Exchange of climate relevant gases in agricultural ecosystems vulnerable to land use and climate change

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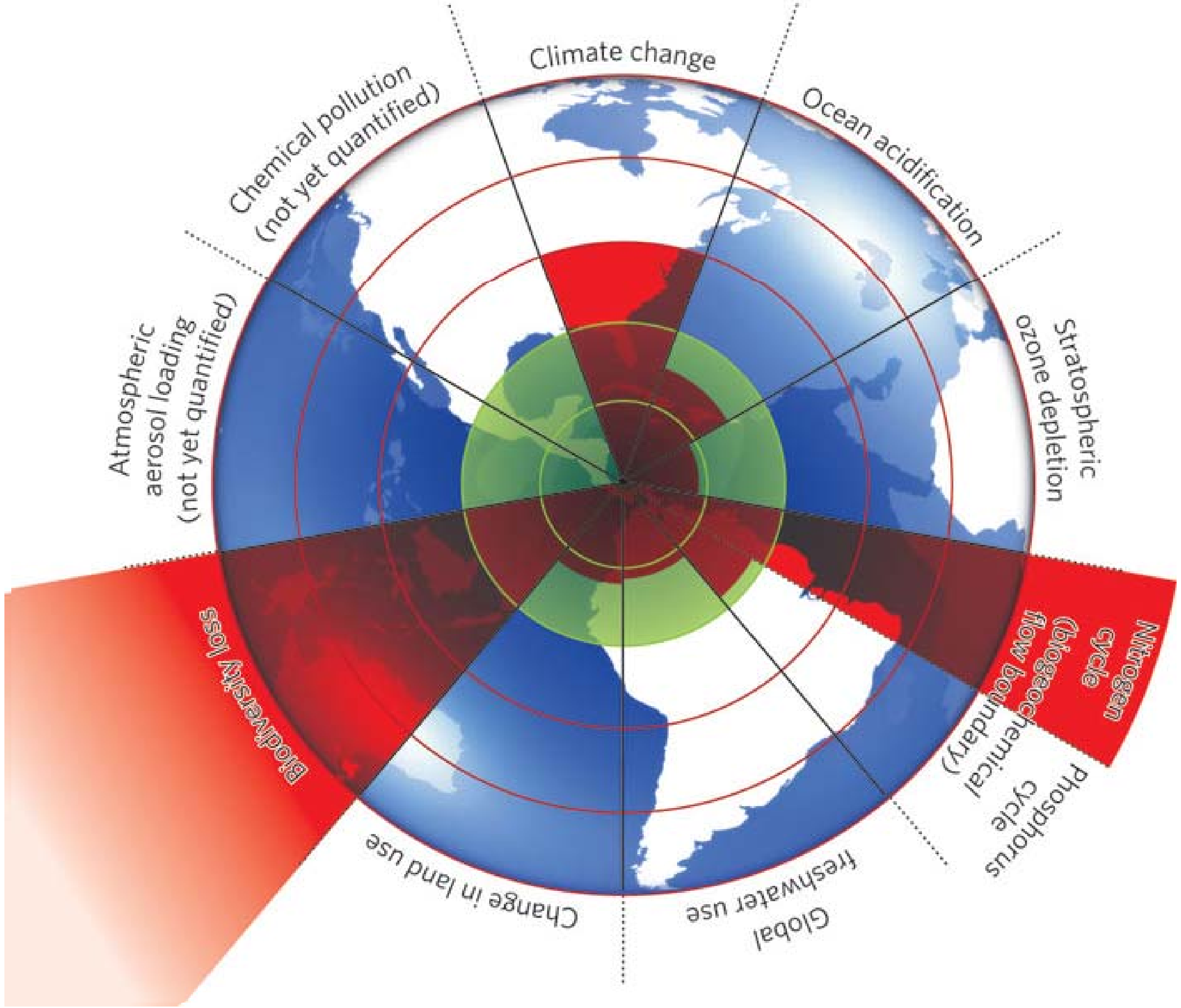
A safe operating space for humanity

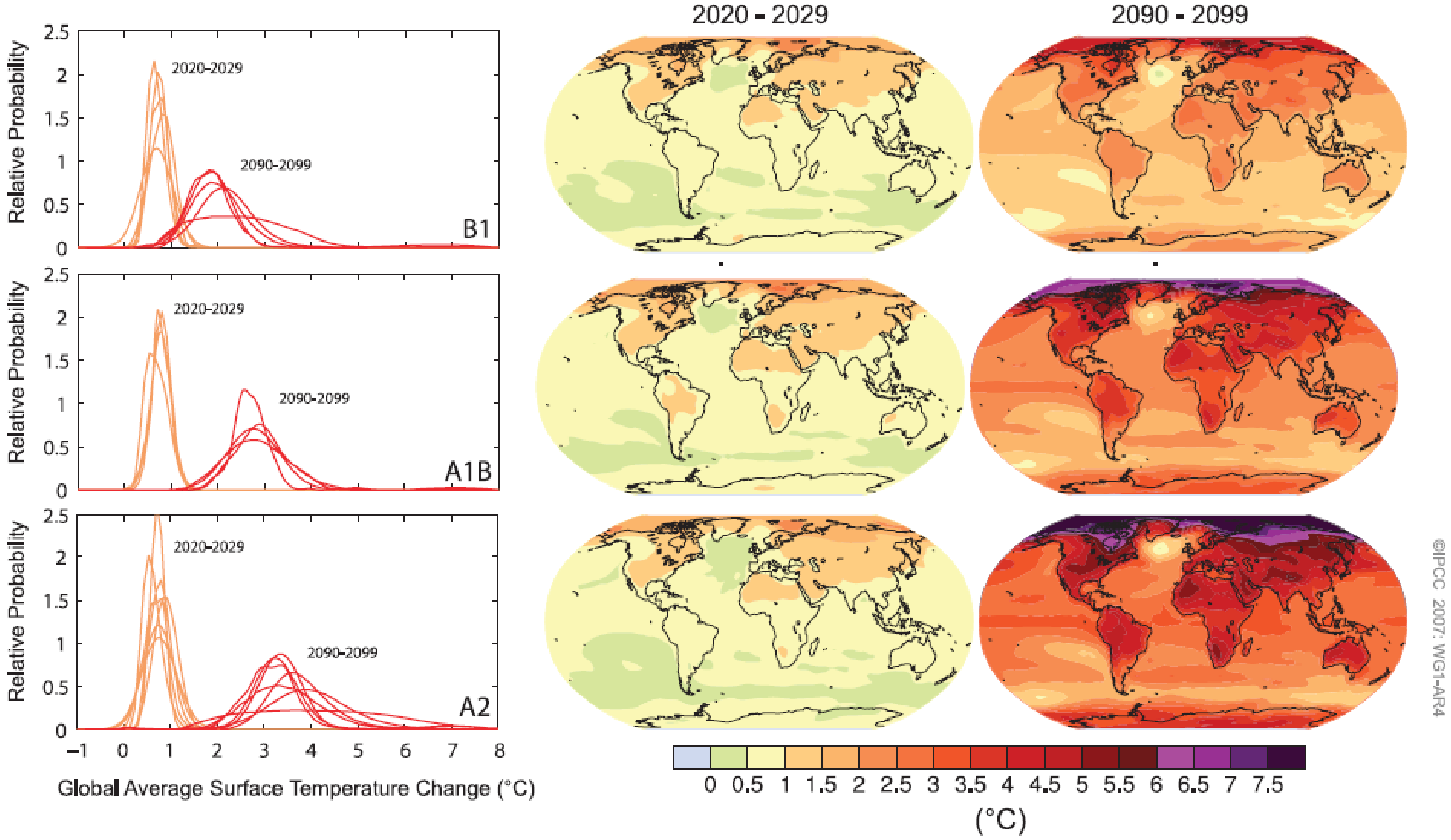
Rockström et al. (2009), *Nature* 461, 472-475



Projection of surface temperatures

IPCC 2007, AR4, WG1

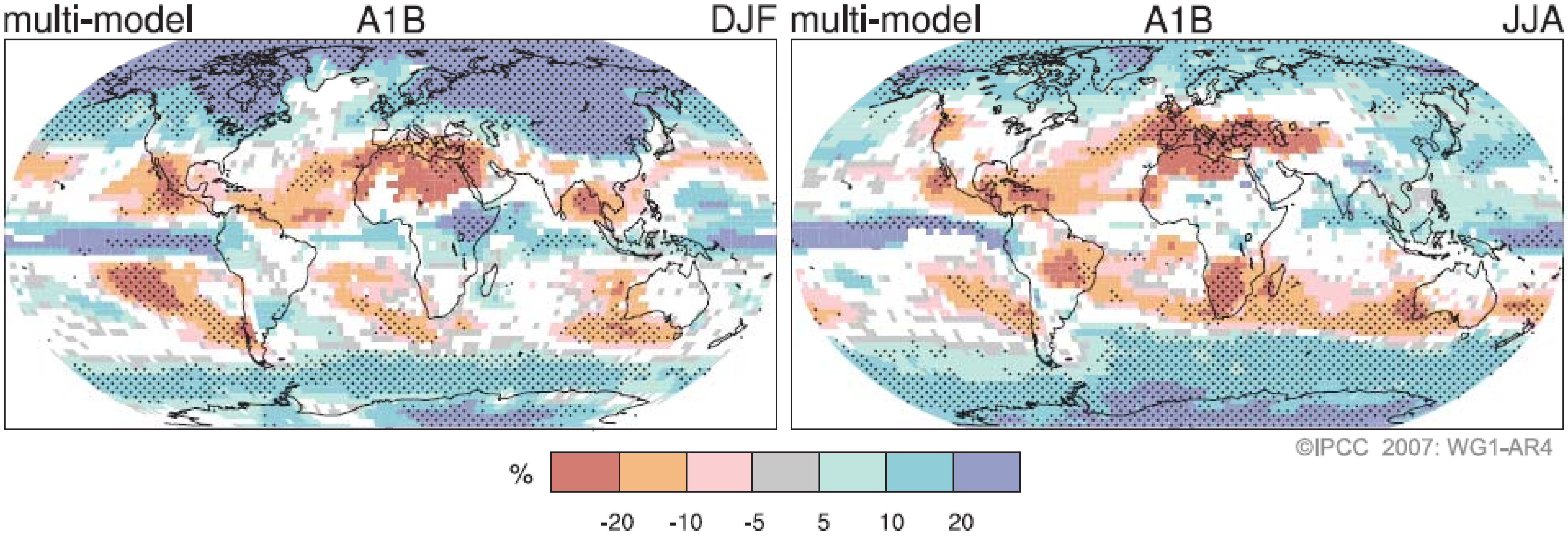
Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999



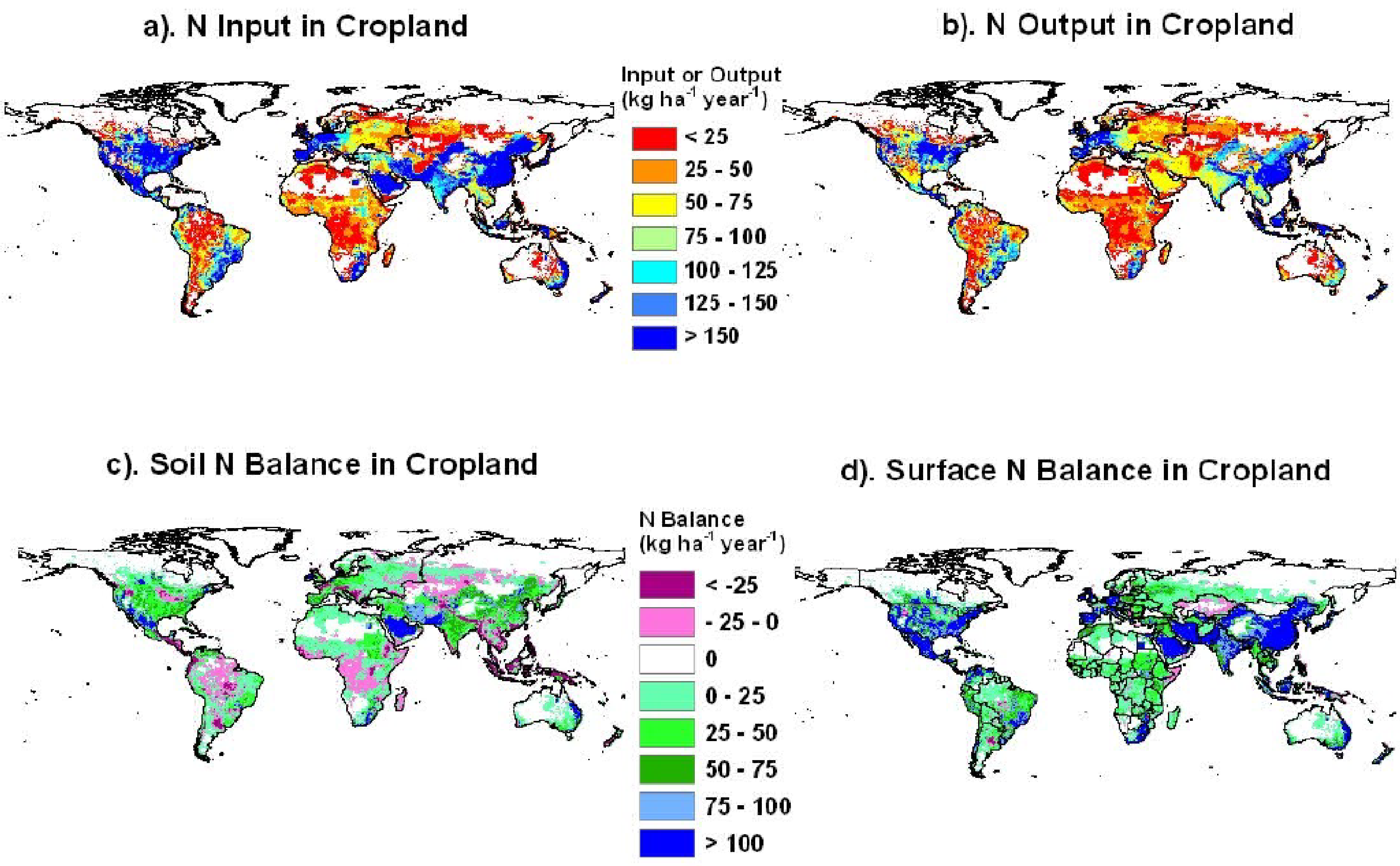
Projected pattern of precipitation changes

IPCC 2007, AR4, WG1

Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999, based on the SRES A1B scenario



Global nitrogen flows in cropland



http://www.geo-bene.eu/?q=node/1761

Ecosystems vulnerable to land use and climate change

Water limitation (mainly rainfed agriculture)

Nutrient limitation (mainly nitrogen)

Case studies

Inner Mongolia: Semi-arid grassland

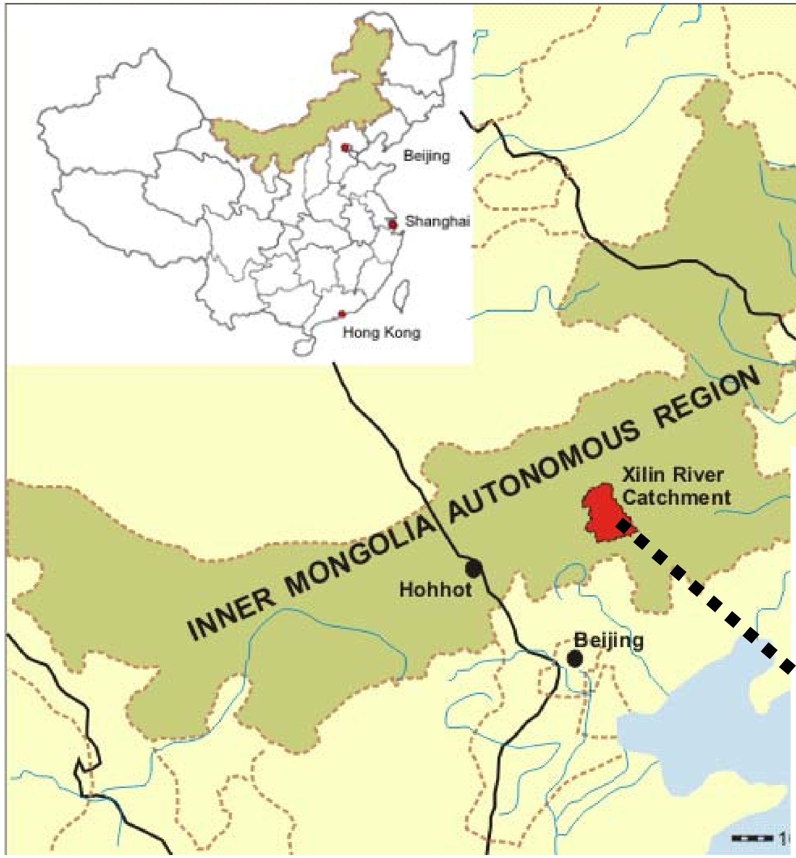
Burkina Faso: Dry-subhumid savanna

Research questions

Inner Mongolia: How do grazing and water addition affect matter fluxes?

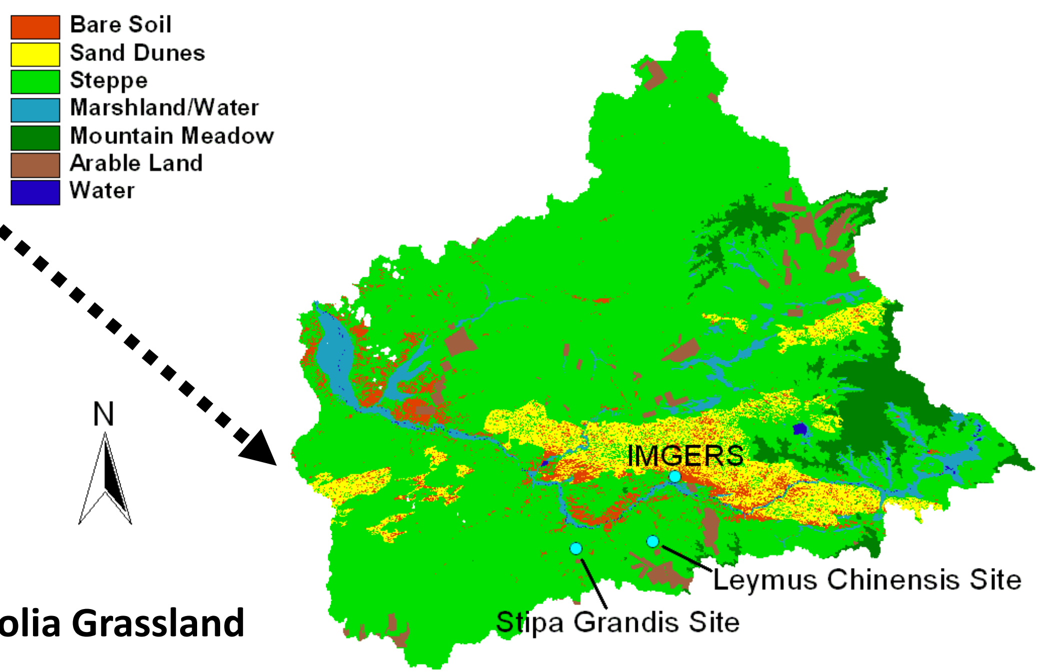
Burkina Faso: How does land-use change affect trace gas exchange?

Location of the study region in Inner Mongolia



Mean annual T: 0.7°C
Mean July T: 20°C
Mean January T: -20°C

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



IMGERS = Inner Mongolia Grassland Research Station

DFG Research Unit 536 „MAGIM“

Intact steppe in Inner Mongolia, PR China

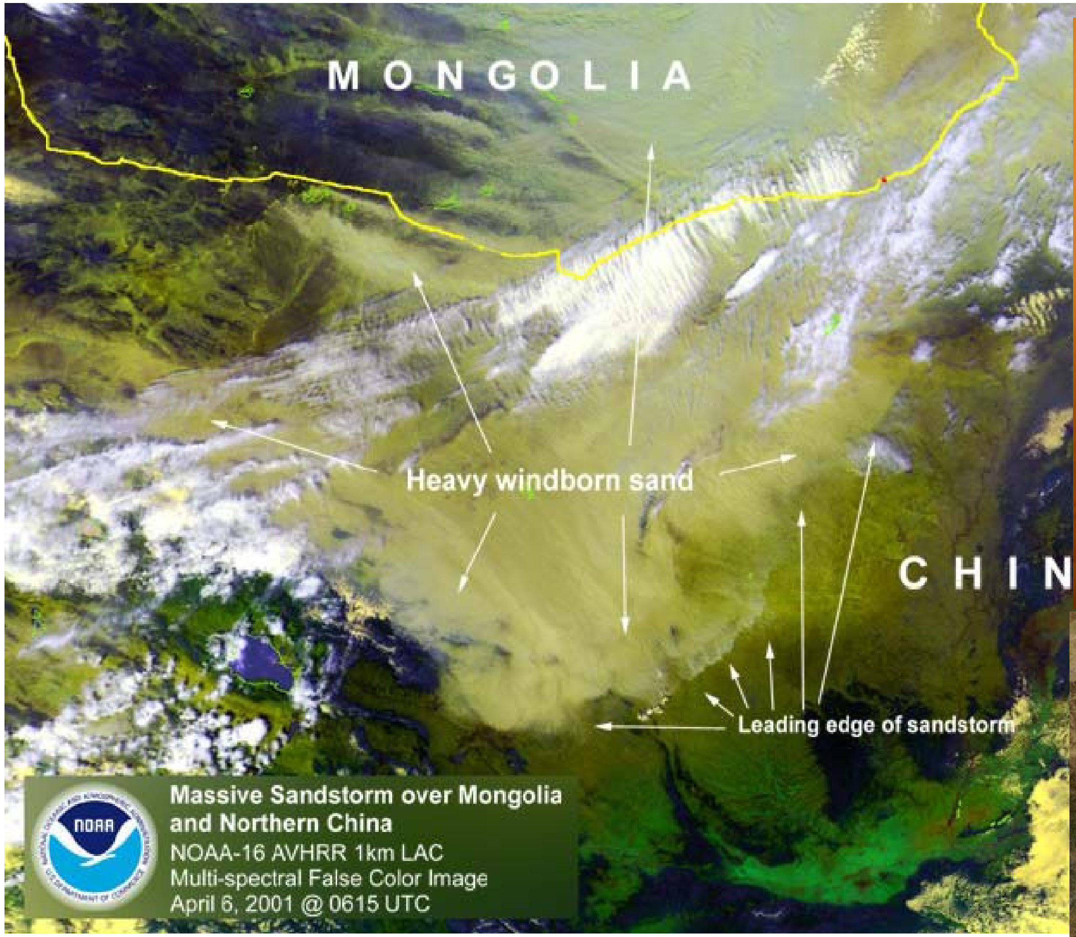
Problem: Overgrazing by sheep and goats

Result: floristic composition changes

Result: reduction of plant cover

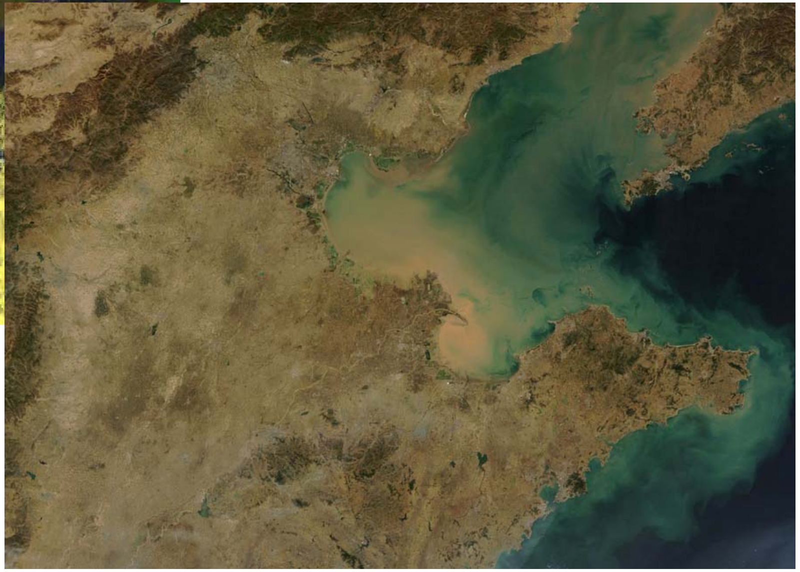
Result: Enhanced water erosion

Large-scale implications of steppe degradation



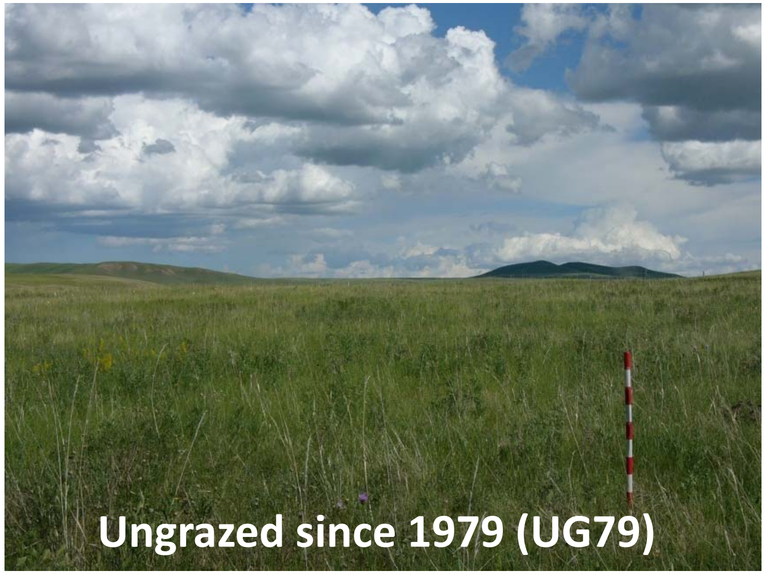
Wind erosion = Sand storms

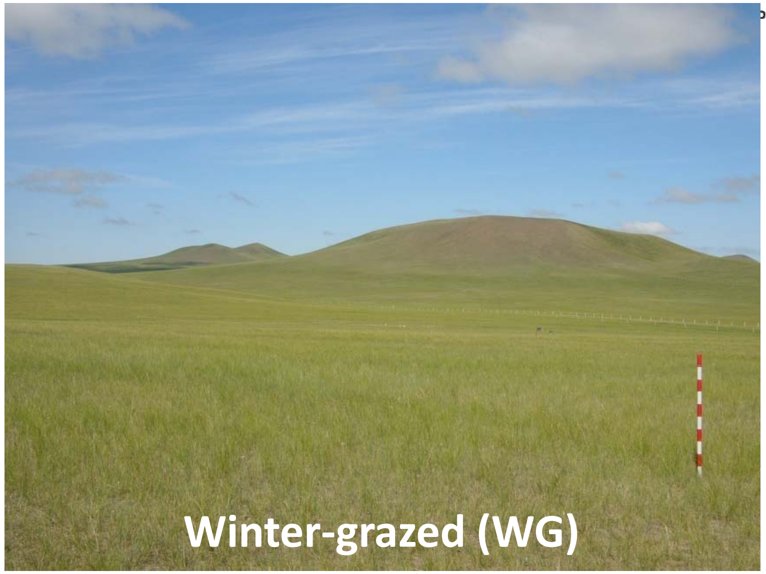
Sand storm in Beijing



Water erosion

Experimental sites in Inner Mongolia

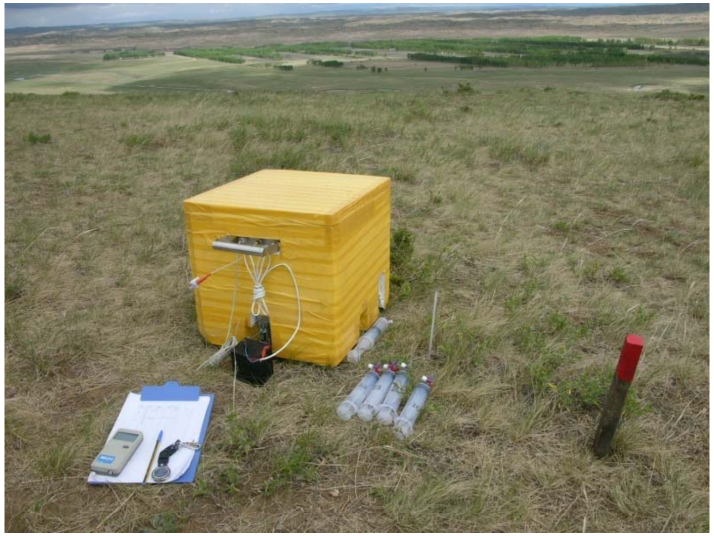

Ungrazed since 1979 (UG79)


Winter-grazed (WG)


Ungrazed since 1999 (UG99)

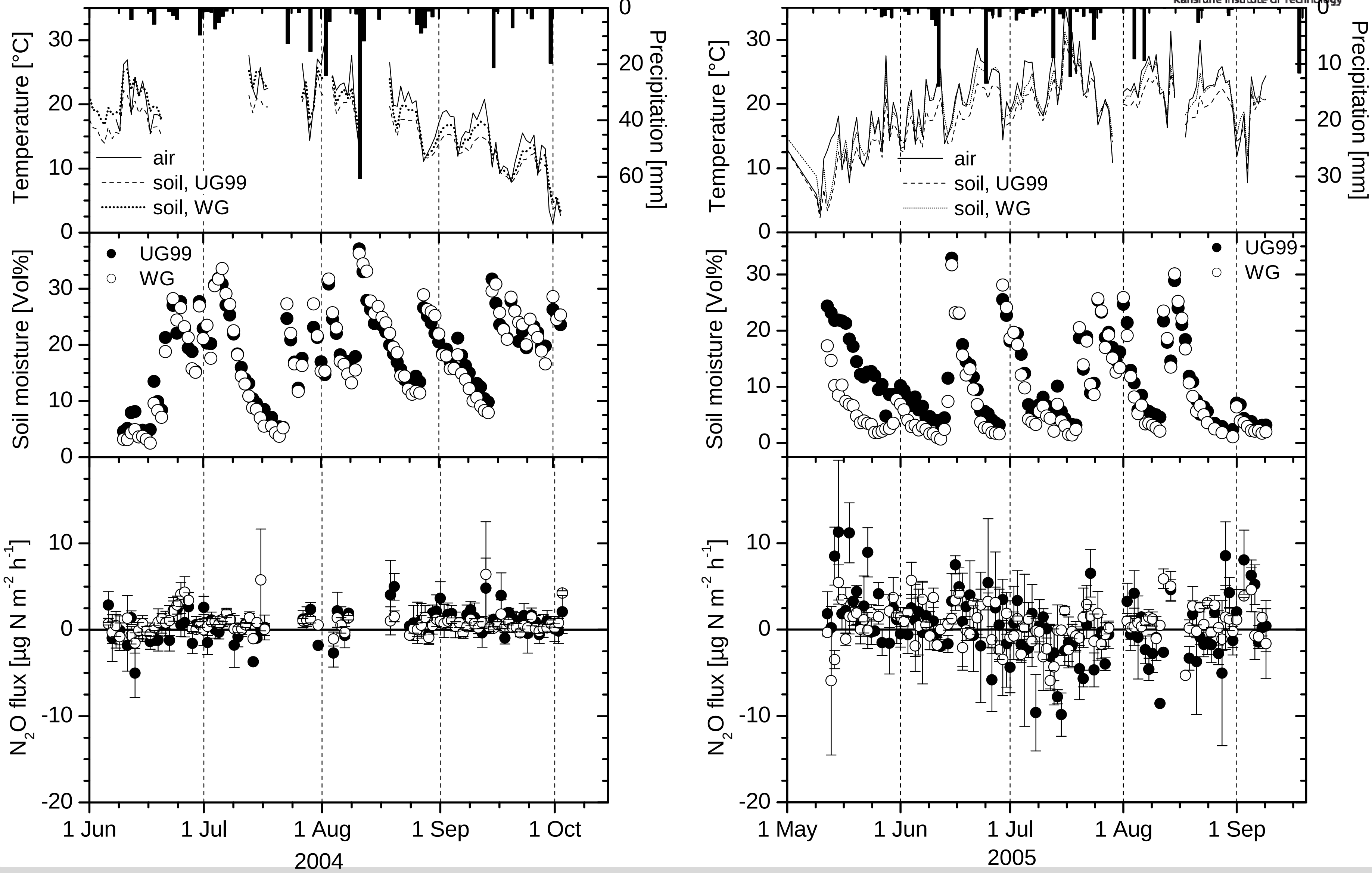

Heavily grazed (HG)

Automated and manual chamber measurements



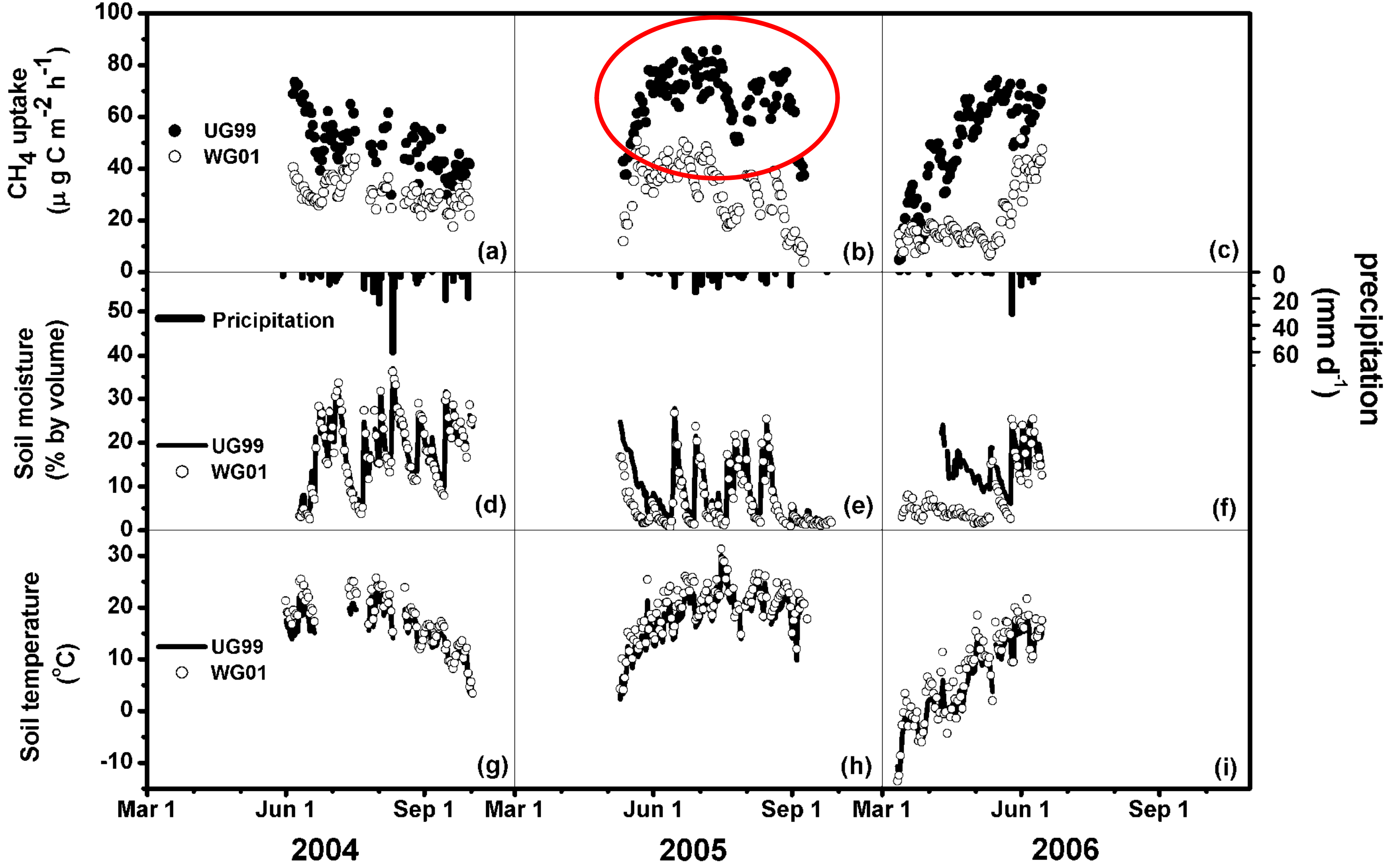
No significant grazing effect on N_2O fluxes

Holst et al. 2007, *Ecosystems* 10, 623–634



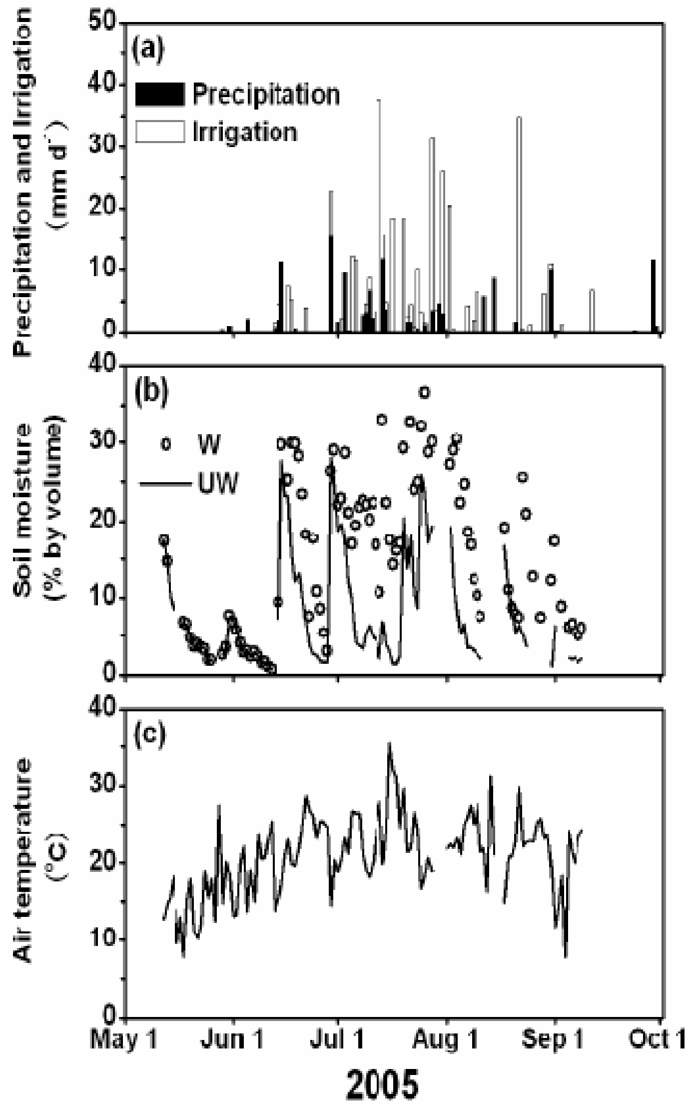
Reduction of CH_4 uptake by grazing/trampling

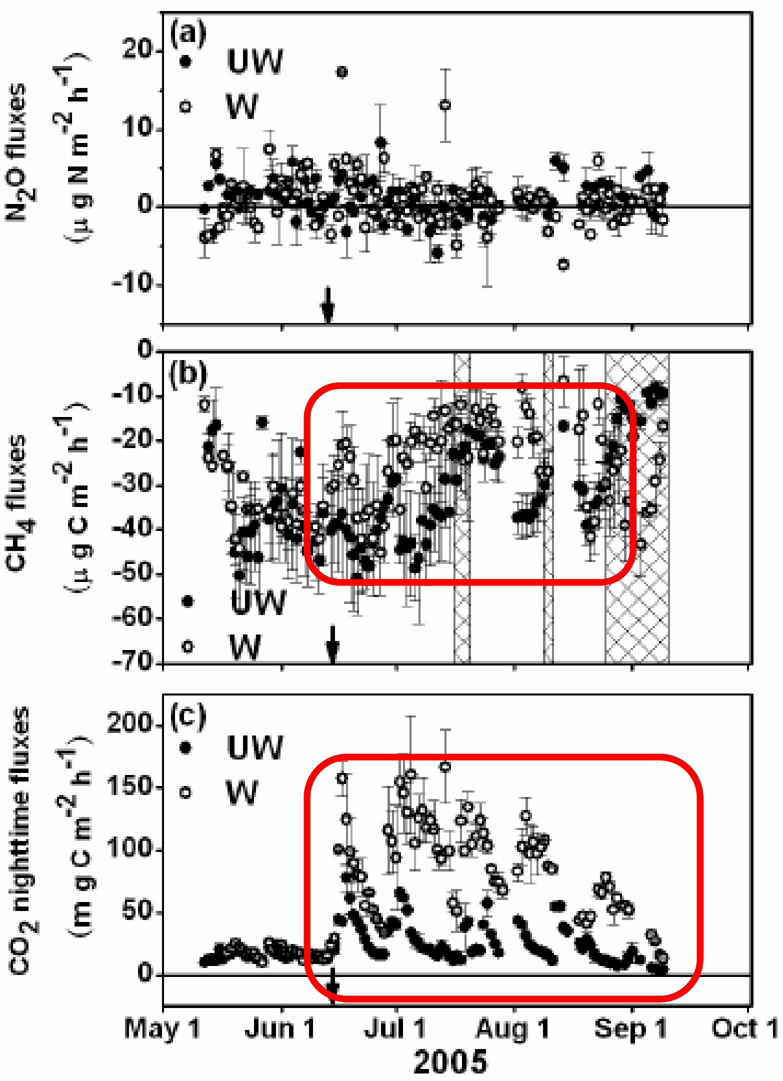
Liu et al. 2007, *Atmospheric Environment* 41, 5948–5958



Significant effects of watering on CO_2 and CH_4 fluxes

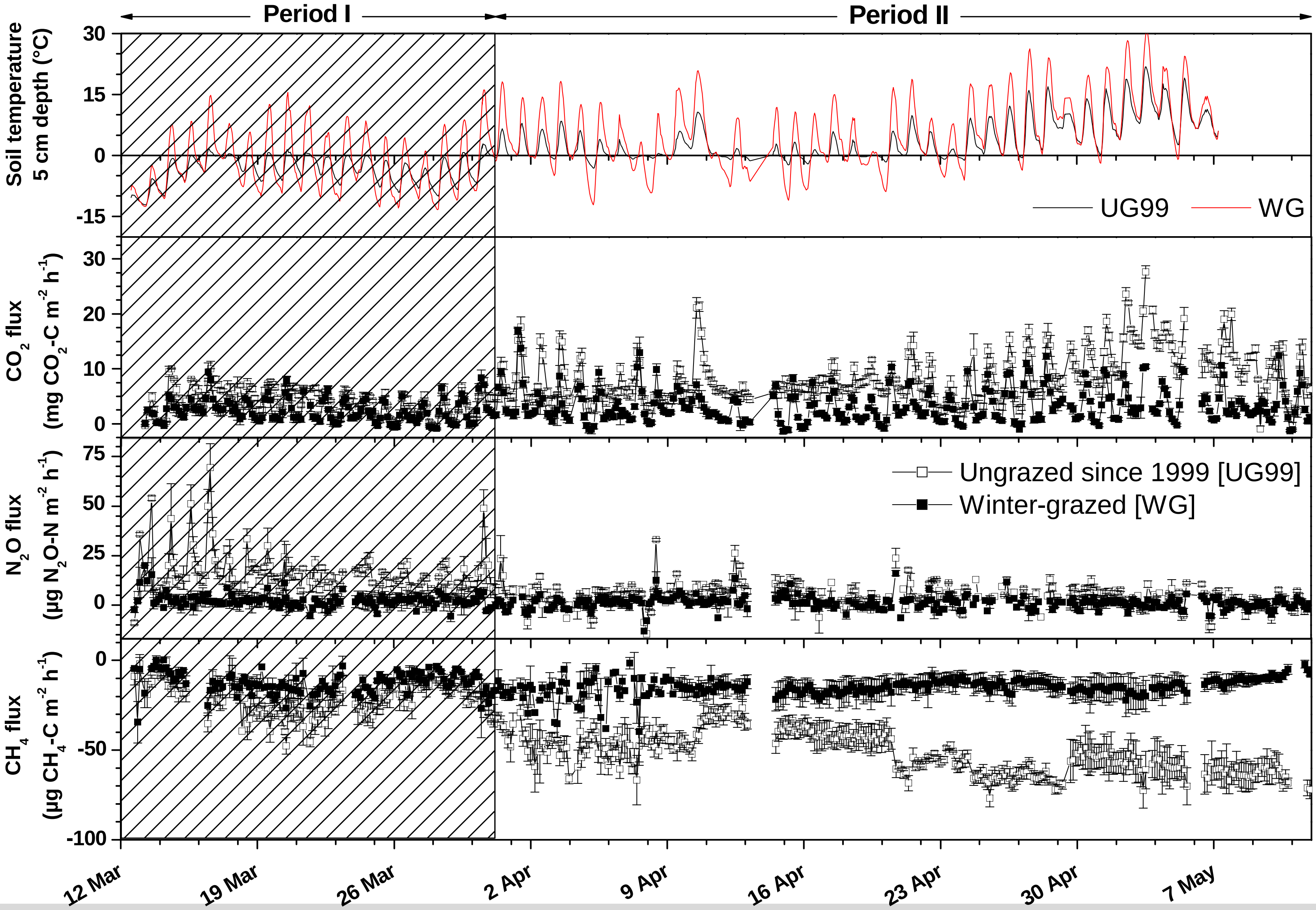
Liu et al. 2008, *Advances in Atmospheric Sciences* **25**, 748–756





Significantly enhanced freeze/thaw N_2O fluxes

Holst et al. 2008, *Plant Soil* 308, 105–117



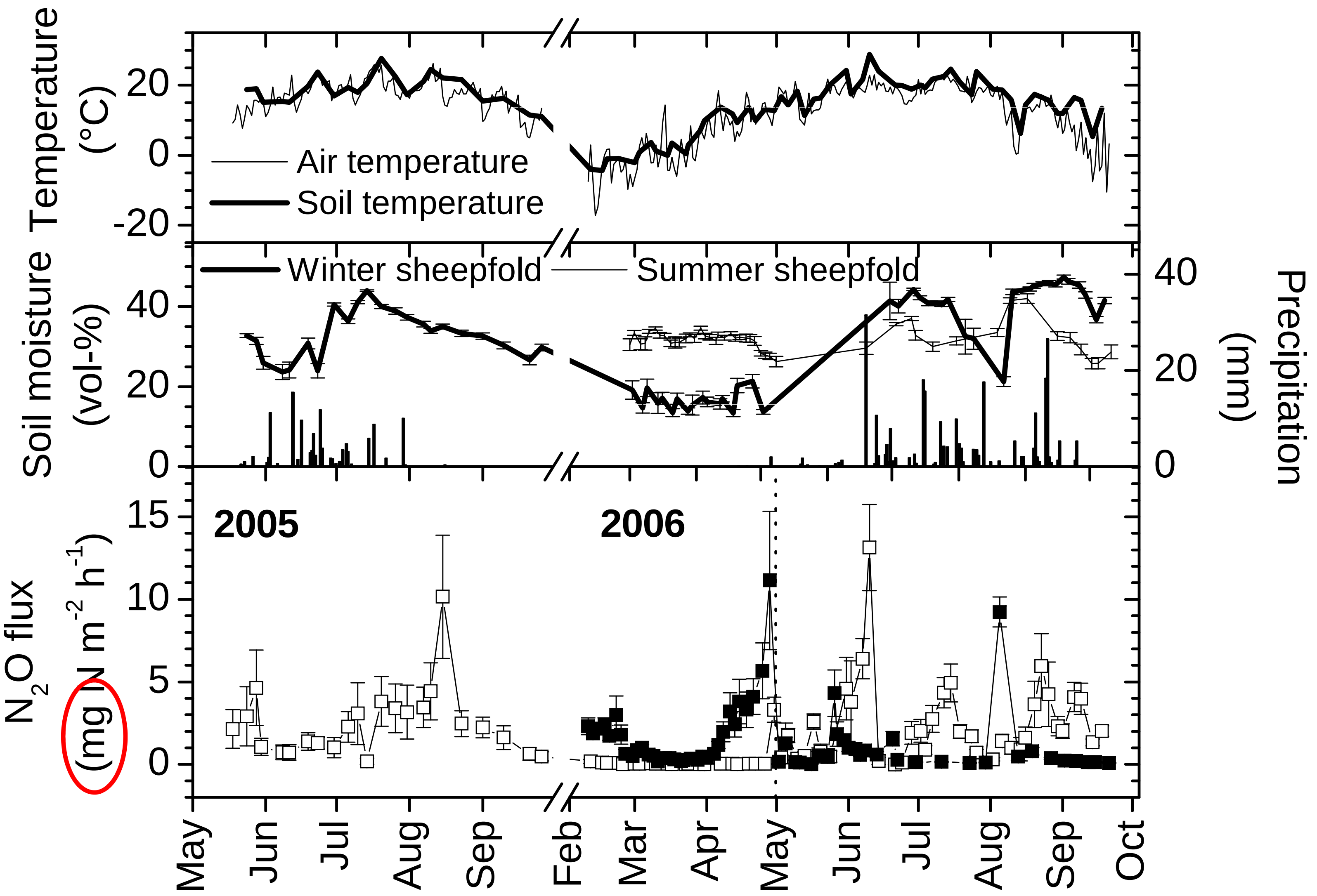
Sheepfolds: Large point sources of N_2O-Emissions

Holst et al. 2007, *Plant Soil* 296, 209–226

Precipitation (mm)

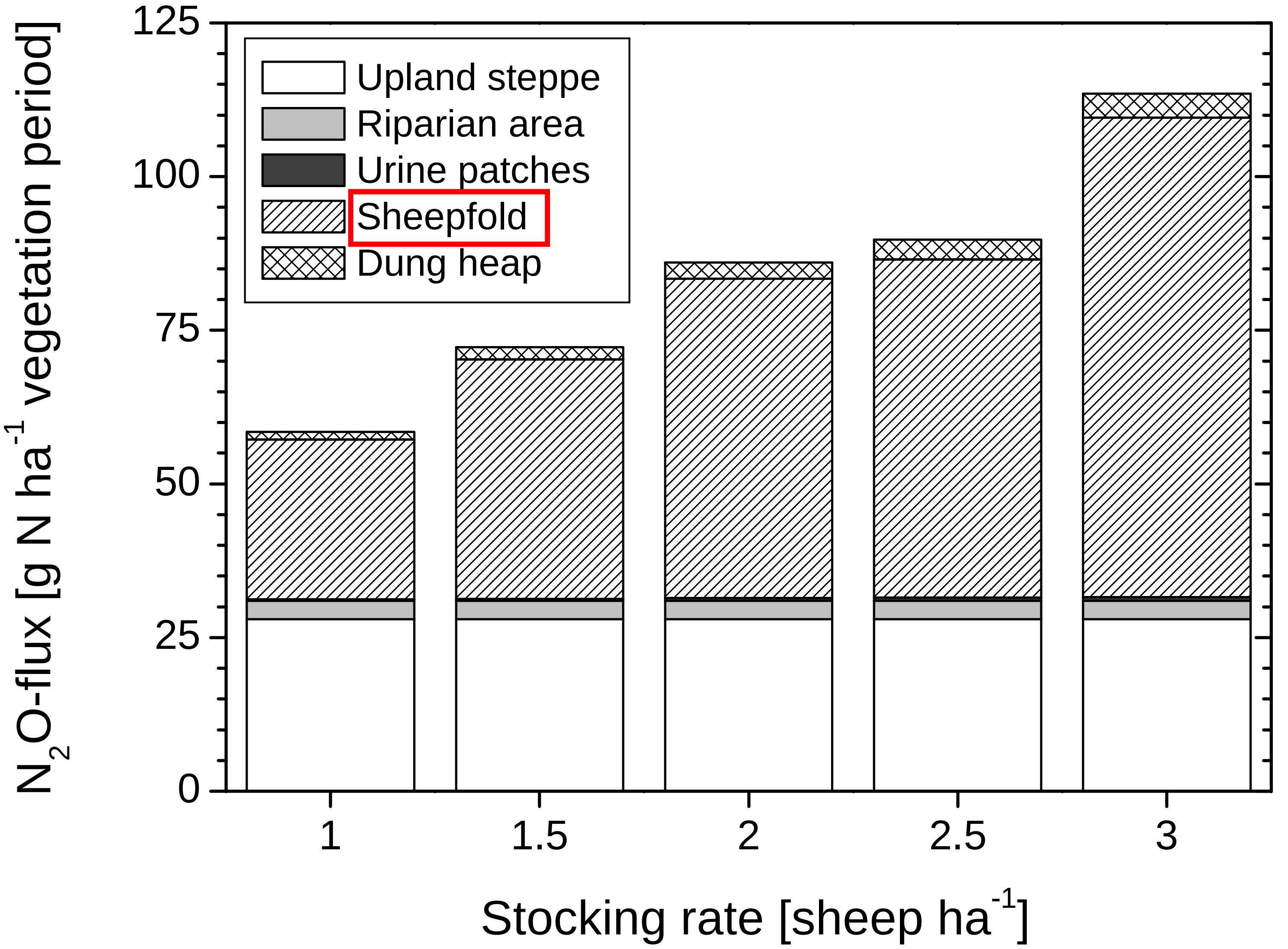
Sheepfolds: Large point sources of N_2O-Emissions

Holst et al. 2007, *Plant Soil* 296, 209–226



Importance of point sources for regional N_2O fluxes

Holst et al. 2007, *Plant Soil* 296, 209–226



Summary for steppe in Inner Mongolia

No significant effect of grazing on soil N_2O fluxes,
very low in this steppe anyway

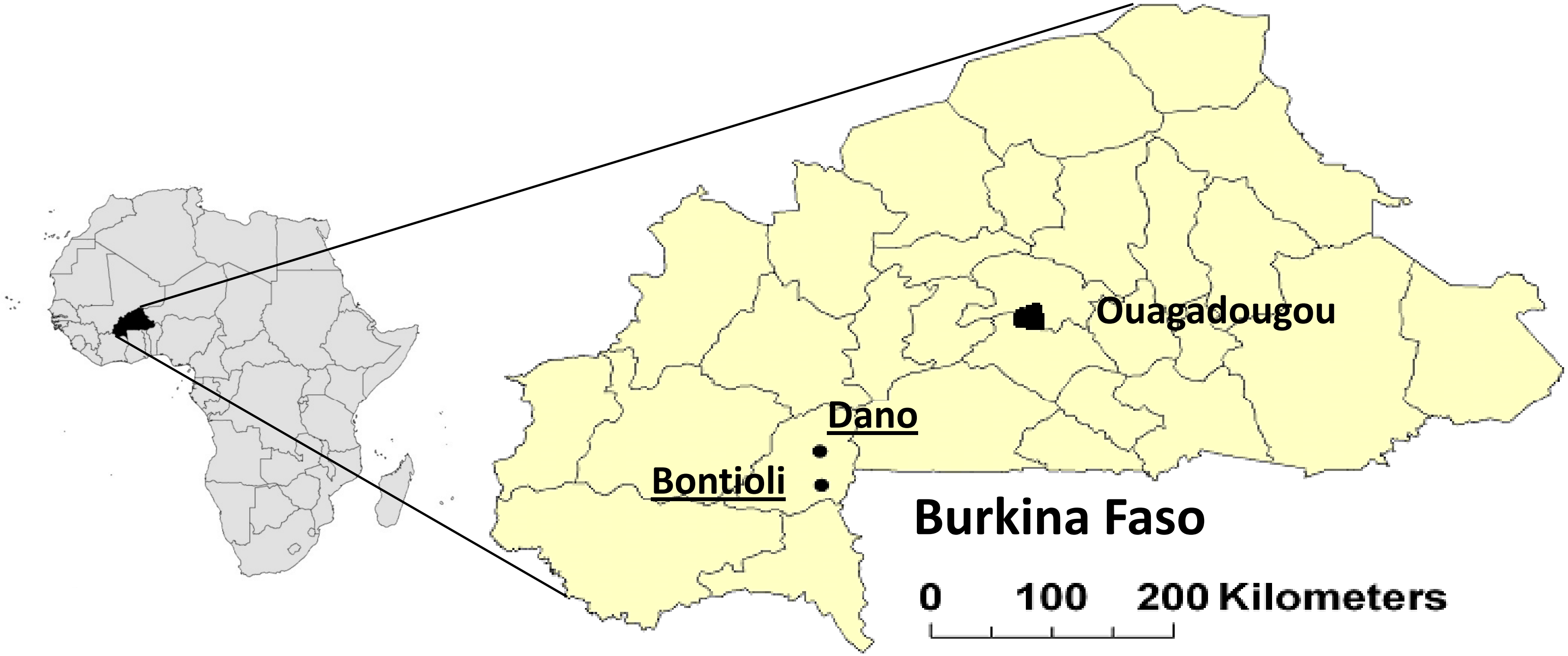
Significant reduction (~50 %) of soil CH_4 uptake due to grazing

Large stimulation of soil CO_2 emissions after water addition

Significant reduction of soil CH_4 uptake after water addition

Export of large amounts of nitrogen from grassland to sheepfolds
=> hotspots of N_2O, NO and CH_4 emission

Location of study area in Burkina Faso



Climate

Mean annual air temperature: 29.5 ° C

Mean annual precipitation: 926 mm

Rainy season: May to October

Field sites

Bontioli


Natural savanna - dry


Natural savanna - wet

<u>Bontioli Reserve</u>
nature park, no farming, no tillage, no livestock


Sorghum – Bontioli

used for agriculture since 15 years

Dano


Sorghum – Dano


Cotton – Dano


Peanut – Dano

used for agriculture since several decades

Experiments

Measurements

- CO_2, CH_4 and N_2O soil fluxes in agricultural fields and natural savanna
- Effect of N fertilization on N_2O soil fluxes

Agricultural practice

Seeds sown in May, no fertilizer application (except fertilizer experiment), topsoil aerated with hoes every 2 to 4 weeks after sowing, harvest in October.

Manual and automated chamber measurements

Sampling with syringes in the field

Manual:
4 chambers at each site, measured 1-3 times per week

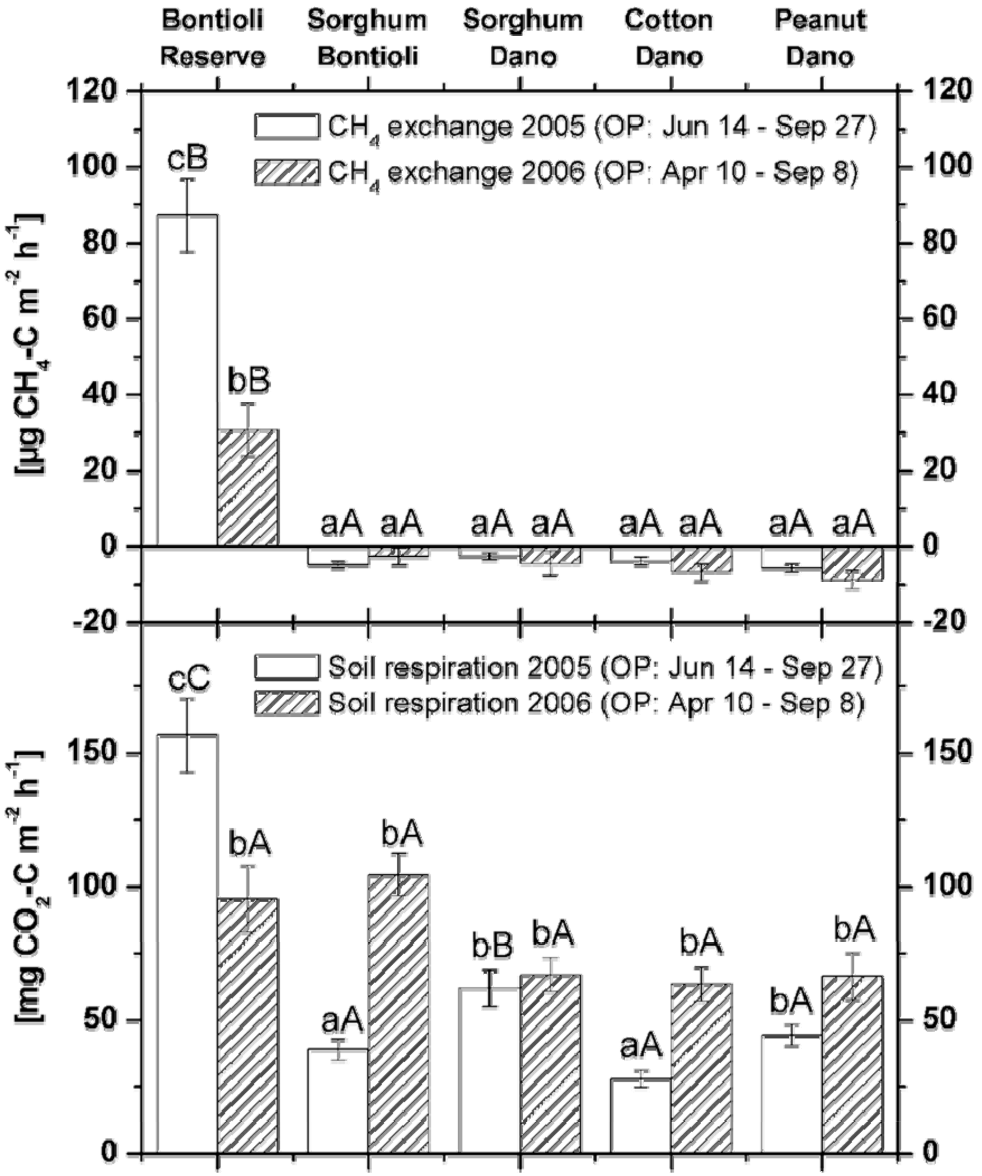
GC analysis at the same day

Pneumatically operated chambers

Automated:
3 chambers at each plot, measured continuously (10 values per day)

On-line GC analysis in the field

Mean CH_4 and CO_2 soil fluxes

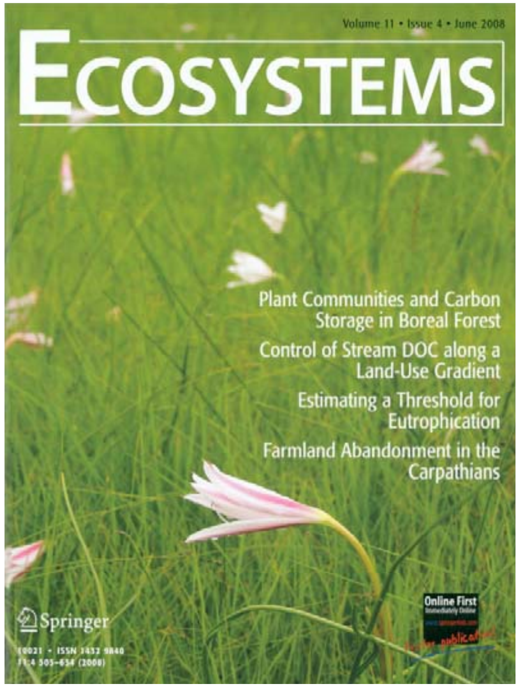


lowercase letters = significant differences ($p < 0.05$) between years; uppercase letters = between sites

Brümmer et al. (2009), *Global Biogeochemical Cycles* **23**, GB1001

Mean N_2O fluxes, no fertilization

Karlsruhe Institute of Technology



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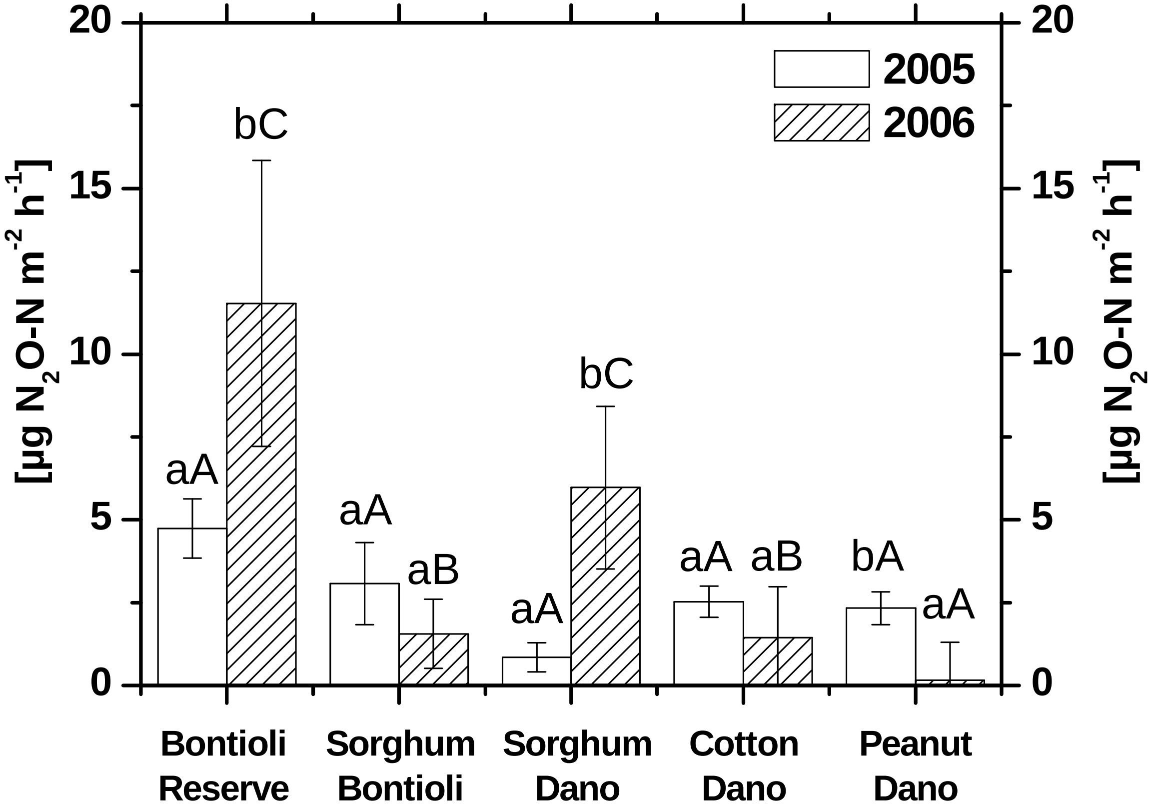
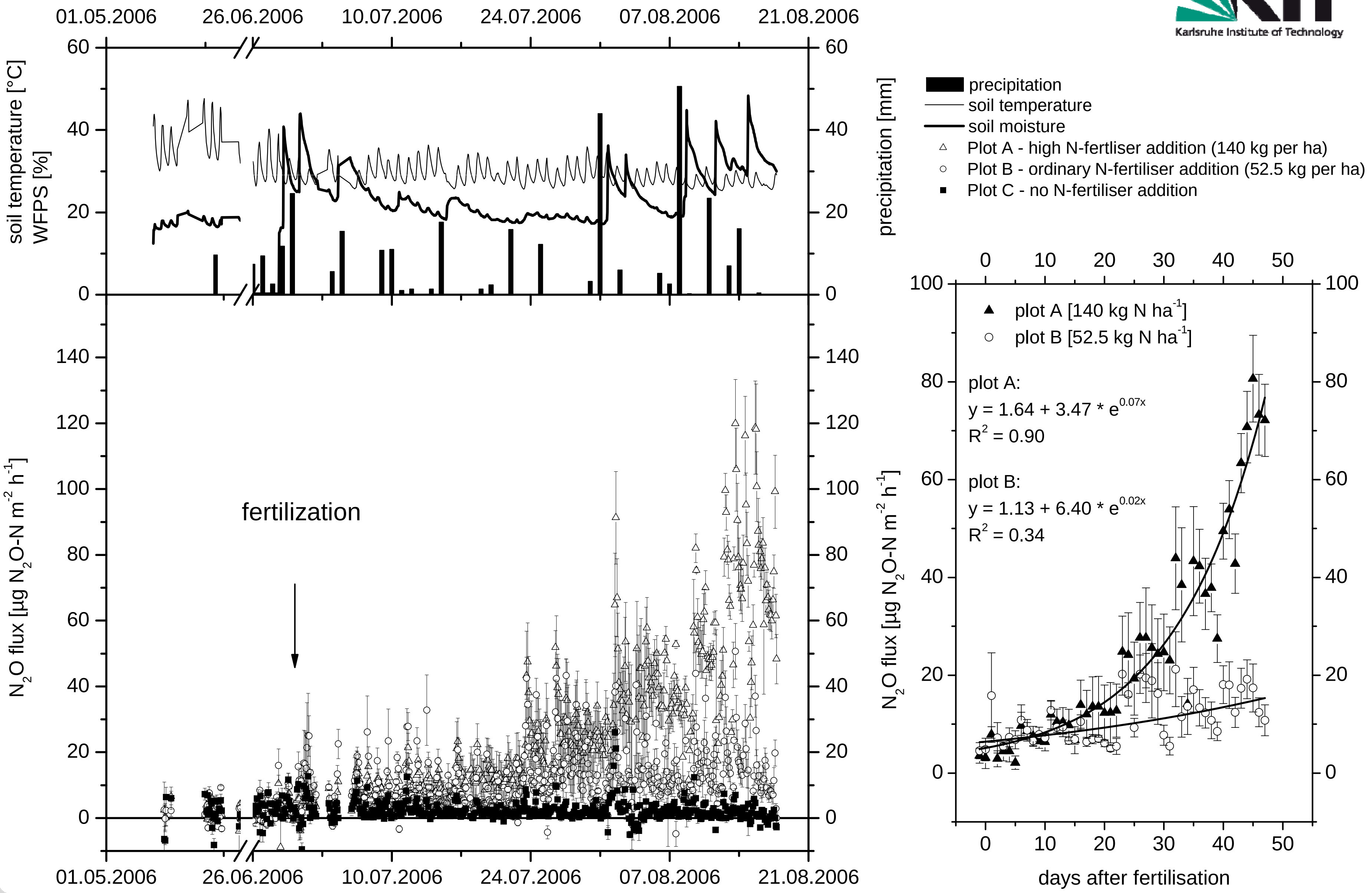
Brümmer et al. 2008,
Ecosystems 11, 582–600



n = 79-162, ± SE;
lowercase letters = significant differences ($p < 0.05$)
between years; uppercase letters = between sites

N_2O fluxes after fertilization

Brümmer et al. 2008, *Ecosystems* 11, 582–600



Summary for savanna in Burkina Faso

Natural savanna soil strong CH_4 source due to flooding in the rainy season

Agricultural soils weak CH_4 sink

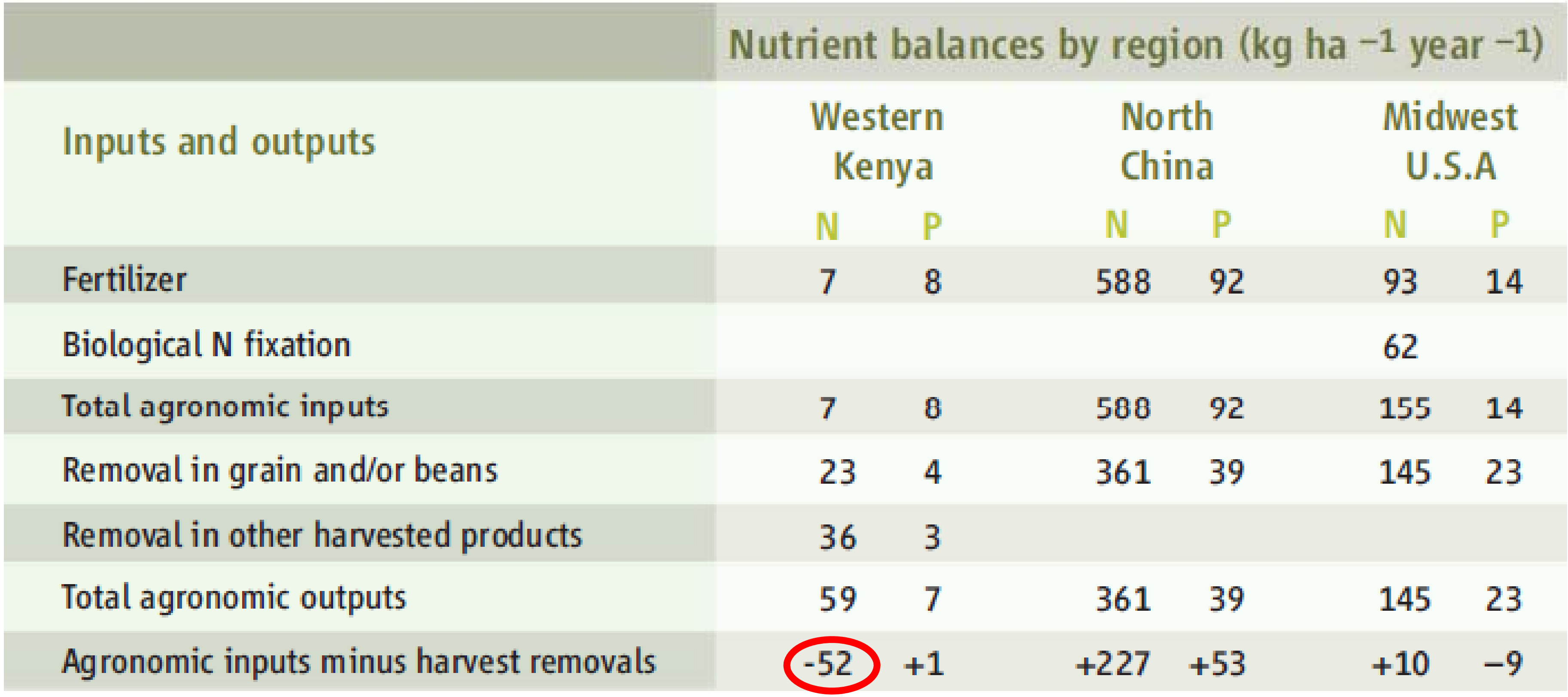
Soil CO_2 emissions higher in natural savanna than in arable land

Soil N_2O emissions low in both natural savanna and arable land

However, NPK fertilizer application leads to a significant increase of N_2O emissions

Conclusions

Anthropogenic **nutrient translocation, concentration and loss** in hotspots exacerbates naturally given productivity constraints in vulnerable ecosystems, but increases regional GHG emissions



	Nutrient balances by region (kg ha $^{-1}$ year $^{-1}$)					
Inputs and outputs	Western Kenya		North China		Midwest U.S.A	
	N	P	N	P	N	P
Fertilizer	7	8	588	92	93	14
Biological N fixation					62	
Total agronomic inputs	7	8	588	92	155	14
Removal in grain and/or beans	23	4	361	39	145	23
Removal in other harvested products	36	3				
Total agronomic outputs	59	7	361	39	145	23
Agronomic inputs minus harvest removals	-52	+1	+227	+53	+10	−9

Vitousek et al. (2009), *Science* 324, 1519-1520

Conclusions (2)

Future management has to focus on returning nutrients to productive areas while reducing/mitigating nutrient losses and GHG emissions

“Nutrients in plant and animal products collected broadly across rural landscapes are increasingly concentrated in urban environ[ment]s where waste removal efforts result in transformation of nutrients into gases, dilution into rivers and marine bodies…”

“Only a fraction of these assets (nutrients and carbon) are ever returned to rural lands. As a result, soils are slowly being drained of trace elements, soil carbon reserves are being depleted, and it is necessary to mine nutrients and chemically produce N fertilizer to satisfy crop demands.”

DeLuca (2009), *Science* 326, 665