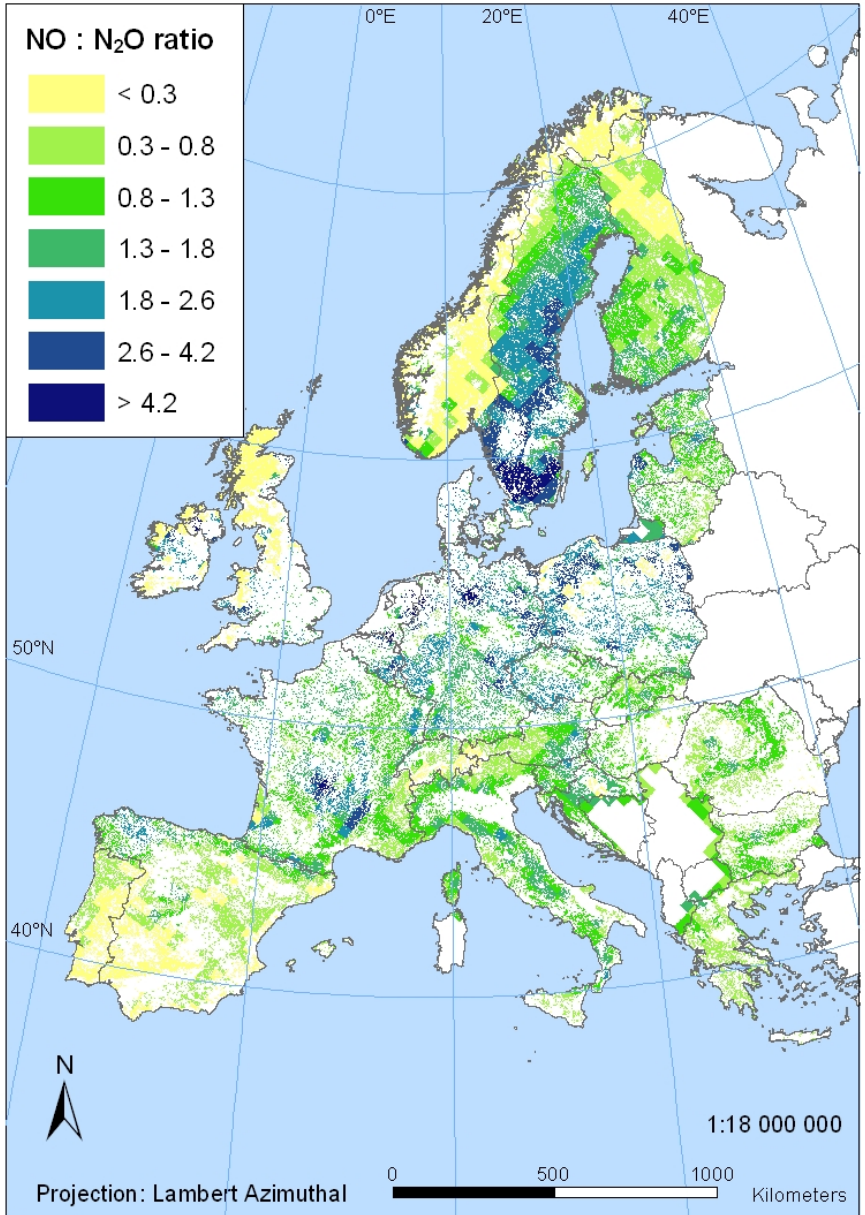




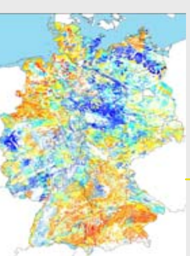


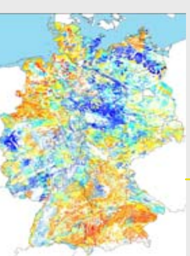
N_2O emission (2000)
0 - 0.25 kg N ha^{-1}
0.25 - 0.50 kg N ha^{-1}
0.50 - 0.75 kg N ha^{-1}
0.75 - 1.00 kg N ha^{-1}
1.00 - 1.50 kg N ha^{-1}
1.50 - 3.00 kg N ha^{-1}
A
20°E
40°E
50°N
40°N
Change in N_2O emission (1990 vs. 2000)
< -40%
-40% to -10%
-10% to -5%
-5% to 5%
5% to 10%
10% to 40%
> 40%
B
0°E
20°E
40°E
50°N
40°N

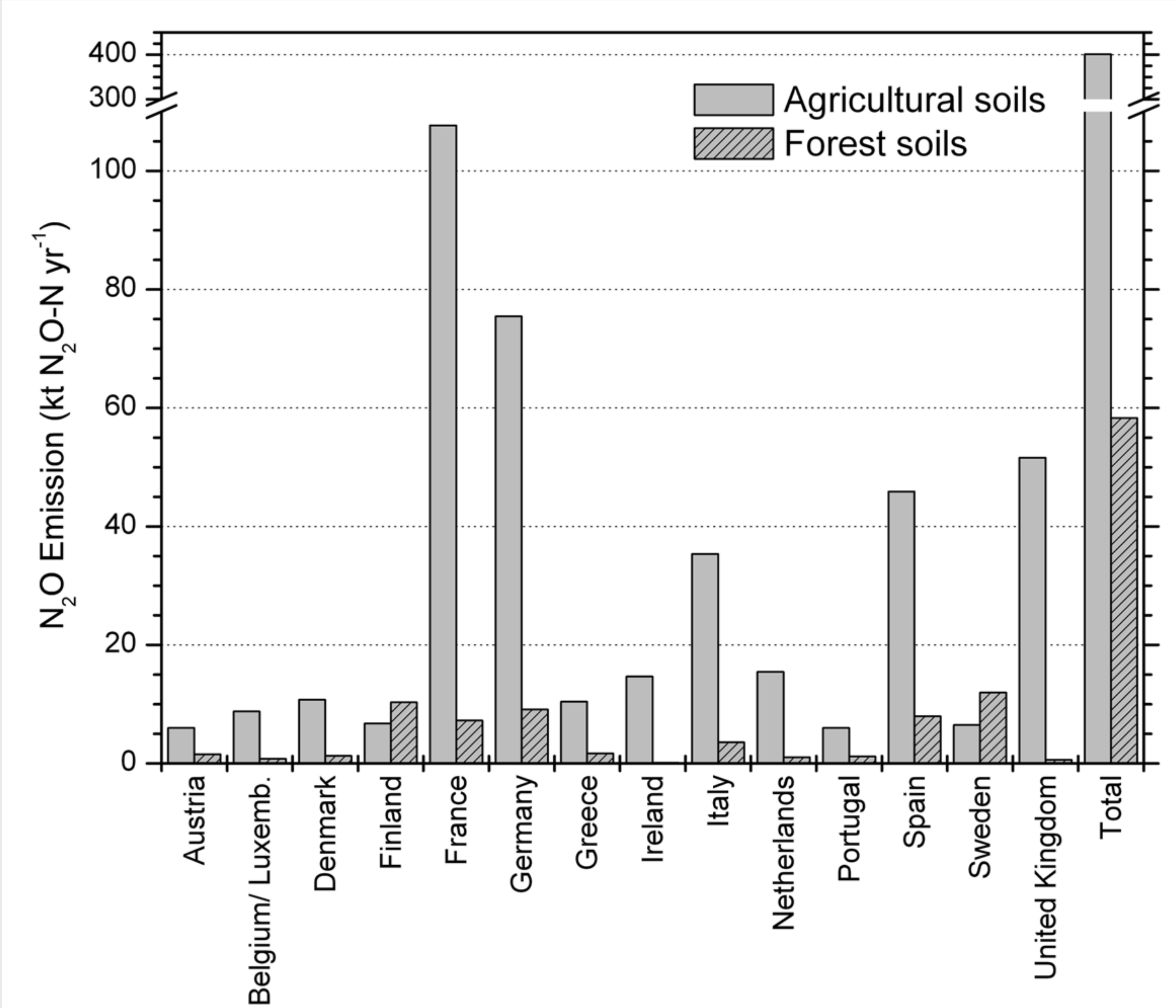


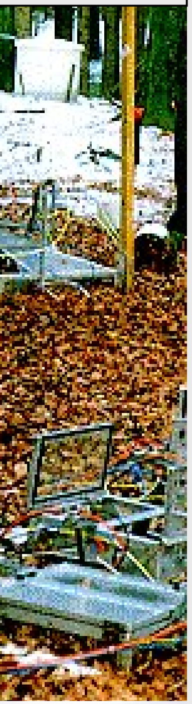


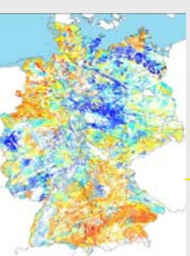
NO : N2O ratio
< 0.3
0.3 - 0.8
0.8 - 1.3
1.3 - 1.8
1.8 - 2.6
2.6 - 4.2
> 4.2
0°E
20°E
40°E
50°N
40°N
N
1:18 000 000
0
500
1000
Kilometers
Projection: Lambert Azimuthal

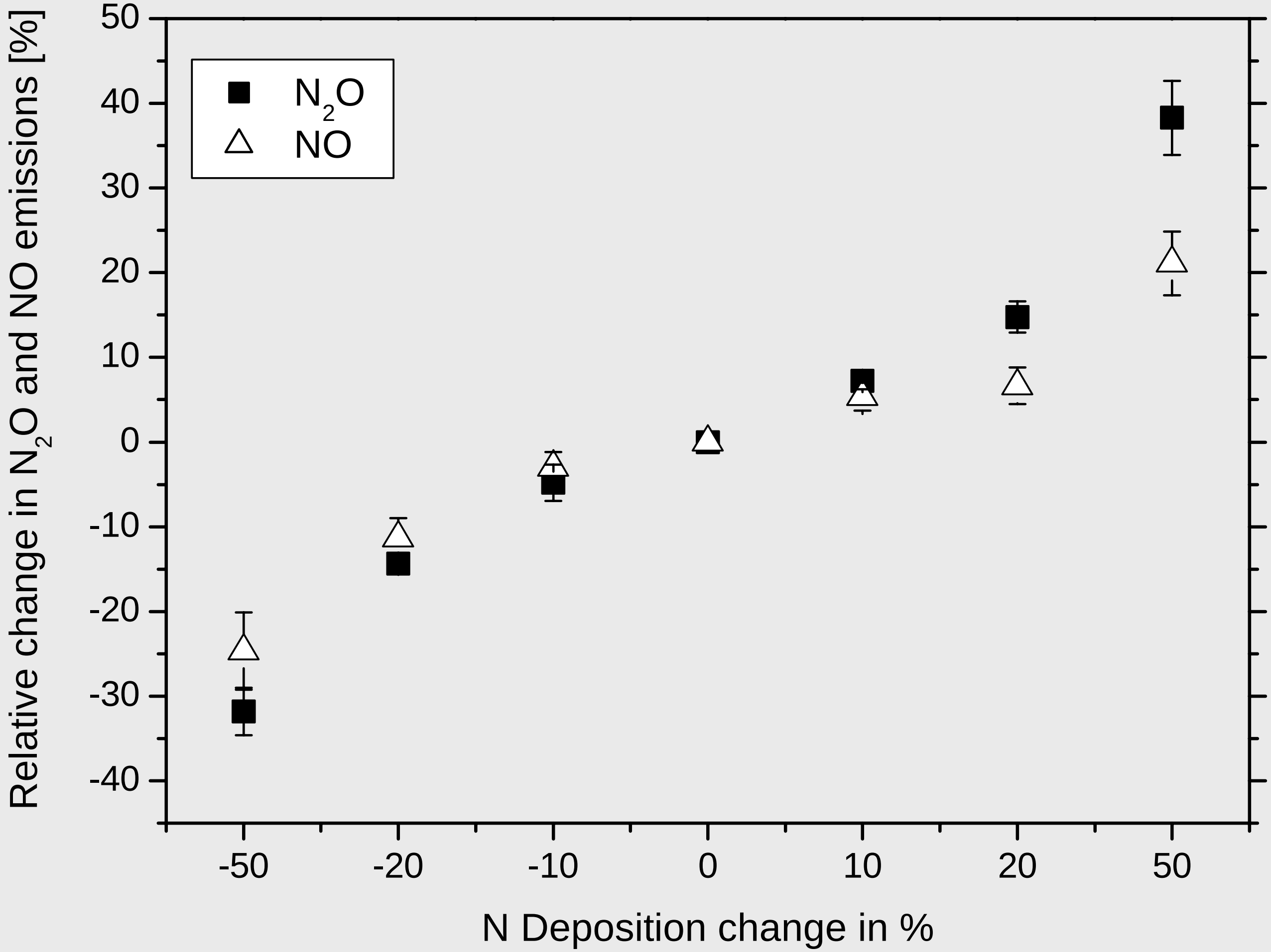




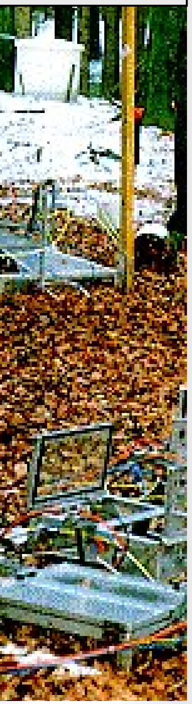

Agricultural soils
Forest soils
N_2O Emission (kt N_2O-N yr^{-1})
400
300
100
80
60
40
20
0
Austria
Belgium/ Luxemb.
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Netherlands
Portugal
Spain
Sweden
United Kingdom
Total

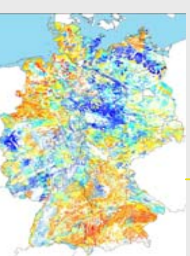


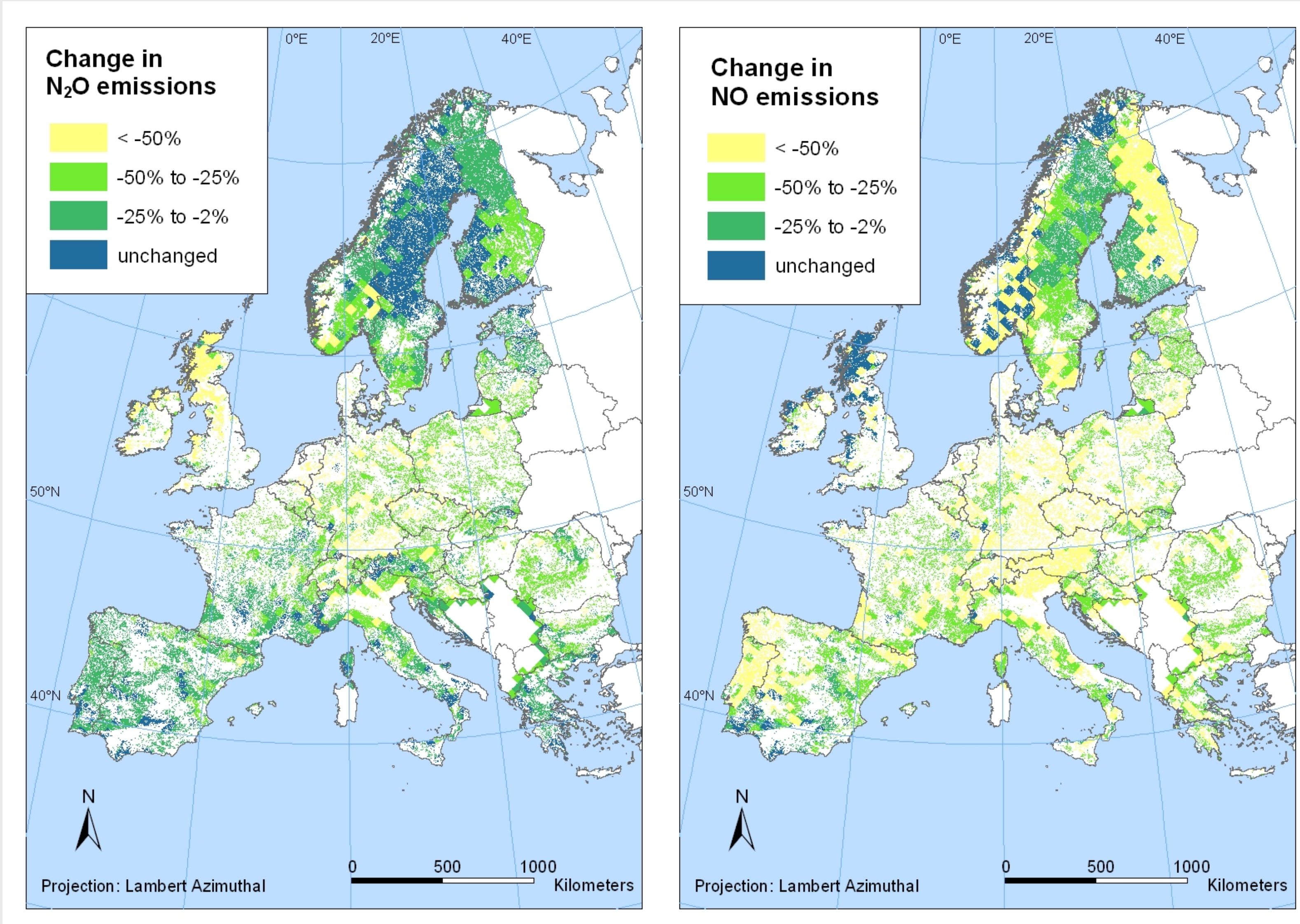


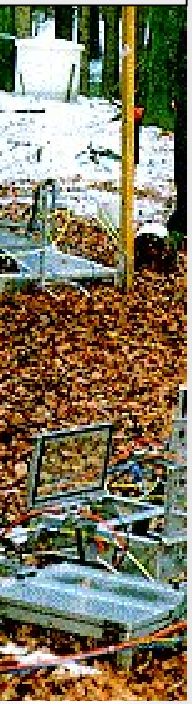


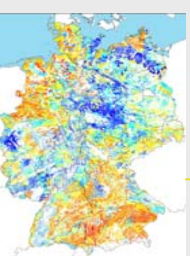
Relative change in N_2O and NO emissions [%]
50
40
30
20
10
0
-10
-20
-30
-40
N_2O
NO
-50
-20
-10
0
10
20
50
N Deposition change in %



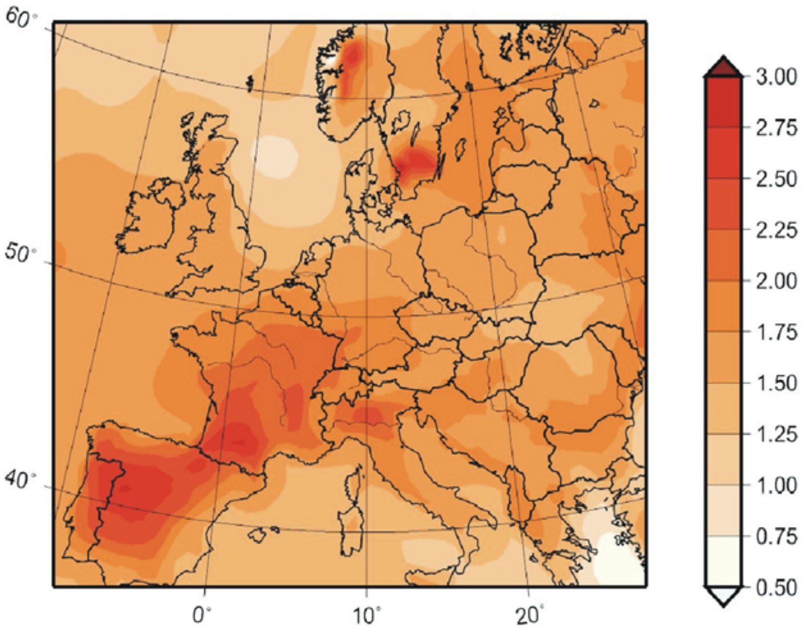



Change in
N_2O emissions
< -50%
-50% to -25%
-25% to -2%
unchanged
0°E
20°E
40°E
50°N
40°N
N
0
500
1000
Kilometers
Projection: Lambert Azimuthal
Change in
NO emissions
< -50%
-50% to -25%
-25% to -2%
unchanged
0°E
20°E
40°E
50°N
40°N
N
0
500
1000
Kilometers
Projection: Lambert Azimuthal

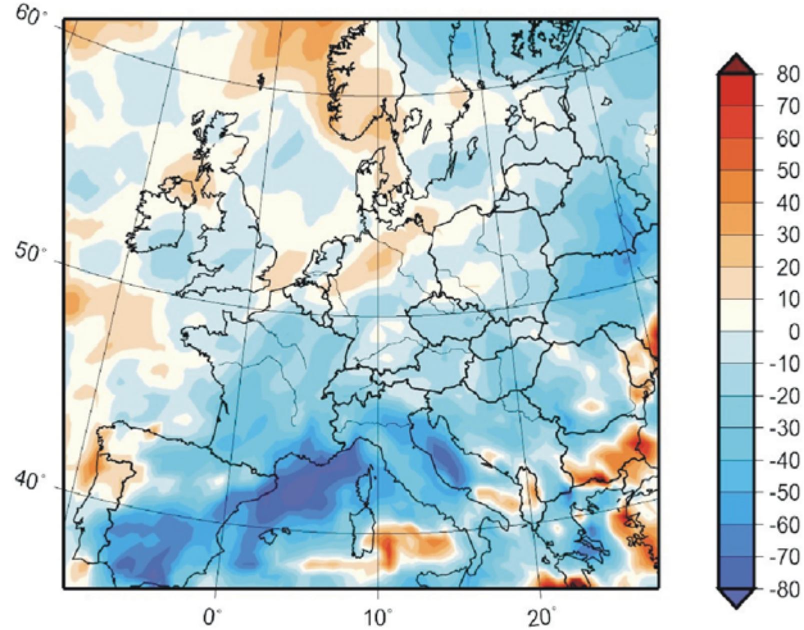




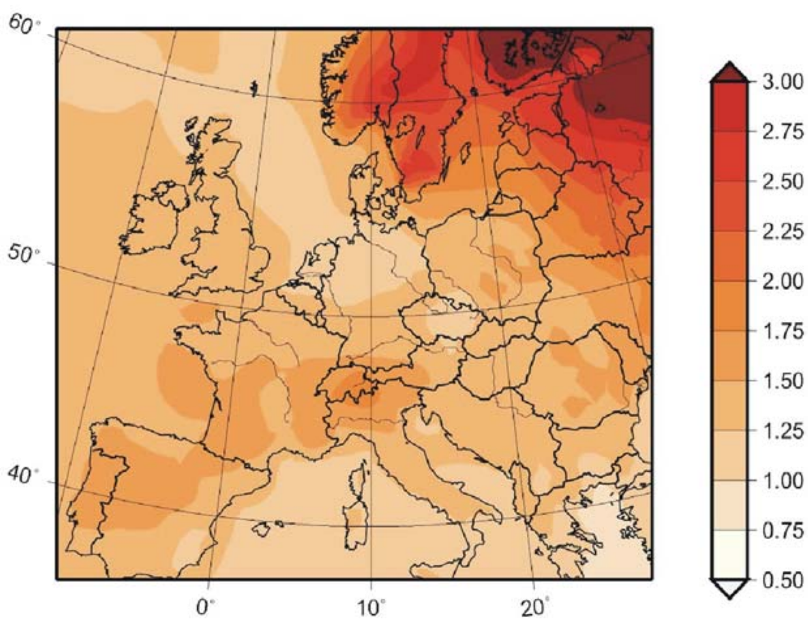
Temperature Change (°C): June - August



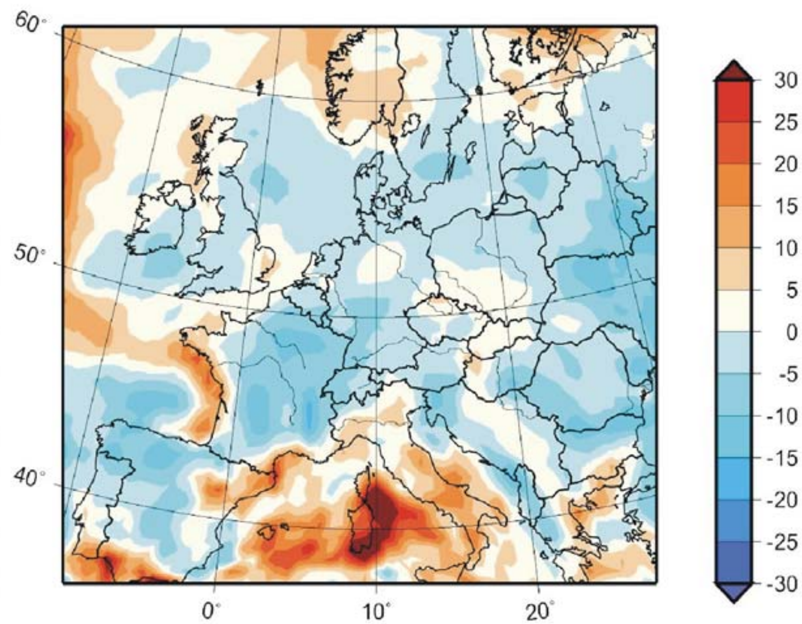
Precipitation Change (%): June - August

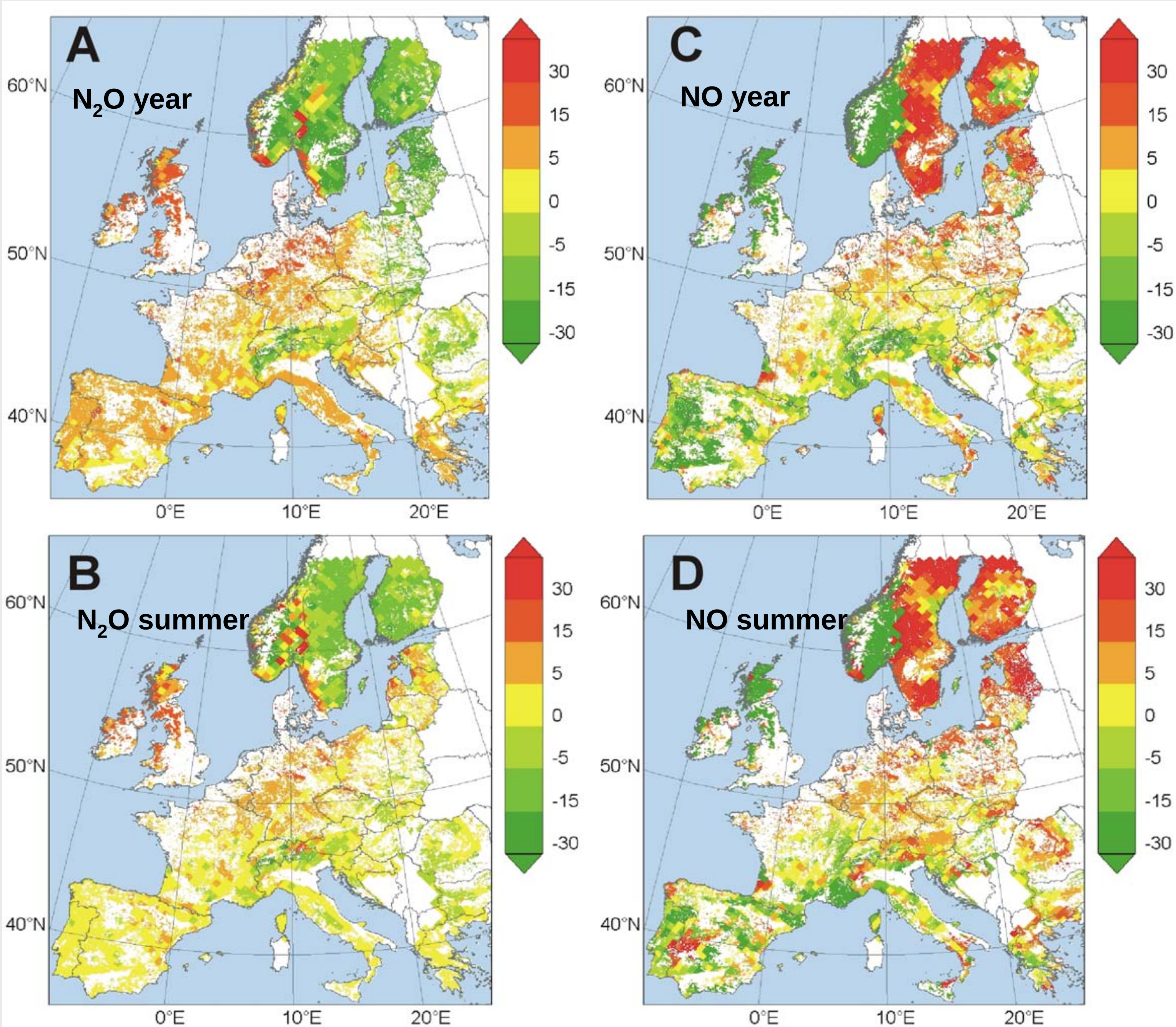


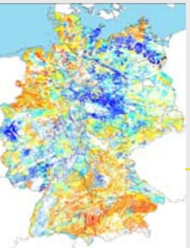
Temperature Change (°C): January - December



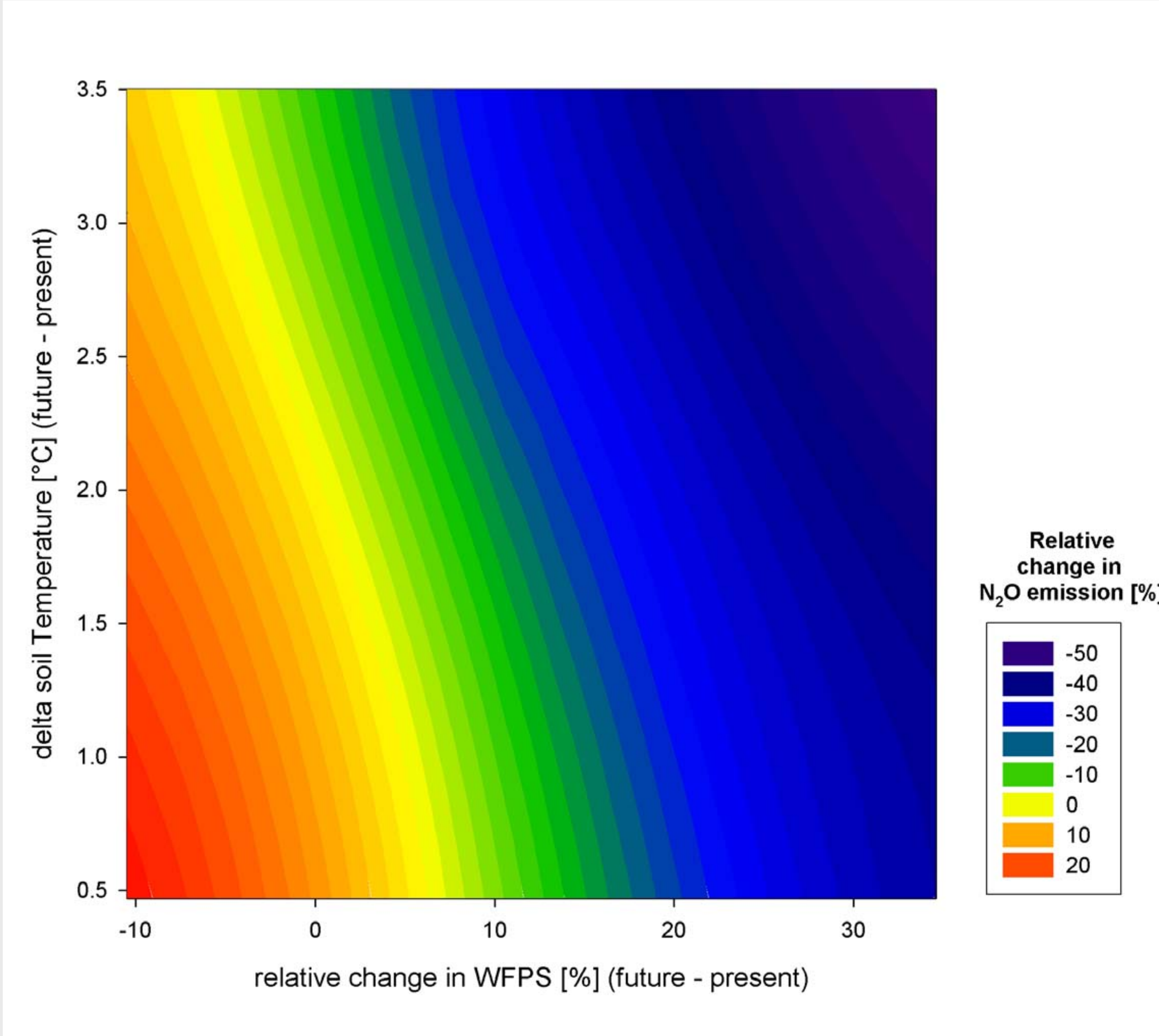
Precipitation Change (%): January - December

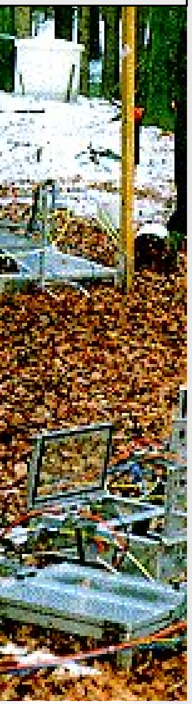


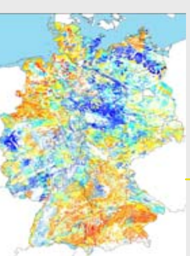


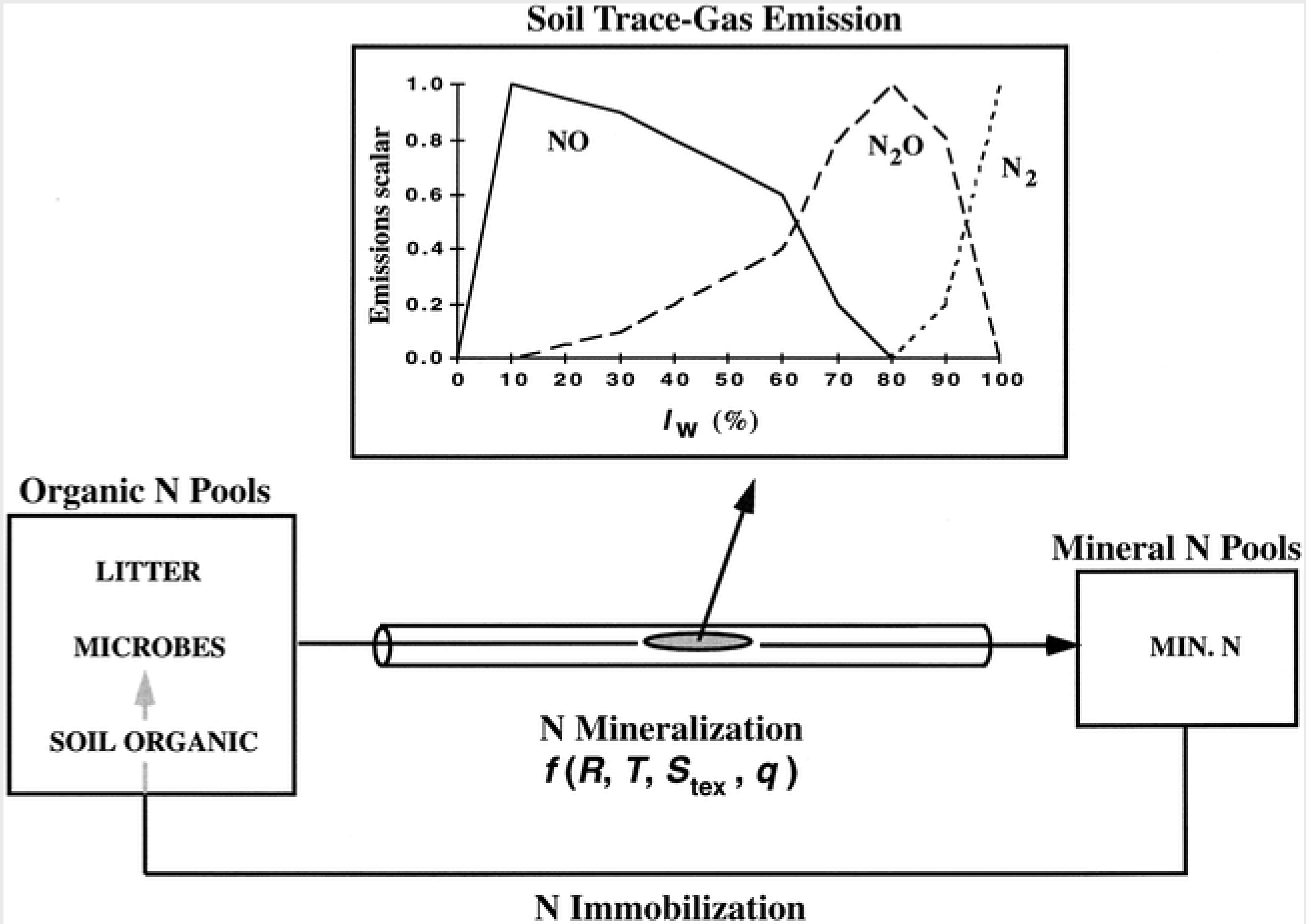


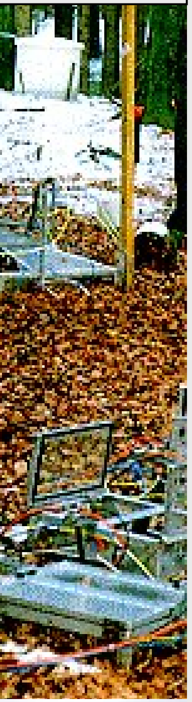
Klaus Butterbach-Bahl, IMK-IFU, FZK, COST 729, The causal relations of nitrogen in the Cascade

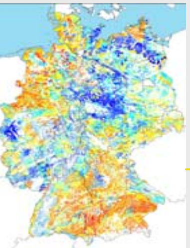

3.5
3.0
2.5
2.0
1.5
1.0
0.5
delta soil Temperature [°C] (future - present)
-10
0
10
20
30
relative change in WFPS [%] (future - present)
Relative change in N_2O emission [%]
-50
-40
-30
-20
-10
0
10
20

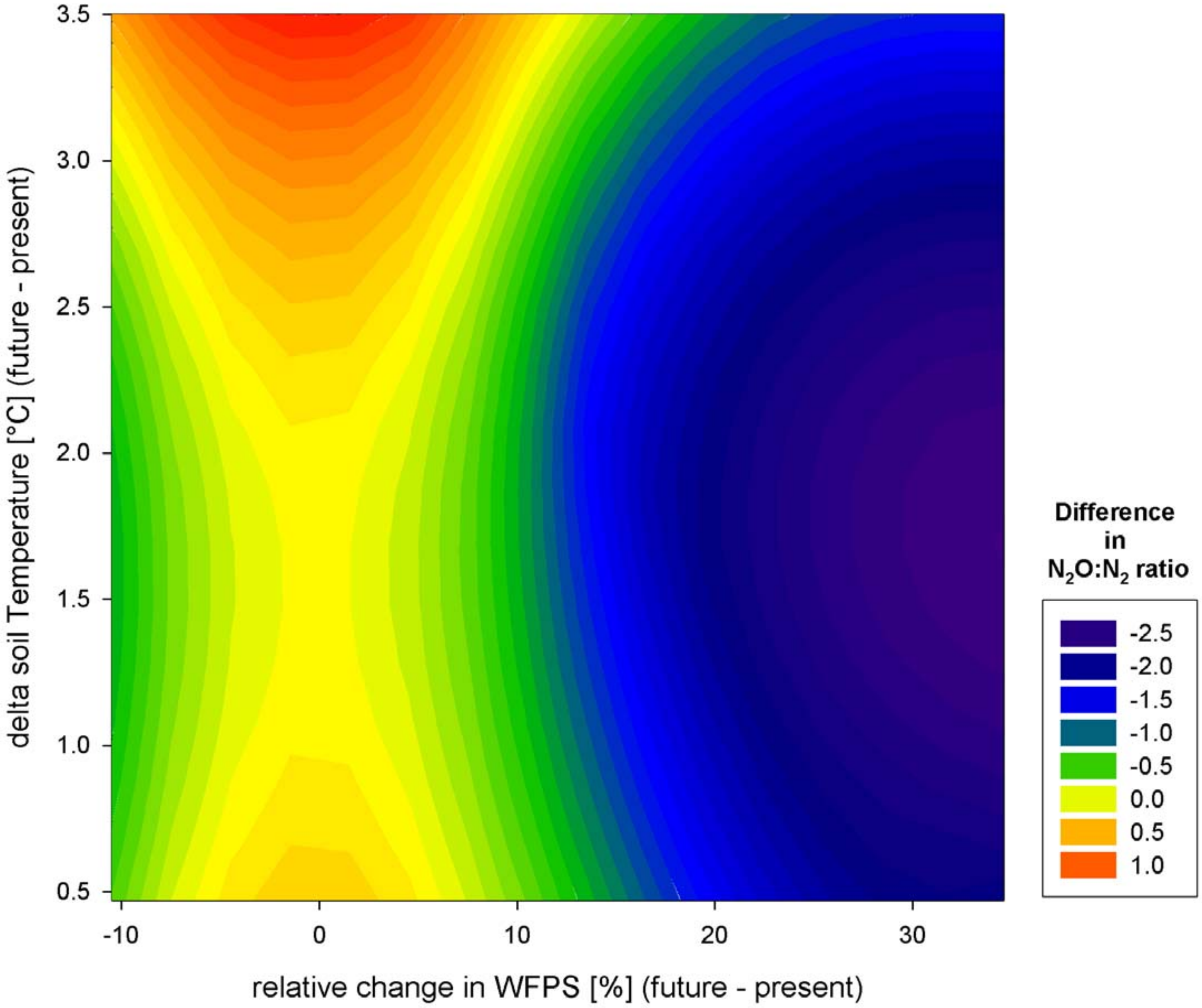


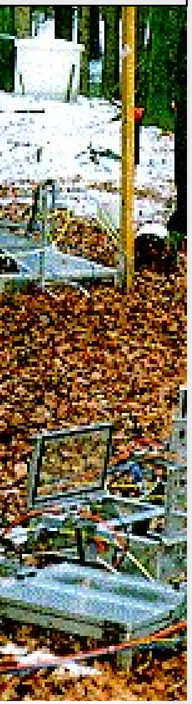


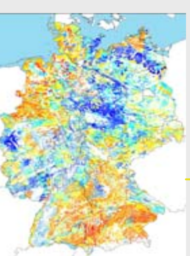

Soil Trace-Gas Emission
Emissions scalar
1.0
0.8
0.6
0.4
0.2
0.0
0 10 20 30 40 50 60 70 80 90 100
I_W (%)
NO
N_2O
N_2
Organic N Pools
LITTER
MICROBES
SOIL ORGANIC
Mineral N Pools
MIN. N
N Mineralization
$f(R, T, S_{tex}, q)$
N Immobilization

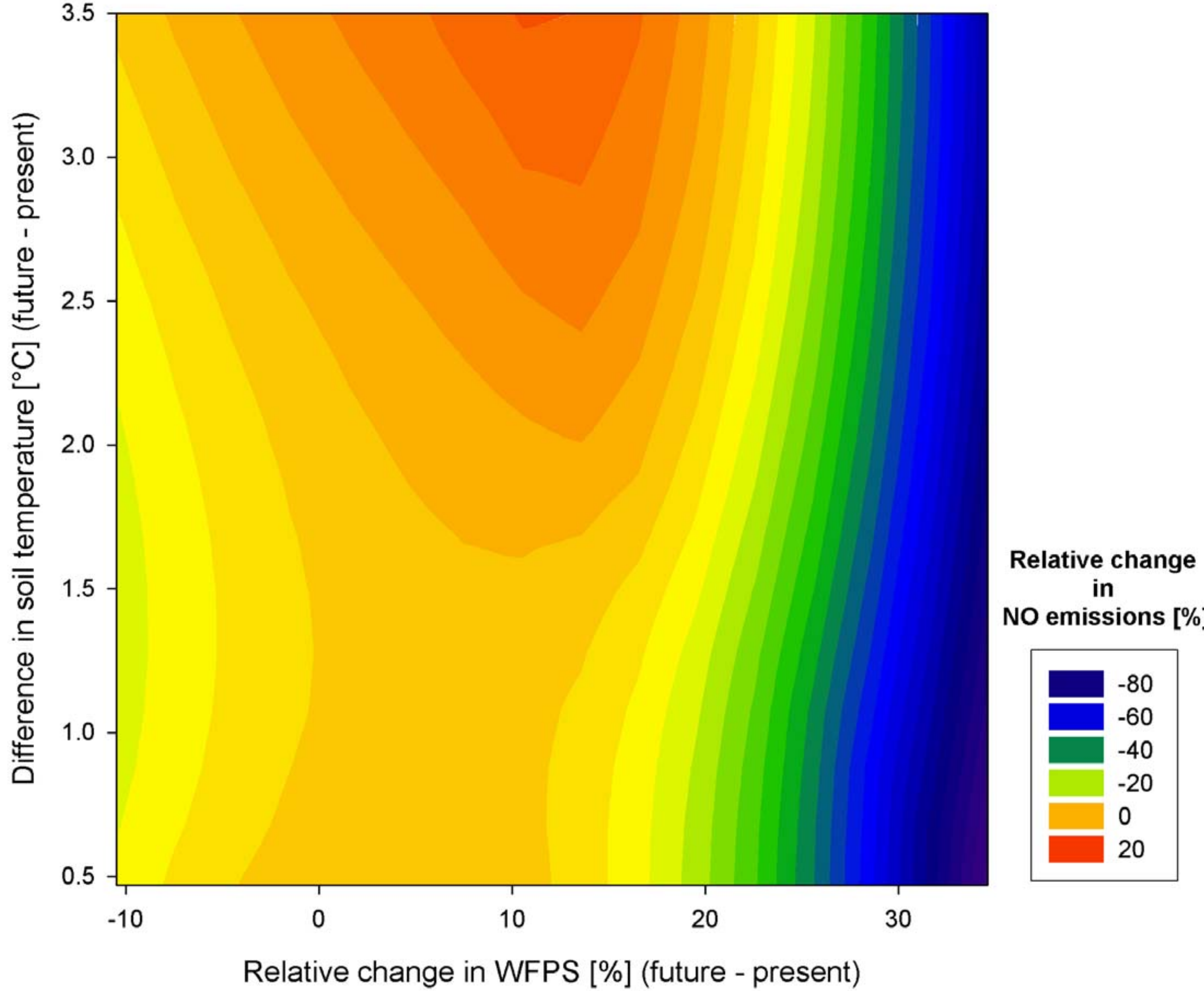


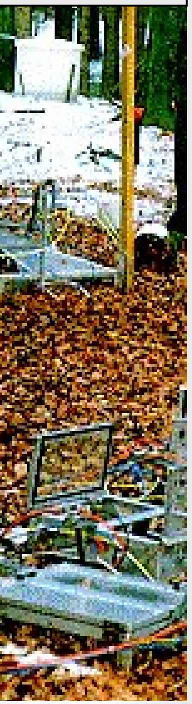


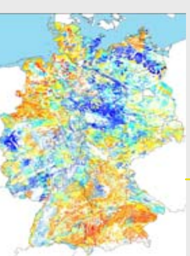

3.5
3.0
2.5
2.0
1.5
1.0
0.5
delta soil Temperature [°C] (future - present)
-10
0
10
20
30
relative change in WFPS [%] (future - present)
Difference in N_2O:N_2 ratio
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0



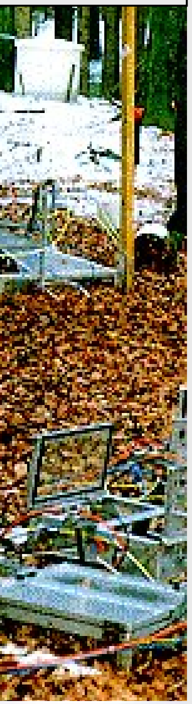


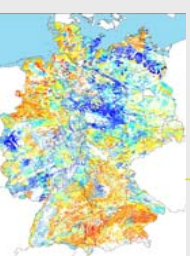

3.5
3.0
2.5
2.0
1.5
1.0
0.5
Difference in soil temperature [°C] (future - present)
-10
0
10
20
30
Relative change in WFPS [%] (future - present)
Relative change
in
NO emissions [%]
-80
-60
-40
-20
0
20





Season		N_2O		NO		Precipitation	Temperature
		kg N ha^{-1}	kt N	kg N ha^{-1}	kt N	mm	°C
December – Februar	**Present**	0.08^{a}	10.3^{a}	0.08^{a}	9.7^{a}	246^{a}	1.1^{a}
	Future	0.08^{a}	10.3^{a}	0.06^{a}	8.3^{a}	257^{a}	2.9^{b}
March – May	**Present**	0.17^{b}	21.4^{b}	0.09^{ab}	12.4^{ab}	181^{b}	5.0^{c}
	Future	0.13^{c}	17.2^{c}	0.12^{bc}	14.8^{bc}	167^{b}	7.2^{d}
June – August	**Present**	0.18^{d}	23.7^{d}	0.22^{d}	28.7^{d}	110^{c}	15.8^{e}
	Future	0.18^{bd}	23.0^{bd}	0.26^{d}	32.8^{d}	104^{c}	17.5^{f}
September – November	**Present**	0.10^{e}	12.8^{e}	0.13^{c}	17.1^{c}	245^{a}	8.4^{g}
	Future	0.11^{e}	13.7^{e}	0.14^{c}	18.4^{c}	245^{a}	9.9^{h}
Year	**Present**	0.53	68.3	0.52	68.0	782	7.6
	Future	0.50	64.3	0.58	74.3	773	9.4





Conlusions:

- Microbial immobilisation of N is the key to understand N losses
- Impact of changes in microbial diversity may feedback on N losses
- Limited understanding of the variability of N trace gas fluxes
  - Limited number of measurements
  - Limited time coverage
  - Missing link with process studies
- Biogeochemical models are ready to be used for simulating site and regional fluxes
  - Need of improvements
  - Assessing uncertainty
- Climate change will feedback on N trace gas emissions, but the feedback is rather complex and regional differentiated