

Effects of sheep grazing and precipitation patterns on sandy grassland vegetation in Inner Mongolia, China

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Abstract—To understand the effects of grazing by domestic sheep and of precipitation on sandy grassland vegetation in northern China, a field grazing and enclosures experiment was conducted from 1992 to 2006 in Horqin Sand Land, Inner Mongolia. Results indicated that (1) overgrazing resulted in severe damage to grassland vegetation, but moderate grazing had no significant effects on species richness and diversity, though it can result in a slight decrease in plant cover and height, while light grazing or no grazing (enclosures by fence) benefited the restoration of degraded vegetation; (2) although average species richness, plant diversity, vegetation cover and canopy height were higher in rainy years or warm, moist periods than in drought years or sustained drought periods, the differences in height and species richness were not significant; (3) continuous overgrazing can result in unpalatable herbage becoming dominant in the grassland community; (4) a sustained wet climate was favorable to perennial herbage and annual mesophytes, while annual xerophytes became dominant under sustained drought; (5) the proper grazing intensity for the Horqin sandy grassland is 3-4 sheep per hectare in rainy years, which should be reduced to 2-3 sheep per hectare in drought years.

Keywords—Sandy grassland; grazing intensity; precipitation effects; Horqin; northern China

I. INTRODUCTION

The effects of world population increase, human activity and climate change on terrestrial ecosystems have become increasingly stronger in recent decades, resulting in severe damage to the ecological environment and to biological resources in many areas [1, 2]. In particular, most of the sandy grassland in the steppe area of northern China is suffering from severe degradation and land desertification because of severe overgrazing and a warming-drying climate, which not only restrains local socioeconomic development, but also brings a severe threat to eco-security in the region [3, 4]. Thus, more and more attention is being paid to the study of the effects of livestock grazing and climatic change on grassland vegetation in China [5, 6].

There is a broad literature concerning the effects of grazing and climate change on grassland vegetation. For example, effects of grazing intensity on aboveground biomass and canopy cover [7, 8], changes in vegetation structure after long-term grazing [9, 10], species richness and biodiversity changes in degraded grasslands under different grazing intensities [6], effects of seasonal fire, bison grazing

and climatic variation on tall-grass prairie vegetation [10], grazing and climatic change effects on alpine vegetation of the Himalaya [2], relationships among a vegetation index and precipitation and air temperature [11], and so on. Many results show that grazing is an important factor determining patterns and dynamics of grassland vegetation [12, 13], and climatic change also has distinct impacts on grassland vegetation development [2, 11]. Appropriate grazing can promote plant growth, while overgrazing can result in grassland degradation [5, 10]. Increasing air temperature can extend the general growing season [1, 11], and drying climate should decrease plant diversity and primary productivity [14, 15].

Inner Mongolia is the largest and most important steppe region in China [4], and one of the most severely degraded areas of grassland [15]. To understand changing mechanisms of grassland degradation in this area, researchers have investigated separately the effects of grazing [3], enclosure [6, 7] and climatic change [4] on grassland vegetation from different viewpoints. However, thus far there have been few studies of the combined effects of grazing and precipitation pattern on sandy grassland vegetation in this region. The main objectives of this study were: (1) to compare changing trends in plant species richness, diversity, canopy cover and height under different grazing intensities; (2) to analyze the effects of precipitation pattern on species richness, diversity, cover and height; and (3) to evaluate the combined effects of grazing and precipitation on species structure in grassland vegetation.

II. MATERIALS AND METHODS

A. Study Area

The study area is located in Naiman county (42° 55' N, 120° 42' E, 345 m elevation) in the eastern part of Inner Mongolia, northern China. Naiman County is located in the hinterland of Horqin Sand Land and has a temperate, continental semi-arid monsoon climate regime. The mean annual precipitation is 353 mm, mean annual potential evaporation is 1935 mm, and mean annual temperature is 6.9 °C. The annual frost-free period is 130 to 150 days. The average annual wind speed is 3.4 m s⁻¹. The geomorphology is characterized by dunes alternating with gently undulating lowland areas in this region. Two soil types predominate in the Horqin Sand Land, sandy Kastanozems under original grassland, generally in the west and remnant elsewhere, and

more widespread Arenosols in desertified central and eastern areas [16, 17]. The study area is dominated by Arenosols, with remnant Kastanozems in the least degraded portions. Dominant plant species in the region are grasses and forbs: *Pennisetum centrasiaticum*, *Phragmites communis*, *Setaria viridis*, *Chloris virgata*, *Cleistogenes squarrosa*, and *Aristida adscensionis* [3]. Shrubs and trees are minor components of the vegetation.

B. Experimental Design

The experiment was conducted during the years 1992 to 2006. A flat and open natural grassland, with an area of about 100 ha, was selected in the spring of 1992 in the central part of Naiman county. The grassland is part of an area monitored long-term by the Naiman Desertification Research Station, Chinese Ecosystem Research Network (NDRS-CERN). The grassland had been exposed to long-term grazing by sheep, and the mean grazing intensity before the trial was 4.5-5.0 sheep ha⁻¹ [3]. The grassland was experiencing slight degradation due to overgrazing by sheep, according to the classification criteria of grassland degradation degree of Zhu and Chen [18]. The site was fenced into experimental plots of 1.5 ha (200m×75 m) in 1992. The experiment was divided into two stages. The first stage was a grazing trial in 1992-1996 to study effects of grazing by sheep on the grassland vegetation. The trial design was four grazing treatments by three spatial replications. The grazing treatments were heavy grazing (HG, 6 sheep ha⁻¹), moderate grazing (MG, 4 sheep ha⁻¹), light grazing (LG, 2 sheep ha⁻¹), and no grazing (NG, 0 sheep ha⁻¹). To minimize the potential effects of wind erosion on the HG sites and transport of sand to the others, the experimental plots were arranged in increasing order of disturbance along the dominant wind direction: NG, LG, MG and HG. Plots were adjacent and contiguous to one another. Sheep were kept on the plots in the daytime and in off-plot shelters at night, and the same sheep were kept on the same plot each day during the trial period from June 1 to September 30 each year. The second stage of the overall experiment was a restoration trial in 1997-2006. The sheep were removed from all grazing plots at the end of the grazing trial and these plots were used to monitor restoration processes of the grassland exposed to different grazing intensities (but these restoration data for the grazed sites were not analyzed in this paper, only the data from non-grazed sites).

C. Data Collection and Analysis

For the trial period, three fixed parallel sample belts were set in each plot. The length and width of each sample belt were 200m and 1m, and the space between sample belts was about 15m. Twenty fixed quadrats (1m×1m) with a 10m interval were established along each belt. The number of plant species in each quadrat, average canopy height, cover and frequency of each species observed were recorded in early August each year from 1992 to 2006. Canopy height was the mean height of the plants and cover was the aggregate cover of all species inside the quadrats [19]. Species richness was calculated as the average number of species per plot. Importance values of each species were

calculated as $IV=C'+H'+F'$, where C' is relative cover, H' is relative height and F' is relative frequency. Plant diversity was calculated as the Shannon-Wiener index:

$$H = -\sum_{i=1}^s P_i \ln P_i$$

where S is number of species, and P_i is the proportional importance value of the i th species for each plot [7].

The climatic data were collected from the weather station of the NDRS-CERN at a distance of 1200m from the experimental grassland. As can be seen in Figure 1, mean annual precipitation was 325.4 mm and mean annual air temperature was 7.6 °C during the trial period. The climate condition in the trial period can be divided into two stages: a warm-mesic stage (1992-1999) and a warm-xeric stage (2000-2006), with mean precipitation of 383.9mm and mean temperature of 7.6 °C in the former, and 258.6mm and 7.6 °C in the latter.

Statistical analysis of the data was carried out with the SPSS program for Windows, version 11.5. Multiple comparison and one-way analysis of variance (ANOVA) procedures were used to compare the differences among the treatments. Least significant difference (LSD) tests were performed to determine the significance of treatment means at $P < 0.05$ [20]. Pearson's r correlation coefficients were used to evaluate relationships between vegetation parameters and grazing intensity, precipitation and air temperature. Data for five years (1992-1996) were used, with plant parameters from three spatial replicates averaged for each grazing intensity level.

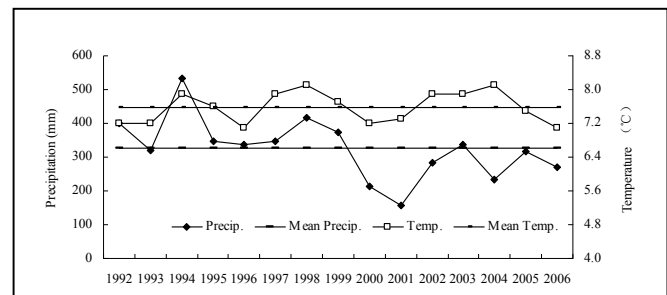


Figure 1. Annual mean precipitation and air temperature during the experimental trial

III. RESULTS

A. Change in species richness and diversity in the grazed sites

Plant species richness and diversity showed different trends of change in the different grazing treatments (Figure 2). Species richness and diversity had increased significantly in all grazing treatments after the first two years of the trial ($P < 0.05$), with the magnitude of change being $MG > HG > LG$. In the latter three years of the study, species richness and diversity decreased significantly in the HG sites ($P < 0.05$), showed a slight decrease in the MG ($P > 0.05$), and increased significantly in the LG ($P < 0.05$). At the end of the trial (1996) compared to conditions before it (1991), species

richness and diversity increased by 67.4% and 14.9% in the LG sites, and by 61.3% and 12.5% in the MG sites, and

decreased by 9.6% and 1.2% in the HG sites.

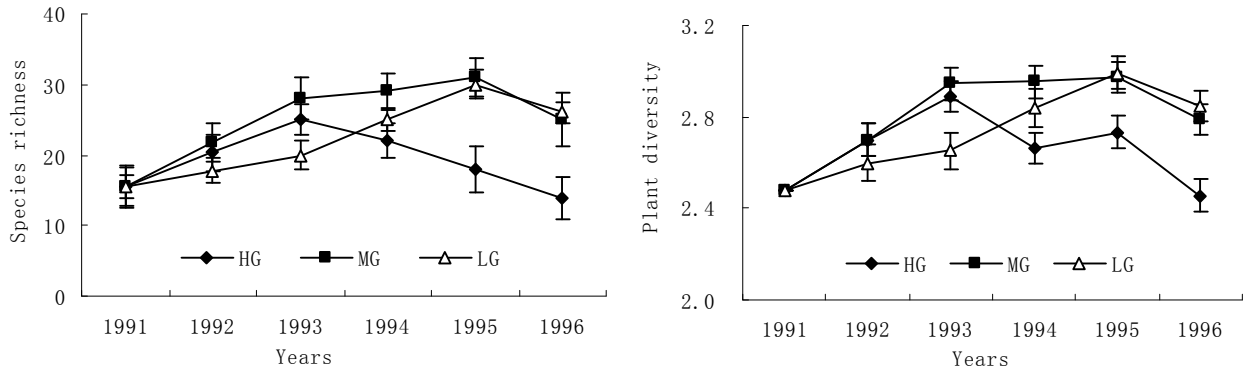


Figure 2. Changes in species richness (left) and plant diversity (right) under different grazing intensities. HG: Heavy Grazing; MG: Moderate Grazing; LG: Light Grazing. Bars represent means±SD.

B. Change in species richness and diversity in the non-grazed sites

Plant species richness and diversity increased significantly soon after the plots' enclosure by fence ($P < 0.05$), with increases of 106.5% and 28.2% in 1995 compared with 1991 (Figure 3). Species richness and

diversity at first showed fluctuating changes, becoming relatively stable at high levels in 1995 to 1999, and decreased significantly after 1999. Species richness and diversity decreased by 13.3% and 27.8% in 2006 compared with 1999, but were still 67.8% and 12.9% higher in 2006 compared to pre-enclosure levels (1991).

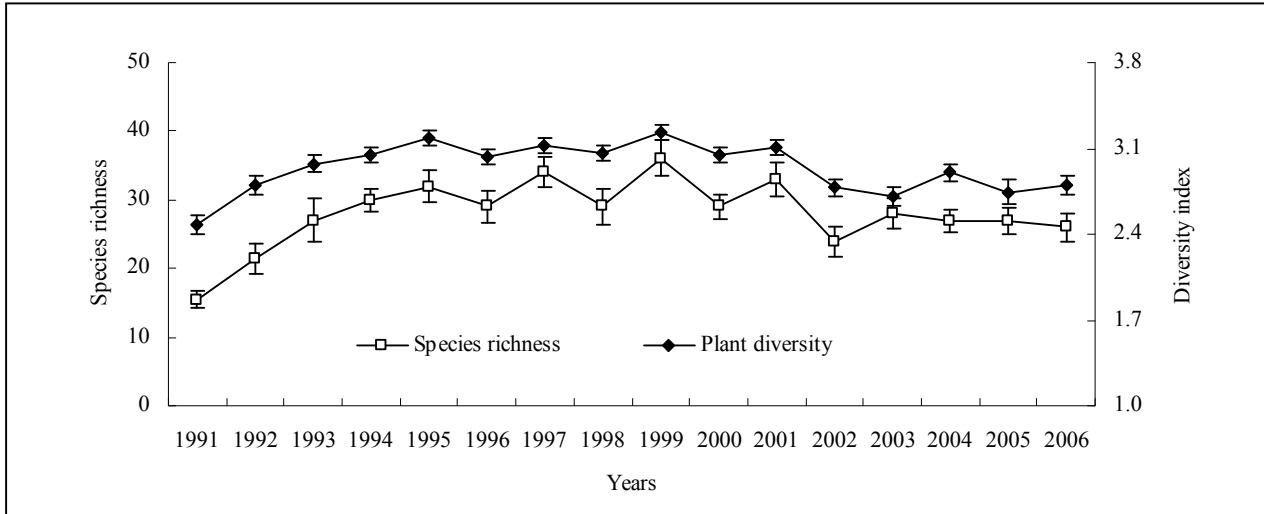


Figure 3. Changes in species richness and plant diversity on enclosed, non-grazed sites. Bars represent means±SD.

C. Change in plant canopy cover and height in the grazed sites

Plant cover and height decreased significantly in the HG sites ($P < 0.05$), by 95.3% and 79.4% in 1996 compared to 1991 (Figure 4). In the MG sites, cover and height slightly increased in the first two years, then decreased slightly in the

following three years, and were 3.4% and 8.0% lower in 1996 than in 1991. In the LG sites, cover and height were relatively stable in the first two years, then increased significantly in the following three years, being 35.7% and 52.0% higher in 1996 than in 1991.

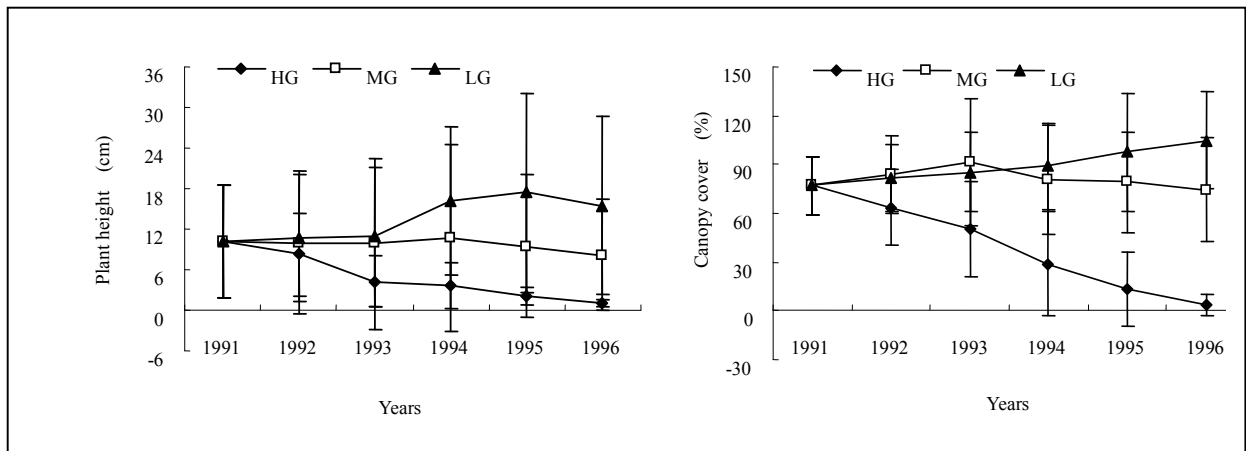


Figure 4. Changes in plant height (left) and canopy cover (right) under different grazing intensities. HG: Heavy Grazing; MG: Moderate Grazing; LG: Light Grazing. Bars represent means±SD.

D. Change in plant canopy cover and height in the non-grazed sites

As seen in Figure 5, cover and height showed broadly similar trends of change after removal of grazing: significant increase ($P < 0.05$) in the first several years, then a period of fluctuating change, then a significant decrease ($P < 0.05$)

from peak levels. But the magnitude of increase in height was greater than for cover in the early period of enclosure, while the magnitudes of decrease were opposite in the later term. The cover was 60.1% lower, and the height was 130.4% higher at the end of the trial (2006) than before it (1991).

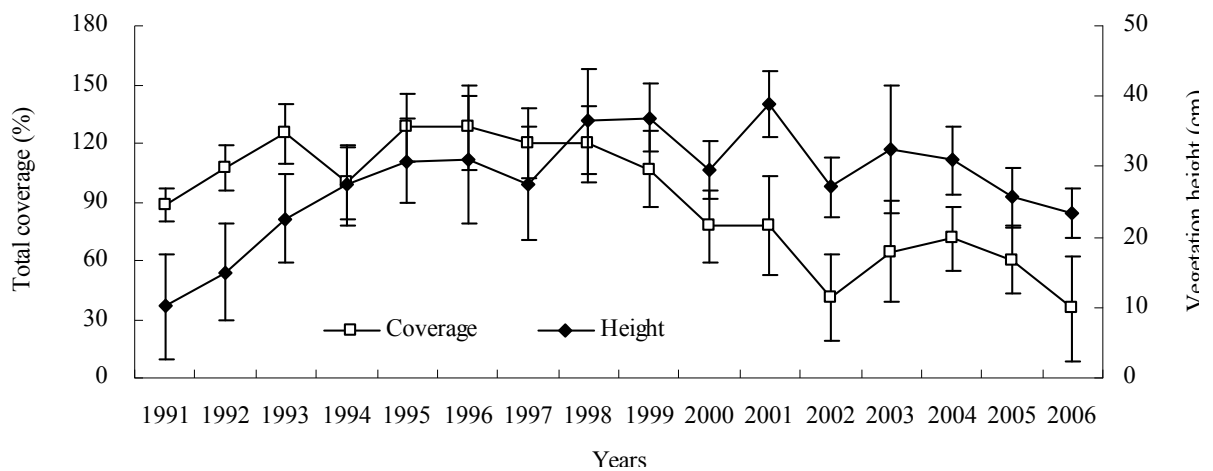


Figure 5. Changes in plant height and canopy cover on enclosed, non-grazed sites. Bars represent means±SD.

E. Changes in plant community structure in the grazed sites

The importance values of some primary species changed differentially under the different grazing densities (Table 1). In the HG sites, values for the perennial *Lespedeza davurica* and the annuals *Chloris virgata* and *Eragrostis pilosa* increased significantly, while values for the perennial *Aneurolepidium dasystachys* and annuals *Setaria viridis*,

Digitaria ciliaris and *Aristida adscensionis* decreased. Values were relatively stable for most primary species in the MG sites, except for an increase in *A. adscensionis*. In the LG sites, values for the perennial *Phragmites communis* and the annual *A. adscensionis* increased, while values for the perennial *Pennisetum centrasiaticum* and the annual *S. viridis* decreased.

TABLE I. CHANGES IN IMPORTANCE VALUES OF PRIMARY PLANT SPECIES IN THE GRAZING TREATMENT SITES. HG: HEAVY GRAZING; MG: MODERATE GRAZING; LG: LIGHT GRAZING.

sites	year	Perennial plants				Annual plants						
		Pece	Phco	Anda	Leda	Sevi	Chvi	Arad	Erpi	Dici	Arad	Saco
LG	92	0.17	0.09	0.07	0.04	0.12	0.03	0.11	0.00	0.08	0.00	0.05
	93	0.16	0.07	0.10	0.03	0.11	0.03	0.12	0.00	0.07	0.00	0.05
	94	0.10	0.08	0.06	0.03	0.07	0.03	0.18	0.00	0.07	0.01	0.07
	95	0.06	0.10	0.04	0.04	0.05	0.02	0.15	0.02	0.05	0.01	0.08
	96	0.07	0.12	0.05	0.04	0.04	0.02	0.18	0.01	0.03	0.06	0.06
MG	92	0.05	0.08	0.12	0.05	0.16	0.02	0.00	0.00	0.06	0.02	0.02
	93	0.04	0.08	0.13	0.04	0.13	0.03	0.08	0.01	0.07	0.02	0.02
	94	0.02	0.05	0.13	0.05	0.11	0.03	0.12	0.01	0.08	0.04	0.02
	95	0.03	0.05	0.12	0.03	0.09	0.03	0.17	0.02	0.07	0.03	0.02
	96	0.04	0.06	0.14	0.03	0.12	0.04	0.19	0.01	0.04	0.03	0.03
HG	92	0.07	0.00	0.08	0.03	0.15	0.03	0.08	0.02	0.09	0.09	0.01
	93	0.05	0.02	0.07	0.04	0.17	0.04	0.09	0.02	0.08	0.08	0.01
	94	0.04	0.00	0.08	0.04	0.14	0.16	0.10	0.05	0.09	0.05	0.00
	95	0.03	0.02	0.00	0.05	0.06	0.22	0.05	0.08	0.08	0.10	0.01
	96	0.02	0.00	0.00	0.11	0.06	0.16	0.00	0.19	0.00	0.08	0.00

F. Changes in importance values of dominant species in the non-grazed sites

In the enclosure sites, the importance values show undulating change for the perennials *P. centrasiatricum*, *P. communis* and *L. davurica*, a significant decrease for the perennial *Aneurolepidium dasystachys* and the annuals *S. viridis*, *D. ciliaris* and *A. adscensionis*, and a significant

increase for *Artemisia scoparia* in the warm-mesic period (1992-1999) (Table 2). In the warm-xeric period (2000-2006), the annuals *S. viridis* and *Chenopodium acuminatum* showed a significant increase in importance value, while most other species decreased in importance value.

TABLE II. CHANGES IN IMPORTANCE VALUES OF PRIMARY PLANT SPECIES IN THE ENCLOSED, NON-GRAZED SITES.

Year	Perennial plants				Annual plants							
	Pece	Phco	Anda	Leda	Sevi	Chvi	Arad	Erpi	Dici	Arsce	Saco	Chac
91	0.03	0.10	0.01	0.04	0.15	0.00	0.08	0.00	0.16	0.00	0.13	0.00
92	0.10	0.10	0.05	0.05	0.09	0.01	0.07	0.00	0.10	0.00	0.09	0.00
93	0.12	0.11	0.06	0.06	0.07	0.02	0.06	0.01	0.06	0.00	0.08	0.00
94	0.09	0.15	0.05	0.06	0.05	0.02	0.07	0.01	0.04	0.02	0.07	0.00
95	0.07	0.12	0.00	0.07	0.05	0.01	0.06	0.01	0.06	0.06	0.06	0.01
96	0.07	0.12	0.00	0.06	0.03	0.00	0.04	0.00	0.02	0.16	0.04	0.01
97	0.07	0.11	0.01	0.06	0.03	0.00	0.02	0.00	0.02	0.16	0.04	0.02
98	0.06	0.10	0.02	0.05	0.06	0.00	0.03	0.00	0.02	0.14	0.03	0.03
99	0.07	0.10	0.01	0.04	0.06	0.01	0.04	0.01	0.02	0.11	0.4	0.04
00	0.06	0.12	0.02	0.05	0.03	0.00	0.00	0.00	0.00	0.07	0.11	0.00
01	0.05	0.08	0.00	0.03	0.08	0.02	0.01	0.03	0.03	0.06	0.14	0.10
02	0.04	0.09	0.00	0.02	0.09	0.03	0.02	0.04	0.04	0.01	0.07	0.08

TABLE III. COMPARISON OF AVERAGE VEGETATION PARAMETERS AMONG DIFFERENT PRECIPITATION PATTERNS IN THE ENCLOSED, NON-GRAZED SITES. NORMAL YEARS ARE THOSE WITH 90% TO 110% OF AVERAGE RAINFALL; RAINY YEARS MORE THAN 110% AND DRY YEARS LESS THAN 90%. VALUES ARE MEANS ± SD. VALUES WITH THE SAME LETTERS WITHIN ROWS ARE NOT SIGNIFICANTLY DIFFERENT AT $P < 0.05$.

Items	Rainy years	Normal years	Dry years	Warm-wet period	Warm-dry period
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Items	Rainy years	Normal years	Dry years	Warm-wet period	Warm-dry period
Cover (%)	108.7±10.3a	100.3±34.6b	60.7±20.7c	118.2±11.0a	61.2±17.0c
Height (cm)	33.6±5.4a	29.5±2.8a	30.0±5.7a	30.4±5.1a	29.7±5.1a
Species richness	31.7±3.8a	30.0±2.9a	27.8±3.4b	31.0±3.2a	27.7±2.8b
Species diversity	3.1±0.1a	3.0±0.2a	2.9±0.2a	3.1±0.1a	2.9±0.2a

G. Comparison of vegetation parameters among different precipitation patterns

As seen in Table 3, there were great differences in measured vegetation parameters under different precipitation patterns. For this study, rainy years were defined as those with precipitation more than 10% above average, dry years as those with less than 90% of average, and normal years as those with 90% to 110% of average. The average vegetation cover, species richness and diversity varied as: rainy years > normal years > dry years. Somewhat surprisingly, canopy height varied as: rainy years > dry years > normal years. Cover and species richness were significantly lower in dry years than in rainy or normal years ($P < 0.05$), but differences in plant height and diversity were not significant between the dry years and rainy or normal years ($P > 0.05$). Similarly, the cover, height, species richness and diversity were higher in the warm-mesic period than in the warm-xeric period, but the differences in height and diversity did not reach significant levels.

Correlations of vegetation parameters with grazing intensity, precipitation and air temperature are presented in Table 4. The results showed that species richness, diversity, plant cover and height had a significant negative correlation ($P < 0.05$) with grazing intensity, while correlation coefficients did not reach significant levels among the vegetation parameters and precipitation or temperature ($P > 0.05$), except for the correlation between species diversity and temperature in the moderate grazing treatment.

IV. DISCUSSION

A. Effects of grazing by domestic sheep on the vegetation

Livestock grazing is one of the main causes of grassland vegetation change [7, 14]. The effects of grazing on grassland vegetation are mainly from differential consumption of plant species, direct trampling of plants, and indirect effects of soil compaction or disturbance [4, 10]. Some studies have suggested that canopy cover and plant height are very sensitive to grazing intensity because the grazing and trampling can result in direct loss of plant stems and leaves [3, 7]. The greater the grazing intensity was, the lower the cover and height [8, 10, 21]. In the present study, plant cover and height decreased significantly with an increase in grazing intensity. By the end of the grazing trial, cover and height had decreased by 97.2% and 96.8%, respectively, in the heavy grazing sites, by 41.7% and 73.5% in the moderate grazing sites, and by 18.1% and 49.8% in the light grazing sites, compared to the non-grazed sites. However, in comparison with conditions before the trial (1991), only the heavy grazing resulted in a significant

decrease of cover and height, while changes in cover and height were not significant in the moderate grazing sites, and cover and height actually increased in the light grazing sites. These results showed that the continuous grazing previous to the study had done some damage to the vegetation, keeping plant cover and height low, comparable to the study's moderate grazing treatment, while the light grazing treatment actually represented a reduction in grazing intensity and so promoted some recovery of plant cover and height in the degraded grassland. This result is consistent with previous studies by Liu et al. [5] and Cooper et al. [10]

The effects of grazing on plant species richness and diversity were not as strong as those on cover and height. Although individual plant mortality from grazing and trampling in the pasture may be prevalent, it is less common for whole plant populations die out [5, 7]. Thus, the sensitivity of species richness and diversity to grazing intensity is generally lower than that of cover and height [22]. In the present study, the decrease in species richness and diversity with grazing intensity was significantly less compared to the cover and height, though it did occur. At the end of the grazing experiment (1996), species richness and diversity had decreased by 51.7% and 19.1%, respectively, in the heavy grazing sites, by 13.8% and 7.9% in the moderate grazing sites, and by 10.3% and 5.9% in the light grazing sites, compared to the non-grazed sites. But compared to the time before the trial (1991), species richness and diversity increased continuously in both the light and moderate grazing sites, and showed a significant decrease only in the heavy grazing sites. This result was not in agreement with a study by Wang and others [23] in the adjacent zonal Castanozems grassland of Xilinguole, where species richness and diversity on overgrazed sites had not shown a significant decrease in an 8-year trial period. Our results also were not consistent with those of Huston [24], where the highest species richness and diversity occurred at intermediate levels of disturbance or under moderate grazing. The main reason for this is that the soil in the Horqin sandy grassland is more vulnerable to trampling and wind erosion than that in the other type of grassland [3, 18]. Trampling and wind erosion can markedly accelerate the deterioration of grassland vegetation and result in a rapid dying-off of some plant populations [15].

Zhang et al. [25] suggested that the species composition of a grassland community can be altered by selective grazing of plants and differential response of species to grazing pressure. Results by Wang et al. [23] showed that quality, palatable forage species decreased and unpalatable species increased under long-term overgrazing. In the present study, unpalatable *Eragrostis pilosa* and *Chloris virgata*, and grazing-resistant *Lespedeza davurica* increased significantly,

while the importance values of palatable species *Pennisetum centrasiaticum*, *Phragmites communis*, *Aneurolepidium dasystachys* and *Setaria viridis* were lower or decreased in the heavy grazing sites. It was the reverse in the LG and MG sites. This again showed that overgrazing prior to this study not only altered grassland quality, but also had significant effects on species composition and structure in the grassland vegetation. This result is in agreement with Dong et al. [8] and Liu et al. [6].

B. Effects of precipitation pattern on the vegetation

It is common knowledge that the distribution and abundance of most terrestrial vegetation is controlled in part by climate conditions [1]. Changes in climate, especially precipitation pattern, may be expected to result in changes in the structure and function of the vegetation [6, 8]. Research has confirmed that synchronous increasing of precipitation and temperature is favorable to an increase in plant diversity and biomass, while decreased precipitation and increased temperature are not beneficial to plant growth [4, 15]. If precipitation decreases and climate warms, plant growth should be restrained particularly in arid and semiarid areas [4, 1]. In the present study, degraded grassland began to recover naturally when high intensity grazing pressure was reduced or removed. In the first four years after enclosure of the experimental plots with fencing (1992-1995), plant species richness, diversity, cover and height all increased significantly, and then maintained relative stability in the medium term (1995-1999), but decreased significantly late in the experimental term (1999-2006). As can be seen Figure 1, the weather was relatively warm-humid in 1992-1999, and it was warm-dry in 2000-2006. In our experiment, vegetation change visibly corresponded with changes in precipitation,

suggesting that an increase in precipitation was favorable to restoration and stabilization of the grassland vegetation, and a drying climate was unfavorable to plant growth and vegetation stabilization. The results also showed that the sensitivity of different vegetation properties to precipitation changes differed significantly. Differences in species richness and vegetation cover were significant, but the slight differences in species diversity and canopy height were insignificant between the warm-mesic period and the warm-xeric period. This showed that precipitation had more effect on species richness and cover than on plant height and diversity.

Precipitation pattern can also have significant effects on species composition of the community [4]. In the present study, the perennials *P. centrasiaticum*, *P. communis*, *A. dasystachys* and *L. davurica* maintained stable populations in the warm-mesic period, and decreased or died out in the warm-xeric period, which showed that more precipitation was favorable to perennial plants, while sustained drought can result in degradation and loss of diversity of perennial herbaceous vegetation. The mesic-adapted perennial *P. communis* and annual *A. scoparia* became dominant species in the community under the sustained moister climate, while the drought-resistant annuals *S. viridis* and *C. acuminatum* became dominant species in the community under sustained drought, which showed that a rainy climate was favorable to the mesophytes, while a sustained dry climate was favorable to xerophytes. This confirmed the view of Nautiyal and others [2] that climatic changes, especially precipitation changes, can drive species composition and vegetation structure in grasslands.

TABLE IV. CORRELATION COEFFICIENTS OF THE VEGETATION PROPERTIES TO GRAZING INTENSITY AND TO CLIMATE FACTORS UNDER THREE GRAZING TREATMENTS. HG: HEAVY GRAZING; MG: MODERATE GRAZING; LG: LIGHT GRAZING.

Vegetation properties	Correlation to grazing intensity	Grazing treatments	Correlation to climate factors	
			Precipitation	Air temp
Richness	-0.741*	HG	0.244	0.211
		MG	0.102	0.692
		LG	-0.011	0.474
Diversity	-0.906**	HG	-0.066	0.104
		MG	0.414	0.885*
		LG	0.082	0.487
Height	-0.978**	HG	0.228	-0.147
		MG	0.624	0.383
		LG	0.221	0.609
Cover	-0.959**	HG	0.109	-0.246
		MG	-0.029	-0.308
		LG	-0.275	0.037

To help understand the possible effects of climate change on the vegetation in our grazing trial, we correlated the above-mentioned vegetation parameters with grazing intensity, precipitation and air temperature (Table 4). As previously noted, species richness, diversity, plant cover and height had a significant negative correlation ($P < 0.05$) with grazing intensity, while correlations were not significant among the vegetation parameters and precipitation or temperature ($P > 0.05$), except for the correlation between species diversity and temperature in the moderate grazing

treatment. This showed that grazing intensity was a primary factor influencing vegetation properties in the experimental sites, while precipitation and temperature were less influential, though they may have long-term effects on species composition.

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REFERENCES

- [1] X.W.Chen, and L. Li, "Tree diversity change in remaining primary mixed broadleaved Korean pine forest under climate change and human activities," *Biodiversity and Conservation*, 13, 2004, pp. 563–577.
- [2] M.C. Nautiyal, B.P. Nautiyal, and P. Vinay, "Effect of Grazing and Climatic Changes on alpine vegetation of Tungnath, Garhwal Himalaya, India," *The Environmentalist*, (24), 2004, pp. 125–134.
- [3] H.L. Zhao, X.Y. Zhao, T.H. Zhang, R.L. Zhou, S.G. Li, T. Ohkuro, and S. Drake, "Desertification Processes of Sandy Rangeland Due to Over-grazing in Semi-arid Area, Inner Mongolia, China," *Journal of Arid Environments*, 62, 2005, pp. 309-319.
- [4] X. Li, X.B. Li, H. Wang, F. Yu, H.J. Yu, and H. Yang, "Impact of climate change on temperate grassland in northern China," *Journal of Beijing Normal University*, 42(6), 2006, pp. 618-624.
- [5] Y. Liu, D.L. Wang, X. Wang, L. Ba, and W. Sun, "The effect of grazing intensity on vegetation characteristics in *Leymus chinensis* grassland," *Acta Prataculturae Sinica*, 11(2), 2002, pp. 22-28.
- [6] Z.G. Liu, and Z.Q. Li, "Plant biodiversity of *Artemisia frigida* communities on degraded grasslands under different grazing intensities after thirteen-year enclosure," *Acta Ecologica Sinica*, 26 (2), 2006, pp. 475-482.
- [7] W. Zhang, "Changes in species diversity and canopy cover in steppe vegetation in Inner Mongolia under protection from grazing," *Biodiversity and Conservation*, 7, 1998, pp. 1365-1381.
- [8] Q.M. Dong, Q.Y. Li, Y.S. Ma, F.J. Li, and Y.F. Li, "Effect of grazing intensity on above ground biomass and vegetation structure in summer alpine meadow," *Qinghai Prataculture*, 11(2), 2002, pp. 8-11.
- [9] H.A. Thomas, P.A. Gregory, and E.M. Mark, "Changes in vegetation structure after long-term grazing in Pinyon-Juniper," *Ecosystems*, 6, 2003, pp. 368–383.
- [10] T. Cooper, McCann, and E. Ballard, "The effects of livestock grazing and recreation on Irish machair grassland vegetation," *Plant Ecology*, 181, 2005, pp. 255–267.
- [11] P.A. Schultz, and M.S. Halpert, "Global analysis of the relationships among a vegetation index, precipitation and land-surface temperature," *International Journal of Remote Sensing*, 16, 1995, pp. 2755-2777.
- [12] H.D.S. Georgia, W.G. Thomas, C.B. John, and A.T. Graham, "Use of remote sensing techniques to determine the effects of grazing on vegetation cover and dune elevation at Assateague Island National Seashore: Impact of Horses," *Environmental Management*, 34(5), 2004, pp. 642–649.
- [13] H.L. Zhao, S.G. Li, T.H. Zhang, T. Ohkuro, and R.L. Zhou, "Sheep gain and species diversity in sandy grassland, Inner Mongolia," *Journal of Range Management*, 57, 2004, pp. 187-190.
- [14] A.R. Malo, and S.E. Nicholson, "A study of rainfall and vegetation dynamics in the African Sahel using normalized difference vegetation index," *Journal of Arid Environments*, (19), 1990, pp.1-13.
- [15] H.L. Zhao, X.Y. Zhao, T.H. Zhang, and W. Wu, "Desertification processes and its restoration mechanisms in the Horqin Sand Land," Beijing: China Ocean Press, 2003.
- [16] L.H.Cheng, F.X. Li, X.M. Di, and J.X. Zhang, "Arenosols Sandy Soil in China," Beijing: Science Press, 1997.
- [17] Y.Z. Su, H.L. Zhao, T.H. Zhang and Y.L.Li, "Processes and characteristics of soil degradation in rainfed farmland in the Horqin sandy land," *Journal of Soil and Water Conservation*, 16, 2002, pp. 25-28.
- [18] Z.D. Zhu, and G.T. Chen, "Sand desertification in China," Beijing: Science Press, 1994.
- [19] S. Jiang, "Methods of research on grassland ecology," Beijing: Agriculture Press, 1988.
- [20] R.R. Sokal, and F.J. Rohlf, "Biometry," New York: W. H. Freeman, 1995.
- [21] G.H.D. Stoppelaire, T.W. Gillespie and J.C. Brock "Use of remote sensing techniques to determine the effects of grazing on vegetation cover and dune elevation at Assateague Island National Seashore: impact of horses," *Environmental Management*, 34 (5), 2004, pp. 642–649.
- [22] W.Y. Wang, and Q.J. Wang, "The effect of grazing intensity on vegetation characteristics in *Leymus chinensis* grassland," *Acta Prataculturae Sinica*, 10(3), 2001, pp. 8-14.
- [23] D.L. Wang, X.I. Lu, and W.D. Luo, "Analysis to Effects of Different Grazing Density on Characteristics of Rangeland Vegetation," *Acta Prataculturae Sinica*, 5(3), 1996, pp. 28-33.
- [24] M. Huston, "Biological diversity, soils, and economics," *Science*, 262, 1993, pp. 1676-1680.
- [25] T.H. Zhang, H.L. Zhao, S.G. Li, and R.L. Zhaou, "Grassland changes under grazing stress in Horqin sandy grassland in Inner Mongolia, China," *New Zealand Journal of Agricultural Research*, 47, 2004, pp. 307–312.