Long-term grazing exclosure: implications on water erosion and soil physicochemical properties (case study: Bozdaghin rangelands, North Khorasan, Iran)

S.S. Dastgheyb Shirazi · A. Ahmadi · N. Abdi · H. Toranj · M. R. Khaleghi

Abstract Grazing exclosure (GE) is used to improve rangelands in the dry area of the world, so it is important to investigate its effects on soil physicochemical and erodibility properties. This study was conducted to evaluate the effect of long-term GE on the physicochemical and erodibility properties of soil and vegetation as compared with open grazing (OG) areas in Bozdaghi region of North Khorasan province, Iran. Soil and vegetation data were sampled from two sites in the grazing exclosure and the open grazing in early autumn in a randomized complete block design with three replications. Therefore, in each area (GE and OG), three transects of 500-m length and 200-m intervals) were set up. Along each transect, five soil samples were taken at the depths of 0–15 and 15–30 cm in a random-systematic method (15 soil samples in each area) and transferred to the laboratory. In the laboratory, some soil physicochemical properties such as saturation percentage, soil texture (clay, silt, and sand), bulk density, porosity, percentage of soil organic matter (SOM), total nitrogen (TN), exchangeable sodium, potassium, pH, and electrical conductivity (EC) were measured and Soil Erodibility Index (SEI) was calculated by using the modified clay ratio relation. After installing the transects (with a length of 50 m) in three blocks in each area, the parameters of species composition and canopy cover were investigated by the linear-contact method. Data analysis was performed by using an independent t test on Statistical Package for Social Sciences (SPSS) *v. 23* software. The results indicate that the application of GE in the Bozdaghi area has a significant positive effect on soil physicochemical properties ($P < 0.05$). Also, the application of GE has increased the amount of SOM and TN in the surface layer of the soil by about twice as much as the OG pastures. Due to these changes, during 20 years in the GE area, the effects of GE can be positively assessed. According to the obtained results, especially the positive changes in vegetation and the soil physicochemical and erodibility properties, it is recommended to execute the GE plan in the study area.

Keywords Soil erosion · Grazing exclosure · Rangeland · Long-term vegetation change · Soil organic matter

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Introduction

An OG system can have an important effect on soil physicochemical and biological properties (Ozaslan et al. 2015; Wang et al. 2016; Wolf et al. 2017; Kazemi et al. 2018; Ma et al. 2020; Oggioni et al. 2020; Zhou et al. 2020). Reducing the entry of plant debris into the soil affects the dynamics of soil organic matter (SOM), which is the only source of nitrogen, phosphorus, and other nutrients in natural rangeland soils (Shariff et al. 1994).

Numerous studies have shown the negative effects of overgrazing on the rangeland soil's physical, chemical, and biological properties. According to Raiesi and Riahi (2014), these negative effects are most evident in the rangelands of arid and semi-arid regions due to limited resources (lack of litter and available water). Negative consequences of overgrazing include wastage of water and soil resources (Van pollen and Lacey 1979; Kazemi et al. 2018; Aryafar et al. 2019), reduced vegetative vigor (Ren et al. 2012; Angassa 2014), reduced regeneration and lack of seedlings of valuable rangeland species (Qian et al. 2014), and change in composition and density of high-quality species. Warren et al. (1986) mentioned the change of plant type in the rangeland (Blackburn et al. 1982), the change of soil fertility, and endangering the stability of the ecosystem (Archer and Smeins 1991; Dormaar and Walter 1998; Ren et al. 2012; Taormina et al. 2012; Gholami et al. 2015).

In this regard, various researches have been done to investigate the connection of this research with previous researches, the following cases are mentioned: Bower et al. (1952), Frank et al. (1995), and Han et al. (2008) in their study concluded that OG reduced SOM, carbon, and TN. Dormaar et al. (1997) by comparing the effects of long-term GE and rest-rotation grazing systems on soil and vegetation characteristics in Alberta, Canada, showed that the long-term GE area has less total carbon and a TN but more available phosphorus than the rest-rotation grazing area. Steffens et al. (2008), in a study of semi-arid ecosystems in China, concluded that soil organic carbon (SOC), TN, and soil sulfur content had a significant downward rate with increasing grazing intensity so that these three variables have a very high correlation with grazing intensities. Haarmeyer et al. (2010) reported that the abundance of two important endemic species (*Drosinthemum schoenlandianum* and *Argyroderma fissum*) has increased at the site with moderate grazing intensity, and different grazing intensities have changed the species structure. Dhaou and Abdullah (2010) in their research concluded that in the GE area, an increase in soil nutrients (TN, potassium, sodium, and magnesium) occurred, while the percentage of SOM, calcium concentration and acidity in the two regions (GE and OG) were equal and GE had no significant effect on phosphorus. The results can be attributed to the destruction of topsoil in the OG area. Mut and Ayan (2011) found that the soil of the rest-rotation treatment area had more SOM, P, and Ca than the GE area. Teague et al. (2011), in their study in

grasslands, concluded that light and open heavy grazing compared to GE caused a significant reduction in soil SOM and cation exchange.

It is obvious that each of the different methods of livestock grazing management has different effects on the performance of rangeland ecosystems (Adler et al. 2001) and livestock and plants in natural ecosystems are always interacting with each other (McNaughton 1979). Han et al. (2008), in the study of the effect of livestock grazing intensity on TN, soil carbon in a lawn step, concluded that these two substances are severely reduced under heavy grazing intensity and soil depth (up to the first 20 cm). Pei et al. (2008), in a study, concluded that 6-year grazing exclosure increased soil moisture by 30% compared to open heavy grazing and also, OG compared to 2- and 6-year-old grazing exclosure significantly reduced OM and TN. Sandhage-Hofmann et al. (2015) in studying the effect of grazing on soil properties in the bio-savannah of South Africa reported that in the vicinity of drinking water, the levels of acidity, calcium, magnesium, potassium, and zinc increased and decreased of edible grasses. Wang et al. (2016) investigated the grazing effects on soil characteristics and vegetation of grassland in China and recommended moderate grazing as the preferred management for grasslands. Zhang et al. (2020) found that the intensity of grazing affects soil physicochemical properties and also the soil bacterial community composition. Zhan et al. (2020) found GE and a low grazing system suitable for the sustainable development of worldwide dryland management.

In general, the goals and benefits of the GE can be such as creating a suitable opportunity for reproduction and vegetative growth and reproduction of rangeland plants (Aeinebeygi and Khaleghi 2016), creating conditions and opportunities for vegetation reconstruction and increasing its quantity and quality (Gholami et al. 2020a), creating conditions to increase rangeland production capacity and preventing further soil erosion (Gholami et al. 2008), increasing palatable species and changing plant composition, and preserving rare species and the opportunity for their reproduction (Shariff et al. 1994; Haarmeyer et al. 2010; Gholami et al. 2020b).

In the Bozdaghin rangelands with an area of about 6880 hectares, excessive grazing, the unclear status of land ownership, frequent droughts, and poor participation and cooperation of farmers with the management of natural resources are the important problems of the region. Due to the need to quantify the results of GE, to justify the continuation of the GE and also to reflect the results to

the decision-making authorities, it is important to study the effects of GE on soil properties and vegetation.

The main purpose of this paper is to evaluate the changes in some soil physicochemical and erodibility properties as a result of long-term GE in comparison with OG. In this regard, the main hypothesis of this research is that the application of GE in the Bozdaghin rangelands has a significant effect on soil physicochemical and erodibility properties.

Methods and materials

Study area

The present study is performed in the Bozdaghin rangelands, 60 km northwest of the capital (Bojnourd) of North Khorasan Province. The study area is located in the east, north of Iran (56° 45′ 9″ to 56° 50′ 13″ E longitude and 37° 49′ 39″ to 37° 55′ 34″ N latitude) and that has an area of 68.8 km^2 (Fig. 1). The mean annual rainfall and temperature in this area are about 264 mm and 16.2 °C respectively. The average weight height of the study area above sea level is 833 m. According to the De Martonne classification, the study area is located in a semi-arid climate. The precipitation of the region is in the form of rain and snow and mostly in autumn and winter. The soil is deep and fertile with a loamy-clay texture. According to the Ambrothermic curve of the Bozdaghin rangelands (Fig. 2), the driest months are mid-May to October. Also, the wettest months are from November to May. The vegetation of the region is grass-shrub-land and the method of exploiting the pastures is seasonal grazing (late autumn to early spring by rural-nomadic herders with a combination of grazing livestock mainly sheep (more than 95% and goats less than 5%). The habitat of the region in terms of rangeland plants and climatic conditions is part of the flora of the Irano-Turanian Steppe. The enclosed area has been under grazing enclosure since 1999 to restore vegetation and by the Natural Resources Department of North Khorasan Province.

Sampling and measurement of soil properties

To investigate the effect of long-term GE on physical and chemical properties of soil, in each of the two areas of the long-term GE and the OG system, areas that had the same conditions in terms of elevation, climate, and geology and only in terms of management were identified. Soil and vegetation data were sampled from two sites in the GE and the OG in early autumn in a randomized complete block design with three replications. Therefore, in each area (GE and OG), three transects of 500-m length and 200-m intervals) were set up. Along each transect, five soil samples were taken at the depths of 0–15 and 15–30 cm in a random-systematic method (15 soil samples in each area) and a total of 60 soil samples were transferred to the Soil Laboratory of Mashhad Research Center. In the laboratory, soil samples were dried in the air. Some of the samples were separated from the rest of the samples to measure the specific bulk density of the soil. Then all soil samples were sieved by a 2-mm sieve after the crumbling process. To reduce the effect of interfering factors, 5 samples were taken from each block and merged. In the laboratory, some soil physical and chemical properties such as SOM (by wet burning method), TN (by Kajdal method), absorbable phosphorus (Olsen experimental method), absorbable potassium (by extract method 1 M ammonium acetate with acidity 7), acidity (pH meter), the electrical conductivity of soil (EC meter in saturated extract), soil texture (clay, silt, and sand) by hydrometric method (Bouyoucos 1962), percentage of soil saturated moisture by weight (Famiglietti et al. 1998), and bulk density were measured using clods and paraffin (Blake 1965). Also, the total porosity of the samples was calculated using a specific bulk density. After installing the transects (with a length of 50 m) in three blocks in each area, the parameters of species composition and canopy cover were investigated by the linear-contact method. Soil Erodibility Index (SEI) was calculated using a modified clay ratio and by Eq. 1 (Kumar and Kushwaha et al. 2013; Niknahad Gharemakher et al. 2018):

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

Statistical analysis

Data analysis was performed by using a *t* test in *SPSS v. 23* software. To compare the soil properties of the GE area with the OG area, an independent *t* test was used and to compare the soil properties of the first depth with the second depth of each area, a paired *t* test was used. It should be noted that before the independent *t* test, the homogeneity test of variance (Levene's test) was performed. In this regard, except for pH and EC, in all variables, the significance of the Levene's test was more
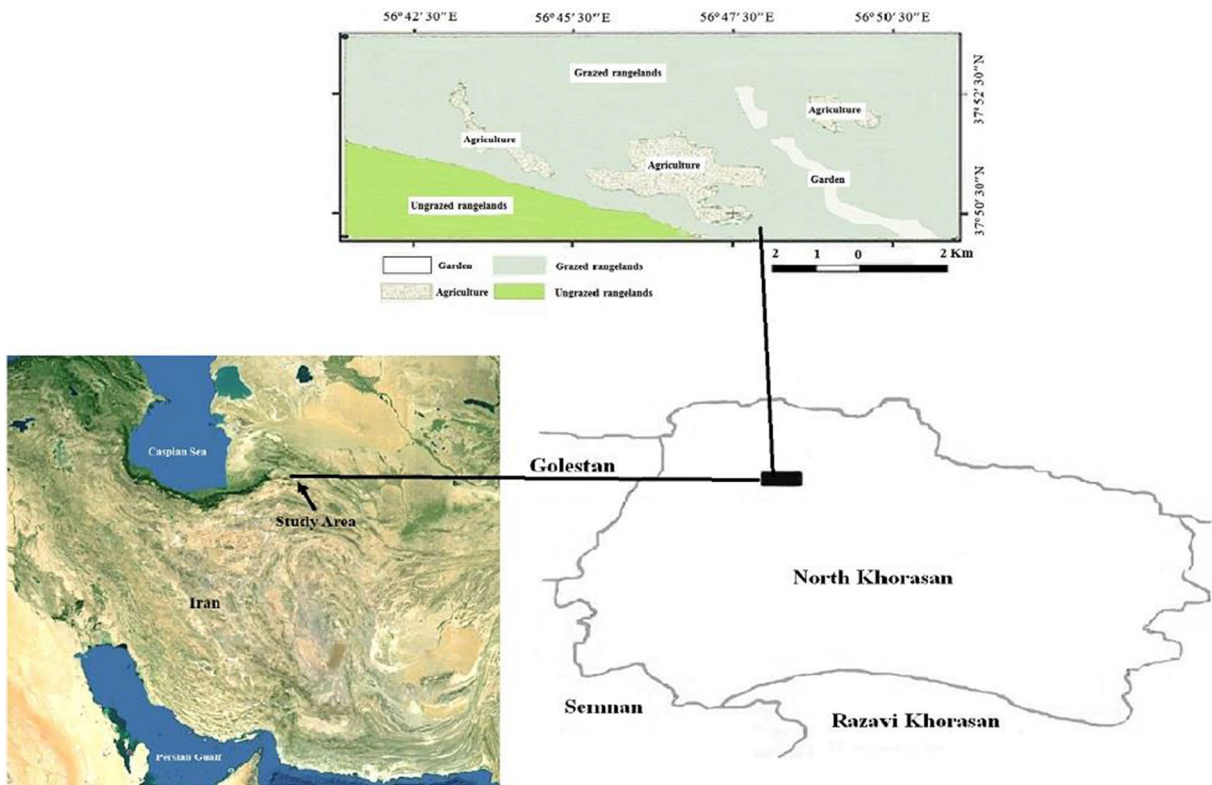
Fig. 1 Sampling sites in the Bozdaghin rangelands, Maneh and Samolghan city (Niknahad Gharemakher et al. 2018)

than 0.05. Therefore, assuming the homogeneity of variances, *t* and its significance were followed.

Results

The results of the *t* test to compare the soil properties of the two studied depths in the two study sites are presented in Table 1.

Percentage of soil texture components The results (Table 1) indicate that the texture of both study areas is loamy sand. As a result of the GE, the average percentage of clay in the soil texture of the GE area increased significantly ($P < 0.05$) from 18.4 to 21.11%. But no significant difference was observed in the average percentage of silt in the soil texture ($P > 0.05$). On the other hand, the average percentage of sand in the soil texture of the enclosed

Fig. 2 The Ambrothermic curve corresponds to the study area
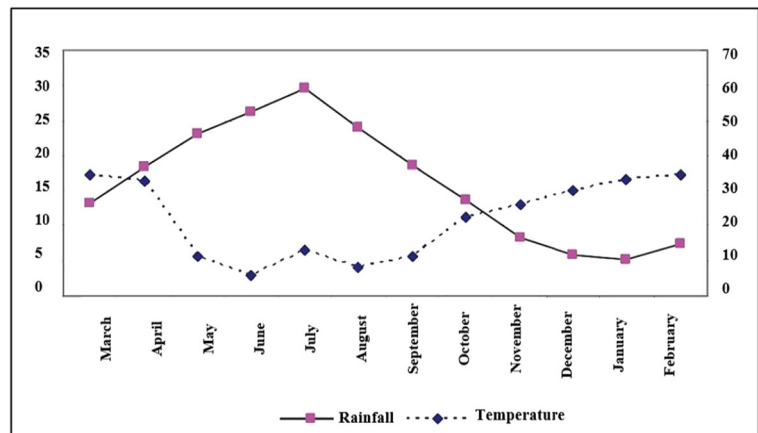
Table 1 The results of *t* test to compare the soil properties of the two studied depths in the two study sites

Depth (cm)	Variable	The GE area	The OG area	*t* value	Sig.
0–15	Soil moisture (%)	4.83	4.56	− 0.289	0.787
	TN (mg/kg soil)	0.049	0.024	3.182	0.041*
	Clay (%)	21.11	18.4	− 0.267	0.000**
	Silt (%)	36	26	22.6	0.35
	Sand (%)	44.75	54.51	− 3.742	0.025*
	Potassium (mg/kg soil)	270.7	299	− 1.041	0.357
	SOM (%)	1.36	0.87	4.258	0.034*
	Acidity (pH)	7.36	7.75	− 2	0.041*
	Phosphorus (mg/kg soil)	8	8.3	− 0.925	0.401
	Bulk density (gr/cm^3)	1.09	1.26	7.2	0.027*
	EC (dS/m)	0.28	0.34	− 1.4	0.021*
	Porosity (%)	52.4	47.3	4.6	0.042*
15–30	Soil moisture (%)	6.86	6.79	− 0.779	0.469
	TN (mg/kg soil)	0.03	0.02	1.51	0.205
	Clay (%)	19.33	19.33	0.000	1
	Silt (%)	35.33	32	1.58	0.189
	Sand (%)	45.33	48.64	− 2.23	0.089
	Potassium (mg/kg soil)	158.66	213.30	− 1.20	0.295
	SOM (%)	0.32	0.18	1.72	0.160
	Acidity (pH)	7.31	7.89	− 1	0.423
	Phosphorus (mg/kg soil)	7.8	8.5	− 0.9	0.502
	Bulk density (gr/cm^3)	1.11	1.26	7.2	0.34
	EC (dS/m)	0.29	0.28	2.6	0.41
	Porosity (%)	49.1	48.4	4.6	0.74

*, **= indicates a significant at 5% and 1%, probability levels, respectively

area decreased significantly ($P < 0.05$) from 54.51 to 44.75%.

Percentage of TN The results (Table 1) show that the amount of TN in the GE area compared to the OG area is significantly higher ($P < 0.05$) and has increased from 0.024 to 0.049%.

Acidity (pH) The results (Table 1) indicate that the soil acidity of the GE area is significantly lower than the OG area ($P < 0.05$) and has increased from 7.75 to 7.36.

Soil organic matter The results (Table 1) show that the SOM of the GE area is significantly higher than the OG area ($P < 0.05$) and has increased from 0.87 to 1.36.

Apparent bulk density The results (Table 1) indicate that the bulk density of the soil in the GE area is significantly

lower than the OG area ($P < 0.05$) and has decreased from 1.26 to 1.09.

Electrical conductivity The results (Table 1) indicate that the EC of the soil of the GE area is significantly lower than the OG area ($P < 0.05$) and has decreased from 0.34 to 0.28.

Porosity The results (Table 1) indicate that the soil porosity of the GE area is significantly higher than the OG area ($P < 0.05$) and has increased from 47.3 to 52.41.

Soil Erodibility Index SEI in the enclosed area is significantly lower than the grazed area ($P < 0.05$) and has increased from 4.231 to 5.147 (Table 2).

Canopy cover The results of canopy cover sampling of plant species based on vegetative forms are presented in

Table 2 Comparison of the average Soil Erodibility Index between the confined area and the grazing area

Variable	The GE area: 0–15	The OG area: 0–15	t value	Sig.
SEI	4.231	5.147	16.837	0.003

Table 3. The vegetation of the region is mainly covered by Artemisia sieberi and Stipa barbata. The average percentage of vegetation in the GE area is 36.76% and in the OG area is 14.24% (Niknahad Gharemakher et al. 2018). The results show that the highest percentage of canopy cover in the GE area belongs to the Compositae family and the lowest canopy cover belongs to the families of Dipsacaceae and Cyperaceae. Also, the highest and the lowest canopies in the grazing area belong to the families of Compositae and Plumboginaceae, respectively.

Figure 3 shows the logarithmic diagram of the rank distribution of species abundance. According to this chart, the GE area is located with a gentler slope and in a higher rank than the OG area. This indicates more diversity and uniformity in the GE area. Therefore, it can be concluded that the GE system in this area has increased plant diversity.

Discussion

PH is an important indicator that affects the solubility and availability of necessary nutrients for plant growth (Al-Seekh et al. 2009; Asadi et al. 2020). The results show that the first and second soil depths of the GE site have the lowest acidity (7.36 and 7.31, respectively). A significant reduction in soil acidity as a result of GE is consistent with the results of Aarons et al. (2004), Somda et al. (1997), and Marcos et al. (2019). There are several reasons for this decrease in pH. Marcos et al. (2020) declared that GE induced lower soil pH and particle size, and higher soil C and N contents. Pei et al. (2008) declared that the decrease in soil acidity in the GE is due to high vegetation or dense root system and high SOM. The secretion of organic acids from the roots and the carbon dioxide emitted from the roots and microorganisms can reduce soil pH. Therefore, the decrease in soil pH of the GE site compared to the OG site could be due to high root biomass and high SOM accumulation and metabolism of highly active microorganisms in the rhizosphere (Nelson and Sommers

1982). This effect has been such that the depth below this site has not been unaffected and has been affected by the effect of roots and has a low pH (7.31). On the other hand, more soil porosity in the GE area causes more water infiltration (Fallatah 2020; Shende and Chau 2019) into the soil than in the OG area, and as a result, surface soil carbonate is transferred to a lower depth, which reduces the pH of the topsoil (Aarons et al. 2004). Somda et al. (1997) attributed the cause of high acidity at the OG site to the accumulation of animal urine (pH between 8.4 and 8.6).

pH Significant reduction in soil salinity (pH) as a result of the GE application is consistent with the results of Chaneton and Lavado (1996) and Aarons et al. (2004). In the GE area, higher vegetation and litter and reduced evaporation from the soil increased soil moisture, resulting in a decrease in salt concentration, so the soil EC significantly decreased compared to the OG area (Chaneton and Lavado 1996).

Bulk density The results of this study indicate a significant increase in soil bulk density due to livestock grazing and kicking. In other words, GE caused a decrease in bulk density, which is in line with the findings of Greenwood et al. (1998) and Zhao et al. (2007). Lemenih et al. (2005) considered that the decrease in bulk density and the increase in the percentage of total soil porosity are due to the increase in SOM, which is also confirmed by the results of this study. However, this difference in bulk density is not seen in the second depth (15–30 cm) and indicates that the effect of intense grazing has not been transferred to the deep layer (Vaillant et al., 2009).

Percentage of soil texture components The existence of suitable microclimatic conditions for clay particles in the GE area has caused the amount of these particles in the GE area to be higher than the OG area. This finding is consistent with the results of Kumbasli et al. (2010) and Al-Seekh et al. (2009). The reason for the existence of less clay in the area under grazing is the lower speed of weathering and suitable erosion conditions and

**Table 3** Percentage of canopy cover of each plant family in the study area

Family	OG	GE	Family	OG	GE
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	-	-	-

surface flows and transfer of fine clay particles from the area (Thurow 1991) and surface flows (due to lack of vegetation) and the transfer of fine clay particles from these areas.

Soil organic carbon Significant increase in the amount of SOM and the percentage of clay in the soil of the GE can be the reason for the higher percentage of saturated moisture in the GE area compared to the OG area (Givi and Asadi 2001). The increase in soil organic matter in the grazing area can be attributed to the principal grazing that has led to the search for plants, followed by increased production and the percentage of the vegetation canopy. Also, the presence of livestock in the area, in addition to mixing the litter with the soil, has increased the percentage of soil organic matter by adding waste. A significant increase in SOC in the GE area is consistent with the results of Bower et al. (1952), Frank et al. (1995), and Dormaar et al. (1997). The dense vegetation of the GE areas returns larger amounts of roots in the soil and therefore these areas are prone to more accumulation of surface litter. These two factors are the most important sources of SOM supply in rangelands and any restriction on them will reduce soil OM (Derner et al. 1997). Changes in soil moisture and temperature change the microbial and vital activity of the soil, which in turn

Fig. 3 Logarithmic diagram of the rank distribution of species abundance in the study area
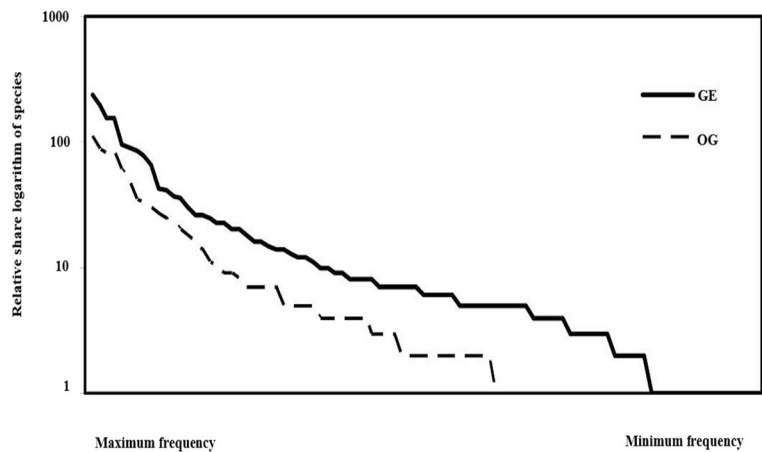
changes the intensity of decomposition (McGill et al. 1988). Improving the physical properties of the soil as a result of the GE area has improved the vegetation characteristics of the GE area compared to the OG area. This increases the inflow litter, increases soil moisture and decreases its temperature, and changes the ratio of incoming carbon (primary net production) to carbon loss (microbial respiration and decomposition of SOM). As a result, SOC in the GE area has increased significantly compared to the OG area.

Total nitrogen Significant increase in TN in the GE area is consistent with the results of Bower et al. (1952), Berg et al. (1997), and Dormaar et al. (1997). The studies of Niknahad-Gharmakher et al. (2012) on the effects of litter quality on mineralization and organization of nutrients indicate that litter quality has a significant effect on the intensity of litter decomposition and release of nutrients such as soil TN. Plant litter in the GE area is probably of higher quality compared to the litter in the OG area, so the degradation process results in an increase in SOM and TN in the GE area compared to the OG area. Due to the increase in the percentage of SOM, soil granulation has improved and with increasing porosity and soil aeration, water infiltration capacity has increased. As a result, sodium and potassium have been leached from the soil of the GE area and its average has decreased (Neff et al. 2005). On the other hand, the presence of livestock causes crushing and burial of plant debris in the OG area and accelerates their degradation process (Frank and Groffman 1998). More accumulation of livestock feces in the OG area compared to the GE area since animal waste contains many nutrients can be another effective cause in this case (Rossignol et al. 2006).

Soil Erodibility Index According to the results of this study, the implementation of the GE 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 OG areas. The results are in line with the findings of George et al. (2004); Varamesh, (2009), and Teague et al. (2008, 2010). The increase in the percentage of clay and soil organic carbon in the GE area may have significantly reduced the SEI compared to the OG area (Johansen et al. 2001; Campo et al. 2006; Larsen et al. 2009; Wolf et al. 2017). The increased SEI from the OG area is attributed to the reduced canopy and litter cover and also increased bare ground. This illustrates the critical role of

vegetation cover due to the OG system in reducing water erosion (Ozaslan et al. 2015). Indirect grazing indirectly increases surface soil erodibility by destroying plant foliage and directly by compressing livestock venom, compacting and pulverizing topsoil. According to Zhou et al. (2010), any reduction in soil cover makes the soil more susceptible to erosion. Vegetation cover has the most important role in intercepting raindrops and reducing runoff and soil erodibility and loss (Wu and Chau 2011). The increased SEI in the results of the decreased runoff rates for the OG area also suggests that the OG system diminished the soil surface permeability to water. The results of Givi and Asadi (2001) also indicate more soil stability in the GE area. Also, according to Green and Kauffman (1995), livestock grazing indirectly increases surface soil erodibility by destroying plant foliage and directly by pesticide pressure, compacting and pulverizing topsoil.

Crown and canopy cover According to the results of this study, the implementation of the GE has increased the amount of SOM and TN in the surface layer of the soil by about twice as much as the OG areas that have been under permanent and excessive grazing. The findings of Shariff et al. (1994) and Bagheri et al. (2009) also point to the negative effect of overgrazing on SOM. The results of this section are in line with the findings of these researchers. Increasing the canopy cover in the GE area has caused more protection and a significant increase in surface layer silt particles, which are the most sensitive particles to water erosion, compared to the OG area. Also, litter caused by plant debris resulting from the increase of total canopy cover has caused a significant increase in SOM and consequently the amount of soil TN in the GE area (Raiesi and Asadi 2006).

The results of this study in the vegetation sector indicate an increase in the vegetative form of shrubs and shrubs in the design area by 3.8 and 5%, respectively. These vegetative forms are important in that they are the main source of forage supply and are in higher sequence series. The results of this section were consistent with the findings of Riginos and Hoffman (2003) and also Barger et al. (2004). Because the change in vegetation is much faster than the soil in the sequencing process, so in this study, we saw deeper changes in vegetation both in terms of species and the percentage of canopy cover. Applying high grazing 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 and Hoffman 2003). Because in this regard, the study of species composition with indicators of diversity and richness can be effective in providing management programs and setting policies, so the study of diversity and richness in study sites is recommended.

Although the results of this study showed that in the topsoil (0–15 cm) of the GE area, the increase in SOM was associated with a significant increase in TN, and in the second depth (15–30 cm), no tangible alignment was observed between changes in SOM and TN. The results of Bagheri et al. (2009) and Kohandel et al. (2006) also indicate the mismatch of TN and SOM changes in dry periods. Because TN becomes a mineral during drought, so the alignment of changes in TN and SOM in this study, unlike the studies of Han et al. (2008) and Steffens et al. (2008), was not observed.

Conclusion

The lack of significant change in some soil properties in this study can be related to unsuitable moisture and temperature conditions for the evolution and phenomenon of soil formation (pedogenesis) of soils in arid areas. This was evident in the topsoil of the OG area due to the decrease in canopy cover and the increase in bare soil exposed to sunlight. Raiesi and Riahi (2014) in their study in the semi-arid regions of central Iran did not consider the 17-year exclusion period to be sufficient to increase soil TN. Schuman et al. (1999) considered non-breaking of plant residues and non-mixing of these residues with soil as the main reason for not increasing soil TN during a 40-year GE design period.

According to the findings of this study, because the change in vegetation in the region was significant as a result of the GE design, so other parameters, including microelements, may be influential in the formation of plant species in the region. Therefore, in evaluating grazing management plans, complete and comprehensive soil decomposition and also considering the role of trace elements is suggested.

In general, the higher the density of livestock, the presence, and movement of livestock in the pasture, the lower the percentage of fine particles due to erosion, increase in bulk density, and decrease in moisture retention of the first depth, and such changes are expected to cause rapid destruction of the field. Among the applied grassland management strategies in these conditions, it is possible to limit livestock grazing periods in critical points by the GE or rest-rotation grazing system or reduce livestock density in these critical points by increasing the number of watering holes and resting places in the field and also artificial regeneration of critical and vulnerable areas. The GE system has reduced the soil bulk density and its acidity and increased the percentage of clay and the percentage of moisture in it. This change is related to the joint effect of not kicking livestock in the area and increasing its vegetation. Long-term monitoring of changes in soil properties and soil erosion under the GE systems is required across different climate conditions and years to further assess how the GE changes to soil and environment properties and sustainability of grazing ecosystems.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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