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Emission of Nitrogen Species from Soils

Klaus Butterbach-Bahl

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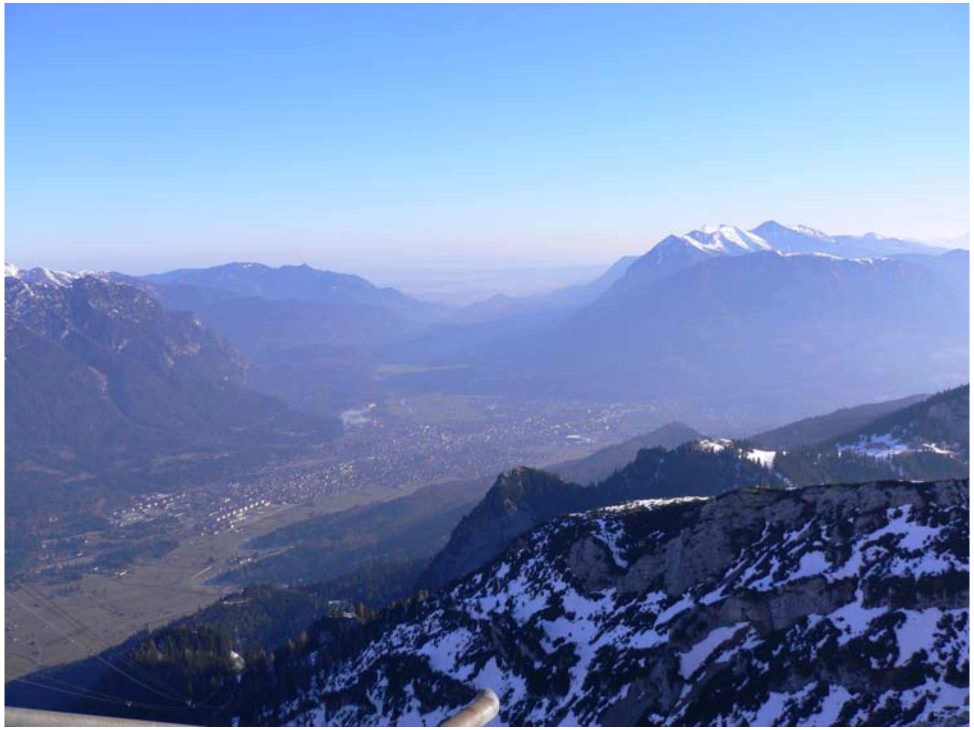
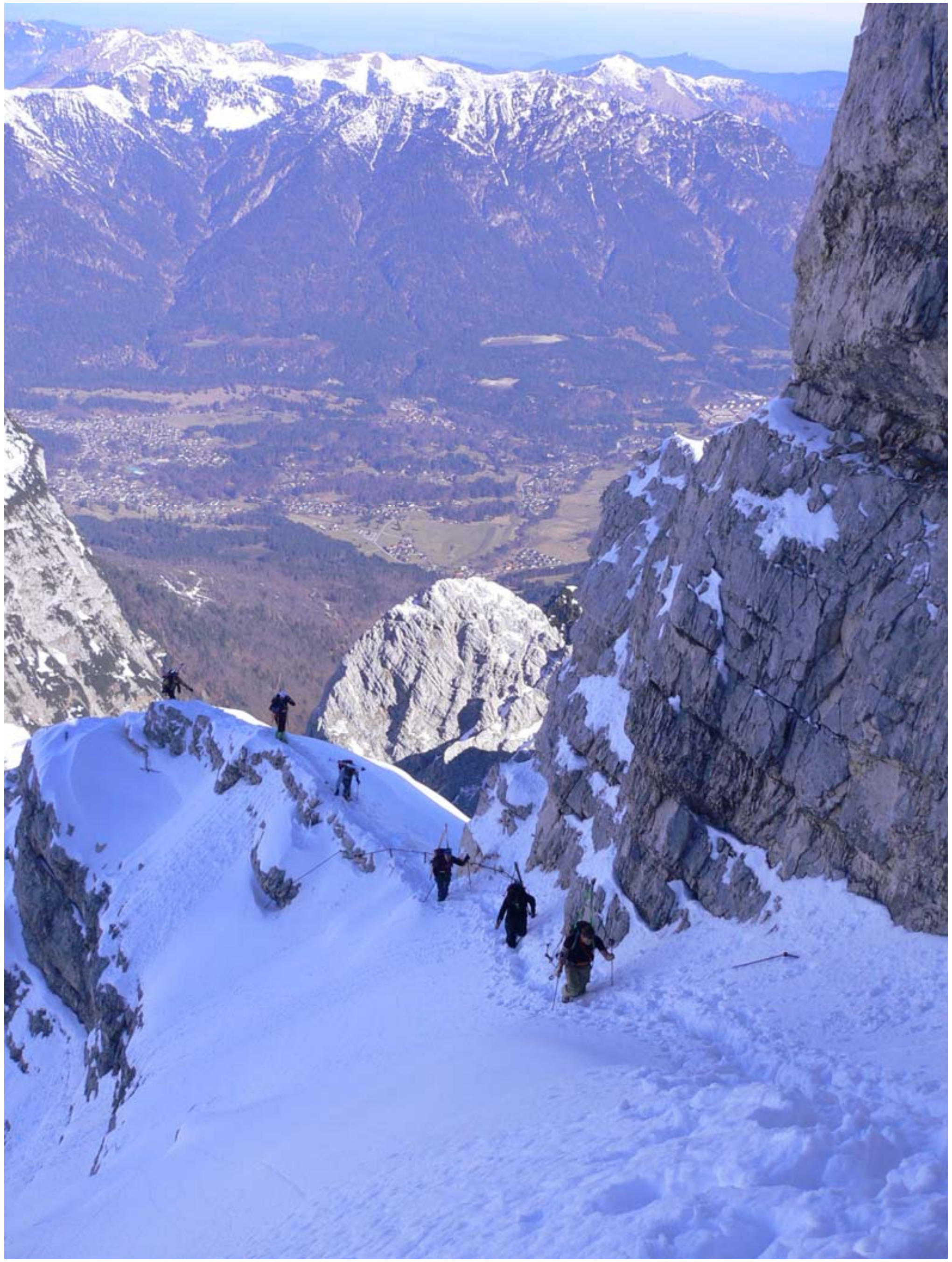
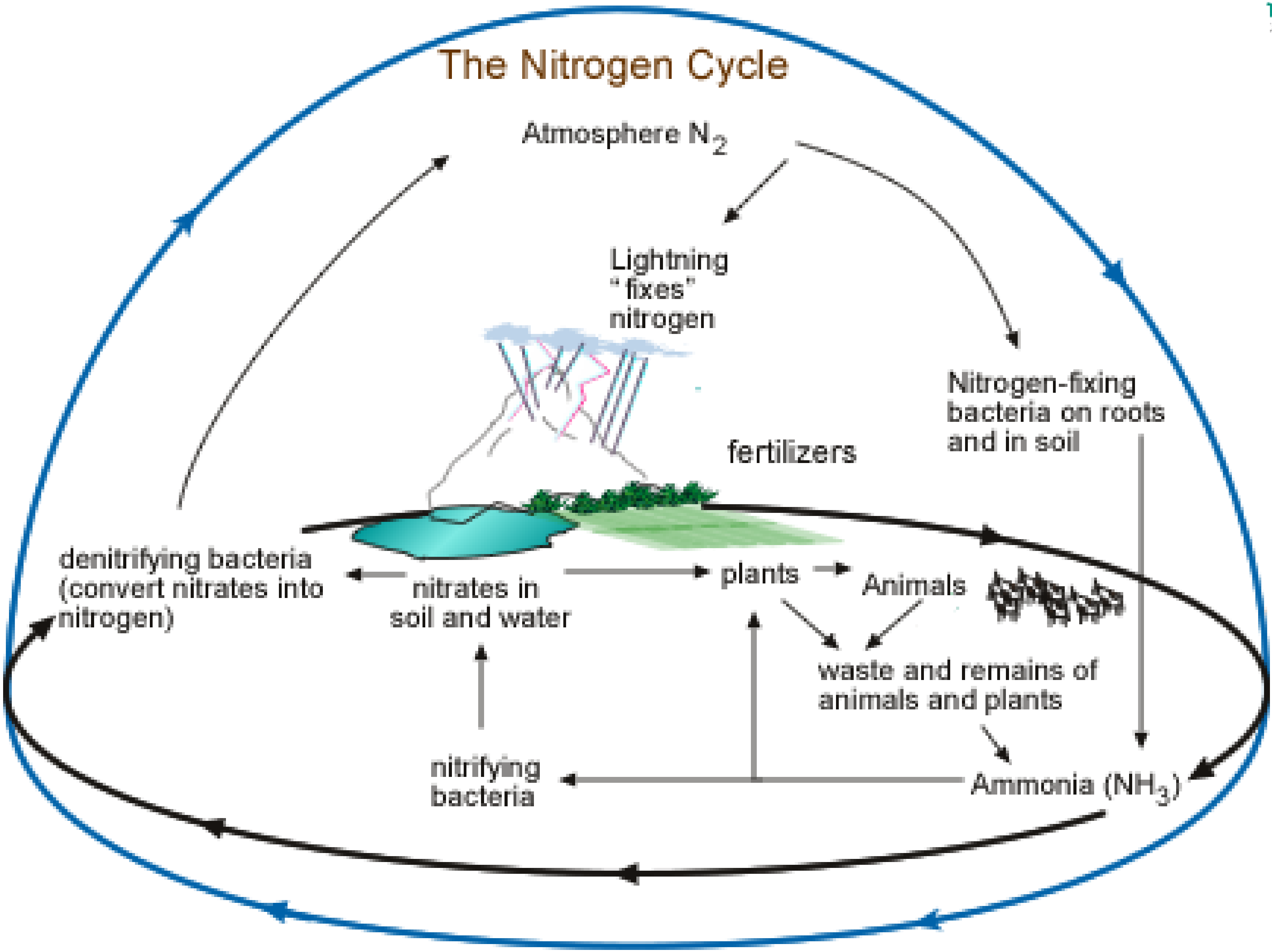
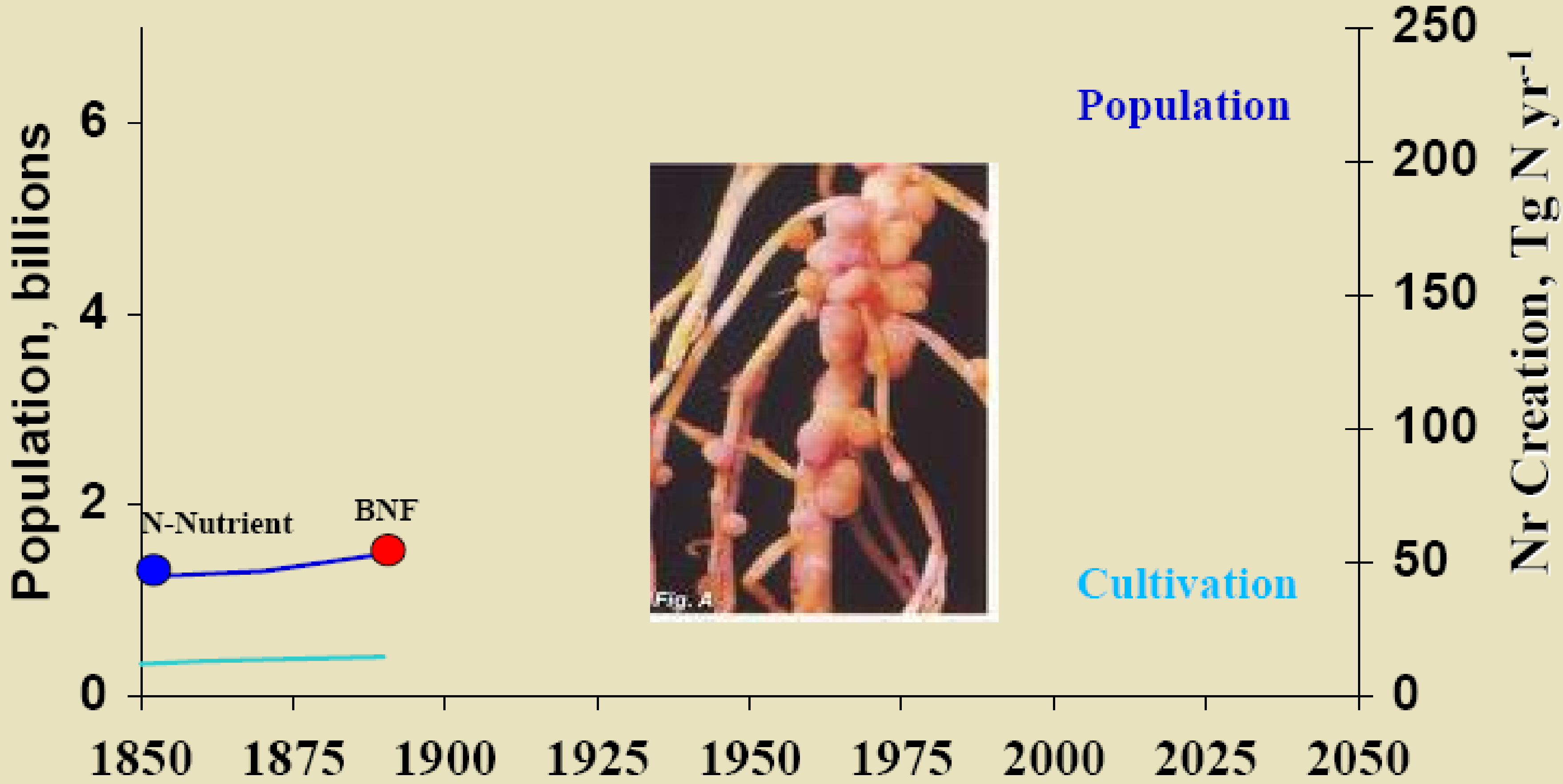




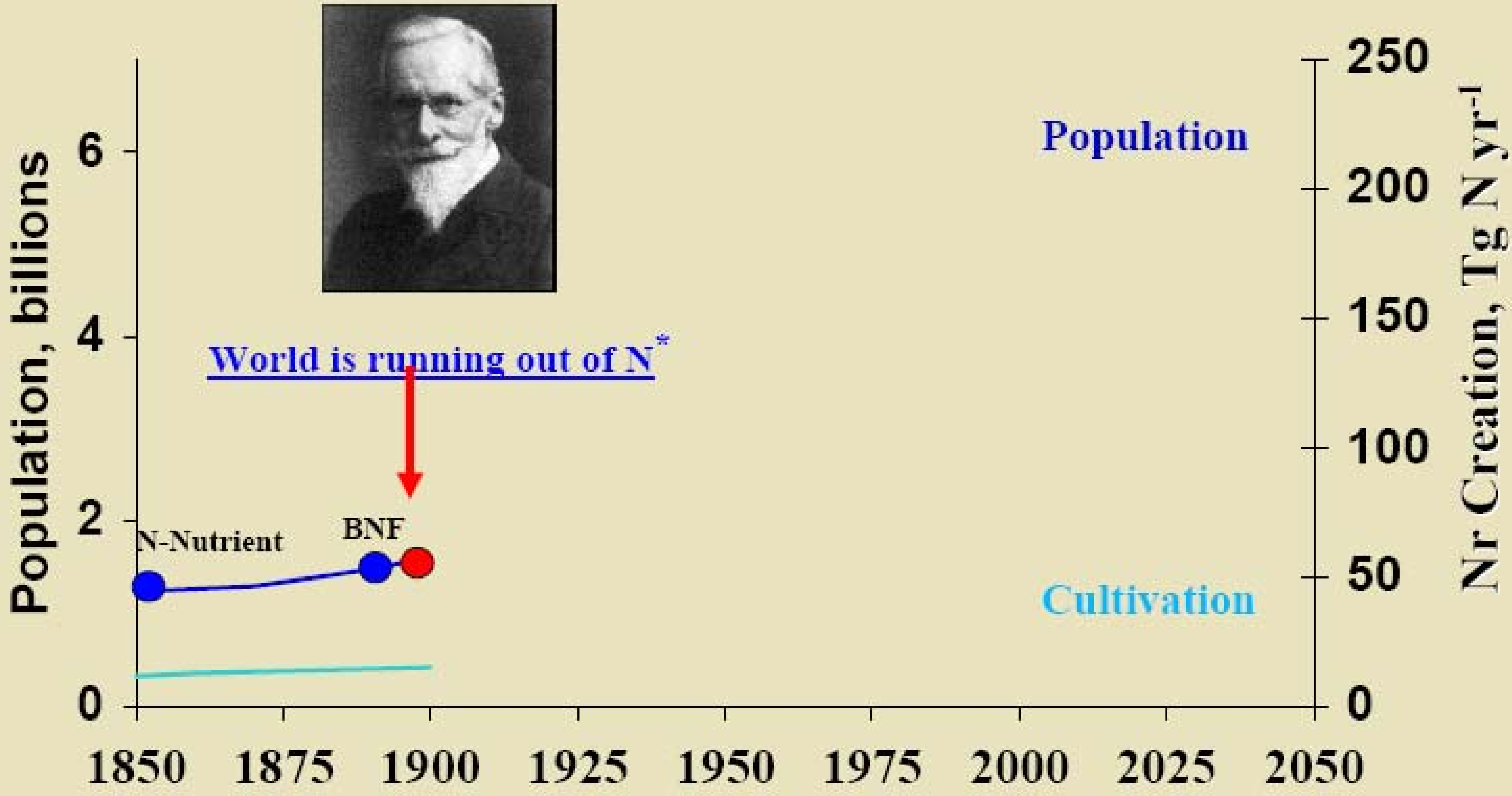

The Nitrogen Cycle
Atmosphere N_2
Lightning "fixes" nitrogen
fertilizers
Nitrogen-fixing bacteria on roots and in soil
denitrifying bacteria (convert nitrates into nitrogen)
nitrates in soil and water
plants
Animals
waste and remains of animals and plants
nitrifying bacteria
Ammonia (NH_3)

Timeline of Global Reactive N Creation by Human Activity 1850 to 2000



Galloway et al., 2003

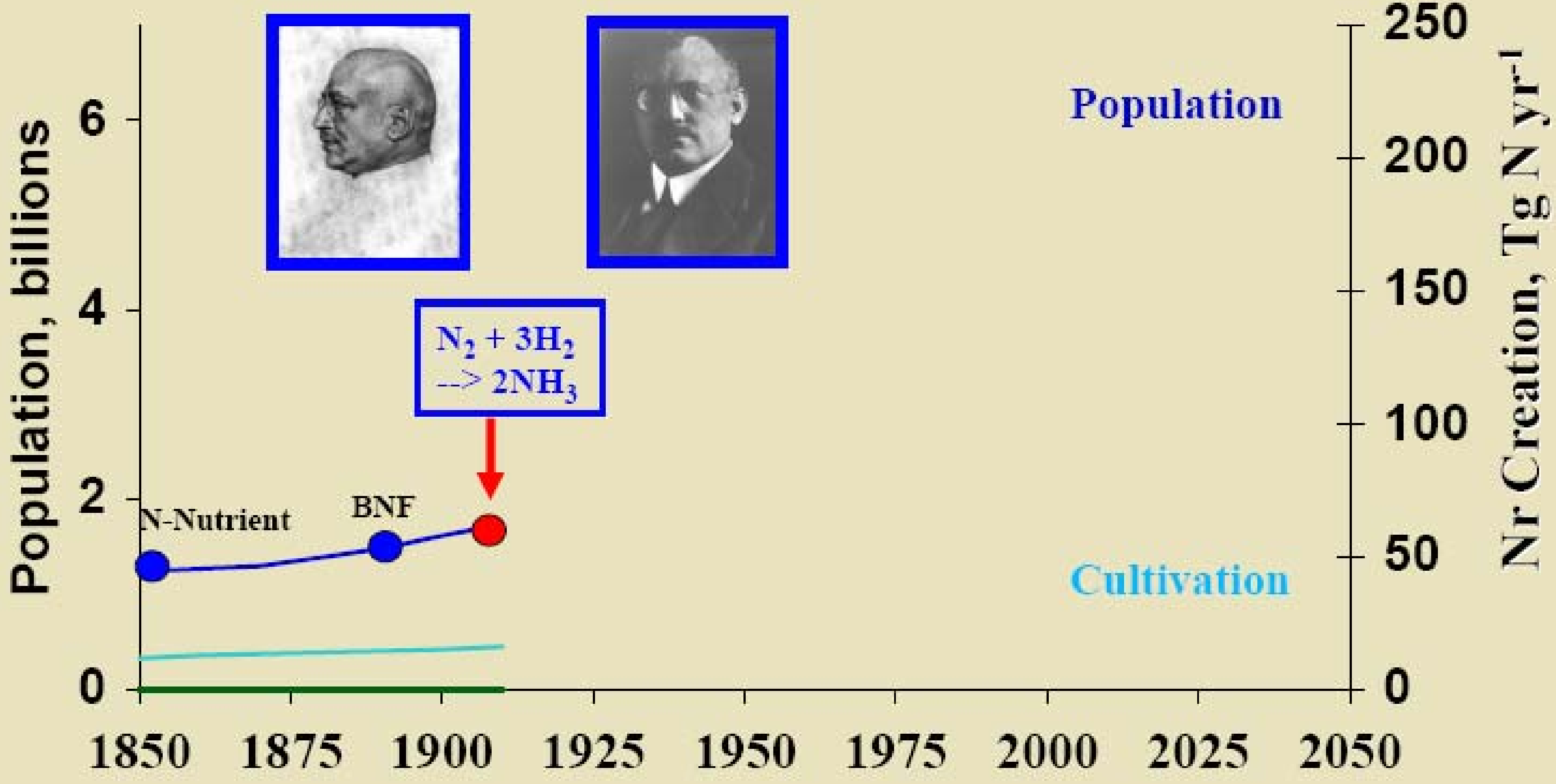
Timeline of Global Reactive N Creation by Human Activity 1850 to 2000



*1898, Sir William Crookes, president of the British Association for the Advancement of Science

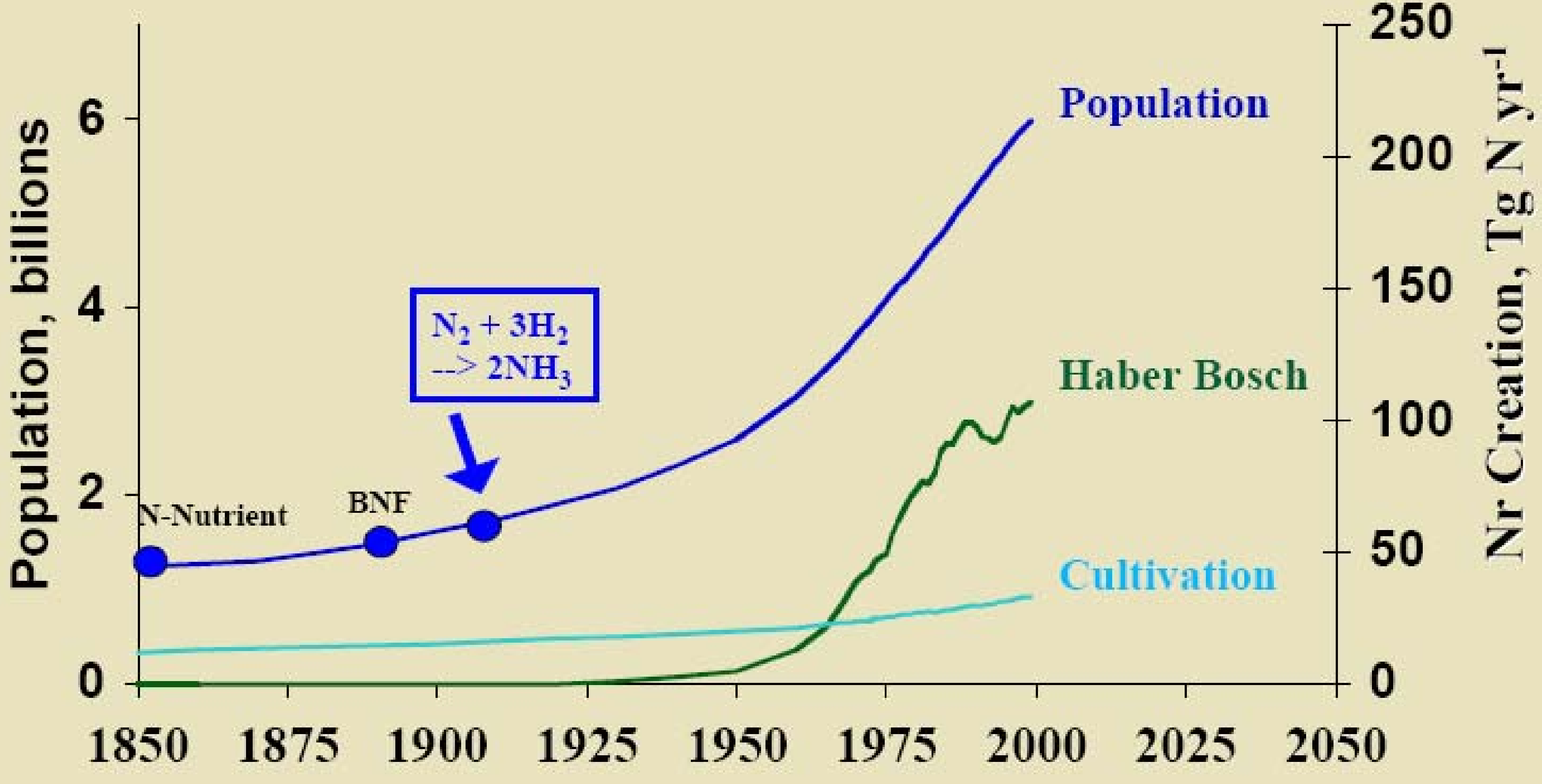
Galloway et al., 2003

Timeline of Global Reactive N Creation by Human Activity
1850 to 2000



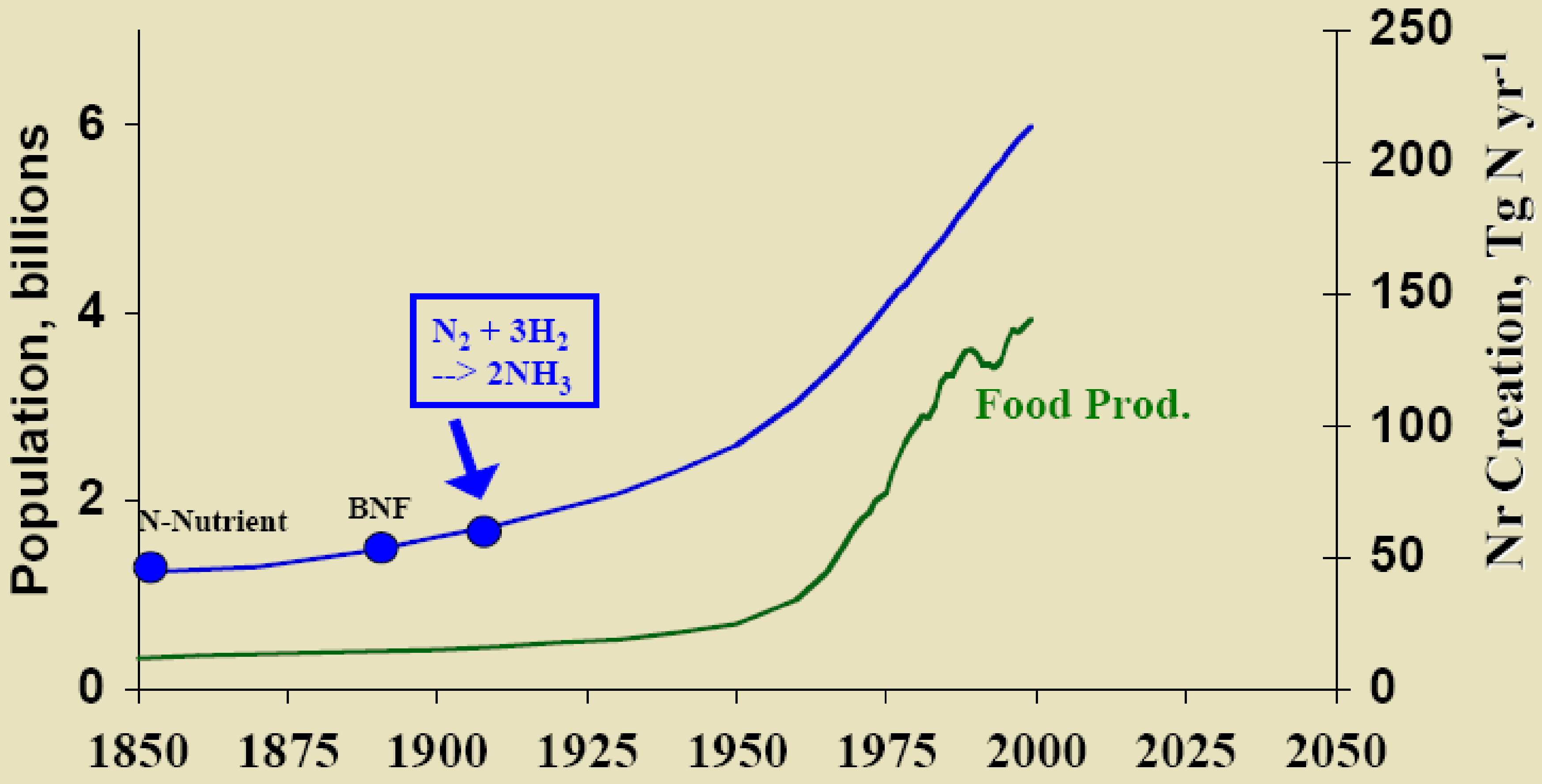
Galloway et al., 2003

Timeline of Global Reactive N Creation by Human Activity 1850 to 2000



Galloway et al., 2003

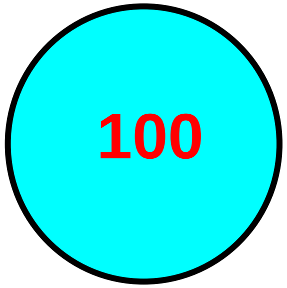
Timeline of Global Reactive N Creation by Human Activity 1850 to 2000



Galloway et al., 2003

The fate of nitrogen

N Fertilizer Produced



The fate of nitrogen

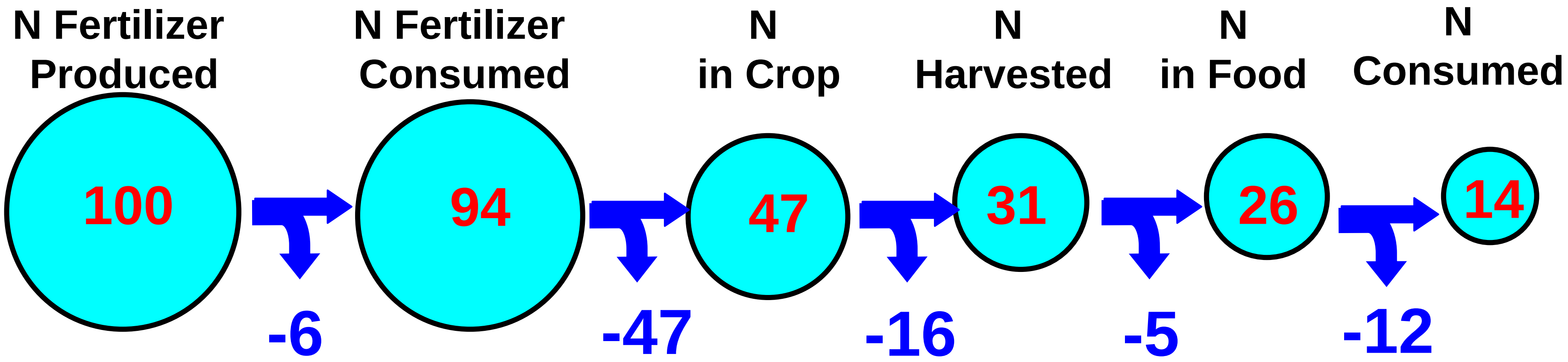
N Fertilizer Produced

N Consumed

14% of the N produced in the Haber-Bosch process enters the human mouth……….

Galloway JN and Cowling EB. 2002

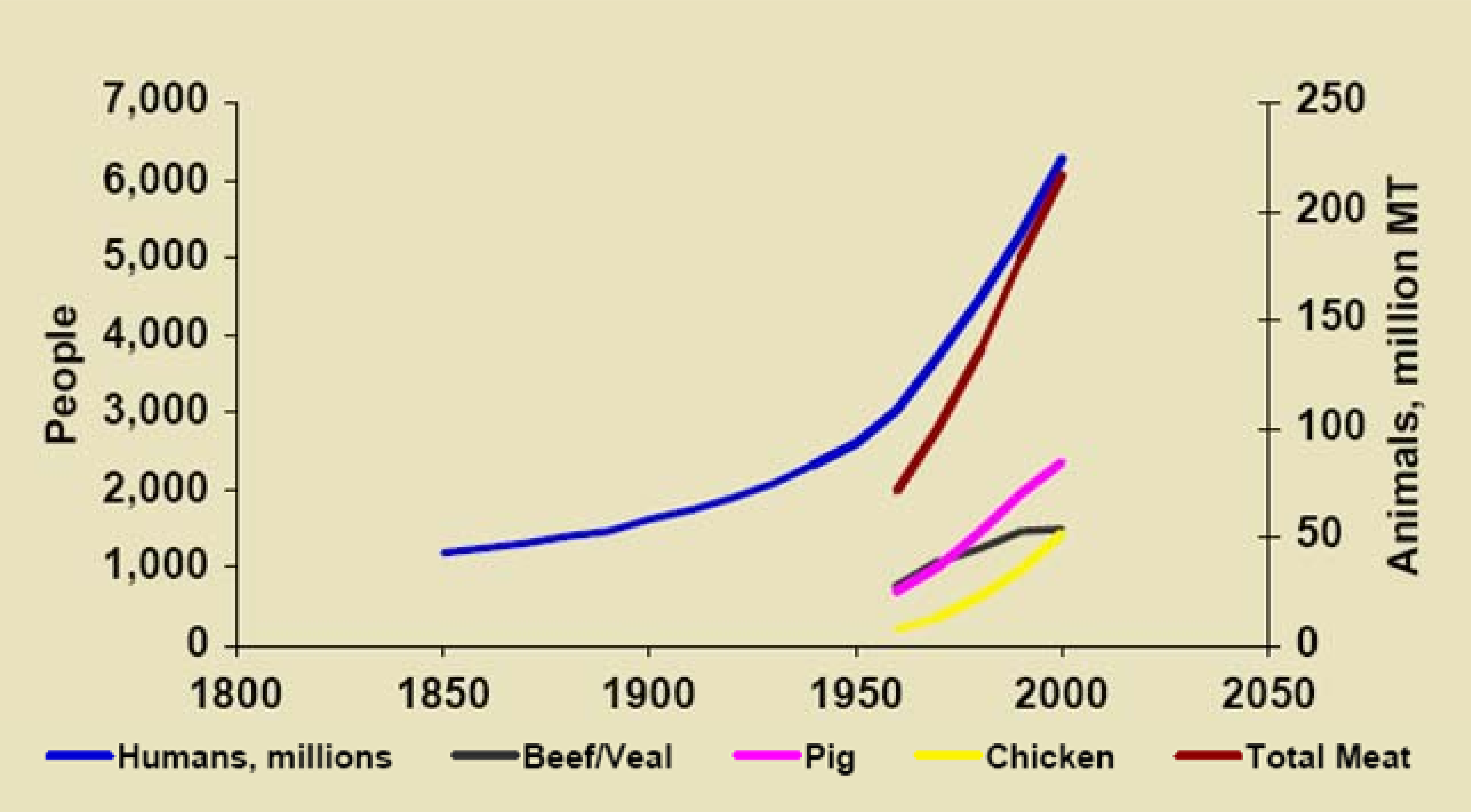
The fate of nitrogen



14% of the N produced in the Haber-Bosch process enters the human mouth……….if you are a vegetarian.

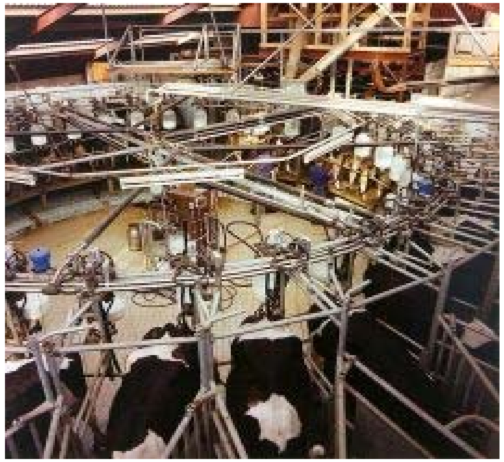
Galloway JN and Cowling EB. 2002

Global human population and meat production

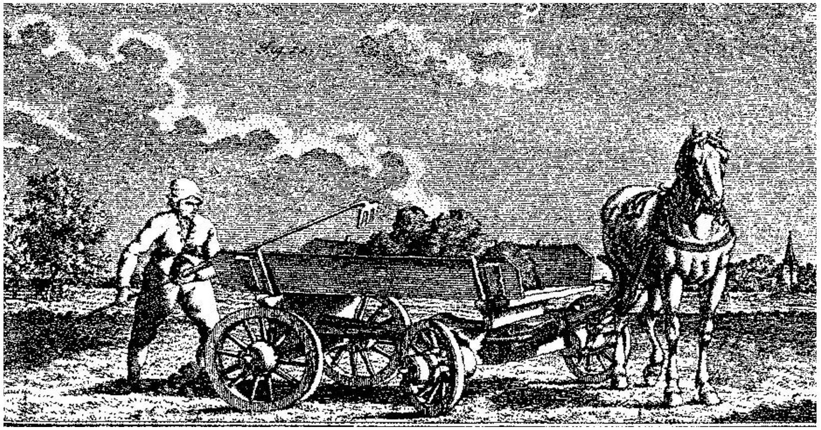


Historical development

Closed nutrient cycles



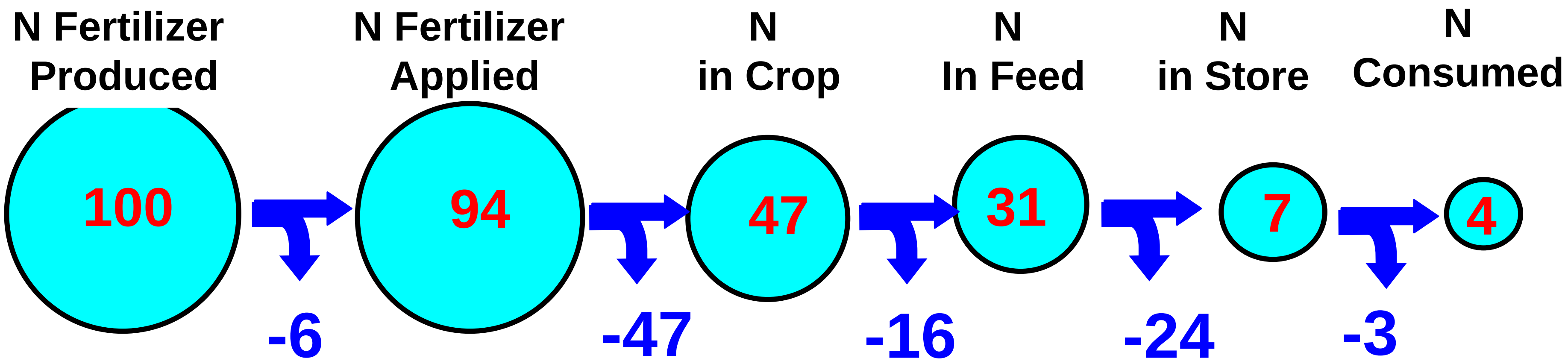
Intensive agriculture



Man labor

Industrialisation

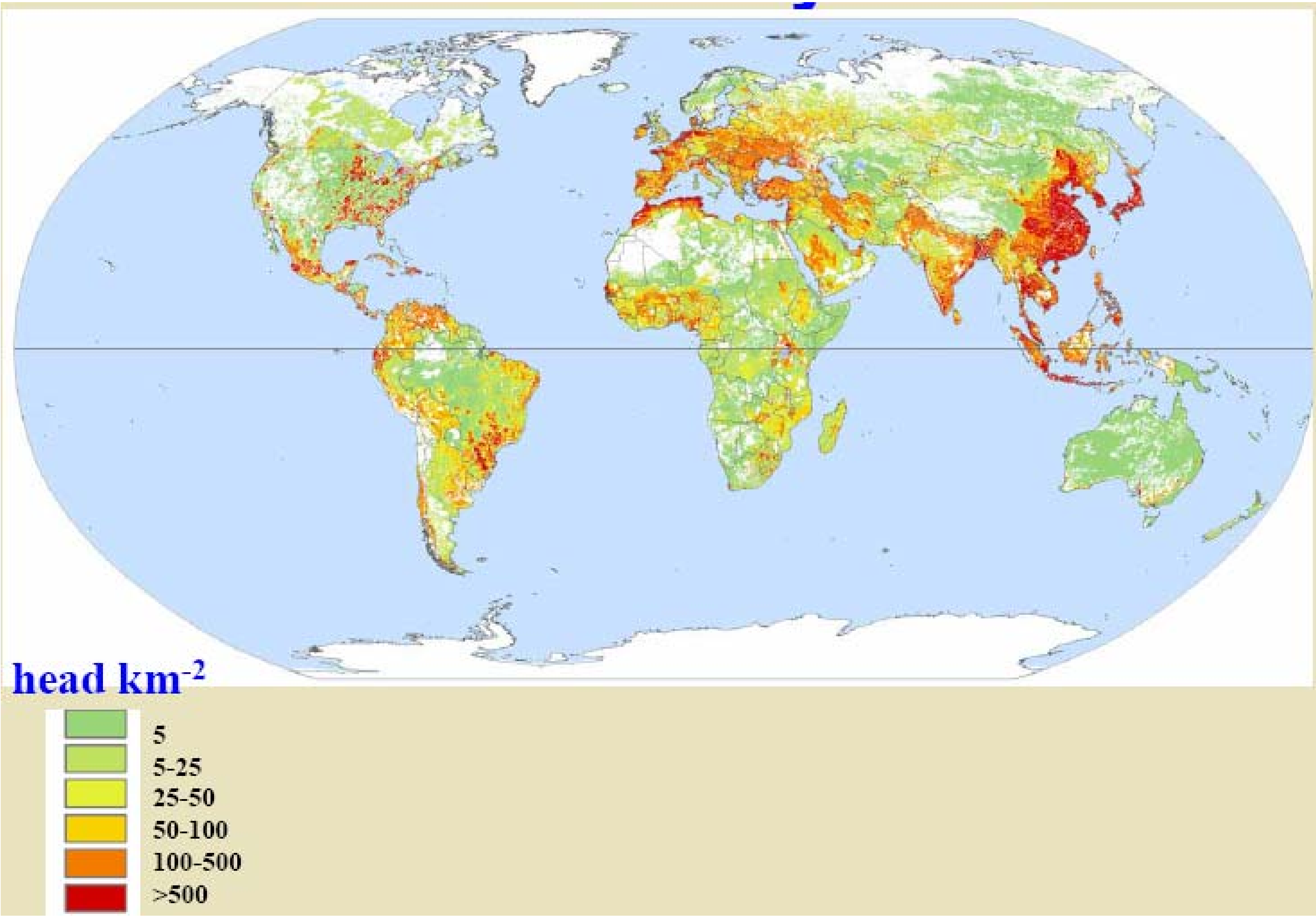
The fate of nitrogen



4% of the N produced in the Haber-Bosch process and used for animal production enters the human mouth.

Galloway JN and Cowling EB. 2002

Poultry density



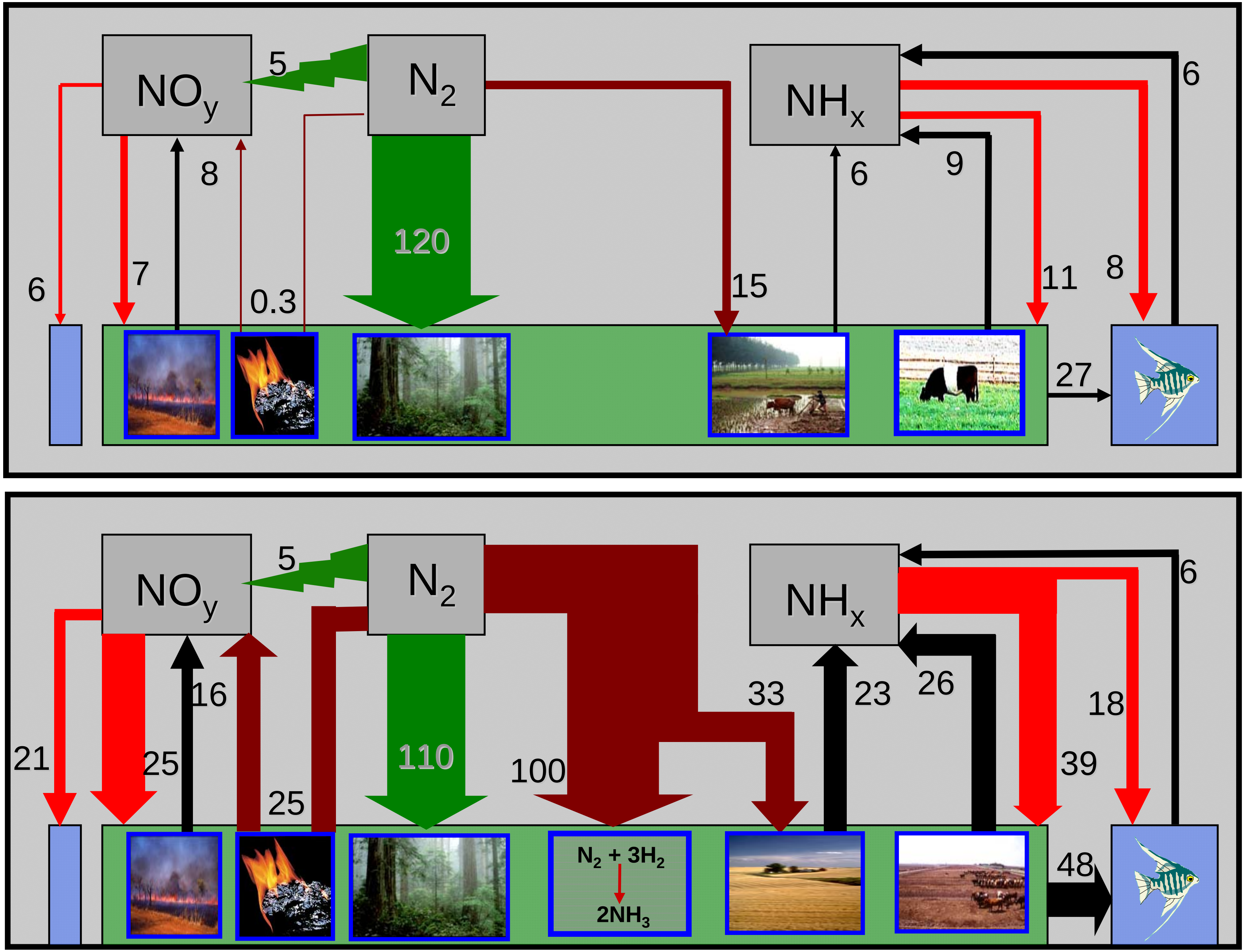
The global nitrogen cycle

The Global Nitrogen Budget in 1860 and mid-1990s, TgN/yr

Karlsruhe Institute of Technology

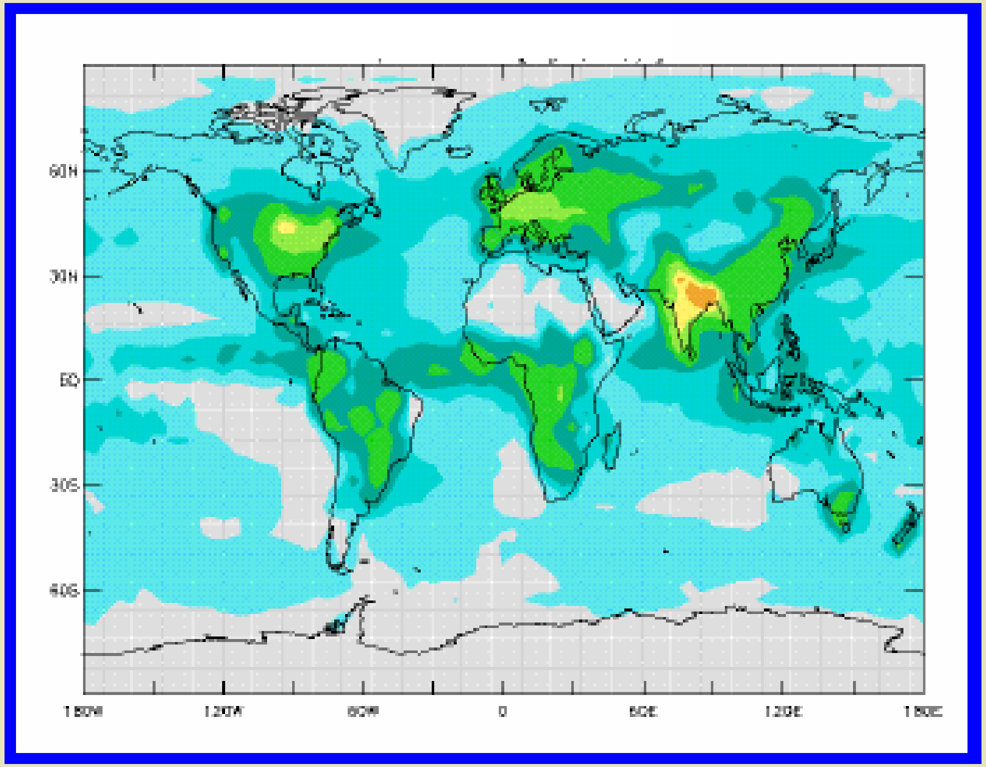
1860

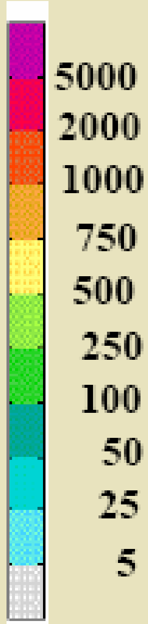
mid-1990s



Galloway et al., 2003

Nr deposition in 1860 and 1993 [mg m^{-2} yr^{-1}]



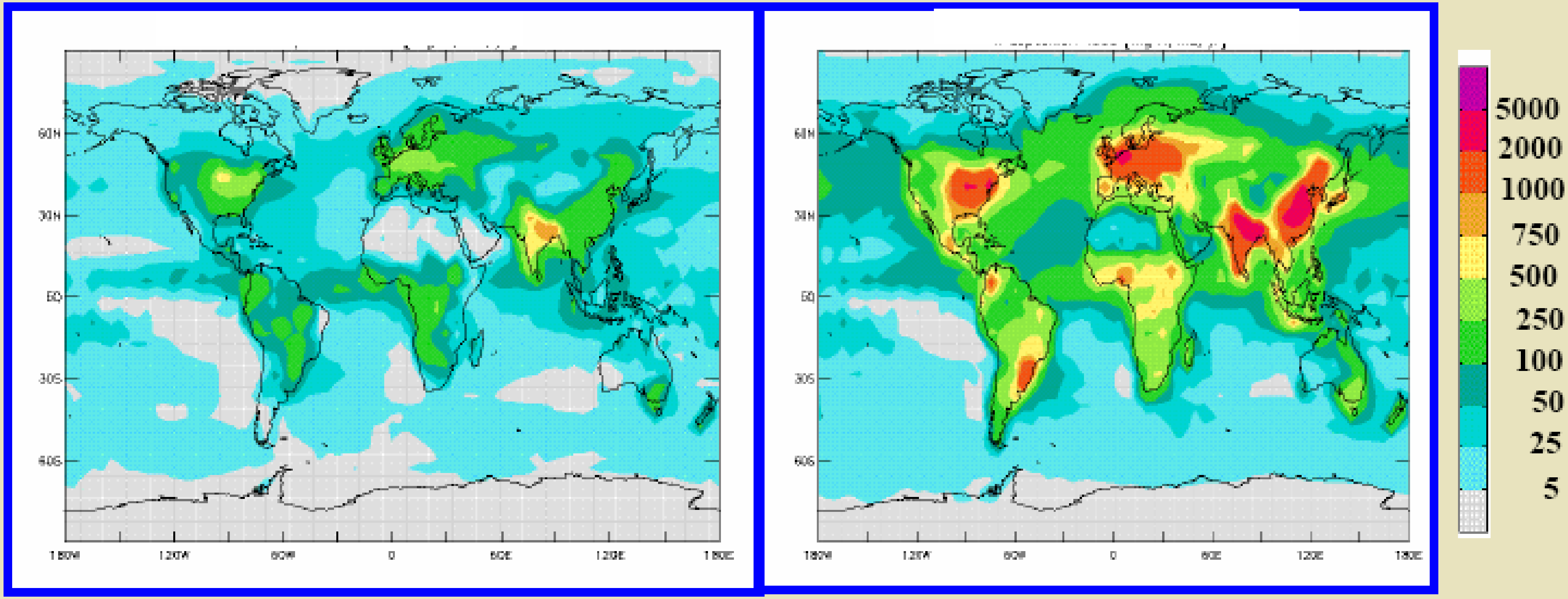


1860

- Nitrogen is emitted as NOx to the atmosphere by fossil fuel combustion
- Nitrogen is emitted as NH_3 and NOx from food production.
- Once emitted, it is transported and deposited to ecosystems.
- In 1860, human activities had limited influence on N deposition.

Galloway et al., 2003b

Nr deposition in 1860 and 1993 [mg m^{-2} yr^{-1}]



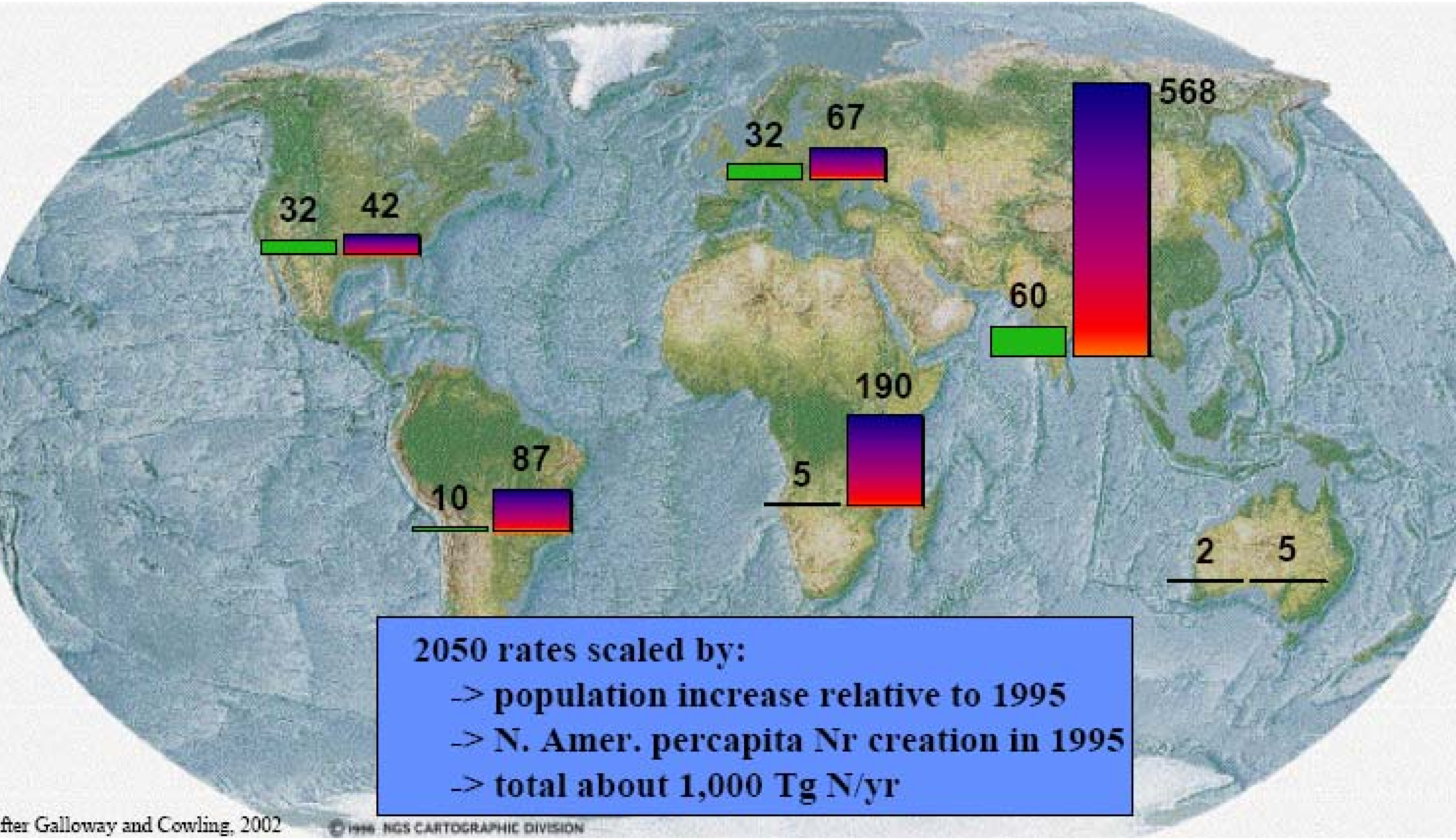
1860

1993

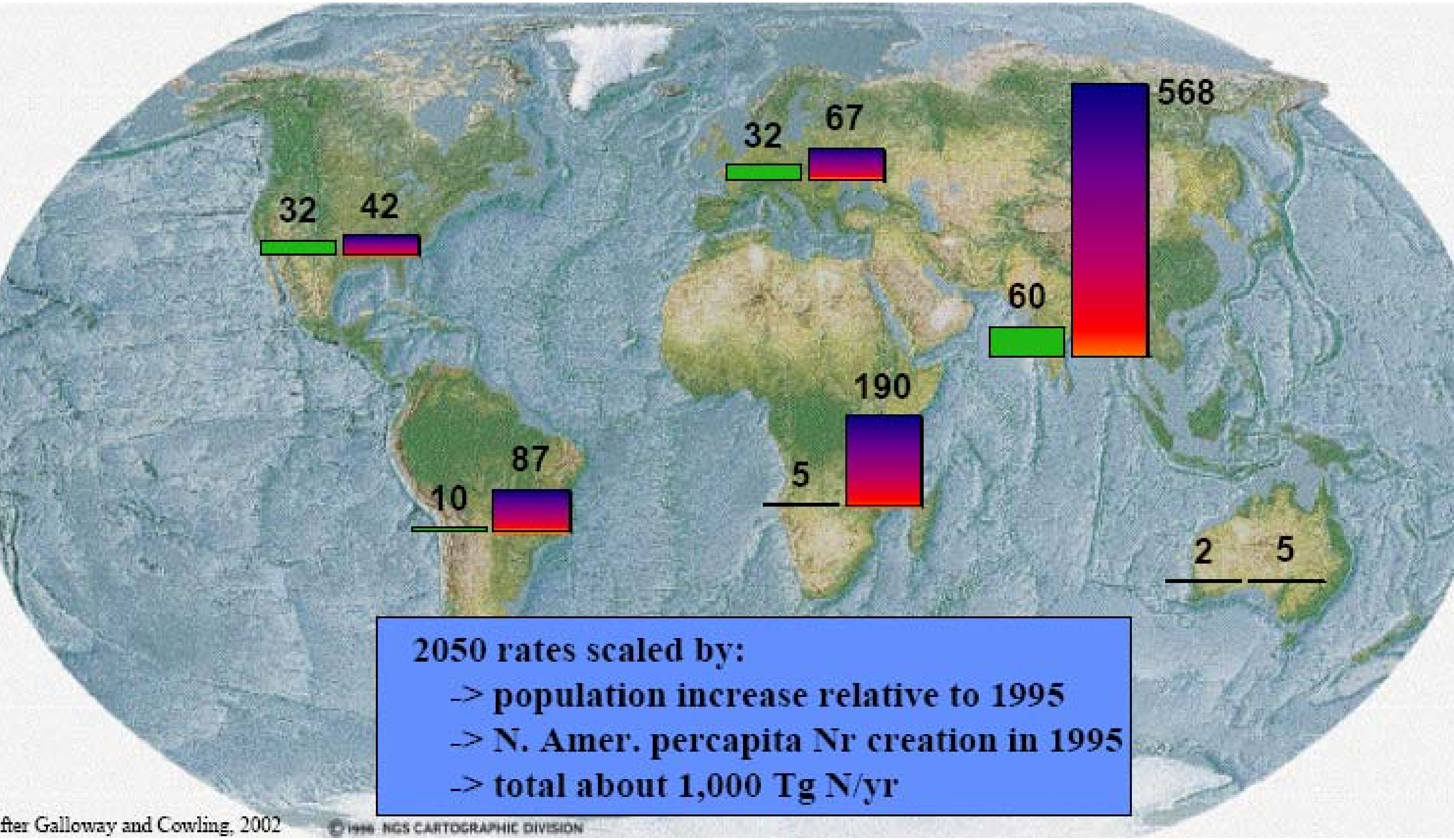
- Nitrogen is emitted as NOx to the atmosphere by fossil fuel combustion
- Nitrogen is emitted as NH_3 and NOx from food production.
- Once emitted, it is transported and deposited to ecosystems.
- In 1860, human activities had limited influence on N deposition.
- By 1993, the picture had changed.

Galloway et al., 2003b

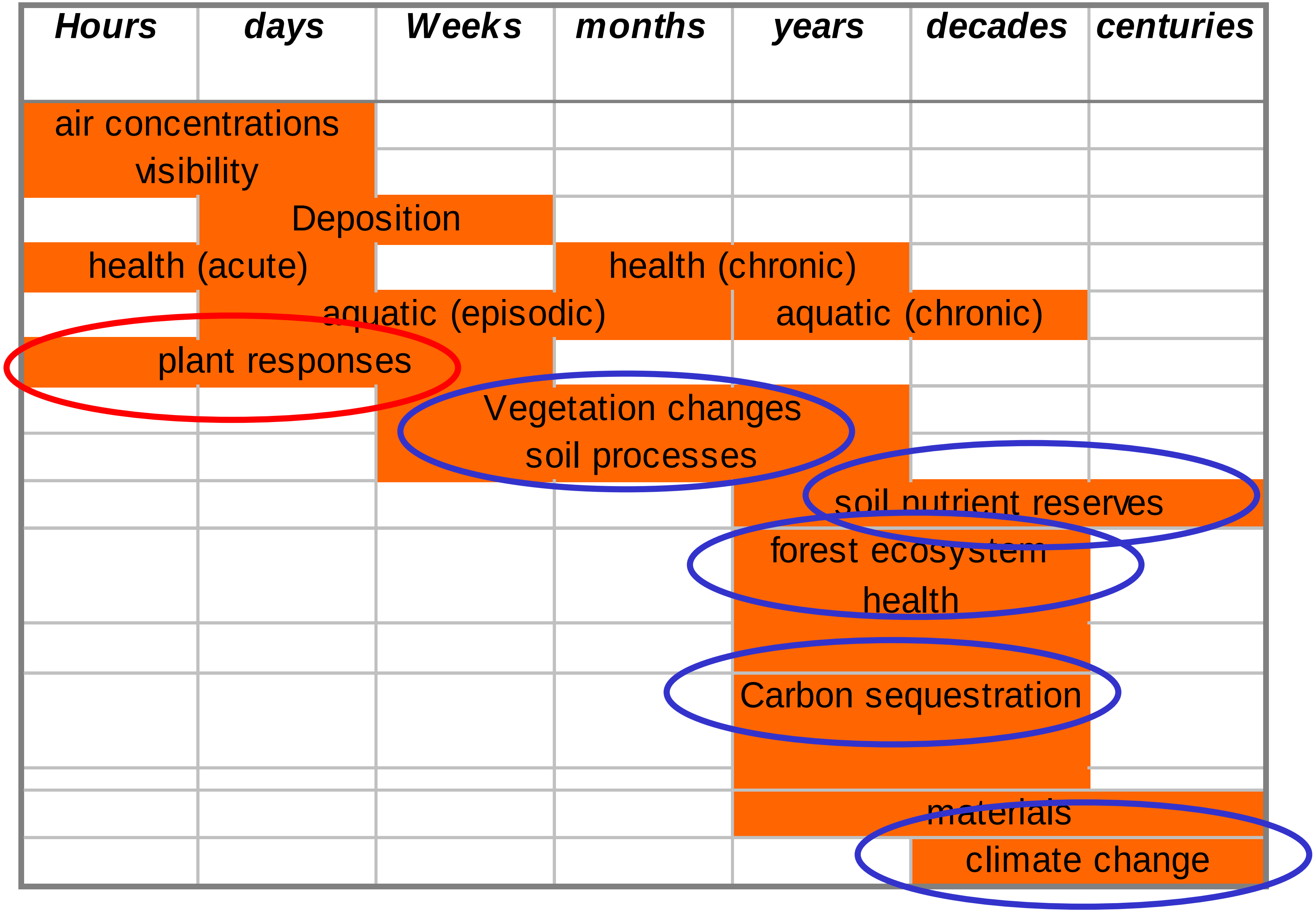
Nr creation 1995 (left) and 2050 (right) [Tg N yr^{-1}]



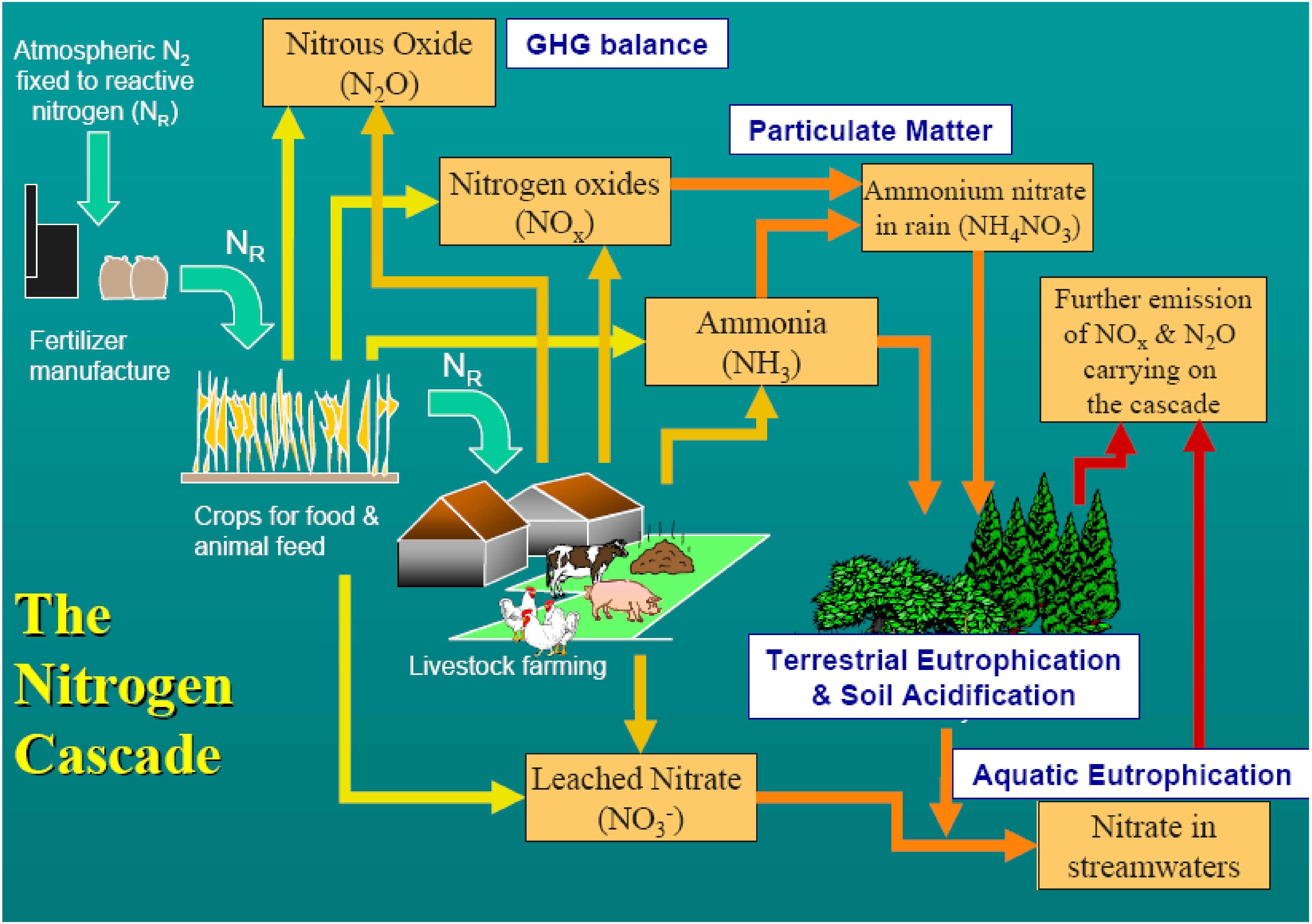
Nr creation 1995 (left) and 2050 (right) [Tg N yr^{-1}]



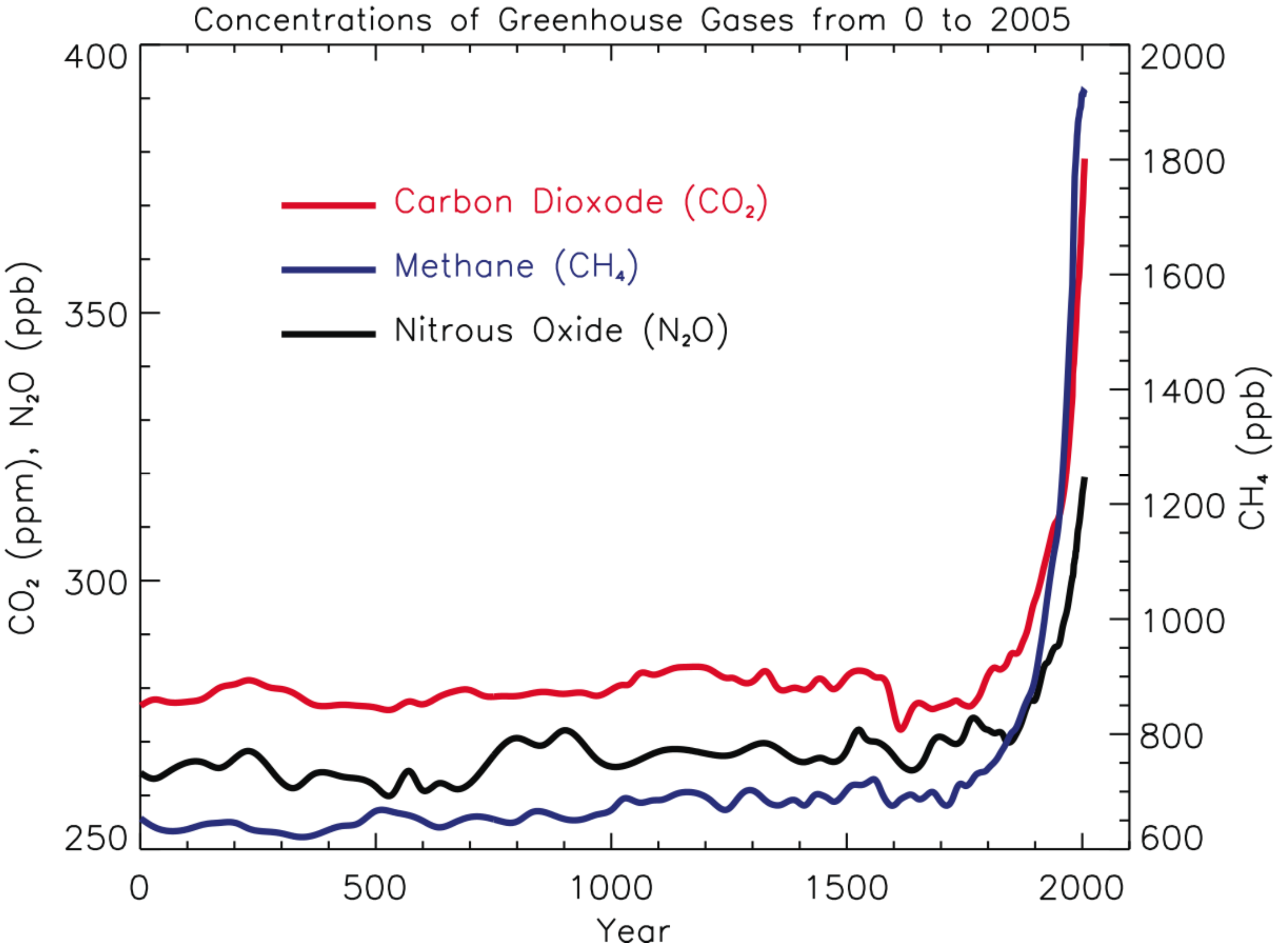
Ecological and social consequences of Nr



The Nr cascade



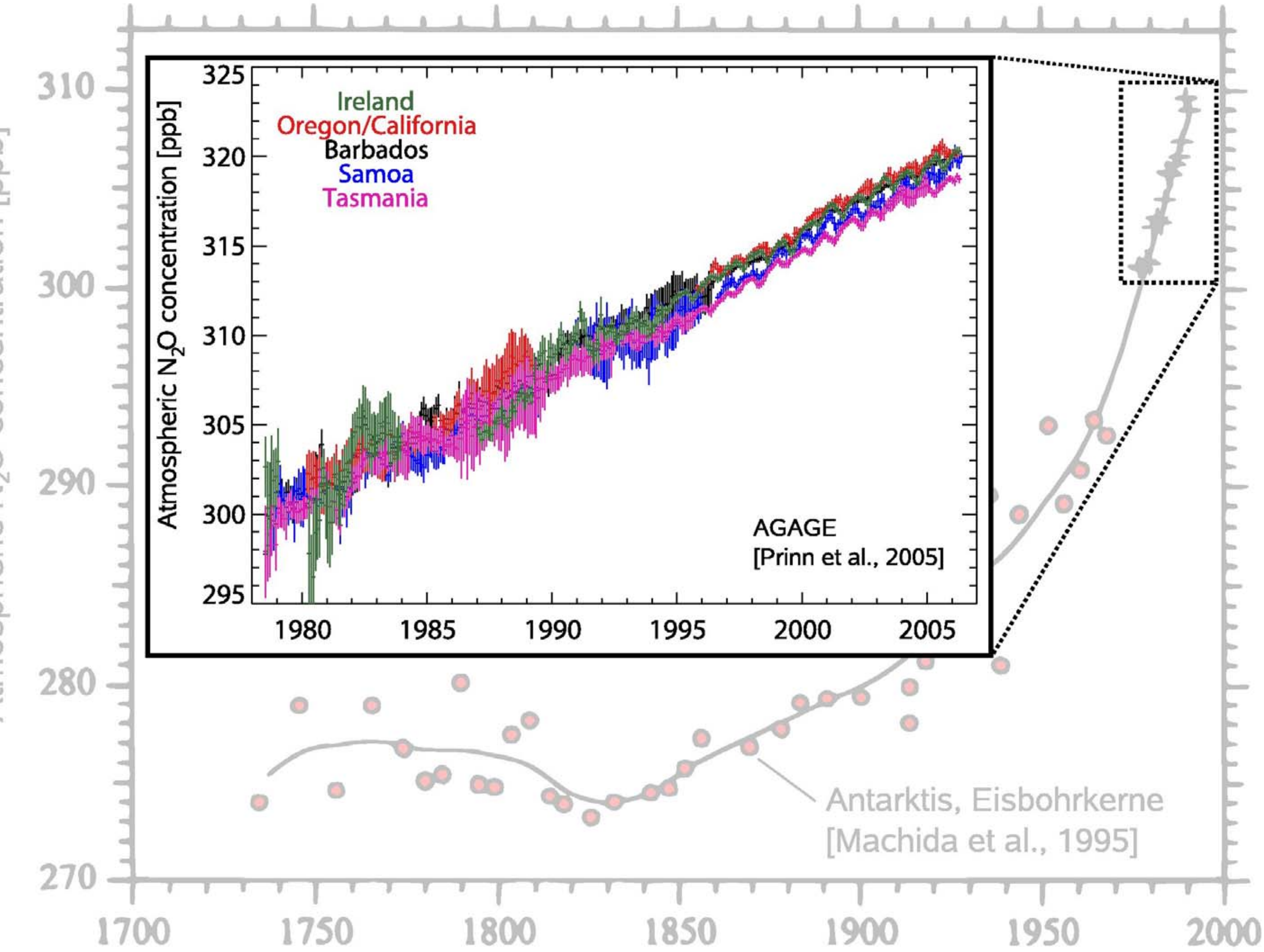
N_2O



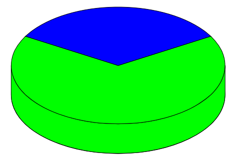
IPCC 2007

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency ($W\ m^{-2}\ ppb^{-1}$)	Global Warming Potential for Given Time Horizon SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4×10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7×10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03×10^{-3}	310	289	298	153

Atmospheric N_2O concentrations



Industrial sources



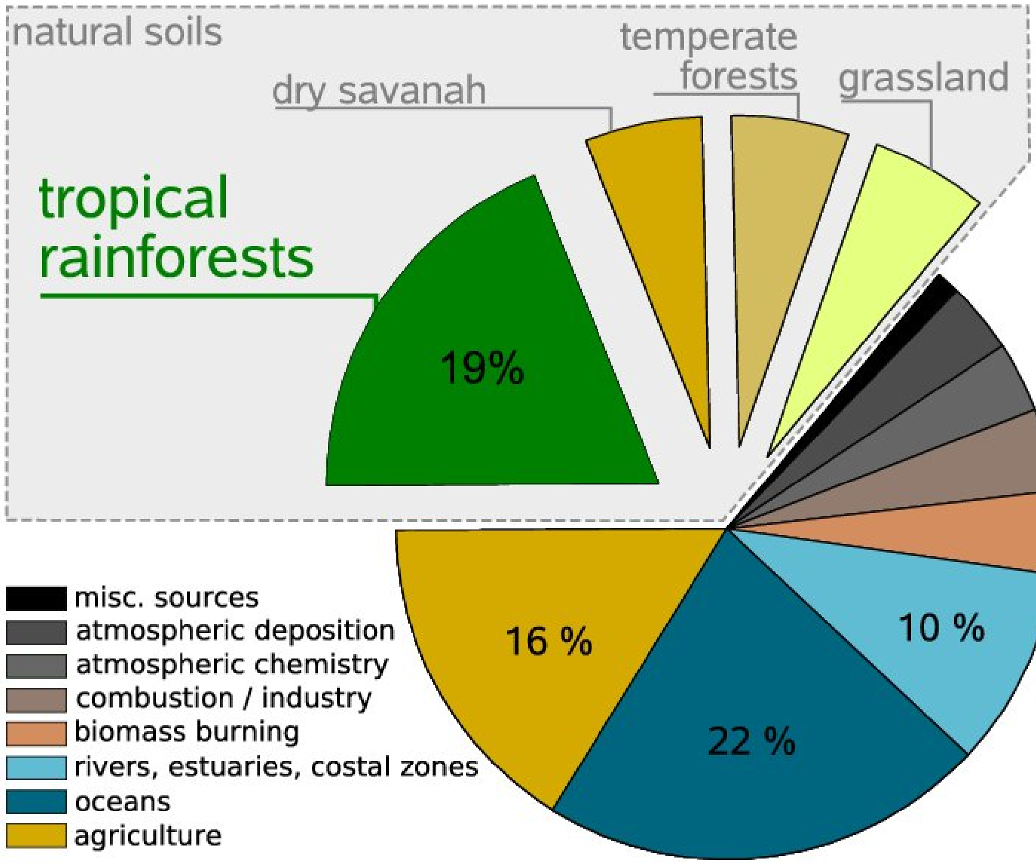
Agriculture, forests, ozeans

N_2O

Soils: 60-70%

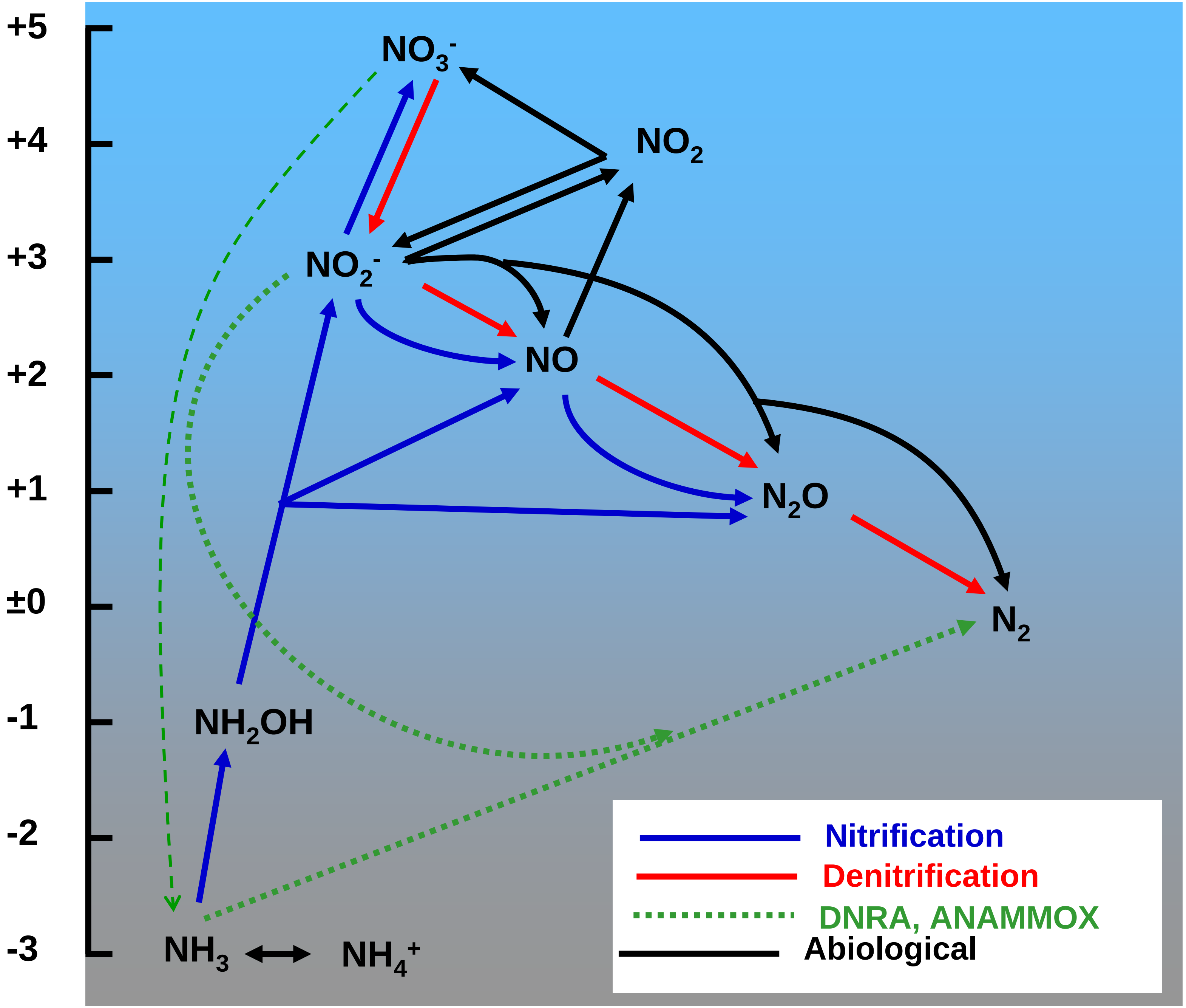
Sources and sinks of N_2O

N_2O-sources	Relative contribution to all identified sources [%]	Tg (10^{12} g) N_2O-N a^{-1}	
Natural N_2O sources			
Ocean	18.5	3.0	(1.0-5.0)
Tropical soils			
Wet forests	**18.5**	**3.0**	**(2.2-3.7)**
Dry savannas	**6.2**	**1.0**	**(0.5-2.0)**
Temperate soils			
Forests	**6.2**	**1.0**	**(0.1-2.0)**
Grasslands	**6.2**	**1.0**	**(0.5-2.0)**
Anthropogenic N_2O sources			
Agricultural soils	**20.4**	**3.3**	**(0.6-14.8)**
Biomass burning	3.1	0.5	(0.2-1.0)
Industrial sources	8.0	1.3	(0.7-1.8)
Cattle and feedlots	13.0	2.1	(0.6-3.1)
Total N_2O sources		16.2	(6.4-34.4)
N_2O sinks and atmospheric increase			
Stratospheric destruction		12.3	(9.0-16.0)
Removal by soil microbes		**?**	**(?)**
Atmospheric increase		**3.9**	**(3.1-4.7)**

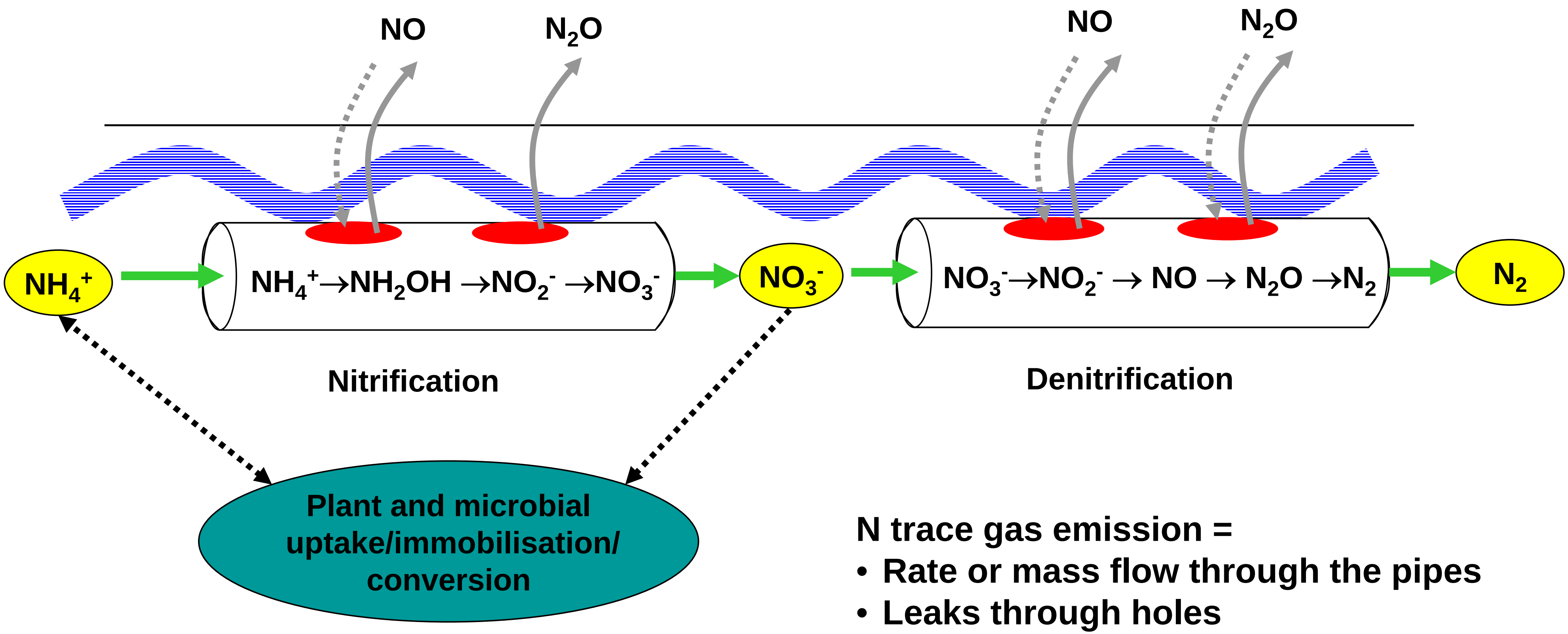


IPCC 2001, 2007

Complexity of Nr reactions in soils



N trace gas production in soils

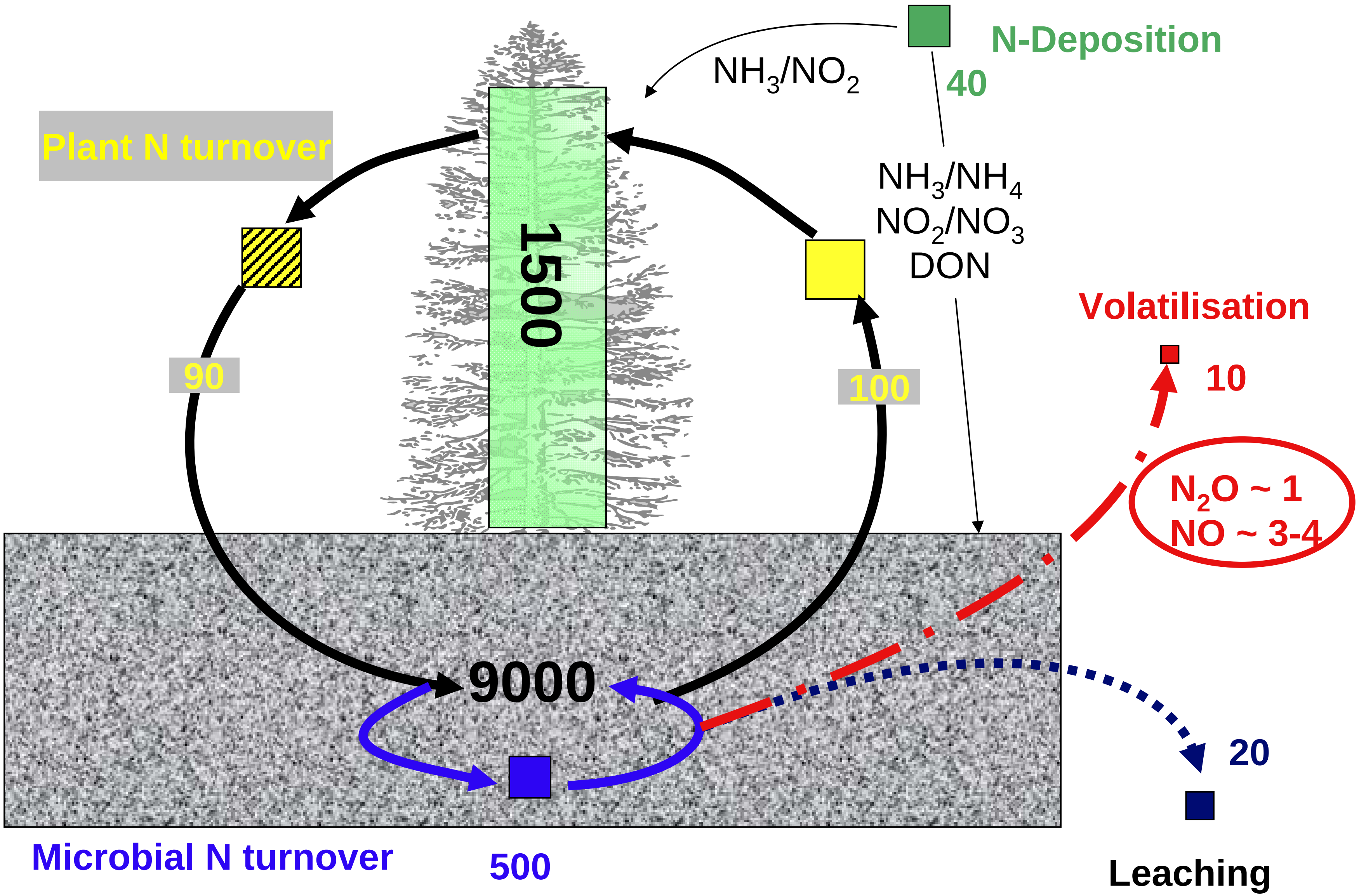


N trace gas emission =

- **Rate or mass flow through the pipes**
- **Leaks through holes**

Davidson et al., 1993, 2000

N trace gases and ecosystem N cycling



How have regional and global changes in management and N use affected nitrogen cycling in natural and semi-natural systems and associated N_2O exchange ?

→case study: Steppe ecosystem of Inner Mongolia

MAGIM

-

An Interdisziplinary Sino-German Research Project on Effects of Grazing on Matter Fluxes in Grasslands of Inner Mongolia

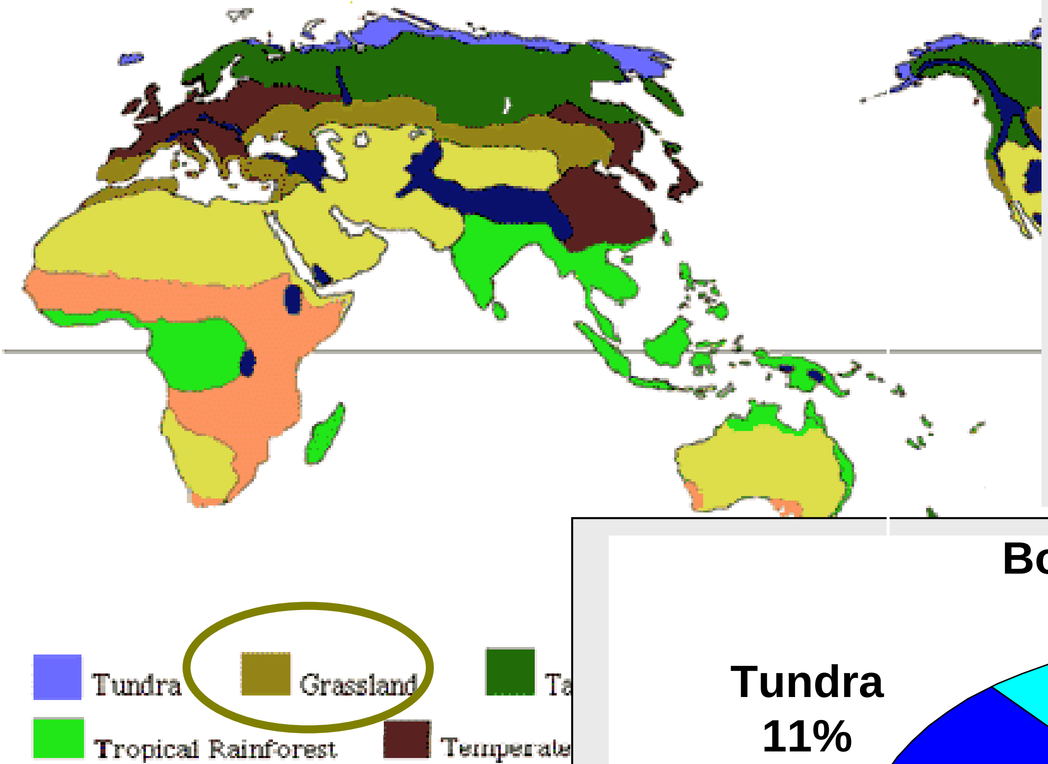
Klaus Butterbach-Bahl

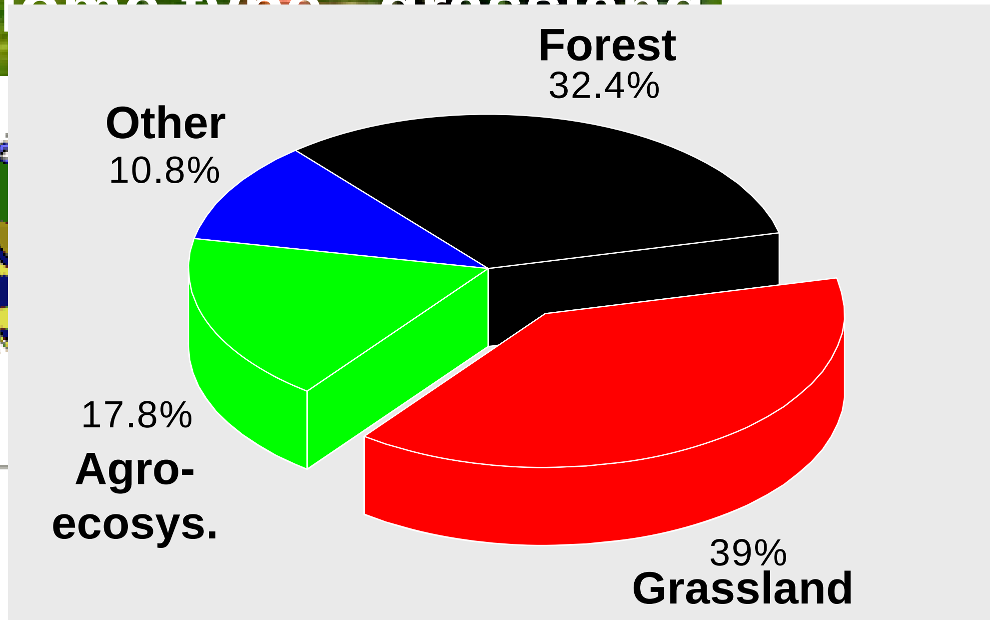
Institute for Meteorology and Climate Research

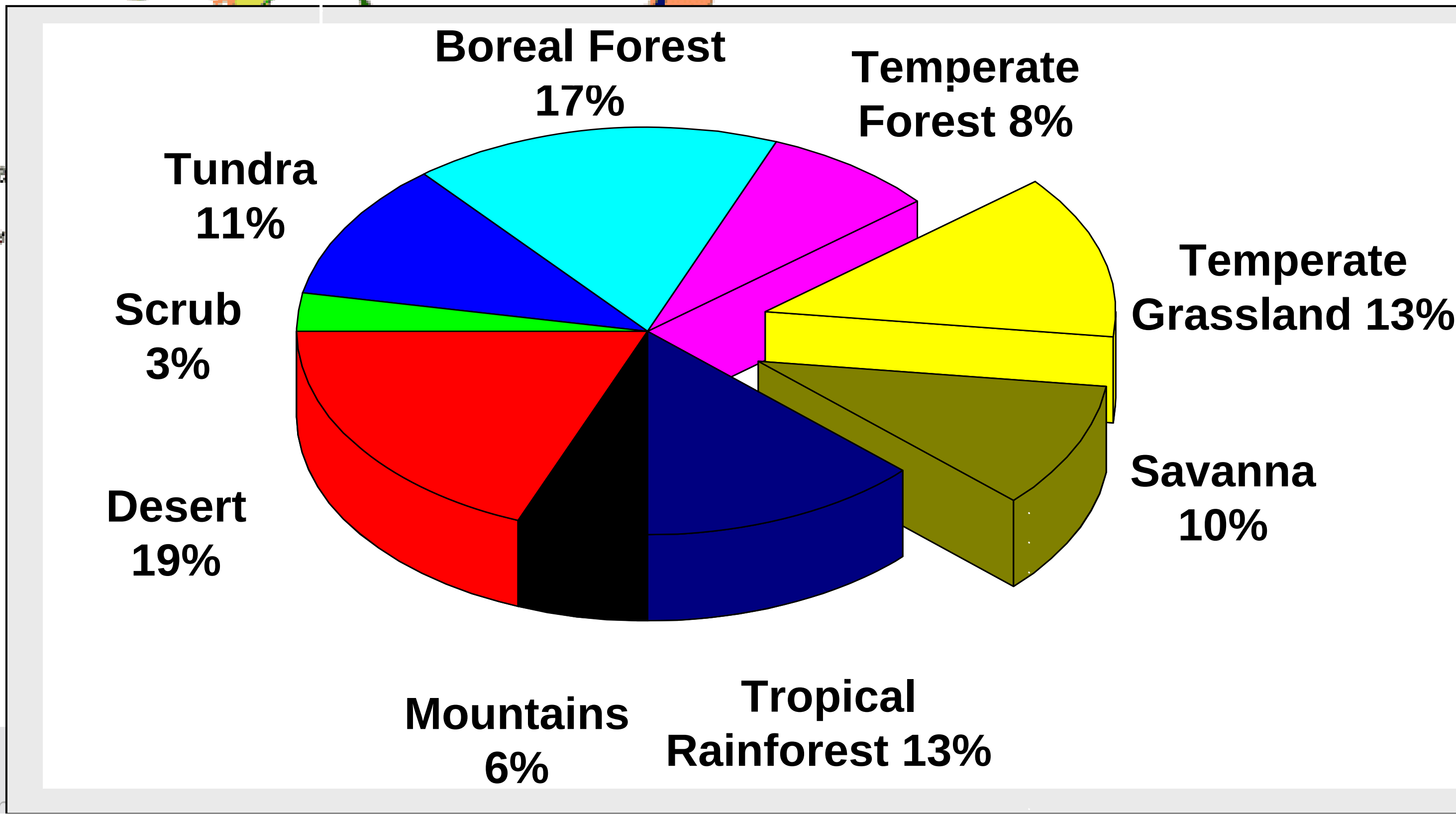
Garmisch-Partenkirchen, Germany

MAGIM

Global importance of the bi



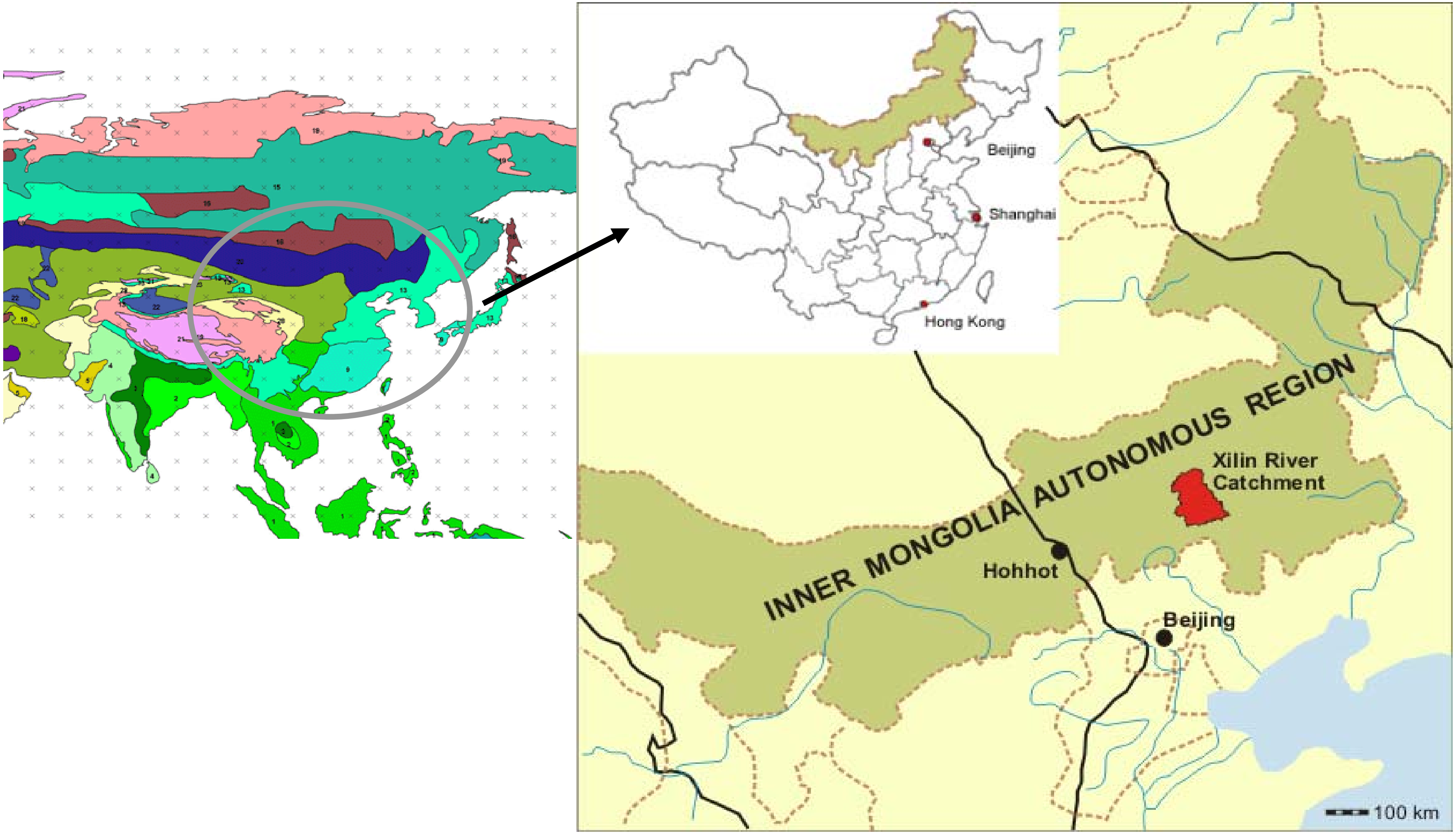


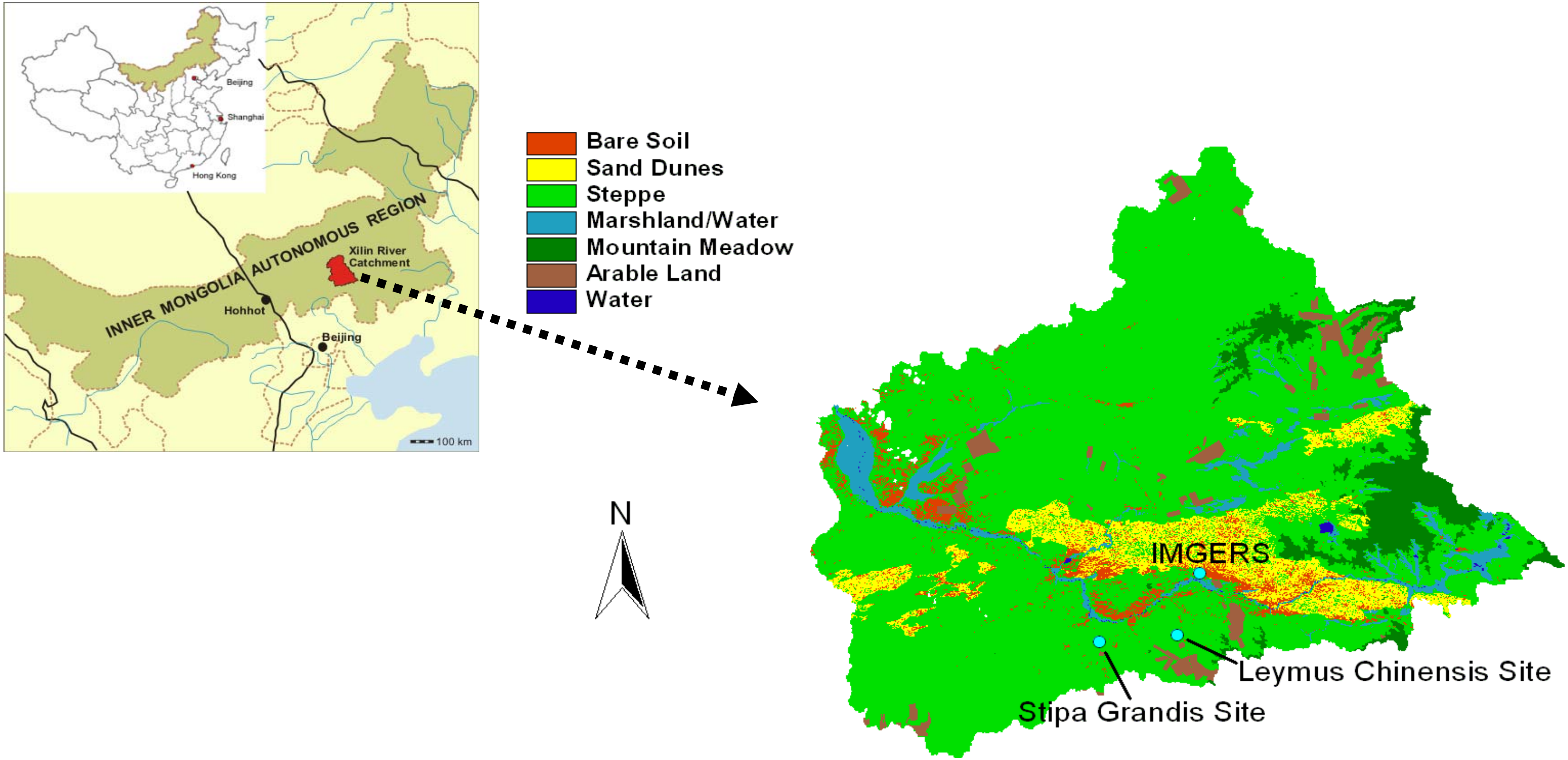


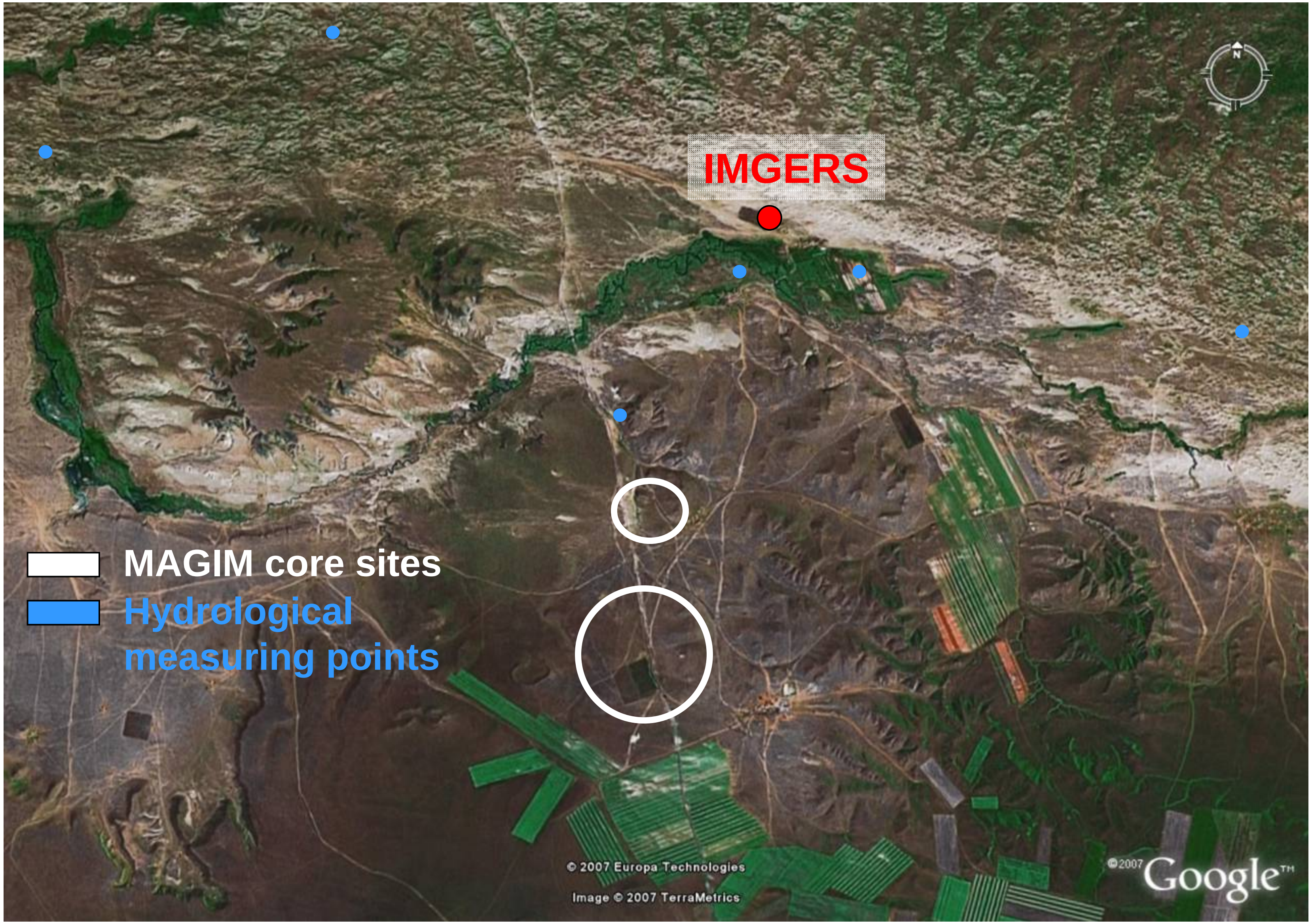
Research teams within MAGIM

Forschungszentrum Karlsruhe Institute for Meteorology & Climate Research (IMK-IFU), Garmisch-P.	• Microbial turnover • Trace gas exchange
Technical University Munich	
Lehrstuhl für Bodenkunde	• SOC dynamics • Soil aggregation
Lehrstuhl für Grünlandlehre	• Ecophysiology • Isotopic signatures
Christian Albrechts University	
Institute for Plant Nutrition and Soil Science	• Plant production • H_2O/N interactions
Institute for Plant Nutrition and Soil Science	• Soil hydrology • Soil physics
Institute of Crop Science and Plant Breeding	• Grassland science • Feed quality
Institute of Animal Nutrition and Physiology	• Animal production
Justus-Liebig University Department of Agriculture and Environmental Protection, Giessen	• Regional hydrology • Central database
Technical University of Dresden Institute for Hydrology and Meteorology, Dresden	• CO_2/H_2O exchange • Remote sensing
Leibniz-Centre for Agricultural Landscape Research (ZALF) Institute of Soil Landscape Research, Müncheberg	• Winderosion on local and regional scales
German Meteorological Service Meteorological Observatory Lindenberg	• Remote sensing • Precipation

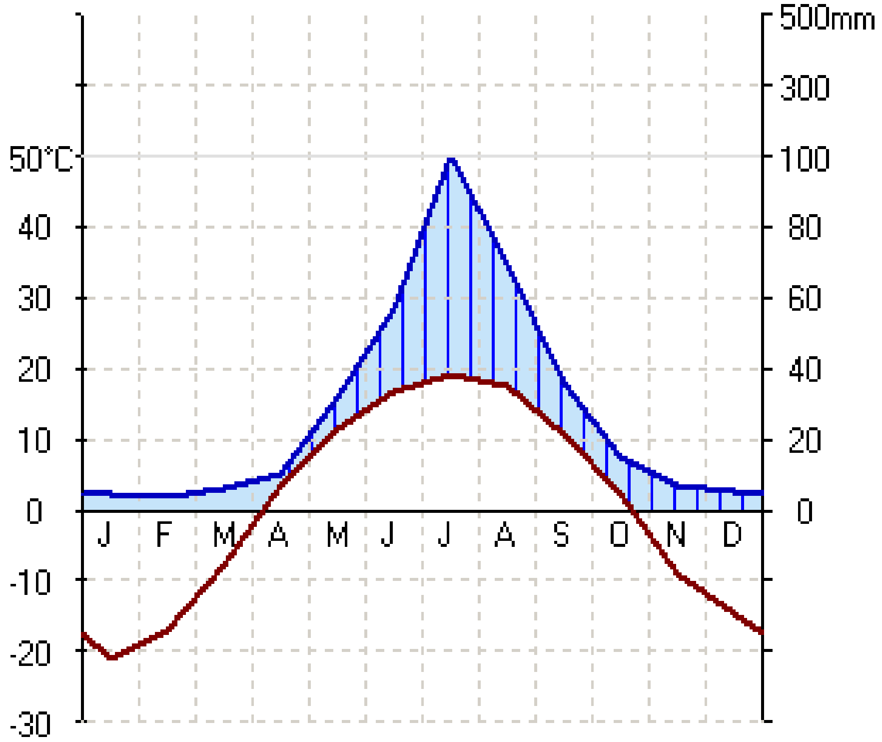
Location of the target region




Beijing
Shanghai
Hong Kong
INNER MONGOLIA AUTONOMOUS REGION
Xilin River Catchment
Hohhot
Beijing
100 km
Bare Soil
Sand Dunes
Steppe
Marshland/Water
Mountain Meadow
Arable Land
Water
N
IMGERS
Leymus Chinensis Site
Stipa Grandis Site


IMGERS
MAGIM core sites
Hydrological measuring points
© 2007 Europa Technologies
Image © 2007 TerraMetrics
©2007 Google™

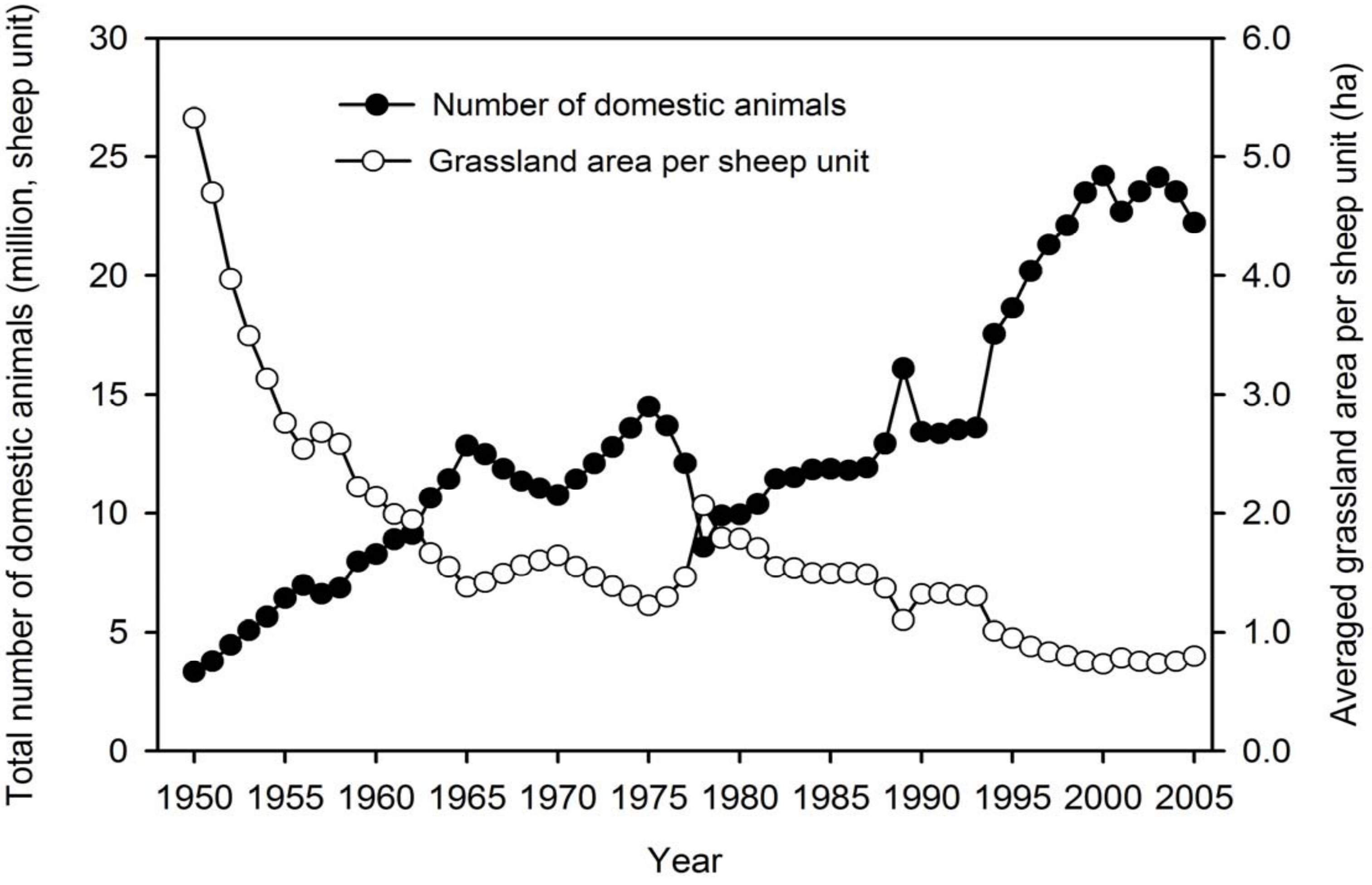
Climatic constraints



	Precipitation [mm]
Mean	343.4
2003	371.3
2004	324.6
2005	166.1

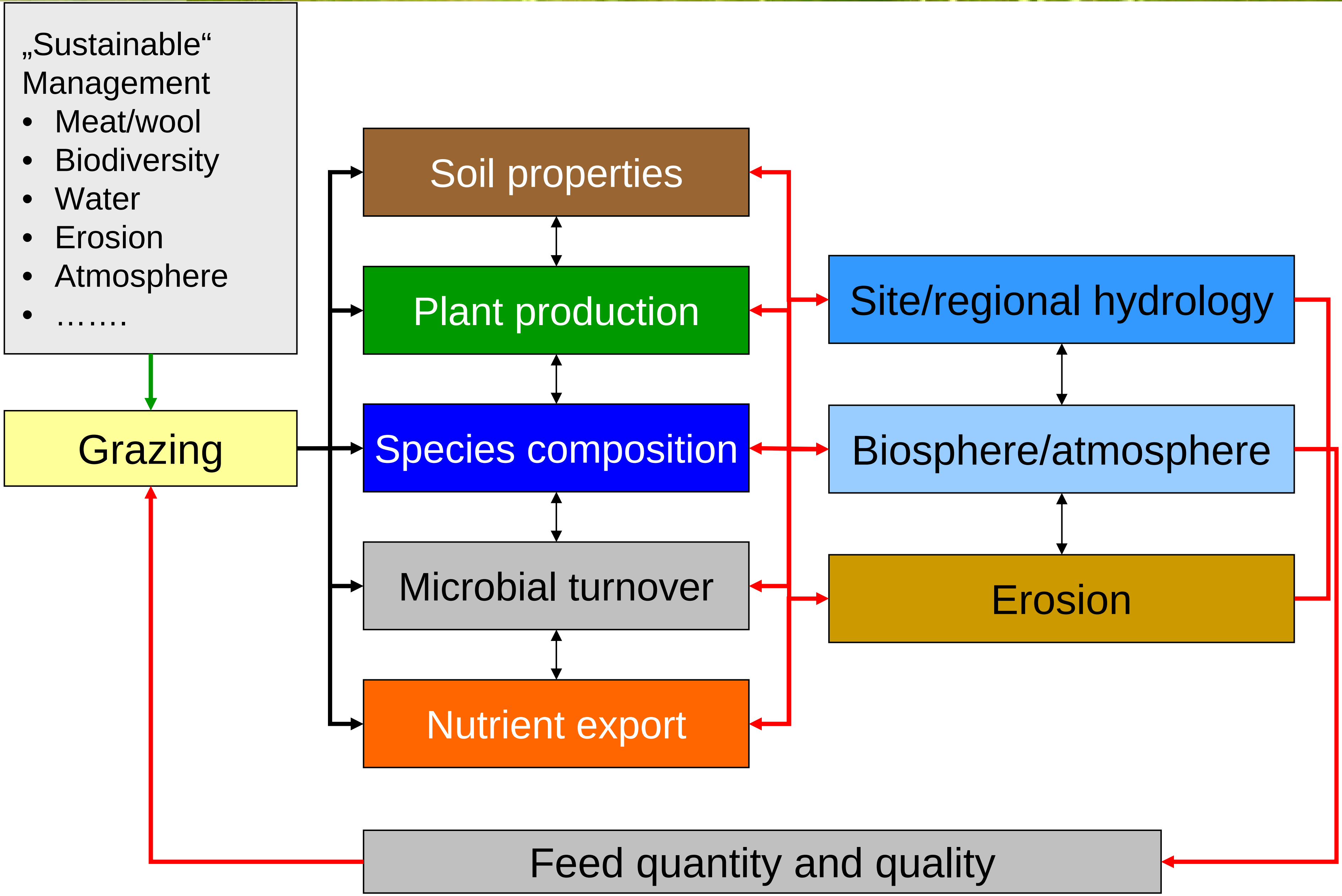
→ **The climatic conditions limits NPP and make the steppe vulnerable to land use changes and grazing intensification**

Grazing pressure and degradation



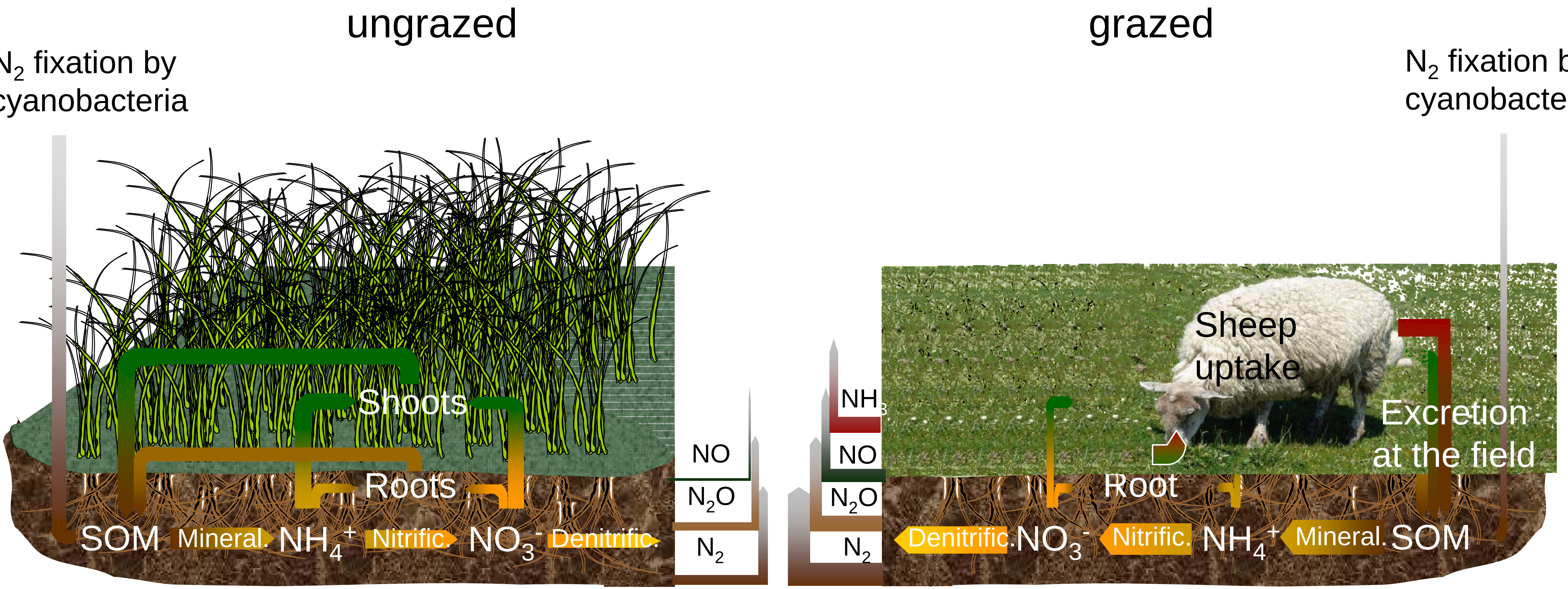
KIT – die Kooperation von
Forschungszentrum Karlsruhe GmbH
und Universität Karlsruhe (TH)

Grazing effects



Steppe degradation

Scheme of N fluxes at the plot scale



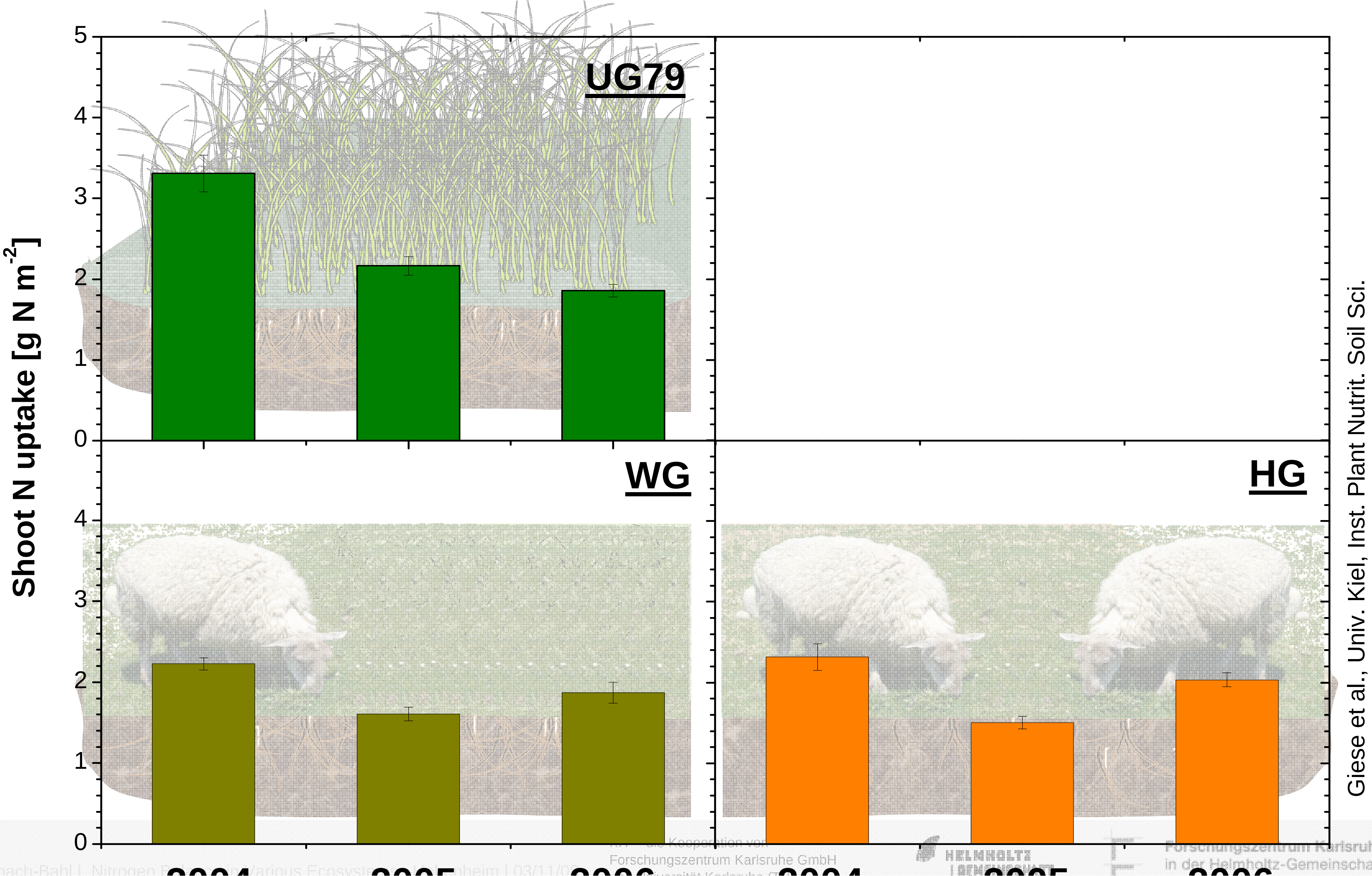
Hypothesis 1: Grazing reduces plant N uptake

Hypothesis 2: Grazing increases soil N cycling

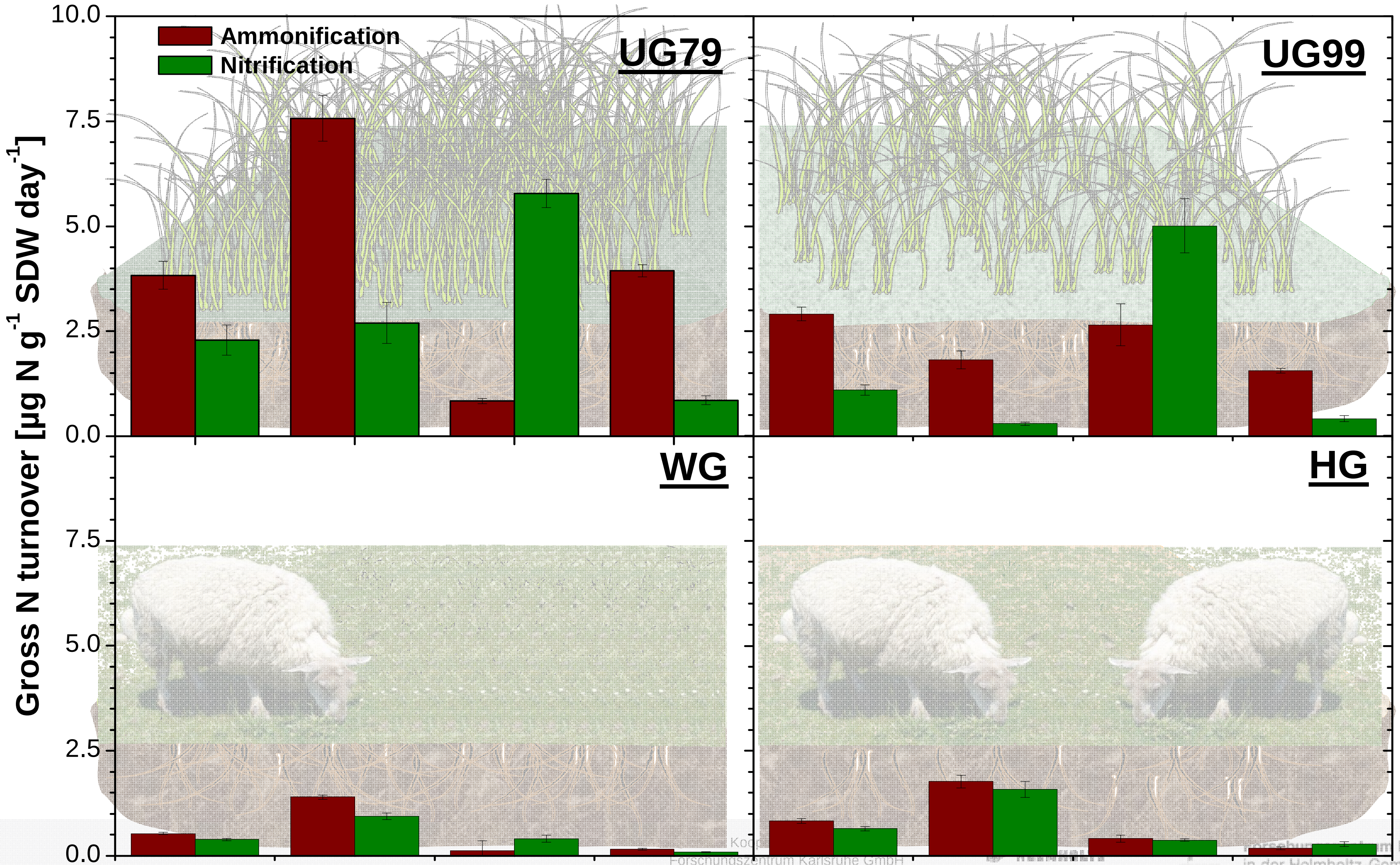
Hypothesis 3: Grazing increases N trace gas production

Hypothesis 4: Grazing reduces non-symbiotic N_2-fixation by cyanobacteria

Plant N uptake: No significant differences between grazed and ungrazed sites

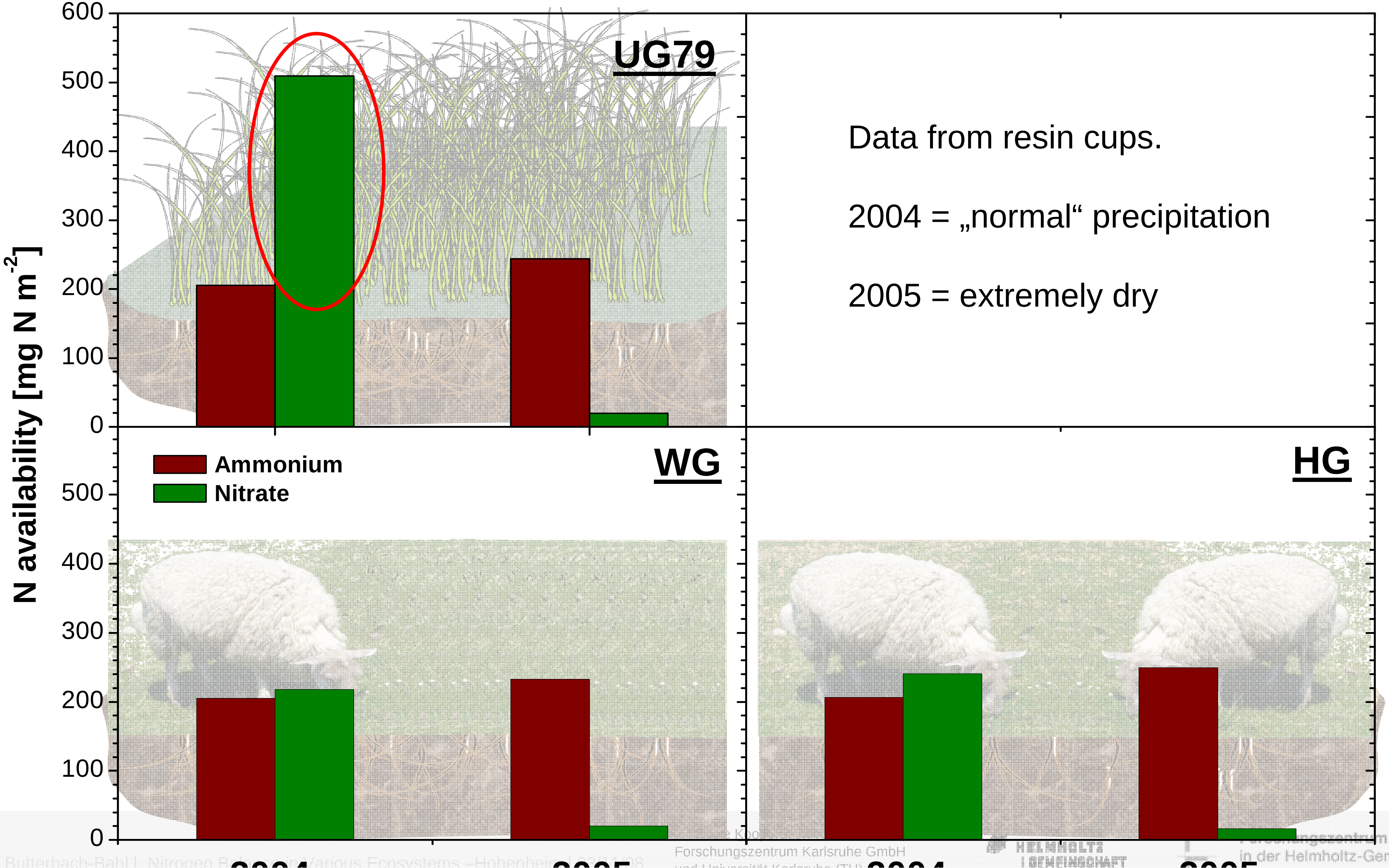


Gross N turnover rates: Significant differences between grazed and ungrazed sites



Holst et al., 2008, Ecosystemsc

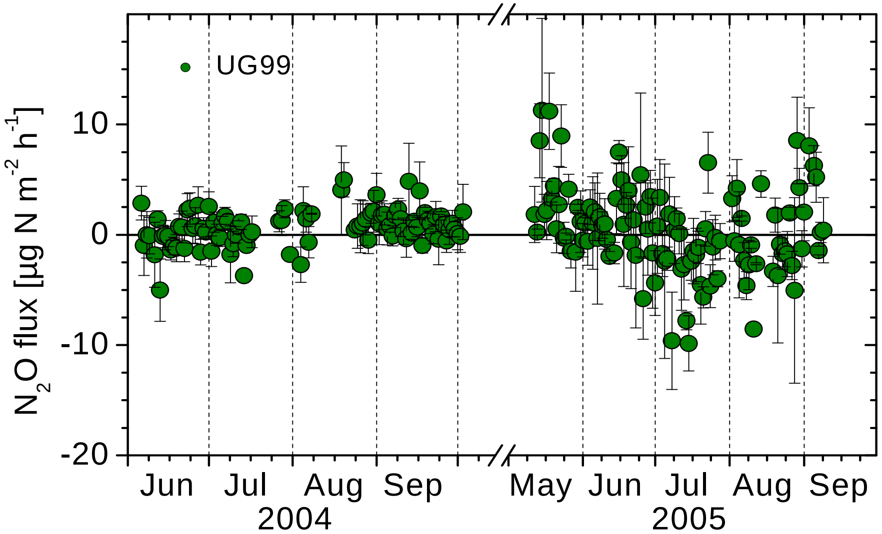
Soil N availability: Significantly higher NO_3^- availability at the ungrazed site



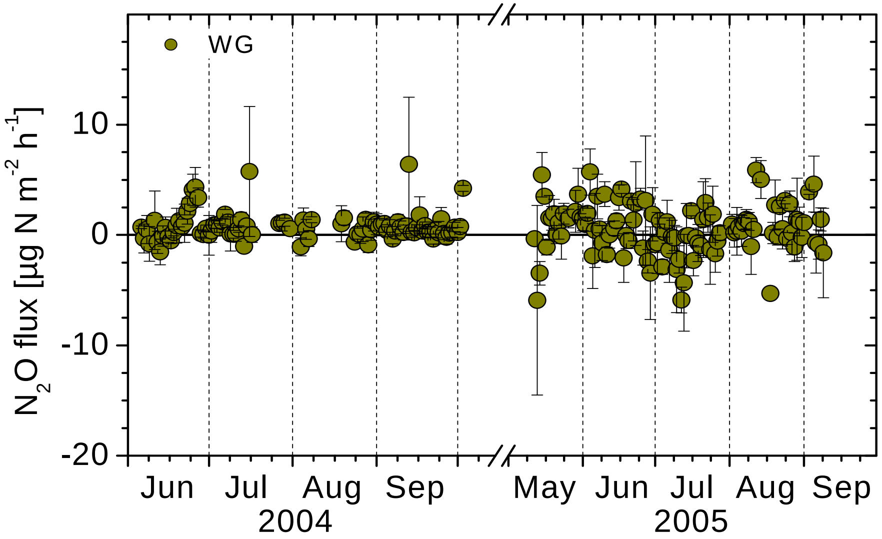
Giese et al., Univ. Kiel, Inst. Plant Nutrit. Soil Sci.

N_2O fluxes: Very low and no significant differences between sites

UG99

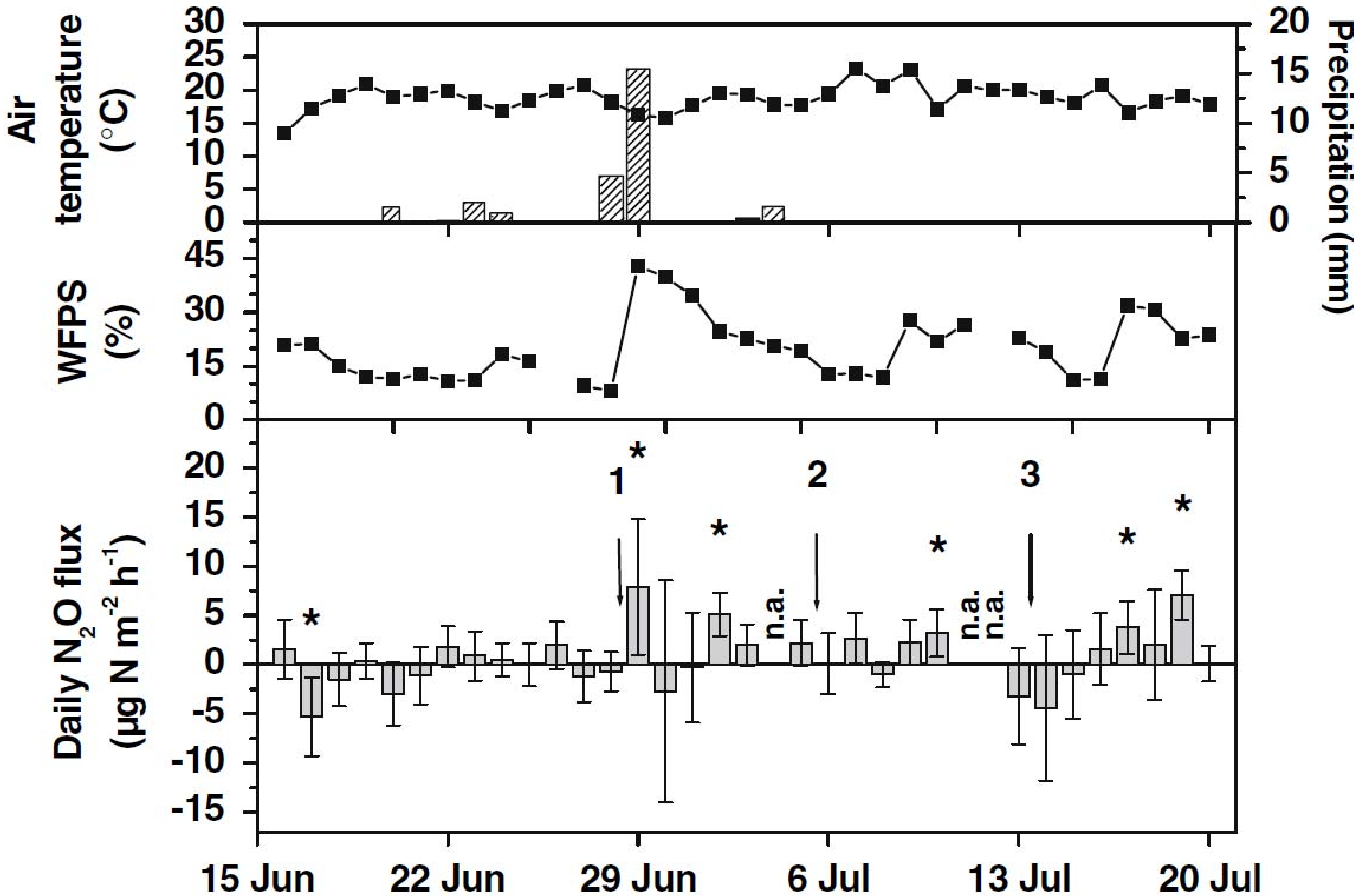


WG



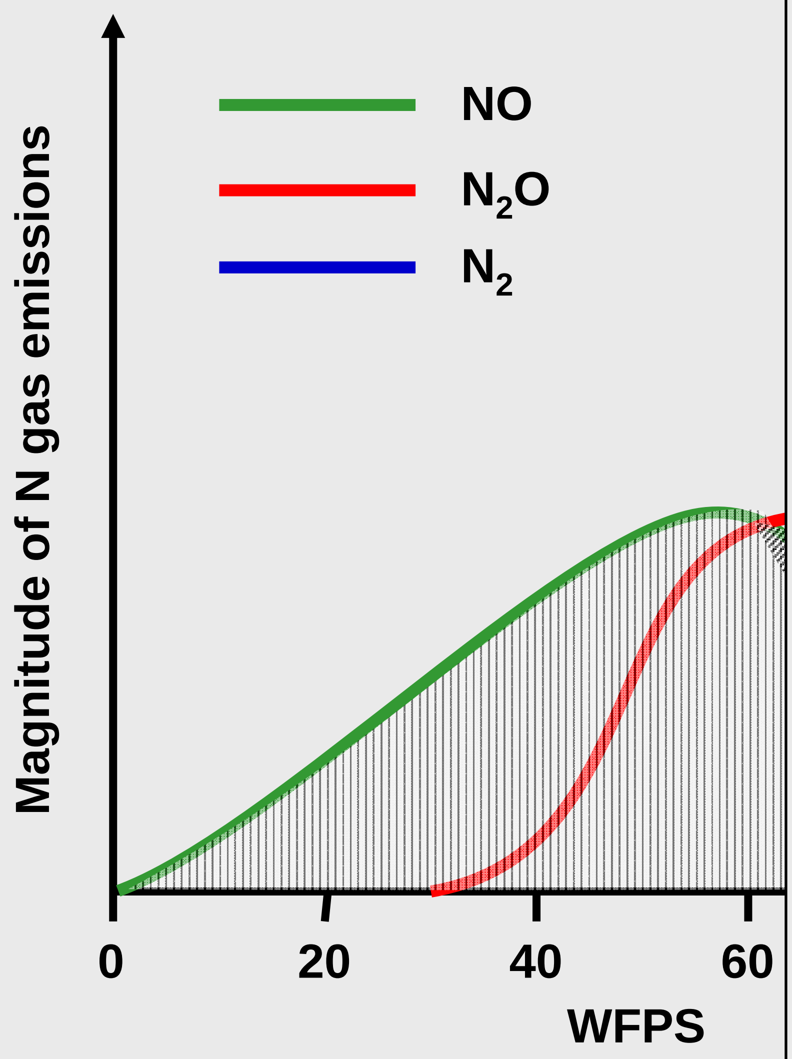
Holst et al., 2008, Ecosystems

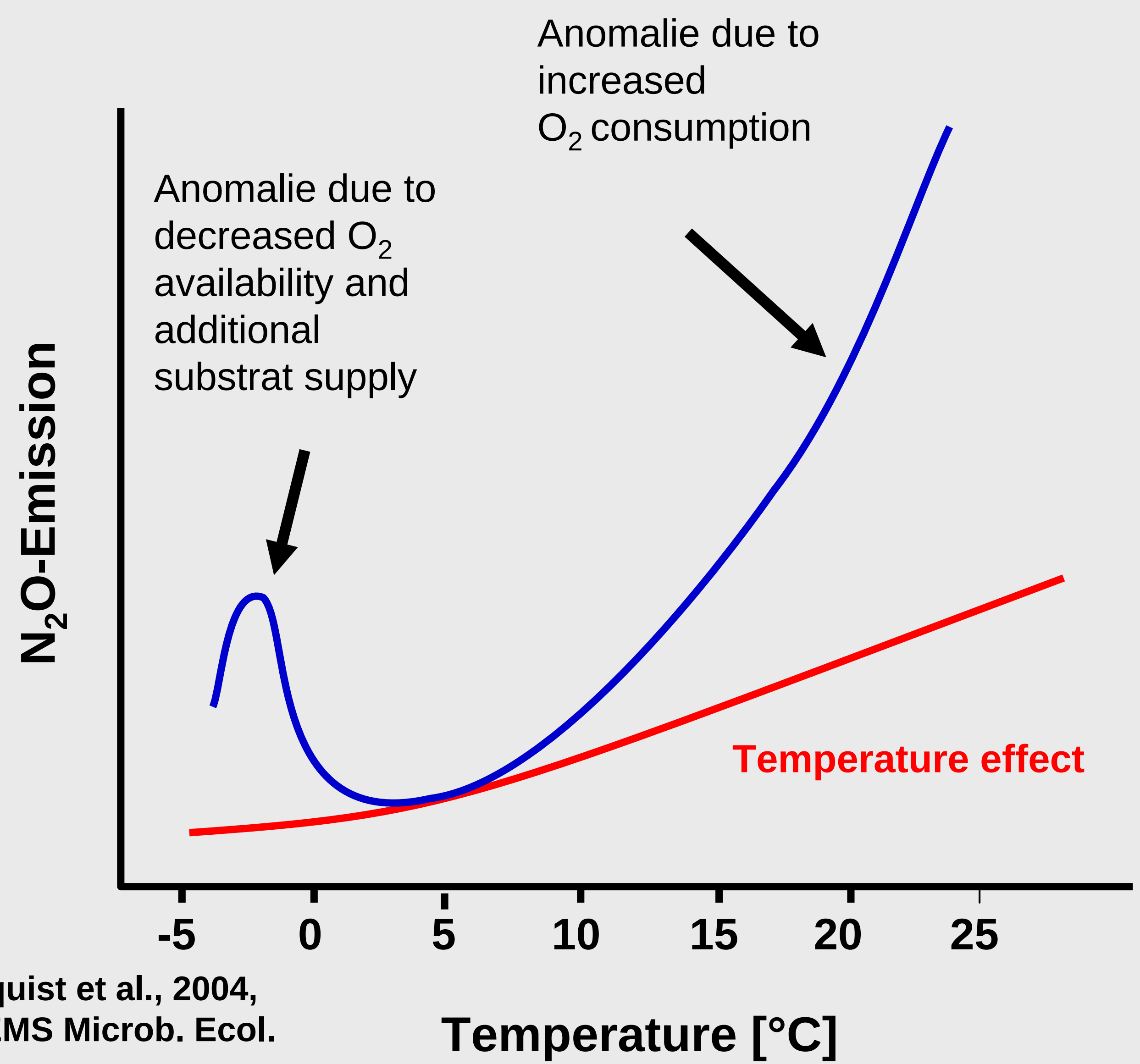
N_2O fluxes: Faeces/ urine additions have a minor effect



Holst et al., 2007, Plant & Soil

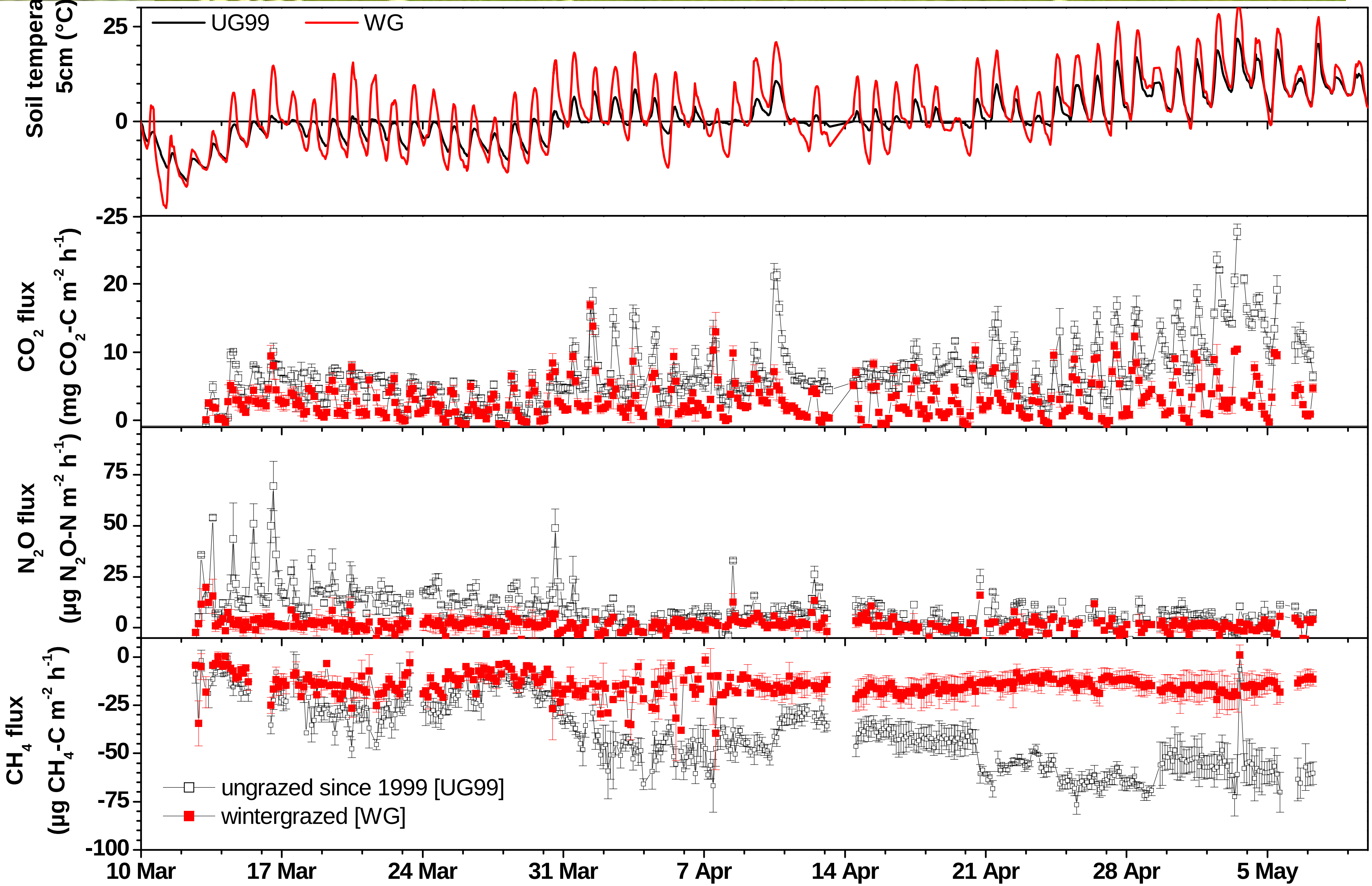
N_2O fluxes: Are winter fluxes low too?





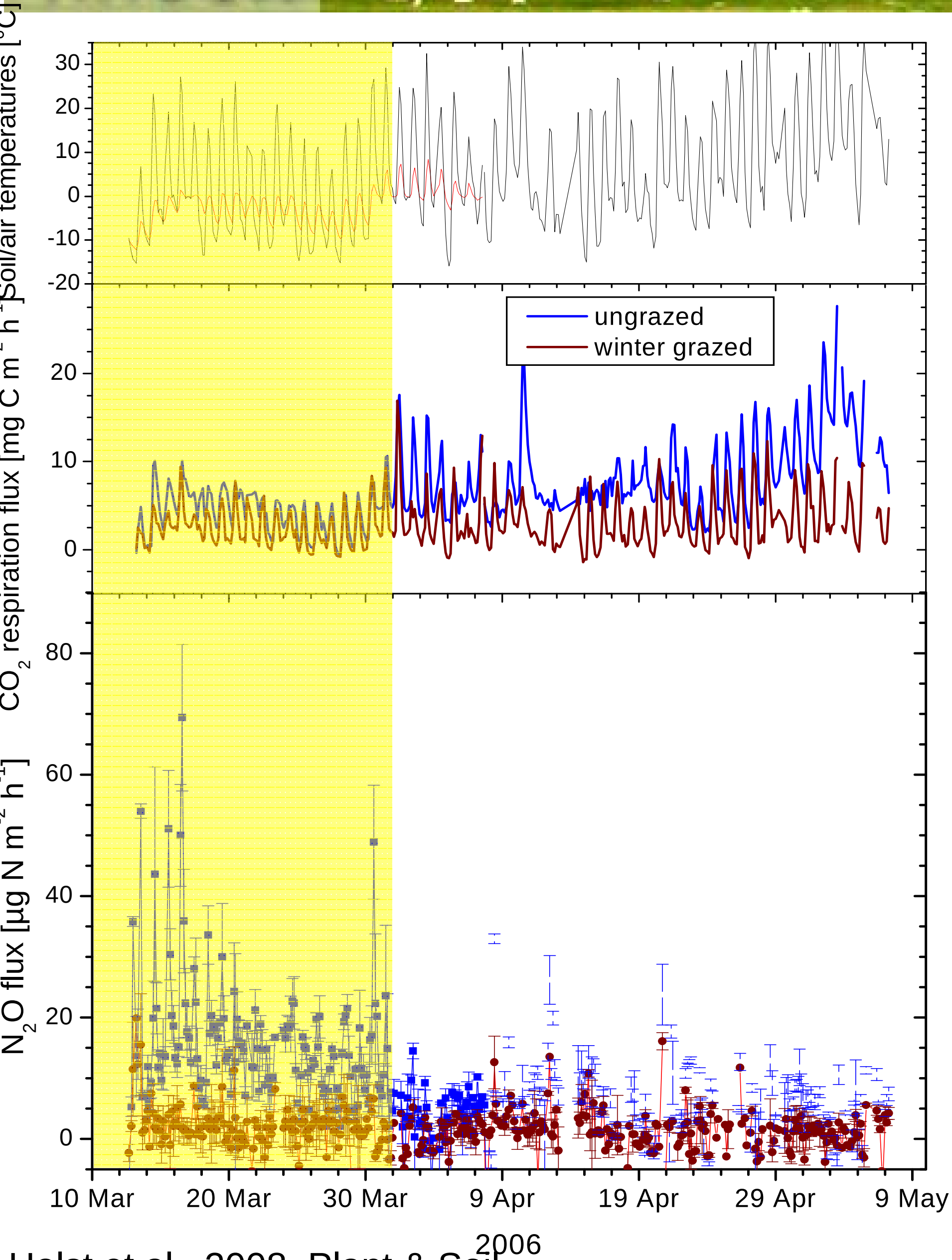
Öquist et al., 2004, FEMS Microb. Ecol.

N_2O fluxes: Are winter fluxes low too?



Holst et al., 2008, Plant & Soil

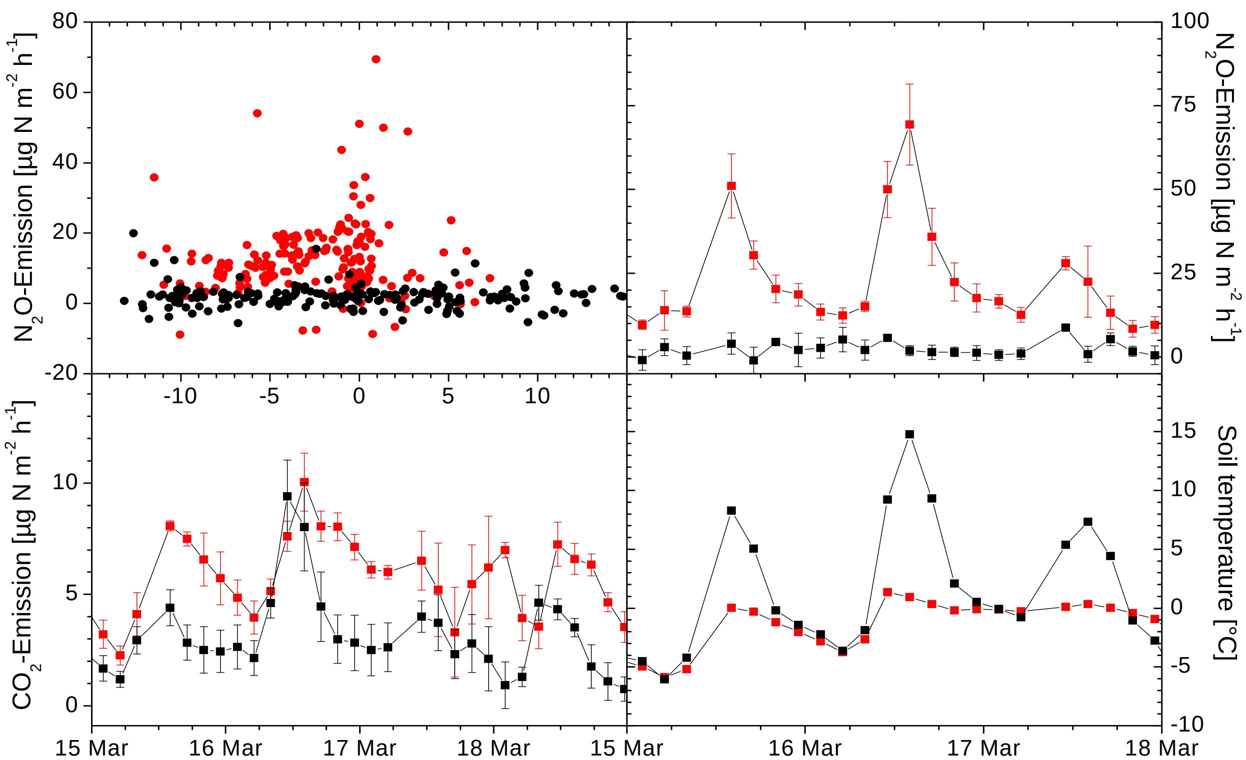
Freezing/ thawing effect on N_2O emissions only on ungrazed steppe



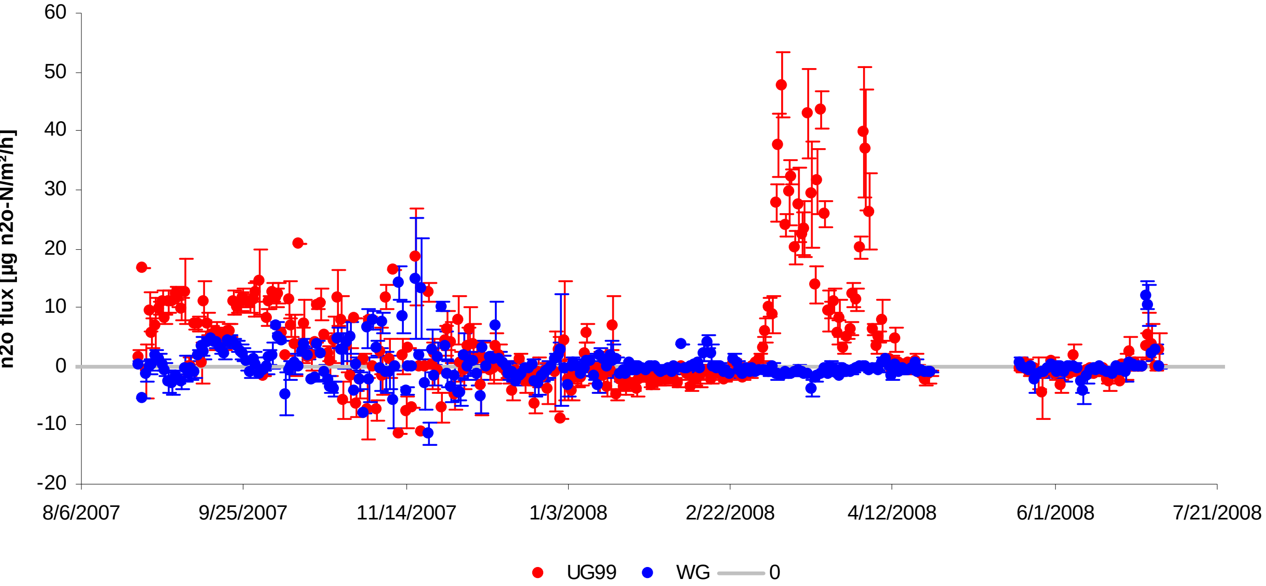
Holst et al., 2008, Plant & Soil

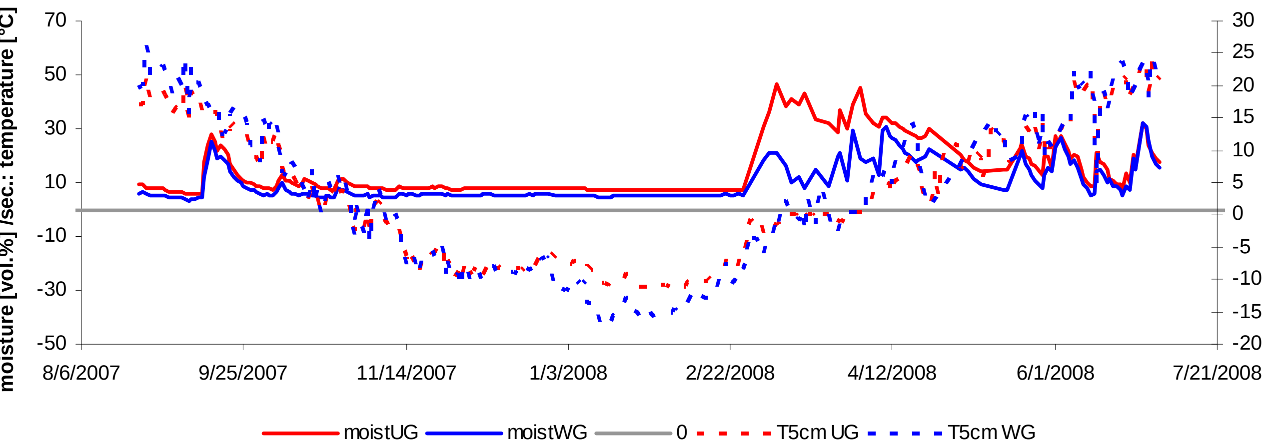
Uncoupling of N_2O fluxes for T<0°C

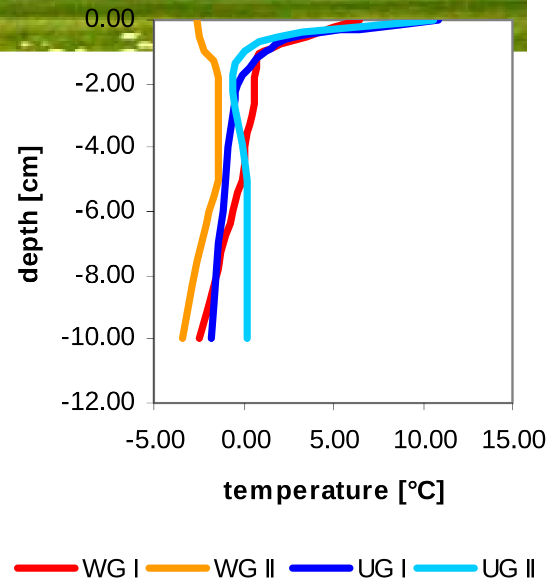
Diurnal variations of N_2O emissions following daily T

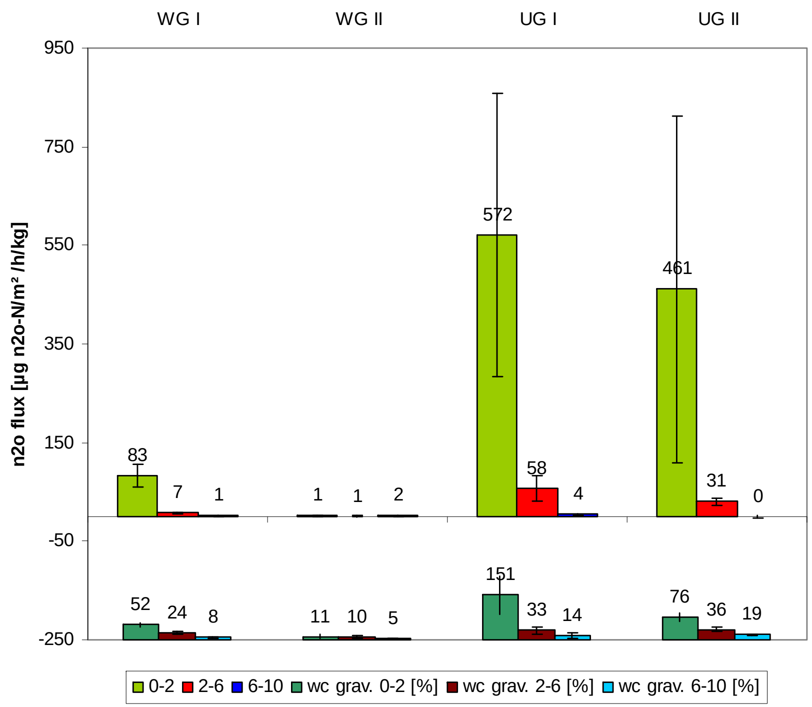


N_2O fluxes: Winter fluxes and the annual budget

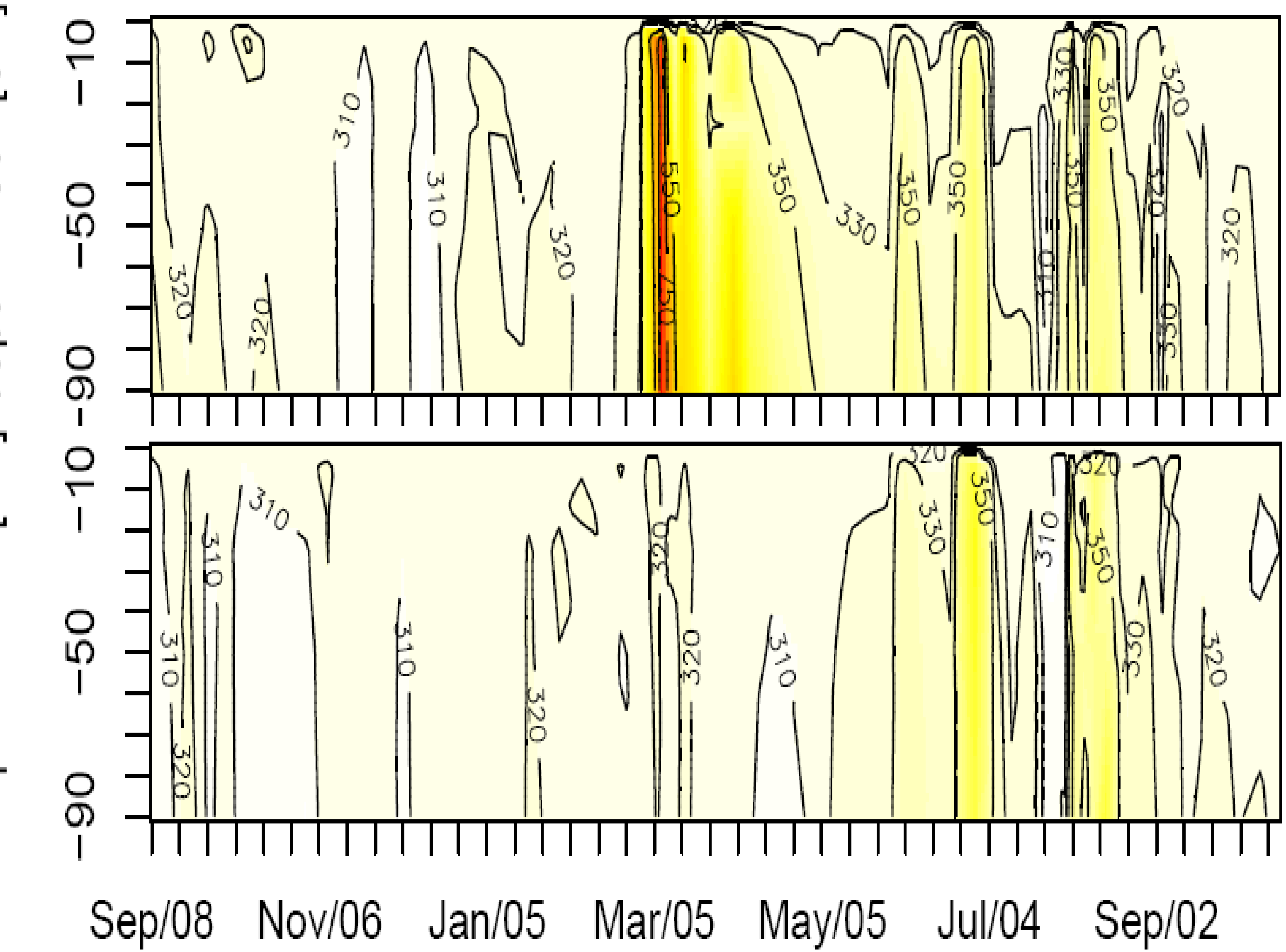




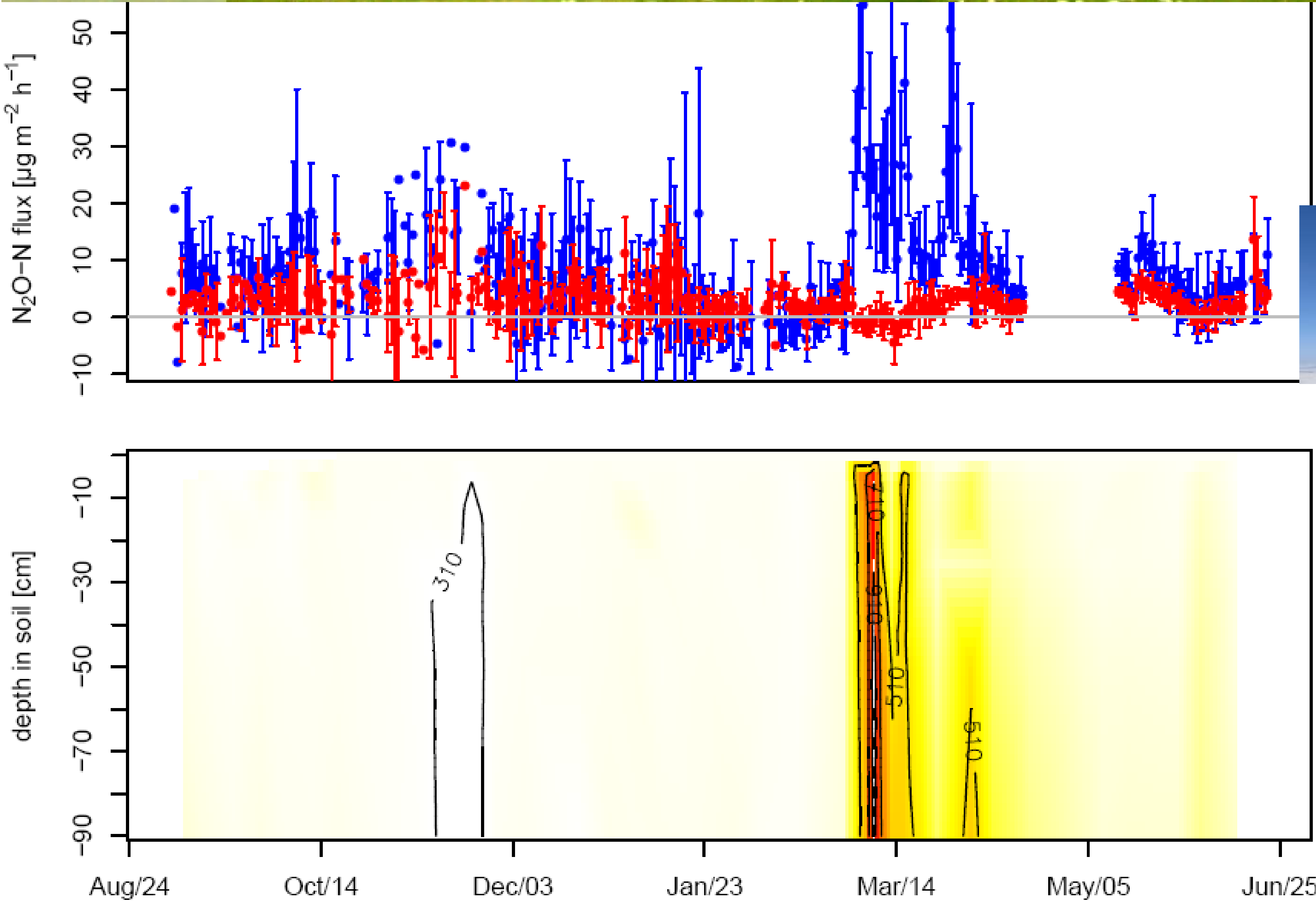




N_2O fluxes: soil gas concentrations



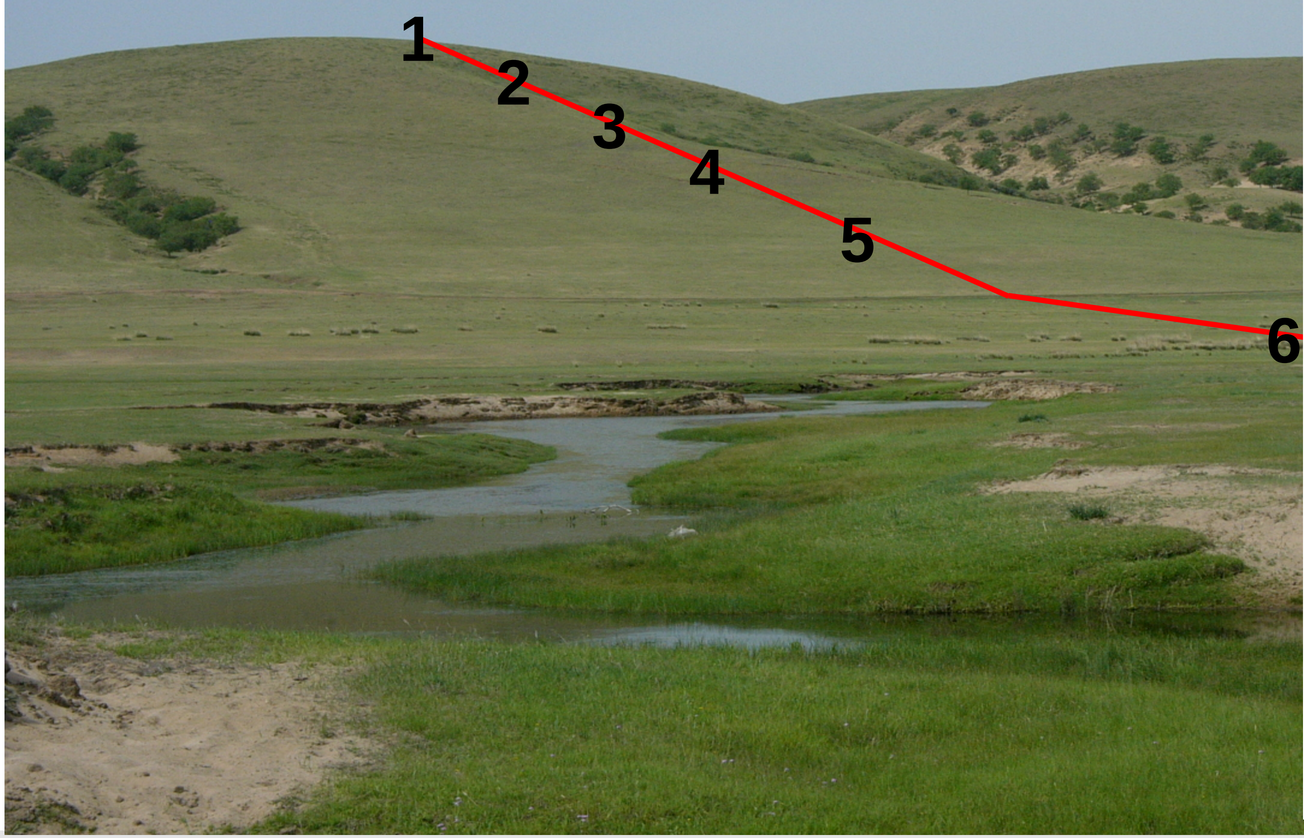
N_2O fluxes: Soil gas concentrations and emissions

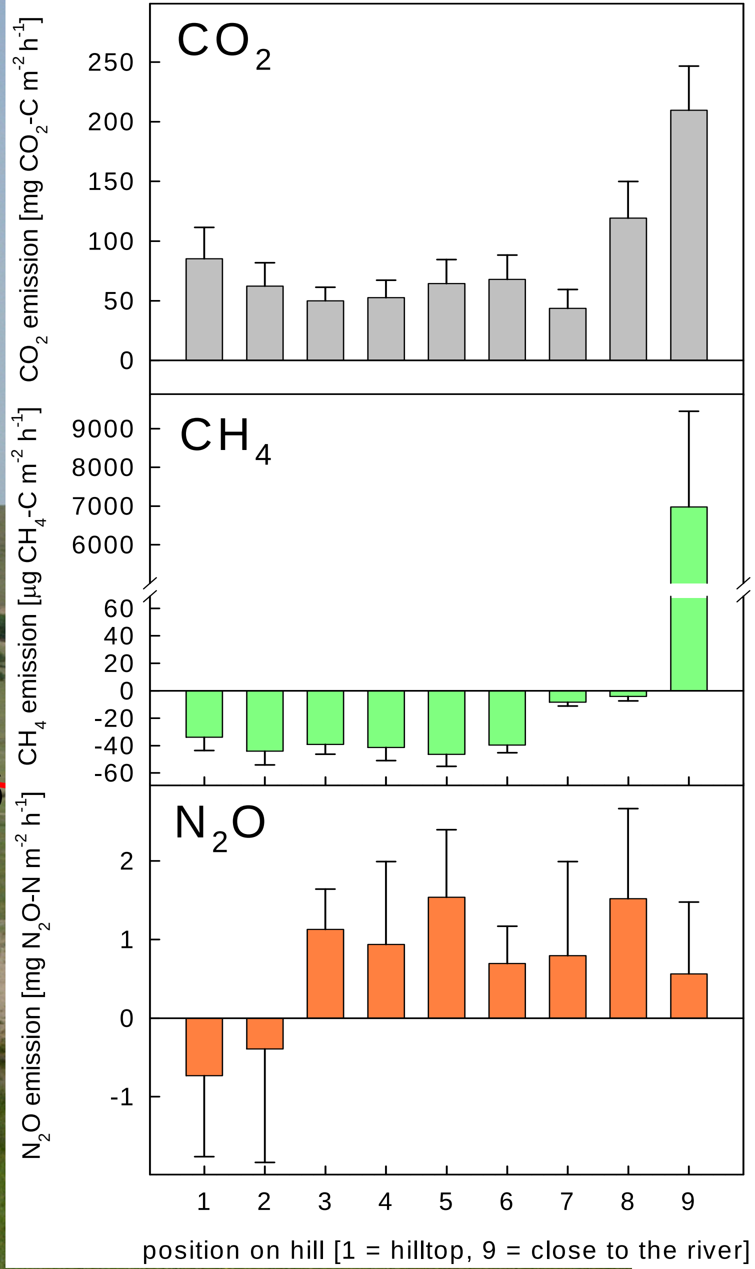


N_2O fluxes: Rather low landscape variability

Hypothesis:
The landscape position has a major influence on C and N trace gas fluxes in steppe ecosystems.

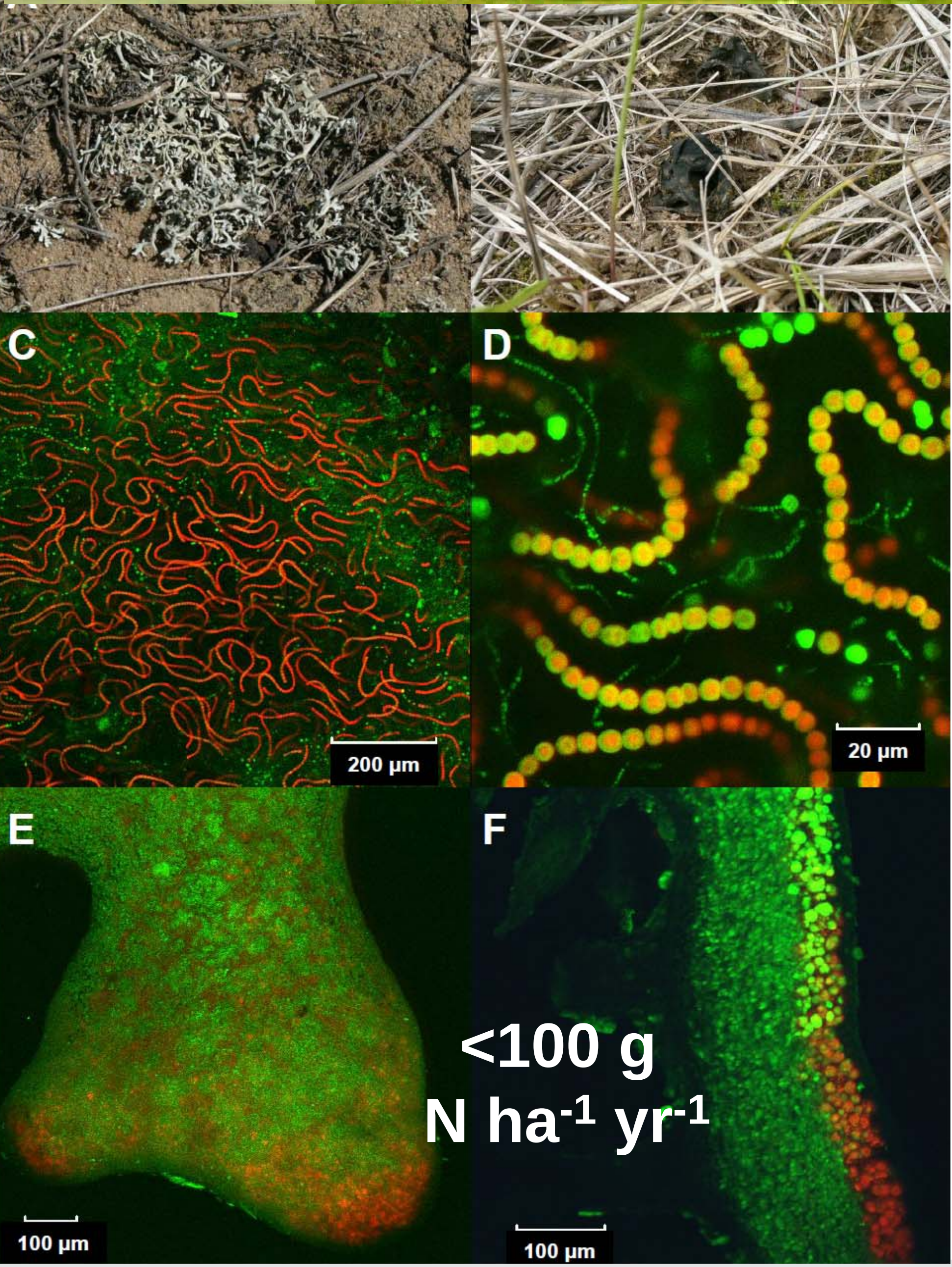
Hypothesis could not be confirmed.
Only very close to the river trace gas emissions were significantly enhanced.



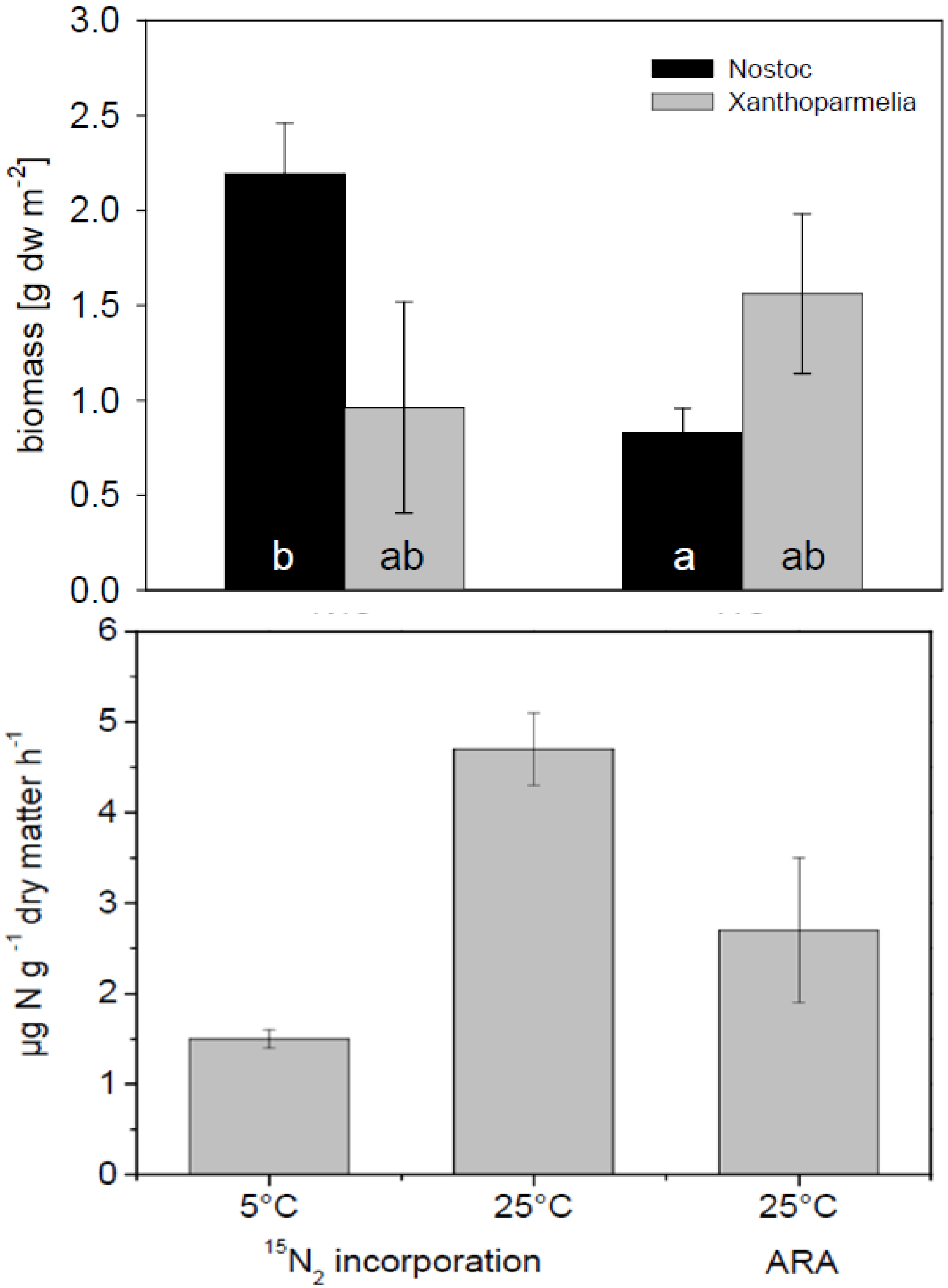


Holst et al., 2007, Plant & Soil

Biological N_2 fixation: Low but significant

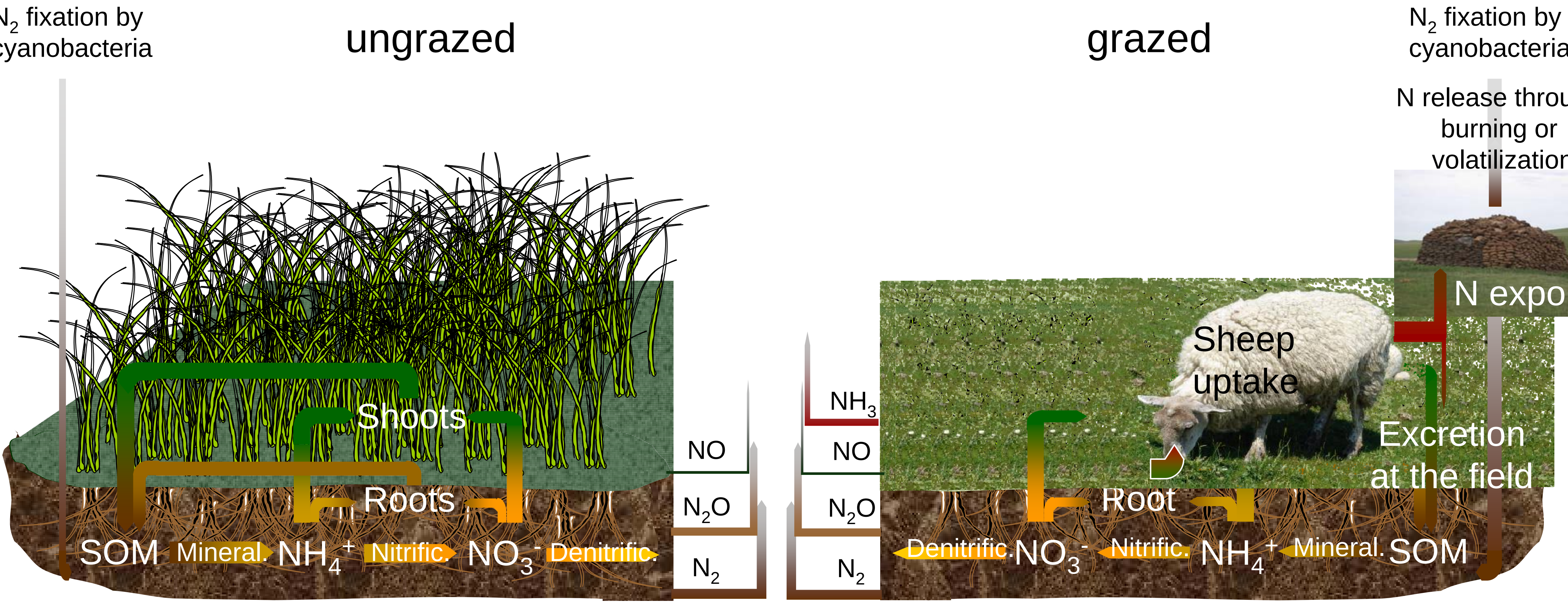


<100 g
N ha^{-1} yr^{-1}



Holst et al., 2008, Biol. Fert. Soils, subm.

Scheme of N fluxes at the plot scale



Hypothesis 1: Grazing reduces plant N uptake

Hypothesis 2: Grazing increases soil N cycling

Hypothesis 3: Grazing increases N trace gas production

Hypothesis 4: Grazing reduces non-symbiotic N_2-fixation by cyanobacteria

KIT
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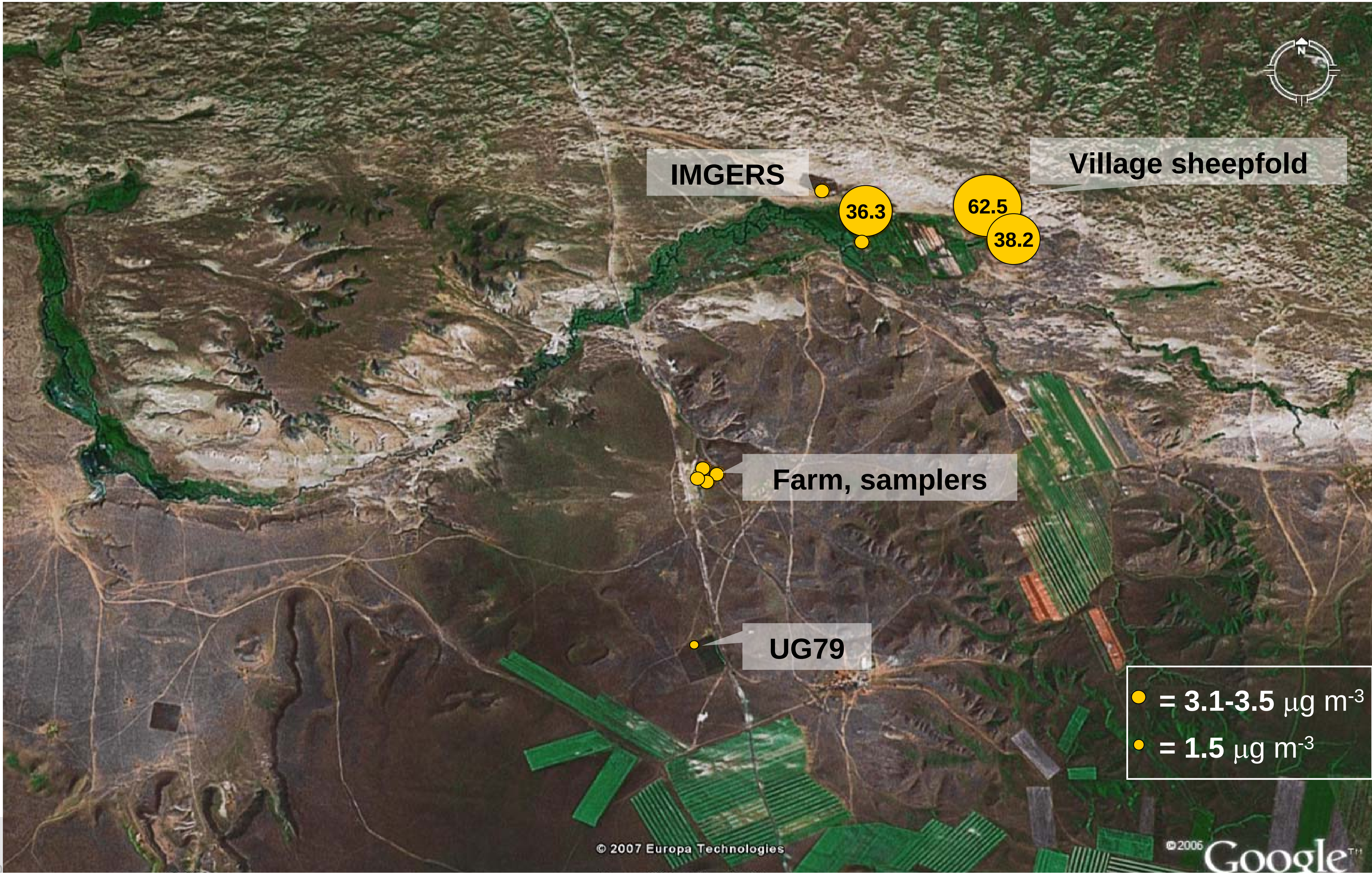
Mean NH_3 air concentrations from 24/03-21/07, 2006

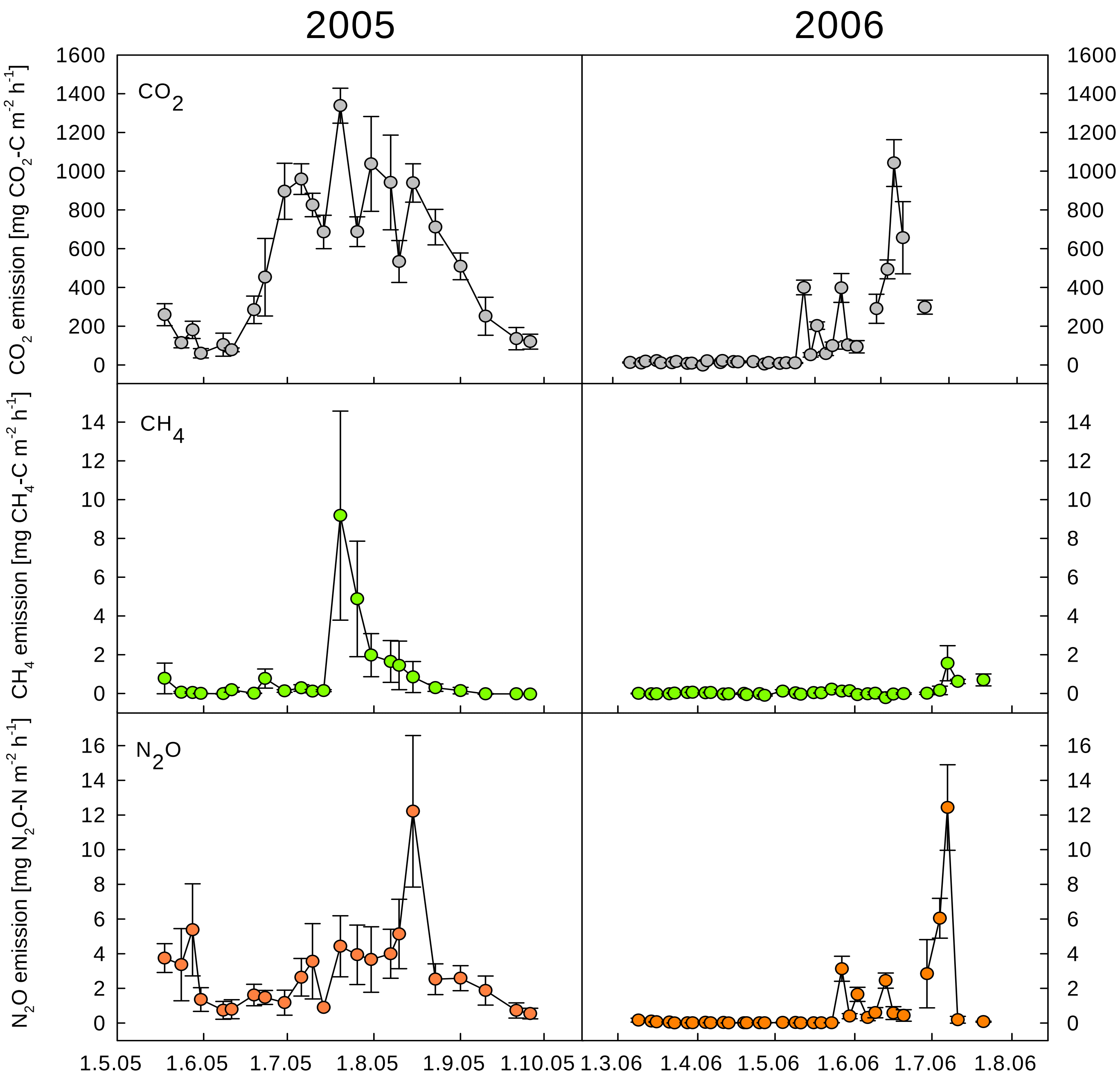


Matter fluxes in grasslands of Inner Mongolia as influenced by stocking rate

MAGIM

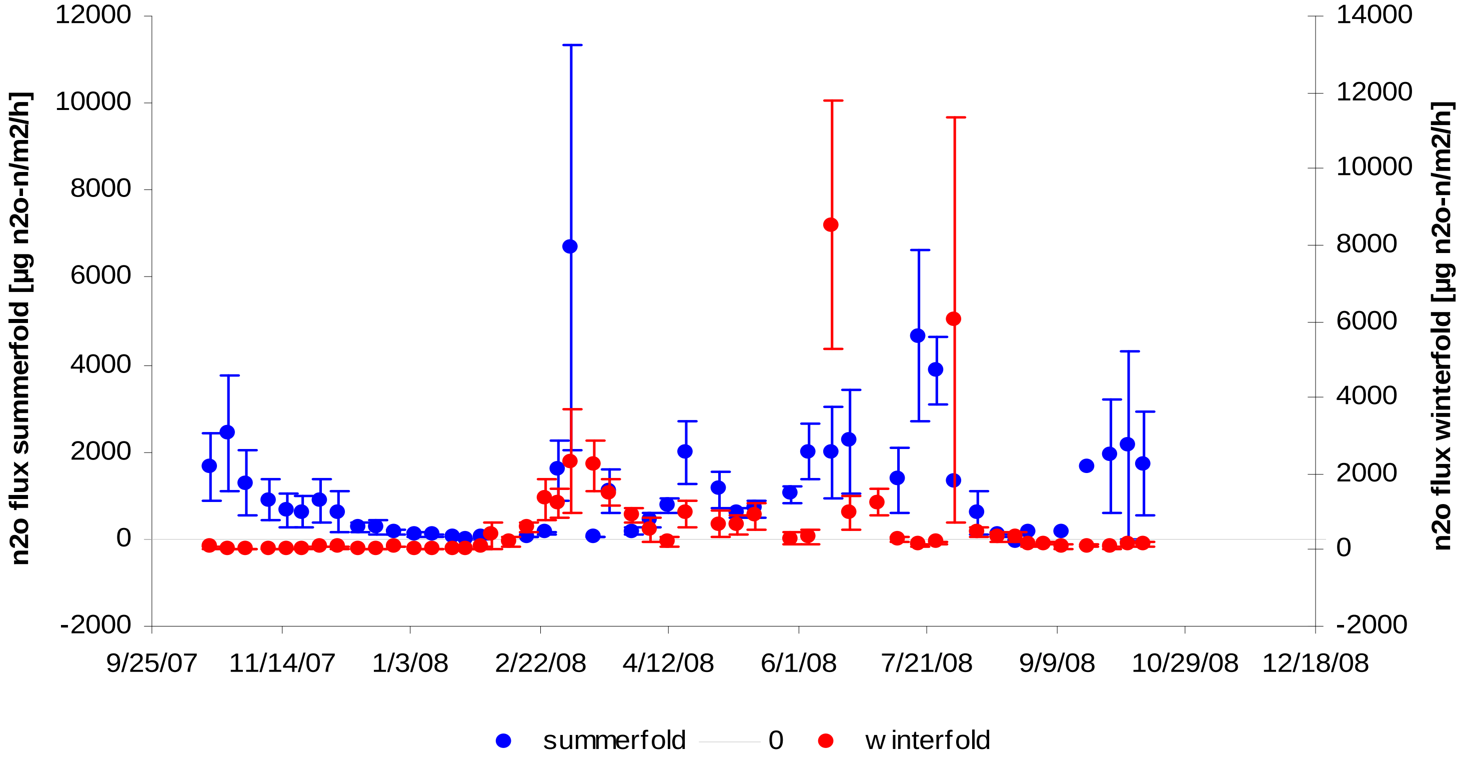
Karlsruhe Institute of Technology

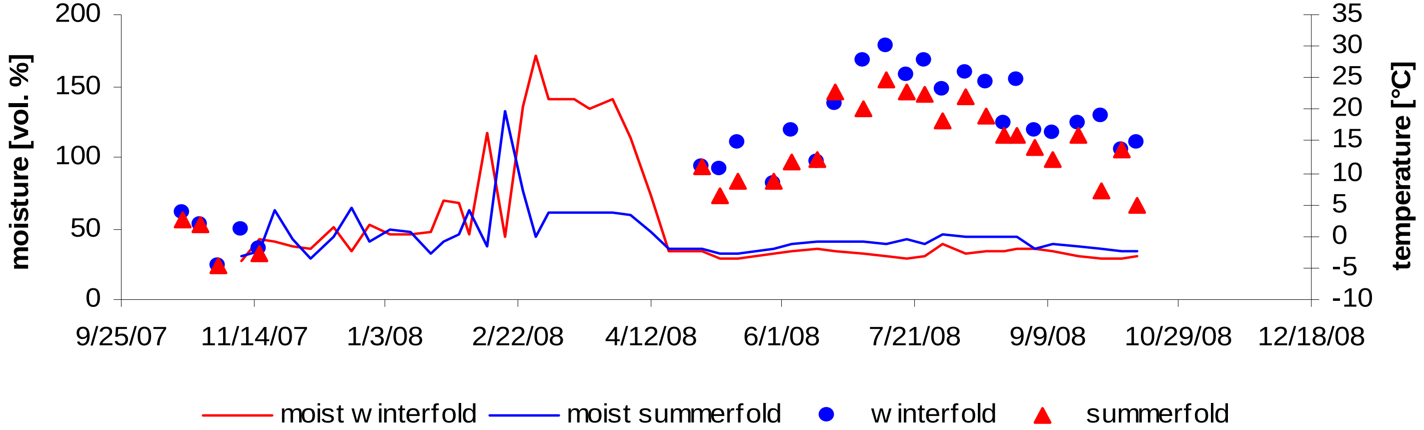
What happens with the N exported?



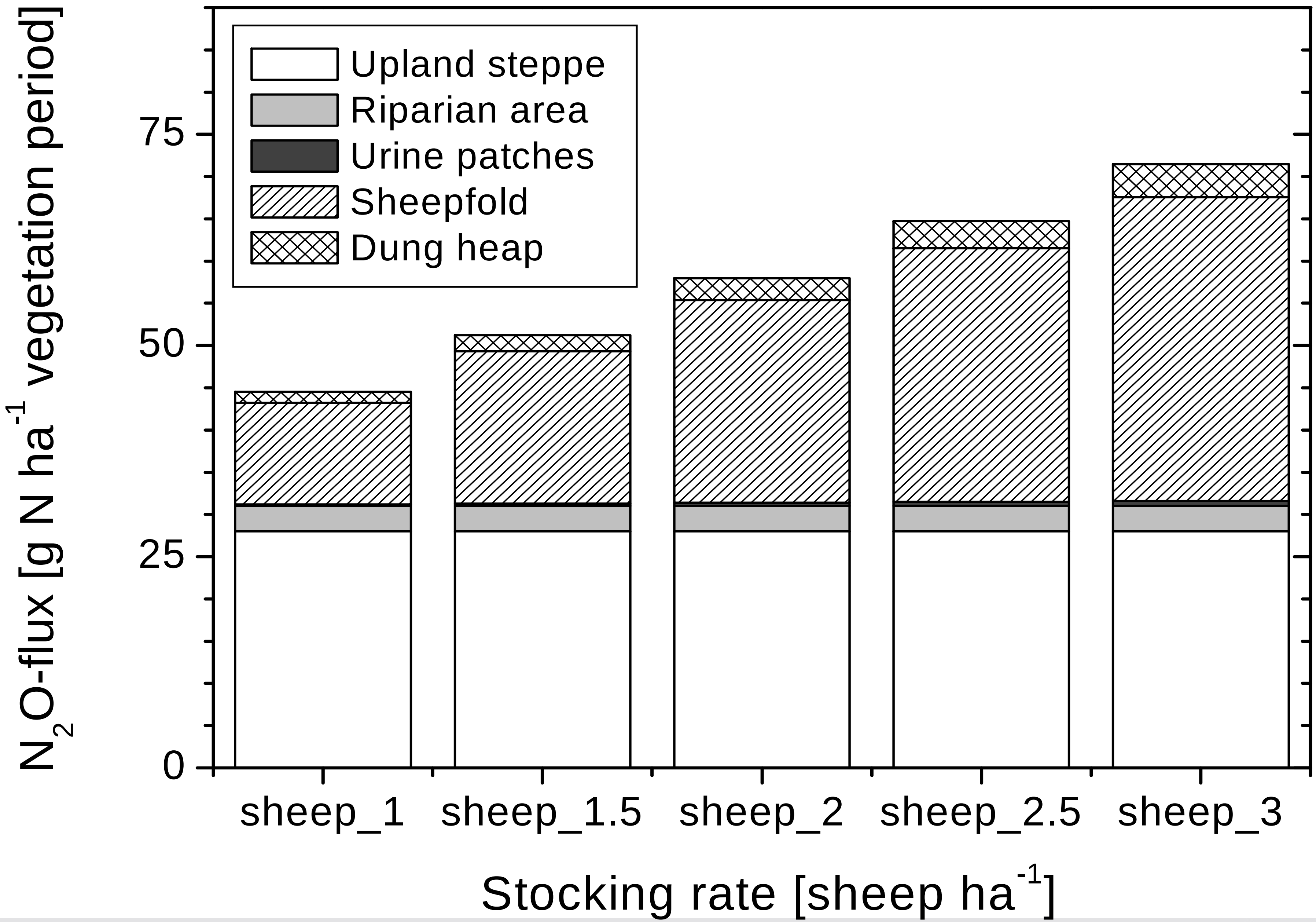
Sheepfolds are temporarily large point sources of CO_2, CH_4 and N_2O

N_2O fluxes: Annual fluxes





Management related N_2O emissions can dominate



Summary

- Grazing management has largely affected N cycling and, thus, N_2O emissions from steppe:
  - decreasing winter emissions
  - increase in N_2O emissions from sheep folds
- Understanding of N_2O fluxes on a regional scale requires an understanding of regional N cycling