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Overgrazing is a Critical Factor Affecting Plant Diversity in Nowa-Mountain Rangeland, West of Iran

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Abstract. In western Iran, mountainous rangelands provide significant resources for livestock productions. Many ecosystems that are of high environmental and economic value are threatened by climate change and social economic pressures. This is especially important for semi-arid rangelands which have a multifunctional system. Quantifying the direct and indirect effects of grazing disturbance on plant biodiversity in the semi-arid mountainous rangelands can provide sight into the appropriate measures to restore degraded rangelands and conserve biodiversity. Here, the effects of different levels of grazing intensity (Light Grazing (LG), Moderate Grazing (MG), and Heavy Grazing (HG)) on plant biodiversity were examined in Nava-mountain rangeland in Kermanshah Province, Western Iran in 2016. The results showed that increasing grazing intensity led to a decrease in species richness, Margalef's richness index, and Shannon-Wiener index (p<0.05). Stepwise regression analysis was used to investigate the effect of grazing intensity (independent variables) on species diversity and richness (dependent variable). The estimate parameters were significant (p<0.01) for species richness, Margalef's richness and Shannon-Wiener indices in the different levels of grazing intensity. In overall, grazing intensity explained 47%, 47% and 50% of the variation for species richness, Margalef's richness, and Shannon-Wiener indices, respectively. In addition, species richness and diversity were affected in response to grazing disturbance intensity and reducing grazing pressure can contribute to maintain relatively high species diversity in Nowa-mountain rangeland.

Key words: Plant diversity, Grazing intensity, Diversity indices, Grazing disturbance

Introduction

Grazing is an important global ecosystem process that transforms the amount of plant biomass into animal biomass. Rangeland grazing plays a considerable role in livestock farming and livelihoods of local people (Herrero and Thornton, 2013), but herbivores grazing is the first disturbance affecting the productivity and functioning of rangelands (Liu *et al*., 2015). In the soil-plant-herbivore system, herbivores grazing affects species composition and diversity of plant communities (Belsky, 1992), soil physical and chemical properties (Zhou *et al*., 2010), productivity and ecosystem processes in various habitats (Huntly, 1991). Intensive grazing can cause changes in vegetation including the fact that by selective removal of plant biomass based on its palatability, it changes the species composition of herbaceous communities, the distribution and frequency of traits, and the type of function (Diaz *et al*., 2007, Hempson *et al*., 2015, Linstädter *et al*., 2014, Moreno García *et al*., 2014). Also, long-term grazing disturbance can lead to a transition from dominated perennial C_3 grasses to C_4 grasses in the plant community (Augustine *et al*., 2017).

By investigating the effect of livestock grazing intensity on plant species diversity in semi-steppe rangelands of Darrehshahr, Ilam province, Iran, Zeinivand *et al.* (2018) found that the highest values of Simpson and Shannon diversity indices were related to control treatment and the lowest values of these indices were related to heavy grazing treatment. They reported the highest values of Margalef and Menhinick richness in moderate grazing treatments and the lowest values of these indices in heavy grazing treatments. Therefore, they concluded that the intensity of heavy grazing by livestock can have an adverse effect on the diversity of plant species in semi-steppe rangelands (Zeinivand *et al*., 2018).

In Khabr National Park and Ruchun Wildlife Refuge located in Kerman Province, Iran, a study was conducted to analyze the effect of livestock grazing on the species diversity and plant functional types of arid and semi-arid rangeland. The results of this study showed that with increasing grazing intensity from light grazing to heavy grazing, species richness and diversity decreases. Also, plant functional types showed similar behavior and pattern. In this study, it was concluded that livestock grazing had a negative effect on the plant communities structure and reduced the species diversity and plant functional types in the study area (Sharafatmandrad *et al*., 2014).

In Iran, rangelands are located mainly in mountainous areas. Mountain ranges and mountainous areas cover about one-half of the entire territory of Iran, and Zagros range is considered as one of the most important biological and vegetated sites in Iran (Mahmoudi *et al*., 2018). This mountain range extends from northwest to southeast of Iran and covers about 1,700 km (Noroozi *et al*., 2016). Zagros vegetation, especially its herbaceous species, is often used as mountainous rangelands for livestock grazing. Nowa-mountain in the Southwest of Kermanshah province, Iran is one of the important sites of mountainous rangelands in Zagros, covering 7,000 ha of land. In this area, plant coverage, especially herbaceous plants, is grazed by both livestock (sheep and goat) of local herders and livestock of nomadic herders. Therefore, depending on the topographical position and proximity to the village, plant coverage is endured a various range from light grazing to heavy grazing. In this area, grazing occurred during the fall season (November, when plant growth begins, to June).

According to the intermediate disturbance hypothesis, light and moderate grazing intensity helps to increase community productivity and more diversity due to plant compensatory effects (McNaughton, 1983). However, heavy grazing intensity has a negative effect on the litter accumulation and soil coverage (Rutherford *et al.*, 2014, Schönbach *et al.*, 2011, Schuman *et al*., 1999), and it weakens the aboveground and underground plant

productivity (Liang *et al*., 2009). Some previous studies have pointed out that in assessing the effects of grazing on diversity and productivity have been exaggerated in comparison with the effects of environmental factors (Christensen *et al*., 2004), and they have stated that short-term grazing has a weak effect on species composition and diversity (Ren *et al*., 2012). However, plant diversity and species composition were recognized as key factors in plant community productivity and grazing had strong direct effects on the richness of herbaceous species (Shi *et al*., 2016, Tilman *et al*., 2001).

In this study, our general objective was to evaluate the effects of grazing intensity on species diversity and richness in Nowa-mountain rangeland. Also, determining the net contribution of grazing variable on species diversity and richness was our applied objective to use in the management of Nowa-mountain rangeland.

Materials and Methods

Site description

The study site was a mountainous rangeland located in Southwest of Kermanshah province, Iran (34°18'21" N to 34°20'21" N, 46°03'02" E to 46°05´02" E) (Fig. 1). In the native language, it is known as Nowa-mountain and covers an area of 7,000 ha. This region has a semi-arid climate with hot summers and almost cold winters, and the rainy season lasts from mid-November to mid-May. Meteorological records over 10 years show that annual mean precipitation is 400 mm and the annual min and max mean temperature are 11.7°C and 27.6°C, respectively. The region has a range from 1178 to 2428 masl and has the soil with a sandy, sandy loam, or sandy clay texture.

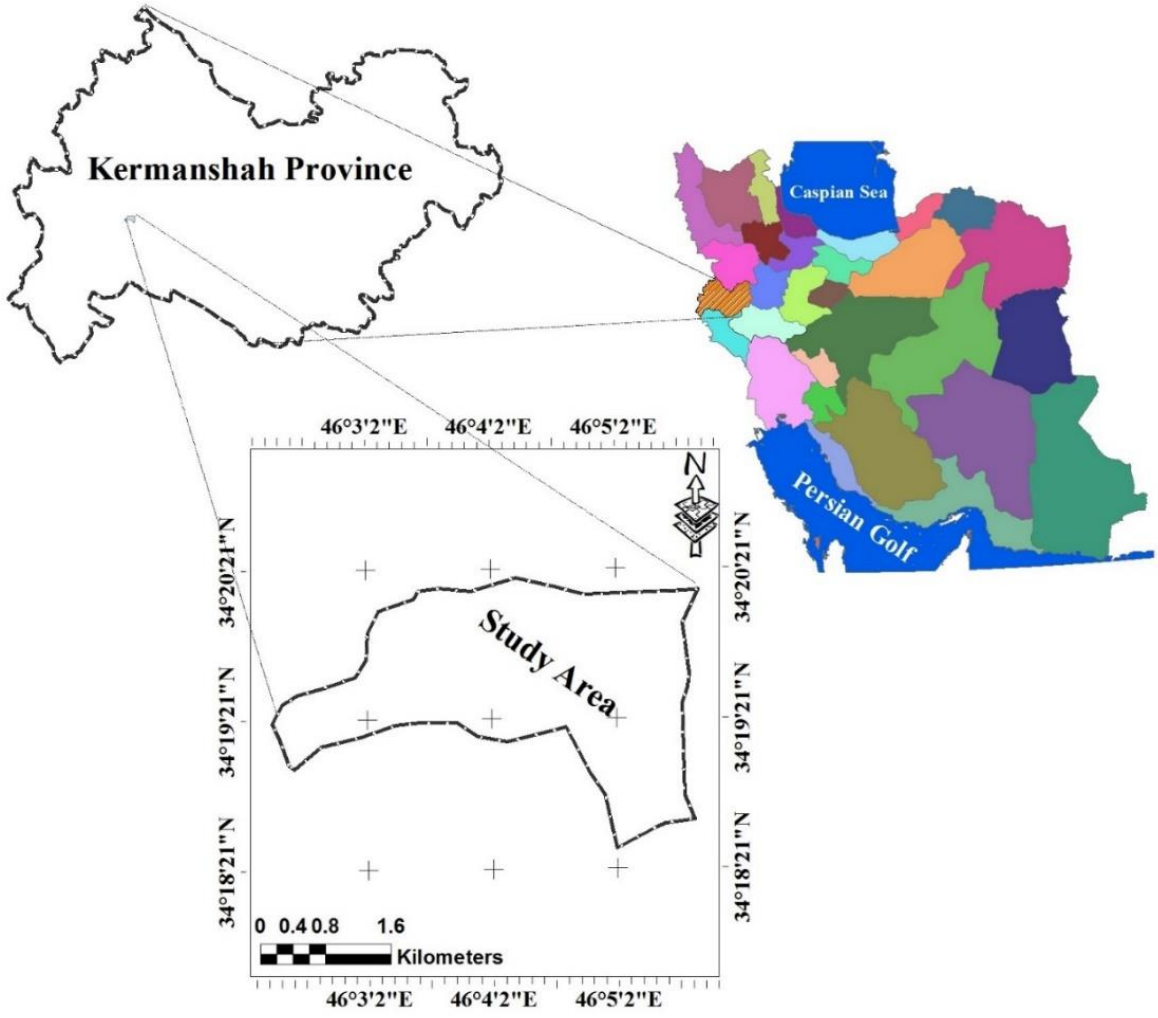

Fig. 1. Location of the study site in Nowa-mountain in Kermanshah Province, Iran

There are many villages around Nowa-mountain. Local livelihoods are based on agriculture and animal husbandry, and sheep and goat account for about 80% of the local livestock population, which plays an important role in the economy and food security for herders. Local herders, as well as nomads, use the vegetation of this area to graze their herds. Livestock grazing continues from the beginning to the end of the growing season and has been heavily added in recent years.

Sampling Method

The first field study was conducted to determine the critical points of grazing in Nowa-mountain ecosystem in 2016. Then, a range close to 180 ha of this ecosystem was determined according to the coordinates of the critical points. This area is at the exclosure of some indigenous and nomadic families, and they prevent others from entering the enclosed area. Therefore, the number of livestock in these households represents the density of livestock. A face-to-face interview with the owners of the enclosures (herdsmen) resulted in an estimate of the average number of livestock in at least the last 10 years. About 70 ha of the area was enclosed by several indigenous households with an average number of sheep of 3 heads per ha and about 110 ha of the study area was enclosed by several nomadic families with an average number of sheep of 8 head/ha. This area has a very small number of grazing wild animals and have no wild goats, so grazing of the wild animals was negligible. All livestock included sheep and domestic goats, so the number of 1.5 goats became the equivalent of a sheep. However, due to the centralization of livestock's in grazing, estimating the average number of livestock per hectare is a poor criterion and that's why the grazing time is very important. According to the field survey and interview with the herders, the grazing time was determined according to the proximity to the herdsmen's settlement point and water resources so that the highest centralization of grazing occurs at a distance of about one km far away the settlement point (about 8 hours per day). A systematic-randomized design was used for sampling and data were collected from 208 quadrats and 13 transect-lines. According to the amount of livestock waste in the plots as well as estimates of grazing time, three levels of grazing (light (LG), moderate (MG), and heavy grazing(HG)) could be deduced, and there was no grazing area except in precipices where it does not matter much in terms of biodiversity due to its rocky nature. For each quadrat, scientific names and canopy cover were recorded for all herbaceous species. For unknown species, the specimens were collected and sent to Herbarium of the Agricultural and Natural Resources Research Center of Kermanshah Province, Iran. The abundance of herbaceous species was calculated by frequency percentage (aggregate canopy cover of sampling units for each species/ total of canopy cover of sampling units for all species × 100). Species richness was estimated by the number of species in the quadrate scale.

Margalef's richness index was calculated as (Equation 1)

$$\boldsymbol{D} = (\boldsymbol{S}-\mathbf{1})/\boldsymbol{lnn} \quad (1)$$

Where, D is Margalef's richness index, *S* is the number of species, and *n* is the number of individuals.

Shannon-Wiener index was calculated as (Equation 2)

$$\boldsymbol{H'} = -\sum_{\boldsymbol{i=1}}^{\boldsymbol{s}} (\boldsymbol{P_i})\,(\boldsymbol{lnP_i}) \quad (2)$$

Where, H'= Shannon-Wiener index, *Pi* is the proportion of individual species *i* representing the relative density of plant species (species density/total density for all species ×100).

Smith and Wilson evenness index was calculated as (Equation 3)

$$E_{var} = 1 - (2/\pi)\left(arctan\left(\sum_{i=1}^{s}\left[log\sum_{e}^{ni} - \sum_{j=1}^{s} log_e^{nj/s}\right]^2/S\right)\right) \quad (3)$$

Where, *ni*: the number of individuals of the i^{th} species in sample, *nj*: the number of individuals of the j^{th} species in sample, *S*: the number of species in sample.

Statistical analysis

All data were analyzed using SPSS-22 statistical software package. Normality of data distribution was done by Kolmogorov–Smirnov test, and homogeneity of error variances was performed by Leven's test. One-way variance analysis (ANOVA) was used to determine the effects of grazing intensity on diversity indices. Means comparisons were made using least significant difference (LSD) test. Stepwise regression analysis was used to investigate the effect of grazing intensity as (independent variables) on species diversity and richness as (dependent variable). Significance was measured at 5% probability level (p<0.05). The diversity indices were calculated by Ecological Methodology 7.2 software.

Results

In total, 158 herbaceous species were identified, which belonged to 104 genera and 27 families. The highest frequency belonged to the Poaceae family, which contained about 45% of canopy cover in sampling quadrats. Mean ± SE of the diversity indices in 208 specimens for species richness, Margalef's richness index, Shannon-Wiener index, and Smith and Wilson evenness index were 6.11±0.26, 1.16±0.05, 1.86±0.06, and 0.57±0.01, respectively. The dominant species of the study area with respect to different grazing levels are shown in Table 1.

Table 1. The dominant species of the study area with respect to different grazing levels

Grazing intensity	Dominant species	Family	N	Mean (% Cover per quadrates)	SD	Max (% Cover per quadrates)	Min (% Cover per quadrates)
LG (N=96)	*Heteranthelium piliferum*	Poaceae	20	36	14	60	20
	Bromus tectorum	Poaceae	7	31	13	50	10
	Trifolium campestre	Papilionaceae	7	30	10	50	20
	Catabrosa aquatica	Poaceae	6	38	23	80	15
	Carduus pycnocephalus	Asteraceae	5	34	16	60	20
	Phlomis lanceolata	Lamiaceae	4	30	12	40	20
	Trifolium scabrum	Papilionaceae	4	30	12	40	20
	Trifolium arvense	Papilionaceae	3	50	10	60	40
	Trifolium stellatum	Papilionaceae	3	33	6	40	30
	Hordeum spontaneum	Poaceae	3	25	9	35	20
	Gundelia tournefortii	Asteraceae	3	18	3	20	15
MG (N=56)	*Bromus tectorum*	Poaceae	11	34	11	50	15
	Astragalus ambelopsis	Papilionaceae	3	67	32	90	30
	Ferulago carduchorum	Apiaceae	6	62	80	70	50
	Tanacetum polycephala	Asteraceae	4	33	12	40	15
	Heteranthelium piliferum	Poaceae	3	37	15	50	20
	Bromus danthoniae	Poaceae	3	32	14	40	15
HG (N=56)	*Bromus tectorum*	Poaceae	11	39	23	80	15
	Ferulago carduchorum	Apiaceae	6	77	26	100	40
	Prangos ferulacea	Apiaceae	4	46	6	50	38
	Marrubium astracanicum	Lamiaceae	4	38	6	45	30
	Astragalus amblolepis	Papilionaceae	3	70	36	100	30
	Aethionema grandiflorum	Brassicaceae	3	67	12	80	60

significant effect of grazing intensity on Smith & Wilson index for all of three diversity indices and the values were decreased (p<0.05) from LG to MG and HG, respectively (Fig. 2).

The results of the analysis of variance showed that grazing intensity had significant effect (p<0.05) on species richness, Margalef's richness, and Shannon-Wiener indices (Table 2). There was no

Table 2. The results of the analysis of variance for the effects of grazing intensity on the diversity indices

Grazing Effects	Diversity indices			
	Species richness	Margalef's index	Shannon-Wiener index	Smith & Wilson index
p values	< 0.001	< 0.001	0.044	0.872

Note: P < 0.05 is acceptable

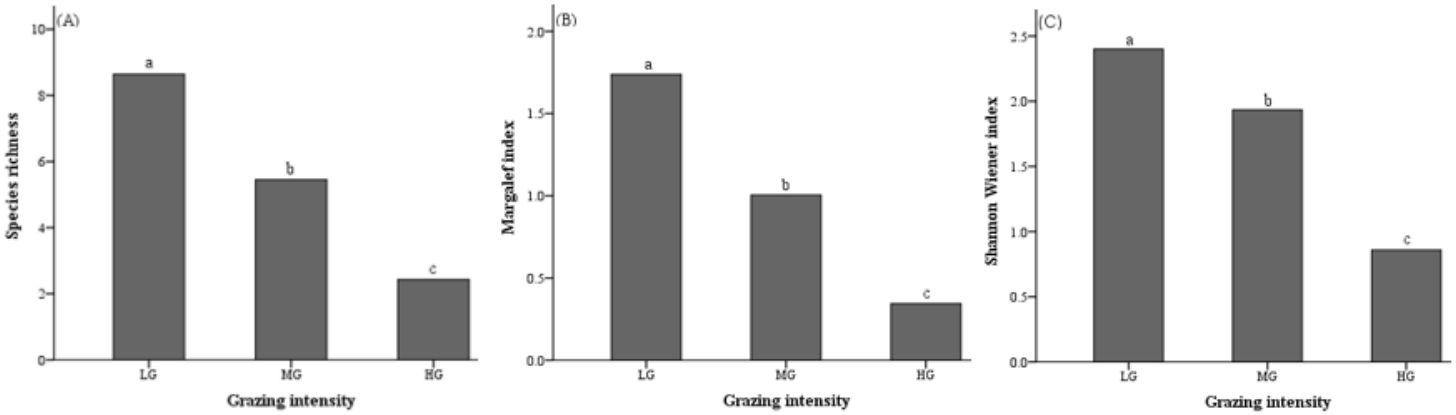

Fig. 2. Means comparisons of different levels of grazing intensity on the diversity indices: species richness (a), Margalef's index (b), and Shannon-Wiener index (c). Means of column with similar letters had no significant differences based on LSD (p<0.05)

Using stepwise regression analysis, the effect of grazing intensity on species diversity and richness was investigated and the result indicted significant relationships between grazing intensity and species richness, Margalef's and Shannon-Wiener indices (p<001), There was no significant relationship between grazing intensity and Smith & Wilson index (Table 3).

Result of regression analysis showed that grazing intensity was negatively associated with species richness, Margalef's richness and Shannon-Wiener indices with values of standardized regression coefficients (β) -0.69, -0.69, and -0.71, respectively. Similarly, grazing intensity accounted for 47%, 47% and 50% of the total variation for species richness, Margalef's richness and 50% Shannon-Wiener indices, respectively (Table 4).

Table 3. Results of regression parameters estimated by grazing intensity on diversity indices

Diversity indices	Parameter	B	95% CI	*P*
Species richness	Intercept	2.43	(1.69, 3.15)	< 0.001
	LG	6.22	(5.29, 7.13)	< 0.001
	MG	3.02	(1.98, 4.04)	< 0.001
	HG	-		
Margalef's index	Intercept	0.34	(0.18, 0.50)	< 0.001
	LG	1.39	(1.18, 1.60)	< 0.001
	MG	0.66	(0.43, 0.89)	< 0.001
	HG	-		
Shannon-Wiener index	Intercept	0.86	(0.70, 1.01)	< 0.001
	LG	1.54	(1.34, 1.74)	< 0.001
	MG	1.08	(0.85, 1.30)	< 0.001
	HG	-		

Smith & Wilson index	Intercept	0.57	(0.50, 0.63)	< 0.001
	LG	-0.02	(-0.10, 0.06)	0.63
	MG	-0.06	(-0.03, 0.15)	0.21
	HG	-		

LG, MG, and HG show light grazing, moderate grazing, and heavy grazing, respectively

Table 4. Summary of regression analysis on relation between grazing intensity and the diversity indices (N= 208)

Diversity indices	Variable	*B*	SE *B*	β	*P*
Species richness	Constant	8.63	0.26		< 0.001
	Grazing	-3.12	0.23	-0.69	< 0.001
	R^2 (Adj. R^2)	0.471			< 0.001
Margalef	Constant	1.73	0.06		< 0.001
	Grazing	-0.7	0.05	-0.69	< 0.001
	R^2 (Adj. R^2)	0.473			< 0.001
Shannon-Wiener	Constant	2.46	0.06		< 0.001
	Grazing	-0.75	0.05	-0.71	< 0.001
	R^2 (Adj. R^2)	0.506			< 0.001

Note: B, unstandardized coefficient. β, standardized coefficient.

Discussion

Our results showed that species richness, Margalef's richness, and Shannon-Wiener indices were in the highest values in low grazing area, and significantly decreased with increasing grazing intensity. Our results for prediction of species richness indicated that considering three identical quadrats, it could be expected that species richness in LG (equal to 6.22) and MG (equal to 3.02) would be significantly higher than HG. For Margalef's richness index and Shannon-Wiener index, a downward trend was also predicted from LG to HG.

Plant communities can exhibit higher species diversity in the presence of grazing disturbance (Augustine *et al*., 2017). There are published studies that showed a decline in species richness and biodiversity as a result of grazing exclusion (Bugalho *et al*., 2011, Mayer *et al*., 2009, Shi *et al*., 2013). Also, some studies found no significant change in biodiversity by grazing exclusion (Yan and Lu, 2015). However, the results of our study showed that species richness and plant diversity gradually declined with increasing grazing intensity, which is supported by Zhang *et al.* (2018). They investigated the effects of four grazing intensity treatments, including no grazing, light grazing, moderate grazing, and heavy grazing, on the plant community with sheep grazing over 12 years in a desert steppe in Inner Mongolia, northern China, and found that increasing grazing intensity resulted in decreased species richness, Shannon-Wiener and Palou's index, as well as above- and underground biomass. They stated that grazing disturbance had a greater indirect effect on aboveground biomass via plant diversity, and consequently, plant diversity is a key indirect factor that determines community productivity in response to grazing disturbance (Zhang *et al*., 2018). The effect of herbivores on plant diversity is related to regional variation in soil fertility, water availability, and the avoidance or tolerance strategies of plant species (Olff and Ritchie, 1998). Also, dietary preferences of different grazer types have a major contribution affecting plant diversity, as sheep grazing has less impact on species traits and functional diversity in short-grass plant communities compared to cattle grazing (Tóth *et al*., 2018). Various studies have shown that overgrazing has an important influence on plant diversity via various ways, such as soil compaction by hoof actions and roughing up (Akhter and Arshad, 2006, Khan and Frost, 2001, Qureshi and Bhatti, 2005), increasing soil erosion and weed invasions, and anthropogenic activities (Qureshi and Ahmad, 2010), which leads to alter plant communities and floristic composition.

Therefore, in our study, the additive effects of these factors may lead to negative tendency in species richness and plant diversity in response to grazing disturbance. This indicates that plant diversity in the semi-arid rangeland of Nowa-mountain is very sensitive and vulnerable to long-term grazing disturbance because the limitation of moisture in semi-arid climate and human disturbance, such as fire, can cause more and more vulnerable plant communities to grazing disturbance.

Conclusion

This study demonstrates that increasing sheep grazing intensity can lead to a decline in species richness and plant diversity in semi-arid mountainous rangelands. Therefore, in order to prevent declining tendency of species richness and plant diversity in response to grazing disturbance and also to conserve plant diversity and restore degraded mountainous rangeland of Nowa-mountain, management approaches should be taken as soon as possible to reduce grazing pressure. In this study, herbaceous species was surveyed, and quantifying the changes of tree species diversity and species population in response to grazing disturbance were the limitations of this study, which is suggested to be considered in future studies.

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چرای زیاد یک عامل بحرانی مؤثر بر تنوع زیستی گیاهی در مرتع کوه نوا، غرب ایران

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چکیده. در غرب ایران، مراتع کوهستانی منابع قابل توجهی را برای تولیدات دامی فراهم می‌آورند. بسیاری از اکوسیستم‌هایی که دارای ارزش بالای زیست محیطی و اقتصادی هستند توسط تغییرات اقلیمی و فشارهای اقتصادی اجتماعی تهدید می‌شوند؛ این موضوع به‌ویژه در مورد مراتع نیمه‌خشک، که یک سیستم چند کارکردی محسوب می‌شوند، بسیار با اهمیت است. بنابراین تعیین کمیت اثرات مستقیم و غیرمستقیم اختلال چرا بر تنوع زیستی گیاهی در مراتع نیمه‌خشک کوهستانی می‌تواند ارائه دهنده یک بینش نسبت به سنجش‌های مناسب برای احیای مراتع تخریب شده و حفاظت از تنوع زیستی باشد. در این مطالعه، اثرات سطوح مختلف شدت چرا (چرای سبک، چرای متوسط و چرای سنگین) بر تنوع زیستی گیاهی مرتع کوهستانی نوا در استان کرمانشاه، در غرب ایران، در سال ۱۳۹۵ بررسی شده است. بر اساس نتایج بدست آمده، افزایش شدت چرا به کاهش غنای گونه‌ای، شاخص غنای مارگالف و شاخص شانون-وینر منجر شد ($p<0.05$). برآوردهای پارامتر برای غنای گونه‌ای، شاخص غنای مارگالف و شاخص شانون-وینر در سطوح مختلف شدت چرا نیز معنی‌دار ($p<0.01$) بودند. در مجموع، شدت چرا توجیه کننده ۴۷٪ از واریانس غنای گونه‌ای و شاخص غنای مارگالف و ۵۰٪ از واریانس شاخص شانون وینر بودند. در مجموع، غنا و تنوع گونه‌ای تحت تاثیر شدت اختلال چرا قرار گرفتند و کاهش فشار چرا می‌تواند به حفظ غنا و تنوع گونه‌ای نسبتاً بالا در مرتع نوا کوه کمک کند.

کلمات کلیدی: تنوع زیستی گیاهی، شدت چرا، شاخص‌های تنوع، اختلال چرا