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RESPONSE TO GRAZING PRESSURE ON THE SOIL PROPERTIES AND SHRUB COMMUNITIES IN THE SEMI-DESERT STEPPE, MONGOLIA

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Abstract: Soil physical properties (topsoil density, 0-30cm density, soil organic carbon and soil organic matter) was significant of grazing intensity in the semi-desert steppe of Mongolia. Soil physical properties are playing an important role for formation of arid ecosystem. Grazing of abundant livestock can alter for the spatial heterogeneity of vegetation and soil structure, especially of arid ecosystem. According to our results, soil organic carbon was remarkably different among all sites (*F=13.8, P<0.0001*). This study conducted to identifying grazing effects of both livestock and wild ungulates (as large herbivores) on both herbaceous shrub communities' characteristics, including their physical performance *(DF=4, F=46.73, P<0.0001)* such as, height, canopy diameter, basal diameter and annual shoot in Ikh Nart Nature Reserve. Our findings revealed the soil physical characters such as topsoil density, bulk density, SOC and SOM were decreased with increased grazing intensity, as well as grazing of herbivores was negatively affected for height, canopy diameter and annual shoot of shrub communities. Therefore, our findings clearly indicated the negative effects of grazing to studied soil properties and shrub communities in semi-desert region of Mongolia. The results also showed that there is still need well managed pasture management that covered conservation of shrub communities alongside with other-species in semi-desert region.

Keywords: Soil properties; soil organic carbon; soil organic matter; shrub community; grazing; semi-desert steppe

1. Introduction

Ikh Nart Nature Reserve (NR) hosts argali sheep (*Ovis ammon* Linnaeus, 1758), ibex (*Capra sibirica* Pallas, 1776) and goitered gazelle (*Gazella subgutturosa* Guldenstadt, 1780), which assessed as threatened by the IUCN Red List categories and criteria (Harris & Reading, 2008; Amgalanbaatar *et al.,* 2000; Amgalanbaatar & Reading, 2003; Reading *et al.,* 2001). The number of domestic animals owned by herders in the Dalanjargalan district has doubled in the last decade, from 53.92 thousand in 2000, to 196.77 thousand in 2021 (Mongolian Statistical Office, 2021). Consequently, livestock and wild ungulates significantly affect plant diversity, soil properties, and shrub communities' growth (Bayanmunkh & Enkhtuvshin, 2018; Enkhtuvshin, 2018; Dechinperlii *et al.,* 2022).

Increasing domestic animal's populations and vegetation degradation by overgrazing also are likely to have a negative impact on wild ungulates as a result of enhanced competition for resource and habitats (Taro Sugimoto *et al.,* 2018).

Ecosystem changes, such as soil erosion, degradation, and changes in soil properties caused by the grazing of many livestock over a long period of time, reduce the organic

and mechanical structure of the soil that supports plant growth (Gervasio *et al.,* 2010; Kaiyang *et al.,* 2018). Moreover, researchers note that many factors, such as plant distribution characteristics, biodiversity, and vegetation biomass, are inextricably linked to the soil type and its organic composition (Silva & Batalha, 2008).

The positive influence of shrubs for any ecosystem may vary depending on factors such as regional climate, size of shrub, nurse and beneficiary identity, and temporal scale (Lopez *et al.,* 2009). Also, currently, most of the information regarding the role of shrubs on shaping community structure and diversity in xeric regions comes from the northern hemisphere including Asian steppes (Lopez *et al*., 2009). Furthermore, a space beneath of their canopies has a more mesic microclimate, contributes to improve soil water and nutrient conditions, and providing many plant species by protection from the herbivores (Callaway, 1995). The fact that shrubs create variations in an otherwise more or less uniform habitat of open spaces means that different ecological niches become available for many herbaceous species (Schmide & Whittaker, 1981; Bruno *et al.,* 2003).

The study of the physical properties of the soil and the impact of grazing on the growth of shrub communities is important for the development of conservation management for the protection of rare ungulates, their habitats and the ecosystem as a whole in similar areas. Therefore, this objective to examine the grazing effects of large herbivore on soil properties and shrub community growth forms in the different grazing intensity area (high intensity, low intensity).

a. How does grazing effect by livestock and wild ungulates on the soil physical properties?
b. Does it affect the vegetative and generative organs due to selective eating of animals and wild ungulates?

2. Material and methods

Study area

The reserve is located in the Dalanjargalan district of the Dornogobi province, and covers a transition zone between semi-desert and steppe ecosystems (Reading et al., 2011; Ganbold et al., 2019). The landscape of the reserve is mainly characterized by rocky outcrops (Ganbold et al., 2019), which provide safe habitats for several wild ungulates, including Argali (*Ovis ammon*), Ibex (*Capra sibirica*), and Goitered gazelle (*Gazella subgutturosa*), alongside various livestock. The reserve provides pasture resources for wild ungulates and livestock. The climate condition is characterized by very limited precipitation (annually 100-150 mm) with a widely varying temperature range between cold winter (-21ºC) and hot summer (25ºC) (Reading et al., 2011; Schneider, 2014). The vegetation of the reserve is dominated by short grasses (*Stipa gobica* Roshev, *S. glareosa* P. Smirn.), forbs (*Allium polyrrhizum* Turcz. ex. Regel, *Haplophyllum davuricum* (L.) G. Don.), and shrubs (*Amygdalus pedunculata* Pall., *Atraphaxis pungens* (Biab.) Juab. Et Spach, *Spiraea hypercifolia* L., and S. *aquilegifolia* Pall.) (Jackson *et al.,* 2006; Reece *et al.,* 2019). Sampling sites were covered in the northern area of the nature reserve (Figure 1) and are described in Table 1. Moreover, Mongolia's soil is divided into five latitudinal zones, and according to this classification, the ikh Nart Nature Reserve belongs to the brown soil zone of the semi-desert steppe. Brown soils are characterized by low humus content, lack of common gypsum, no gypsum, and are almost completely covered with gravel (Tsegmid, 1969).

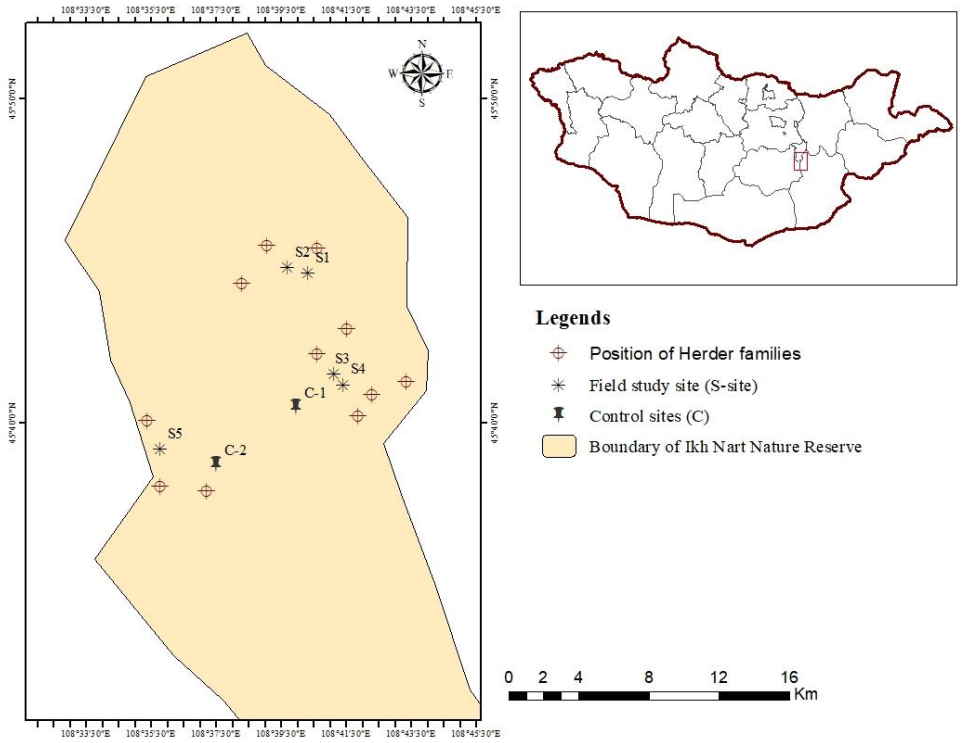

Figure 1. Study area – Ikh Nart Nature Reserve, and the sampling sites.

The estimation of grazing intensity

To access grazing intensity in each sites, we based on number of livestock in herder family and around of the herders in study sites. As well as, the habitat of livestock and wild ungulates such as Argali sheep and Siberian ibex are considered based on spatial information in the area (Table 1).

Table 1. The descriptions of the study sites in Ikh Nart Nature Reserve.

Study sites	Soil physical properties	Dominant species	The around of study sites in herder family and number of livestock (Count of Sheep)
S-1	Sand (Su)	Leek-*Allium polyrrhizum* Turcz. Ex Regel, Needlegrass-*Stipa glareosa* P.Smirn, Crested Wheat grass-*Agropyron cristatum* (L.) Beauv.	Herder family: 1, Number of livestock: 489
S-2	Sand (Su)	Needlegrass - *Stipa glareosa* P.Smirn, Leek -*Allium polyrrhizum* Turcz. Ex Regel, Chiazospermum - *Hypecoum erectum* L.	Herder family: 2, Number of livestock: 965
S-3	Sand (Su)	Leek - *Allium polyrrhizum* Turcz. Ex Regel, Gobi Needlegrass - *Stipa gobica* Roshev. Fringed Sage - *Artemisia frigida* Willd.	Herder family: 2, Number of livestock: 1.471.8
S-4	Sand (Su)	Leek - *Allium polyrrhizum* Turcz. Ex Regel, Fringed Sage - *Artemisia frigida* Willd.	Herder family: 3, Number of livestock: 2.454.3
S-5	Sand (Su)	Leek - *Allium polyrrhizum* Turcz. Ex Regel, Fringed Sage - *Artemisia frigida* Willd. Bindweed - *Convolvulus ammanii* Desr.	Herder family: 3, Number of livestock: 2.763.8

Characterization of Soils

We used the loss-on-ignition (LOI) procedure for soil organic matter (SOM) and soil organic carbon (SOC) estimation. The soils are dried at 105ºC for 1 h to remove moisture (Wang *et al.,* 2011). Then, we combusted soil in a muffle furnace at 375ºC for 16 h. Soil organic matter is calculated as the weight loss between 105ºC and 375ºC (Wang *et al.,*

2011). Moreover, soil organic carbon is calculated by the procedure provided by Hoogsteen et al. (2015). We used "core" method for soil bulk density estimation (Blake & Hartge, 1986). In addition, we determined to soil density, soil carbonates, and mechanical composition of the soil (Han *et al.,* 2021).

Shrub community methods

We surveyed shrub community from May until August 2019 to 2021, and shrub community morphological measured in from every sites. All site considered based on spatial situation by livestock and wild ungulates home range. The total of five sites were different grazing intensity. Moreover, two site (10m x 10m grids) were controlled for grazing intensity. Morphological measurements of shrub (height, crown, basil diameter and annual shoots) were performed according to the method of Miralles-Crespo et al. (2010) for each shrub occurring in the form of radiation in each field design (north, southeast, southwest) in a 100m straight line (Line transect methods).

Data analysis

One-way analyses of variance (ANOVA) were performed to determine whether there is a significant different among the sites in soil physical properties and morphological forms of shrub due to herbivory grazing. Moreover, we tested to compare (T-test) in grazing and un-grazing sites. As well as, the multi-variance analysis were among morphological form of shrub and soil physical properties.

3. Result

Soil characteristic

The content of soil organic carbon and organic matter in the soil varies statistically between areas with different grazing intensities ($F=20.6$, $P<0.0001$). High grazing intensity S2 and S5 site were lowest of the soil organic carbon. However, S1 and S3 sites were highest of the soil organic carbon. Therefore, all sites were among significantly different ($F=20.6$, $P<0.0001$) (Table 2). In addition, sample site has an significantly different for the soil layer has a depth of 0-30 cm ($F=4.2392$, $P>0.02$) and soil weight ($F=7.8251$, $P<0.04$) (Table 2). The relatively high physical properties of soils in low pastureland areas indicate that they depend on pastureland impacts.

Table 2. Site differences of soil characteristic in Ikh nart nature Reserve.

Sites	Soil depth (0-30 cm)	Soil weight	Soil Organic Carbon (SOC, g kg^{-1})	Soil Organic Matter (SOM, g kg^{-1})	Soil Bulk Density (g/cm^3)
S1	1.03±0.07	106.2±6.1	1.372±0.07	2.92±0.15	0.044±0.001
S2	1.33±0.02	134.1±2.2	0.705±0.04	1.5±0.47	0.048±0.002
S3	1.29±0.09	1.3±9.4	1.504±0.47	3.2±1.01	0.041±0.002
S4	1.04±0.04	1.0±4.2	1.41±0.44	3.02±0.95	0.043±0.002
S5	1.35±012	1.4±6.5	1.13±0.35	2.42±0.76	0.046±0.001
P – value (One-way ANOVA between the sites	0.0291*	0.004*	0.001*	0.001*	0.2470

The grazing effect on growth of shrub communities

Grazing has differently affected morphological variable; height (F=3.02, P<0.0216), canopy diameter (F=3.36, P<0.01), and annual shoot (F=46.7348, P<0.0001) significantly differed in the sites, while basal diameter (F=1.68, P<0.16) did not respond to grazing (Figure 2). As well as, shrub height displayed significantly fence and unfence sites (t = 4.49, df = 14, P = 0.0004), and annual shoot of shrub community (t = 5.0739, df = 11, P = 0.0002) (Figure 3; Figure 4).

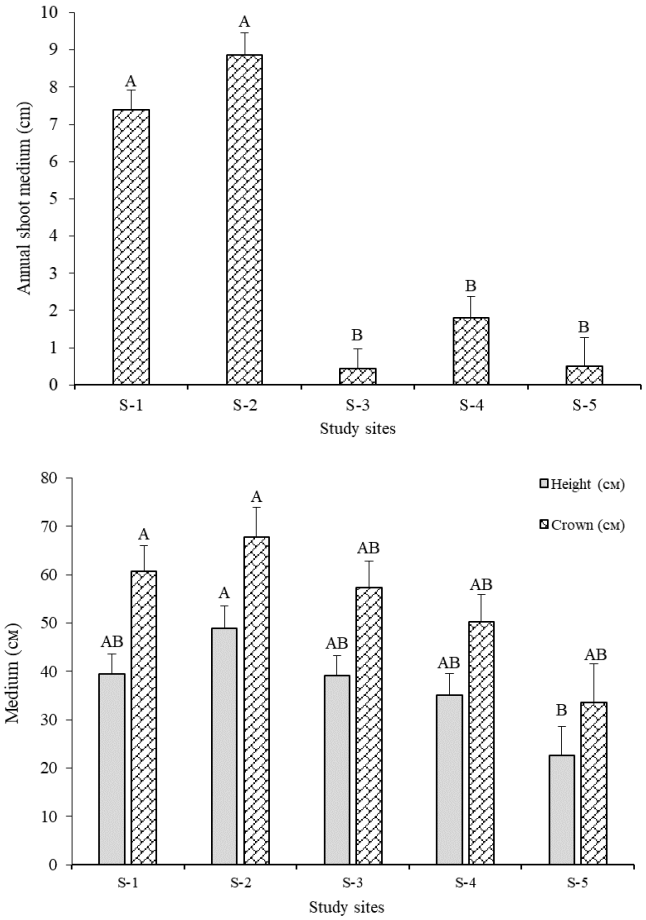

Figure 2. The morphological measurment of shrub community (Height, canopy cover and annual shoot).

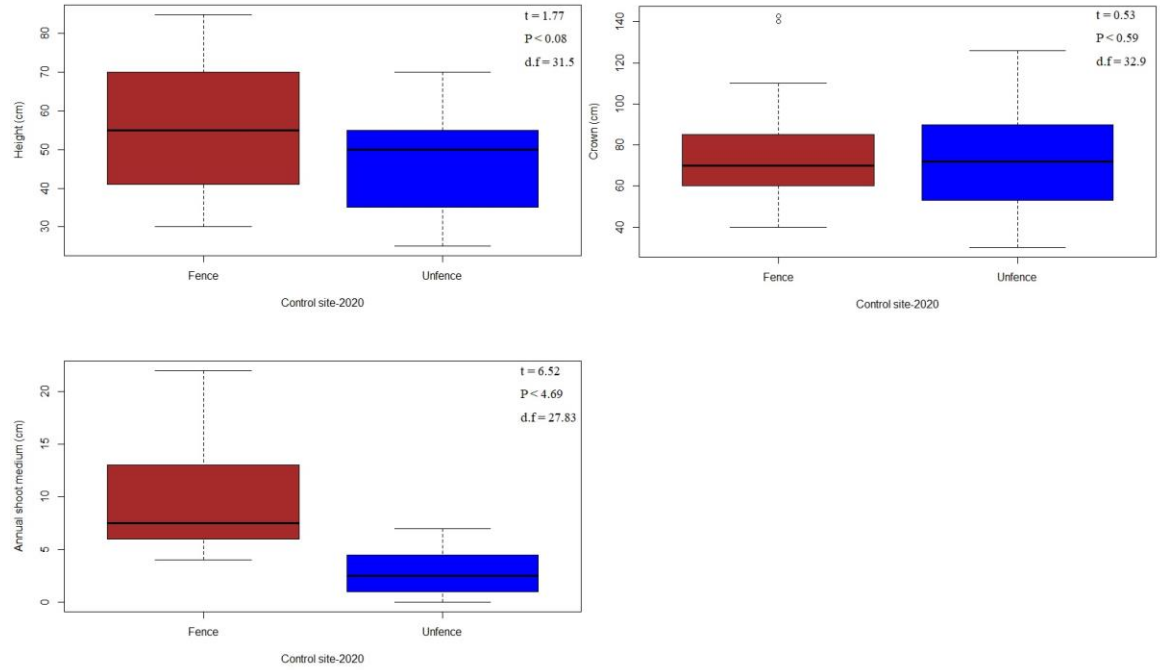

Figure 3. Box plot comparisons of significant differences means of three measured metrics of control site-2020 in the Ikh Nart Nature Reserve, Mongolia.

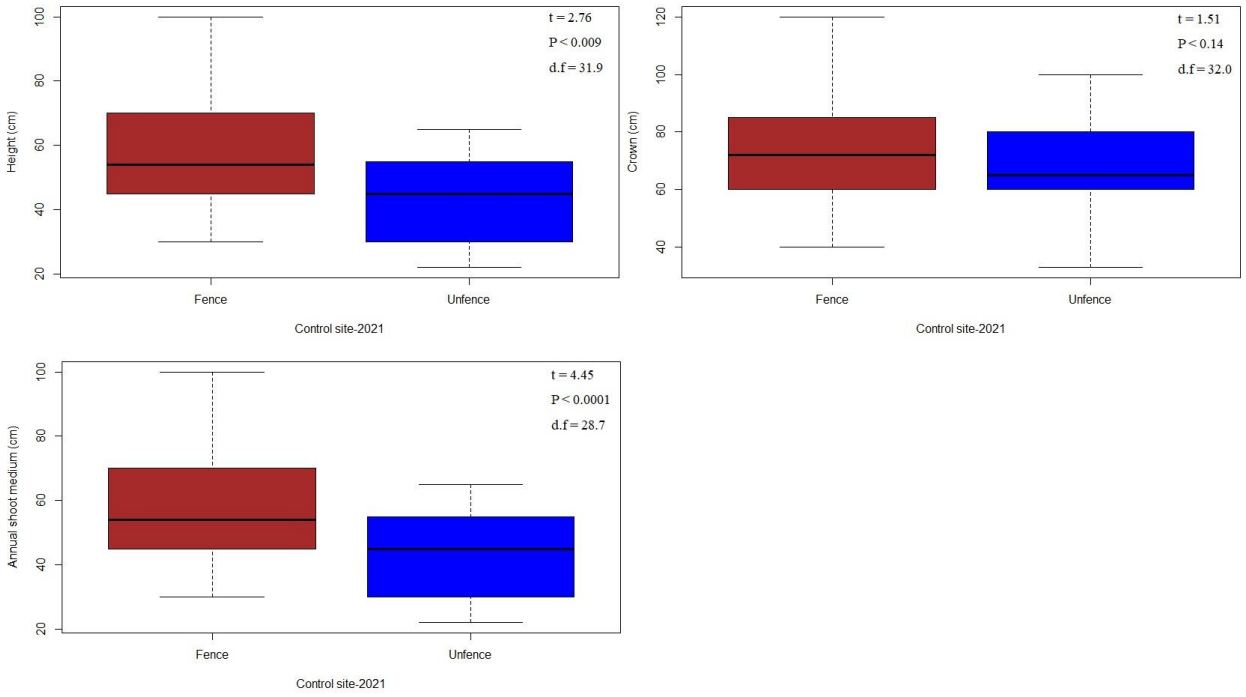

Figure 4. Box plot comparisons of significant differences means of three measured metrics of control site-2021 in the Ikh Nart Nature Reserve, Mongolia.

Relationship of shrub morphological and soil characteristic

We found some positive relationship among shrub morphological type and soil properties (Table 3). In addition, soil density was significantly and positively correlated with shrub morphology in both height (r=0.28) and canopy cover (r=0.28).

Table 3. Relationship of soil properties and shrub morphological measurement.

№	Pearson corelation analysis	Value
1	Soil density *shrub height	*r=0.28*
2	Soil density*shrub canopy cover	*r=0.30*
3	Soil porosity*shrub stem count	*r=0.31*
4	Soil humidity*shrub stem count	*r=0.50*
5	Soil weight*soil density	*r=0.94*
6	Soil pH*shrub height	*r=0.58*
7	Soil pH*shrub canopy cover	*r=0.56*

4. Discussion

In our study, variation in soil bulk density, plant diversity, and composition appear to reflect the impact of livestock and wild ungulate grazing in the desert-steppe of Mongolia. Several studies were conducted on livestock effects on biodiversity and habitat degradation (Gao & Carmel, 2020). The most convincing sign of the overstocking effect of livestock and wild ungulates in the study is soil compaction, which corroborated increased bulk density in the S2 and S5 sites. Soils in the vicinity high grazing intensity area had the highest soil bulk density, where we find the highest overlapping populations of livestock and wild ungulates. The higher soil bulk density in the heavily stocked areas may be due to greater pressure onto soils through animal hooves (up to 200 kPa), and the loss of perennial vegetation cover and soil cryptogams (Proffitt *et al.,* 1995; Daniel *et al.,* 2002; Yates *et al.,* 2008).

Heavy grazing pressure may result in decreased diversity with a dominance of only a few tolerant species. The dominant species in heavy grazing pressure sites were fringed sage (*Artemisia frigida*) and needle leaf sedge (*Carex duriuscula*), which are tolerant to grazing and known to increase with moderate to heavy grazing pressure (Yunatov 1977; Narantsetseg *et al.,* 2018).

Shrubs are one of the main food sources for grazing animals in arid ecosystems because young shoots and leaves of shrubs containing high nutrition contribute more than 70% percent to the food composition of wild ungulates and livestock (Eric *et al*., 1988; Argiuar & Sala, 1999; Wenxuan Xu *et al*., 2012). In previous studies (Wingard *et al*., 2011; Wenxuan Xu *et al*., 2012), researchers have reported that herbivores, including gazelles, argali, and ibex, had a hard time looking for food resources due to occasional snow covers. Therefore, shrub communities become valuable food sources for these animals during winter rather than in other seasons (Wenxuan Xu *et al*., 2012). In our study sites, young shoots and leaves of shrubs including *A. pedunculata, S. aquilegifolia,* and *S. hypericifolia* were recorded as completely eaten by wildlife or livestock. The dominant and subdominant shrubs are resistant to defoliation by grazing through avoidance strategies as they become shorter and less dense, which is less available to grazing, within their architectural plasticity (Hofmann, 1988). These shrub species will likely exclude the communities if the grazing intensity passes the shrubs' resistant threshold (Briske 1996).

There are very few attempts studying responses of *A. pedunculata* to grazing. This species is a late-successional and regionally dominant plant of Mongolia's low-mountainous semi-desert ecosystems (Tuvshintogtokh, 2014). Dashnyam (1974) reported that grazing by herbivores such as wild ungulates and livestock impact negatively on heights of *A. pedunculata* because they only consume leaves and flowers. However, the grazing intensity wasn't mentioned, but the shrub community in the semi-desert steppe has been left out. For instance, Wingard *et al*., (2011) investigated the diet composition of wild Argali sheep (*Ovis ammon*) and domestic sheep using their fecal in Ikh Nart NR. Our study complemented his results by adding the effect of wild ungulates and livestock on

the shrub community in the semi-desert steppe of Mongolia. Our study showed that the highest grazing intensity (S1 and S2) negatively affected the species' morphology.

The density of this shrub has been diminished at the sites with high grazing intensity. It could indicate that the shrub's grazing resistance has exceeded, and the species has loosened its competitive advantage. If the grazing remains the same in intensity, the species will persist as small, scattered plants or locally extinct (Connor 1991). In summary, our finding indicated the negative effect of grazing on the physical properties of soil in the Semi-desert of Mongolia. Consequently, land degradation and plant morphological trait changes can harm the ecosystem goods and services in the semi-desert of Mongolia. Therefore, the study results suggest that appropriate grazing management is required in the semi-desert regions across Mongolia.

Conflict of interest: The authors declare that there is no conflict of interest.

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