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ARTICLE

Effects of Grazing on vegetation in the Gobi desert region of Mongolia

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Abstract: Mongolia is a massive, semi-arid country in Central Asia with a huge territory of 1,500,000 km^2, with rangeland making up around 75% of the country's territory. These rangelands have supported herders and grazing animals for millennia. The transition from nomadic to stationary livestock husbandry in Mongolia’s rangeland has resulted in major changes in vegetation communities due to increased livestock numbers. The primary objective of this study is to examine the impacts of grazing on the vegetation of rangelands in the desert steppe ecosystem. The purpose of this study is to examine the impacts of livestock grazing by measuring vegetation standing crop biomass, vegetation cover, and species' richness. The study was carried out in Khanbogd soum (district), Umnugovi aimag, the southern province of Mongolia. To assess the grazing impact, we sampled fourteen winter camps of herders who are members of the four herder groups, who were located at 1000 m and 2000 m from each. In total, we sampled 28 plots in two consecutive years. Our results indicate that aboveground biomass, cover, and species' richness did not differ with increasing distance from winter camps. Similar grazing pressures were shown at 1,000 and 2,000 meters away from the winter camps as well.

Keywords: *grazing intensity, range condition, environmental variability;*

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INTRODUCTION

Mongolian rangelands cover nearly 75% of the nation's territory, supporting the livelihood of a one third of Mongolia's population of almost 3.3 million, whilst providing a habitat to major wildlife populations [1]. These rangelands are important for grazing. Archaeological records indicate that people have been raising livestock in Mongolia for thousands of years [2], [3]. Mongolian rangeland ecosystems are classified into the following six main types: alpine tundra (covering 3.0% of the total rangeland), mountain taiga (4.1%), mountain and forest-steppe (25.1%), grass steppe (26.1%), desert steppe (27.2%), and desert (14.5%) [4]. Mongolia's steppes are particularly important grazing environments [5].

Mongolian rangelands are one of the most highly impacted ecosystems in the world. It is estimated that biotic and abiotic factors, as well as human activities, have less severely or severely degraded about 70% of the rangelands [6]. However, at present, there is significant inquiry surrounding the fundamental question of the extent to which the Mongolian rangelands have undergone degradation. Over the last several decades, the average temperature has dramatically increased in central and semiarid North-Eastern Asia [7]. The mean annual temperature in Mongolia has increased by $2^{\circ}C$ over the last 70 years [8]. Additionally, patterns of precipitation have changed since 1960. Precipitation has increased in the eastern and southern parts of the country, while it has decreased by 1-2.0 mm per year in other areas [9].

A decrease in precipitation and a rise in air temperature are the main contributing factors causing rangeland degradation in Mongolia, while other factors, such as livestock density, land cultivation and wildfires, exacerbate the effects of these climatic shifts [10]. These changes appear to have a greater impact on vegetation of rangelands in the mountain steppe zone than on those in the desert steppe regions [9]. The plant communities in the mountain steppe zone of Mongolia are especially susceptible to climate change and have experienced severe impacts [11]. Between 1940 and 2003, the mean temperature in Mongolia increased by 1.8 degrees Celsius, and the increase was more noticeable in winter than in summer in the Gobi desert [13]. Animal husbandry and other land uses have been negatively affected by this changing climate, thereby impacting herders' livelihood as well. Dzud, a wintertime extreme weather condition characterized by severe frosts and significant snowfall, occurs frequently in Mongolia. Yet the frequency of Dzud has increased in recent years and now it occurs as often as every 3 to 5 years. Livestock numbers decreased by 30% during the consecutive dzud that hit the country between 1999 and 2002 [8]. However, the number of livestock recovered quickly and reached to the pre-dzud level by 2001. Dzud and droughts are major threats to vegetation growth, plant cover, and net primary production [13]. Insufficient research has been conducted on the ecological reactions of the desert steppe to the combined impacts of human disturbances, such as livestock grazing, and also environmental stressors, such as climate change [11]. Rangeland degradation can lead to urban migration, resulting in overpopulated cities and increased poverty levels [4]. It is essential to assess the level of degradation and factors causing rangeland degradation in order to introduce sustainable rangeland management [14].

Overgrazing is considered one of the main factors contributing to rangeland degradation in Mongolia [15]. Mongolian rangeland scientists and policy makers tend to use conventional estimates, which show that 70% of Mongolian rangelands are

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degraded [16] moderately to very severe. A standardized degradation framework has been developed in response to the need for clarity and specificity when defining degradation [17]. Mongolia had 60 million livestock in 2017 [18]. Changes that reduce ecosystem function and loss of native rangeland plant species are considered as degradation among ecologists, whereas for herders, degradation means loss of forage availability and reduction of seasonally appropriate vegetation, these being factors that directly affect livestock by reducing access to essential key resources and plants. Both of these views are valid and important when interpreting degradation.

Livestock husbandry is an important sector of the Mongolian economy and one that relies on favorable rangeland conditions. Until mining activity became a significant part of the economy in 2010, livestock products were the premiere sector in the economy. The Mongolian economy transitioned to a free market in the 1990s, which resulted in a significant change in terms of livestock ownership. Before the 1990s, herders had relied on salaried income provided by the *negdel* or herding collective, but after the transition, herders relied solely on their personally-owned livestock for subsistence. One consequence has been that herders have been tempted to increase the number of livestock as this directly equates to increased income. Higher livestock number has led some to argue that overgrazing has caused land degradation in many regions around Mongolia [19]. Traditionally, the Mongolian nomadic herding lifestyle practiced four-season mobility. However, due to the limited availability of water sources, herders cannot always move four times a year across arid land. They move to different camps within a distance of 5-80 kilometers of the water source; without a water source, the rangeland is not considered a rangeland.

The previous studies conducted in the desert steppe concluded that total coverage vegetation has a low to moderate correlation with the distance from the source of water [20]. In the desert steppe, plants are sparse compared to plants in the steppe and mountain steppe regions of Mongolia [19]. In the desert steppe, shrubs and perennial forbs cover is higher than the cover of annual grasses, perennial grasses, and annual forbs. Plant standing crop biomass is dependent on the amount of summer precipitation [21]. Standing crop biomass in the desert steppe ranges from 290 to 380 kilograms per hectare, and the plant communities are heterogeneous [13]. During summers with drought, many annual plants become absent, whereas in summers with higher precipitation some annual plants grow, and consequently, primary production and biomass increase [22]. Overgrazing has been less problematic in the desert steppe zones than in the mountain steppe and forest-steppe zones, due to lower livestock numbers and lower grazing intensity [3], [23]. For the desert steppe zone, rainfall and not grazing pressure is the primary driving factor for plant growth [24]. The seasonal movement of livestock over short and long distances is a well-established practice of Mongolian herders in response to drought conditions [25]. Herders tend to move north when drought occurs [26], this is because there are lower precipitation fluctuations and higher rainfall as one moves further north in Mongolia [22].

To improve grazing capacity and sustainable land use, it is critical to assess the conditions of utilized rangelands. A very common practice in Mongolia to improve the condition of degraded rangeland, unless it has crossed the tipping point, is to exclude grazing on the rangelands for a period of time (especially during growing season) which facilitates natural recovery [27].

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Vegetation cover and species richness are main indicators for assessing and monitoring the rangelands [28]. In order to monitor rangeland ecosystems, researchers have mainly focussed on vegetation cover, species' richness and species' composition [29].

The concept of the present study is to assess whether proximity to winter camps can serve as an indicator of the level of grazing pressure, with higher pressure observed close to the winter camps and lower pressure further away. It is commonly assumed that grazing pressure and livestock density mostly increase with proximity to the winter camps and water sources [30]. In our study, we hypothesized that livestock grazing pressure would vary with distance from the center of the winter camps, we further hypothesized that livestock grazing pressure would be greater if the animals are grazed close to the winter campsites and this could be detected by the changes in vegetation standing crop biomass, cover, and species' richness.

MATERIALS AND METHODS

Study area

The study area is located in Khanbogd *soum*, a rural district in Umnugobi aimag - province in southern Mongolia (Figure 1). We sampled on the rangelands of the herders of the four subdistricts (*bagh*) including Nomgon, Javkhlant, Bayan, and Gaviluud in Khanbogd soum. The total territory of the Khanbogd soum is 15,150 km^2, which is qualified as dry rangeland. Total annual precipitation is around 100 mm. Light brown soil is dominant, and the soil character comprises light white color, which is very low in humus and nutritional content. There are four types of ecological sites in the study area: saline bottomland, calcareous gravelly, clay, and sandy soils. The flora consists of 155 species in 38 families and 118 genera. Among these species, seven are rare plant species, 68 species are important for medicinal uses, nine are used for livestock forage, four are tree species, and 27 are shrub species.

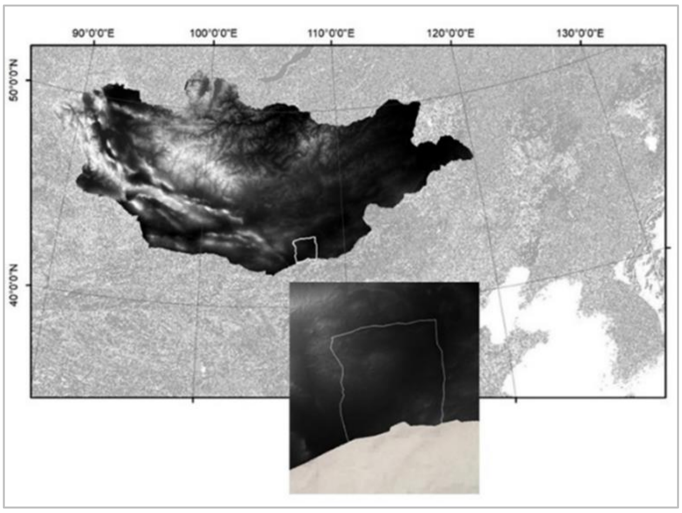

Figure 1. The study area location

The average elevation of the study area is 1068 m above sea level. The mean annual temperature was 8.9℃ in 2014 and was 8.3℃ in 2015. The total annual rainfall in 2014 was 101.6 mm, whereas in 2015 it increased to 134.2 mm (Table 1). The long-term coefficient of variation (CV) for precipitation (15 years) was 73%. Non-equilibrium model is likely to occur where the CV is greater than 33% and annual precipitation is less than 250 mm in Mongolia [31]. The study area is regulated by the non-equilibrium model because of accumulated annual precipitation (<250 mm), and CV for precipitation (>33%). According to the non-equilibrium model of rangeland dynamics, rainfall patterns rather than grazing activities are primarily responsible for driving vegetation dynamics in areas with low annual precipitation and significant year-to-year variations in rainfall [32].

Table 1. Site characteristics of Khanbogd soum, Umnugobi aimag

	2014	2015
Annual precipitation (min-max)	101.6 mm (0.3-34)	134.2 mm (0.6-45.2)
January temperature	-7℃	-6.9℃
July temperature	27℃	25℃

(Source: From Rangeland monitoring report in Khanbogd soum 2015).

Total number of livestock in Khanbogd increased dramatically after 1990. However, the number of cattle fell precipitously between 1993 and 2001 due to dzud and drought (Figure 2).

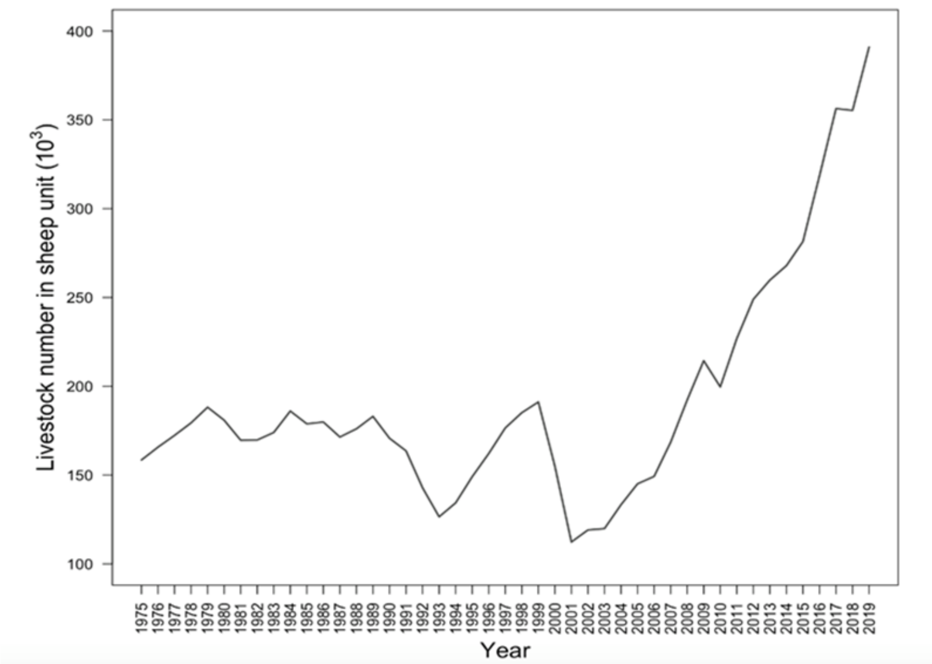

Figure 2. Livestock numbers in 1975-2015 in Khanbogd soum (sheep unit)

Design of the study

For this study, 28 monitoring plots were sampled in August of 2014 and 2015 from 14 winter camps in the four herder groups (Bayan, Gaviluud, Javkhlant, and Nomgon) at two distances (1000 m and 2000 m). Plots were selected from winter camps with similar physical conditions and without any other winter camps nearby (within 2000 m radius) to avoid overlapping. Prior to developing a study design, aimed at evaluating grazing pressure in desert steppe ecosystems, we received recommendations provided by local herders to set plots and therefore, we located the plots at distances of 1000 m and 2000 m from the winter campsites. Each monitoring plot is rectangular in shape and 50m x 50m in size (2.500m^2). We set 5 vertical transects within the plot, spaced roughly 12.5 meters apart (0m, 12.5m, 25m, 37.5m, and 50m), extending from the bottom transect to the

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top transect. The line point intercept (LPI) method was used along the each vertical transect in every meter to estimate vegetation cover. We used zig zag walk inside the entire plot in search of every species to record species' richness. We measured the open gaps between the bases of perennial plants along the five vertical transects to measure the basal gap. We collected the standing biomass by plant functional types, grasses, forbs, shrubs, and debris separately. Biomass was gathered within each 1m^2 plot in every transect. Biomass samples were cut by 0 meter above the surface. Collected biomass were oven dried at 60^{0}C temperature for 48 hours, and weighed separately for grass, forbs, shrubs, and litter.

Also, at each plot we recorded geomorphological data, such as altitude, slope, aspect, landform, and geographic location.

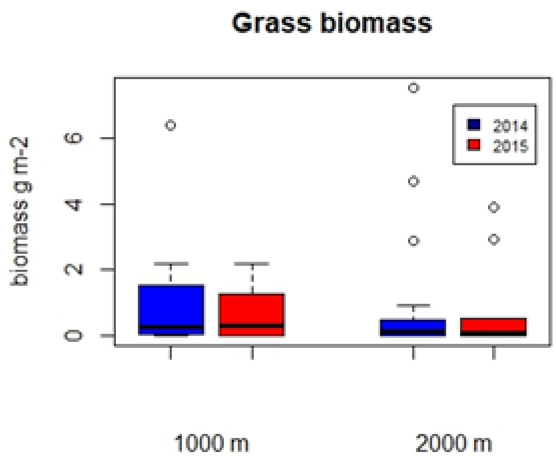
Data analysis

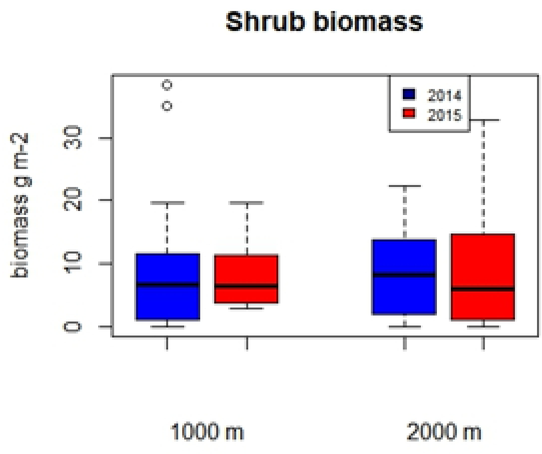
We used a repeated measurement analysis of variance to compare the effect of distances from winter camps and years on biomass, vegetation cover, and species' richness. T-test was used to compare biomass, vegetation cover and species' richness between different distances from winter camps and years. Two-way analysis of variance (ANOVA) was used to compare foliar cover of plant functional groups at the two distances. Statistical tests were considered significant at $p<0.05$. In addition, we used correlation to compare the number of livestock to the species' richness of plant in four herder's *bagh*. We used the R software for statistical analysis.

RESULTS AND DISCUSSION

Biomass

In our study site, shrub and grass were the plant functional groups that contributed the most to the total standing crop biomass at both distances. Shrub, grass and forb biomasses did not differ along the grazing gradient (at 1000m and 2000m), although the total shrub and grass biomass tended to be (not significant) greater in 2014 than in 2015. In contrast, forb standing crop biomass was lower in 2014 than in 2015 (p=0.98). Litter biomass was greater at 2000 m than at 1000 m, which was consistent in two sampling years, in 2014 and 2015 (Figure 3) respectively.





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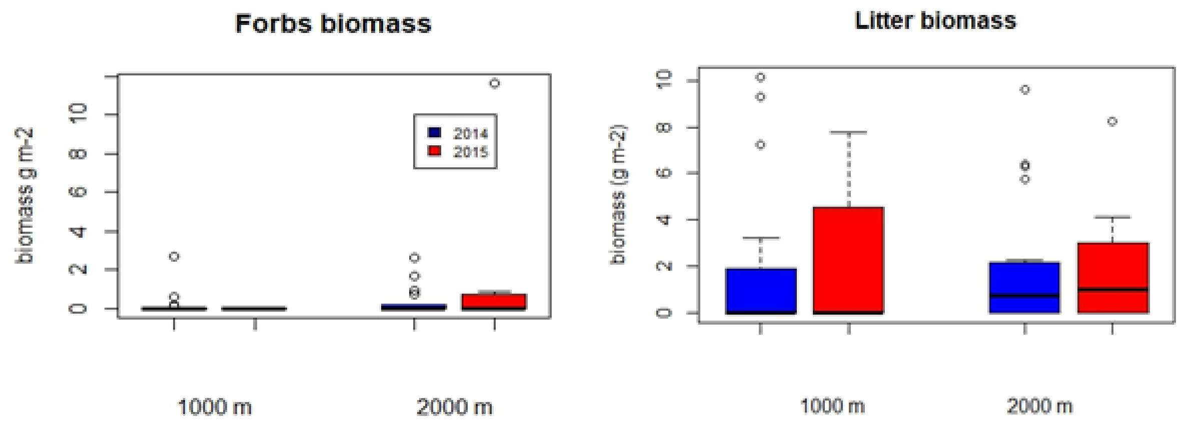

Figure 3. Boxplot showing the biomass (g/m^2) in areas with two different distances (1,000 and 2,000 m) from the winter camps in 2014 and 2015 at Khanbogd soum

Vegetation cover

There was no significant difference in vegetation cover between the two distances (p = 0.92). The vegetation consisting of shrubs and grass had the greatest extent in both 2014 and 2015 (Figure 4). In both 2014 and 2015, the levels of forbs and litter cover were lower compared to other plant functional groups.

There was no significant difference in the total vegetation cover between the two distances (p = 0.99). However, the total vegetation cover varied between the two sample years. In 2014, the overall vegetation cover was significantly lower (p = 0.01) compared to 2015, where it was much higher (p = 0.001).

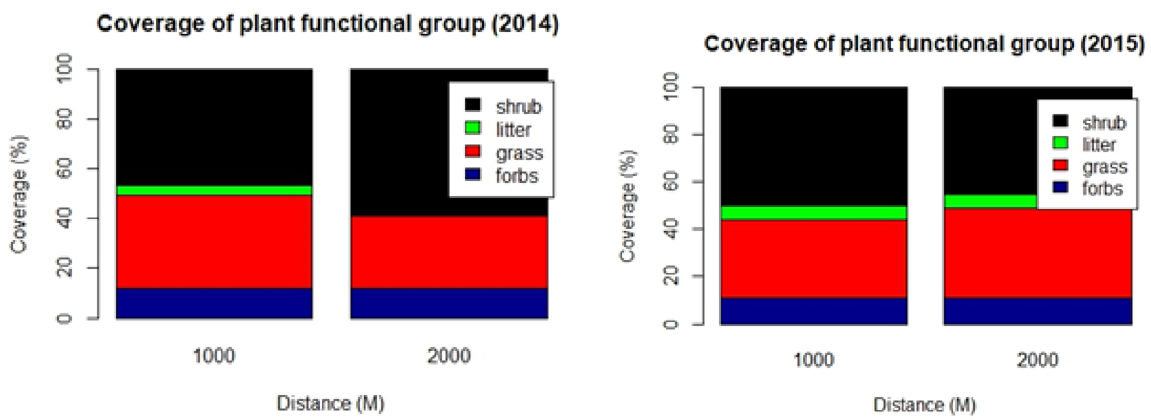

Figure 4. Boxplot showing the coverage of plant functional groups at two different distances (1,000 and 2,000 m) from the winter camps in 2014 and 2015

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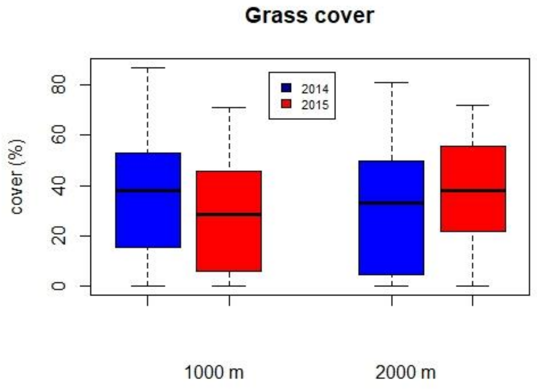
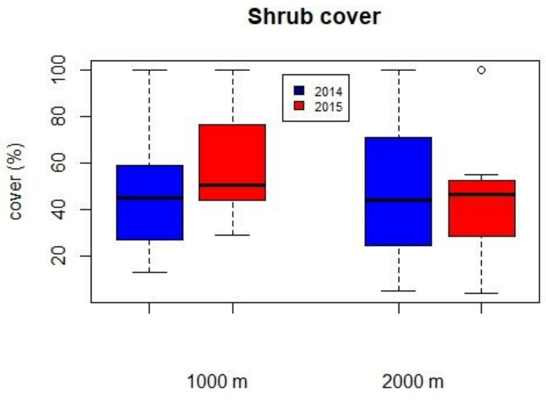
None of the plant functional groups were significantly different in 2014 and 2015. Total biomass was not significant in 2014 and 2015 (p=0.26). Grass, forb, shrub, and litter biomass were not significant in 2014 and 2015 (Table 2).

Table 2. Repeated-measure analysis of variance (ANOVA) of the effects of distance from winter camps and year on biomass

Variable	Source	d.f.	sum sq.	F
Grass biomass	distance	1	0.42	0.15
	year	1	0.09	0.03
	distance: year	1	0.25	0.08
Forb biomass	distance	1	1.70	0.63
	year	1	4.66	1.73
	distance: year	1	6.21	2.13
Shrub biomass	distance	1	163	1.96
	year	1	0	0.0
	distance: year	1	22	0.26
Litter biomass	distance	1	8.7	0.91
	year	1	0.1	0.009
	distance: year	1	0.1	0.01
Total biomass	distance	1	51	0.51
	year	1	125	1.27
	distance: year	1	76	0.77
Species richness	distance	1	0.5	0.04
	year	1	64.5	5.70
	distance: year	1	2.9	0.25

Grass and shrub cover were greater than forbs and litter cover in 2014 and 2015 (Figuer 5). Shrubs and grasses were the most abundant functional group along both distances. Shrub cover was greater in 2014 than in 2015. There was no litter at 1000 m and a small amount of litter at 2000 m both in 2014 and in 2015.





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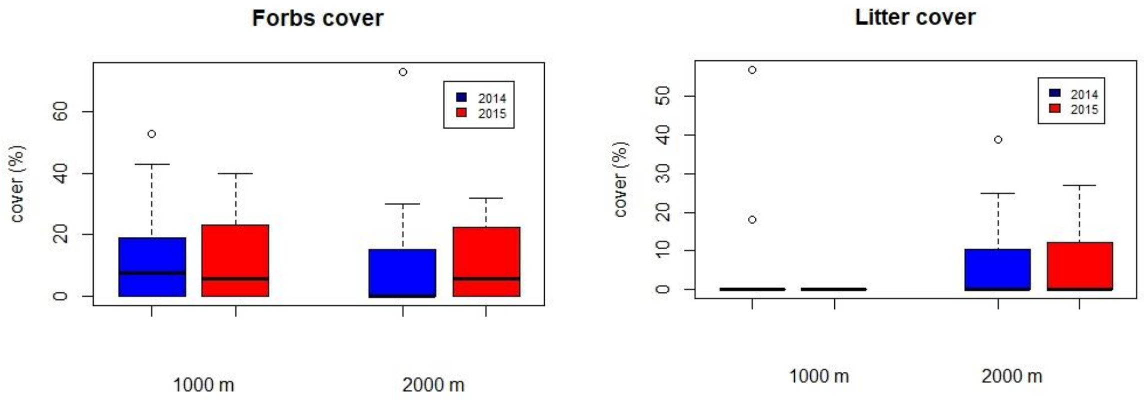

Figure 5. Boxplot showing each plant functional group's coverage at two different distances (1,000 and 2,000 m) from the winter camps in 2014 and 2015 at Khanbogd soum. The blue color represents the year 2014 and the red color represents the year 2015

Species richness

The total number of species observed at the two different distances in 2014 and 2015 did not show a significant difference ($p = 0.83$). However, there was a difference in the number of different species present between the years 2014 and 2015 ($p = 0.02$). This discrepancy might be attributed to varying levels of precipitation in the respective years. The average number of species was 9 at an altitude of 1000 m, 14 at an altitude of 2000 m in 2014, 10 at an altitude of 1000 m, and 11 at an altitude of 2000 m in 2015 (Figure 6).

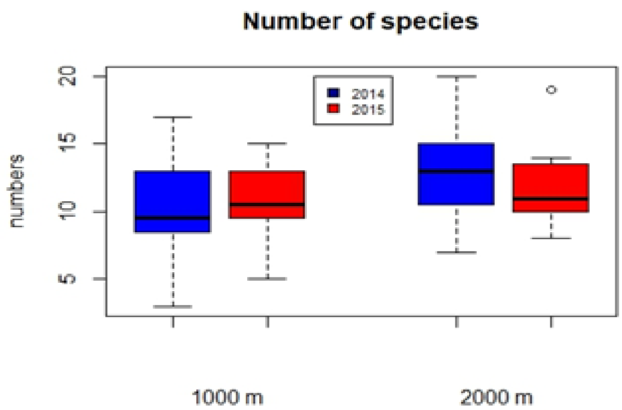

Figure 6. Boxplot showing plant species richness at two different distances (1,000 and 2,000 m) from the winter camps in 2014 and 2015, Khanbogd soum

There was insignificant positive correlation in Bayan herder's group (r^2=0.16, p=0.61), in Gaviluud (r^2=0.16, p=0.1), and insignificant negative correlation in Javkhlant (r^2= -0.37, p=0.61), Nomgon (r^2= -0.31, p=0.28) between the number of plant species and livestock numbers at two different distances (1,000 and 2,000 m) from the winter camps (Figure 7).

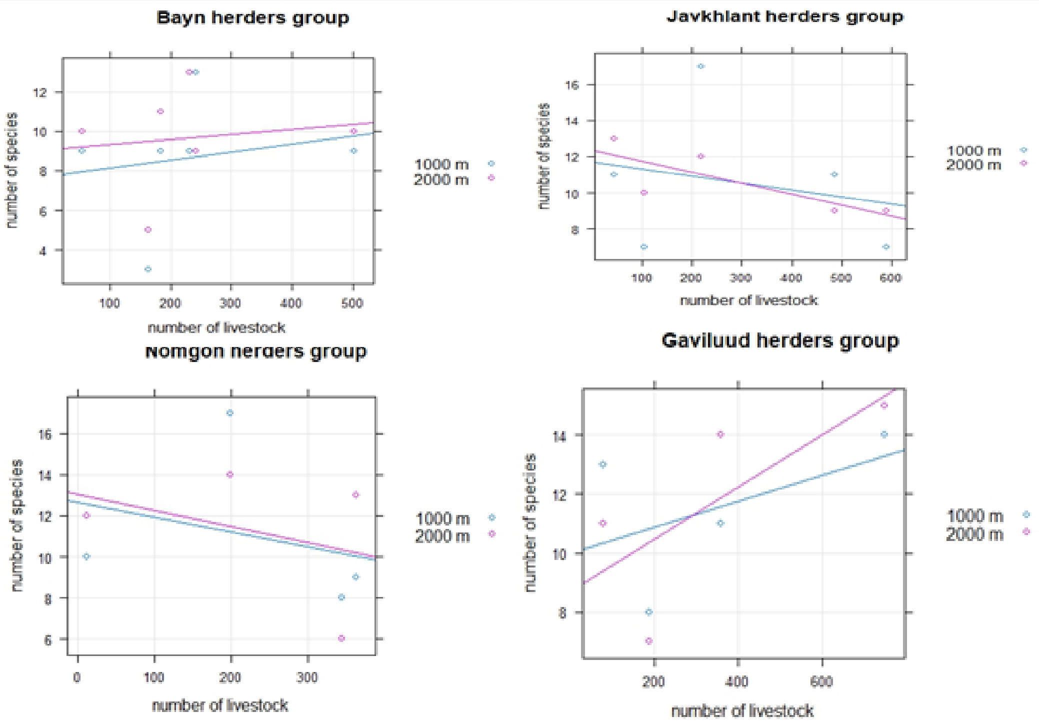

Figure 7. Scatterplot showing the linear model relationship between number of species and number of livestock

Before carrying out this study to assess the grazing impact on vegetation in the desert steppe, we relied on recommendations from local herders. People, who live in Khanbogd *Soum*, believe that numerous factors contribute to the state of the rangeland and its current variations. These factors encompass abiotic factors, such as soil composition, water availability and usage, land form, and climate variables, including precipitation throughout both the growth and dormant seasons, as well as diurnal and nocturnal temperatures. They also encompass the impact of wildlife, livestock, and other forms of land utilization. Herders attribute these shifts to fluctuations in temperature, the expansion of mining activities, the construction of new roads, and other advancements in infrastructure. The increasing livestock numbers, the lack of supportive policies and enforcement measures, the lack of cooperation between the local government and the communities, the decline of traditional knowledge, and the development of herding techniques are just a few of the factors contributing to rangeland degradation and alteration. The residents of Khanbogd hold the belief that the available rangelands have been diminishing in size as a result of road building, degradation of areas near water sources, and the presence of mining activities.

We hypothesized that biomass, vegetation cover, and species richness would increase with distance from winter camps. We did not find any difference between the two grazing distances except litter biomass and cover. This finding has significance since variations in litter at some level imply less grazing farther from the winter campsite (at 2000 m), which also was a potentially greater protection against wind erosion and a higher flow of nutrients into the soil through litter decomposition.

Shrub and grass covers were higher than any other plant functional groups.

Shrubs were the dominant vegetation type in our study area. According to the range condition model [33], high livestock grazing intensity leads to a reduction in perennial grasses and an increase in weedy annuals. But in this case, most plant functional groups had a similar cover, except for shrubs and perennial grasses. This does not mean that the study area is degraded, as the desert steppe has less vegetation cover than other ecological zones in Mongolia due to high variable precipitations [26]. Annual grasses had low cover in all four herder groups, possibly caused by low precipitation. Precipitation greatly influences the vegetation biomass and species richness [22] and is the limiting factor of vegetation growth in desert steppe [13].

Our study showed that there was a trend that species' richness at two distances from winter camps differed, but not the significant difference in species' richness with increasing grazing pressure. Grazing pressure has less effect on vegetation in the desert steppe. In the winter camps, species' richness averaged 14 plant species.

Previous studies have shown that vegetation cover and species' richness differ with distance from water or winter camps. However, these differences depend on the ecological zones: in mountain steppe and steppe there are higher levels of grazing pressure with proximity to livestock camps or water points, as compared to the desert steppe [34].

At three different distances (500, 500-2,000 m, >2,000 m) from water sources, Fernandez-Gimenez & Allen-Diaz (1999) examined the impact of livestock grazing pressure on vegetation, based on biomass, vegetation cover, and species' richness in three different ecological zones (desert steppe, mountain steppe, and steppe) in Mongolia.

They compared data from 1994 and 1995. Their study showed that there were significant differences in biomass, vegetation cover, and species' richness with increasing grazing pressure in mountain steppe and steppe, but not in the desert steppe, which supports our study findings. In a related study, despite an additional factor of elevation differences, vegetation changes along a gradient from water sources in the steppe and mountain-steppe zones were consistent with typical patterns of vegetation change in response to increased grazing pressure, and in the desert steppe, no persistent vegetation effects induced by grazing gradients were detected [34].

In the dry environment of Khanbogd, a longer timeframe is needed to measure changes in rangeland in order to understand the grazing impact and carefully delink the grazing effect from the climatic factors. Our results suggest that an alternative way of measuring grazing effects would be to maintain monitoring plots over a long-term period (at least 5 years) of time to promote collaboration and participation of local people in rangeland monitoring.

CONCLUSIONS

The results of our study indicate that there was no statistically significant difference in terms of biomass, vegetation cover, and species' richness between distances of 1,000 and 2,000 meters from winter camps. However, it is important to note that there were notable variations in litter biomass and cover. The presence of litter provides enhanced protection against wind erosion and facilitates a larger influx of nutrients into the soil via the process of litter decomposition. The correlation analysis conducted on the Nomgon and Javkhlant herder groups revealed that grazing by livestock accounted for 31% and 37% of the observed decrease in plant species, respectively.

The results indicate that the grazing impact is similar at both distances. The local people in Khanbogd perceive changes in various aspects of the rangelands, including plant composition, soil, water, rangeland conditions, climate, wildlife, and livestock. These changes are attributed to climate change, mining development, road construction, increased livestock numbers, and loss of traditional knowledge and practices. Grazing pressure in the desert steppe was found to have less effect on vegetation composition compared to other ecological zones. Species' richness in the desert steppe was relatively low, but this does not necessarily indicate degradation. Previous studies in similar ecological zones have shown that plant cover and species richness change depending on how close they are to water sources or camps. Places closer to these sources had higher levels of grazing pressure. However, in the desert steppe, there were no obvious vegetation changes as a result of grazing gradients. Grazing-tolerant plant communities have taken the place of palatable herbaceous plant communities near water sources, while shrub groups have disappeared in drier areas. Herbaceous plant communities have the ability to recover from grazing more quickly as compared to shrub ecosystems. In summary, our results confirm that the study area should be considered as desert steppe, which is regulated by a non-equilibrium model due to accumulated annual precipitation being less than 250 mm, and precipitation coefficient of variation is more than >33%.

Our findings can be utilized to improve rangeland management in Mongolia's arid areas. Additional research is required to investigate how desert-steppe vegetation communities respond to grazing pressure.

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