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Moderate grazing is the best measure to achieve the optimal conservation and soil resource utilization (case study: Bozdaghin rangelands, North Khorasan, Iran)

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Abstract The study of the variability of physical and chemical factors of soil due to different intensities of livestock grazing can help in the management and maintenance of soil and vegetation. Accordingly, the effect of livestock grazing intensities on soil properties and vegetation in Bozdaghin rangelands of North Khorasan province was investigated. To investigate the effect of different livestock grazing intensities, Three 5-hectare plots in the study area were determined under different treatments (ungrazed (UG), moderate grazing (MG), and heavy grazing (HG)), and the effect of three grazing intensities on vegetation and soil physicochemical and erodibility properties (SPEP) was evaluated. The soil sampling process was performed at depths of 0–15, 15–30 cm and SPEP including soil saturation moisture (SSM), soil texture (percentage of clay, sand, and silt), absorbable potassium (K), electrical conductivity (EC), soil organic matter (SOM), absorbable phosphorus (P), acidity (pH), and bulk density were evaluated, and Soil Erodibility Index (SEI) was calculated by implementing the modified clay ratio relation. To assess the impact of various grazing intensities on all measured characteristics, multivariate analysis of variance (MANOVA) and Duncan tests were utilized to compare the means and their grouping. The results showed that HG compared to MG causes worrying consequences in the first soil depth. Also with increasing grazing intensity, plant production percentage ($P < 0.05$) and vegetation density ($P < 0.01$) decreased, and the amount of bare soil ($P < 0.01$) increased. Also, with increasing grazing intensity, the amount of pH, EC, clay, saturated moisture, and N decreased ($P < 0.01$), but the amount of silt, sand, K, P, calcium (Ca), lime, and SOM increased ($P < 0.01$). UG improves soil quality, MG intensity causes optimal conservation and utilization of soil resources, and HG intensity causes severe changes in rangeland soil properties. In areas with MG intensity, due to the increase of the percentage of vegetation (an increase of SOM and prevents the direct impact of raindrops on the soil aggregates) and as a result improvement of soil structure and texture, an increase of water infiltration, and decrease of runoff, and the rate of soil erodibility and water erosion, the rangeland soil decreases and results in sustainable production. This results in optimal conservation and utilization of soil resources. So to sustainably exploit and balance the conservation of biodiversity, livestock production, and soil carbon and nitrogen management, MG is recommended.

Keywords Grazing intensity · Soil properties · Vegetation · Rangeland · Erodibility

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Introduction

Rangelands are defined as a group of grassland and desert ecosystems that are managed as "natural" ecosystems. The intricacy of sustainable rangeland management is increasingly known as a consequence of our better understanding of the intricacy of ecological phenomena (Berkes et al., 2003) and the social-ecological system (SES) (Sick, 2008; Mitchell, 2010). Rangelands and their dependent communities rely on the protection and conservation of water and soil resources to preserve them over time Wu and Chau (2011), Shende and Chau (2019) (Mitchell, 2010; Alizadeh et al., 2018) Asadi et al. (2020). Rangeland is a natural ecosystem that includes genetic resources of plants and animals and microorganisms on which a large part of livestock production depends (Archer & Smeins, 1991). Grazing intensity is a key management variable that affects the structure and composition of grassland ecosystems (Wang et al., 2016).

Also, different levels of livestock grazing intensity change the SPEP as well as the plant composition of the rangelands Steffens et al. (2008), Mut and Ayan (2011). Since the needs of plants for soil moisture, temperature, and air are very different, after identifying these needs, the SPEP, which meets the plant needs, must be considered to apply proper management (Dastgheyb Shirazi et al., 2021). Factors such as soil texture as well as the way the rangeland is used can change the SPEP (Hiernaux et al., 1999). Soil permeability, bulk density, mechanical strength, porosity percentage, texture, soil structure, and chemical properties are very important in plant nutrition and growth. These factors play an important role in creating suitable conditions for the activity of microorganisms and plant nutrition and providing the plant with the required moisture (Amiri et al., 2008). Livestock grazing with different intensities can have different effects on soil elements and vegetation (Rahmanian et al., 2019) Lin et al. (2010).

At present, Iran's rangelands are regressing due to overgrazing, and the livestock in the rangelands is more than three times their production capacity. If Iran's rangelands are in the orbit of scientific and correct management, it can have production up to five times the current production (Moghadam, 1998). Given that the soil is more stable than vegetation and is usually affected afterward, it can be hoped that if this process is prevented in the early stages of degradation, it will be easy to regenerate vegetation with spending the least amount of time and effort. But if uncontrolled grazing continues and livestock grazing is not done according to scientific principles, the degradation of rangeland soil, especially its physical properties, will follow (Kosmas et al., 2015).

Studying and recognizing the type and amount of the effect of grazing intensity on the composition and production of vegetation and SPEP will help us in the scientific and principled management of rangelands (Liacos, 1962). Also, recognizing the variability of soil characteristics and indicators against grazing can indicate the impact of management activities in the region (Ludwig et al., 1997). Aggregates are the key to maintaining the stability of soil structure and an effective factor in erosion control (Cambardella & Elliott, 1992;Gholami et al., 2018, 2021; Dastgheyb Shirazi et al., 2021; Sahour et al., 2021). Conditions prevailing in rangeland ecosystems such as grass species diversity, age of plant rootstocks, and grazing intensity affect aggregates and soil texture (Blanco-Canqui et al., 2005).

Numerous studies have proved the undesirable effects of overgrazing on the SPEP of rangeland. Alvaro and Silva (2003) concluded that changes in soil quality due to livestock grazing and its compaction lead to reduced forage production in pastures. Raiesi and Riahi (2014) believe that overgrazing in arid regions has more obvious destructive effects due to a lack of vital resources (lack of litter and available water). These destructive effects include the change of soil fertility and endangering the stability of the ecosystem (Ren et al., 2012), reduced vegetative vigor (Angassa, 2014), reduced regeneration, and the change of plant type (Blackburn et al., 1982). Bari et al. (1995) found that the UG treatment has the lowest runoff and sediment among the studied treatments, and grazing treatment with the least amount of SOM remaining in the soil has led to the most erosion. John and Wiliam (2000) stated that grazing can cause surface soil compaction and loss of soil structure due to soil mass density. He et al. (2009) studied the changes of soil quality factor (organic carbon) at three depths of

0–10, 10–20, and 20–40 cm against livestock grazing and concluded that the lack of livestock grazing had significantly increased soil carbon at a depth of 0–10 cm compared to grazed grassland. Kohandel et al. (2009) in the study of the effect of different intensities of livestock grazing on SOM, nitrogen, phosphorus, and potassium at two depths of 15–15 and 15–30 cm concluded that livestock grazing had a significant effect on the chemical properties of the soil in areas with different grazing intensities, and the soil depth factor was effective on the amount of SOM, nitrogen, and phosphorus in the soil. Kohandel et al. (2011) concluded that with decreasing grazing in the region, the percentage of canopy cover of wheat, shrubs, and permeability increased, and with increasing grazing intensity, acidity, potassium, electrical conductivity, humidity, and mechanical strength increased at a depth of 0–15 cm. Yao et al. (2019) compared the effects of continuous grazed management and long-term exclosure on vegetation and soil properties and suggested a combined method of grazed and rotational non-grazed treatment to improve biodiversity in grassland ecosystems Binkley et al. (2003). Studies conducted by researchers show that rangeland exclosure increases the quality of forage species Zhang et al. (2020), and Zhan et al. (2020) (Sharifi & Akbarzadeh, 2016), reduces erosion and sediment production Su et al. (2006), optimizes the use of available water in watersheds, reduces the specific gravity of soil and increases soil nitrogen and EC Schuman et al. (1999), and reduces the vegetative transformation of plants from shrubs to perennials. Also, exclosure increases the production of plant species, improves the rate of water penetration into the soil and soil fertility, and improves some of SPEP of the soil (Dastgheyb Shirazi et al., 2021). One of the effects of livestock grazing on the SPEP is the reduction of SOM (Mcnaughton, 1979). Exclosure soils are protected by vegetation and over time increase SOM and plant activity, improve the structure, and increase soil permeability capacity, resulting in reduced soil erosion (Jeddi & Chaieb, 2010). Livestock grazing is one of the most important factors affecting soil and vegetation that can affect the structure and function of vegetation in various ways (Noy-Meir et al., 1989). Livestock grazing can significantly change the structure, productivity, diversity, and competitiveness of plants in grazing ecosystems (Manier & Hobbs, 2007). The previous studies emphasize the effects of grazed intensities on plants and soil in the grassland. Further investigations are needed to investigate the effect of livestock grazing on SPEP, erodibility, and vegetation cover (Dastgheyb Shirazi et al., 2021).

Past studies indicate that the density and type of vegetation and SOM are effective in soil erosion, and soil covered with dense plants has maximum resistance to water flow. SOM from vegetation prevents intensified erosion even on steep slopes and heavy rainfall (Zuazo & Pleguezuelo, 2008). One of the effective methods in preventing water erosion is increasing soil permeability and reducing surface runoff. Soil compaction due to livestock traffic reduces permeability and increases surface runoff (Nawaz et al., 2013; Shah et al., 2017). Due to the few studies conducted in Iran on the effect of different grazing intensities on the important factor of unstable soil particles and having little information about the impact of particulate SOM and the distribution of aggregates at different depths, in addition to the effect of different grazing intensities on SPEP, some of the most important soil factors (soil erodibility) that have not been seen in other studies should also be considered. In general, it can be said that livestock grazing, especially heavy grazing, poses serious risks to soil quality (ability to grow plants and prevent soil erosion) and the health of rangeland ecosystems. Therefore, recognizing these changes is essential for the management of a rangeland ecosystem, especially in mitigation policies, restoration programs, and ecological requirements of cultivable species in the region. Although the grazing intensity method has been tested in different parts of the world and its efficiency has been proven in many areas, in some areas, it has not had the necessary efficiency (Jafari et al., 2015). Therefore, it is necessary to test the appropriate methods of assessment of degradation in Bozdaghi rangelands so that they can be used to assess the degradation of these rangelands. Therefore, this research aimed to assess the impact of different grazing intensities (UG, MG, and HG) on SPEP, vegetation, and species composition. Studying the grazing gradient and examining and recognizing the type and amount of grazing effect on the composition, diversity, and production of vegetation and physical and chemical properties of the soil will help us in the scientific and principled management of rangelands.

Methods and materials

Study area

This study was carried out in Bozdaghi rangelands located 45 km north of Maneh and Samolghan city in North Khorasan province with east longitudes of 56º 45′ 9″ to 56º 50′ 13″ and north latitudes of 37º 49′ 39″ to 37º 55′ 34″ with an average altitude of 833 m above sea level. The study area is 4400 ha, which includes 2230 ha of UG area and 2170 ha of grazing area. The average rainfall is 262 mm, and the average annual temperature and relative humidity are 16 °C and 68%, respectively. According to the Embrothermic curve of the study area, the dry season begins in May and lasts until mid-November. De Martonne's method was used to determine the climate (Khaleghi, 2018). Accordingly, this region has a semi-arid climate with a coefficient of 10.03.

Experimental design

To investigate the effect of different livestock grazing intensities, three 5-ha plots in the study area were determined under different treatments (ungrazed (UG), moderate grazing (MG), and heavy grazing (HG)), and the effect of three grazing intensities on vegetation and soil physicochemical and erodibility properties (SPEPs) was evaluated. The rangelands of the region are grazed by livestock during the year, but the UG area is safe from livestock grazing and has been under protection since 1999. In 2020, three grazing intensities were set up: UG (0 sheep/ha), MG (6.2 sheep/ha), and HG (8.9 sheep/ha). The HG site is typical of the historical grazing intensity in this area. The grazing gradient utilized in this study represented the range of grazing pressures that will be found in this region (Ma et al., 2014).

Measurements

In this research, first, through Google Earth satellite images, field navigation, and using the Global Positioning System (GPS) device, the boundaries of the study area were determined (Gholami et al., 2017). Then, according to the objectives of the research and also the criteria of speed, accuracy, and cost, the random-systematic method was used. Field sampling and laboratory studies were used to collect raw data. For this purpose, 30 soil samples were taken from depths of 0–15 and 15–30 cm and randomly — systematically, along 3 transects with a length of 500 m and at a distance of 200 m from each area (UG, MG, and HG), and a total of 90 soil samples were transferred to a laboratory. In the laboratory, soil samples were dried in the open air. Some of the samples were separated from the rest of the samples to measure the specific gravity of the soil. All soil samples were then sieved with a 2-mm sieve. Soil texture was measured by hydrometric method (Bouyoucos, 1962), percentage of soil saturation moisture by weight (Famiglietti et al., 1998), and dry bulk density using lumps and paraffin method (Black, 1965) and the total porosity of the samples was calculated using particle and dry bulk density. Soil erodibility index (SEI) was calculated using the modified clay ratio (Shamshirband et al., 2019) and by Eq. 1 (Kumar et al., 2009):

$$\textit{Modified clay ratio} = (\textit{Sand}\% + \textit{Silt}\%)/(\textit{SOM}\% + \textit{Clay}\%) \quad (1)$$

Soil pH was obtained using the saturated paste method (McLean, 1988; Robbins & Wiegand, 1990), and the electrical conductivity (EC, dS m^{-1}) of soil water extracts was measured using saturated extract using an electrical conductivity meter (EC meter) (Page et al., 1982). The percentage of soil organic carbon was obtained by the Walkley–Black method (Sato et al., 2014), the soil texture (clay, silt, and sand) by hydrometric method (Bouyoucos, 1962), the total nitrogen content by the Kjeldahl method (Rhee, 2001), the amount of exchangeable sodium and potassium by using a flow meter, and the exchangeable amounts of calcium and magnesium by titration (Junsomboon & Jakmunee, 2011). Cation exchange capacity was also calculated by Bower et al. (1952). Vegetation sampling of the area was done during the growing season and when most plant species in the area had reached full growth. A sampling at different intensities of the UG, MG, and HG was selected based on the principles of the grazing gradient framework (Andrew, 1988), which decreases grazing intensity by increasing the distance from the crisis center.

Data analysis

First, in Excel, data were collected and recorded. Then, data were tested for normality distribution using the Shapiro–Wilk test and homogeneity of variance with the Levene test. Differences in soil properties and vegetation characteristics between grazing intensities were evaluated using MANOVA. For each of the parameters of different sites and at two different depths, analysis of variance and comparison of means were performed based on the Duncan test at the level of 1%. Also, regression relationships (Varvani & Khaleghi, 2019) were performed between canopy volume and shoot biomass of each rootstock and also shoot and total root weight of each rootstock (Table 4). Statistical analysis was performed by SAS 19.

Table 1 Multivariate analysis of variance of Wilks' lambda

Effect	Value	*F*	Sig
Depth	0.224	13.741**	0.000
Site	0.0032	6.364**	0.000
Depth × site	0.0018	3.725**	0.000

**Significant at 1% level, *Significant at 5% level

Results

SPEP

The results in the results in the multivariate analysis of the variance table (Table 1) show that all three sites (UG, MG, and HG) were studied, and both soil depths are significantly different in terms of soil properties. Also, the interaction effect of the site in-depth on soil properties is significant at the level of 1%. According to the results, there were significant

Table 2 Analysis of variance of the studied parameters between different sites and depths

Parameter		Source	Type III sum of squares	Mean squares	*f*	Sig
pH		Between groups	0.77	0.088	4.19**	0.000
		Within the group	0.44	0.021		
EC (µmos/cm)		Between groups	373,232.3	414,708.3	3.56**	0.031
		Within the group	3,657,499.7	116,458.2		
Soil texture	**Sand**	Between groups	1174.4	131.45	2.22 ns	0.057
		Within the group	2247.3	59.55		
	Clay	Between groups	634.5	69.67	3.15**	0.036
		Within the group	729.1	22.11		
	Silt	Between groups	791.6	86.29	1.81 ns	0.17
		Within the group	1738.2	47.53		
Bulk density (gr/cm^3)		Between groups	3.11	0.29	13.81**	0.000
		Within the group	0.85	0.021		
SSM (%)		Between groups	1745.4	194.7	24.55**	0.000
		Within the group	248.3	7.93		
Absorbable phosphorus (P)		Between groups	2174.5	1240.37	35.97**	0.004
		Within the group	2347.6	34.12		
Absorbable potassium (K)		Between groups	4,231,456.21	45,627.36	743.69**	0.024
		Within the group	3,298,122.47	61.40		
SOM (%)		Between groups	33,245.21	749.46	5.37**	0.000
		Within the group	24,456.01	139.47		
SEI		Between groups	34,721.2	462.7	5.11**	0.031
		Within the group	15,478.1	90.54		

ns not significant

**Significant at 1% level; *significant at 5% level

Table 3 Descriptive statistics of soil parameters at the studied sites and depths (mean ± standard error of the mean)

Parameter		Depth	UG	MG	HG	F value
pH		0–15	7.7 ± 0.02a	7.8 ± 0.01b	7.73 ± 0.02a	24.21**
		15–30	7.45 ± 0.07b	7.77 ± 0.04b	7.46 ± 0.04b	0.91 ns
EC (μmos/cm)		0–15	0.46 ± 0.04a	0.46 ± 0.01a	0.48 ± 0.06a	0.41 ns
		15–30	0.45 ± 0.01a	0.44 ± 0.01a	0.44 ± 0.01a	0.63 ns
Soil texture	**Sand**	0–15	19.36 ± 1.06c	15.33 ± 0.002b	22.66 ± 0.35a	17.15*
		15–30	19.34 ± 1.01b	15.31 ± 0.01b	20.32 ± 0.35b	0.11 ns
	Clay	0–15	3.31 ± 35.1ab	2.15 ± 30.28bc	1.90 ± 29.5bc	24.85**
		15–30	0.4 ± 35.02ab	1.62 ± 28.3bc	2.56 ± 28.3bc	0.54 ns
	Silt	0–15	55.78 ± 1.30b	53.16 ± 0.5b	56.76 ± 0.5a	14.23*
		15–30	3.25 ± 33.1c	2.06 ± 44.30ab	4.04 ± 38.5abc	0.23 ns
Bulk density (gr/cm^3)		0–15	0.09 ± 1.08b	0.11 ± 1.33b	0.13 ± 1.88a	72.51**
		15–30	0.07 ± 1.48bc	0.07 ± 1.53bc	0.07 ± 1.87a	0.44 ns
SSM (%)		0–15	38.59 ± 0.09c	36.79 ± 1.04c	33.61 ± 2.12c	81.24**
		15–30	39.84 ± 2.13c	38.33 ± 2.35c	34.89 ± 3.62c	0.49 ns
Absorbable phosphorus (P)		0–15	12.15 ± 0.43b	14.02 ± 0.48a	17.15 ± 0.43c	10.34**
		15–30	13.81 ± 2.47c	14.27 ± 3.14c	14.15 ± 0.28b	0.38 ns
Absorbable potassium (K)		0–15	430.42 ± 2.95c	407.34 ± 5.95b	538.78 ± 6.77a	163.66**
		15–30	414.47 ± 2.24a	412.34 ± 5.9a	456.74 ± 6.9a	0.29 ns
SOM (%)		0–15	1.40 ± 0.28b	1.56 ± 0.39a	1.65 ± 0.33b	44.67**
		15–30	0.83 ± 0.28b	1.12 ± 0.36b	1.24 ± 0.25b	0.72 ns
SEI		0–15	4.23 ± 0.2a	4.54 ± 0.2b	5.13 ± 0.2c	58.27**
		15–30	–	–	–	–

ns not significant

**Significant at 1% level; *significant at 5% level

differences among the three sits in terms of soil properties in the upper soil layer (0–15 cm). In the lower depth (15–30 cm), all parameters (except for silt and sand percentage) are significantly different ($p < 0.01$) (Table 2). Table 3 presents the results of the analysis of variance, and comparison of means that was performed based on the Duncan test at the level of 1% for each of the parameters of different sites and at two different depths. The results of the analysis of variance for SPEP in the grazing gradient showed that the effect of grazing intensity on all soil properties studied including pH, EC, K, P, SOM, soil texture (sand and clay), bulk density, and SEI was significant.

Ground cover characteristics

In the UG area, there are 92 species of 75 genera and 24 families with 64.65% canopy cover, and in the grazing area (GA; MG and HG), there are 71 species of 61 genera and 26 families with 27.01% canopy cover. The results of canopy cover sampling of plant species based on vegetative forms are presented in Table 4. The vegetation of the region is mainly covered by *Artemisia sieberi* and *Stipa barbata*. The average percentage of vegetation in the UG area is 36.76% and in the GA area is 14.24% (Niknahad Gharemakher et al., 2018). The results show that the highest percentage of canopy cover in the UG area belongs to the Compositae family, and the lowest canopy cover belongs to the families of Dipsacaceae and Cyperaceae. Also, the highest and lowest canopy in the grazing area belongs to the families of Compositae and Plumboginaceae, respectively.

Figure 1 shows the logarithmic diagram of the rank distribution of species abundance. According to this chart, the UG area is located with a gentler slope and in a higher rank than the grazing area (GA). This indicates more diversity and uniformity in the UG area. Therefore, it can be concluded that the UG system in this area has increased plant diversity.

Table 4 Percentage of canopy cover of each plant family in the study area

Family	GA (MG & HG)	UG	Family	GA (MG & HG)	UG
Apiaceae	0.775	1.68	Liliaceae	0.298	0.288
Boraginaceae	0.148	0.23	Malvaceae	0.24	0.000
Brasicaceae	0.074	0.001	Papaveraceae	0.25	0.121
Caryophyllaceae	3.98	0.74	Papilionaceae	3.88	4.27
Chenopodiaceae	21.97	3.49	Plumboginaceae	0.019	0.000
Compositae	30.02	5.37	Poaceae	16.87	23.38
Convolvulaceae	0.148	0.000	Podophyllaceae	0.081	0.094
Cruciferae	0.81	1.11	Polygonaceae	1.09	0.000
Cucurbitaceae	0.51	0.001	Ranunculaceae	0.001	0.074
Cypraceae	1.03	0.019	Resedaceae	0.91	0.000
Dipsacaceae	0.000	0.018	Rosaceae	5.02	3.18
Ephedraceae	0.000	1.64	Rubiaceae	0.068	3.27
Euphorbiaceae	2.54	1.25	Scrohulariaceae	0.000	0.089
Geraniaceae	0.096	0.112	Solanaceae	0.002	0.081
Iridaceae	0.177	0.358	Zygophyllaceae	3.42	0.51
Labiatae	5.13	1.69	–	–	–

OG grazing intensity, *GE* grazing exclosure

The HG area was initially a uniform environment, but due to continuous grazing and stress, it tended to a pressurized environment. Therefore, the exploitation of the region is not balanced grazing, and this region has tended to regress. In this regard, the same annual species (*Androsace manima*, *Ceratocarpos arenarius*, *Glaucium corniculatum*, *Hyssopus angustifolius*, *Bromus danthoni*, *Eremopyrun distans*) and perennial and non-edible species (*Dianthus crinitus*, *Noaea mucronata*, *Iris acutiloba*, *Citrullus coloynthis*) have prevailed in grazing areas. Because these pastures are grazed throughout the year. As a result,

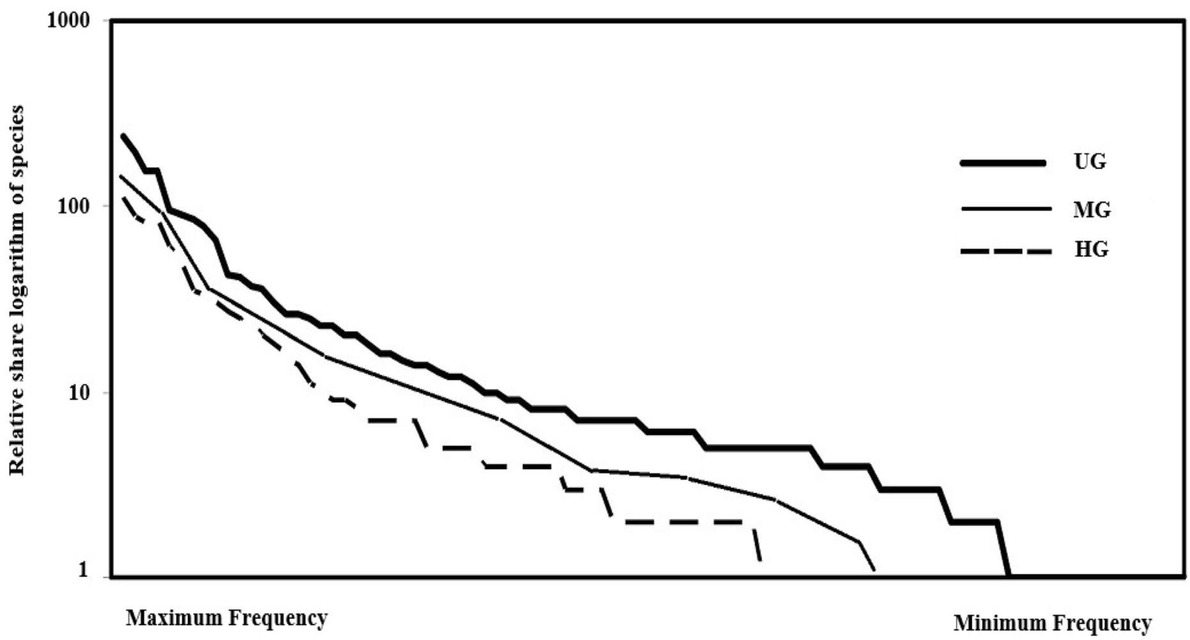

Fig. 1 Logarithmic diagram of the rank distribution of species abundance in the study area

Table 5 Regression relationships between vegetation variables in the study areas

Treatment	Independent variable (X)	Dependent variable (Y)	Regression relationship	R^2	Mean squared	F analysis of variance
UG	Standing volume (cm^3)	Aerial biomass (g)	$\mathbf{Y=0.003x+66.30}$	0.9	122,045.79	150.21**
	Aerial weight (g)	Total root weight (g)	$\mathbf{Y=0.59x+25.10}$	0.86	75,462.2	101.45**
MG	Standing volume (cm^3)	Aerial biomass (g)	$\mathbf{Y=0.0033x+55.20}$	0.87	151,345.4	115.11**
	Aerial weight (g)	Total root weight (g)	$\mathbf{Y=1.30x+33.95}$	0.67	74,265.3	87.67**
HG	Standing volume (cm^3)	Aerial biomass (g)	$\mathbf{Y=0.00325x+38.3}$	0.79	9,562,342.5	94.74**
	Aerial weight (g)	Total root weight (g)	$\mathbf{Y=1.24X}$	0.52	13,546.4	14.33**

**Significant at 1% level; *significant at 5% level

in addition to the fact that the canopy cover of the species has decreased from 64.65% in the UG area to 36.45% and 27.01% in the MG and HG areas, perennial and succulent species in the GE area (*Agropyron cristatum*, *Bromus tomentellus*, *Astragalus brivedens*) have become more widespread than livestock grazing agents have been reduced or eliminated in areas under grazing.

Regression relationships between plant parameters

Regression relationships between canopy volume as an independent variable and shoot biomass of each rootstock as a dependent variable and also shoot biomass as an independent variable and total root weight of each rootstock as a dependent variable indicate a linear and significant correlation between these factors. Therefore, to estimate aerial, underground, and total biomass, appropriate regression equations were used for each treatment. According to Table 5, about the correlation between the variables of standing volume (cm) and aerial biomass weight (g), the highest and lowest correlations were obtained in the areas of UG and HG equal to 0.9 and 0.79, respectively. Also, about the correlation between the variables of shoot weight (g) and total root weight (g), the highest and lowest correlations in HG and UG areas were equal to 0.86 and 0.52, respectively.

Comparison of composition, density, and total production at different grazing intensities

The highest production was in UG (178.54 g/m^2), and the lowest production was in HG (131.28 g/m^2), which was a significant difference between the average production in HG and UG ($P < 0.05$), but MG (163.12 g/m^2) was not significantly different with UG (Table 6). A comparison of density showed a significant difference among UG, MG, and HG ($P < 0.01$). The highest density was observed in MG (526.47) and the lowest in HG (361.17). A comparison of canopy cover of all species did not show a significant difference among UG, MG, and HG (Table 5). The highest percentage of canopy cover was observed in MG grazing (82.13%) and the lowest in HG (78.56%).

Table 6 Comparison of average parameters of rangeland surface cover at different distances

Soil surface parameters	UG	MG	HG	F
Total production	178.54 ± 7.5a	163.12 ± 7.5b	131.28 ± 8.02c	5.11**
Total density	433.07 ± 13.5b	526.47 ± 13.5a	361.17 ± 13.5c	23.41**
Total canopy (%)	79.17 ± 2.5a	82.54 ± 2.5a	78.56 ± 2.5ab	1.26 ns
Litter (%)	9.02 ± 0.5a	7.02 ± 1.5ab	4.02 ± 0.23b	6.37**
Bare ground without any covers (%)	11.22 ± 1.5b	13.22 ± 1.15ab	17.22 ± 2.45a	4.11*
Stones and pebbles (%)	0.006 ± 0.004a	0.006 ± 0.01a	0.006 ± 0.11a	0.55 ns

Non-common letters indicate statistical differences

ns not significant

**Significant at 1% level; *significant at 5% level

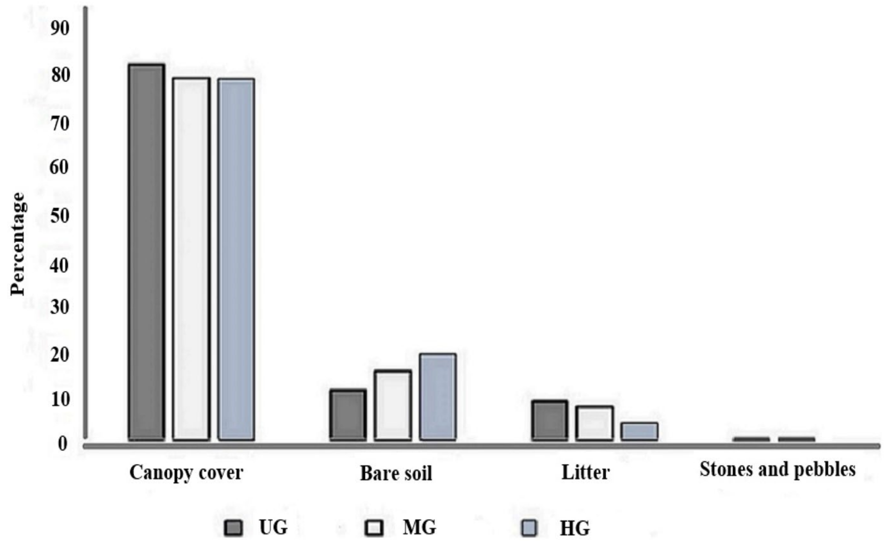

Fig. 2 Changes in soil surface cover at different grazing intensities

Comparison of soil surface properties at different grazing intensities

The highest percentage of stones and pebbles was observed in HG (0.05%) and the lowest in UG (0.002%) which did not show a significant difference between the average percentages of stones and pebbles in different grazing intensities.

Percentages of bare ground and without any covers (%) showed a significant difference between UG (11.22%), MG (15.13%), and HG (19.12%) intensities ($P < 0.05$). The highest distribution of litter and plant residues was observed in UG (9.09%) and the lowest in HG (4.03%). There was a significant difference between the average litter percentage in HG and MG ($P < 0.01$), but this parameter was not significantly different in UG with MG (7.18%) (Table 6; Fig. 2).

Discussion

Investigation of vegetation characteristics

The results showed that with increasing distance from the HG area and decreasing grazing pressure, the percentage of canopy cover and crop production increased, and the highest percentage of canopy cover and production was observed in the UG area. In the arid and semi-arid regions, any degree of grazing intensity reduces green vegetative organs, in other words, reduces food production. As plant nutrients are depleted, sugar production and storage are reduced, and root growth is reduced, which will eventually reduce production. In arid and semi-arid regions, the negative effects of repeated grazing on rangeland plants are greater than the intensity of grazing, because each time, grazing (even UG) plant metabolism is disrupted and weakens the plant. Accordingly, it is observed that vegetation in areas with MG intensity, due to having the necessary storage energy, in addition to increasing the percentage of cover, has a suitable height growth, which increases plant production and also changes it significantly. Excessive grazing of forage located in HG areas, on the one hand, causes frequent exploitation of high-quality and tasty rangeland species and, on the other hand, causes excessive compaction of soil in such areas, which causes gradual elimination of high quality and tasty species (*Agropyron cristatum*, *Bromus tomentellus*, *Astragalus brivedens*) in the mentioned areas. This finding is consistent with Yong-Zhong's studies (2005) in Mongolia, China. The researchers reported that due to the kicking of livestock, the topsoil is bare and exposed to wind erosion, reducing soil fertility, which can affect the quantity and quality of vegetation. Applying HG pressure increases the abundance of some species and decreases the abundance of others, thereby causing changes in the structure and composition of plant communities (Riginos & Hoffman, 2003). Given that livestock is selective in selecting species for grazing (Harrington et al., 1984), and since palatable species are grazed selectively and abundantly, excessive grazing and kicking of livestock weakened them, and they will not be able to regenerate, and as a result, their amount in the plant composition will decrease due to the increase in grazing intensity. Analysis of plant composition percentage and density of succulent species showed that there is a significant difference between different intensities of grazing. The highest and the lowest percentage of composition and density were observed in UG and HG respectively. These results are in line with the results of Wang et al. (2016).

Soil physicochemical properties

The results of MANCOVA show that there is an interaction between depth and sites in terms of total soil parameters. This shows that changes in soil properties at different depths do not follow a specific trend at different sites, and depending on the presence of livestock and the type of use and kicking of livestock at different sites, the depth of impact is different, and the parameters change in two depths do not change regardless of intensity. Each of the parameters is discussed below.

PH In the first soil depth (0–15), compared to the HG and UG, the highest pH increase is related to the MG. The results of this research are in line with the results of Somda et al. (1997), Aarons et al. (2004), and Wang et al. (2016). In the case of UG, the lower pH can be attributed to the high percentage of vegetation and the density of the root system (Pei et al., 2008), and also the higher porosity of the soil. The higher porosity of the soil in MG, in turn, causes more water penetration into the soil compared to the HG area, and as a result, the surface soil carbonate is transferred to a lower depth, which reduces the pH of the surface soil. The secretion of organic acids from the roots and the carbon dioxide emitted from the roots and microorganisms can reduce soil pH. While in the HG, this decrease can be attributed to livestock excrement (Somda et al., 1997). The reason for the high pH in HG compared to the UG (7.69) can be attributed to the effect of ruminants and the accumulation of urine on the soil surface (pH 8.4–8.6) in increasing pH (Somda et al., 1997). Accordingly, it was expected that in MG intensity, due to having more vegetation than HG intensity, the pH would decrease, but in HG intensity, livestock waste had a reducing role of pH and caused the pH to decrease.

The reason why the second depth of the soil is not affected by the increase in pH can be attributed to the action of diluting the urine by the moisture in the soil to reach the second depth and also the effect of humus penetration in reducing the pH of this depth (Aarons et al., 2004).

Soil erodibility index (SEI) SEI in all sites is significantly different. It has increased from 4.231 (UG) to 4.54 (MG) and 5.147 (HG). According to the results of this study, the utilization of the UG has decreased the amount of SEI in the surface layer of the soil (0–15 cm) by about one-fifth (0.21) as much as the HG areas. The results are in line with the findings of George et al. (2004); Varamesh (2009), and Teague et al. (2008, 2010). The decrease in the value of SEI index in the UG area compared to the MG and HG areas can be attributed to an increase in the content of clay and SOM (Johansen et al., 2001; Campo et al., 2006; Larsen et al., 2009; Wolf et al., 2017). In the HG area due to reduced vegetation (canopy and litter cover), increased bare ground, and livestock kicking, which leads to soil compaction and reduced soil pores (Aryafar et al., 2019; Fallatah, 2020), water permeability is reduced and surface runoff is increased, which leads to the transfer of fine soil particles and ultimately increase soil erodibility. While in UG and MG areas, due to the increase of vegetation and as a result improvement of soil structure, decrease of runoff, and increase of water infiltration, the rate of soil erodibility and water erosion decreases (Ozaslan et al., 2015). This results in a decrease in the SEI index.

EC The highest EC was observed in HG (0.48 μs/cm) and the lowest in MG (0.46 μs/cm), but no significant difference was observed between different grazing intensities. The results are in line with the findings of George et al. (2004) and Aarons et al. (2004). This difference can be related to the intrinsic difference in the soil. Probably, the conditions imposed on the rangeland ecosystem by the grazing process could be another reason for this result. The grazing process causes the accumulation of salt in the surface layer of the soil due to livestock grazing and reducing soil fertility factors and increasing the exchange capacity of cations (Aarons et al., 2004; Motevalli et al., 2019). It also increases the temperature in the soil and the evapotranspiration of soil moisture, which by reducing soil moisture, there is a possibility of increasing the amount of salt and soil salinity and consequently EC. In the UG area, the germination of plants is better formed, and as a result, the percentage of canopy cover and plant production in the area has increased. Therefore, it seems that compared to MG, increasing vegetation and adding litter in the topsoil has increased the number of solutes in the soil and increased EC. In the UG and MG areas, compared to HG area, higher vegetation and litter and reduced evaporation from the soil caused an increase in soil moisture, resulting in a decrease in salt concentration, so the soil EC significantly has decreased compared to the HG area (Hante et al., 2005).

(K) The lowest (407.34) and highest (538.78) K levels are in the areas of MG and HG, respectively. The UG area has a moderate amount (430.42) of K. The results are in line with the findings of Tamartash et al. (2007), Kavianpour et al. (2015), and Kazemi et al. (2018). In the HG area, due to the presence of livestock and the addition of animal waste to the soil, the amount of soil K increases, and due to low plant density in this area, less K is consumed, and this factor also increases soil K in the area (Kazemi et al., 2018). Tamartash et al. (2007), in a study conducted in Kojour Rangelands, it was found that the effect of livestock grazing on the amount of soil K in different grazing situations is different.

SSM The amount of SSM varies among different sites and depths from 3.96 to 24.73%. Compared to MG (36.79%) and HG (33.61%), the UG area (38.59%) has a higher SSM. This can be attributed to the presence of more vegetation in the UG area. Vegetation diminishes the direct evaporation from the soil surface and increases the amount of SSM in the soil surface. The results are in line with the results of Pie et al. (2008), Al-Seekh et al. (2009), and Kumbasli et al. (2010). In the second depth, in all of the sits, the SSM was lowest.

Bulk density The amount of bulk density varies among different sites and depths from 0.09 to 0.13 (g/cm^3). Compared to MG (0.11 g/cm^3) and HG (0.13 g/cm^3), the UG area (0.09 gr/cm^3) has the lowest bulk density. As the results show, as the intensity of livestock grazing increases, the bulk density of the soil increases. With increasing the bulk density of the soil, the amount of SSM, SOM, and C/N ration decreases and as a result increases the soil compaction, followed by increasing the surface runoff and finally increasing the soil erosion and SEI index. This finding can be attributed to the grazing and kicking of livestock. The results are in line with the results of Zhao et al. (2007), Agha Mohseni et al. (2008), Vaillant et al. (2009), Xie and Wittig (2004), and Zhao et al. (2011). Examination of different sites about surface density indicates that there is no significant difference in the second soil depth. The cause of this phenomenon can be attributed to the lack of pressure transfer due to kicking and grazing livestock to the second layer. Agha Mohseni et al. (2008) considered the effect of livestock grazing on the second depth of the soil to be ineffective.

SOM The amount of SOM, varies among different sites and depths from 1.40 to 1.65 (%). Compared to UG (1.40%) and MG (1.56%), the HG area (1.65%) has the highest SOM. As the results show, with increasing grazing intensity, the percentage of SOM increased and the highest percentage of SOM was observed in HG and the lowest in UG ($P < 0.01$). The results are in line with the results of Li et al. (2011) and Medina-Roldan et al. (2012). The amount of SOM increases with increasing grazing intensity through several mechanisms. First, by increasing the compaction and bulk density of the soil, the oxygen storage of the soil decreases, and the rate of decomposition slows down (Li et al., 2011). Second, severe grazing can affect the contribution of root biomass SOM by changing plant composition and root-to-stem ratio (Reeder et al., 2004). Livestock grazing increases the contribution (weight) of underground biomass to SOM (Hui & Jackson, 2005). Increased carbon can in turn increase the grazing effects on root biomass and plant debris, as roots and plant debris are important sources of carbon (Stewart & Frank, 2008) Han et al. (2008). Third, livestock grazing affects the flow and cycle of nutrients in pasture ecosystems through nutrient intake, return through livestock excrement, redistribution, and extraction (McNaughton et al., 1979). Li et al. (2011) declared that with increasing grazing intensity, the amount of SOM increased significantly and acknowledged that livestock grazing could have a potentially positive effect on soil properties, including SOM. But to sustainably exploit and balance biodiversity conservation, livestock production, and soil carbon and nitrogen management, MG was recommended.

Absorbable phosphorus (P) The amount of P varies among different sites and depths from 12.15 to 17.15 ppm. Compared to UG (12.15 ppm) and MG (14.02 ppm), the HG area (17.15 ppm) has the highest P. As the results show, with increasing grazing intensity, the amount of P increased, and the highest amount of P was observed in HG and the lowest in UG ($P < 0.01$). The results are in line with the results of Kumbasli et al. (2010) and Wang et al. (2016). P was significantly different in the topsoil of different grazing intensities, but in the second depths of the three sites, there was no significant difference. The highest value was in HG intensity, and the lowest value was in the UG area. But the difference between MG and HG was not significant. In HG intensity, the amount of P increases, and the reason is the positive effect of livestock on the amount of soil P through traffic and animal waste. P is removed from the soil either by harvesting this element by the plant or by leaching and erosion, so changes in soil P can be attributed to its harvest by plants and the addition of this element by livestock and mixing animal waste and litter to the soil. In MG intensity, because the presence of livestock is less, the amount of P fertilizer increase is not significant and because there is an opportunity for plants to regrow, as a result of P consumption by the plant increased. Tamartash et al. (2007) in justifying the increase in P in HG intensity state that the amount of P that is harvested in HG intensity through livestock grazing, by adding it by livestock traffic and mixing animal waste and litter to the soil, has been compensated. With increasing grazing intensity, the amount of P has increased. Increasing the amount of soil P due to HG can be attributed to high livestock traffic that causes more burial of litter, high animal waste compared to the two intensities of UG and MG, and also more mobility of P in the soil surface due to livestock traffic, trapped and disturbed surface soil. Most of soil P is in combination with SOM, so soils rich in SOM have more P. According to the research results, the SOM in HG intensity is more than UG and MG, which can be one of the reasons for the increase in P in HG intensity (Tamartash et al., 2007). In MG intensity, because a significant amount of plant organs are placed on the ground after drying, due to livestock traffic, they are more under the soil, so the possibility of increasing P in this grazing intensity increases.

Soil texture (clay, silt, and sand) The results of data analysis for soil texture in our study showed that soil texture did not change significantly. So that in both distances with UG intensity and MG, the soil texture class was silty loam, but in the area with HG intensity, the texture class was gradually changed from silty clay loam to loamy class. In other words, the soil has moved toward sanding, which has resulted in more sanding in its silt particles. The amount of clay varies among different sites and depths from 1.9 to 3.31%. Compared to UG (3.31%) and MG (2.15%), the HG area (1.9%) has the lowest clay. As the results show, with increasing grazing intensity, the amount of clay decreased and the highest amount of clay was observed in UG and the lowest in HG ($P < 0.01$). The results are in line with the results of Kumbasli et al. (2010) and Wang et al. (2016). Clay was significantly different in the topsoil of different grazing intensities, but in the second depths of the three sites, there was no significant difference. Kumbasli et al. (2010) attributed the lack of clay in the HG area to the slower weathering rate and the appropriateness of water erosion and transfer of fine clay particles from these areas. The amount of silt varies among different sites and depths from 15.33 to 22.66%. Compared to UG (19.36%) and MG (15.33%), the HG area (22.66%) has the highest silt. As the results show, with increasing grazing intensity, the amount of silt increased ($P < 0.01$). The amount of sand varies among different sites and depths from 55.78 to 56.76%. Compared to UG (55.78%) and MG (53.16%), the HG area (56.76%) has the highest silt. As grazing intensity increases, the soil tends to become sandy ($P < 0.01$). These results are consistent with the findings of Warren et al. (1986) who considered severe grazing to be the main cause of bareness and soil compaction in silty-clay tissues. The percentage of sand and the percentage of clay were also variable, but there was no significant difference between areas with different grazing intensities. So that the highest percentage of clay in terms of quantity was observed in UG intensity and the lowest amount was observed in HG intensity. The highest amount of sand was related to HG intensity, and the lowest amount was related to UG intensity. Percentage of soil silt as a part of soil texture was one of the parameters that were affected by livestock grazing, and a significant difference was observed between different grazing intensities. So that with the proximity to the crisis center and the increase in livestock grazing intensity, the amount of soil silt has decreased, and the highest amount was observed in the region with light and medium grazing intensity and the lowest in the region with heavy grazing intensity (Aeinebeygi & Khaleghi, 2016). The results are in line with the results of Mirza Ali and Mesdaghi (2006). The percentage of soil silt as a component of soil texture was one of the parameters that were affected by livestock grazing. With the movement of livestock on the soil surface, the structure of the soil is disturbed and next to it, due to the rains, the soil whose structure is destroyed, fine-grained materials such as silt and coarse particles remain, and the soil in this conditions have turned to sand. Also, in areas with different intensities of exploitation by livestock, the percentage of aggregates is somewhat variable, which is due to the presence of different SOM and coating surfaces, which prevents the direct impact of raindrops on the soil structure. As a result, the stability of soil structure in the area with UG or MG intensity is higher. These results are consistent with the results of Mudahir and Taskin (2003) who stated that UG has more aggregate stability than HG. Kumbasli et al. (2010) and Al-Seekh et al. (2009) have achieved similar results, and the reason for less clay in grazed and kicked areas is due to lower aeration rate and suitable erosion conditions and surface currents; ultimately, these factors have led to the transfer of fine clay particles from these areas. Kizza et al. (2010) in the study of the effect of severe grazing on soil particles, comparing the soil properties of these areas with their surrounding areas, concluded that the percentage of large soil particles such as sand and silt has not changed much compared to the surrounding area. Examination of different sites about soil texture indicates that there is no significant difference in the second soil depth.

Conclusion

This study contributes to the understanding of the effects of livestock grazing on the SPEP of the soil and vegetation characteristics of grasslands in northern Iran. The results showed that with increasing grazing intensity, the pH and percentage of soil clay decreased, and the amount of soluble potassium and phosphorus in the soil increased. Changes in soil parameters due to grazing intensity have negative effects on the SPEP of the soil. Also, livestock grazing reduces plant residues in the soil by reducing vegetation. Any reduction in the entry of SOM reduces the fertility of the soil by disrupting the activity of decomposing microorganisms and reducing the decomposition of SOM. In addition to reducing vegetation, livestock grazing affects the number of soil nutrients by changing the vegetative form of plants and also kicking. By changing the type and form of plants, due to the different types and volumes of plant roots and root secretions, the SPEP of the soil will change. Therefore, in the management of rangeland ecosystems and the implementation of breeding and rehabilitation programs, the SPEP of the soil should be considered. The results showed that HG compared to MG causes worrying consequences in the soil. HG endangers the stability of rangeland ecosystems by causing negative changes in soil nutrients and vegetation. Overall, UG improves soil quality, MG intensity causes optimal conservation and utilization of soil resources, and HG intensity causes severe changes in rangeland soil properties. Therefore, MG, which has balanced grazing, is recommended for the use of rangelands in the region, which leads to the optimal and sustainable use of its soil resources. If the grazing intensity is MG, the rangeland soil is less degraded and can have sustainable production. Therefore, the use of grazing systems, in addition to reducing costs and gaining the satisfaction of ranchers, is more successful in maintaining the ecosystem of semi-arid regions than long-term exclosure. However, in this study, only one area has been selected, and this framework must be used in several other areas to produce a more complete practical result for the implementation department so that the implementation department can use this framework in the study of rangelands in the region. It is suggested to use biological projects such as mulching, seeding, and the like to repair and rehabilitate critical and vulnerable areas.

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