Precipitation and aridity index regulating spatial patterns of vegetation production and species diversity based on alpine grassland transect, Tibetan Plateau

Jian Sun Corresp. [1]

[1] Institute of Geographical Sciences and Natural Resources Research

Corresponding Author: Jian Sun
Email address: sunjian@igsnrr.ac.cn

Although the relationship between the aboveground net primary production (ANPP) and speciesdiversity (SR) have been widely reported, there is considerable disagreement about the fitting patterns of SR–ANPP, which has been variously described as ‘positive’, ‘negative’, ‘unimodal’, ‘U-shaped’ and so on. Not surprisingly, the effect-factors including precipitation, aridity index and geographic conditions (e.g.,altitude, longitude and latitude) on ANPP and SR continue to interest researchers, especially the effects at high altitude regions. We investigated ANPP and SR from 113 sampled sites (399 plots) across alpine meadow and steppe in the Tibetan Plateau, which included Tibet, Qinghai and Sichuan province. The effects of various environmental factors (precipitation, temperature, aridity index, altitude, longitude,latitude and vegetation type on SR and ANPP) were explored. The results indicate that a unimodal pattern was confirmed between ANPP and SR in alpine steppe (R^2 =0.45, P <0.0001), alpine meadow (R^2 =0.4, P <0.0001), and all samples across alpine grassland (R^2 =0.52, P <0.0001). For the aboveground net primary production, the appropriate precipitation and aridity is 600mm and 42, respectively. Under thesame moisture conditions, the maximum value of diversity is 0.75. Longitude (R^2 =0.69, P <0.0001) and altitude (R^2 =0.48, P <0.0001) have positive and negative effects on aboveground net primary production, and a similar relationship exists with diversity (R^2 =0.44, P <0.0001 and R^2 =0.3, P <0.0001).The same patterns of diversity and production responding to precipitation and the aridity index were evident in alpine steppe and meadow, and a unimodal pattern was confirmed between ANPP and SR in both locations.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2495v1 | CC BY 4.0 Open Access | rec: 2 Oct 2016, publ: 2 Oct 2016

Precipitation and aridity index regulating spatial patterns of vegetation production and species diversity based on alpine grassland transect, Tibetan Plateau

Running head: Vegetation biomass and species diversity

Jian Sun

Synthesis Research Centre of Chinese Ecosystem Research Network, Key Laboratory of Ecosystem Network Observation and Modelling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

* Corresponding to: sunjian@igsnrr.ac.cn

Tel.: +86 18301068172

Address: Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (CAS), 11A, Datun Road, Chaoyang District, Beijing, 100101, China

The number of words in the Abstract: 218

The number of words in main body of the paper:2637

The number of references:23

The number of Tables: 1

The number of Figures:7

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2495v1 | CC BY 4.0 Open Access | rec: 2 Oct 2016, publ: 2 Oct 2016

Abstract

Although the relationship between the aboveground net primary production (ANPP) and species diversity (SR) have been widely reported, there is considerable disagreement about the fitting patterns of SR–ANPP, which has been variously described as 'positive', 'negative', 'unimodal', 'U-shaped' and so on. Not surprisingly, the effect-factors including precipitation, aridity index and geographic conditions (e.g., altitude, longitude and latitude) on ANPP and SR continue to interest researchers, especially the effects at high altitude regions. We investigated ANPP and SR from 113 sampled sites (399 plots) across alpine meadow and steppe in the Tibetan Plateau, which included Tibet, Qinghai and Sichuan province. The effects of various environmental factors (precipitation, temperature, aridity index, altitude, longitude, latitude and vegetation type on SR and ANPP) were explored. The results indicate that a unimodal pattern was confirmed between ANPP and SR in alpine steppe (R^2=0.45, P<0.0001), alpine meadow (R^2=0.4, P<0.0001), and all samples across alpine grassland (R^2=0.52, P<0.0001). For the aboveground net primary production, the appropriate precipitation and aridity is 600mm and 42, respectively. Under the same moisture conditions, the maximum value of diversity is 0.75. Longitude (R^2=0.69, P<0.0001) and altitude (R^2=0.48, P<0.0001) have positive and negative effects on aboveground net primary production, and a similar relationship exists with diversity (R^2=0.44, P<0.0001 and R^2=0.3, P<0.0001). The same patterns of diversity and production responding to precipitation and the aridity index were evident in alpine steppe and meadow, and a unimodal pattern was confirmed between ANPP and SR in both locations.

Keywords: Precipitation, aridity index, aboveground net primary production, species diversity, Tibetan Plateau

INTRODUCTION

Scientists have assessed the variation of grassland vegetation via remote sensing data, combined with field investigations, and explored the relationship between grassland and long-term environmental change (Roa-Fuentes *et al.*, 2012). Although NDVI (Normalized Different Vegetation Index) across the Tibetan Plateau shows increasing values due to global warming, different types of grasslands have different degrees of degradation, such as alpine meadow in

Nagqu. To some extent, grassland degradation means a decrease in grassland productivity and species richness, and although both net primary production and diversity play an important role in the ecosystem, the relationship between productivity and species diversity is not clear.

Classical theory holds that species-rich communities should be more productive. Although many hypotheses relate species diversity with productivity, including a linear positive relationship, there is insufficient evidence to support any one of them in different ecological habitats (Rusch *et al.*, 1997). Previous studies have highlighted the positive relationship between plant diversity and aboveground net primary production (Odat *et al.*, 2010, Palmborg *et al.*, 2005, Sabais *et al.*, 2011), and some studies suggest that the effects of species diversity on biomass and resource-use are complementary (Dukes, 2002, Palmborg, Scherer-Lorenzen, Jumpponen, Carlsson, Huss-Danell and Hogberg, 2005). Moreover, previous research found that the difference among plant communities would impact the relationship between aboveground net primary production and species-richness (Odat *et al.*, 2004, Terheerdt *et al.*, 1991).

Many researchers have focused on the pattern of species richness, diversity, and productivity in grassland communities. In fact, control experiments could not indicate the effect on biomass by climate and diversity in the natural ecosystem {Bernhardt-Romermann, 2011 #10}. However, much less emphasis has been placed on the environmental factors affecting species diversity, and so, for the time being, it remains unclear whether the species diversity gradients respond to environmental factors (Houseman *et al.*, 2011). The objectives of this study are as follows: (a) What is the relationship between aboveground net primary production and diversity across the Tibetan Plateau? (b) What is the relationship between the environment and ANPP and SR? (c) What is the response difference between alpine meadow and alpine steppe to precipitation factors?

METHODS

Study area

The Tibetan Plateau (80°–105°E, 27°–37°N) in western China has an alpine climate with an annual mean temperature of 4°C, an annual mean precipitation of 400 mm, and the mean altitude is over 4000m. Annual mean precipitation increases gradually from the northwest to the southeast, and mainly falls in June-September, which is significant for the rainy season and dry season. The high mountain plateau climate results in a temperature decrease as altitude increases, and the total area of the Tibetan Plateau is 2,400,000 km^2. Fig.1 shows that the vegetation types are dominated by alpine meadow and alpine steppe in the east and northwest of the Tibetan Plateau. Resistance to cold and drought is a characteristic of the alpine steppe, but most species of alpine meadow in the region are perennial.

Data collection and analysis

In August 2015, 113 locations were selected in alpine meadow and steppe across the Tibetan Plateau (Supplementary file 1), including Qinghai, Tibet and Sichuan province (Field experiments were approved by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences). For each location, three samples of 50cm × 50cm were randomly selected to investigate the height, cover percentage and number of species, the raw data for species diversity. The number of species in the samples was recorded, and the clipping method used to measure the aboveground net primary production. Three examples of aboveground net primary production were dried in an oven at 80°C and then weighed.

Simpson's diversity index is used to indicate the α diversity of biodiversity, which focuses on the species number whining-habitat regional scale, and is calculated as (Vujnovic *et al.*, 2002):

$$D = 1 - \sum p_i^2$$

Where p_i is the proportional abundance of the species (i) in the community. It is the most suitable index because of its unbiased estimate (Morris *et al.*, 1979). The figures and table in this study were created with SPSS and R Core Team (R: A language and environment for statistical computing. The R Project for Statistical Computing, Vienna, Austria. http://www.R-project.org/. supplementary file 2).

RESULTS

Variations of vegetation production and diversity in alpine steppe and meadow

Fig.2 shows the results and range of aboveground net primary production and diversity in alpine meadow and alpine steppe. The mean value of ANPP in the alpine meadow is 143.15 g m^{-2}, which is higher than the alpine steppe with a mean value of 55.81 g m^{-2}. Otherwise, the range of both is similar; the domain of meadow is dispersed while that of steppe is mainly below 100 g m^{-2}. There was a difference in the Simpson diversity index between alpine steppe and meadow, which is due to differing species-richness and species-evenness. As for the content of ANPP, the species diversity of meadow is higher than that of the steppe. The median of both is 0.75 and 0.565, respectively, and the range of the second median is approximately 0.063.

Within each vegetation type, species diversity increased aboveground net primary production (Fig.3) and shows a curved relationship. Although the shape of the diversity-ANPP curves differed between meadow ($y=0.51+0.0026x-(5.47E+006)x^2$, $R^2=0.40$, $P<0.0001$) and steppe ($y=0.37+0.0053x-(1.72E+005)x^2$, $R^2=0.45$, $P<0.0001$), both vegetation types show similar unimodal lines with peaks at 250 g m^{-2} and 160 g m^{-2} of ANPP, respectively. In fact, the influence of diversity on ANPP was more sensitive in meadow than in steppe, but the correlation coefficient between ANPP and species diversity across the Tibetan Plateau is higher ($y=0.42+0.0038x-(9.04E+006)x^2$, $R^2=0.52$, $P<0.0001$) than for each vegetation type, with peak values of 240 g m^{-2} of ANPP and 0.75 of species diversity. In the low productivity sites, there was no effect of diversity on aboveground net primary production.

Changes in vegetation production and species diversity along environmental gradients

To test whether moisture was the crucial environmental factor that affects the productivity-diversity pattern in two vegetation types, we used partial correlation in SPSS to analyze the relationship among environment factors, as shown in Table 1. As a result, annual mean temperature has no significant effect on aboveground net primary production and diversity, except to show a significant negative relationship with aridity (R^2=-0.38). In addition, latitude shows a positive effect on community production (R^2=0.42) but not on species diversity. Hence latitude and temperature are excluded in the latter research. To summarize, longitude, precipitation and aridity performance have a positive affect while altitude shows a negative influence on aboveground net primary production and diversity.

Fig. 4 shows that the influence of precipitation and aridity on ANPP is similar, because aridity takes into account evaporation. For the alpine meadow, ANPP increases with moisture, and annual mean precipitation of 600mm is appropriate for the accumulation of organic matter with 250 g m^{-2} ANPP based on the fitting line. Correspondingly, aridity with 48 is conducive to meadow growth across the Tibetan Plateau. On the other hand, most, though not all, of the ANPP sample values of is approximately 100 g m^{-2}. For steppe, the suitable value of annual mean precipitation and aridity is approximately 310mm and 28, respectively – after which ANPP decreases as precipitation increases and aridity rises. As a consequence, the peak of ANPP is 120 g m^{-2} in steppe. What this means is that too much precipitation has no positive effect on aboveground net primary production, as a ratio of evaporation and precipitation. Nevertheless, the relationship between ANPP and precipitation is positive across the Tibetan Plateau. Within the range of 0-150 gm^{-2}, the appropriate precipitation is 420mm, which is below the value of alpine meadow but above the alpine steppe. In terms of aridity, the feasible value is 42, which is close to the value of alpine meadow.

Alpine grassland biomass increased significantly with increasing longitude ($y=82.62+0.18x+0.0004x^2$, $R^2=0.69$, $P<0.0001$), but decreased with increasing altitudes ($y=4758.47-9.28x+0.12x^2$, $R^2=0.48$, $P<0.0001$) (Fig.5). Generally, this was true, from west to east, across the Tibetan Plateau. The alpine meadow biomass increased slightly with longitude at 150 gm^{-2} while it is almost invariant with ANPP at 200 gm^{-2}. At the same time, increased alpine steppe biomass caused by longitude was significantly below 140 gm^{-2}. As for the alpine grassland in the Tibetan Plateau, the positive relationship between ANPP and longitude was insignificant when the value was 100 of longitude. Different results of aboveground net primary production between alpine meadow and steppe is significant. The range of altitude in meadow and steppe is 4700-3500m and 5000-3700m, respectively, and many samples were located in high altitude regions. It is worth noting that the ANPP of meadow is more than that of the steppe at the same altitude, especially under 3500m. The response of steppe to altitude was more sensitive than meadow.

The impact of moisture on diversity differs from ANPP, because the fitting correlation between precipitation and diversity is at the right of the unimodal fitting lines ($y=221.43-232.20x+705.56x^2$, $R^2=0.36$, $P<0.0001$) (Fig.6) – which is to say, precipitation and aridity have a significant positive impact on species diversity. Furthermore, species richness is more sensitive to high rainfall in alpine meadow regions than in the alpine steppe. As the annual mean precipitation increased from 200mm to 400mm, species diversity increased from 0.25 to 0.75 in the steppe.

Fig.7 shows the relationship between longitude, altitude and diversity. Clearly, the former indicates a positive relationship ($y=87.13-15.55x+36.40x^2$, $R^2=0.44$, $P<0.0001$) while the latter is negative ($y=3557.26-4407.82x-5120.60x^2$, $R^2=0.30$, $P<0.0001$). Most samples in the steppe are distributed at 80°E-100°E, while sites of alpine meadow are located at 90°E-100°E, and the species diversity index changed from 0.50 to 0.75 on 100°E approximately.

DISCUSSION

Size of vegetation production and species diversity

ANPP and species diversity of meadow are both higher than those of the steppe, which shows a correlation with vegetation types. At a low diversity value, many studies suggest that increasing diversity is conducive to greater biomass production {Ram, 1989 #71}{Aarssen, 1997 #61}. In general, many results conclude that this from controlled experiments, such as standards of dominant species (Terheerdt, Bakker and Deleeuw, 1991). In fact, at the same level of aboveground net primary production, species richness of alpine meadow is more than that of alpine steppe, owing to the different characteristics of plant species. For grassland across the Tibetan Plateau, aboveground net primary production increased as the species richness increased with a curve line.

In addition, different ecological communities are an important factor in the relationship between biomass and diversity. In other words, different ecological system types have different vegetation types, which indicate that species composition determines the aboveground net primary production. What is worth noting is that species have not had a positive effect on biomass production, even though it is a common negative influence of production on diversity in mature natural systems because of competitive exclusion although not in the control of species diversity (Grace *et al.*, 2007). As the results of this study show, when diversity increases to 0.75, the aboveground net primary production shows a decreasing trend afterwards. Moreover, high production in a community is more likely to result from containing productive species but not all species (Aarssen, 1997).

Environmental gradient patterns of vegetation production and species diversity

For plants that are particular to biotic and resource conditions, classical niche theory holds that species richness is controlled by local environment factors (Gazol *et al.*, 2012). Aridity is soil moisture by another name, with an extremely significant positive correlation for precipitation by 0.89 (Table 1). The influence of precipitation and aridity on aboveground net primary production and diversity is similar overall. The Tibetan Plateau was called “The third pole”, with a mean altitude of 4000 meter. Complex geologic conditions impacted the alpine steppe and the meadow, and both changed in a specific range. This area, which has high rainfall, has high evaporation, which is distributed in meadow vegetation in the center of the Tibetan Plateau. Nevertheless, quantitative soil nutrients may limit the increase of aboveground net primary production even if the precipitation increases – although this is not true for species richness because of the ecological niche for moisture of various species. Because of drought-induced transformations in plant-soil resources, high plant species-richness was promoted (Bloor *et al.*, 2012). In the alpine grassland of the Tianshan mountains, rainfall in the early growing period and snowfall in winter play an important role on plant growth (Li *et al.*, 2015).

Form west to east across the Tibetan Plateau, the annual precipitation increased as the longitude from 80°E to 105°E. The relationship between longitude and aboveground primary net production, diversity shows in the horizontal variation. In the vertical variation, altitude response is negative for precipitation and temperature, and especially with annual precipitation. There is, however, a different pattern concerning the effect of environment factors on aboveground net primary production and diversity. Nevertheless, it is important to analyze the response to environmental factors. Plenty of aboveground net primary production could ensure the development of livestock, especially in winter when grassland resources are short. In recent years, with global temperatures increasing, the annual mean precipitation has also increased, and extreme climate events such as drought and rainfall influence vegetation. Normalized different vegetation index (NDVI) shows an increased tendency under climate change, and the suggestion that grassland across the Tibetan Plateau has degraded has been confirmed. On the other hand, species richness has an important role in the ecological system, not only because of the natural gene pool, but also to strengthen the region's capacity to adapt to the changing climate.

In addition, many factors should be explored through future research. Although the cornerstone ecological theory holds that the number of species control the nutrient availability in a community, there has been no effect of NO_3^- on distributive patterns of species diversity at the small scale (Anderson *et al.*, 2004). In terms of plant production, light became the control element with denser canopy (Eek *et al.*, 2001). Some studies have explored the various elements that effect production and species diversity such as invertebrate herbivores (Brady *et al.*, 2001, Buschmann *et al.*, 2005). Although grazing was another important factor on the variation of biomass and species diversity, grassland degradation would be caused by overgrazing over the long term (Zhao *et al.*, 2004). However, climate variables have less influence on biomass than biodiversity

(Bernhardt-Romermann *et al.*, 2011). Moreover, the influence of anthropogenic activity on diversity and the characteristics of the natural community are increasingly significant (Webster *et al.*, 2002).

CONCLUSIONS

The relationship between biomass and species richness is a topic of considerable interest to environmental scientists. There are several traditional assumptions about the relationship, but we cannot explore the internal mechanism of biomass and diversity by referring only to correlative patterns. To be sure, the relevance model changes with location, and the relationship between aboveground net primary production and species richness fits a unimodal model. Nevertheless, the variation range in the alpine steppe is smaller than in alpine meadow. Thus, the relationship between aboveground net primary production and species richness is non-linear: as species richness increased, aboveground net primary production of grassland increased to 250 g m^{-2}, but then decreased after that. According to the aforementioned results, precipitation, aridity and longitude show a positive effect on aboveground net primary production and diversity while altitude indicates a negative effect on the whole. Clearly, the response of alpine meadow to environment factors is more sensitive than the response of alpine steppe.

ACKNOWLEDGMENTS

We appreciate all the people (Weipeng Li, Jianbo Wu, Xiaojing Qin, Tiancai Zhou, Hongwu Ran, Wei Jiao and Hong liu) who contributed their field work to the database. This work was funded by the National Natural Science Foundation of China (No. 41501057), West Light Foundation of The Chinese Academy of Sciences and the Open Fund of the Key Laboratory of Mountain Surface Processes and Eco-regulation.

REFERENCE

Aarssen LW (1997). High productivity in grassland ecosystems: Effected by species diversity or productive species? *Oikos* **80**:183-184.

Anderson TM, McNaughton SJ, Ritchie ME (2004). Scale-dependent relationships between the spatial distribution of a limiting resource and plant species diversity in an african grassland ecosystem. *Oecologia* **139**:277-287.

Bernhardt-Romermann M, Romermann C, Sperlich S, Schmidt W (2011). Explaining grassland biomass - the contribution of climate, species and functional diversity depends on fertilization and

mowing frequency. *Journal of Applied Ecology* **48**:1088-1097.
Bloor JMG, Bardgett RD (2012). Stability of above-ground and below-ground processes to extreme drought in model grassland ecosystems: Interactions with plant species diversity and soil nitrogen availability. *Perspectives in Plant Ecology Evolution and Systematics* **14**:193-204.
Brady MJ, Slade NA (2001). Diversity of a grassland rodent community at varying temporal scales: The role of ecologically dominant species. *Journal of Mammalogy* **82**:974-983.
Buschmann H, Keller M, Porret N, Dietz H, Edwards PJ (2005). The effect of slug grazing on vegetation development and plant species diversity in an experimental grassland. *Functional Ecology* **19**:291-298.
Dukes JS (2002). Species composition and diversity affect grassland susceptibility and response to invasion. *Ecological Applications* **12**:602-617.
Eek L, Zobel K (2001). Structure and diversity of a species-rich grassland community, treated with additional illumination, fertilization and mowing. *Ecography* **24**:157-164.
Gazol A, Tamme R, Takkis K, Kasari L, Saar L, Helm A, Partel M (2012). Landscape- and small-scale determinants of grassland species diversity: Direct and indirect influences. *Ecography* **35**:944-951.
Grace JB, Anderson TM, Smith MD, Seabloom E, Andelman SJ, Meche G, Weiher E, Allain LK, Jutila H, Sankaran M, Knops J, Ritchie M, Willig MR (2007). Does species diversity limit productivity in natural grassland communities? *Ecology Letters* **10**:680-689.
Houseman GR, Gross KL (2011). Linking grassland plant diversity to species pools, sorting and plant traits. *Journal of Ecology* **99**:464-472.
Li KH, Liu XJ, Song L, Gong YM, Lu CF, Yue P, Tian CY, Zhang FS (2015). Response of alpine grassland to elevated nitrogen deposition and water supply in china. *Oecologia* **177**:65-72.
Morris MG, Lakhani KH (1979). Responses of grassland invertebrates to management by cutting .1. Species-diversity of hemiptera. *Journal of Applied Ecology* **16**:77-98.
Odat N, Hellwig FH, Jetschke G, Fischer M (2010). On the relationship between plant species diversity and genetic diversity of plantago lanceolata (plantaginaceae) within and between grassland communities. *Journal of Plant Ecology* **3**:41-48.
Odat N, Jetschke G, Hellwig FH (2004). Genetic diversity of ranunculus acris l. (ranunculaceae) populations in relation to species diversity and habitat type in grassland communities. *Molecular Ecology* **13**:1251-1257.
Palmborg C, Scherer-Lorenzen M, Jumpponen A, Carlsson G, Huss-Danell K, Hogberg P (2005). Inorganic soil nitrogen under grassland plant communities of different species composition and diversity. *Oikos* **110**:271-282.
Roa-Fuentes LL, Campo J, Parra-Tabla V (2012). Plant biomass allocation across a precipitation gradient: An approach to seasonally dry tropical forest at yucatan, mexico. *Ecosystems* **15**:1234-1244.
Rusch GM, Oesterheld M (1997). Relationship between productivity, and species and functional group diversity in grazed and non-grazed pampas grassland. *Oikos* **78**:519-526.
Sabais ACW, Scheu S, Eisenhauer N (2011). Plant species richness drives the density and diversity of collembola in temperate grassland. *Acta Oecologica-International Journal of Ecology* **37**:195-202.
Terheerdt GNJ, Bakker JP, Deleeuw J (1991). Seasonal and spatial variation in living and dead plant-material in a grazed grassland as related to plant-species diversity. *Journal of Applied Ecology* **28**:120-127.
Vujnovic K, Wein RW, Dale MRT (2002). Predicting plant species diversity in response to disturbance magnitude in grassland remnants of central alberta. *Canadian Journal of Botany-Revue Canadienne De*

Botanique **80**:504-511.
Webster G, Embley TM, Prosser JI (2002). Grassland management regimens reduce small-scale heterogeneity and species diversity of beta-proteobacterial ammonia oxidizer populations. *Applied and Environmental Microbiology* **68**:20-30.
Zhao HL, Li SG, Zhang TH, Ohkuro T, Zhou RL (2004). Sheep gain and species diversity: In sandy grassland, inner mongolia. *Journal of Range Management* **57**:187-190.

Table 1 The correlation coefficient of ANPP, diversity and environment factors.

Factors	ANPP	Diversity	Latitude	Longitude	Altitude	Precipitation	Temperature	Aridity
ANPP	1	0.64**	0.42**	0.75**	–0.70**	0.69**	-0.01	0.63**
Diversity		1	0.21	0.64**	–0.48**	0.69**	0.11	0.58**
Latitude			1	0.62**	–0.69**	0.13	-0.21	0.42
Longitude				1	–0.78**	0.82**	0.02	0.72**
Altitude					1	–0.49**	-0.21	–0.33**
Precipitation						1	0.05	0.89**
Temperature							1	–0.38**
Aridity								1

Figure captions

Fig. 1 Map of the Tibetan Plateau of China with locations of the 113 samples

Fig. 2 Aboveground primary production and diversity differences between grasslands factor

Fig. 3 Species diversity as a function of ANPP at vegetation type

Fig. 4 The influence of precipitation and aridity on ANPP

Fig. 5 The influence of longitude and altitude on ANPP

Fig. 6 The influence of precipitation and aridity on diversity

Fig.7 The influence of longitude and altitude on diversity

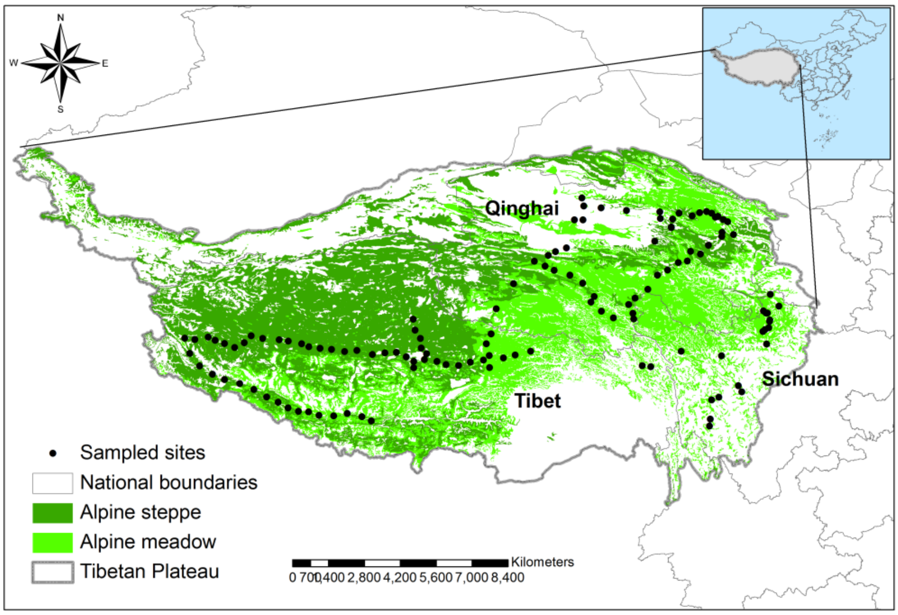

N
W
E
S
Qinghai
Tibet
Sichuan
Sampled sites
National boundaries
Alpine steppe
Alpine meadow
Tibetan Plateau
Kilometers

Fig. 1

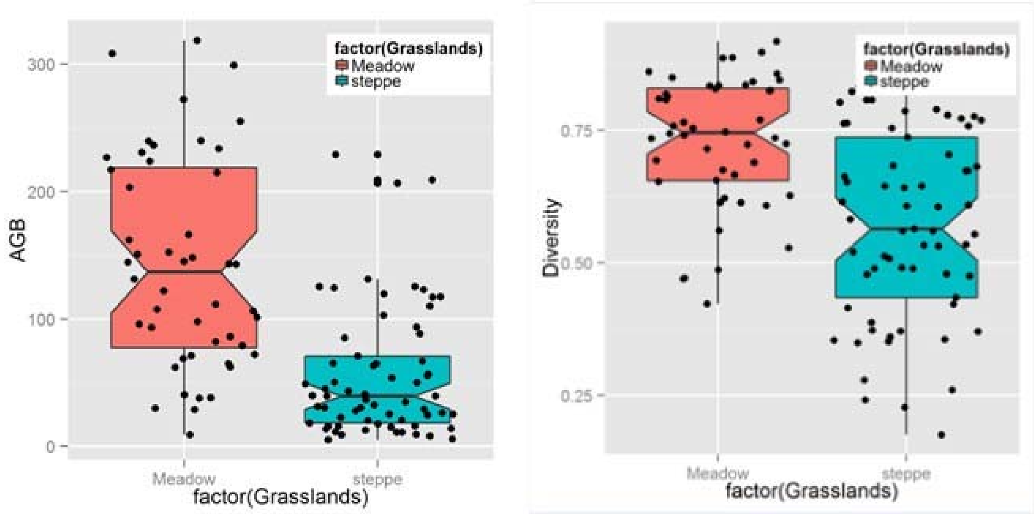

factor(Grasslands)
Meadow
steppe
AGB
300
200
100
0
Meadow
steppe
factor(Grasslands)
factor(Grasslands)
Meadow
steppe
Diversity
0.75
0.50
0.25
Meadow
steppe
factor(Grasslands)

Fig. 2

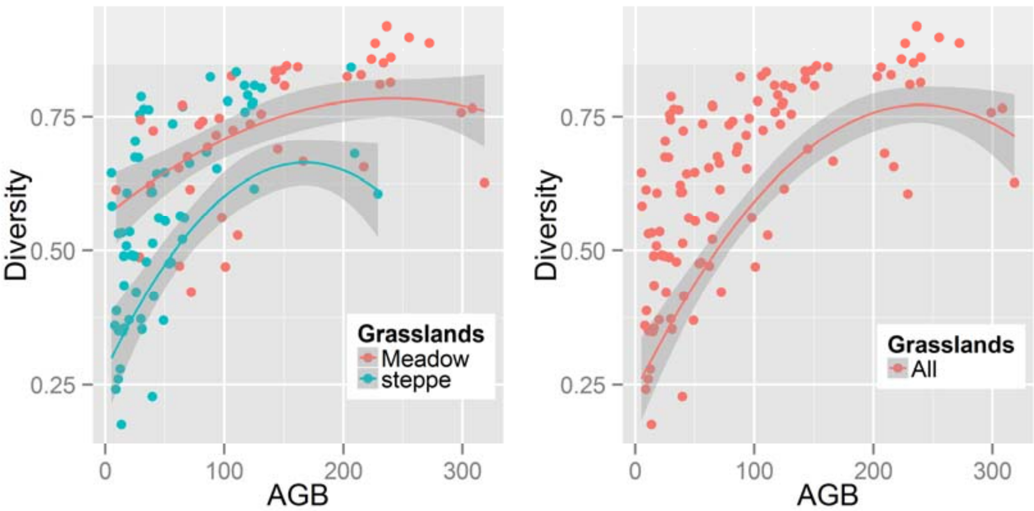
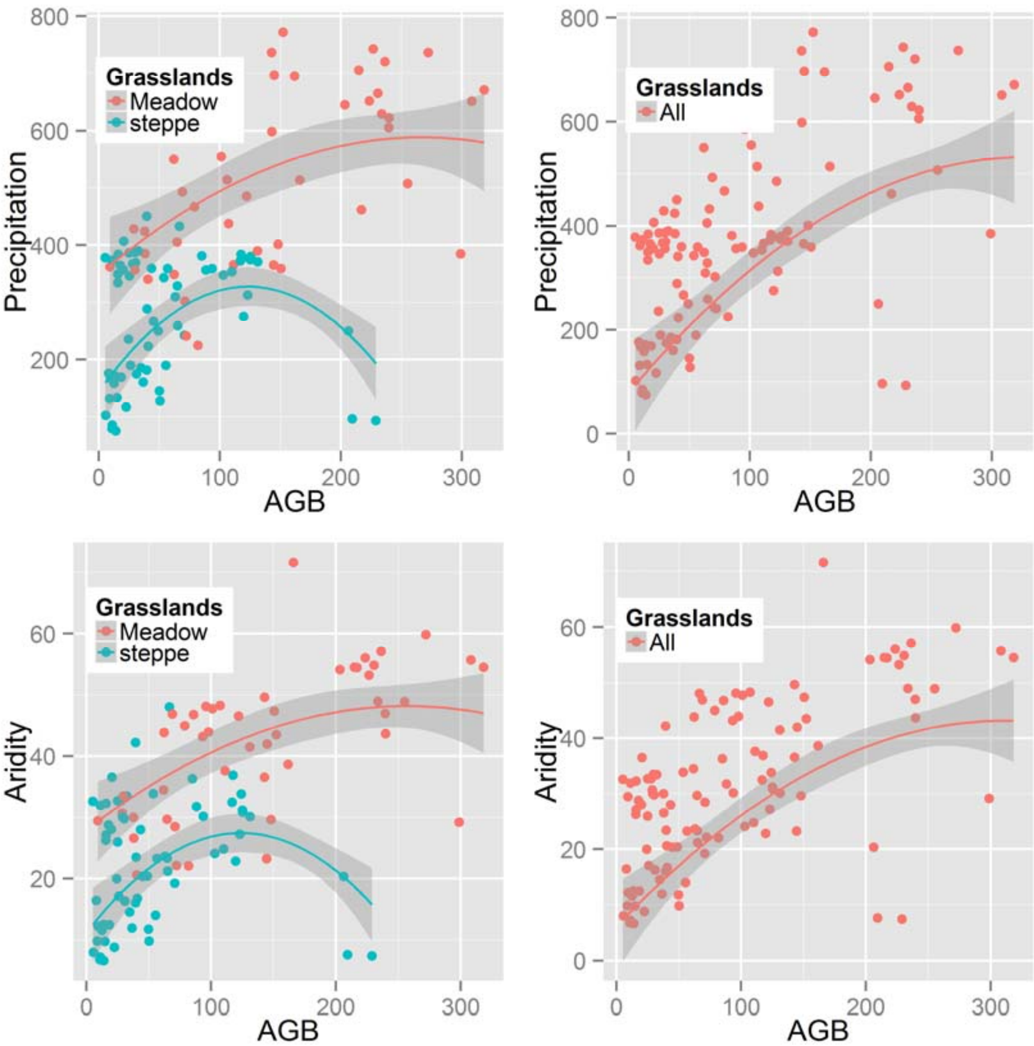

Diversity
0.75
0.50
0.25
0
100
200
300
AGB
Grasslands
Meadow
steppe
Diversity
0.75
0.50
0.25
0
100
200
300
AGB
Grasslands
All

Fig. 3



Grasslands
Meadow
steppe
Precipitation
AGB
Grasslands
All
Precipitation
AGB
Grasslands
Meadow
steppe
Aridity
AGB
Grasslands
All
Aridity
AGB

Fig. 4

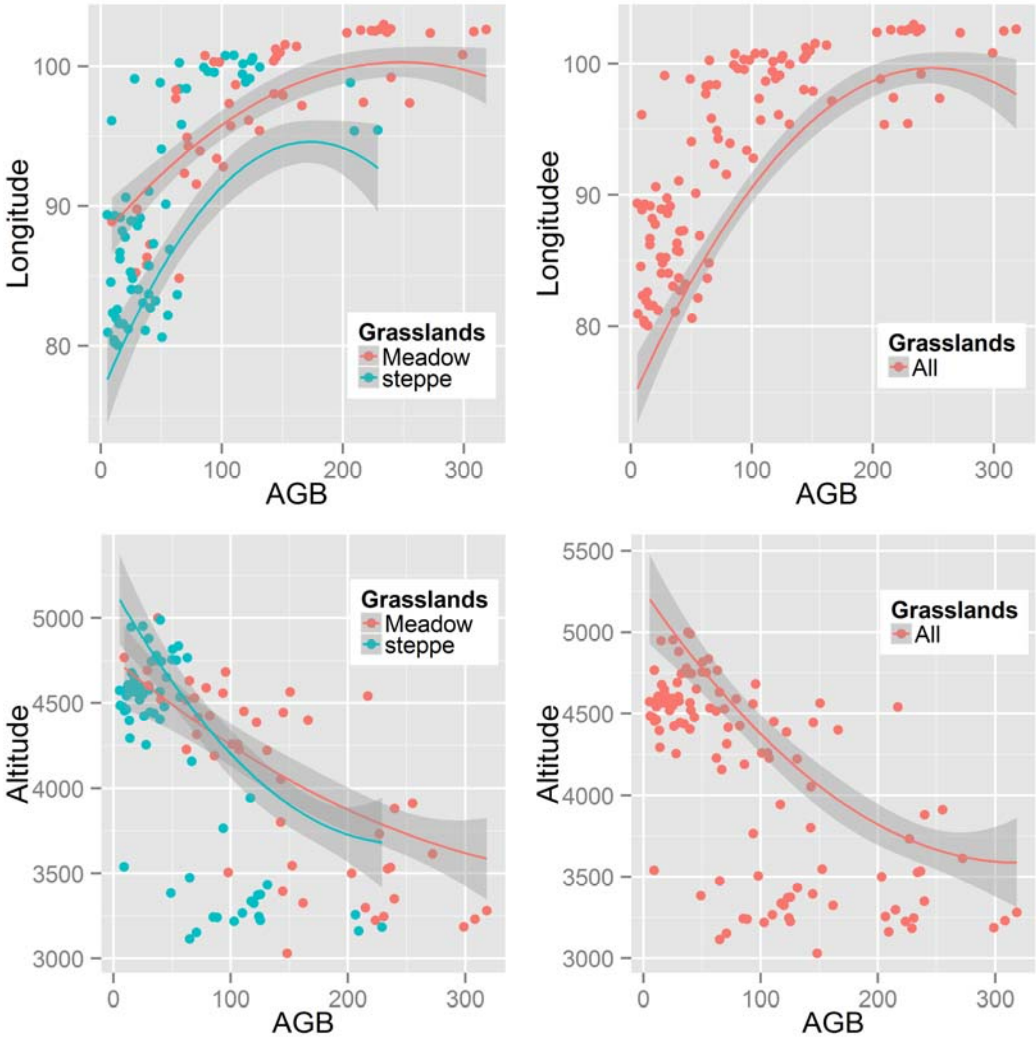
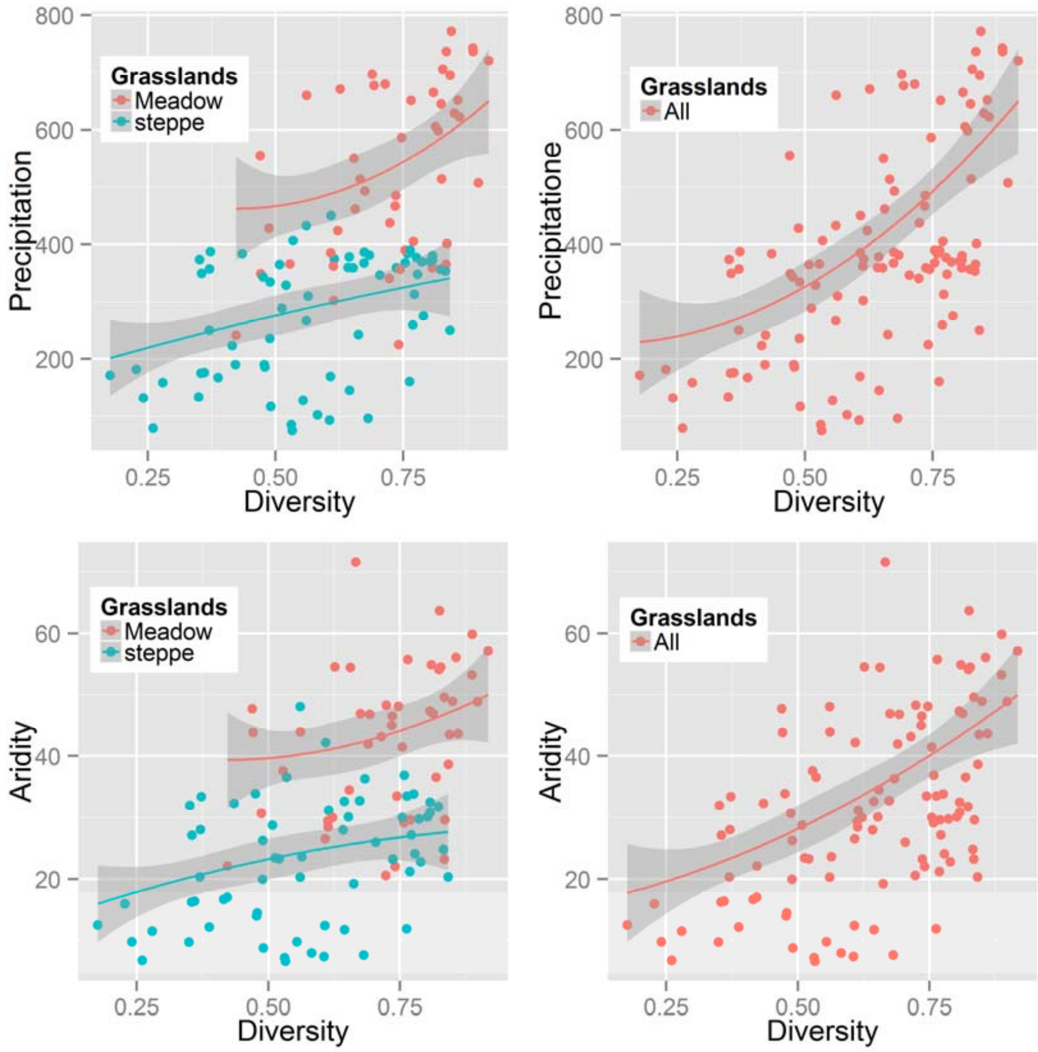

Longitude
100
90
80
0
100
200
300
AGB
Grasslands
Meadow
steppe
Longitudee
Grasslands
All
Altitude
5000
4500
4000
3500
3000
5500

Fig. 5



Grasslands
Meadow
steppe
Precipitation
Diversity
Grasslands
All
Precipitatione
Diversity
Grasslands
Meadow
steppe
Aridity
Diversity
Grasslands
All
Aridity
Diversity

Fig. 6

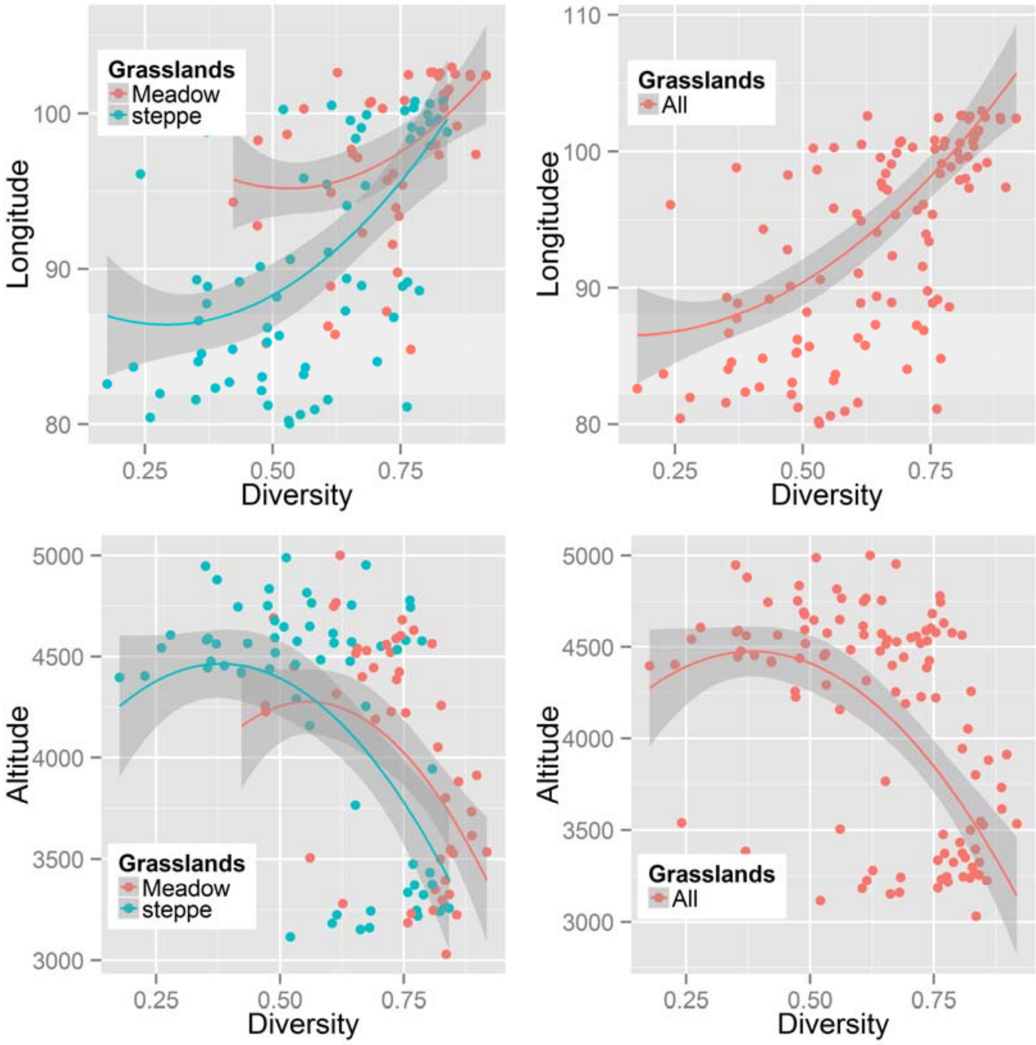

Grasslands
Meadow
steppe
Longitude
Diversity
Grasslands
All
Longitudee
Diversity
Altitude
Diversity
Altitude
Diversity

Fig.7