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Soil Bio-physicochemical Properties Changes in Response to Grazing Intensity and Seasonal Variations in an Arid Rangeland Ecosystem of Iran

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ABSTRACT

Aims: This study investigates the response of some soil bio-physicochemical properties under different grazing intensities management in a 17-year-old arid rangeland ecosystem of Iran.

Material & Methods: The grazing intensity gradient was as follows: (1) without herbivore grazing over a whole year (NG), (2) grazing by sheep and goats done communally from November to May (RG), and (3) continuous and heavy grazing over a whole year (HG). The soil samples were collected from the upper 20 cm in November and May.

Findings: The significantly higher bulk density values ($P<0.05$) were measured with increasing grazing intensities, i.e., 1.65, 1.82, and 1.96 $g.cm^{-3}$ in NG, RG, and HG, respectively. The management system affected significantly ($P<0.05$) organic carbon (OC), total nitrogen (TN), available phosphorus (P), exchangeable potassium (K), as well as enzyme activity of acid- and alkaline phosphatase (ACP, ALP) and urease. Similarly, the time of sampling affected significantly ($P<0.05$) OC, P, C, ACP, ALP, and urease activity in the soil. The soil OC ranged from 0.46 to 2.78 %, K ranged from 51.81 to 92.06 ppm, TN and P showed significantly ($P<0.05$) higher HG and RG values than NG. The soil pH ranged from 7.89 to 8.32, and EC (electric conductivity) ranged from 0.47 to 0.93 $dS.m^{-1}$, which was significantly affected neither by the grazing management system nor by sampling time. The TN showed a high positive correlation with ALP (r = 0.89), urease (r = 0.72), and dehydrogenase (r = 0.76). The OC, P, ACP, and ALP responded more sensitively to grazing management systems.

Conclusion: The presence of animals in our study site positively affected soil fertility. However, similar studies are required to complete our knowledge under different climatic conditions, vegetation-grazer types, and grazing duration.

Keywords: *Artemisia sieberi*; Ecological Balance; Pasture; *Salsola laricina;* Soil Enzymes.

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Introduction

Rangeland degradation is supposed to be a global ecological challenge [1], instigated by other environmental issues such as global warming, reduction of precipitation, rangeland use conversion, and excessive animal grazing [2,3]. It can lead to soil erosion, nutrient losses, and threats to food security and ordinary human life [4].

There is a wide variance of findings regarding the effects of grazing on soil properties in different pasture ecosystems. For instance, [5] found 12% lower organic C in grazed pasture sites compared to no-grazed study sites in Northern Yinshan Mountain Grasslands. Contradictory, Abdalla et al. found a 6% higher rate of organic matter in light-grazed pastures compared to no-grazed ones in dry-warm pasture ecosystems, on average, worldwide [6]. Moreover, [7] showed that the grazing significantly increased soil moisture, bulk density, and nitrogen amount by 12%, 7%, and 14% in Properties in the Semi-Arid Grassland of Northeast China, respectively. It also showed that the CEC (cation exchange capacity) and soil pH were not affected by grazing in the rangeland of Portugal [8].

Moreover, livestock grazing can affect above-ground biomass, such as plant diversity and coverage, as well as soil properties, e.g., organic matter, nutrient cycling, and soil structure via feeding, trampling, and feces extraction [9]. Furthermore, graying can affect the activities of soil enzymes, which are essential in soil chemical properties [10]. The soil enzymes, such as dehydrogenase, urease, and acid-alkaline phosphatase, respond rapidly to environmental changes. Therefore, they could be used as early indices of soil quality affected by management practices [11]. Therefore, soil nutrient content and biological activity measurements have been beneficial for evaluating soil and plant conditions in arid degraded lands [12,13].

Overgrazing may also lower biodiversity and stability, change plant-soil structure and function, and finally lead to organic matter losses in pasture ecosystems [14]. The degree of degradation can differ mainly according to the grazing intensity, duration, and ecological conditions of the exploited site [6,15].

Under grazing intensity, the enzyme and microorganism's activities can also be affected differently. The soil urease and sucrase activities showed significantly lower values in overgrazed sites in Stipa in *Inner Mongolia* [16]. Also, Wang et al. (17) showed that under grazing conditions, urease and cellulase enzyme activities were decreased by 79% and 166%, respectively. In contrast, the catalase activity was increased by 500% in steppe rangeland of northeastern China. It was also found that grazing exclusion significantly increased microbial and bacterial richness (5%) and fungal richness (9%) compared to grazed sites [18].

The seasonal differences can temporarily change the soil's bio-physicochemical properties by changing the root activity and litter fall [19]. The moisture and temperature change within a year, changing soil acidity, nutrient contents, and enzyme activity [20]. Also, [21] showed that the organic carbon and microbial biomass increased parallel with increasing temperature in the growing season in alpine ecosystems. However, it is shown that the activities of glucosidase and acetyle-glucosaminnidase were not affected by seasonal variations in turfgrass systems [22].

We have researched an arid rangeland ecosystem in central Iran under different grazing management, i.e., no-grazed, rotating, and heavy-grazed sites. We hypothesized that soil bio-physicochemical properties change via grazing management systems and seasonal variations. Therefore, the results can help us 1) to find more sensitive soil factors that can better reflect the soil changes under different grazing intensities,

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and we can also test 2) how the sampling time, i.e., spring and autumn, change the results of different grazing management systems, which could be helpful in further future similar studies. The results could be practical in optimizing our decisions for future precise selection and investigation of grazing management systems.

Materials & Methods

The experimental site was located in the Markazi Province in central Iran at 1400 m a.s.l. (Long. 50° 35′ to 50° 49′ E, Lat. 35° 23′ to 35° 30′ N). The study site's mean annual temperature was 19.3°C, and the average annual precipitation was 190 mm (Figure 1). The dominant species are *Artemisia sieberi*, *Salsola laricina*, and *Stipa hohenackeriana*. On average, 24% of our study site had vegetation cover, and *Salsola laricina*, *Artemisia Siberia*, and *Stipa hohenackeriana* were dominant plants with coverage of 10%, 6%, and 3%, respectively [23].

The focus of the present study was on three grazing patterns listed by increasing intensity according to grazing time as follows: (1) without herbivore grazing over a whole year within a fence (NG), (2) grazing by sheep and goat done communally during early November (Fall) to early May (Spring) with rotation and rest of the grazing pasture (RG), and (3) continuous and heavy grazing (4 Animal unit Month/ha) over a whole year (HG). All three grazing practices were applied in this pasture for 17 years. They are located across the same geographical areas and environmental conditions. The experiment randomized design was used, and two 5 × 5 m plots (>10 m from each other) were randomly established in each grazing experimental site for soil sampling. In May and November, soil samples were collected from the upper 20 cm for each experimental treatment. Three soil cores (10 cm in diameter, 20 cm in depth) were collected from each plot, leading to 36 soil samples (3 grazing treatments × 3 replicates × 2 seasons× 2 plots).

In this study, the soil texture was determined using the hydrometer method. Soil pH and EC were measured in the saturated soil paste, and soil bulk density was determined [25]. In addition, soil exchangeable K was extracted with $NH_4C_2H_3O_2$ and analyzed on an atomic absorption spectrophotometer with a flame atomizer [26]. OC was determined via titration procedure [27]. TN was measured using the Kjeldahl method . Available P extracted with 0.5 M $NaHCO_3$ was analyzed calorimetrically using the ascorbic acid molybdate method [29].

ACP and ALP activities were determined in 1 g (wet weight) aliquots of the soil from each treatment using p-nitrophenyl phosphate (pNPP) as an orthophosphate monoester analogue substrate. They were reported on a soil dry weight basis [30]. The concentration of urea in the assay wells was 20 mM. The plates were incubated at 20 °C for roughly 18 hr. The colorimetric salicylate and cyanurate reagent packets from Hach were applied to quantify the Ammonium released by the reaction. Urease was determined spectrophotometrically at 610 nm [31]. The activity is shown as a micromole of Ammonium released per gram of soil hourly (μmol NH_4^+ g^{-1} h^{-1}). Dehydrogenase was specified using 2, 3, and 5-triphenyl tetrazolium chloride (TTC) as a substrate, and the results were recorded as μg triphenyl formazan (TPF) g^{-1} dry soil h^{-1}. Samples and controls (by adding the substrate after the reaction ended) were put for analysis in triplicate and averaged. Controls were carried out for dehydrogenase assay with Tris–HCl buffer instead of TTC [32].

One-way ANOVA was performed to compare means for soil texture and bulk density amongst grazing treatments. A two-way ANOVA was applied to determine the

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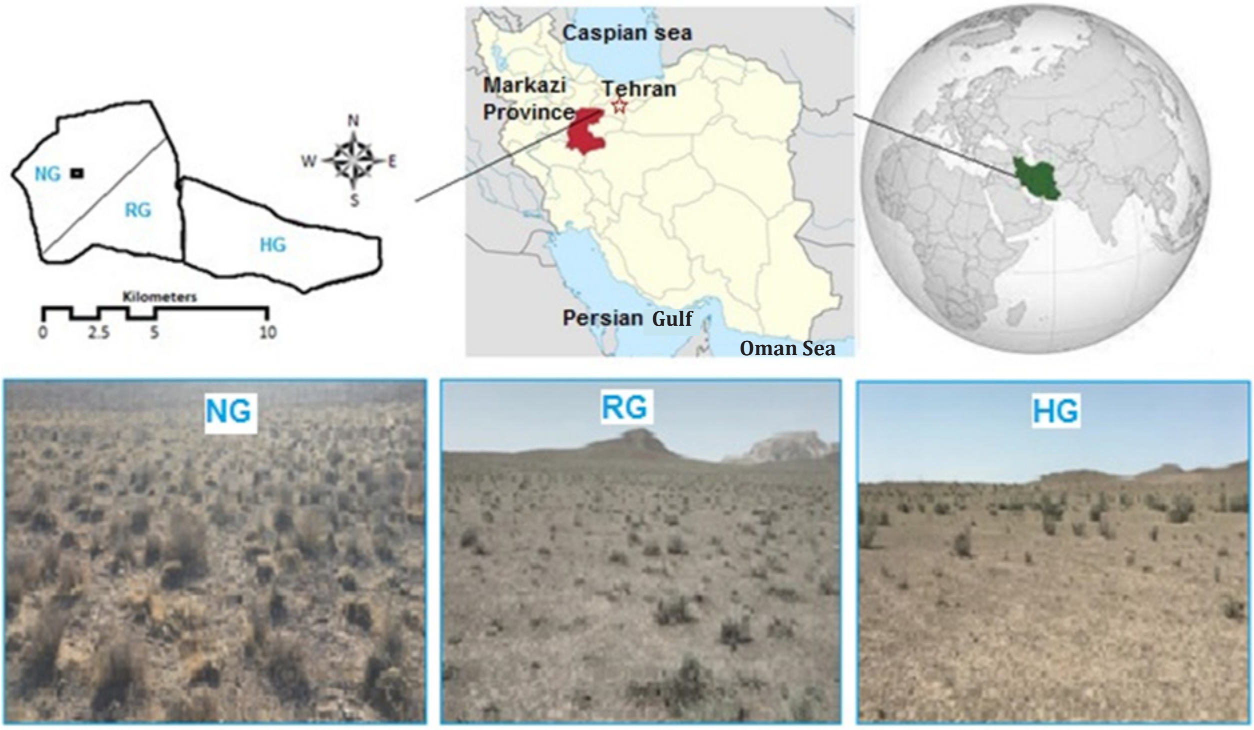

Figure 1) The study area in Markazi province in Iran. Grazing systems: NG no grazing, RG rotating grazing, HG heavy grazing**.**

effects of sampling time (two levels) and grazing treatments (three levels) and their interactions; when the grazing management effects were statistically significant, the two-way ANOVA was followed by Tukey's test for further grazing management comparisons. The Pearson correlation coefficients also tested the correlations between soil enzymes and chemical parameters. Some data sets were changed in terms of logarithm to meet the requirement of ANOVA regarding normality and homogeneity of variances. The Kolmogorov-Smirnov test was used to check the normality of data, and the Levene test was applied to investigate the equality of variances. All of the analyses were performed using SPSS 26 software.

Findings

In all three management systems, the soil texture was characterized as sandy loam (Table 1). However, high grazing treatment determined the lowest sand and highest silt contents (Table 1). Furthermore, the significantly higher bulk density values (P<0.05) were measured with increasing grazing intensities in the study site, i.e., 1.65, 1.82, and 1.96 g.cm^{-3} in NG, RG, and HG, respectively (Table 1).

The results of two-way ANOVA showed that the management system affected significantly (P<0.05) soil chemical factors (i.e., OC, TN, P, K, EC, and C:N ratio), as well as enzyme activity of ACP, ALP, and urease (Table 2 & 3). Similarly, the time of sampling and interaction of two variables affected significantly (P<0.05) OC, P, C:N ratio as well as ACP, ALP, and urease activity in the soil (Tables 2 & 3). Nevertheless, the soil pH ranged from 7.89 to 8.32, and dehydrogenase ranged from 8.04 to 9.38 **μg** TPF g^{-1} soil h^{-1} were significantly affected neither by the grazing management system nor sampling time (Table 2 & 3).

The soil OC ranged from 0.46 to 2.78 %, and K ranged from 51.81 to 92.06 ppm amongst different management systems, and sampling time showed significantly (P<0.05)

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Table 1) Bulk density and percentage contribution of silt, clay, and sand as soil texture.

Management	Bulk density ($g.cm^{-3}$)	Clay %	Silt%	Sand%	Soil Texture
NG	1.65 ± 0.04^{c}	17.94 ± 0.66	6.74 ± 0.24^{b}	75.32 ± 0.67^{a}	Sandy loam
RG	1.82 ± 0.02^{b}	17.51 ± 0.99	8.31 ± 0.57^{b}	74.18 ± 0.60^{a}	Sandy loam
HG	1.96 ± 0.34^{a}	16.50 ± 0.58	15.21 ± 0.56^{a}	68.27 ± 0.53^{b}	Sandy loam

Mean values within columns followed by different lower-case letters indicate significant differences among mange systems. NG stands for no grazing, RG for rotating grazing, and HG for heavy grazing.

higher values in HG and RG compared to NG (Table 2). Similarly, the highest significant values of TN (0.05%) and P (8.30 ppm) and lowest values of C: N (50.59) were measured in HG (Table 2). Moreover, the results showed increased activity of enzymes ACP, ALP, and urease with increasing grazing intensity (Table 3). The OC had higher values in November than in May, whereas the ASP, ALP, and P showed higher values in May than in November (Tables 2 & 3).

Some soil chemical properties were correlated with enzyme activity in the soil significantly (Table 4). The TN showed high positive correlation with ALP (r = 0.89), urease (r = 0.72) and dehydrogenase (r = 0.76) (Table 4), while ACP showed high positive correlation with pH (r = 0.67), P (r = 0.93), OC (r= 0.56) and C:N ratio (r = 0.83) (Table 4).

Discussion

Altogether, the results of the present study suggest that both grazing intensities result in considerable differences in the soil parameters in the ecosystem of arid rangeland (Tables 1, 2, & 3). Furthermore, our results showed increased C, N, and K contents in RG and HG sites compared with NG (Table 2). The results are consistent with those of [6,33], which found a higher rate of organic matter (6%) and (7.5%) in the grazed pastures compared to the no-grazed ones, respectively. Grazing by livestock on pastures leads to urines and dung excretions in the soil, which, in turn, increase the carbon and nitrogen contents of the soil [34]. Nearby, grazing increases root C contents at the driest and wettest sites, decreasing root C contents at intermediate precipitation levels (400–850 mm) [35]. The average annual precipitation in our study site is approximately 190 mm. However, Yang et al. found 12% lower organic C in grazed pasture sites compared to no-grazed in Northern Yinshan Mountain Grasslands [5]. Similarly, [36] showed more carbon biomass of soil in light-grazed sites compared to grazed sites (1.17 vs. 0.57 ton/hectare) in the rangelands in the Northwest of Iran. This might be due to reduced canopy cover and litter amount [37]. Nevertheless, it is also shown that [38] the complete resting of grazing can decrease soil organic matter content in pasture ecosystems.

Additionally, the C:N ratios in our study sites range from 51 to 73 (Table 2), indicating very slow organic matter decomposition. Consequently, the lower rate of organic matter decomposition than the accumulation rate may result in higher organic matter values in the heavy-grazing sites. There was no significant difference between rotating and heavy-grazed sites regarding C content (Table 2). It is also suggested that the relationship between grazing intensity and soil organic carbon is not mostly linear [39]. The grazing has increased the bulk density in

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Table 2) The effects of management systems and sampling time and their interactions on soil chemical variables.

Factor	Probability			Management	November	May
	M	T	M×T			
pH	(F = 12.90)^{ns}	(F = 197)^{ns}	(F = 15.47)^{ns}	NG	7.89 ± 0.09	7.92 ± 0.16
				RG	7.94 ± 0.12	7.98 ± 0.05
				HG	7.98 ± 0.07	8.01 ± 0.08
EC (dS.m^{-1})	(F = 110.2)**	(F = 75.06)^{ns}	(F = 86.07)^{ns}	NG^c	0.54 ± 0.01	0.47 ± 0.04
				RG^a	0.93 ± 0.06	0.82 ± 0.08
				HG^b	0.60 ± 0.06	0.66 ± 0.02
OC (%)	(F = 34.19)**	(F = 331.1)**	(F = 9.59)**	NG^b	1.56 ± 0.17	0.46 ± 0.03
				RG^a	2.54 ± 0.34	0.98 ± 0.03
				HG^a	2.78 ± 0.52	1.05 ± 0.03
TN (%)	(F = 303.95)**	(F = 19.28)^{ns}	(F = 13.57)^{ns}	NG^b	0.02 ± 0.01	0.02 ± 0.01
				RG^b	0.03 ± 0.01	0.02± 0.02
				HG^a	0.05 ± 0.01	0.05 ± 0.01
K (ppm)	(F = 99.20)*	(F = 34.89)^{ns}	(F = 15.61)^{ns}	NG^b	63.24 ± 6.21	51.81 ± 7.51
				RG^a	79.91 ± 4.27	82.25 ± 2.32
				HG^a	92.06 ± 2.29	72.48 ± 4.15
P (ppm)	(F = 39.98)**	(F = 1208)**	(F = 8.09)**	NG^b	7.65 ± 0.90	20.43 ± 1.50
				RG^c	5.91 ± 0.48	17.75 ± 0.75
				HG^a	8.30 ± 0.55	23.78 ± 1.69
C:N ratio	(F = 13.23)**	(F = 367.2)**	(F = 9.52)**	NG^a	73.34 ± 10.60	21.41 ± 2.03
				RG^a	75.13 ± 9.83	22.43 ± 1.29
				HG^b	50.59 ± 9.05	20.02 ± 1.25

Mean values (±SD) within columns followed by different upper-case letters indicate significant differences among management systems. M refers to Management systems: NG no grazing, RG rotating grazing, HG heavy grazing, and T time. EC electric conductivity, OC organic carbon, TN total nitrogen, K potassium, P phosphorus, C/N organic carbon / total nitrogen. *P ≤ 0.05; **P ≤ 0.01; ^{ns} P ≥ 0.05

our study site from 1.65 to 1.96 g.cm^{-3} (Table 1). Similar observations have also been reported by [40], which found that trampling caused significantly greater bulk densities in the no-grazed sites compared to the grazed sites (0.25 vs. 0.40 g.cm^{-3}). However, [41] reported lower bulk density in light-grazed compared with no-grazed fields in 7-60 cm soil depth.

In the current study, pH ranging from 7.89 to 8.32 showed no significant difference amongst management systems (Table 2). Similarly, the soil pH ranged from 5.3 to 5.5 in 0-15 depth of soil was unaffected by different grazing intensity management [8]. Nevertheless, some previous studies showed different results, such as urine additions by livestock in grazed soils increasing soil

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pH [42], while others reported decreased pH levels in response to high grazing [43]. The EC values in our study site amongst management systems show a variability of 0.47- 0.93 dS.m^{-1}, indicating that salinity is not the primary concern that could affect the grazed field.

The grazing increased enzyme activity in our study site, possibly due to more organic matter in our grazed vs. no-grazed site. However, [16] showed lower urease and sucrase enzyme activities in overgrazed sites in Stipa in Inner Mongolia. The urease, ACP, and ALP show higher activity in the high-grazed treatment, where the soil contains more organic matter (Tables 2 & 3). Contrary to our results, [17] reported lower urease and cellulase enzyme activities by 79% and 166% in grazed sites in steppe rangeland of northeastern China, respectively.

Correspondingly, in agreement with [44], our results indicated a strong correlation between urease activity and nitrogen (r = 0.72). Urease activity is essential for decomposing urea into ammonia, making it a vital enzyme in the nitrogen cycle [45]. In the HG site, the soil contains higher concentrations of animal urine, which could increase urease activity directly [46]. However, we found no significant effect of grazing intensity on dehydrogenase activity. However, [47] found that the dehydrogenase has higher activity in the grazed pastures in arid ecosystems. We also found a positive correlation of ACP with soil pH (r=0.67), which is consistent with those of [48], and similarly found the critical role of soil pH in the activity of ACP enzyme.

The effects of grazing intensity on soil characteristics are long-term. In contrast,

Table 3) The effects of management systems and sampling time and their interactions on soil biological variables.

Factor	Probability			Management	November	May
	M	T	M×T			
Dehydrogenase	(F = 50.37)^{ns}	(F = 9.60)^{ns}	(F = 10.56)^{ns}	NG	8.72 ± 2.19	9.38 ± 0.82
				RG	8.17 ± 0.75	8.04 ± 1.14
				HG	9.37 ± (1.35)	9.06 ± 1.35
Alkaline phos.	(F = 953.1)*	(F = 70.85)**	(F = 25.94)**	NG^{b}	67.14 ± 8.39	86.11 ± 7.59
				RG^{b}	79.11 ± 4.26	95.75 ± 9.07
				HG^{a}	163.37 ± 5.96	206.93 ± 5.66
Acid phos.	(F = 125.1)**	(F = 715.4)**	(F = 23.76)**	NG^{c}	13.27 ± 2.09	48.87 ± 4.84
				RG^{b}	12.99 ± 1.31	37.08 ± 5.58
				HG^{a}	26.40 ± 1.54	72.82 ± 5.58
Urease	(F = 480.7)*	(F = 17.99)*	(F = 564.9)*	NG^{c}	303.84 ± 6.66	296.65 ± 13.12
				RG^{b}	416.17 ± 6.29	232.07 ± 21.95
				HG^{a}	359.70 ± 24.79	620.60 ± 15.75

Mean ± SD (n=6). Different letters indicate significant differences among management systems. M refers to Management systems: NG: no grazing, RG: rotating grazing, HG: heavy grazing, and T: time. Dehydrogenase (*µg* TPF g^{-1} soil h^{-1}), alkaline phosphatase (µg p-nitrophenol g-1soil h-1), acid phosphatase (µg p-nitrophenol g-1 soil h^{-1}), and urease (µg N/g. dm. 2h). *P ≤ 0.05; **P ≤ 0.01, ^{ns} P ≥ 0.05.

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Table 4) Correlation coefficient (r) between soil enzyme activities and soil properties.

Factor	pH	EC	OC	TN	C:N	P	K
Dehydrogenase	0.18^{ns}	-0.25^{ns}	0.12^{ns}	0.76**	-0.45**	0.40*	0.18^{ns}
Alkaline phosphatase	-0.01^{ns}	-0.10^{ns}	0.17^{ns}	0.89**	-0.36*	0.78*	0.39*
Acid phosphatase	0.67**	-0.29^{ns}	0.56**	0.32^{ns}	0.83**	0.93**	-0.22^{ns}
Urease	0.07^{ns}	0.12^{ns}	0.19^{ns}	0.72**	-0.10^{ns}	0.30^{ns}	0.09^{ns}

EC: electric conductivity, OC: organic carbon, TN: total nitrogen, K: potassium, P: phosphorus, C/N: organic carbon / total nitrogen. $^{*}P \leq 0.05$; $^{**}P \leq 0.01$; ^{ns} $P \geq 0.05$

the seasonal differences in the effects on soil bio-physicochemical properties are temporary, as they change the soil temperature, root activity, and litterfall [19]. The results of the present study showed a significant role of sampling time on enzyme activity, so the ACP and ALP activity in all grazing intensities presented higher values in May than in November. It might be due to the lower autumn temperatures in our study site that could decrease enzyme activities [20]. Furthermore, higher values of OC in November than in May can be attributed to plant litterfall in autumn. However, P showed higher values in May than in November, maybe due to the higher activity of ACP and ALP enzymes, as both showed a high correlation with P availability (Table 4) in our study area. Soil phosphatases such as ACP and ALP can hydrolyze several low molecular weight P compounds such as polyphosphate, sugar phosphate, and mononucleotide, which result in higher P availability in the soil [49]. The pH ranging from 7.89 to 8.32 and EC ranging from 0.47-0.93 dS.m^{-1} showed no significant difference in sampling time.

In this study, we only focused on the impact of grazing on soil physical-chemical properties and enzyme activities. Therefore, further research on above-ground biomass (i.e., plant coverage, composition, and nutrient cycling) can help us understand the soil-plant response to grazing intensity in arid rangeland ecosystems more clearly.

Conclusion

Grazing management systems and seasonal variation changed the bio-physicochemical properties of soil in our study site, which confirms our initial hypothesis for this study. Furthermore, the presence of animals in our arid land ecosystems positively affected soil fertility by increasing the soil's OC, TN, K, and P content. Moreover, helpful soil enzymes like ACP, ALP, and urease had higher activity levels in the grazed site. We found no adverse effects of heavy grazing on soil acidity and salinity in the grazed site. However, grazing harmed the soil structure by increasing soil compaction. The soil biochemical factors, i.e., OC, P, ACP, and ALP, responded more sensitively to the different grazing management systems. Moreover, the soil biochemical factors, i.e., pH, EC, TN, and dehydrogenase, are more stable and not sensitive to sampling time. Similar studies are necessary to improve our knowledge of other climatic conditions with different vegetation-grazer combinations and grazing duration.

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Conflict of Interests: The authors have no conflict of interest.

Authors' Contribution: Elham Nouri (First author) collected and analyzed the soil samples and Introduction author (30%); Alireza Moshki (Second author), Methodologist/ statistical analysis/ Discussion author (40%); Mohammad Matinizadeh (Third author), Methodologist/ Discussion author (30%);

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