

Grassland Community Composition Response to Grazing Intensity Under Different Grazing Regimes

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ARTICLE INFO

Article history:

Received 24 March 2017

Received in revised form 21 July 2017

Accepted 25 September 2017

Key Words:

continuous grazing

grazing intensity

grazing regime

plant community composition

seasonal grazing

ABSTRACT

Grazing plays a key role in many ecosystems worldwide and can affect the structure and composition of terrestrial plant communities. Nonetheless, how grazing management, especially grazing regime (yearlong continuous and seasonal grazing), affects the relationship between grazing and vegetation on alpine grasslands has not been extensively studied. Here, we performed a grazing experiment in Gangcha county of Qinghai province of the Qinghai-Tibetan Plateau to test the effects of different stocking rates and grazing regimes on grassland biomass and plant structure and composition. Six stocking rates (ranging from 0 to 5.62 sheep ha⁻¹) were used for continuous grazing, and three grazing intensities (1.72, 2.87, and 5.62 sheep ha⁻¹) were used for seasonal grazing (grazed only in the growing season, from June to October) at the study sites. Plant biomass and grass functional community composition were characterized in two different yr (2011 and 2012). Additionally, species richness and plant diversity indexes were estimated to quantify the impacts of grazing on plant community composition. Our results indicated that grazing intensity best explained the plant biomass decrease in low-productivity environments, and different grazing regimes also influenced these results. The shifts in plant community structure and composition in response to increased grazing intensity differed considerably between continuous grazing and seasonal grazing. Seasonal grazing maintained greater amounts of palatable plant species, and fewer undesirable species in plant communities when compared with the composition after continuous grazing. Our results emphasize the importance of grazing regime in regulating the effects of grazing on plant communities and the importance of seasonal grazing for ecosystem maintenance, especially in the Qinghai-Tibetan Plateau. This suggests that periodic resting of grasslands could be a good management strategy to keep palatable species, thereby minimizing undesirable species in the overall species composition.

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Introduction

Domestic herbivore grazing is the primary land use of rangelands (grassland) worldwide (Herrero and Thornton 2013). In water-limited ecosystems, aboveground net primary production is the main determinant of forage consumption by large herbivores, which is associated with meat and dairy production (Derner et al. 2008a; Craine et al. 2013; Reeves et al. 2013) and hence economic return (Torell et al. 2010; Ritten et al. 2014). Such herbivores have strong effects on the composition, richness, physical structure, and successional patterns of plant communities across multiple biomes and continents (Bakker et al. 2006; Beguin et al. 2011), and changes in their abundances can lead to dramatic direct and indirect effects on plant-animal interactions and ecosystem processes (Young et al. 2013). However, the magnitude and direction of the effects of herbivores on plant communities are variable (Vesk and Mark 2001) and influenced by grazing management.

Nonetheless, how grazing management, especially grazing regime (yearlong continuous and seasonal grazing), affects the relationship between grazing and vegetation on alpine grasslands has not been extensively studied.

Grazing intensity can elicit vegetation changes through shifts in dominant plant functional groups (Derner and Hart 2007; Derner et al. 2008b; Lauenroth and Burke 2008). The response of plant composition varies according to grazing intensity (Deng et al. 2014). Previous studies have indicated that increasing the grazing intensity in the shortgrass steppe and northern mixed-grass prairie results in changes of plant functional groups and composition (Derner and Hart 2007; Derner et al. 2008b). Changes in vegetation composition from palatable grasses and sedges to less palatable forbs resulting from heavy grazing have been reported in many ecosystems (Sun et al. 2011 in northwest China; Zatout 2014 in Libya; Bakker et al. 2003 and Koerner and Collins 2014 in North America and South Africa, and Cingolani et al. 2003 in Argentina). These studies have shown that proper grazing intensity may increase plant biodiversity and promote species equitability (evenness) by removing competitive dominant species (Schultz et al. 2011). Therefore, a better understanding of the effects of grazing

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intensity on the dynamics of plant composition in relation to sustainable utilization is required for rational management of grasslands. Moreover, grazing timing (or grazing regime) is another factor affecting the plant composition of grasslands. Sternberg et al. (2015) suggested that different grazing regimes had different effects on plant composition. Seasonal grazing gives grasslands a time window for plant restoration, which might increase their resistance to grazing and change the development of plant composition, especially under heavy grazing. Therefore, grazing regime (seasonal grazing) may be used as a management tool for the maintenance of high production and biodiversity in grasslands.

The Qinghai-Tibet Plateau is one of the world's most extensive and highest grazing ecosystems. More than half of the plateau is covered by the alpine grassland, which supports some 70 million livestock (Zhou et al. 2006). Recently, the grazing pressure on this plateau has been increasing due to human population expansion. Owing to its important ecological and environmental roles at both regional and global scales, this alpine ecosystem has attracted abundant attention. However, little information is available on how grazing regime affects this unique alpine ecosystem. In particular, comparative analyses of continuous and seasonal grazing regimes are needed.

In this study, we examined the roles of grazing regime in regulating the response of local plant communities to different grazing intensities in the Qinghai-Tibetan Plateau. Our specific objectives were as follows: 1) to analyze seasonal variation in total aboveground biomass and its response to grazing management, 2) to study the responses of plant functional groups to changes in the timing and intensity of grazing, and 3) to assess the relationships between the grazing intensity and species richness, species diversity index, and equitability under different grazing regimes.

Materials and Methods

Study Site

The study was conducted in Gangcha County in the northeastern part of Qinghai Province (37°21'N, 100°04'E, 3 313 m above sea level; for detailed site characteristics, see Wang et al. 2016), 200 km from Xining, the capital city of Qinghai Province (Fig. 1). The study site is flat, with a slightly undulating plateau. The site experiences a continental monsoon-type climate with an annual temperature ranging from -17.5°C (January) to 11.0°C (July) and a mean annual precipitation of about 370.5 mm with approximately 79–93% falling in the short and cool summer (May–September). The growing season is closely associated with the rainfall distribution. The patterns of mean monthly temperature were similar in 2011 and 2012, but the precipitation was slightly greater in 2011 than in 2012 (Fig. 2). The alpine steppe vegetation was dominated mainly by *Elymus nutans* (Poaceae), *Kobresia humilis* (Cyperaceae), and *Stipa purpurea* (Poaceae). Other species were *Astragalus polycladus* (Leguminosae), *Heteropappus altaicus* (Compositae), *Koeleria cristata* (Poaceae), *Potentilla bifurca* (Rosaceae), *Radix bupleuri* (Apiaceae), and so on. Fire, either natural or human induced for pasture management, is uncommon in this area. The soil is classified as Mat-Gryic Cambisol (Luo et al. 2009), and is relatively homogeneous. Basic soil properties were organic C 21.16 g kg^{-1} , pH 7.67, total N 5.74 g kg^{-1} , and total P 0.73 g kg^{-1} at soil depths of 0–10 cm (Xu et al. 2015).

Experimental Design

A grazing experiment was established in June 2010, and grazing lands were subjected to 2 yr of grazing. Grazing treatments comprised

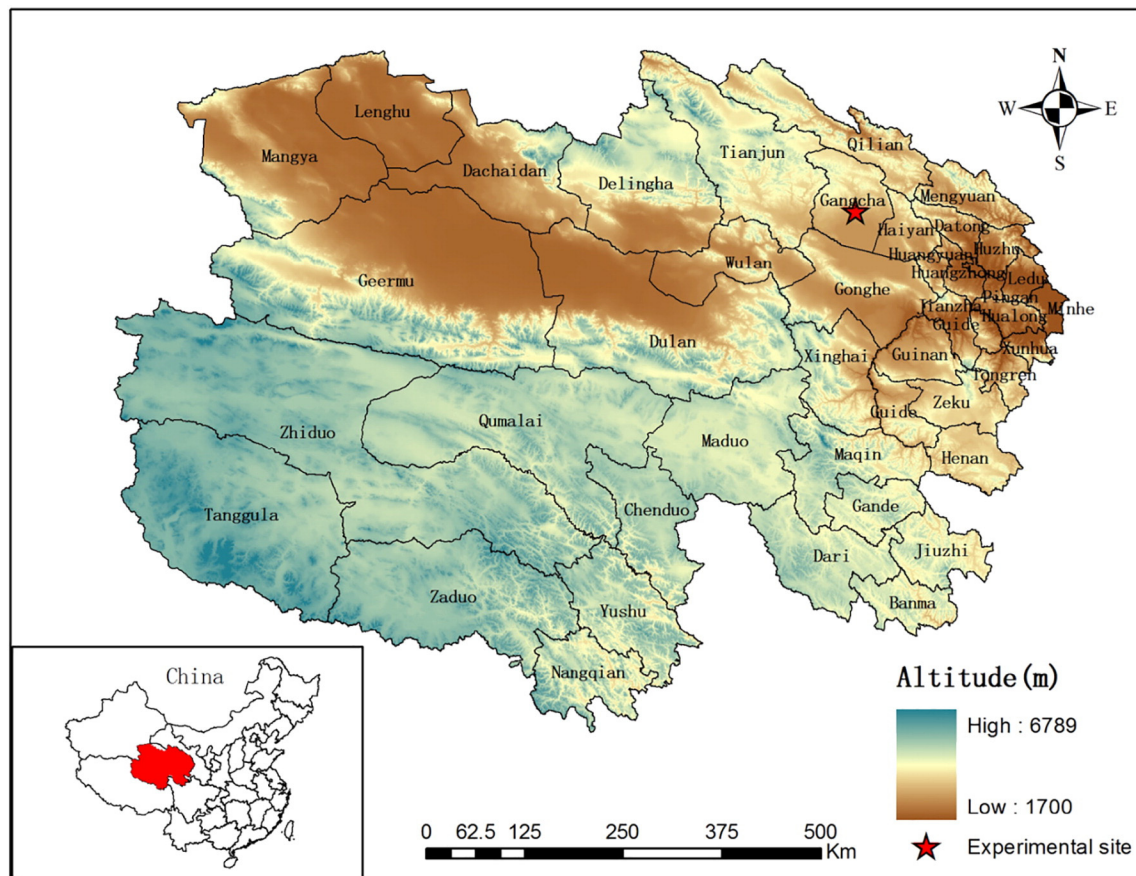


Figure 1. Location of experimental site.

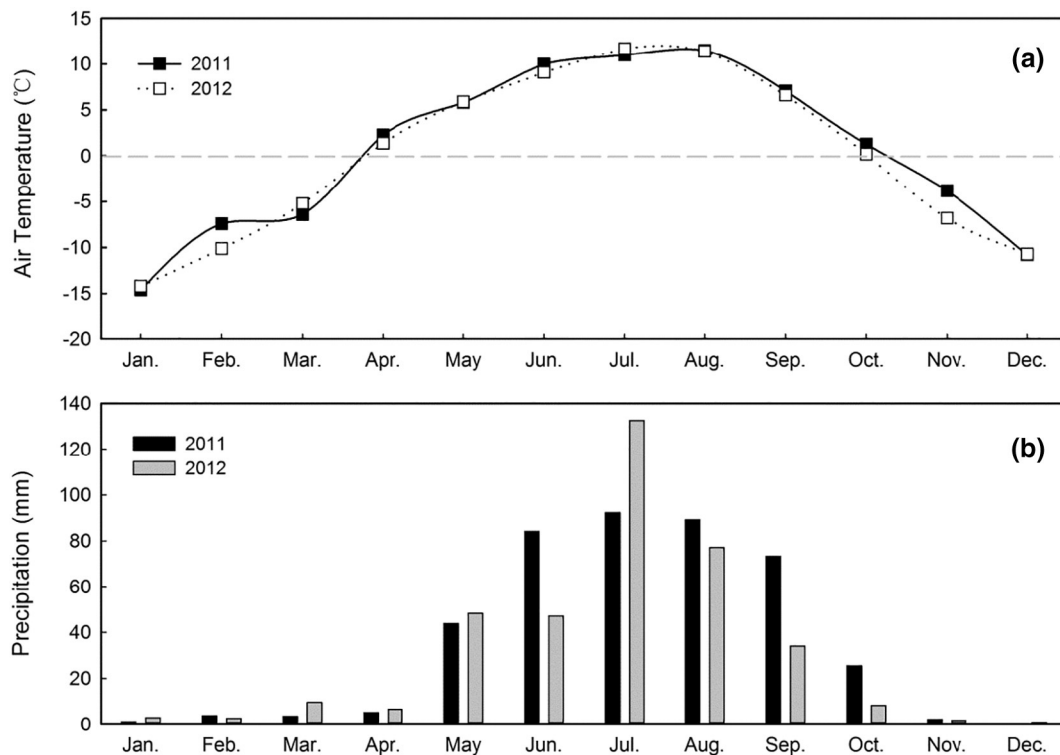


Figure 2. Study site mean monthly (a) air temperature and (b) precipitation for 2011 and 2012.

three blocks, each consisting of three grazing regimes: continuous grazing, seasonal grazing, and a control plot with a grazing intensity of 0 sheep ha^{-1} (0.58 ha in size). In the continuous grazing sites, grazing lasted from January to December and there were five intensity levels: 1) light grazing (C-LG, targeted for 30% utilization of peak growing season biomass, and approximately 1.72 sheep ha^{-1}); 2) moderate light grazing (C-MLG, 40% utilization, and approximately 2.29 sheep ha^{-1}); 3) moderate grazing (C-MG, 50% utilization, and approximately 2.87 sheep ha^{-1}); 4) moderate heavy grazing (C-MHG, 60% utilization, and approximately 4.13 sheep ha^{-1}), and 5) heavy grazing (C-HG, 70% utilization, and approximately 5.62 sheep ha^{-1}), using fenced plots of five sizes (2.91, 2.18, 1.74, 1.45, and 1.25 ha, respectively). In the seasonal grazing sites, grazing lasted from June to October (fenced from November to May to avoid large livestock) and three grazing intensities were applied: 1) light grazing (S-LG, 30% utilization, and approximately 1.72 sheep ha^{-1}); 2) moderate grazing (S-MG, 50% utilization, and approximately 2.87 sheep ha^{-1}); and 3) heavy grazing (S-HG, 70% utilization, and approximately 5.62 sheep ha^{-1}), using fenced plots of three sizes (2.91, 1.74, and 1.25 ha, respectively).

Grazing animals were mature (16 months old), medium-frame Tibetan sheep with an average weight of about 17 kg. In the grazing period, grazing lasted from 0800 h to 1900 h with no supplementary feeding. In addition, the sheep were watered twice a day.

Data Collection and Calculations

At each experimental site of the three blocks, sampling points were established along a large “W” (one quadrat sampled at every inflection point), resulting in five replications per site. For all grazing regimes, a vegetation survey was conducted in every month of the growing season (June to October) during 2011 and 2012. Within each quadrat (0.5 m \times 0.5 m), all living biomass (all aboveground biomass) was harvested (hand clipped to ground level), sorted by species, oven dried at 85°C for 24 h to a constant mass, and weighed. In the meantime, the covers of all species were monitored using the step-point method (Mueller-Dombois and Ellenberg 1974) and plant height was recorded using a ruler.

The vegetation was classified into four plant functional groups according to the following categories: Poaceae, Cyperaceae, Leguminosae, and weeds. The biomass of these four plant functional groups was used in statistical and multivariate analyses to test the effects of grazing treatments on vegetation composition. Species richness (S) was estimated as the number of species per quadrat. Relative importance values of each species (P_i) were calculated from the average of related biomass, related cover, and related height. P_i was used to calculate the Simpson diversity index D ($D = 1 - \sum P_i^2$) and equitability J' . Equitability (evenness) was calculated as $-\sum P_i \times \ln(P_i) / \ln(S)$ (Magurran 1994).

Statistical Analysis

All statistical analyses were implemented in SPSS 22.0 for Windows (Microsoft, Redmond, WA). Statistical significance was defined at the 95% confidence level ($\alpha = 0.05$). Mean values in the text are averages of three blocks per treatment ± 1 SE. The effects of grazing regimes were tested by comparing the three matching stocking rates (1.72, 2.87, and 5.62 sheep ha^{-1}). Three-way analysis of variance (ANOVA) was employed to examine the effects of month, grazing regime, and grazing intensity on total aboveground biomass, as well as the biomass of Poaceae, Cyperaceae, Leguminosae, and weeds in 2011 and 2012. One-way ANOVA was used to test the influences of grazing intensity on total aboveground biomass and biomass of the four functional groups in each month of 2011 and 2012. Before ANOVA, the total aboveground biomass and biomass of the four functional groups were transformed using the natural logarithm to improve the normality of the data. Linear regression was performed to evaluate the impact of grazing intensity on total aboveground biomass and biomass of the four functional groups at the continuous and seasonal grazing sites. Using data from August of 2011 and 2012, three-way ANOVAs were employed to examine the effects of year, grazing regime, and grazing intensity on species richness (S), Simpson diversity index (D), and equitability (J'). Relationships among species richness (S), Simpson index (D), and equitability (J') in the continuous and seasonal grazing sites with grazing intensity were

assessed by linear regression. All curves were fit with SigmaPlot version 12.5 (Systat Software, Inc., San Jose, CA).

Results

Effects of Grazing Treatments on Total Aboveground Biomass

Averaged across the four matching stocking rates, aboveground standing crop was greater ($P < 0.001$) in the seasonal grazing treatments than in the continuous treatments in both 2011 and 2012 (Fig. 3). Moreover, at both seasonal grazing and continuous grazing sites, total aboveground biomass showed significant seasonal variation during the study period (Table 1, $P < 0.0001$ for 2011 and $P < 0.0001$ for 2012), with a unimodal pattern (see Fig. 3). In addition, grazing intensity did not affect the pattern of seasonal variation in the total aboveground biomass in either year (see Table 1, $P = 0.538$ and $P = 0.233$ for 2011 and 2012, respectively), while different grazing regimes had a significant impact (see Table 1, $P < 0.0001$ and $P < 0.0001$ for 2011 and 2012, respectively). In each month of both years, grazing intensity mostly explained the changes in total aboveground biomass (see Table 1, $P < 0.0001$ and $P < 0.0001$ for 2011 and 2012, respectively) at both grazing sites; as grazing intensity increased, the total aboveground biomass decreased (see Fig. 3). Month, grazing regime, and grazing intensity did not have significant interaction effects on total aboveground biomass in 2011 (see Table 1, $P = 0.179$ and $P = 0.430$, respectively). However, in 2012, total aboveground biomass was related to the grazing regime \times grazing intensity interaction and the month \times grazing regime \times grazing intensity interaction (see Table 1, $P = 0.006$ and $P = 0.029$, respectively), possibly due to the differences in precipitation patterns between 2011 and 2012 (see Fig. 2b).

The regression analysis showed that total aboveground biomass had a significantly negative relationship with grazing intensity (or stocking rate) at both seasonal and continuous grazing sites (see Fig. 3, $R^2 =$

Table 1

Results (F values) of three-way analysis of variance on the effects of months (M), grazing regimes (GR), grazing intensities (GI), and the interactions on aboveground biomass, biomass of Poaceae, Cyperaceae, Leguminosae, and weeds during 2011 and 2012

	df	Aboveground biomass	Biomass of Gramineae	Biomass of Cyperaceae	Biomass of Leguminosae	Biomass of others
2011						
M	4	191.20***	53.58***	10.35***	42.90***	6.32***
GR	1	12.48**	5.91*	18.25***	59.15***	46.89***
GI	4	84.66***	41.22***	4.17**	8.91***	3.25*
M \times GR	4	8.97***	0.98	2.99*	14.31***	4.55**
M \times GI	16	0.93	1.79*	1.11	1.98*	1.93*
GR \times GI	2	1.75	6.90**	0.69	3.22*	4.64*
M \times GR \times GI	8	1.02	2.81**	2.35*	7.55***	0.97
2012						
M	4	215.16***	103.18***	8.05***	17.18***	4.99**
GR	1	29.15***	0.96	6.89*	38.21***	6.62*
GI	4	95.12***	57.46***	8.21***	2.13	1.90
M \times GR	4	12.62***	7.90***	1.07	3.46*	4.12*
M \times GI	16	1.29	3.77***	1.21	3.40**	1.34
GR \times GI	2	5.42**	2.51	9.12***	0.58	11.73***
M \times GR \times GI	8	2.27*	1.70	2.61*	3.41**	1.11

df indicates degrees of freedom; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

0.447 and 0.543, respectively, $P < 0.0001$). For the seasonal grazing sites, the slope of the regression function (23.08, Fig. 4a) was less than that for the continuous grazing sites (27.61, Fig. 4b), which indicated that the impact of grazing intensity at seasonal grazing sites was less than that at continuous grazing sites.

Effects of Grazing Treatments on Biomass of Plant Functional Groups

When total aboveground biomass was sorted into four plant functional groups, we found that the biomass of Poaceae, Cyperaceae,

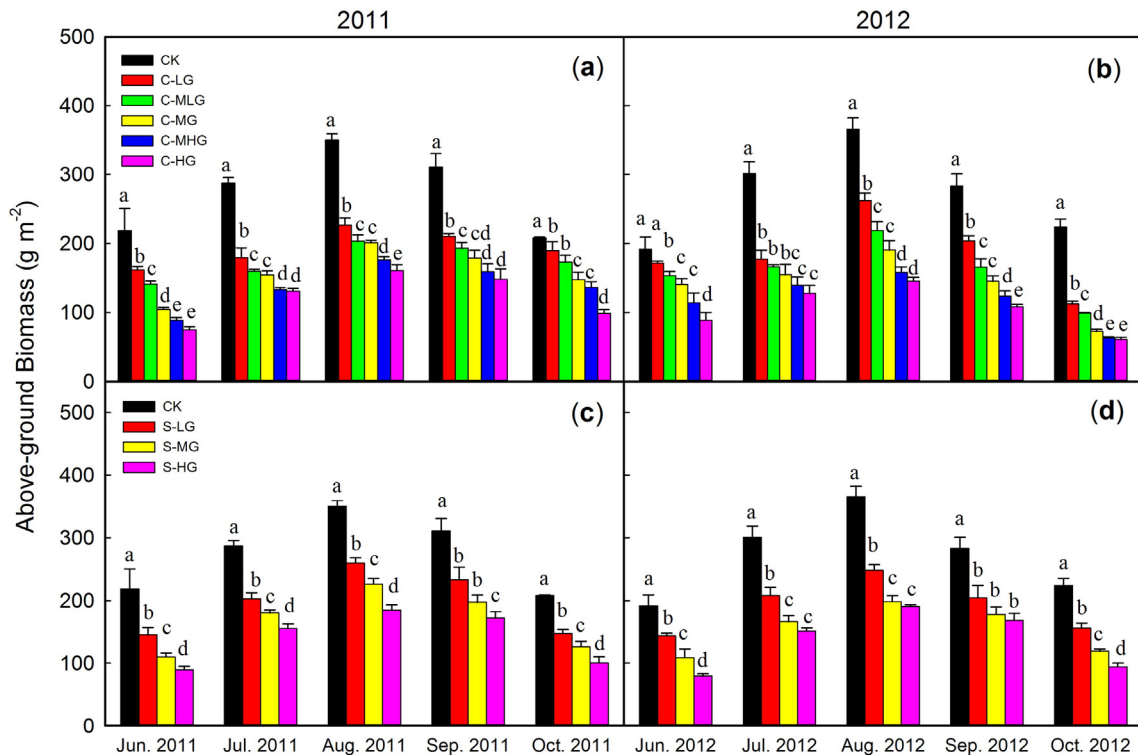


Figure 3. Aboveground biomass at the continuous grazing site during 2011 (a) and 2012 (b) and at the seasonal grazing site during 2011 (c) and 2012 (d). Different letters denote significant difference ($P < 0.05$) between grazing intensity in each month.

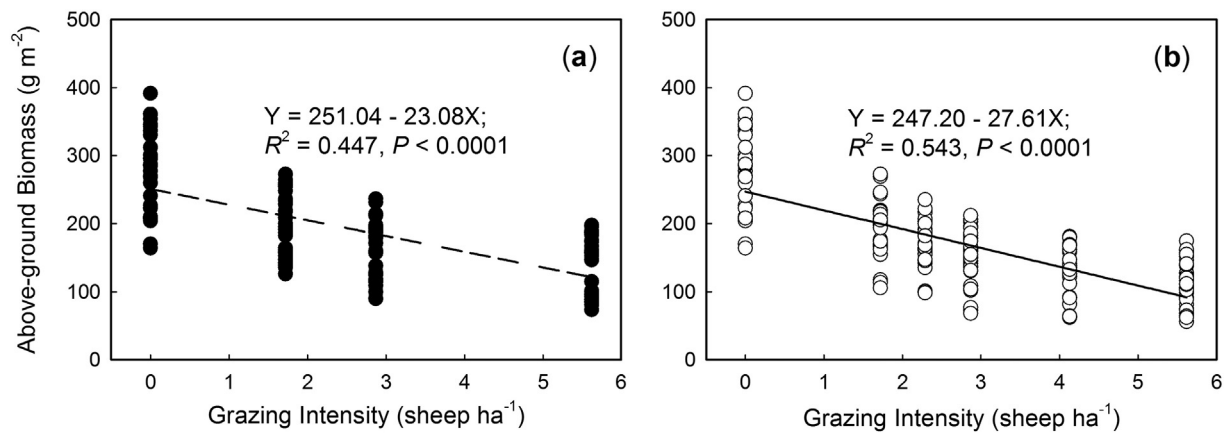


Figure 4. Relationships between aboveground biomass and grazing intensity at the seasonal grazing site (a) and continuous grazing site (b).

Leguminosae, and weeds all showed significant seasonal variation in both years (Table 1 and Figs. S1–S4, available online at <https://doi.org/10.1016/j.rama.2017.09.007>). The biomass of the four plant functional groups were all significantly related to grazing regime in both 2011 and 2012 (see Table 1), except for Poaceae in 2012 ($P = 0.330$, see Table 1). Grazing intensity had a significant effect on the biomass of the four plant functional groups in 2011 but only influenced the biomass of Poaceae and Cyperaceae in 2012 (see Table 1). Poaceae had the greatest biomass, and Poaceae biomass explained the majority of variance in total aboveground biomass (see Figs. 3 and S1), which exhibited a unimodal pattern in both 2011 and 2012 (see Fig. S1). However, the biomass of Cyperaceae, Leguminosae, and weeds showed more complicated seasonal patterns during the study period (see Figs. S2–S4). Weeds had the lowest biomass in both seasonal and continuous grazing sites.

Like the total aboveground biomass, the biomass of Poaceae, Cyperaceae, and Leguminosae all showed significantly negative correlations with grazing intensity ($P < 0.05$, Fig. 5a–f). However, the biomass of weeds increased as the grazing intensity increased, especially for the continuous grazing sites in 2012 ($P < 0.001$, Fig. 5h). All slopes of the regression functions showed that grazing intensity had greater effects on the biomass of the four plant functional groups at the continuous grazing sites than at the seasonal grazing sites (see Fig. 5).

Effects of Grazing Treatments on Species Richness (S), Simpson Index (D), and Equitability (J')

On the basis of data obtained in August of 2011 and 2012, it was found that grazing treatment had the same effect on species richness (S) in both years; as grazing intensity increased, the species richness (S) decreased, but this trend was not significant (Table 2, $P = 0.054$) (Fig. 6a and b). There was no significant difference in species richness (S) between 2011 and 2012 (see Table 2, $P = 0.100$) (see Fig. 6a and b). Grazing regime did not influence the species richness (see Table 2, $P = 0.286$). The impact of grazing intensity on species richness (S) did not differ ($P = 0.833$, see Table 2) between the two grazing regimes (see Fig. 6a and b).

At both sites, as grazing intensity increased, the species diversity index (Simpson index, D) decreased significantly (see Table 2, $P < 0.0001$) (see Fig. 6c and d), except for the seasonal grazing sites in 2011 (see Fig. 6c). No significant difference in the Simpson index (D) was found between 2011 and 2012 (see Table 2, $P = 0.784$) (see Fig. 5c and d). The influence of grazing intensity on the Simpson index (D) at the seasonal grazing sites was less than that at the continuous grazing sites (see Table 2, $P = 0.001$) (see Fig. 6c and d).

The equitability (or evenness, J') showed a pattern of increase followed by a decrease as grazing intensity increased, with the greatest values at 1.72 sheep ha⁻¹ (see Fig. 6e and f). However, there was no significant correlation between equitability (J') and grazing intensity at the seasonal grazing sites in 2012 (see Fig. 6f). In addition, there was no significant difference in equitability (J') between 2011 and 2012 (see Table 2, $P = 0.436$) (see Fig. 6e and f). Likewise, the influence of grazing intensity on equitability (J') at the seasonal grazing sites was not different from that observed at the continuous grazing sites (see Fig. 6e and f).

Discussion

The results of this study show that 1) as grazing intensity increased, total aboveground biomass declined significantly (see Fig. 4); 2) different plant functional groups had different responses to grazing intensity, indicating that plant composition changed under grazing treatments, and the effects of grazing intensity on the biomass of plant functional groups were weaker for seasonal grazing than continuous grazing (see Fig. 5); and 3) on the basis of observed species richness (S), Simpson diversity (D), and equitability (J'), grazing intensity had a clear tendency to reduce species diversity, but this effect was not observed at seasonal grazing sites in 2011 (see Fig. 6). Therefore, seasonal grazing might be a better management practice to maintain biomass production and plant diversity at the experimental site.

In both years, grazing intensity and grazing regime significantly influenced the total aboveground biomass (see Fig. 3), consistent with previous results obtained in the same place (Wang et al. 2016) and a similar study in the Qinghai-Tibet plateau (Wu et al. 2014). Aboveground biomass at all sites showed significant seasonal variation, coinciding with changes in precipitation (data not shown). Two yr of monitoring at the experimental site revealed that the plant composition was affected by changes in grazing intensity and by grazing regime, to a certain degree (see Figs. S1–S4). Changes in plant composition were largely driven by declines in the biomass of palatable species (especially Poaceae) and an increase in the biomass of weeds (less palatable) (see Figs. S1–S4). Similar results were observed by Sternberg et al. (2015). As grazing intensity increased, Poaceae dominance decreased and other plant functional groups became more competitive (see Fig. 4). However, even under the most extreme grazing conditions (C-HG and S-HG, 70% utilization), Poaceae was still most abundant (see Fig. S1), indicating a relatively high resistance of Poaceae to grazing. This can be explained by the long grazing history of the Qinghai-Tibet plateau, as suggested by Orenstein et al. (2012) in the eastern Mediterranean region. In such ecosystems, the dominant plant species typically exhibit remarkable resistance, possessing a range of mechanisms for adapting to changes in grazing conditions (Aboling et al. 2008; Ruppert et al.

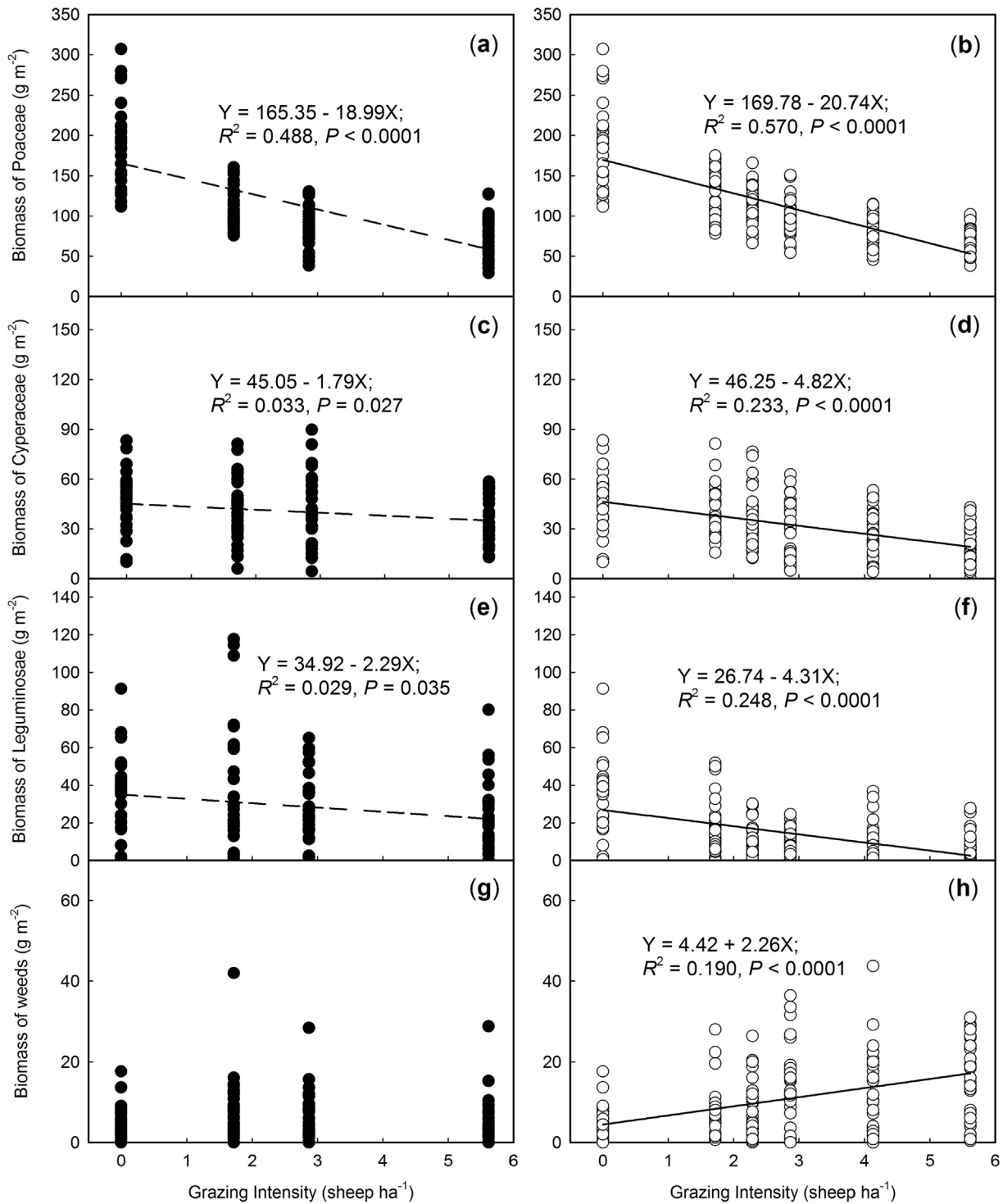


Figure 5. Relationships between biomass of Poaceae (a and b), Cyperaceae (c and d), Leguminosae (e and f), and weeds (g and h) and grazing intensity at the seasonal grazing site (a, c, e, and g) and the continuous grazing site (b, d, f, and h).

2015). Plant community composition changed throughout the experiment, as indicated by changes in biomass, with weed species becoming more abundant under medium and high stocking rate treatments. However, the underlying differences between the continuous and seasonal grazing regimes also induce important changes in plant community composition. Poaceae are more vulnerable to grazing, and thus they are dominant in ungrazed or lightly grazed grassland, while weeds partially avoid grazing and become more competitive under a high grazing intensity.

The grazing intensity did not significantly affect the species richness (see Table 2) in this experiment, consistent with the results of Pizzio et al. (2016) for a subtropical grassland of Argentina. The lack of an effect of grazing intensity on species richness contrasts with the wide differences observed in grazed-ungrazed comparisons in grasslands. For example, Lezama et al. (2014) observed 106% greater species richness in grazed sites than in ungrazed sites across a transect from Pampean to Campos grasslands, and Altesor et al. (2005) found 45% more species in grazed plots than in control plots. There are diverse

Table 2

Results of three-way analysis of variance on the effects of yr (Y), grazing regimes (GR), grazing intensities (GI), and interactions on species richness, Simpson index, and equitability

	df	Species richness (S)		Simpson index (D)		Equitability (J')	
		F	P	F	P	F	P
		Y	1	2.86	0.100	0.08	0.784
GR	1	1.17	0.286	8.00	0.008	2.70	0.109
GI	4	1.72	0.054	59.52	< 0.0001	46.49	< 0.0001
Y × GR	1	1.17	0.286	5.81	0.021	0.09	0.766
Y × GI	4	0.33	0.855	0.50	0.733	0.30	0.877
GR × GI	2	0.18	0.833	8.15	0.001	0.63	0.536
Y × GR × GI	2	0.01	0.990	1.60	0.216	0.61	0.551

Note: Values with significance < 0.05 are indicated in bold.

explanations for how grazing increases species richness (Milchunas and Lauenroth 1993; Han and Ritchie 1998) including: 1) increased resource availability (light and N), 2) increased spatial heterogeneity,

and 3) alteration of the competitive balance between species. In general, grazing changes the competitive hierarchies of plants and so promotes coexistence between plant species. In addition, the effects of herbivores on plant species richness depend on the type and abundance of herbivore species (Han and Ritchie 1998). The effects of herbivores on plant diversity also differ according to the environment (Milchunas and Lauenroth 1988). Increased species richness under grazing has been found in relatively productive grasslands, such as temperate grasslands in Europe (Bakker 1989; Hodgson and Illius 1996; Wieren 1996) and tall grasslands in western Serengeti (Belsky 1992; McNaughton 1994). However, in arid or highly saline environments (less productive), grazing does not change or could even decrease plant diversity (Hobbs and Hueneke 1992; Milchunas and Lauenroth 1988), which was also found in our study. Other researchers have also found that species richness is much more responsive to environmental variation (such as variation in temperature and precipitation) than grazing pressure (Ren et al. 2012; Pizzio et al. 2016).

In contrast to the lack of an effect on species richness, grazing treatments significantly reduced species diversity by influencing equitability

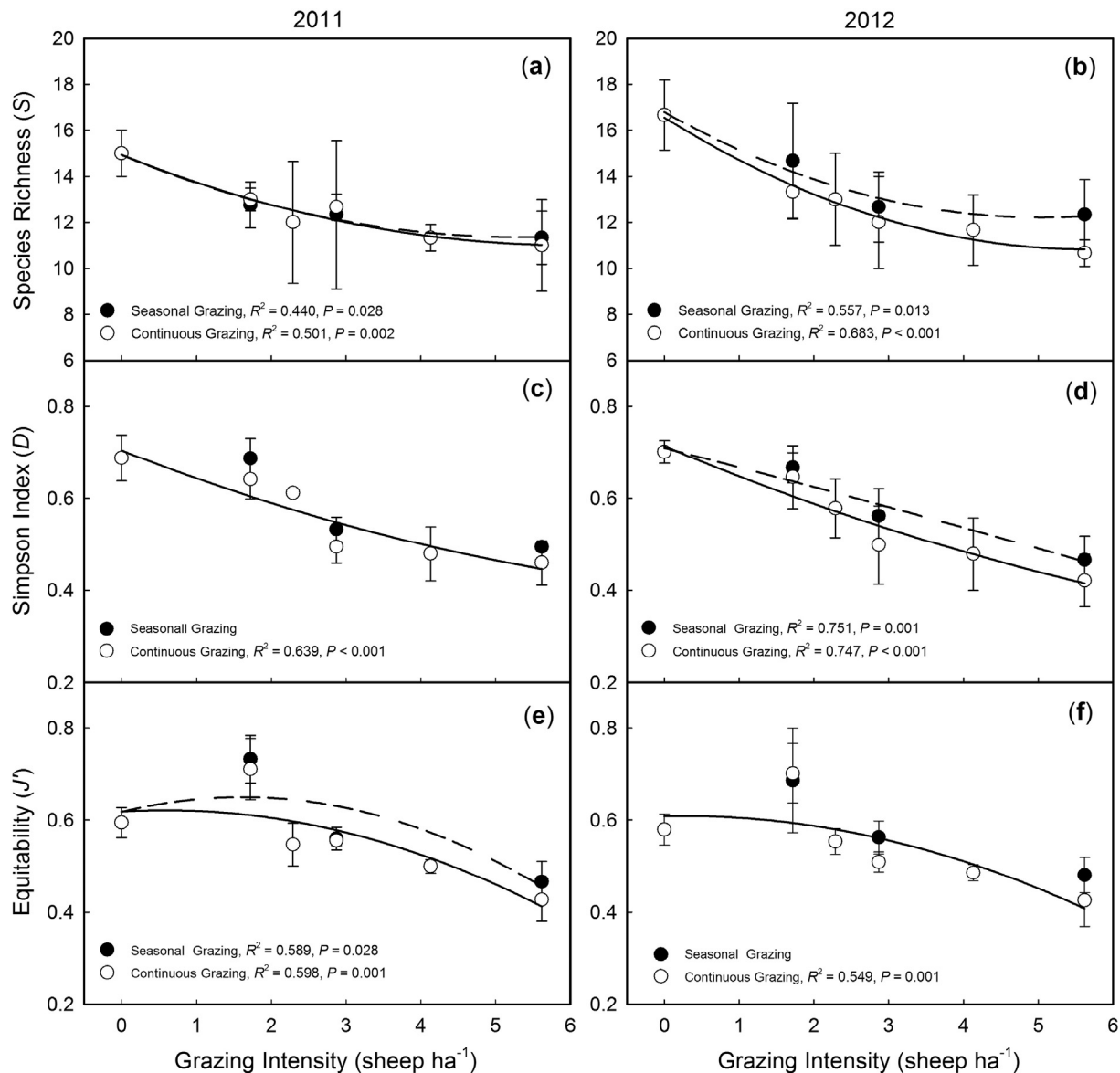


Figure 6. Changes of species richness (S, a and b), Simpson index (D, c and d), and equitability (J', e and f) at the seasonal grazing site (black dots) and continuous grazing site (open dots) during 2011 (a, c, and e) and 2012 (b, d, and f).

(evenness) (see Table 2 and Fig. 6). Likewise, Hillebrand et al. (2008) indicated that evenness is more sensitive to disturbance than species richness. This result contrasts with those of previous studies comparing grazed versus ungrazed treatments, in which grazing always has positive effects on the species diversity index (Rusch and Oesterheld 1997; Altesor et al. 2005; Cingolani et al. 2008). However, in the literature, different levels of stocking rates had diverse effects on plant species diversity (Poza et al. 2006; Dumont et al. 2009; Marriott et al. 2009; Marion et al. 2010; Campbell et al. 2013). Models developed by Milchunas and Lauenroth (1988) and Huston (1979) suggest that the different responses of species diversity might stem from environmental variation between different sites, such as variation in moisture. Additionally, the duration of the grazing experiments and the time scale of the ecosystem response may also account for the differences in responses among studies.

Conclusions

Our results indicated that increasing grazing intensity could lead to dramatic changes in species composition that are likely to reduce forage quality owing to a loss of palatable grasses and increase of weeds. In addition, the reduction in species diversity might compromise the stability of ecosystem functions (Hillebrand et al. 2008). Our results also suggest that the seasonal grazing regime had less effect on species diversity than that of continuous grazing. These findings emphasize the importance of grazing regime in regulating the effects of grazing on plant communities and the importance of seasonal grazing in the maintenance of ecosystems, especially in the Qinghai-Tibetan Plateau. The periodic resting of grassland could be a good management strategy for the promotion of palatable species, thereby minimizing the risk of shifts to undesirable species in the plant community. Our results will also help to better assess how plant community composition will be affected under future climate change conditions.

Acknowledgments

This study was supported by the Natural Science Foundation of China (31370469, 31772655) and the National Science and Technology Support project (2014BAC05B03). We are grateful to Wei Zheng, Xiankuan Hou, Lei Song, and Qihai Zhao for their efforts in the field sampling and to Shulan Su and Meiling Song for help making the figures. We also thank Changgui Wan for his constructive advice in the revising process.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.rama.2017.09.007>.

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