



Article

The Influence of Three-Year Grazing on Plant Community Dynamics and Productivity in Habahe, China

Guoyan Zeng ^{1,2}, Mao Ye ^{1,2,*}, Miaomiao Li ^{1,2}, Weilong Chen ^{1,2}, Qingzhi He ^{1,2}, Xiaoting Pan ^{1,2}, Xi Zhang ^{1,2} , Jing Che ^{1,2}, Jiaoron Qian ^{1,2} and Yexin Lv ^{1,2}

¹ College of Geography Science and Tourism, Xinjiang Normal University, Urumqi 830054, China; zengguoyan@stu.xjnu.edu.cn (G.Z.); 107622022210549@stu.xjnu.edu.cn (M.L.); chenweling2517@stu.xjnu.edu.cn (W.C.); he2543549455@stu.xjnu.edu.cn (Q.H.); panxiaoting@stu.xjnu.edu.cn (X.P.); zhangxi@stu.xjnu.edu.cn (X.Z.); qj101930@stu.xjnu.edu.cn (J.C.); 107622023210468@stu.xjnu.edu.cn (J.Q.); 107622023210564@stu.xjnu.edu.cn (Y.L.)

² Xinjiang Laboratory of Lake Environment and Resources in Arid Zone, Urumqi 830054, China

* Correspondence: yemao@xjnu.edu.cn

Abstract: The stability, diversity, and biomass of grassland plant communities directly impact the functionality and resilience of ecosystems, making them a focal point for ecological research. This three-year study (2021–2023) in the Habahe pastoral area of Xinjiang, China, aimed to investigate the long-term effects of grazing on grassland vegetation structure, community stability, species diversity, and productivity. The results indicate the following. (1) The Habahe pastoral area hosts a relatively rich plant species diversity, with 40 species distributed across 17 families and 37 genera, predominantly comprising perennial and annual herbs. (2) Grazing significantly affected grassland structure and function, resulting in a 4.35% decrease in plant community stability, a 40.74% decrease in species richness, a 21.55% decrease in species dominance, a 5.08% decrease in species diversity, a 46.79% decrease in aboveground biomass, a 61.86% decrease in coverage, and a 72.12% decrease in height. (3) Grazing alters the relationship between species diversity and community stability, shifting it from a positive correlation to a negative one ($p < 0.01$) or rendering it non-significant after grazing. (4) Grazing affects the correlation between aboveground biomass and both species diversity and community stability. While the positive correlation between aboveground biomass and species diversity persists, it is not statistically significant ($p > 0.05$) after grazing. Conversely, the correlation between aboveground biomass and community stability shifts from positive to negative ($p < 0.01$). These results emphasize the need for integrated management strategies that consider both grazing intensity and plant community composition to maintain the health of grassland ecosystems.

Keywords: grazing; Habahe pasture; community stability; species diversity; aboveground biomass



Citation: Zeng, G.; Ye, M.; Li, M.; Chen, W.; He, Q.; Pan, X.; Zhang, X.; Che, J.; Qian, J.; Lv, Y. The Influence of Three-Year Grazing on Plant Community Dynamics and Productivity in Habahe, China.

Agronomy **2024**, *14*, 1855. <https://doi.org/10.3390/agronomy14081855>

Academic Editor: Gianni Bellocchi

Received: 1 July 2024

Revised: 16 August 2024

Accepted: 19 August 2024

Published: 21 August 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Grassland ecosystems cover a significant portion of our country and play a pivotal role in the ecological environment, economic development, and social wellbeing. They provide essential services, such as windbreaks, sand fixation, soil and water conservation, and support for livestock husbandry. Therefore, studying their community structure, function, and stability is crucial [1]. Despite the extensive area of grasslands in China, ecological problems are becoming increasingly severe due to both natural and anthropogenic factors, leading to reduced ecosystem stability and species diversity [2]. Stability is essential for the healthy functioning of ecosystems [3,4]. When external pressures exceed an ecosystem's tolerance threshold, it can trigger changes in both function and structure, resulting in decreased stability and even ecological degradation [5]. Stability refers to an ecosystem's ability to maintain or restore its original state after experiencing disturbances. Although challenging to quantify, stability is closely linked to species diversity and richness, with primary productivity and biomass also serving as important mechanisms for maintaining

ecosystem stability [6]. The diversity–stability theory, which has had a significant impact on ecological studies, addresses the key mechanisms for maintaining ecosystem stability. Originally proposed by MacArthur and Elton, the theory explores the relationship between ecosystem complexity, diversity, and stability, concluding that more complex ecosystems tend to be more stable. Subsequent research by McCann [7], Ives and Carpenter [8], and Li [3], through extensive field experiments, universally supports a positive correlation between biodiversity and ecosystem stability. McNaughton [9] demonstrated that communities with high species richness were more stable in the face of herbivorous disturbances and nutrient fluctuations and also exhibited greater stability in response to seasonal changes. Bai [10], using long-term observational data from typical grasslands in Inner Mongolia, found that different species and functional groups exhibit asynchronous complementary dynamics in response to precipitation fluctuations, further indicating that biodiversity promotes community stability. Yuan [11], through experiments on grassland plant communities on the Loess Plateau, found that communities with high species diversity exhibit strong stability. However, the relationship between diversity and stability has led to controversial conclusions among different ecologists. Wang [4] found both positive and negative correlations between community stability and species diversity. Giehl [12] did not find a significant correlation between community stability and species diversity in their study. Additionally, some scholars argue that the relationship between these two factors is not simply linear but involves more complex interactions. Grazing, as one of the primary disturbance factors in grassland ecosystems, has a complex and profound impact. During grazing, the feeding and trampling of livestock gradually reduce plant coverage. Livestock preferentially consume palatable plants such as grasses, which may lead to grazing-tolerant weeds becoming dominant and affecting community stability [13]. While moderate grazing can promote plant diversity, overgrazing may lead to biodiversity loss and ecosystem instability. Grazing also affects grassland biomass, and generally, grassland ecosystems with smaller biomass fluctuations tend to be more stable [14,15]. Besides grazing disturbances, community stability and species diversity are closely linked to external environmental factors, such as topography, climate, soil, and altitude. Specific environmental factors can directly or indirectly affect species richness, dominance, and evenness [16,17]. While these studies are significant for understanding the relationship between plant diversity and community stability, the relationship between biodiversity and community stability remains controversial and requires further investigation.

The Habahe pastoral area is located within the forest and grassland ecological function zone of the Altai Mountains in Xinjiang, China, representing a typical region for pastoral development. Over 70% of the livestock in the area primarily rely on natural grasslands for grazing, which has intensified pressure on these pasturelands, leading to emerging issues of grassland degradation [18]. Current academic research on the pastoral areas along the Haba River in the Altai Mountains predominantly focuses on topics such as wetland degradation and conservation [19], ecological restoration [20], species diversity [21], and health assessments of grassland and forest ecosystems [22]. However, there is comparatively less research on grassland community stability and species diversity and their relationship with biomass. In response to this research gap, the present study aims to explore the impact of plant diversity on community stability and examine how grazing influences the stability of grassland ecosystems. By investigating the effects of continuous grazing on the stability, diversity, and biomass of grassland plant communities in the Habahe region, this study seeks to provide data to support the establishment of a rational management system for agriculture, forestry, and animal husbandry in Xinjiang. The findings of this research carry significant practical implications and have the potential to generate positive impacts on sustainable land management in the region.

This experiment focused on grassland communities in the Habahe pastoral area of the Altai Mountains, both before and after grazing, to investigate the effects of grazing activities on the relationship between the stability, diversity, and productivity of these plant communities. This study had three specific objectives: (1) to examine the impact of grazing

on species diversity, dominance, richness, and evenness by analyzing the relationship between grazing and the species diversity of plant communities; (2) to study how grazing activities influence the dynamics and stability of grassland plant communities through long-term monitoring and data analysis and to assess the communities' resilience and resistance to disturbances under sustained grazing conditions; and (3) to measure and compare the biomass productivity of grasslands under the influence of grazing, exploring the interrelationships between productivity, diversity, and stability before and after grazing. Finally, by integrating the findings on diversity, stability, and productivity, this study aims to propose strategies for optimizing grazing management to achieve sustainable use and conservation of grassland ecosystems.

2. Materials and Methods

2.1. Overview of the Study Area

Habahe is located in the southern part of the Altai Mountains and on the northern edge of the Junggar Basin in China, with geographic coordinates ranging from 85°33' to 87°18' E and 47°37' to 49°07' N. The landscape is predominantly mountainous, with relatively few plains [23]. Elevations in the region range from 410 to approximately 3839 m above sea level. The area experiences a cold continental climate, with an average annual temperature of 5.3 °C. Temperatures can vary significantly, ranging from a high of 30 °C to a low of −19 °C, and there are considerable diurnal temperature fluctuations. Annual precipitation averages 205.6 mm, characterized by limited rainfall, high evaporation rates, abundant sunshine, and a generally dry climate. The region's seasonal climate features a dry and windy spring, a short and hot summer, a cool autumn, and a cold winter (Figure 1).

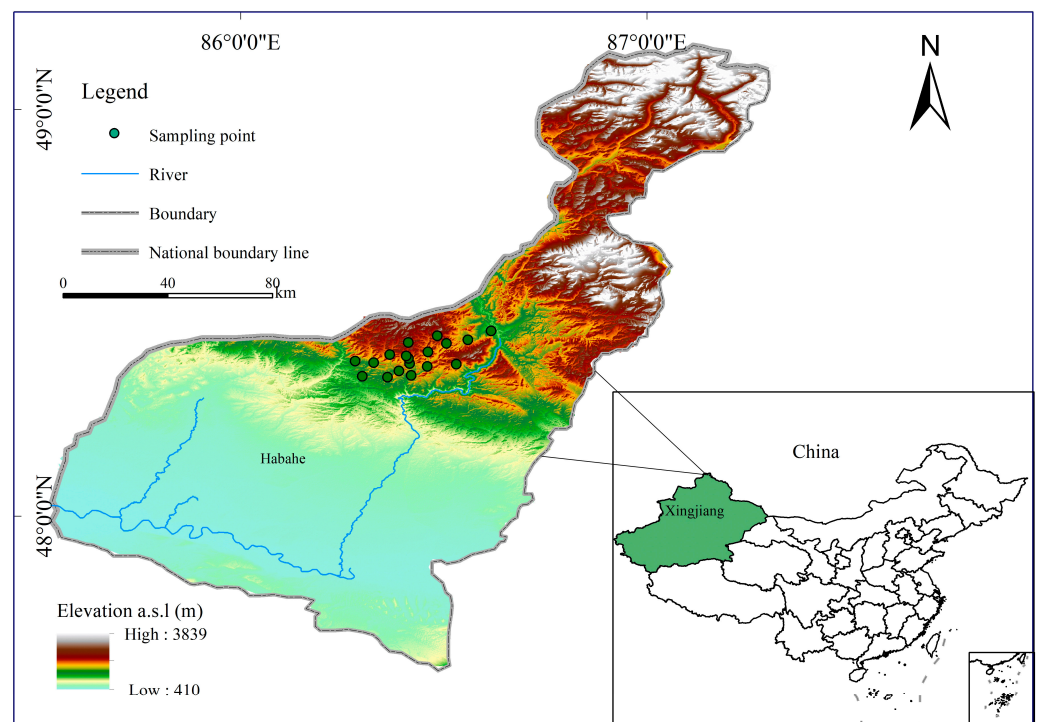


Figure 1. Overview map of the Habahe pastoral study area.

2.2. Data Sources

From 2021 to 2023, a study investigating the effects of sustained grazing on grassland communities was conducted in the Habahe natural pasture in Xinjiang. The study area is transitioning from traditional grassland practices to modern methods, employing a seasonal rotational grazing system. The annual carrying capacity of the pasture is approximately 500,000 head of livestock. The main livestock species include cattle, sheep, and horses,

with wild animals such as rabbits and marmots also present. Grazing occurs annually from 1 July to 10 September.

To explore the impacts of continuous grazing on grassland communities, fixed sample plots were established in the Habahe summer pasture for three years of monitoring. Each sample plot measured 20 m $\times$ 20 m, with three randomly selected 1 m $\times$ 1 m subplots within each plot [24]. In total, 18 sample plots and 54 subplots were established. During sampling, detailed records were kept of species names, abundance, corresponding elevation, and geographic coordinates (latitude and longitude) within each plot. Additionally, species height and coverage were measured. After monitoring was completed, the plants in each subplot were mowed, and the fresh weight of the aboveground biomass of the species was recorded as the biomass of the species.

To ensure that the stability and diversity of the grassland communities and other indicators were not disturbed by external factors, natural grasslands that had been restored to their natural state following a period of grazing prohibition were selected as control sites. The 18 plots were monitored annually from 15 June to 20 June and from 10 September to 11 September. The data collected (including coverage, density, height, biomass, community stability, and species diversity) were averaged across the three 1 m $\times$ 1 m subplots within each plot. These averages were used to compare the initial state before grazing (June 2021) and the final state after grazing (September 2023) (Table 1).

Table 1. Plot information table.

Sample	East Longitude	Northern Latitude	Altitude/m	Average Density before Grazing	Average Density after Grazing
1	86°21'32.40''	48°20'49.00''	1669	957	69.33
2	86°17'42.00''	48°21'41.00''	1367	212	153.33
3	86°24'57.24''	48°22'30.00''	1461	642.67	106.67
4	86°19'44.40''	48°23'15.00''	1560	620	68
5	86°24'39.06''	48°24'03.06''	1984	897.33	312.67
6	86°20'45.06''	48°24'34.56''	1751	496	270.33
7	86°23'27.06''	48°21'46.08''	1491	127.67	60
8	86°24'32.04''	48°22'37.02''	1414	430	110
9	86°27'00.00''	48°22'08.04''	1590	368.67	92.33
10	86°31'37.20''	48°23'06.00''	1869	926.33	184.67
11	86°24'54.00''	48°23'42.00''	1711	502.33	71
12	86°16'51.60''	48°23'06.00''	1286	414.67	69.33
13	86°27'18.00''	48°24'21.06''	1507	558	103
14	86°30'18.00''	48°25'58.08''	1608	690.67	96
15	86°24'43.20''	48°25'58.08''	1733	343.67	95.33
16	86°33'21.60''	48°26'34.08''	1436	462.67	130
17	86°28'51.60''	48°26'45.06''	1809	582.67	131.67
18	86°37'57.00''	48°27'43.02''	1260	276.33	188.67

2.3. Data Analysis

2.3.1. Vegetation Structure

(1) Grassland coverage refers to the percentage of the vertical projection area of grassland in the observation area to the surface area. The cover of the grassland plant community in this experiment was estimated using the grid visual method. Divide the 1 m $\times$ 1 m grassland sample into 100 1 cm $\times$ 1 cm squares; when the vegetation area exceeds 1/2 of the small square area, it is recorded as 1, and when the vegetation area does not exceed 1/2 of the small square area, the result is recorded as 0. Measure three times continuously and record the mean value of the sum of the squares with the three results as '1' as the coverage of the plants in the sample. The total coverage of the community is the mean value of the community coverage in the three plots [25].

(2) Community Density: The area of the quadrat is 1 m², and the density of different plant populations was determined using a counting method. The number of individuals of the same species within a sample was recorded as the population density, and the sum of the densities of different species was recorded as the community density. The average

density across the 3 quadrats in each of the 18 plots was then calculated to determine the overall community density.

(3) Community Height: The heights of the tallest, median, and shortest individuals of each species were measured using a tape measure, and the average height for each species was calculated and recorded [26]. This average height for all species was used as the height for each quadrat (three per sample plot). Finally, the mean height of the 3 quadrats within each of the 18 plots was calculated to determine the overall average community height.

(4) Community Biomass: The plants in each quadrat were harvested, and their fresh weight was recorded. The total fresh weight of all plants in a quadrat was recorded as the community biomass. The biomass for each plot was then calculated as the average biomass of the 3 quadrats within that plot.

2.3.2. Species Importance Values and Dominance

The importance value (*IV*) and dominance degree (*SDR4*) are comprehensive indicators used to assess the status and role of species within a community. In this study, the *IV* and *SDR4* of grassland plant species in the Habahe pastoral area prior to grazing were calculated using relative height, relative frequency, relative coverage, and relative density [27,28]. The formulas for these calculations are as follows:

$$IV_i = \left[\left(\frac{H_i}{\sum H} + \frac{F_i}{\sum F} + \frac{C_i}{\sum C} \right) / 3 \right] \times 100\% \quad (1)$$

$$SDR4_i = \left[\left(\frac{H_i}{H_{max}} + \frac{F_i}{F_{max}} + \frac{C_i}{C_{max}} + \frac{D_i}{D_{max}} \right) / 4 \right] \times 100\% \quad (2)$$

where *IV_i* represents the importance value of species *i* and *SDR4_i* denotes the integrated dominance ratio of species *i*. *H_i* stands for the height of species *i*, *F_i* represents the frequency of species *i*, *C_i* indicates the coverage of species *i*, and *D_i* denotes the density of species *i*. *H_{max}* refers to the height of the tallest species within the community, *F_{max}* represents the frequency of the most frequent species, *C_{max}* indicates the coverage of the most abundant species, and *D_{max}* denotes the density of the most dense species within the community.

2.3.3. Species Diversity Calculations

(1) α -diversity

Patrick's species richness index (*R*), Margalef index (*S*), Simpson's dominance index (*D*), Shannon–Wiener's diversity index (*H*), and Alatalo's evenness index (*Ea*) were chosen to characterize the diversity of species within the community [29,30]. These indices were calculated using the following formulas:

$$Patrick(R) : R = S \quad (3)$$

$$Margalef(S) : S = (S - 1) / \ln N \quad (4)$$

$$Simpson(D) : D = 1 - \sum P_i^2 \quad (5)$$

$$Shannon - Wiener(H) : H = -\sum P_i \ln P_i \quad (6)$$

$$Alatalo(Ea) : Ea = H / \ln S \quad (7)$$

where *S* represents the total number of species in the sample; *N* represents the total number of individuals in the sample; *N_i* represents the number of individuals of the *i*th plant species; and *P_i* represents the proportion of individuals of species *i* relative to the total number of individuals in the sample.

(2) β -diversity

The β -diversity reflects the dissimilarity in species composition between communities inhabiting different habitats along an environmental gradient or the turnover rate of species across that gradient. In this experiment, Sørensen's beta-diversity index (S) and Jaccard's beta-diversity index (J) were selected to quantify community dissimilarity. The calculation methods are as follows [31]:

Sørensen β diversity index (s):

$$C_s = 1 - 2c / (a + b) \quad (8)$$

Jaccard β diversity index (j):

$$C_j = 1 - c / (a + b + c) \quad (9)$$

where a and b represent the total number of species in the two communities and c represents the number of species shared between the communities.

2.3.4. Community Stability Measures

Grassland plant community stability is expressed as the inverse of the coefficient of variation (CV) of community species density (ICV) [32]:

$$ICV = \mu / \sigma \quad (10)$$

where μ denotes the mean density of each species in the sample plot and σ represents the standard deviation of the density of each species. A higher ICV value indicates greater community stability, suggesting that the variability in the density of each species is low.

2.4. Data Processing

The sampled data were initially organized using Microsoft Excel 2019. Independent-sample t tests were conducted with SPSS 26.0 (IBM, New York, NY, USA) to assess differences in community stability before and after grazing. One-way analysis of variance (ANOVA) and least significant difference (LSD) tests were employed to statistically analyze diversity indices and community characteristics to identify significant differences pre- and post-grazing. The Pearson correlation coefficient was used to analyze the relationships between grassland community stability indices, diversity indices, and biomass, while regression equations were employed to assess their linear relationships.

ArcGIS 10.8 (Esri, Redlands, CA, USA) was utilized to create an overview map of the study area, illustrating the spatial distribution and topographic features of the sample plots. Origin 2021 was used to generate additional graphs, including trend graphs depicting grassland community stability, diversity indices, and biomass.

To ensure accurate description and analysis of plant species and habitat types, we referred to specialized literature, such as the Chinese Journal of Vegetation, and consulted with experts to identify wild plants in the Altai Mountains region and compile a list of dominant grassland plant species in the study area.

3. Results

3.1. Characteristics of Grassland Plant Communities in Habahe Pasture before and after Grazing

In the Altai Habahe pastoral area, there are approximately 40 plant species distributed across 17 families and 37 genera, with *Gramineae*, *Asteraceae*, and *Rosa canina* being predominant (Table 2). The majority of plants in the region are perennial and annual herbs. Notable species include *Poa annua*, needle grass, *Stipa capillata*, *Alchemilla japonica*, and *Taraxacum mongolicum* (Table 3). Grazing-tolerant species include *Stipa capillata*, *Poa annua*, *Taraxacum mongolicum*, *Alchemilla japonica*, *Medicago sativa*, *Geranium wilfordii*, *Achillea millefolium*, *Potentilla chinensis*, and *Ranunculus repens*, while grazing-intolerant species include *Helictochloa hookeri*, *Eleusine indica*, *Myosotis alpestris*, *Galium verum*, and *Thalictrum aquilegifolium*.

Table 2. Species composition of grassland plant communities in 18 sample plots in the Habahe pastoral area before grazing.

Sample	Number of Families (17)		Number of Genera (37)		Number of Special (40)	
	Quantity	Percentage in Total Families (%)	Quantity	Percentage in Total Genus (%)	Quantity	Percentage in Total Special (%)
1	5	29.41	5	13.51	5	12.50
2	5	29.41	6	16.22	6	15.00
3	3	17.65	4	10.81	5	12.50
4	6	35.29	7	18.92	8	20.00
5	7	41.18	8	21.62	9	22.50
6	5	29.41	7	18.92	8	20.00
7	6	35.29	6	16.22	6	15.00
8	8	47.06	8	21.62	8	20.00
9	8	47.06	9	24.32	9	22.50
10	6	35.29	6	16.22	6	15.00
11	4	23.53	6	16.22	6	15.00
12	6	35.29	8	21.62	8	20.00
13	6	35.29	8	21.62	9	22.50
14	7	41.18	12	32.43	12	30.00
15	7	41.18	11	29.73	11	27.50
16	9	52.94	16	43.24	17	42.50
17	9	52.94	18	48.65	18	45.00
18	8	47.06	17	45.95	17	42.50

Table 3. Species importance and dominance of grassland plant communities in 18 sample plots in the Habahe pastoral area before grazing.

Sample	Species Name	Life Form	Importance Value (Dominance)/%
1	<i>Alchemilla japonica</i>	P	23.9 (83.7)
	<i>Poa annua</i>	A	23.6 (76.0)
	<i>Ranunculus repens</i>	P	22.5 (61.5)
2	<i>Poa annua</i>	A	30.3 (100)
	<i>Alchemilla japonica</i>	P	28.0 (97.2)
	<i>Ranunculus repens</i>	P	14.1 (41.9)
3	<i>Poa annua</i>	A	34.9 (100)
	<i>Galium boreale</i>	P	24.5 (63.0)
	<i>Thalictrum aquilegiifolium</i>	P	17.2 (44.3)
4	<i>Poa annua</i>	A	28.4 (97.7)
	<i>Taraxacum mongolicum</i>	P	18.3 (58.5)
	<i>Myosotis alpestris</i>	P	13.5 (42.0)
5	<i>Poa annua</i>	A	30.4 (92.1)
	<i>Helictochloa hookeri</i>	P	22.0 (60.0)
	<i>Taraxacum mongolicum</i>	P	11.6 (32.4)
6	<i>Poa annua</i>	A	24.9 (93.6)
	<i>Alchemilla japonica</i>	P	22.7 (87.6)
	<i>Helictochloa hookeri</i>	P	14.1 (48.3)
7	<i>Poa annua</i>	A	27.8 (98.6)
	<i>Alchemilla japonica</i>	P	22.4 (79.9)
	<i>Erythronium japonicum</i>	P	19.0 (58.4)
8	<i>Poa annua</i>	A	28.5 (71.4)
	<i>Galium boreale</i>	P	24.8 (54.1)
	<i>Taraxacum mongolicum</i>	P	12.3 (29.0)

Table 3. Cont.

Sample	Species Name	Life Form	Importance Value (Dominance)/%
9	<i>Poa annua</i>	A	25.7 (100)
	<i>Alchemilla japonica</i>	P	21.2 (80.3)
	<i>Taraxacum mongolicum</i>	P	13.5 (53.7)
10	<i>Poa annua</i>	A	25.6 (94.6)
	<i>Alchemilla japonica</i>	P	24.3 (83.9)
	<i>Geranium wilfordii</i>	P	20.9 (60.6)
11	<i>Setaria viridis</i>	A	38.4 (100)
	<i>Stipa capillata</i>	P	22.1 (70.9)
	<i>Poa annua</i>	A	17.3 (50.0)
12	<i>Setaria viridis</i>	A	25.6 (96.8)
	<i>Poa annua</i>	A	22.6 (85.0)
	<i>Stipa capillata</i>	P	21.9 (80.9)
13	<i>Poa annua</i>	A	29.1 (96.4)
	<i>Taraxacum mongolicum</i>	P	13.4 (50.6)
	<i>Artemisia frigida</i>	P	11.0 (43.4)
14	<i>Poa annua</i>	A	35.4 (70.9)
	<i>Stipa capillata</i>	A	10.2 (76.1)
	<i>Potentilla chinensis</i>	P	7.4 (45.6)
15	<i>Setaria viridis</i>	A	19.5 (93.3)
	<i>Achillea millefolium</i>	P	16.5 (69.5)
	<i>Stipa capillata</i>	A	16.2 (70.8)
16	<i>Setaria viridis</i>	A	16.7 (100)
	<i>Stipa capillata</i>	A	14.9 (84.7)
	<i>Achillea millefolium</i>	P	10.1 (68.9)
17	<i>Stipa capillata</i>	A	20.1 (100)
	<i>Achillea millefolium</i>	P	16.2 (80.2)
	<i>Eleusine indica</i>	A	8.6 (50.3)
18	<i>Poa annua</i>	A	14.6 (91.8)
	<i>Setaria viridis</i>	A	11.4 (60.9)
	<i>Potentilla chinensis</i>	P	11.1 (57.7)

Note: “P” represents perennial herbs; “A” represents an annual herb.

Over a three-year period, grazing significantly impacted the characteristics of the grassland plant communities in the Habahe pastoral area. Specifically, the Margalef index of species richness decreased from 0.81 to 0.48, the Simpson index of dominance decreased from 1.16 to 0.91, the Shannon–Wiener index decreased from 0.59 to 0.56, and the Alatalo index of evenness increased from 0.72 to 0.80. The community stability *ICV* value decreased from 1.38 to 1.32, indicating a slight reduction in community stability due to grazing. Additionally, the aboveground biomass of the grassland community decreased from 215.88 to 114.86 g/m², vegetation cover decreased from 88% to 33.56%, and plant height decreased from 27.73 cm to 7.73 cm. These changes reflect significant alterations in grassland plant community characteristics in response to continuous grazing (Table 4).

Table 4. Characteristics of grassland plant communities before and after grazing in Habahe pastoral area.

	ICV	Richness	Dominance	Diversity	Evenness	Biomass/g·m ⁻²	Cover/%	High/cm
Pre-grazing	1.38 ± 0.39 a	0.81 ± 0.33 a	1.16 ± 0.24 a	0.59 ± 0.09 a	0.72 ± 0.09 b	215.88 ± 24.95 a	88.00 ± 10.02 a	27.73 ± 05.16 a
After grazing	1.32 ± 0.19 a	0.48 ± 0.13 b	0.91 ± 0.15 b	0.56 ± 0.11 a	0.80 ± 0.09 a	114.86 ± 08.66 b	33.56 ± 05.79 b	07.73 ± 01.38 b

Note: Data in the same column followed by different lowercase letters indicate significant differences between different sites ($p < 0.05$).

3.2. Species β -Diversity Analysis of Grassland Plant Communities in Habahe Pastoral Area

To investigate the impact of continuous grazing disturbance on species turnover within grassland communities, Sørensen's β -diversity index and Jaccard's β -diversity index were used to analyze changes in the grassland communities across different grazing years in the Habahe area. Sørensen's β -diversity index values between 2021 and 2022, 2022 and 2023, and 2021 and 2023 ranged from 0.299 to 0.443. These values indicate varying degrees of change in community composition under grazing pressure. The highest β -diversity indices were observed between 2021 and 2023, suggesting the lowest level of species overlap between these years. This trend indicates a decline in species similarity within the same plot over successive years of grazing. Jaccard's β -diversity index corroborated these findings, showing increasing dissimilarity in community composition with each successive year of grazing (Table 5).

Table 5. Jaccard β diversity and Sørensen β diversity of grassland communities in different grazing years.

Year	2021	2022	2023
2021		0.743	0.782
2022	0.310		0.740
2023	0.443	0.299	

Note: The bolded values are Sørensen β -diversity indices, and the unblackened values are Jaccard β -diversity indices.

3.3. Relationship between Stability and Diversity of Grassland Plant Communities in Habahe Pastoral Area before and after Grazing

Analysis of the ICV values related to the stability of the grassland plant communities in the Habahe pastoral area revealed significant findings. Prior to grazing, the ICV values exhibited highly significant positive correlations ($p < 0.01$) with the Margalef richness index, Shannon–Wiener diversity index, and Alatalo evenness index, with R^2 values of 0.483, 0.552, and 0.571, respectively. Additionally, there was a significant positive correlation ($p < 0.05$) between ICV values and the Simpson dominance index (Figure 2).

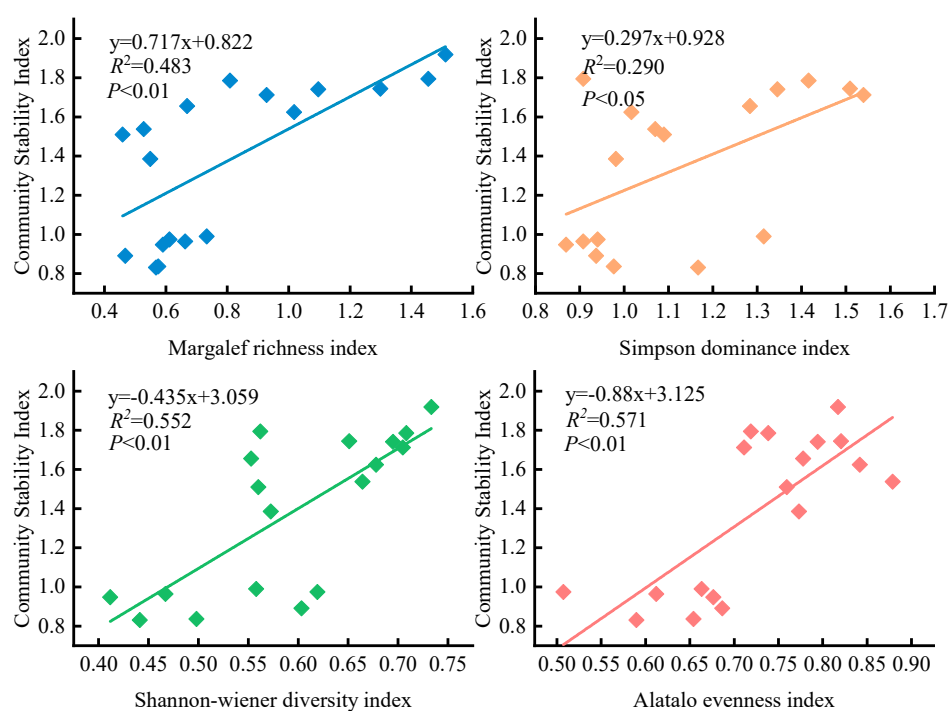


Figure 2. Relationship between grassland plant diversity index and community stability in Habahe pasture before grazing.

However, after grazing, the ICV values showed highly significant negative correlations ($p < 0.01$) with the Margalef richness index, Simpson dominance index, and Shannon–Wiener diversity index, with R^2 values of 0.737, 0.577, and 0.365, respectively. Notably, no significant correlation was observed between ICV values and the Alatalo evenness index (Figure 3).

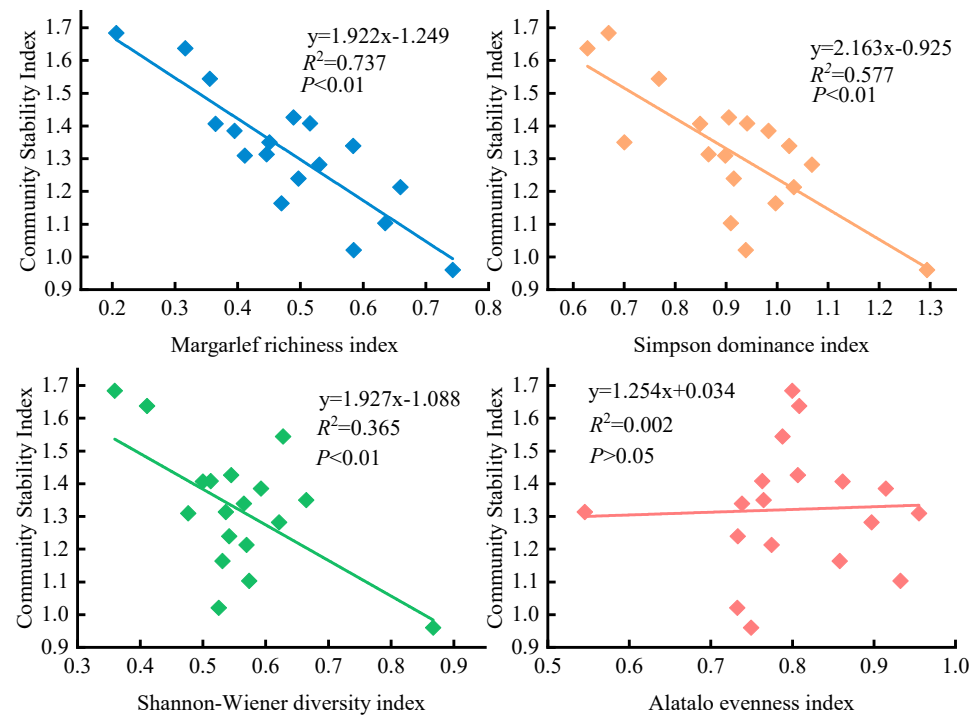


Figure 3. Relationship between grassland plant diversity index and community stability in Habahe pasture after grazing.

Overall, the three years of grazing significantly altered the relationship between stability and diversity within the grassland plant communities in the Habahe pastoral area. Specifically, the correlation between stability and diversity shifted from positive to negative under continuous grazing pressure. Different plant species exhibit varying tolerances to grazing. Overuse of plant resources during grazing depletes plant root systems, affects growth and reproduction, and reduces ecosystem resilience. The diminished recovery ability of the ecosystem makes it more challenging to return to its original state after disturbances, thereby altering the relationship between plant diversity and community stability.

3.4. Relationship between Biomass and Stability and Species Diversity of Grassland Plant Communities in the Habahe Pastoral Area before and after Grazing

Analysis of the relationship between species diversity and aboveground biomass in grassland plant communities revealed significant findings. Prior to grazing, there was a highly significant positive correlation between species diversity and aboveground biomass ($p < 0.01$), with an R^2 value of 0.455. However, after three years of grazing, although species diversity remained positively correlated with aboveground biomass, the correlation was no longer statistically significant ($p > 0.05$) (Figure 4).

Furthermore, analysis of the relationship between ICV values of grassland plant community stability and aboveground biomass showed notable results. Before grazing, community stability was highly significantly positively correlated with aboveground biomass ($p < 0.01$), with an R^2 value of 0.324. In contrast, after three years of grazing, community stability exhibited a highly significant negative correlation with aboveground biomass ($p < 0.01$), with an R^2 value of 0.328 (Figure 4).

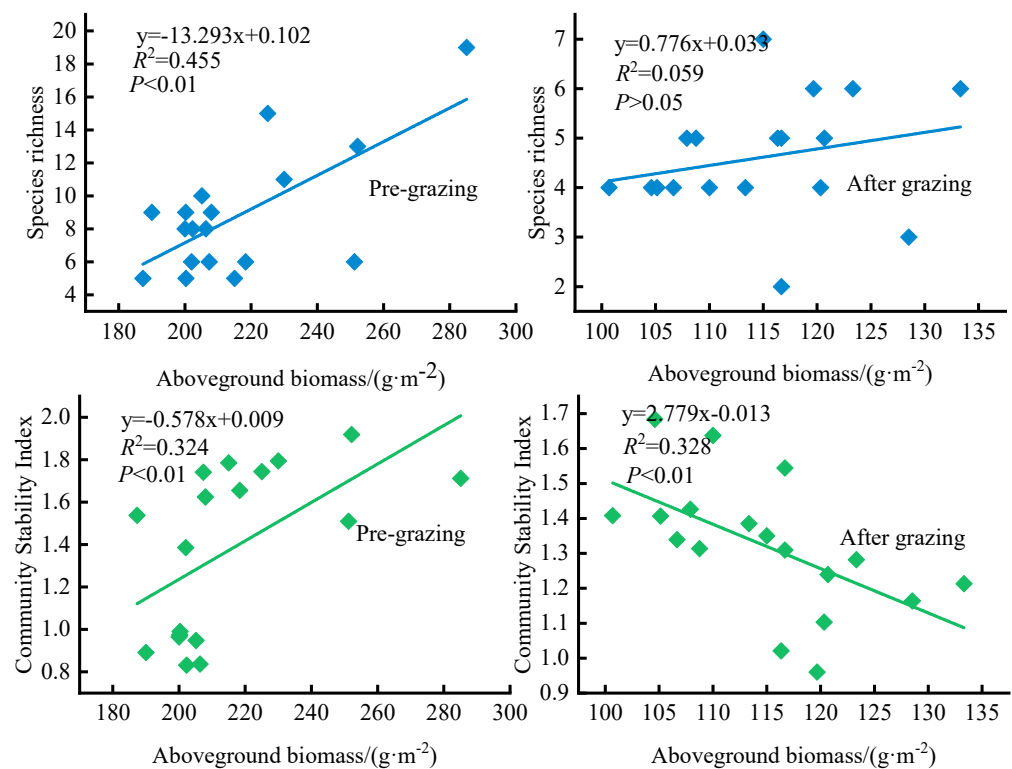


Figure 4. Aboveground biomass of grassland plants in relation to species richness and community stability before and after grazing in Habahe rangeland.

Overall, the Habahe ranch is predominantly dominated by Gramineae species. During grazing, these palatable species may be preferentially consumed. Under grazing pressure, herbaceous plants, such as *Poa pratensis*, *Festuca arundinacea*, and *Medicago sativa*, may exhibit increased growth rates and expanded root systems to compensate for biomass loss due to species depletion. This adaptation can alter the relationship between aboveground biomass and community stability.

4. Discussion

4.1. Effects of Grazing on Grassland Plant Community Characteristics

The composition of grassland plant communities encompasses various aspects, including species richness, dominance structure, and the presence of dominant, subdominant, companion, and occasional species, along with other quantitative characteristics. Key indicators such as species diversity, productivity, plant cover, and height reflect the ecological conditions of grasslands and their habitats [33]. Grassland plant communities are influenced by both biotic and abiotic factors, which dynamically respond to grazing impacts over time. In the study area, the dominant plant families, such as *Gramineae*, *Asteraceae*, *Rosaceae*, *Rubiaceae*, and *Lamiaceae*, are well-adapted to the local ecological environment and form the primary components of the vegetation, consistent with the findings from previous research by Li [34] et al. on various grassland types in the Altai Mountains. The present study observed a significant decline in diversity, biomass, cover, and height of the grassland communities following three years of grazing, mirroring the trends reported by Liu [35] in Tibetan Plateau grasslands. Grazing significantly alters the structure of plant communities through trampling and excretion, impacting plant coverage, density, height, and biomass [13]. Under grazing pressure, species with greater tolerance, such as *Achillea millefolium*, *Potentilla chinensis*, *Ranunculus repens*, and *Geranium wilfordii*, may exploit competitive advantages and dominate the community. Conversely, species with lower tolerance, such as *Helictotrichon hookeri*, *Galium verum*, and *Myosotis alpestris*, may decline significantly, reducing overall community diversity [36]. Grazing can also disrupt plant

growth stages, with varying resistance levels among species, leading to different adaptive strategies and changes in community structure [37]. Moreover, grazing impacts the growth and diversity of dominant plant species, thereby altering the overall characteristics of grassland communities [38].

In the Habahe pastoral area, the intensity of grazing is significant, leading to pronounced effects on plant community characteristics. However, the impacts of grazing on grassland community structure are influenced by factors such as grazing intensity, frequency, duration, and environmental conditions. Therefore, adapting grazing practices to local conditions and implementing suitable grazing systems in future management strategies are crucial for fostering the healthy and sustainable development of grassland communities.

Grasslands play a vital role in maintaining global ecological balance. Grazing, as a key tool in grassland management, directly affects the health of grassland ecosystems, with its appropriateness being crucial. Moderate grazing can stimulate plant regeneration and diversity, contributing to community homeostasis. However, overgrazing can lead to ecological degradation, impairing the ecosystem's recovery and stability [39]. In this study, while the grassland community in the Habahe pastoral area was relatively stable, there was a noticeable decline in community stability under grazing pressure. This trend is consistent with the findings reported by Liu [40] in research conducted in the desert steppe region of Inner Mongolia. The decline is attributed to grazing-induced shifts in species composition and structure, favoring more resilient species while diminishing palatable ones, thereby reducing species diversity and compromising ecosystem function and stability [41].

Grazing impacts vegetation and soils: trampling and livestock defecation can compact soils, disrupt soil structure, and reduce nutrient and water retention capacities, further affecting plant growth and community stability [42]. Grassland community stability is influenced by multiple factors, including inherent community limitations, species and functional diversity, community structure, ecosystem functions, environmental conditions, and human disturbances, all interacting to shape community health and stability. Studying stability in grasslands is a complex endeavor requiring a comprehensive exploration of environmental factors and anthropogenic influences [43].

4.2. Effects of Grazing on the Stability–Diversity Relationship of Grassland Plant Communities

In grassland ecosystems, preserving plant diversity is crucial for maintaining community stability [6]. Research indicates that biodiversity can enhance ecosystem stability. Species respond differently to varying environmental conditions, leading to asynchronous population dynamics that help sustain the stability of populations or ecosystems. The relationship between community stability and diversity is complex and can be categorized into three main types: positive correlation, negative correlation, and nonlinear relationships [44].

In this study, the relationship between grassland community stability and plant diversity showed notable changes before and after grazing, with diversity indices affecting community stability in different ways. Prior to grazing, grassland community stability exhibited a highly significant positive correlation ($p < 0.01$) with all four diversity indices (Margalef richness index, Simpson dominance index, Shannon–Wiener diversity index, and Alatalo evenness index). This aligns with the findings from Tilman [45] and Hu [46], suggesting that communities with higher species diversity are better able to utilize resources such as light, water, and nutrients, thus enhancing community productivity and stability compared to less diverse communities [47].

However, following grazing, the stability of the grassland plant communities in the Habahe pastoral area showed a significant negative correlation ($p < 0.01$) with all three diversity indices (Margalef richness index, Simpson dominance index, and Shannon–Wiener diversity index), reflecting the trends observed in studies of the lower reaches of the Hei River by Si [48]. In grassland plant communities, higher levels of compositional complexity and intermediate relationships generally indicate better organizational capacity and greater

stability. Grazing, however, has diminished this organizational capacity, thereby altering the relationship between diversity and stability [49].

While diversity does influence stability, it is not the sole factor driving this effect [7]. Research has demonstrated that the relationship between plant community diversity and stability is intricate and influenced by factors at various levels. Conclusions drawn from single research methods may not be universally applicable. Therefore, further investigation is required to fully understand the impact of grazing on the diversity–stability relationship [50].

4.3. Effects of Grazing on the Relationship between Biomass and Species Diversity and Stability of Grassland Plant Communities

The condition, production potential, and carrying capacity of grasslands can be effectively assessed through plant biomass. Both aboveground biomass and plant diversity are critical indicators in ecosystem evaluation, drawing considerable attention from ecologists [51,52]. Biomass plays a significant role in the stability and diversity of grassland plant communities. In this study, a positive correlation was observed between biomass and community stability. Research on European grasslands has shown that more diverse communities not only exhibit greater biomass but also possess stronger adaptive capacities to environmental changes [53]. This finding supports the notion that higher diversity in grassland plant communities correlates with increased biomass and enhanced ecosystem stability in the absence of grazing pressure.

However, after three years of grazing, the relationship between biomass, species diversity, and community stability in the Habahe pastoral area exhibited a negative correlation. This shift can be attributed to grazing-induced reductions in vegetation cover and soil water content as well as increased soil temperatures, which impede plant root development and diminish overall growth and recovery capacity. Consequently, a decline in species diversity follows [54]. Grazing typically disrupts plant community structure through continuous feeding and trampling by livestock. This disturbance favors drought-tolerant and grazing-resistant species, such as certain grasses, leading to a homogenization of the pasture grassland community and a reduction in species diversity. Conversely, less drought- and grazing-tolerant species, such as many legumes, may significantly decline or even disappear, further diminishing community species diversity. As species richness decreases, functional diversity and community stability are also affected, altering the interrelationships among these aspects [55].

The stability of grassland ecosystems in relation to diversity and biomass is influenced by environmental conditions and external perturbations, representing a complex dynamic that requires further investigation.

5. Conclusions

(1) Grazing activities exert a significant influence on the structure and functioning of grassland communities, leading to a reduction in stability, diversity, biomass, plant cover, and height. Therefore, implementing sustainable grazing practices and conservation measures is required in management and conservation measures.

(2) Grazing significantly alters the relationship between species diversity and stability of grassland communities, altering the correlation from initially positive to negative or non-existent correlations after grazing.

(3) Grazing impacts the relationships between biomass, species diversity, and community stability. While the positive correlation between aboveground biomass and species diversity persists, it weakens post-grazing. Conversely, the positive correlation between aboveground biomass and community stability shifts to negative after grazing.

In summary, a reasonable grazing system is conducive to maintaining the species diversity of grassland plant communities and maintaining the long-term stability of grassland ecosystems. In the future management, the grazing system should be optimized, the

most suitable grazing method should be selected according to local conditions, and the healthy and stable development of the grassland ecosystem should be further promoted.

Author Contributions: G.Z.: conceptualization, methodology, software, investigation, formal analysis, writing—original draft; M.Y.: conceptualization, funding acquisition, resources, supervision, writing—review and editing; M.L.: data curation, writing—original draft; W.C.: visualization, investigation; Q.H.: resources, supervision; X.P.: software, validation; X.Z.: visualization, writing—review and editing; J.C.: data curation, investigation; J.Q.: resources, validation; Y.L.: investigation, formal analysis. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China and Xinjiang Joint Fund Project (U1803245) and the National Natural Science Foundation of China (42377449).

Data Availability Statement: The data presented in this study are available on request from the corresponding authors. These data are not publicly available due to ethical restrictions.

Acknowledgments: The principal author of this article is, firstly, grateful for the support from the National Natural Science Foundation of China and NSFC—Xinjiang Joint Fund, secondly, grateful to the reviewers for reviewing the manuscript in their busy schedules, and, finally, grateful to my supervisor M.Y. for her guidance and support of my research work.

Conflicts of Interest: The funders had no role in the design of this study; in the collection, analyses, or interpretation of the data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Zhang, H.Y.; Fan, J.W.; Shao, Q.Q.; Zhang, Y.X. Ecosystem dynamics in the “Returning Rangeland to Grassland” programs, China. *Acta Prataculturae Sin.* **2016**, *25*, 1–15.
2. Gong, G.L.; Liu, J.Y.; Shao, Q.Q. Effects of Vegetation Coverage on Soil Conservation Service of Typical Steppe in Inner Mongolia. *J. Geo-Inf. Sci.* **2014**, *25*, 426–434.
3. Li, Z.Y.; Ye, X.Z.; Wang, S.P. Ecosystem stability and its relationship with biodiversity. *Chin. J. Plant Ecol.* **2021**, *45*, 1127–1139. [[CrossRef](#)]
4. Wang, J.; Wang, S.S.; Qiao, X.G. Influence of nitrogen addition on the primary production in Nei Mongol degraded grassland. *Chin. J. Plant Ecol.* **2016**, *40*, 980–990.
5. Liao, Y.J.; Song, C.C.; Guo, Y.D.; Wang, L.; Wang, L.L. Index system and mythology for wetland ecosystem stability in Sanjiang Plain. *J. Arid. Land Resour. Environ.* **2009**, *23*, 89–94.
6. Tilman, D.; Dowing, J.A. Biodiversity and stability in grassland. *Nature* **1994**, *367*, 363–367. [[CrossRef](#)]
7. McCann, K.S. The diversity-stability debate. *Nature* **2000**, *405*, 228–233. [[CrossRef](#)]
8. Ives, A.R.; Carpenter, S.R. Stability and Diversity of Ecosystems. *Science* **2007**, *317*, 58–62. [[CrossRef](#)] [[PubMed](#)]
9. McNaughton, S.J. Diversity and stability of ecological communities: A comment on the role of empiricism in ecology. *Am. Nat.* **1977**, *111*, 515–525. [[CrossRef](#)]
10. Bai, Y.; Han, X.; Wu, J.; Chen, Z.; Li, L. Ecosystem stability and compensatory effects in the Inner Mongolia grassland. *Nature* **2004**, *431*, 181–184. [[CrossRef](#)]
11. Yuan, Z.Y.; Zhang, L.; Liao, L.R.; Wang, J.; Lei, S.L.; Liu, G.B.; Fang, N.F.; Zhang, C. Relationship between grassland plant diversity and community stability and its driving factors on the Loess Plateau. *Acta Ecol. Sin.* **2023**, *43*, 60–69.
12. Giehl, E.L.; Jarenkow, J.A. Disturbance and stress gradients result in distinct taxonomic, functional and phylogenetic diversity patterns in a subtropical riparian tree community. *J. Veg. Sci.* **2015**, *26*, 889–901. [[CrossRef](#)]
13. Zhang, X.L.; Xu, T.W.; Tan, P.Z.; Geng, Y.Y.; Liu, H.J.; Xu, S.X. Effect of Seasonal Grazing on Plant Community and Biomass of Alpine Steppe. *Acta Agric. Boreail-Occident. Sin.* **2019**, *28*, 1576–1582.
14. Zhang, J.Y.; Zhao, H.L. Review on the study of vegetation stability. *Chin. J. Ecol.* **2003**, *22*, 42–48.
15. Beck, J.J.; Hernández, D.L.; Pasari, J.R.; Zavaleta, E.S. Grazing maintains native plant diversity and promotes community stability in an annual grassland. *Ecol. Appl.* **2015**, *25*, 1259–1270. [[CrossRef](#)] [[PubMed](#)]
16. Zhao, Y.J.; Ha, E.; Luo, C.L.; Sang, D.J.; Ba, Y.; Hou, G.T.; Jin, E.B.; Ku, L.Y.; Nure, B.K.; Wang, C.M.; et al. Study on the Production of Spring and Autumn Pasture in Fuyun County, Aletai Region. *Acta Agrestia Sin.* **2018**, *26*, 1020–1025.
17. Liu, Q.F.; Liu, Y.; Sun, X.L.; Zhang, X.F.; Kang, S.; Ding, Y.; Zhang, Q.; Niu, J.M. The explanation of climatic hypotheses to community species diversity patterns in Inner Mongolia grasslands. *Biodivers. Sci.* **2015**, *23*, 463–470. [[CrossRef](#)]
18. Wang, J.Q.; Liu, B.; Chang, F.; Liu, R.K. Species Diversity of Plant Communities and Their Environmental Interpretation in *Gentianella turkestanorum* Habitat in Bayinbrook. *Chin. J. Grassl.* **2021**, *43*, 29–36.
19. Liu, Y. Protection and Restoration of Wetlands in Habahe County, Altay of Xinjiang. *Wetl. Sci. Manag.* **2022**, *18*, 47–50.
20. Tan, F.; Yang, P.N.; Wang, C.; Li, Z.P.; Gao, F.; Xu, Y.; Wu, Q. Water Requirement for Ecological Restoration of Damaged Vegetation in Arid Area—A Case Study at Plain Area in Hahahe County, Xinjiang Wei Autonomous Region. *Bull. Soil Water Conserv.* **2023**, *43*, 244–252.

21. Zhang, K.L.; Ye, M.; He, Q.Q.; Yin, X.K.; Guo, J.X. Analysis of Species Diversity and VOR Index of Different Grassland Types in the Habahe Region of the Altai Mountains. *Bull. Soil Water Conserv.* **2023**, *37*, 262–271+279.
22. Zhou, Q.; Ye, M.; Zhao, F.F. Ecosystem health assessment based on the VOR model analysis in forest area of Altai Mountains. *J. Gansu Agric. Univ.* **2021**, *56*, 137–168.
23. Qiao, M.; Chen, Y.N.; Zhao, X.Y. Analysis and evaluation on the agricultural morphological conditions in Haba river basin, Xinjiang. *Arid. Land Geogr.* **1997**, *2*, 67–72.
24. Zhao, X.Y.; An, S.Z.; Cao, G.M.; Li, X.J.; Lan, D.M.; Chu, J.M. Surveying desert major plant communities in China: Implications, current status, and scheme. *J. Desert Res.* **2023**, *43*, 9–19.
25. Guan, F.; Liang, Z.; Wang, Z.; Guan, Z. Comparison of square grid method and digital image method for determining vegetation cover in salinized grassland. *Northeast Agric. Univ.* **2022**, *30*, 120–196.
26. Li, X.; Yu, H.; Liu, Y.; Chang, S. Biomass and diversity of different grassland types in Xilingol. *Grassl. Sci.* **2022**, *30*, 120–196.
27. Wang, C.; Long, R.; Wang, Q.; Jing, Z.; Ding, L. Importance of species characteristics and evenness in different types of alpine grassland communities. *J. Grassl. Sci.* **2005**, *35*, 320–332.
28. Shen, R.; Zhang, J.; He, B.; Li, F.; Zhang, Z. Structural characteristics and similarity analysis of grassland plant communities in the dry and hot river valley of Yuanjiang basin. *J. Ecol. Environ.* **2010**, *19*, 2821–2825.
29. Ma, K.P. Measuring methods of biodiversity i. Measuring methods of α diversity (part one). *Chin. Biodivers.* **1994**, *2*, 229–239.
30. Ma, K.P. Measuring methods of biodiversity i. Measuring methods of α diversity (part two). *Chin. Biodivers.* **1994**, *2*, 231–239.
31. Baselga, A.; Leprieux, F.; Spencer, M. Comparing methods to separate components of beta diversity. *Methods Ecol. Evol.* **2015**, *6*, 1069–1079. [[CrossRef](#)]
32. Zhang, X.W.; An, H.; Liu, X.P.; Wen, Z.L.; Wang, B.; Du, Z.Y. Effects of short-term nitrogen addition on plant community composition and stability of desert steppe. *Chin. J. Ecol.* **2021**, *40*, 2400–2409.
33. Ning, T.; Guo, Z.S. Characteristics of the soil water cycle in an abandoned sloping field in the semi-arid Loess Hilly Region. *Acta Ecol. Sin.* **2015**, *35*, 5168–5174.
34. Li, X.M.; Song, Y.B.; Jiang, W.L. Tianshan Mountains, Altai Different Types of Grass Lawn Nutrient Evaluation Group. *Caoye Yu Xumu* **2015**, *219*, 44–48.
35. Liu, Y.Z.; Liu, W.T.; Yang, X.X.; Fang, B.; Sun, C.C.; Li, C.D.; Zhao, X.Q.; Dong, Q.M. The effect of herbivore assemblage on plant community characteristics and aboveground net primary productivity in alpine grasslands. *Chin. J. Ecol.* **2023**, *21*, 57–65.
36. Liu, X.M.; Nie, X.M. Effects of enclosure on the quantitative characteristics of alpine vegetation. *Pratacultural Sci.* **2012**, *29*, 112–116.
37. Chen, L.; Saixi, Y.; Yi, R.; Baoyin, T. Characterization of soil microbes associated with a grazing-tolerant grass species, *Stipa breviflora*, in the Inner Mongolian desert steppe. *Ecol. Evol.* **2020**, *10*, 10607–10618. [[CrossRef](#)] [[PubMed](#)]
38. Sanaei, A.; Ali, A. What is the role of perennial plants in semi-steppe rangelands? Direct and indirect effects of perennial on annual plant species. *Ecol. Indic.* **2019**, *98*, 389–396. [[CrossRef](#)]
39. Sasaki, T.; Okayasu, T.; Jamsran, U.; Takeuchi, K. Threshold changes in vegetation along a grazing gradient in Mongolian rangelands. *J. Ecol.* **2008**, *96*, 145–154. [[CrossRef](#)]
40. Liu, J.H.; Wang, Z.W.; Han, G.D. Effects of heavy grazing on the interspecific relationship of main plant species and community stability in a desert steppe. *Chin. J. Ecol.* **2019**, *38*, 2596–2602.
41. Milchunas, D.G.; Lauenroth, W.K. Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecol. Monogr.* **1993**, *63*, 327–366. [[CrossRef](#)]
42. Greenwood, K.L.; McKenzie, B.M. Grazing effects on soil physical properties and the consequences for pastures: A review. *Aust. J. Exp. Agric.* **2001**, *41*, 1231–1250. [[CrossRef](#)]
43. Dong, Y.Q.; Sun, Z.J.; An, S.Z.; Ayimin-Bolati, Y.J.; Li, K. Effect of short-term grazing exclusion on community characteristics and stability in *Artemisia* desert on the northern slopes of Tianshan Mountains. *Pratacultural Sci.* **2018**, *35*, 996–1003.
44. Grime, J.P. Benefits of plant diversity to ecosystems: Immediate, filter and founder effects. *J. Ecol.* **1998**, *86*, 902–910. [[CrossRef](#)]
45. Tilman, D.; Wedin, D.; Knops, J. Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature* **1996**, *379*, 718–720. [[CrossRef](#)]
46. Hu, D.; Lu, G.H.; Wang, H.F.; Yang, Q.; Cai, Y. Response of desert plant diversity and stability to soil factors based on water gradient. *Acta Ecol. Sin.* **2021**, *41*, 6738–6748.
47. Wang, C.T.; Long, R.J.; Ding, L.M.; Lai, D.Z.; Li, Y.F. Species diversity, community stability and ecosystem function--extension of the continuous views. *Pratacultural Sci.* **2005**, *22*, 195–208.
48. Si, R.; Liu, B.; Zhao, W.Z.; Zhu, Z.C.; Zhao, Y. Species diversity and stability patterns of plant communities in the tail area pf the Heihe River. *J. Desert Res.* **2021**, *41*, 174–184.
49. Pontes, L.; Maire, V.; Schellberg, J.; Loualt, F. Grass strategies and grassland community responses to environmental drivers: A review. *Agron. Sustain. Dev.* **2015**, *35*, 1297–1318. [[CrossRef](#)]
50. Pimm, S.L. The complexity and stability of ecosystems. *Nature* **1984**, *307*, 321–326. [[CrossRef](#)]
51. Tilman, D.; Reich, P.B.; Isbell, F. Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 10394–10397. [[CrossRef](#)] [[PubMed](#)]
52. Hooper, D.U.; Adair, E.C.; Cardinale, B.J.; Byrnes, J.E.; Hungate, B.A.; Matulich, K.L.; Gonzalez, A.; Duffy, J.E.; Gamfeldt, L. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature* **2012**, *486*, 105–108. [[CrossRef](#)] [[PubMed](#)]

53. Zhang, J.H.; Huang, Y.M. Biodiversity and stability mechanisms: Understanding and future research. *Acta Ecol. Sin.* **2016**, *36*, 3859–3870.
54. Jin, Y.X.; Liu, F.; Zhang, J.; Han, M.Q.; Wang, Z.W.; Qu, Z.Q.; Han, G.D. Net ecosystem carbon exchange characteristics in *stipa breviflora* desert steppe with different stocking rates. *Chin. J. Plant Ecol.* **2018**, *42*, 361–371.
55. Song, Y.T.; Huo, G.W.; Wu, Y.N.; Zhang, X.L.; Zhang, X.H. Analysis on Characteristics of Community Structure under the Grazing Influence. *J. Anhui Agri. Sci.* **2015**, *43*, 24–127.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.