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Short-term grazing exclusion from heavy livestock rangelands affects vegetation cover and soil properties in natural ecosystems of southeastern Iran

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ABSTRACT

Grazing exclusion is an effective rangeland management practice used to achieve sustainability of natural ecosystems worldwide. To clarify the effects of short-term grazing exclusion on the plant community and soil characteristics, we investigated the plant and soil properties by comparing overgrazing and short-term grazing exclusion (underwent exclusion for 2, 4, 6 years) sites in an arid rangeland of southeastern, Iran. Soil samples were extracted at depth of 0–30 cm. In total, 22 species from 9 families and 18 genera were observed along the plant communities. Results showed that the livestock exclusion significantly affected the community composition for species, genera, and families. The numbers of species, genera, and families increased slowly during exclusion, reaching their maximum value in the 6 years' exclusion, while the minimum number of species, genera, and families were observed in the overgrazed site. The numbers of species and the proportion of annual and perennial species were significantly affected by the exclusion. The 6 years' exclusion exhibited the highest numbers of plant species, of which approximately 63.63% were perennials. The soil nutrient values gradually increased during exclusion. Organic carbon, total nitrogen, available potassium, and available phosphorus attained significantly greater values under the 6 years' exclusion. The pH level was significantly higher in the overgrazed soils compared to the grazing exclusions soils. The EC value was statistically similar under the four treatments. The particle size distribution showed more silt and clay and less sand in the soils of grazing exclusion sites compared with the soil of overgrazed site. The silt and clay values were the highest in the soils under 6 years' exclusion. Totally, the results imply that short-term exclusion had a great influence on the vegetation restoration and soil conservation of degraded ecosystems in arid regions.

1. Introduction

Unreasonable human management of the soil resources is resulting in land degradation due to soil erosion, soil organic matter exhaustion, loss of soil structure, pollution, forest fires or deforestation (Zhao et al., 2013; Keesstra et al., 2014; Lu et al., 2015). This is why there is a need to restore and rehabilitate soils as a source of nutrients and services to humankind (Lu et al., 2015; Roa-Fuentes et al., 2015). Grazing by domestic ungulates is one of those human uses of the land that will effect on many ecosystem processes and functions, such as nutrient pool and cycling, soil moisture and structure, soil degradation, net primary productivity, vegetation composition, belowground biomass productivity, as well as the associated changes in the soil microbial community (Wang et al., 2014; Costa et al., 2015; Tarhouni et al., 2015; Lu et al., 2015). It is critical to obtain a better understanding of how grazing influences the key properties of ecosystem function and sustainability and, thereby, to provide guidelines for improving rangeland management practices (Wang et al., 2014).

In Iran, rangelands are important natural resources with great ecological, economic and social importance due to their crucial role in the development of rural areas. Generally, they support forage for herbivores; offer the opportunity for outdoor recreational activities and enjoyment of nature (Amiri, 2009). In addition, they play great ecological role in conserving biodiversity. However, continuous overgrazing has led to declining biodiversity and vegetation cover, along with accelerated soil erosion (Prieur-Richard and Lavorel, 2000). It has also decreased biodiversity with widespread species loss and the replacement of endemic and specialist species by exotic species (Stanners and Bordeau, 1995).

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Grazing exclusion from the creation of large-scale enclosures has become a common management strategy to prevent rangeland degradation and sustain rangeland ecosystem function by the restoration of degraded vegetation and improvement of soil quality throughout the world in recent decades (Wang et al., 2014; Strahan et al., 2015; Lu et al., 2015). However, few studies have evaluated such management practices in the rangelands of Iran. For instance, soil organic carbon in the surface soil under grazing exclusion conditions was reportedly increased in a semiarid woody rangeland (22 years of grazing exclusion) in the Zagros Mountains, central Iran (Raiesi and Riahi, 2014). An assessment of species composition of exclusion in Kerman provinces of Iran showed that species composition appeared to reach its maximum towards the middle of the succession (Ebrahimi et al., 2014).

Previous studies examining the effect of grazing exclusion on rangeland have primarily investigated the vegetation productivity, plant species and communities (Gonzales and Clements, 2010; Schultz et al., 2011). Nevertheless, soil also plays an important role in supplying organic matter and cycling nutrients, such as nitrogen and carbon; it could also directly affect vegetation productivity, community composition and plant species richness during the rangeland restoration succession process (Mekuria and Aynekulu, 2013). Comparison of vegetation composition and diversity, including species richness and abundance, plant functional groups and soil properties in fenced areas could reflect the system stability and resilience of the rangelands (Metzger et al., 2005; Al-Rowaily et al., 2015). Such approach can help to guide sustainable management strategies for conserving natural ecosystem goods and services (Wang et al., 2014; Al-Rowaily et al., 2015).

However, in Iran, little research has been conducted to determine the effects of grazing exclusion on biodiversity conservation and soil properties in the natural ecosystems. This study was therefore conducted to determine the influence of short-term grazing exclusion with different ages on the vegetation cover and soil properties of the vegetation communities in a steppe rangeland of Iran to determine whether the ecosystem has been restored comparison with open grazing.

We contrast grazing exclusion and open grazing treatments to address the following questions: (1) how does grazing exclusion affect the vascular plants richness and diversity in arid region of eastern Sistan and Baloochestan, Iran? and (2) do the soil properties responses to short-term grazing exclusion differ among different ages? Our hypothesis posits that (1) short-term grazing exclusion helps the establishment of plant species and (2) physico-chemical properties of the soil in the short-term grazing exclusions differ from open grazing.

2. Materials and methods

2.1. Study area

Taftan rangeland is located in Sistan and Baloochestan province in Iran, between latitude 28°30′41″–28°39′00″N and between longitude 60°51′35″–61°00′09″E (Fig. 1). The experimental area is characterized by dry summers, a rainy season, and warm autumn and the cool winter weather. According to data available for the period 2006–2014 at the study site from the National Meteorological Information Center of Iran, the mean annual rainfall levels reach 160 mm. The mean annual evaporation reaches approximately 60.10 mm, denoting a high water deficit in the region. The minimum and maximum elevations are 1382 m in the south and 4042 m in the north. The mean maximum temperatures reach 30 °C in May and June. The mean minimum temperatures range from 8.7 °C in December and January, and occasional periods of subfreezing surface temperature occur. The site was within an area where the topography was characteristic of plains, mounds and ridges. The vegetation types are dominated by arid land vegetation (e.g. *Hammada salicornia*, *Zygophyllum eurypterum*, *Artemisia santolina*, *Salsola tomentosa*). The growing season is from March to May. Vegetation in the area has changed considerably over the past several decades, primarily due to overgrazing by goats.

2.2. Sampling method

Since the restore-rangeland ecological program started in 2010, more than 2000 ha of arid rangelands in Taftan have been fenced to exclude livestock grazing. We conducted a multi-site survey during the growing season from March to June in 2014. We selected three fenced sites that underwent succession for 2, 4 and 6 years. An overgrazed site was conducted as a control. There were no differences between topography, soil type, and spatial heterogeneity among the selected sites. The fenced areas covered a total area of about 10 ha. The mean stocking rate of the grazed rangeland was 60–70 AU ha^{-1} from April to September, and 30–40 AU ha^{-1} from October to November. The data collected for the year of 2014. At each site, we conducted a comprehensive investigation of the vegetation types. The age of enclosures was determined from data provided by Agriculture and Natural Resources Research Center of Sistan and Baloochestan province, Iran. Species identification and nomenclature were carried out in the laboratory, University of Zabol, according to Rechinger (1968, 1970, 1972, 1997, 1984), Rechinger and Schiman-Czeika (1964) and Zielinski (1982). Chorotype of the recorded species were identified according to Zohary (1963). A total of 20 sampling stands (50 m × 50 m) were selected to represent the prevailing habitat and community variations in the sites (5 stands for each). Within each stand, vegetation properties were measured using the simple transect line (100 m) method within quadrats (7 m × 7 m) with a systematically-randomized method. In total, 60 transects were sampled in the sites. Data on vegetation/canopy cover was obtained using the quadrat estimation methods (Hanley, 1978). The plant density was measured by counting the number of individuals of a species in a plot (Coulloudon et al., 1999). Proportion of bare soil and litter in each site was measured using the quadrat estimation methods (Hanley, 1978). Plant species were classified as class I (High) II (Medium) and III (Low) according their palatability. Palatability is a plant characteristic that refers to the relish with which plants or its parts or feed is consumed as stimulated by the sensory impulses of grazing animal (Heath et al., 1985). In the present study, palatability determined using reference texts (Baghestani et al., 2001; Arzani et al., 2004; Bagheri et al., 2007). The importance value (IV) for the plant species was calculated using the following formula (Zhang et al., 2006):

$$IV = RD + RC + RF/3$$

where RD is the relative density (the ratio of the number of individuals of a species to the total number of individuals of all species, %); RC is the relative cover (the ratio of the cover of a species to the total cover of all species, %); and RF is the relative frequency (the ratio of the percentage frequency of a species to the total frequency of all species, %) (Jiang et al., 2006). In total, 150 vegetation plots were sampled in each site. Shannon species diversity index [$H' = -\sum$ pi. lnpi] (Magurran, 1988) were determined by calculating the frequency of each plant species (pi = proportion of points along each transect at which species i was recorded). Plant species richness (S = number of species sampled per transect) and evenness of species abundances (Pielou's J index = H′/lnS) were also calculated for each transect.

The experimental sites consist of soils of silt loam texture that are taxonomically characterized as moderate, loamy, mixed, and