Data Mining From A Long-Term Grassland Ecosystem Monitoring Dataset

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Inner Mongolia Grassland Ecosystem Research Station

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Presentation Outline

- ✓ **Introduction of the Station**
- ✓ **Long-term Monitoring Dataset**
- ✓ **Case Studies**
- ✓ **On-going Activities and Future Directions**

Background

- Inner Mongolia grassland ecosystem research station (IMGERS) was founded in 1979
- N43˚26'-44˚08'， E116˚04'-117˚05'， Elevation 1100-1400m, Semiarid climate, Chestnut soil
- In 1982, accepted as primary station by international ‘Man and Biosphere plan’(MAB)
- In 1989, accepted as opening research station by Chinese Academy of Sciences
- In 1992, accepted as a member by CERN.


热烈庆祝中国科学院内蒙古草原生态系统定位研究站建站20周年

1. The Station

The mission:

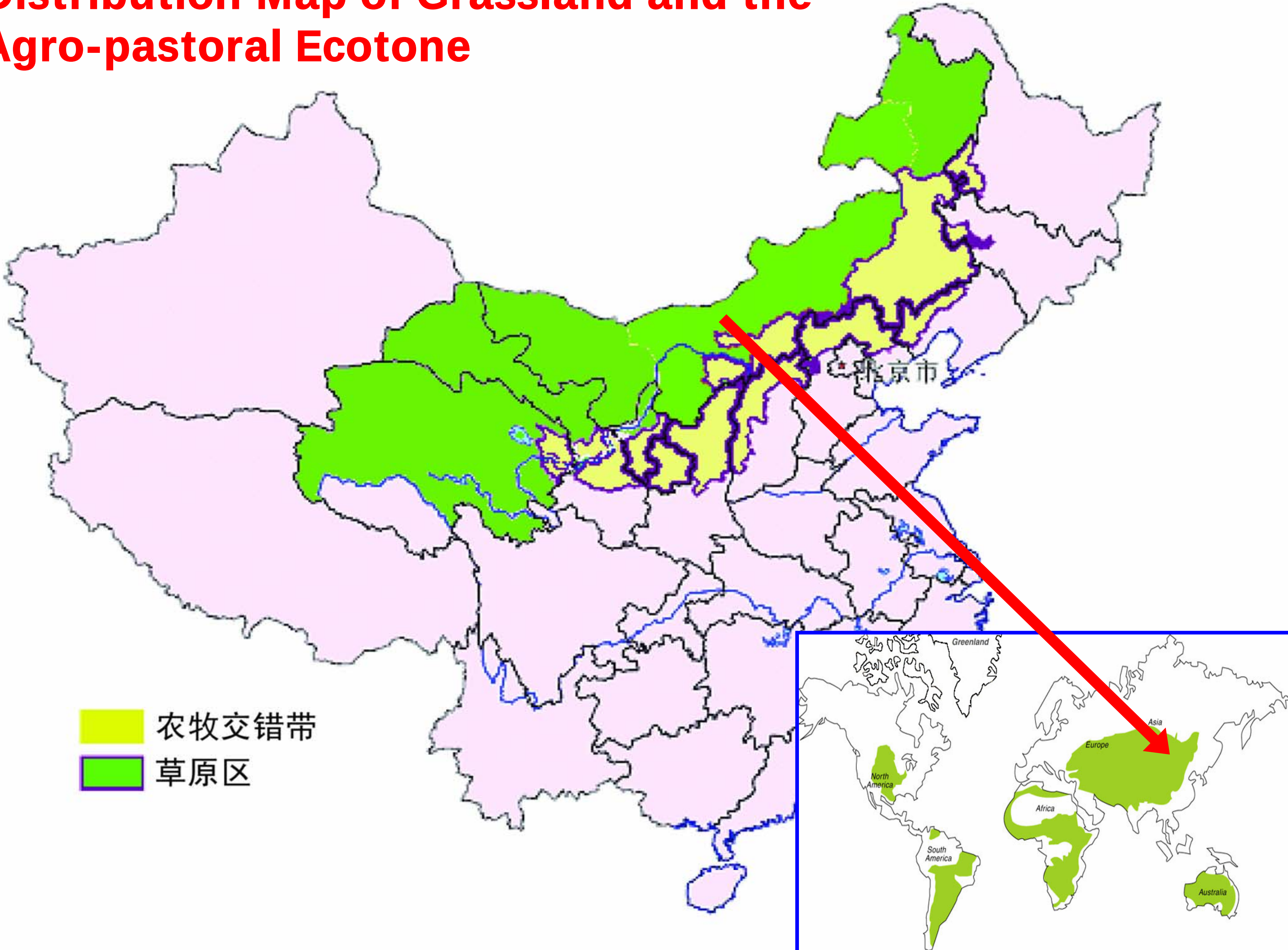
- National Needs： Ecosecurity, food security, dietary change, social stability
- Local Demand： Development and Poverty Eradication
- Scientific questions： Global change, biodiversity conservation, sustainable development

Background

- **Grassland ecosystems occupy about 40% of the land surface, and they provide nearly 30% of the NPP.**

- **The grasslands and the agro-pastoral ecotone in northern China are estimated to be 2.67 million km^2. Over 30 million people are living in this region.**

Distribution Map of Grassland and the Agro-pastoral Ecotone



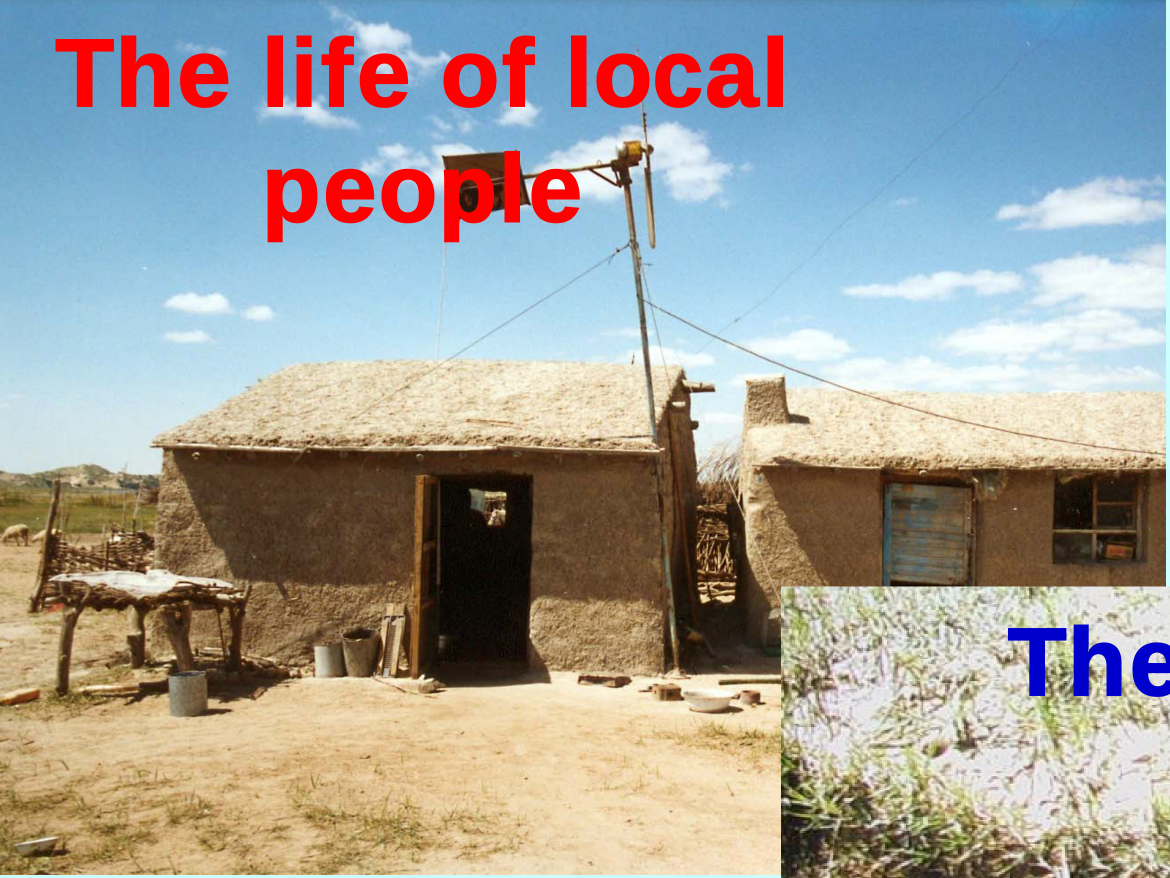
Characteristics and Problems

- Fluctuating environment and sensitive global change
- Front of the desertification
- Origin of many important rivers
- Complex landscapes
- Origin of Mongolian culture


>70% degraded， greatly reduced NPP

# of pests


This problem is still going…


The life of local people

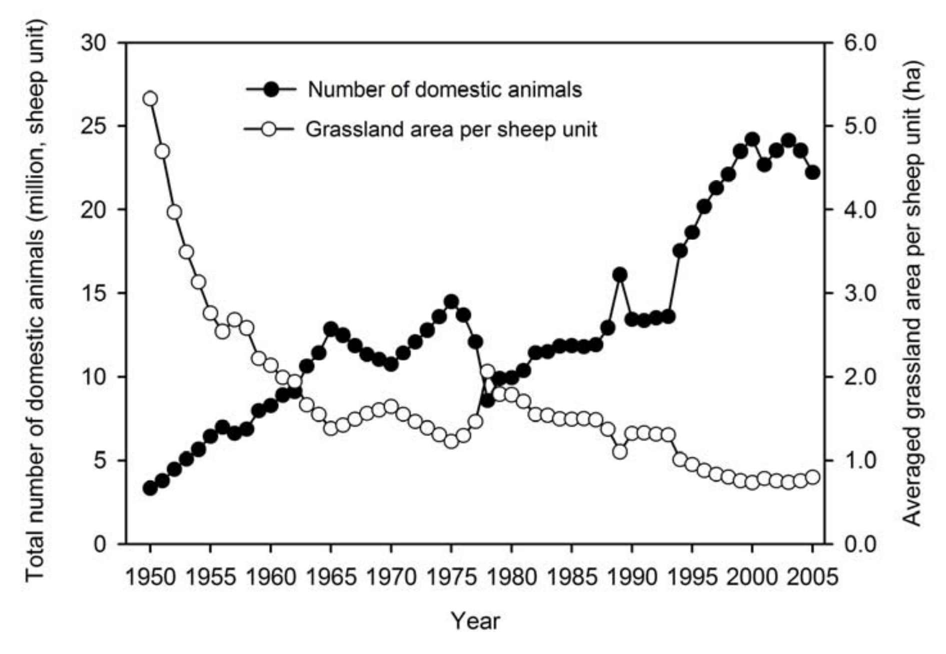

The future?


Dust storms


Dust deposition to Beijing
cnsphoto

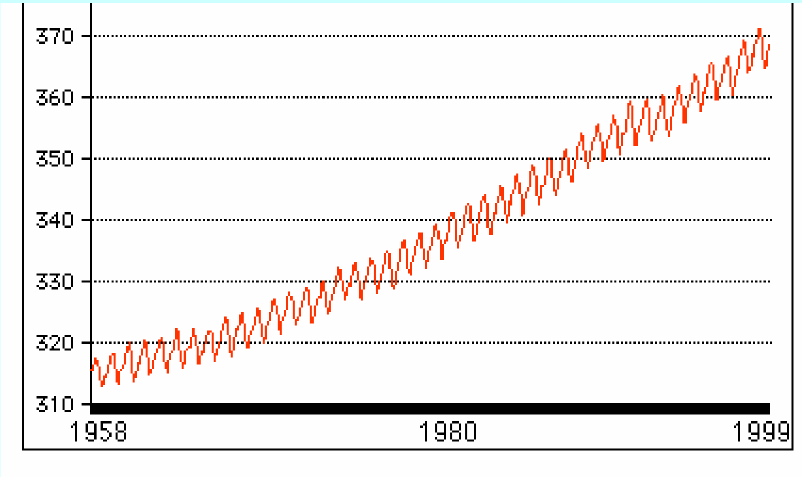
The problem

- Overgrazing
- Climate change
- Land use change
- Public awareness

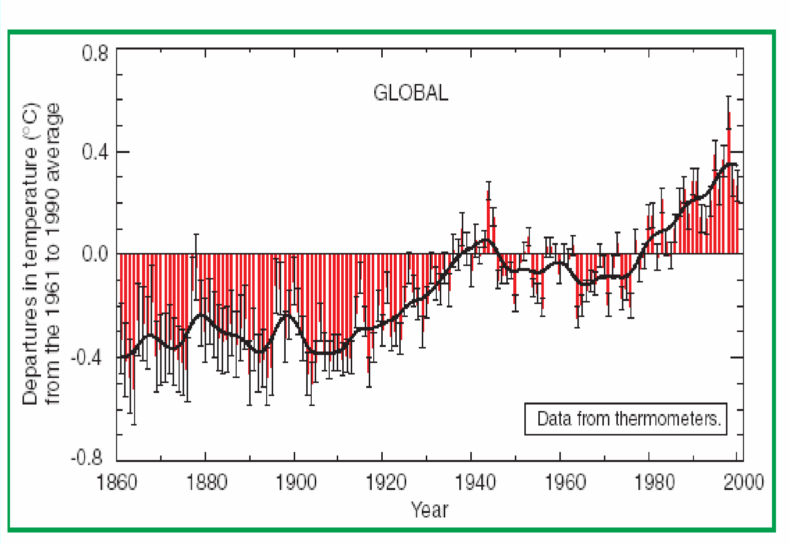


Land conversion

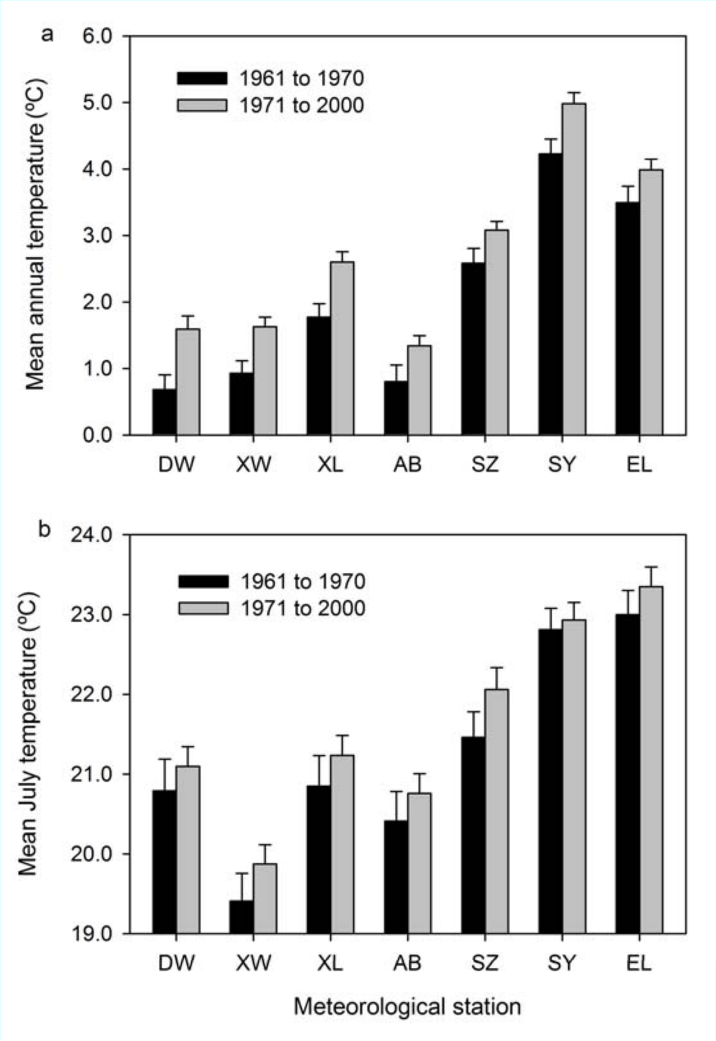
The warming



370
360
350
340
330
320
310
1958
1980
1999



GLOBAL
Departures in temperature (°C) from the 1961 to 1990 average
Data from thermometers.
Year



a
1961 to 1970
1971 to 2000
Mean annual temperature (ºC)
DW XW XL AB SZ SY EL
b
1961 to 1970
1971 to 2000
Mean July temperature (ºC)
DW XW XL AB SZ SY EL
Meteorological station

We study

1. Biodiversity and Ecosystem functioning
2. Life history of major plants
3. Biogeochemistry
4. Restoration ecology
5. Adaptive ecosystem management
6. Sustainability science

Leymus Chinensis Community plot (1979-)


Stipa grandis community plot
(Enclosed in 1979)

What do we monitor?

- Meteorology: Precipitation, temperature, radiation, winds, snowfall, humidity…
- Soil: texture, nutrient contents, pH, soil moisture…
- Hydrology: evaporation, PE, ET, lateral flow…
- Biota: plants, large animals and soil fauna, microbes, litter decomposition…

For plants, we regularly monitor:

- ANPP
- Relative growth rates of each species
- Foliage chemistry
- Root dynamics
- Phenology
- Herbivory

What can we have learned from this dataset

- Ecosystem dynamics
- Biodiversity—productivity relationship
- Rain use efficiency
- Allometry
- Neutrality of the community

Species that we are monitoring

- Leymus chinensis site: Lemus chinensis, Agropyron cristatum, Achnatherum sibiricum, Cleistogenes squarrosa, Koleleria cristata, Poa sphondylodes, Stipa grandis, Allium tenuissimum…
- Stipa grandis site: Stipa grandis, Leymus chinensis, artimesia frigida, A. scoparia, Saposhnikovia divaricata, Carex korshinskyi, Astragalus galactites…

Case study 1

Title:

Ecosystem stability and compensatory effects in the Inner Mongolia grassland

-Bai et al., 2004, Nature, 431:181-184

Problems addressed:

- What are the most important climatic drivers for the aboveground biomass production of steppe communities?
- How does biomass production respond to precipitation fluctuations at different levels of organization (that is, at the species, plant functional group and community level)?
- Are there detectable compensatory effects reducing the variability in biomass production and thus increasing ecosystem stability?

Methods

- Study site: IMGERS
- Plots: Two plots-Leymus chinensis community and Stipa grandis community that had been fenced since 1979;
- Sampling:Aboveground biomass was sampled during 28–30 August each year when community biomass reached the annual peak.
- Statistical analyses were performed using SAS version 8.0. Analysis of variance (ANOVA) and general linear models were used for analysis of variance.

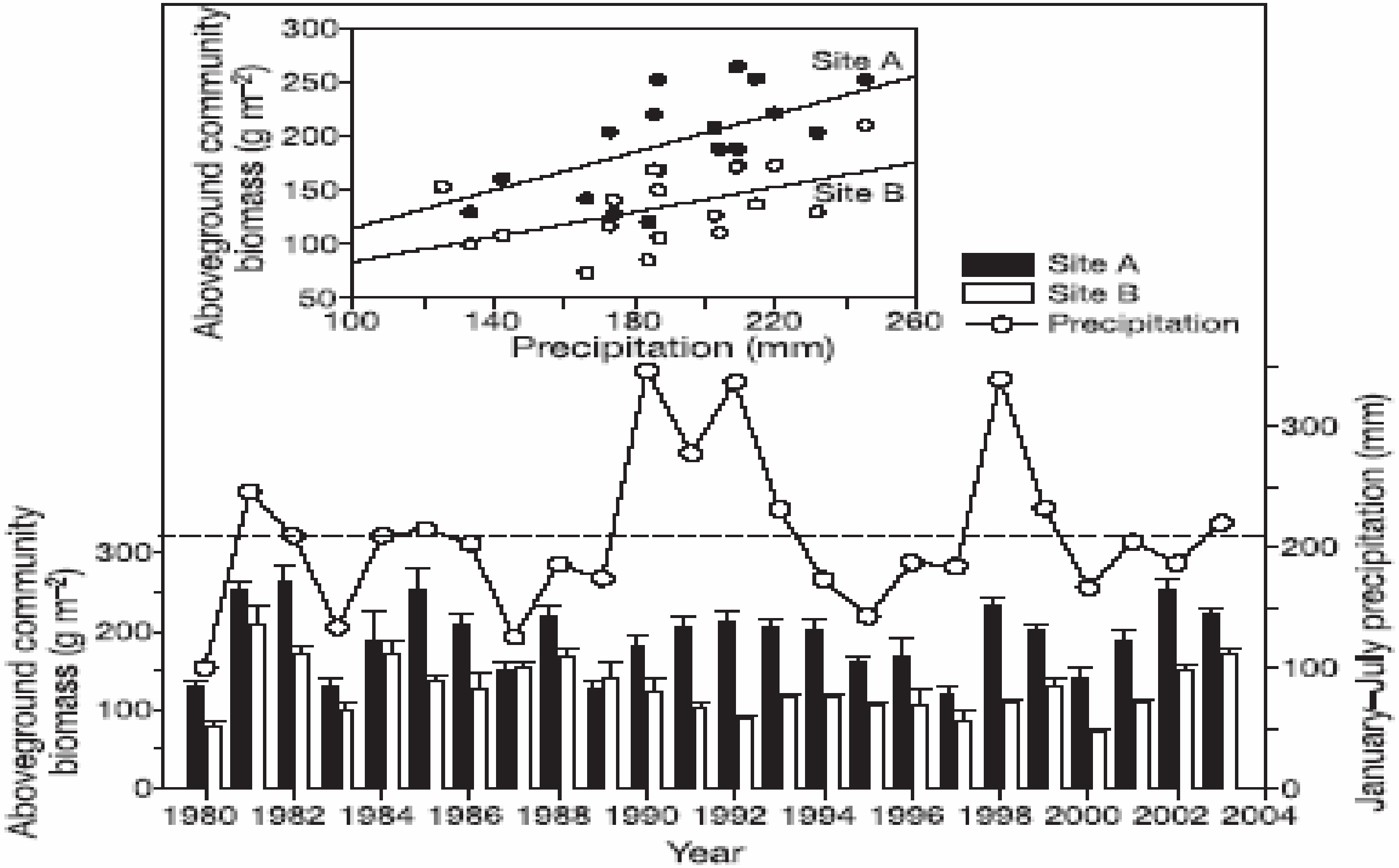
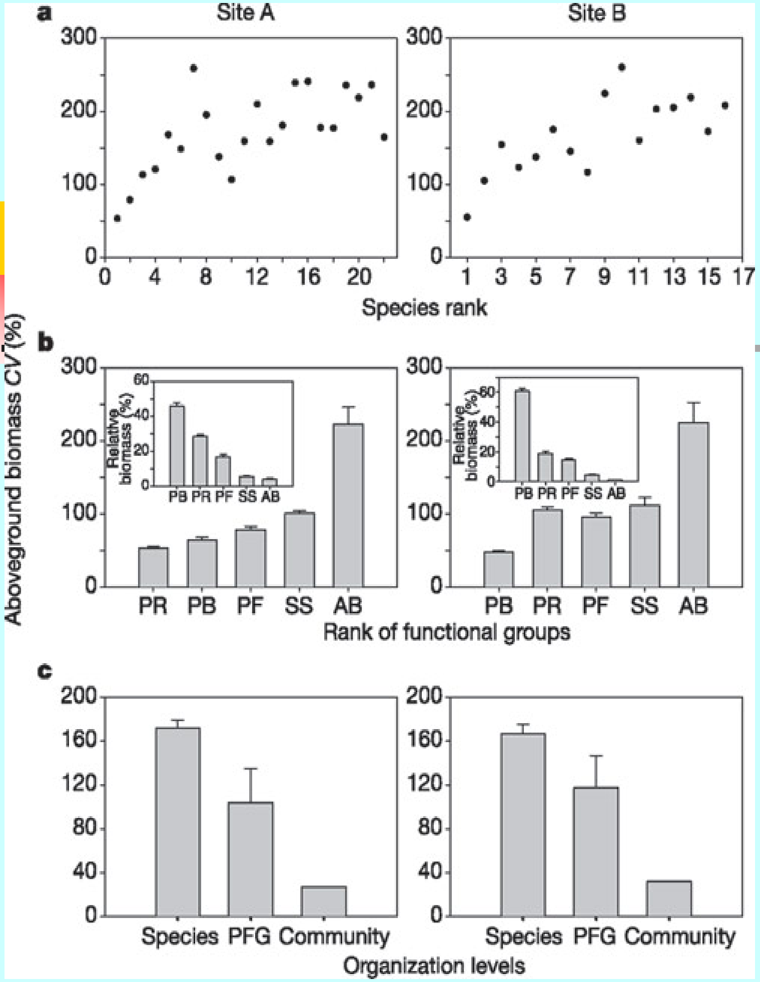
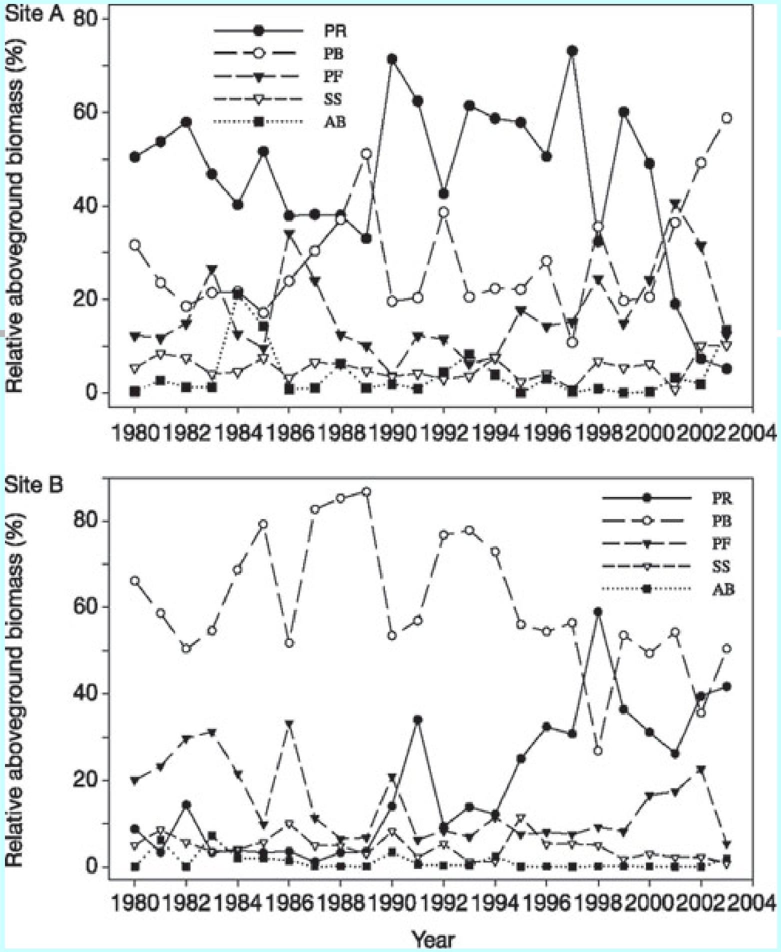


Figure 1 The relationship between January–July precipitation and total community aboveground biomass (B_{comm}) for the *Leymus chinensis* (site A) and *Stipa grandis* (site B) steppe ecosystems of the Inner Mongolia grassland, using data from 1980 to 2003. Bottom panel: B_{comm} was positively correlated to January–July precipitation in site A ($r^2 = 0.25$, $P = 0.01$), but not in site B ($r^2 = 0.003$, $P = 0.81$; $n = 24$). Error bars represent s.e.m., and the horizontal dashed line is the mean January–July precipitation from 1980 to 2003. Top panel: a significant positive correlation was found between B_{comm} and January–July precipitation in both sites after removing the four extraordinarily wet years (1990, 1991, 1992 and1998). For site A (black dots) $r^2 = 0.49$, $P < 0.001$, $n = 19$; for site B (open circles) $r^2 = 0.35$, $P < 0.01$, $n = 19$.





- **ecosystem stability increases progressively along the hierarchy of organizational levels (that is, from species to functional group to whole community);**
- **community-level stability seems to arise from compensatory interactions among major components at both species and functional group levels.**

Case study 2

Title:

- **Positive Linear Relationship between Productivity and Diversity Dominates Inner Mongolia Grasslands**

-Bai et al. 2007. Journal of Applied Ecology (in press)

Problems

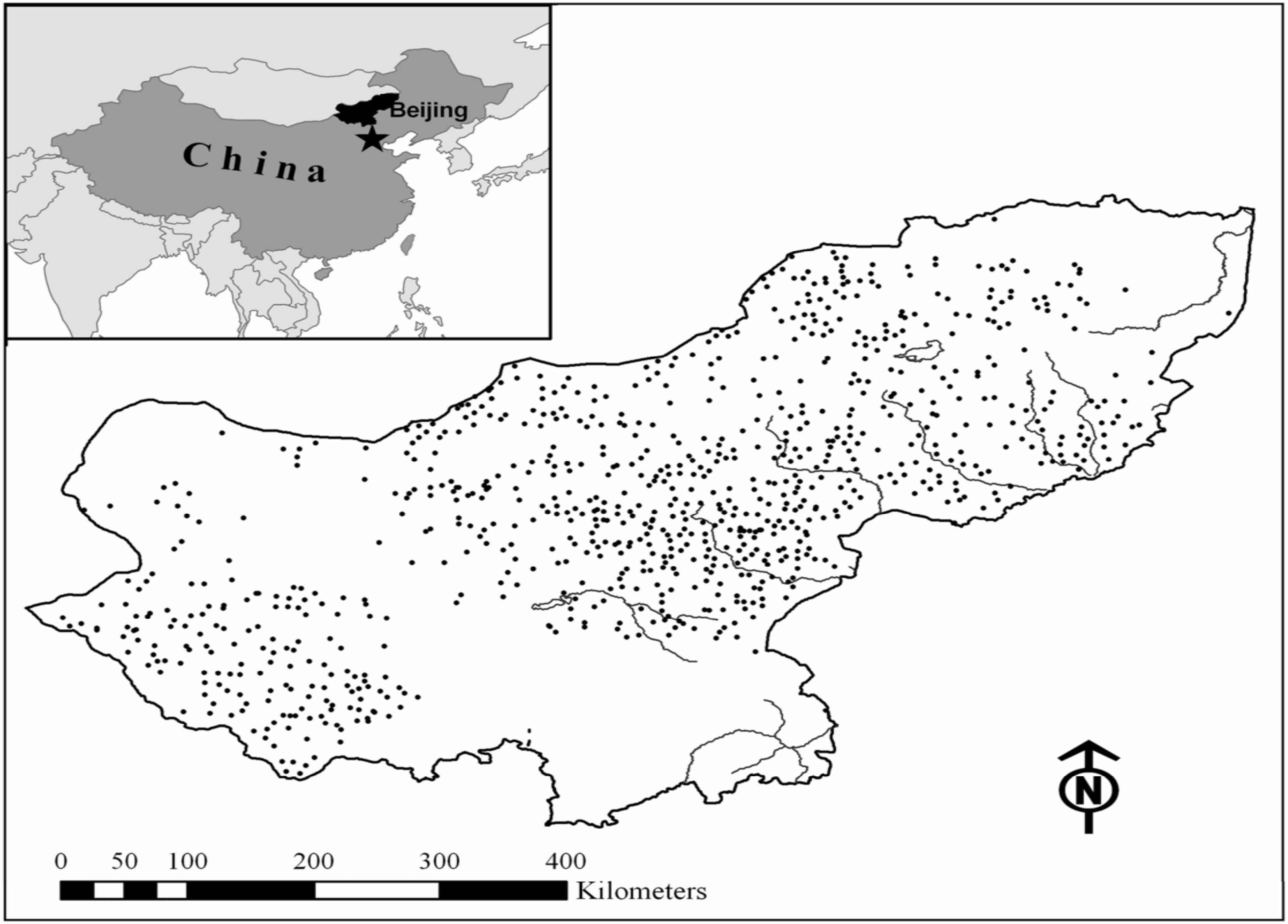
Understanding the productivity-diversity relationship (PDR) is a key issue in biodiversity-ecosystem functioning research, and has important implications for ecosystem management. Most studies have supported the predominance of a hump-shaped form of PDR in which species richness peaks at an intermediate level of productivity. However, this view has been recently challenged on several grounds.

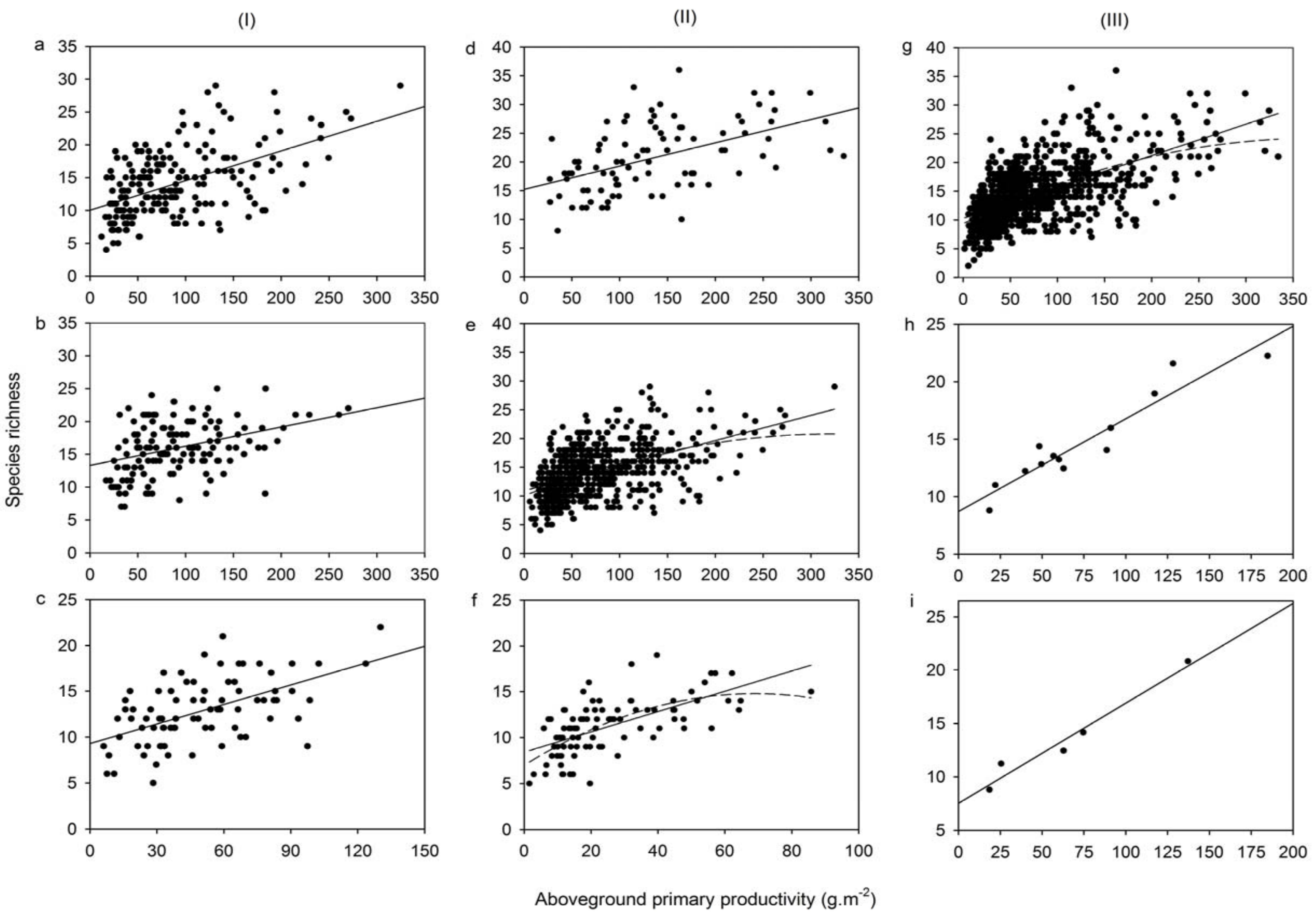
We examined the form of PDR and explored possible controlling factors based on data from 854 field sites in the Inner Mongolia Grassland of the Eurasian Steppe, following a hierarchical approach that explicitly integrates organizational levels (association type, vegetation type, and biome) with spatial scales (local, landscape, and regional).

We wanted to ask:

- First, how does plant species richness respond to variations in productivity at different organizational levels and across spatial scales?
- Second, how does grazing affect the form of PDR?
- Third, what are the underlying processes responsible for the observed forms of PDR, particularly, in terms of abiotic factors and changes in species composition along the environmental gradient?

Materials and Methods





Association type

(Local scale)

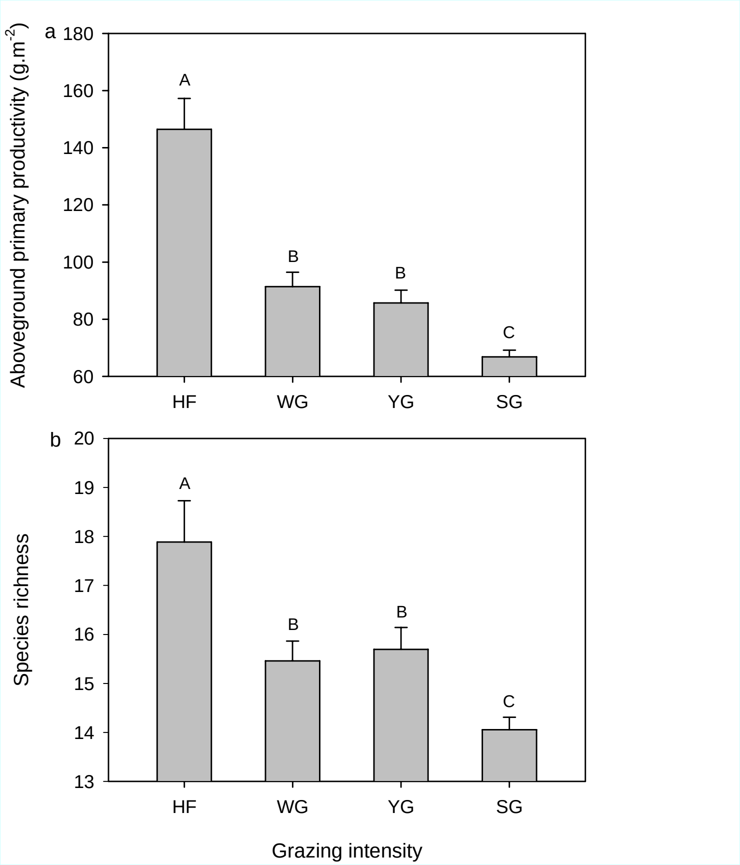
Vegetation type

(Landscape scale)

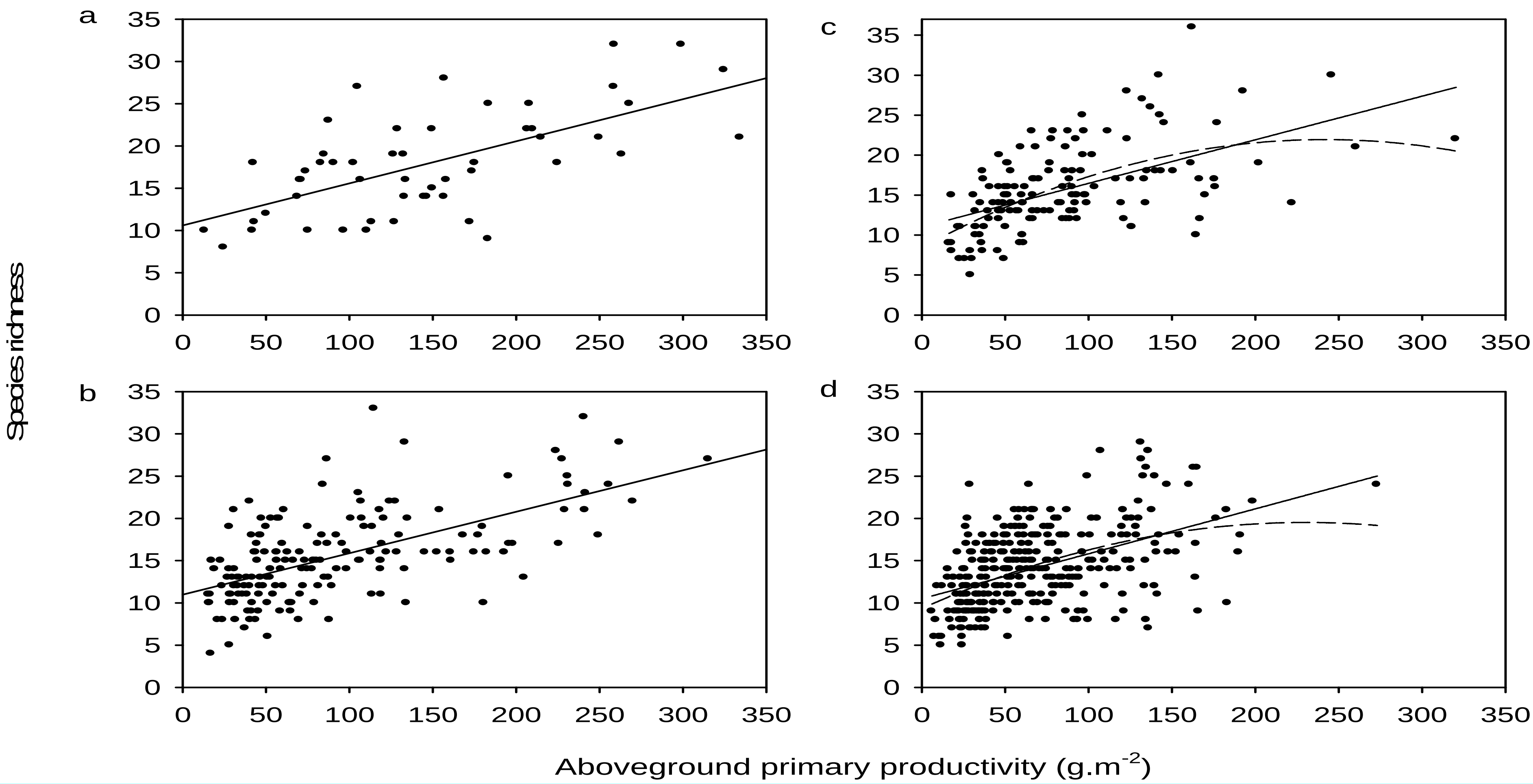
Biome

(Regional scale)

The effect of grazing intensity on species richness and productivity



- HF: Hay field
- WG: Winter grazing
- YG: Year-round grazing
- SG: Summer grazing

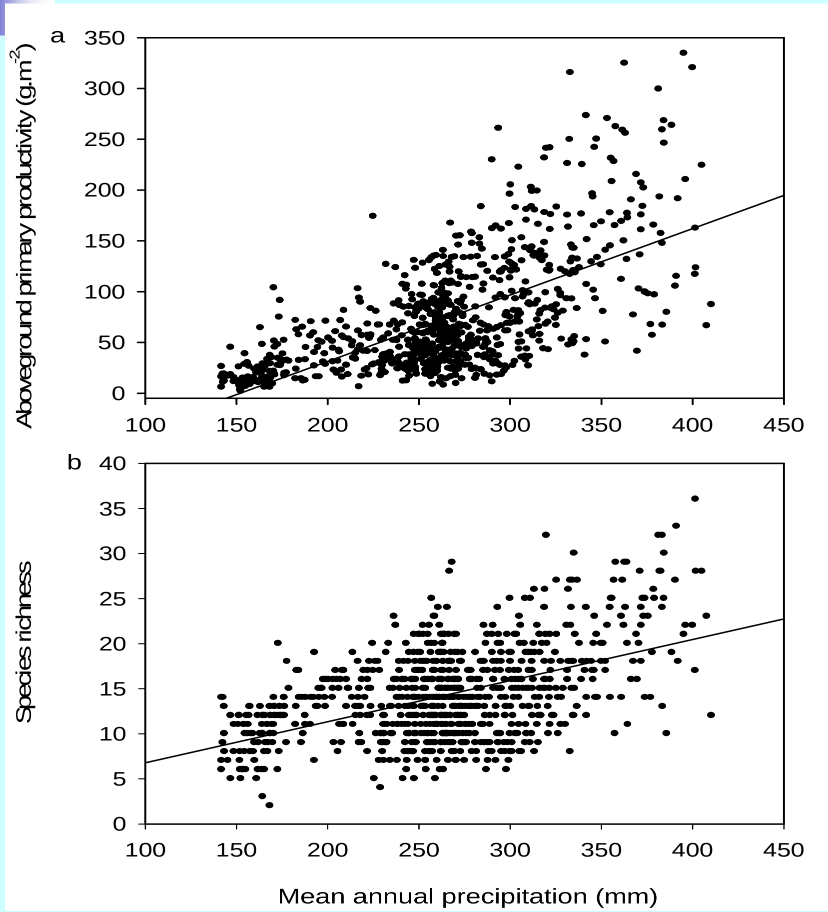


The effect of grazing on species richness/productivity relationship

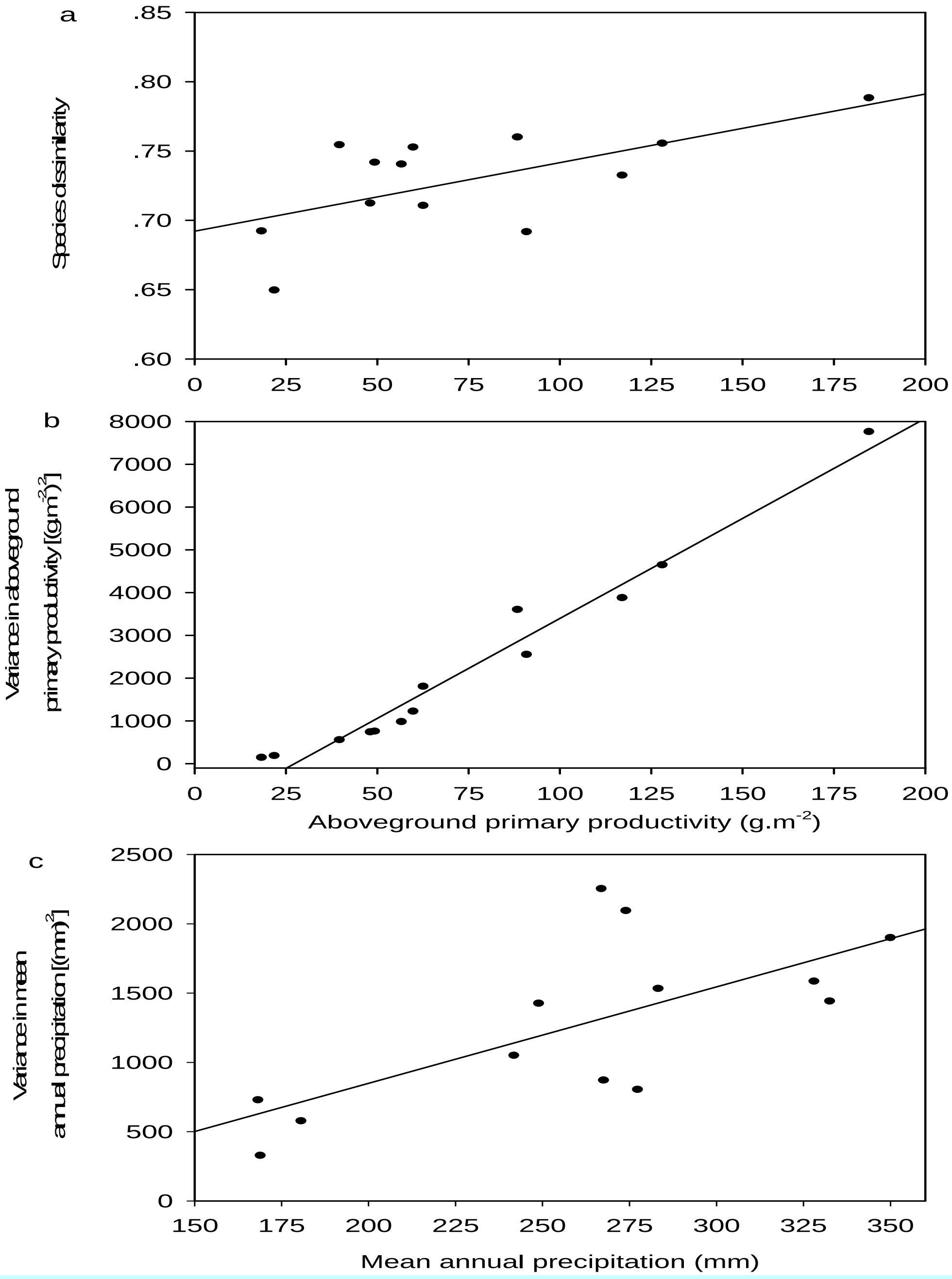
A: Hayfield B: Winter grazing

C: Year-round grazing D: Summer grazing

Species richness and productivity as functions of mean annual precipitation



- MAP affects both ANPP and species richness
- MAP affects ANPP more than species richness



- ANPP affects both species dissimilarity and variance of ANPP
- Higher MAP coincides with greater precipitation variability

Synthesis and applications

This study provides the first direct test of the productivity-diversity relationship for the world's largest contiguous terrestrial biome – the Eurasian Steppe. The predominance of a positive linear relationship in this region defies the commonly-held view that a unimodal PDR dominates terrestrial ecosystems, supported mainly by studies in Africa, Europe, and North America. This difference in PDR may be reflective of the overwhelming effect of precipitation on species diversity and productivity in the Eurasian Steppe. Also, the positive linear relationship is surprisingly robust to grazing. Our results not only shed new light on the productivity-diversity relationship, but also have implications for restoring degraded lands, improving ecosystem management, and understanding ecological consequences of climate change in the Eurasian Steppe.

Case study 3

Title:

Spatiotemporal Patterns of EcosystemPrimary Production and Rain Use Efficiency in Response to Precipitation Variability in the Mongolian Plateau

-Bai et al. 2007. Submitted to Ecology

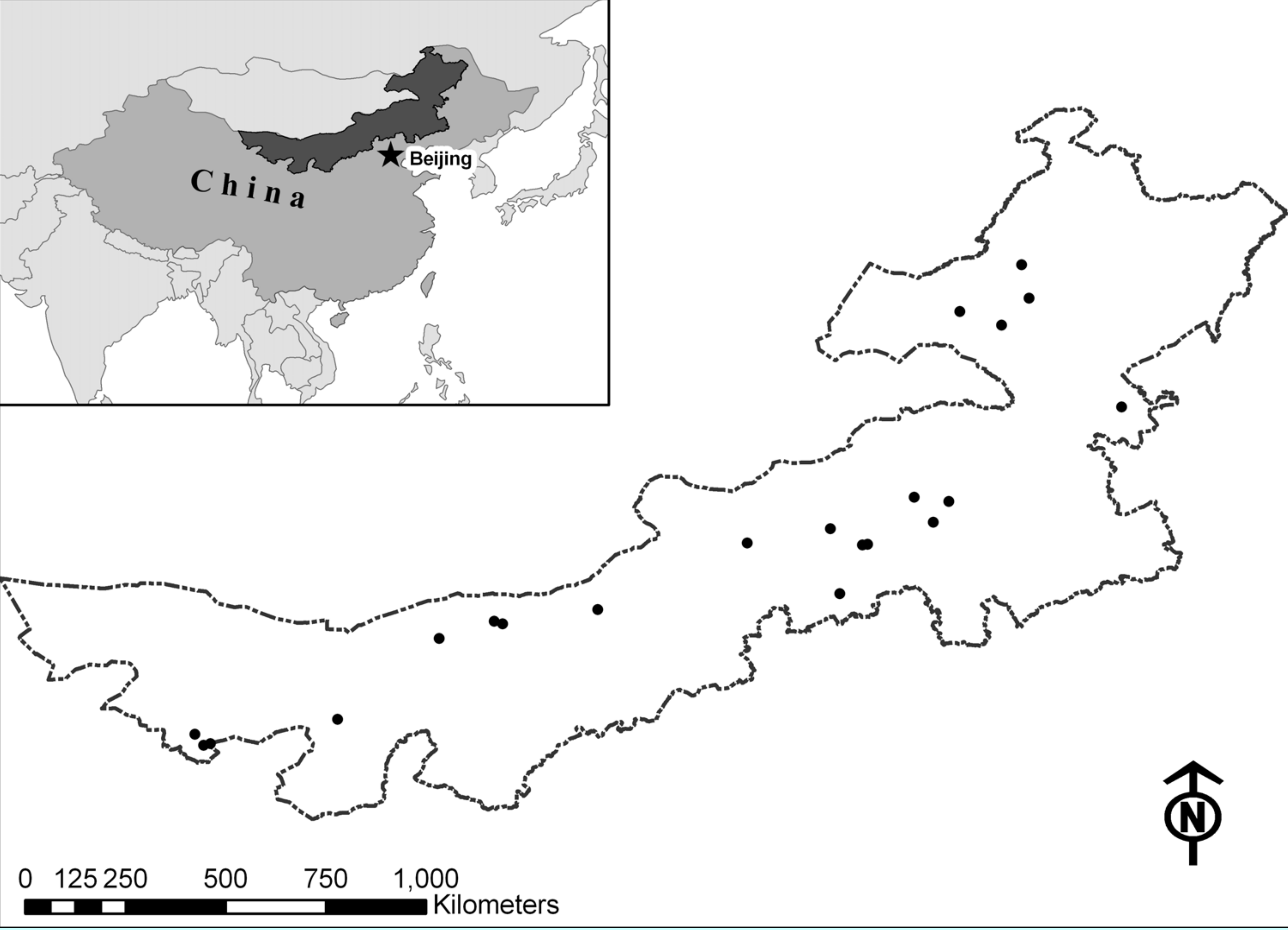
Problems

Understanding how the aboveground net primary production (ANPP) of drylands (47% of the earth's land surface) responds to variations in precipitation is crucial for assessing the impacts of climate change on terrestrial ecosystems. Rain use efficiency (RUE) is an important measure for acquiring this understanding. However, little is known about the response pattern of RUE for the extensive drylands on the Eurasian continent.

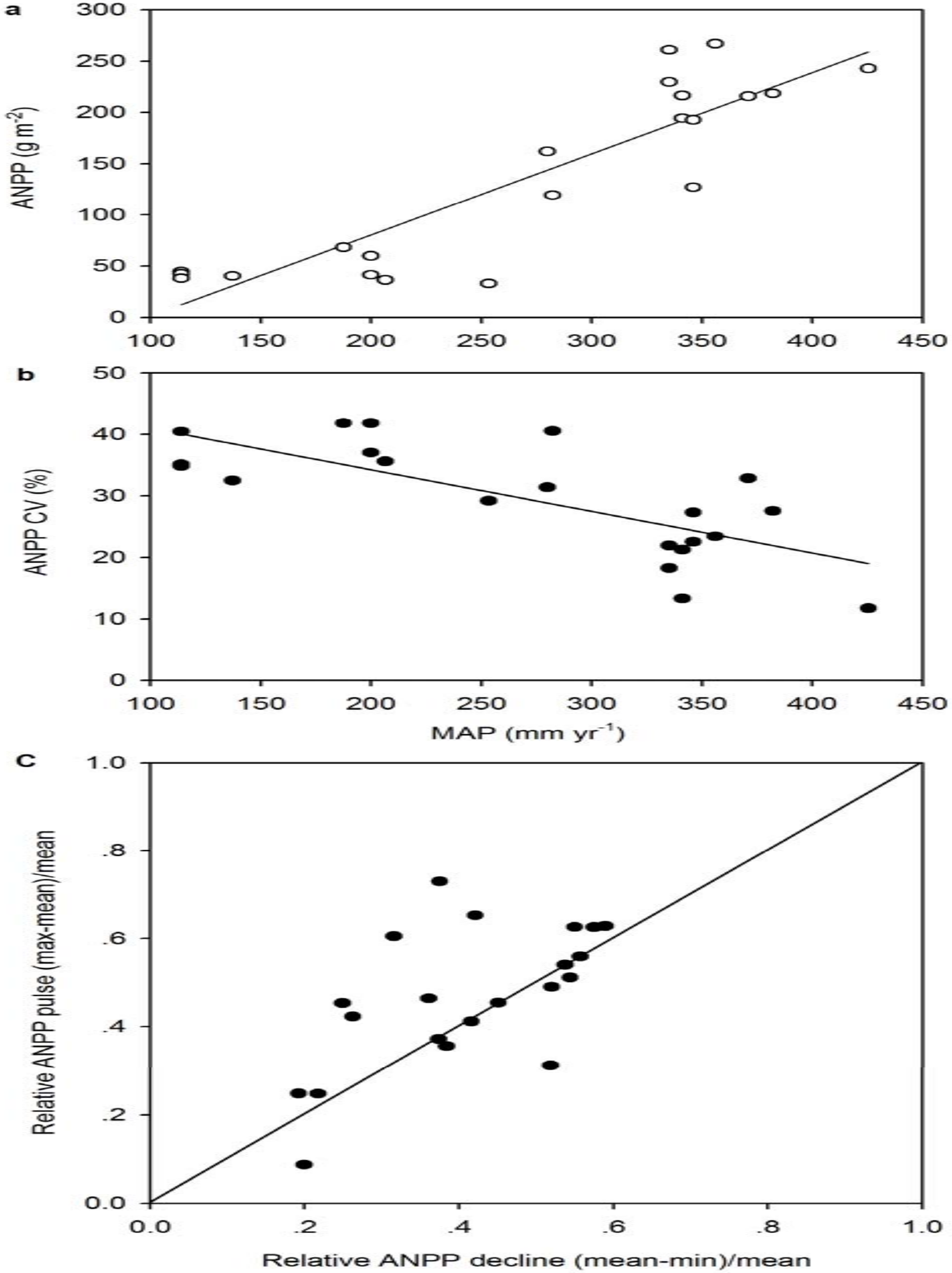
We investigate the spatial and temporal patterns of ANPP and RUE and their key driving factors based on a long-term dataset from 21 natural arid and semiarid ecosystem sites across the Inner Mongolia region, China.

We wanted to ask:

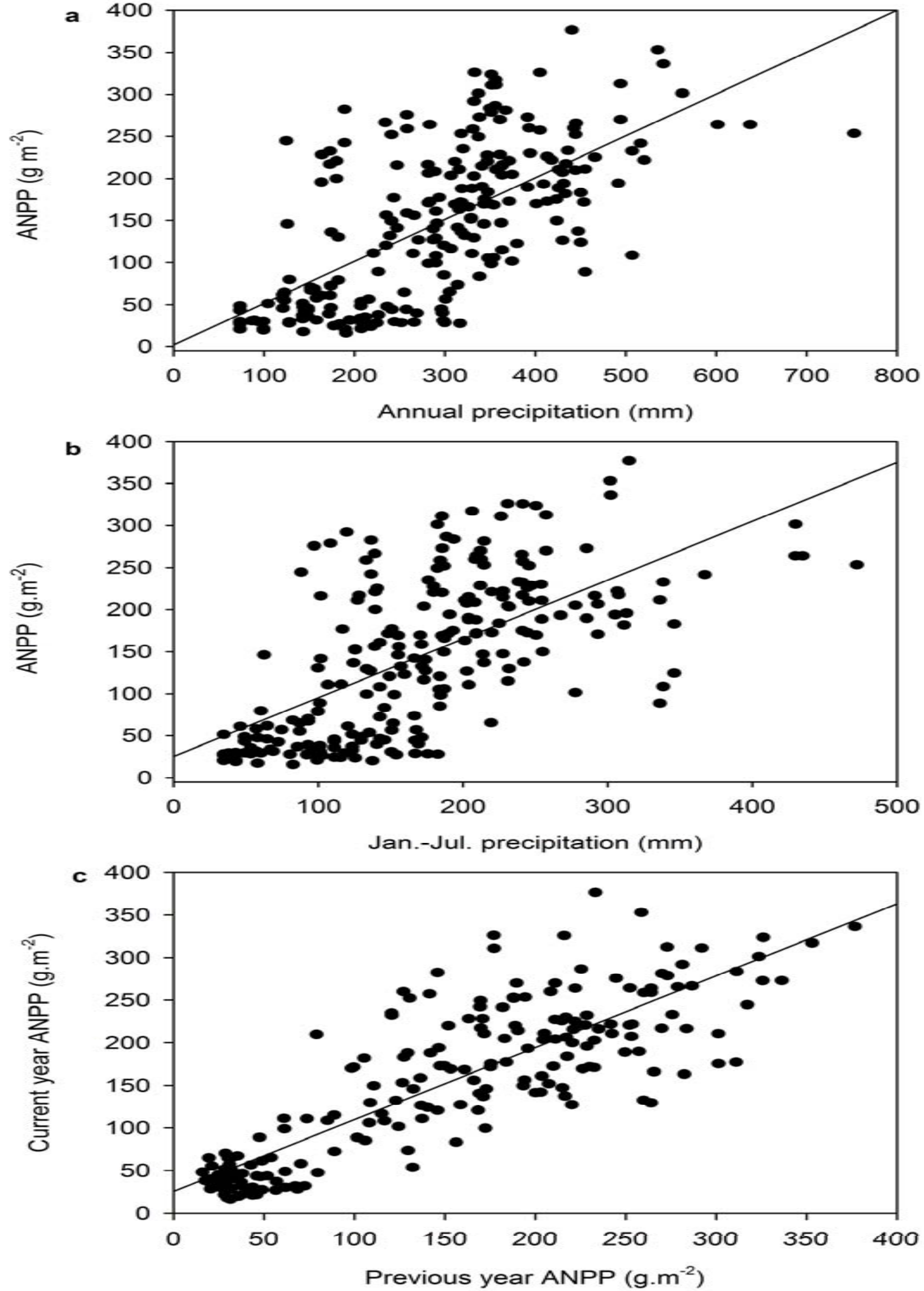
- First, how do ANPP and RUE change along a MAP gradient across arid and semiarid grassland ecosystems?
- Second, how do ANPP and RUE respond to temporal variation in precipitation and N addition?
- Third, how do these patterns, processes, and their key driving factors compare with those found in other parts of the world?



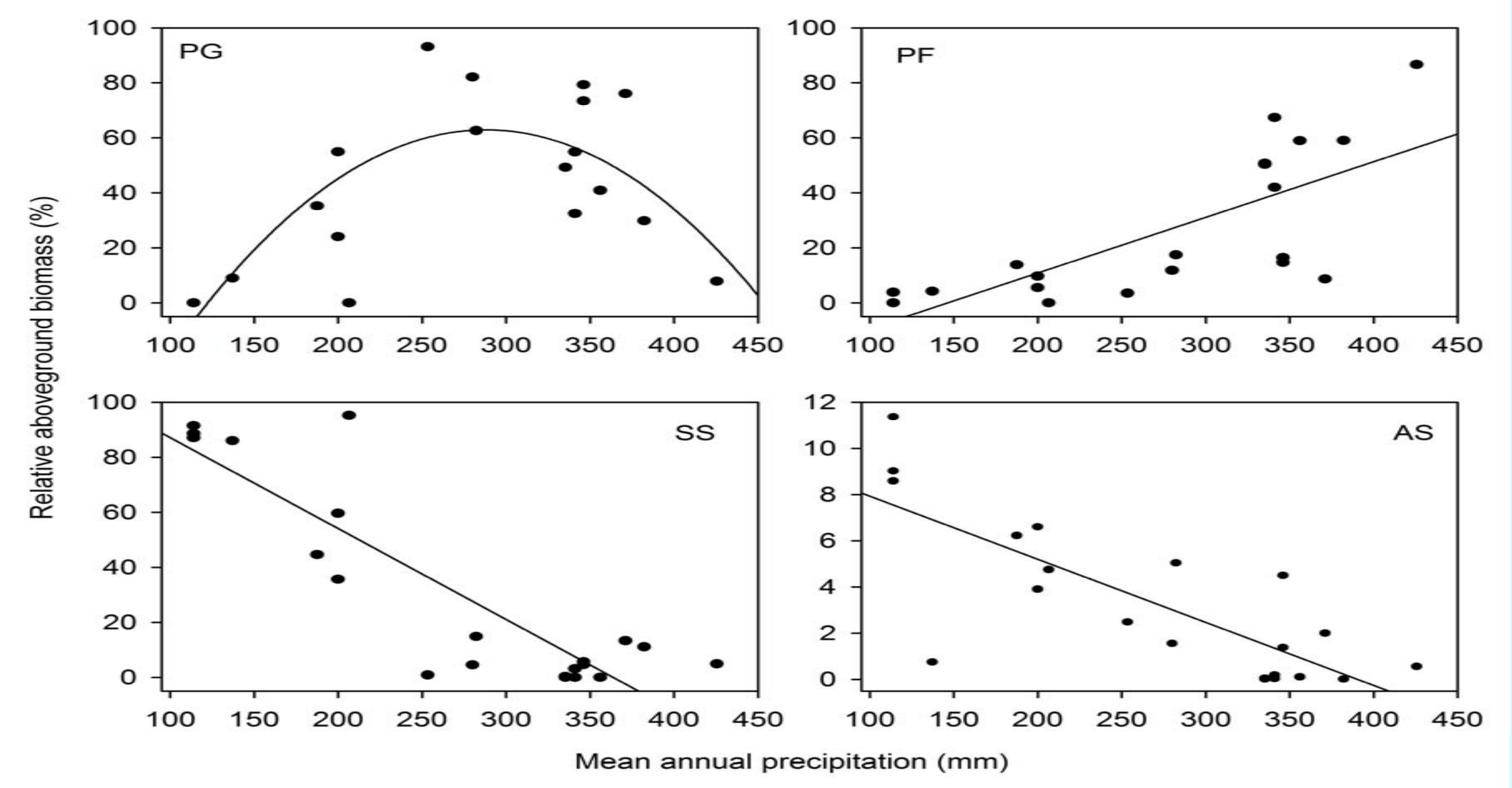
Beijing
China
N
0
125
250
500
750
1,000
Kilometers



- ANPP increases with MAP
- ANPP CV decreases with MAP
- Relative ANPP pulse and relative ANPP decline



- The effects of annual precipitation and January-July precipitation on ANPP
- Previous year ANPP vs. current year ANPP



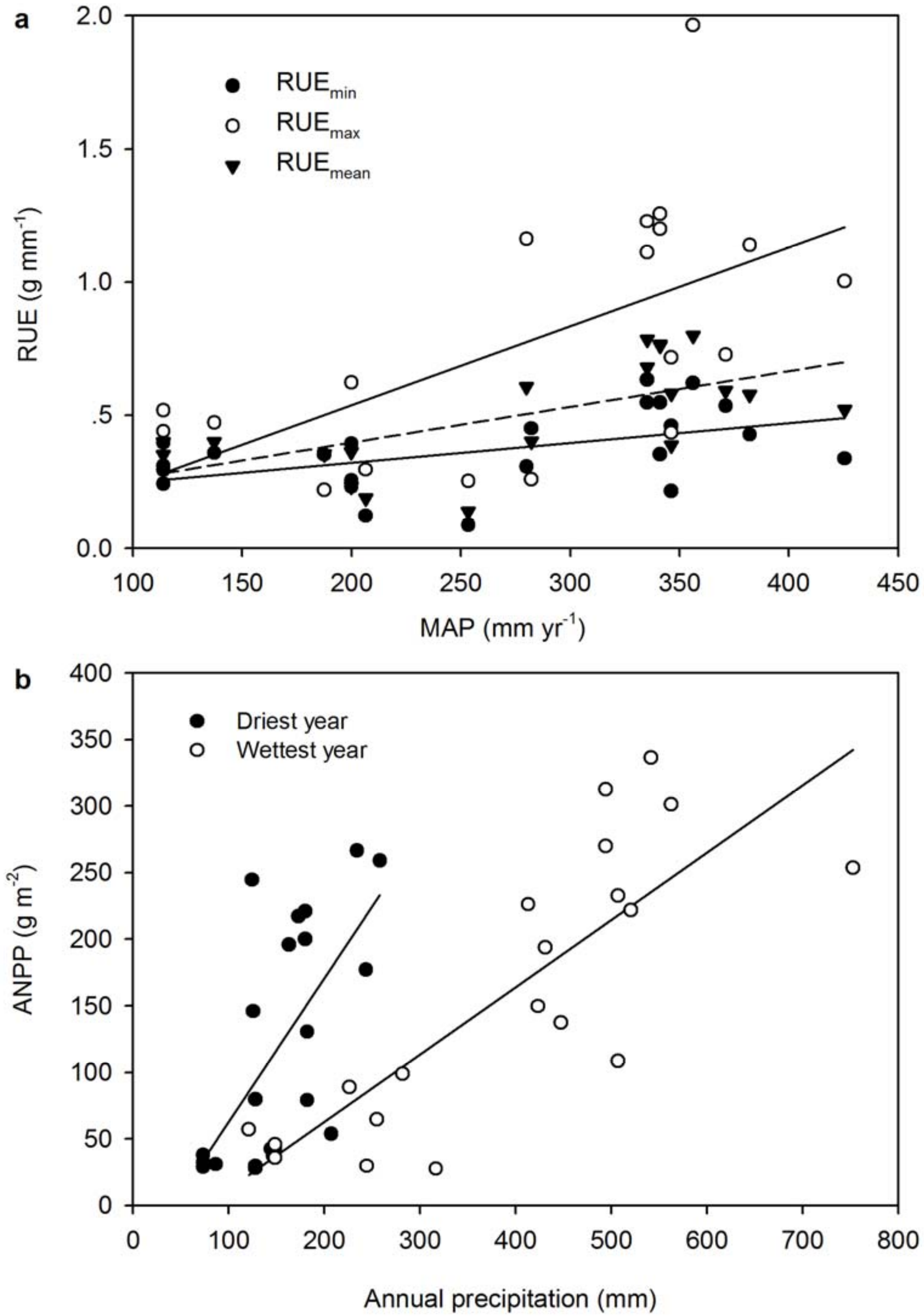
The effect of MAP on relative aboveground biomass of different functional groups

PG: perennial grasses

PF: Perennial forbs

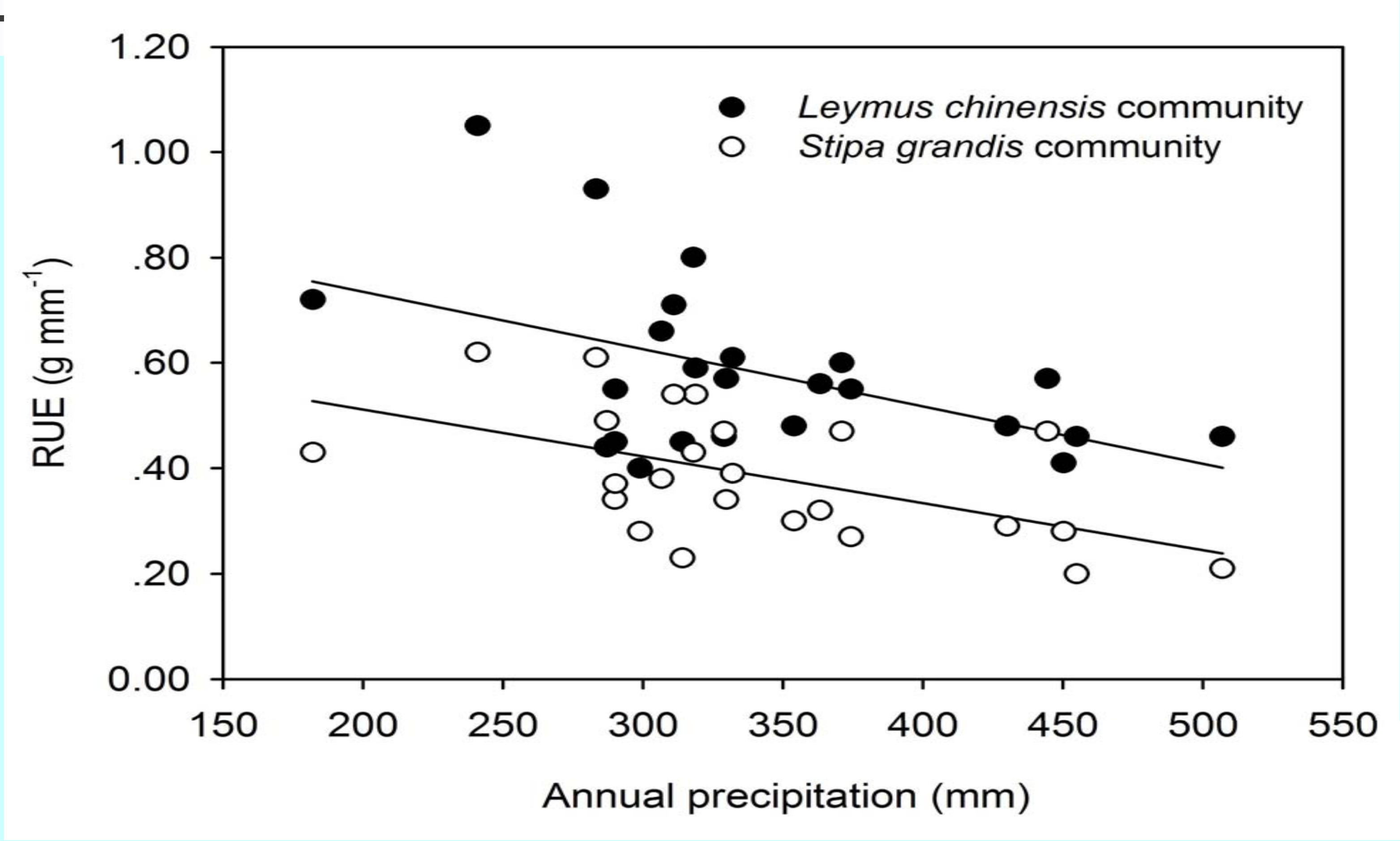
SS: Semishrubs

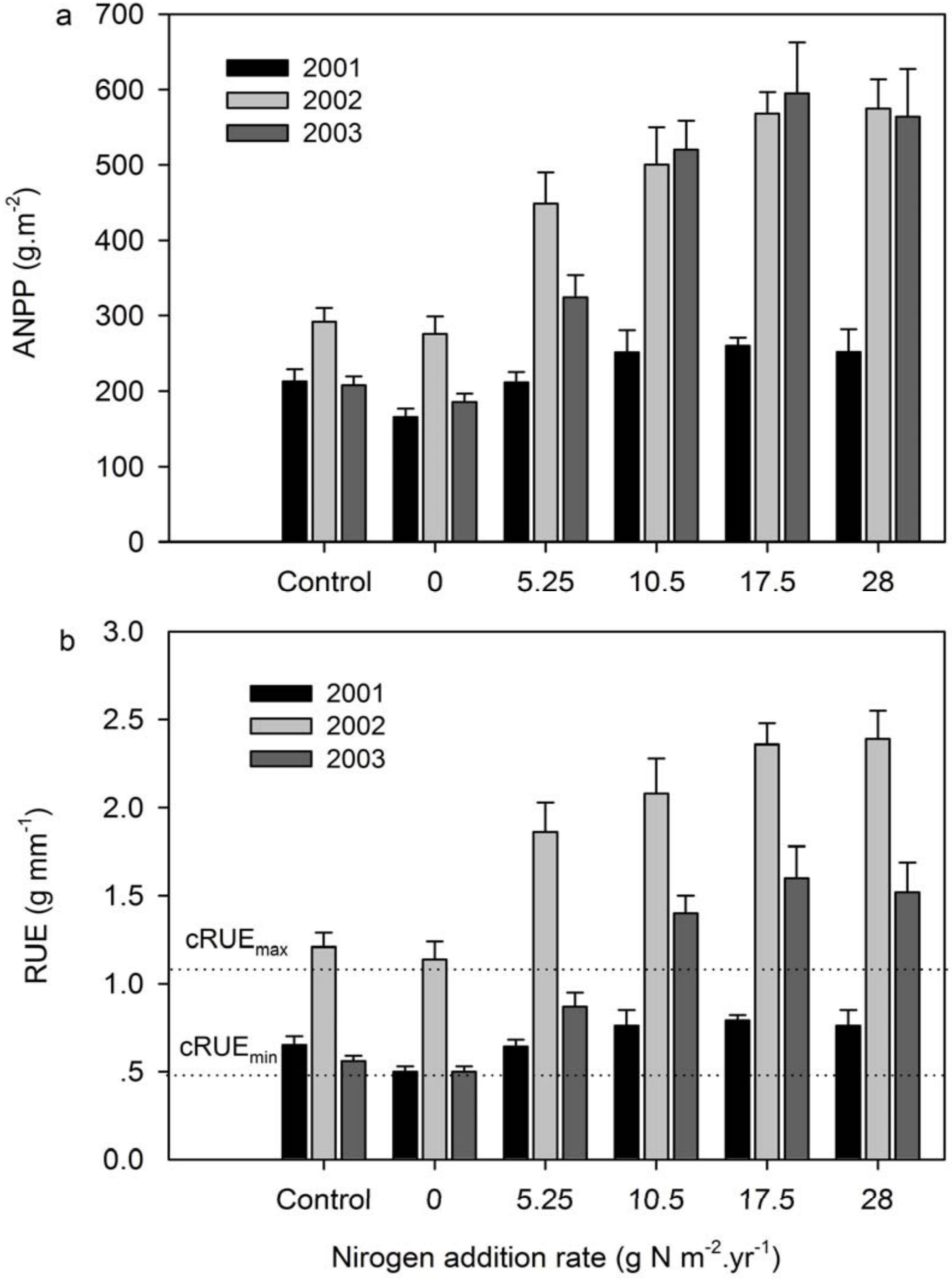
AS: Annuals



- RUE as a function of MAP
- ANPP responded differentially in the driest years and wettest years

RUE as a function of annual precipitation on a local scale





- N addition increases both ANPP and RUE
- RUE can be greatly augmented by changing resource availability in wetter years

Synthesis and applications

1. At the regional scale, ANPP increased with total N concentration in topsoil, species richness, mean January-July precipitation, and variability in annual precipitation along the transect, together accounting for 96% of the variation in ANPP
2. The interannual variability of ANPP (CVANPP) decreased with increasing species richness, mean January-July precipitation, and relative precipitation minima, but increased with increasing relative precipitation maxima.
3. Changes in plant functional group composition also have significant effects on ANPP and CVANPP along the precipitation gradient. ANPP increased whereas CVANPP declined, with increasing relative biomass of perennial forbs.
4. With increasing annual precipitation, RUE increased in space across different ecosystems, but decreased in time for a given ecosystem. These seemingly conflicting patterns of RUE in space versus time may be due largely to interactions between precipitation and soil N.
5. Although our results support the existence of a common maximum RUE, we found that this value could be substantially increased by altering resource availability, such as by N addition.

Case study 4

Title:

Ecosystem Complexity Regulates Metabolic Scaling Components in Natural Grassland Communities

-Wang et al. 2007. In preparation

Problems

1. There has been a great interest in the Metabolic Theory in ecology. However, there has been debate about this theory, and questioned the validity of the constancy of the scaling exponent law when it is actually applied to different organisms belonging to different taxa.

2. Most of published literature has been focused on theoretical development of the theory, and are focused on individual species at the population level or the entire community level

3. There is a great dearth of information on studies that tested the metabolic theory in both terrestrial ecosystems based on data consisting of plant species across large spatial and temporal scales.

4. Moreover, studies on allometric relationships for terrestrial plants have been rarely involved with changes of scaling components with changing hierarchical levels of the community organization, e.g. from species to functional groups to the whole community.

Here we presented a theoretic framework of the allometric relationships that included metabolic rates of all plant species at the species, functional group and the community levels. This theory is further tested using data from two dominant Inner Mongolia grassland ecosystems. Our data set included biomass data of over 75% of the total plant species measured for 27 years.

We wanted to ask:

- How the scaling components operate at different hierachical levels of the community.
- What are the relationships between biodiversity (both species richness and abundance) and scaling components.
- Will this relationship change with community properties.
- What are the roles that minor species and major species play in affecting the community metabolism.

Basic principle

Jesson inequation

$$\frac{1}{n}\sum_{k=1}^{n} f(x_k) \le f\left(\frac{1}{n}\sum_{k=1}^{n} x_k\right) \quad \left(f''(x) \le 0 \right)$$

Individual level

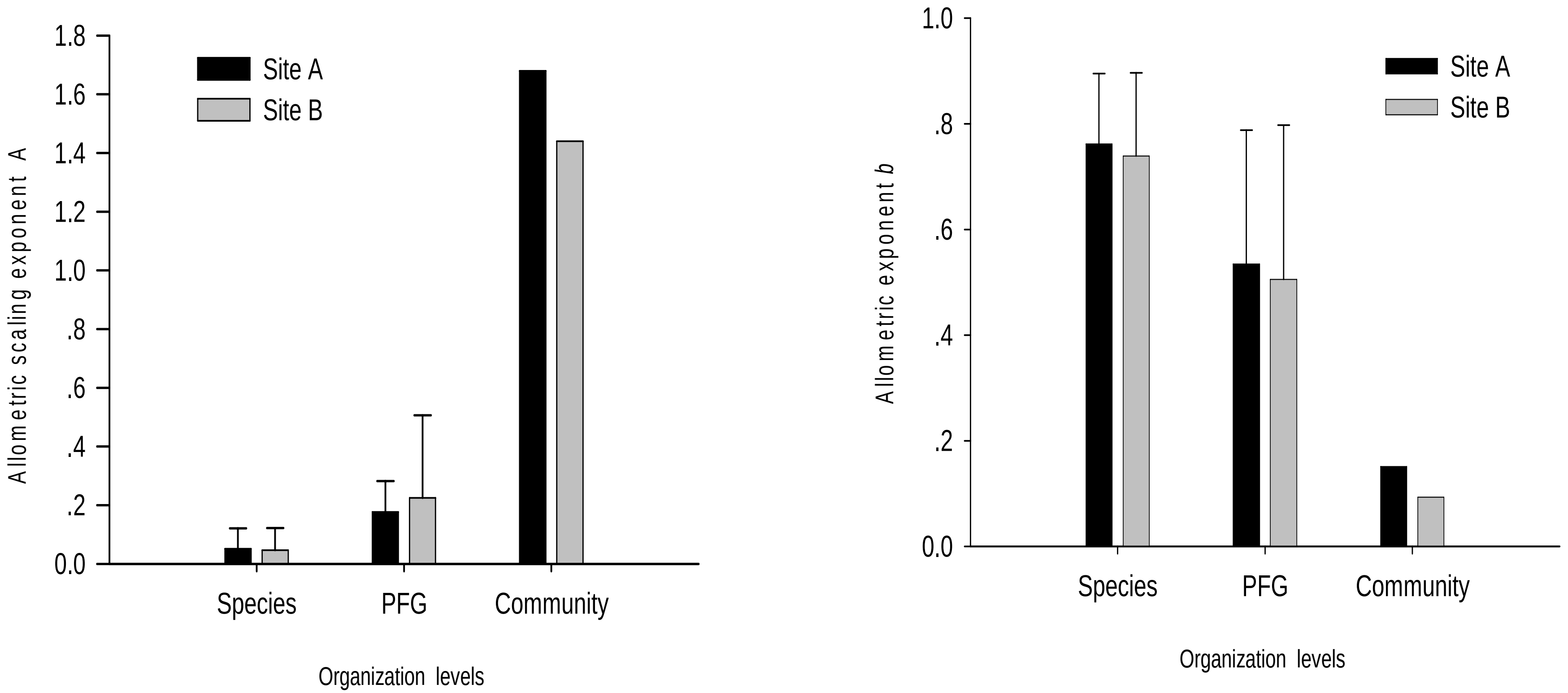
The metabolic rate of individual can be describe by the allometric equation

$$f(m) = am^b \quad (0 \le b \le 1, f''(m) \le 0)$$

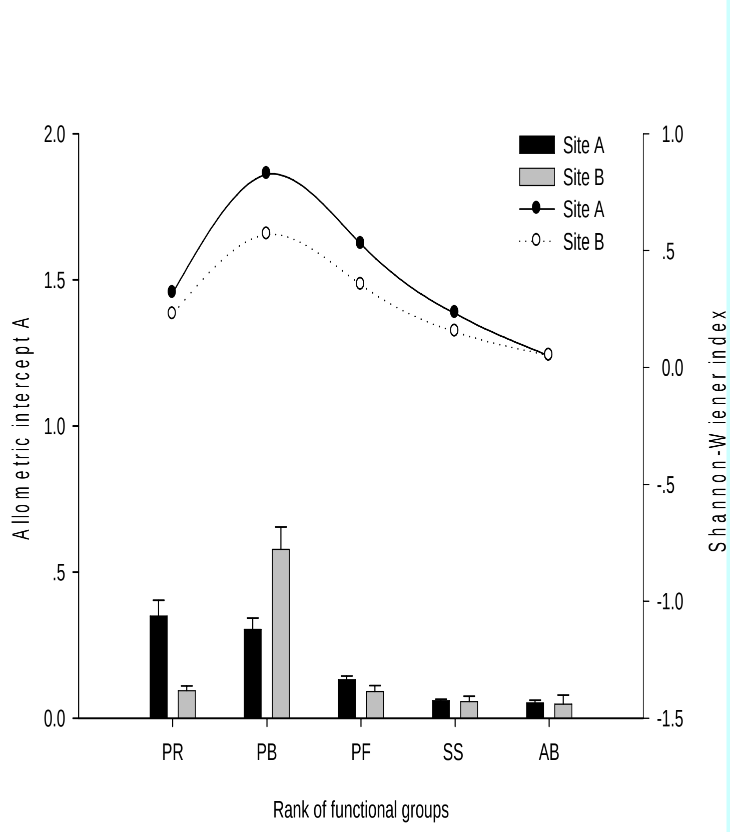
Allometric components at different organizational levels

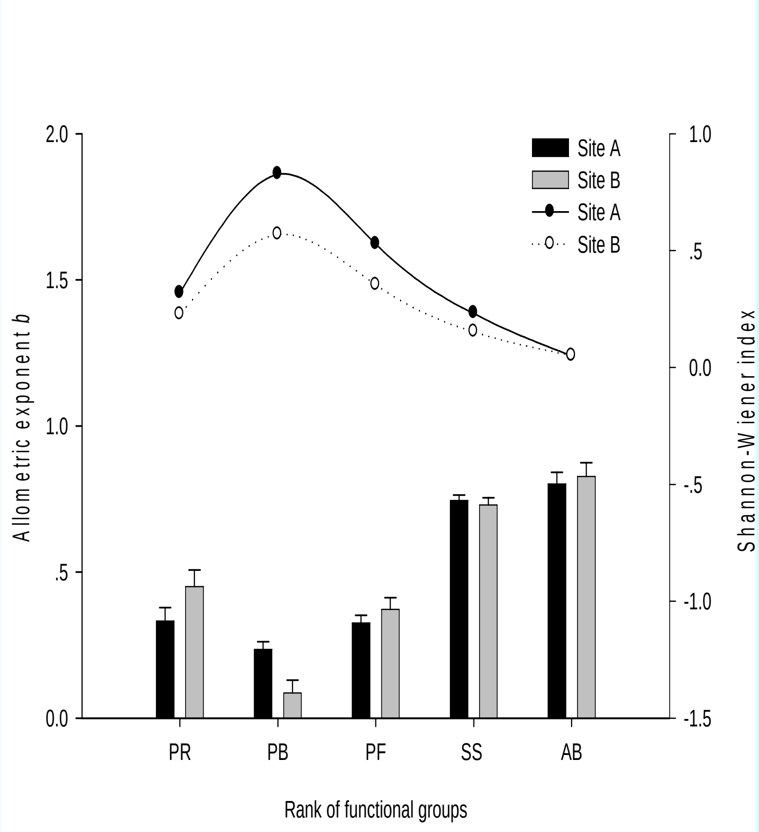
Organization level	Individual	Population	Functional group	Community
Intercept	a	aj^{1-b}	$a_q j_q^{1-b}(m+n)^{1-b-\delta_q}$	$a_{q_u} j_{q_u}^{1-b}(m+n)^{1-b-\delta_{q_u}}(r+s)^{1-b-\delta_{q_u}-\varepsilon_u}$
Scaling exponent	b	$b \pm \delta$	$b+\delta_q \pm \varepsilon$	$b+\delta_{q_u}+\varepsilon_u \pm \theta$

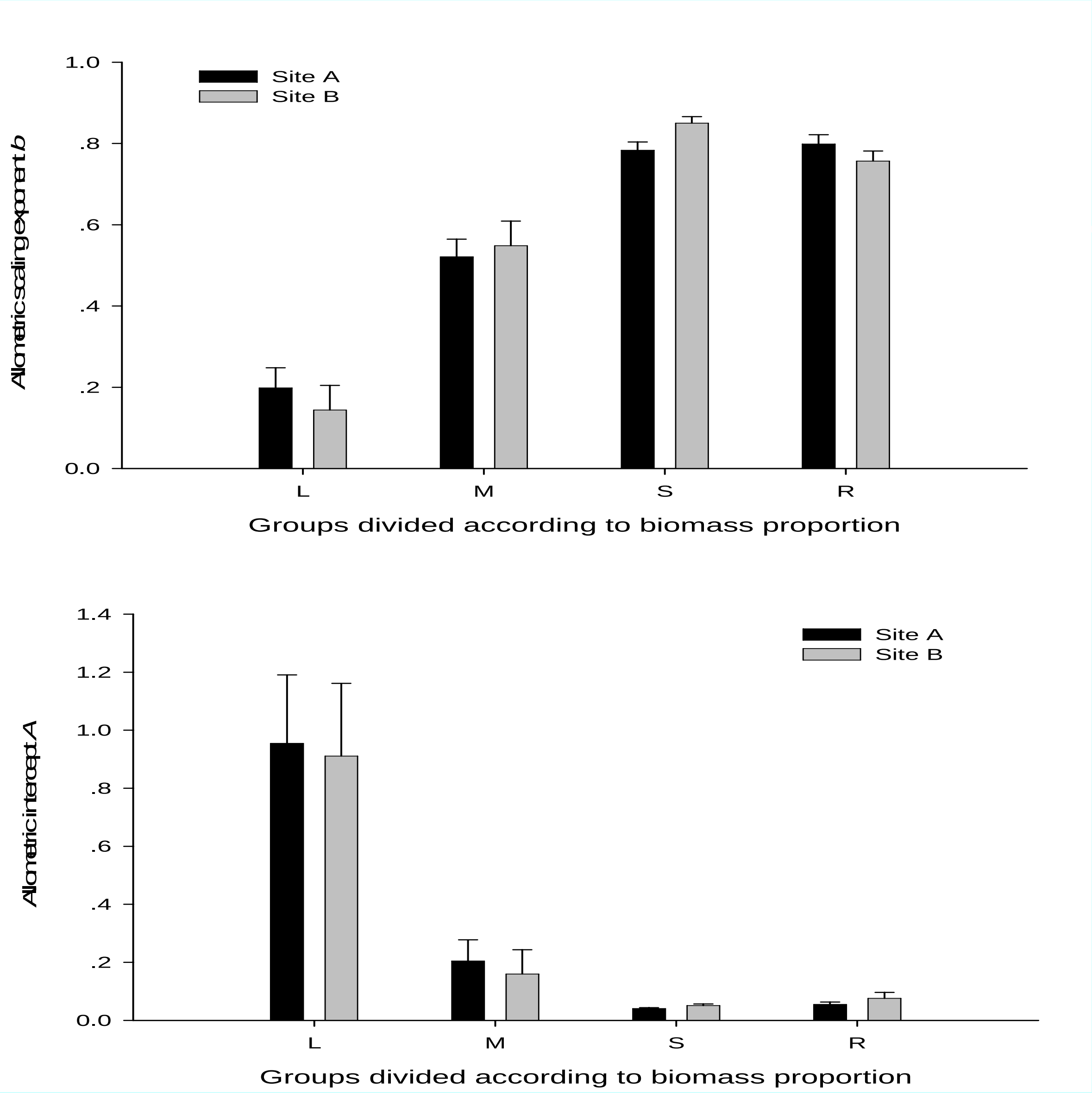
Allometric exponents at different organizational levels



The effect of biodiversity on allometric intercept and allometric exponents







1.0
.8
.6
.4
.2
0.0
Site A
Site B
Allometric scaling exponent b
L
M
S
R
Groups divided according to biomass proportion
1.4
1.2
1.0
.8
.6
.4
.2
0.0
Site A
Site B
Allometric intercept A
L
M
S
R
Groups divided according to biomass proportion

Conclusions

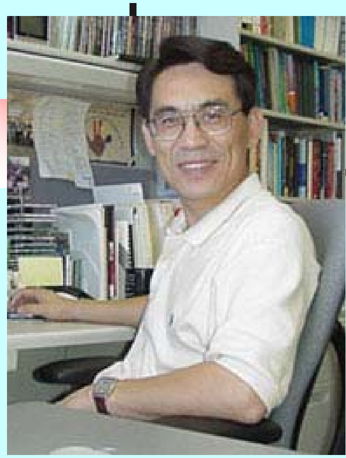
1. From the individual level to community level, the allometric exponent A is decreasing while the allometric exponent B is increasing.

2. The compensating effects exist on different organizational levels. The allometric components are correlative with the community diversity.

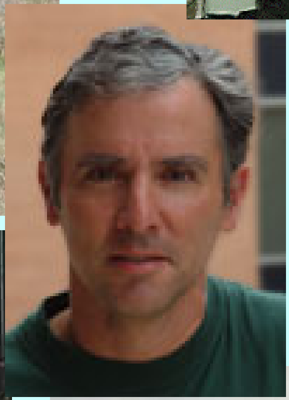
Current research activities

- ➢Sino-German： Matter flux as affected by stocking rate
- ➢Sino-US: The effect of land use change on matter fluxes in Inner Mongolia (NASA Project)
- ➢Sino-US： BEF under a stoichiometric framework (NSF Project)

Participants











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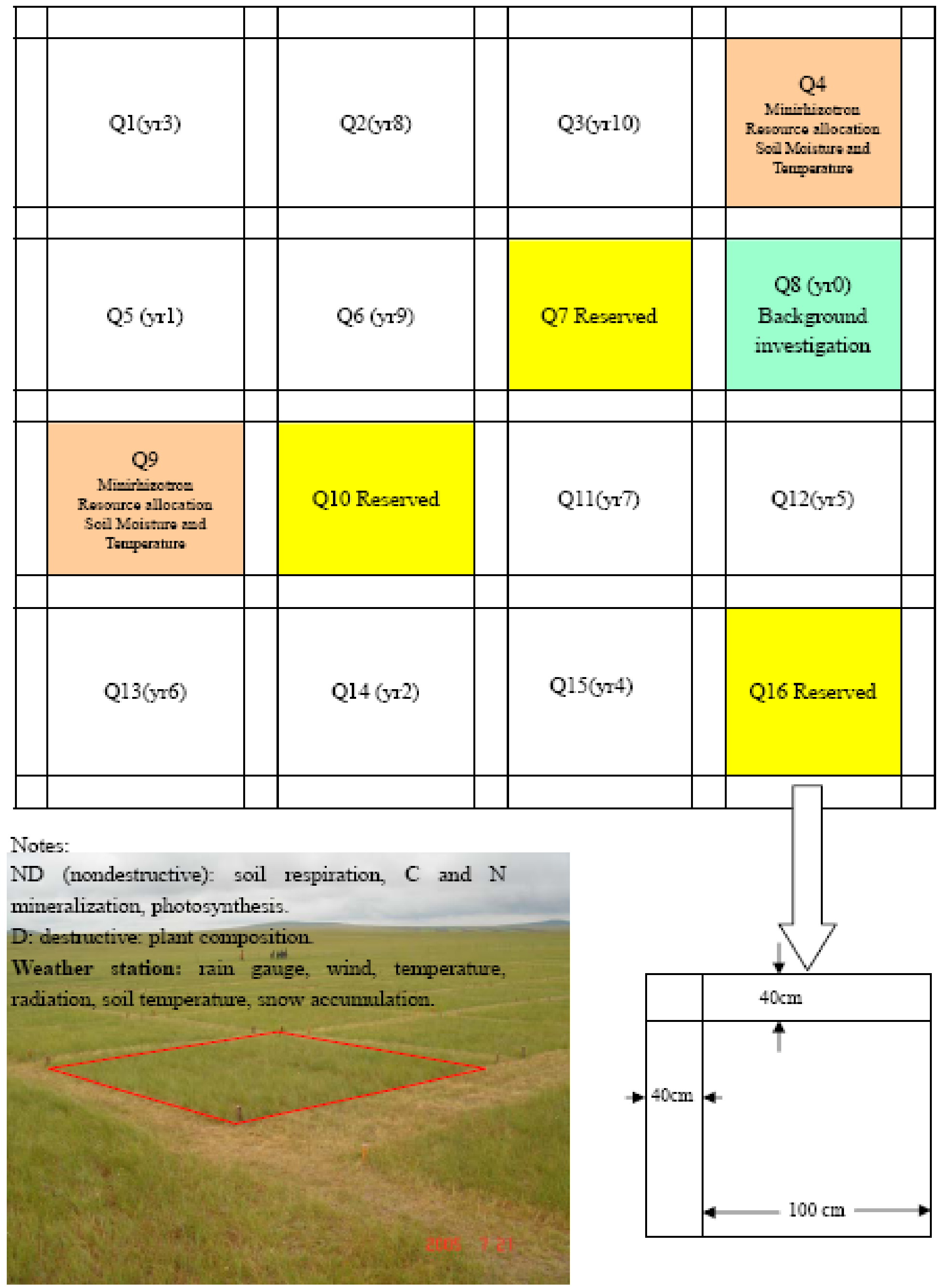
BEF Sampling arrangement for each plot

BEF sampling arrangement for each plot



Response variables and methods (just for reference)

No.	**Response variables**	**Method proposed**	**Responsibility**
1	Microclimate	Micromet stations	Manager
2	Soil moisture	TDR/neutron probe	Manager
3	Soil C and N(DOC/N, fractionation, …...)	Soil cores/lab assays	Huang
4	N availability/mineralization	Resin bags/soil extractions	Huang
5	Soil CO2 efflux	Field chambers/LiCOR IRGA/GC	Wan/Wang Zhiping
6	Microbial biomass/respiration	Fumigation-extraction/	Wang Qibing
7	Microbial community structure	PLFA/Biolog	Wang Qibing
8	Root growth and turnover	Minirhizotron/soil cores/ingrowth cores	Wang Qibing
9	Root biomass and nutrients	Soil cores	Wang Qibing
10	Aboveground NPP	Harvest method	Bai
11	Plant species composition	Quadrat/Canopy coverage	Bai
12	Grass/forb gas exchange	LiCOR 6400 IRGA	Jiang
13	Plant water status	Pressure chamber	Jiang
14	Plant tissue C/N and NUE	C/N analyzer	Han Xingguo
15	Dry and wet deposition	Foss autoanalyzer	Manager
16	Litter decomposition	Litterbags	Huang
17	Resource allocation		Pan
18	soil fauna		Han Xingguo/Xu
19	Trace gases	static chamber/GC	Wan/Wang Zhiping
20	Shrub pattern		Bai/Lin Yan

Response variables and methods (just for reference)

No.	**Response variables**	**Method proposed**	**Responsibility**
21	Phenology		Technician
22	Seed rain/bank		He Nianpeng
23	Isotope		Lin Guanghui
24	NEE		Han Xingguo
25	Clonal integration/plasticity		Yu Feihai
26	N fixation		Han Xingguo
27	soil biological crust		Han Xingguo
28	C/N cycle modelling		Sun Jianxin
29	Mycorhiza		Liang Yu/Guo Liangdong
30			
31	grasshopper		Kang Le/Hao Shuguang
32	Plant-animal interaction		
33			
34			
35			
36			
37			
38			

The research site for BEF

Inner Mongolia Grassland Fire Experiment (IMGFE)

Biogeochemistry Research Group

Institute of Botany, IBCAS

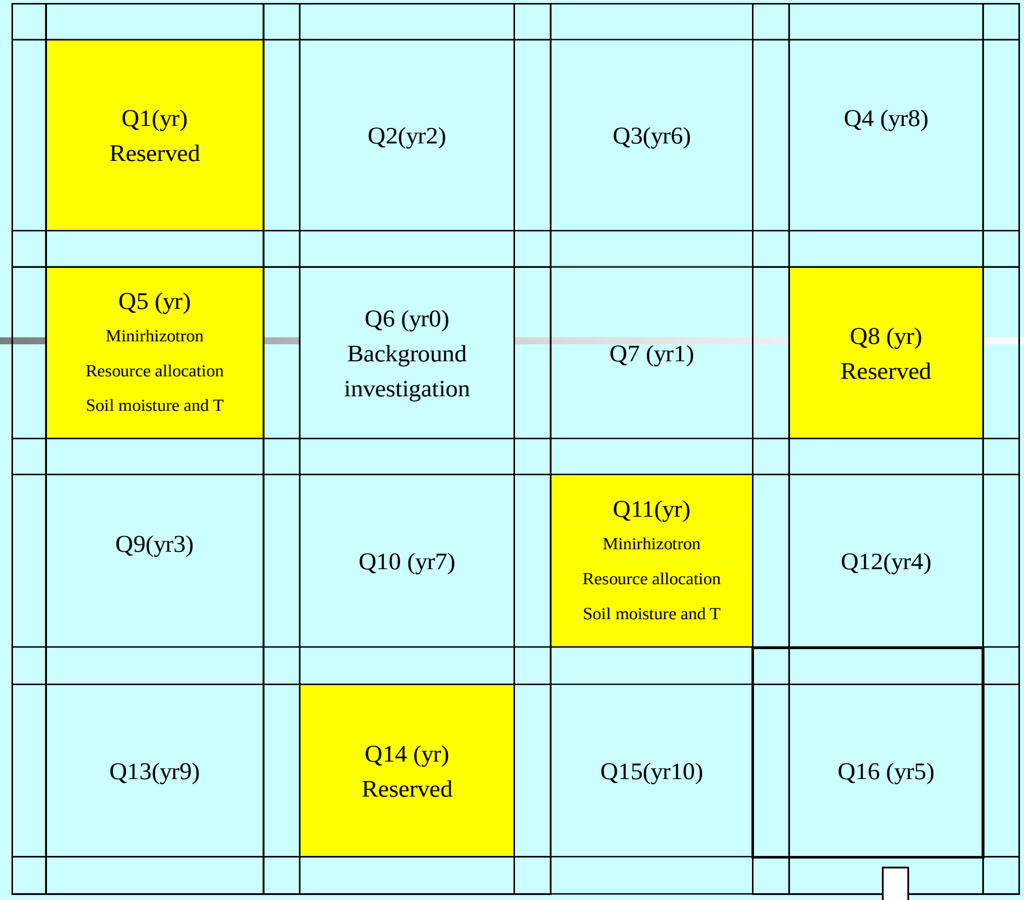
Introduction

- Fire frequency: once every 3-5 yr till mid1980s
- Fire missed for 20+ yr
- Shrub encroachment both in the degraded grassland and matured grassland

The research site of GFE

Experiment Design

	Treatment	Replicates
Fire Frequency （F）		
1	No Burning (Control)	9
2	Burning Once Every Year (0 yr Interval)	9
3	Burning Once Every Two Years (1 yr Interval)	9
4	Burning Once Every Four Years (3 yr Interval)	9
5	Burning Once Every Six Years (5 yr Interval)	9
N Addition Rate （N）		
1	No N addition	9
2	5.25 (g $N.m^{-2}.yr^{-1}$)	9
3	17.5 (g $N.m^{-2}.yr^{-1}$)	9
4	28.0 (g $N.m^{-2}.yr^{-1}$)	9
Mowing Frequency （M）		
1	No Mowing	9
2	Mowing Once Every Year (0 yr Rest)	9
3	Mowing One Year + One Year Rest	9
4	Mowing Three Years + One Year Rest	9
Notes：Number of Treatments：5 Fs × 4 Ns × 4 Ms ＝80 Total Plots：810 （10 m × 10 m）		

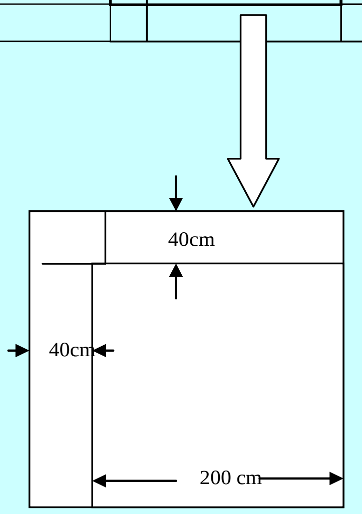


Notes:

ND (nondestructive): soil respiration, C and N mineralization, photosynthesis,

D: destructive: plant composition

Weather station: rain gauge, wind, temperature, radiation, soil temperature.



Sampling arrangement for GEF

样地全景及局部火烧掠影


2006 5 2


2006 5 2

Treatment layout for every block

X01 F1 N28 MC	X02 F2 NC MC	X03 F4 N5 M31	X04 F1 NC M10	X05 FC N1 M31	X06 F1 N17 M10	X07 F6 NC M31	X08 F1 N5 M31	X09 FC N5 MC
X10 F4 N5 M11	X11 TBD	X12 F2 N17 M31	X13 F6 N5 M11	X14 F6 N28 M11	X15 F1 N28 M10	X16 F2 N28 M10	X17 F 2N17 MC	X18 F4 NC M31
X19 FC N17 M11	X20 FC N28 MC	X21 F2 N5 M11	X22 F2 N28 M31	X23 F2 N5 MC	X24 FC N17 M10	X25 F2 N5 M10	X26 F4 N28 MC	X27 F1 N5 MC
X28 F1 N5 M10	X29 F6 NC M10	X30 F2 NC M11	X31 F4 N17 MC	X32 FC NC MC	X33 F2 NC M31	X34 F1 NC M31	X35 F4 NC M11	X36 F2 N17 M11
X37 F6 N17 MC	X38 F2 N17 M10	X39 F6 N5 M10	X40 F6 N5 M31	X41 FC N17 MC	X42 F4 N17 M11	X43 FC N28 M31	X44 F6 N5 MC	X45 F4 N28 M10
X46 F1 N28 M11	X47 F1 N17 M31	X48 FC N5 M31	X49 F1 N17 M11	X50 FC N28 M11	X51 F1 NC MC	X52 F6 N28 M10	X53 F4 N5 MC	X54 F4 N28 M31
X55 F6 N17 M11	X56 F2 N28 MC	X57 F2 N5 M31	X58 F1 N5 M11	X59 FC N5 M11	X60 FC N28 M10	X61 F4 N17 M10	X62 F6 NC M11	X63 F6 NC MC
X64 F4 N1 7M31	X65 F6 N17 M10	X66 F2 NC M10	X67 F6 N28 M31	X68 F2 N28 M11	X69 F4 N28 M11	X70 F1 N17 MC	X71 FC NC M10	X72 F1 NC M11
X73 FC N5 M10	X74 F4 N5 M10	X75 F1 N28 M31	X76 F6 N28 MC	X77 F6 N17 M31	X78 FC NC M11	X79 F4 NC MC	X80 FC NC M31	X81 F4 NC M10

Notes:

X: block#, X = 1, 2, 3, ……, 9;
F*n*: to be burned every *n* yr, *n* = C (0), 1, 2, 4, 6;
N*m*: N addition rate at *m* N g m-2 yr-1; *m* = C(0), 5 (5.25), 17 (17.5), 28 (28.0);
M*l*: Mowing frequency, *l* = control (C), mowing once every year(10), 1 yr mowing + 1 yr rest(11), Mowing 3 yr + 1 yr rest(31).

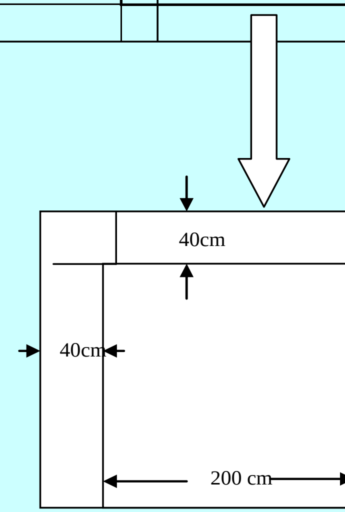
Sampling arrangement for each plot (10m X 10m)

Notes:

ND (nondestructive): soil respiration, C and N mineralization, photosynthesis,

D: destructive: plant composition

Weather station: rain gauge, wind, temperature, radiation, soil temperature.



Response variables and methods (to be cont'd)

No.	Response variables	Method proposed	Responsibility
1	Microclimate	Micromet stations	Manager
2	Soil moisture	TDR/neutron probe	Manager
3	Soil C and N(DOC/N, fractionation, …...)	Soil cores/lab assays	Huang
4	N availability/mineralization	Resin bags/soil extractions	Huang
5	Soil CO2 efflux	Field chambers/LiCOR IRGA/GC	Wan/Wang Zhiping
6	Microbial biomass/respiration	Fumigation-extraction/	Wang Qibing
7	Microbial community structure	PLFA/Biolog	Wang Qibing
8	Root growth and turnover	Minirhizotron/soil cores/ingrowth cores	Wang Qibing
9	Root biomass and nutrients	Soil cores	Wang Qibing
10	Aboveground NPP	Harvest method	Bai
11	Plant species composition	Quadrat/Canopy coverage	Bai
12	Grass/forb gas exchange	LiCOR 6400 IRGA	Jiang
13	Plant water status	Pressure chamber	Jiang
14	Plant tissue C/N and NUE	C/N analyzer	Han Xingguo
15	Dry and wet deposition	Foss autoanalyzer	Manager

Response variables and methods (cont'd)

No.	**Response variables**	**Method proposed**	**Responsibility**
16	Litter decomposition	Litterbags	Huang
17	Resource allocation		Pan
18	soil fauna		Han Xingguo/Xu
19	Trace gases	static chamber/GC	Wan/Wang Zhiping
20	Shrub pattern		Bai/Lin Yan
21	Phenology		Technician
22	Seed rain/bank		He Nianpeng
23	Isotope		Lin Guanghui
24	NEE		Han Xingguo
25	Clonal integration/plasticity		Yu Feihai
26	N fixation		Han Xingguo
27	soil biological crust		Han Xingguo
28	C/N cycle modelling		Sun
29	Mycorhiza		Liang Yu/Guo Liangdong
30	grasshopper		Kang Le/Hao Shuguang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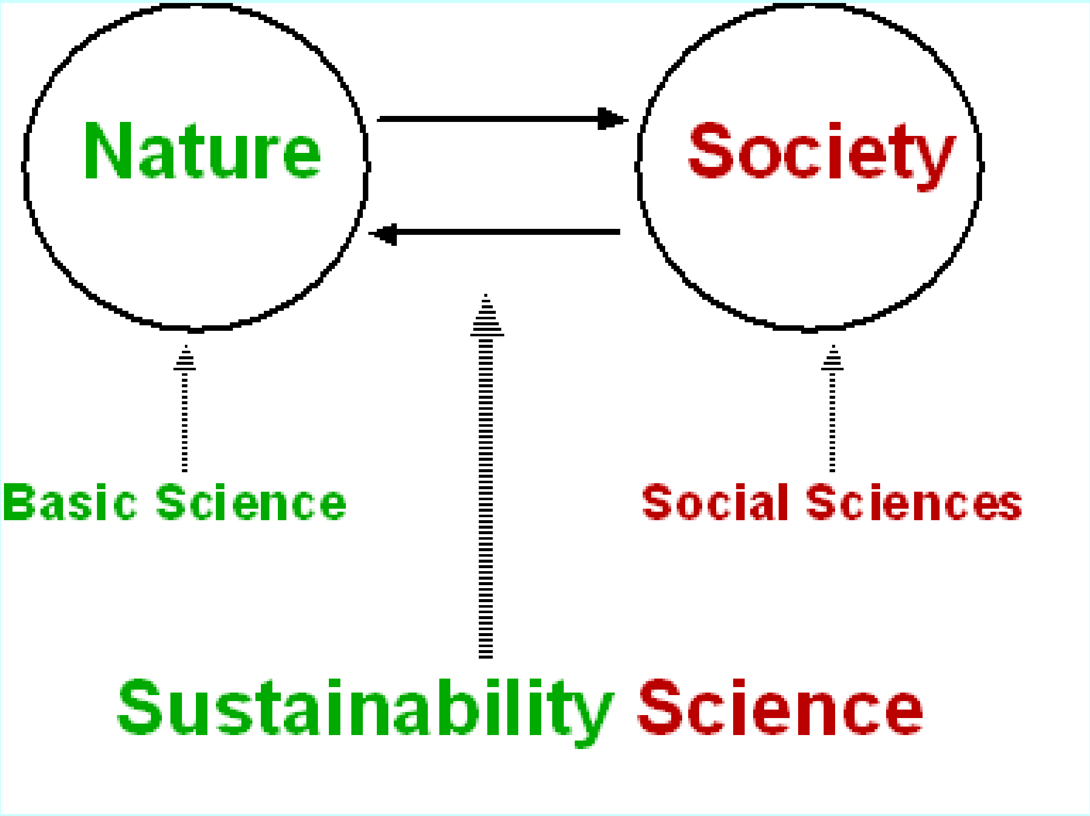
The future

- **A base for long-term monitoring and research**
- **Demonstration projects for local people**
- **Training center for Chinese and international students**

Particularly, we will develop a new framework under the framework of Sustainability Science in Inner Mongolia

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