Effects of open grazing and livestock exclusion on floristic composition and diversity in natural ecosystem of Western Saudi Arabia

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Abstract  Livestock grazing is one of the main causes of rangeland degradation in Saudi Arabia. Fencing to exclude grazers is one of the main management practices used to restore vegetation and conserve biodiversity. The main objectives of this study were to investigate the changes in plant diversity and abundance, floristic composition and plant groups of the major life forms in response to thirty-five years of grazing exclosure in western Saudi Arabia. These vegetation attributes and palatability were compared in 30 sampling stands located in the excluded and grazed sites. Our results showed that livestock exclusion significantly increased covers, density and species richness of annuals, grasses, perennial forbs, shrubs and trees. Exclosure enhanced the abundance and richness of palatable species and depressed the development of weedy species. About 66.7% of the recorded species at the excluded site were highly palatable compared to 34.5% at the grazed site. In contrary, about 55.2% unpalatable species were found in the grazed site compared to 25.8% in the protected site. Jaccard’s similarity index between the excluded and grazed sites showed lower values of 0.39%, 0.40% and 0.31% at levels of families, genus and species, respectively. The results suggest that establishing livestock exclusion may be a useful sustainable management tool for vegetation restoration and conservation of plant diversity in degraded rangelands of arid regions.

1. Introduction

In arid environments, the concentration of both water and nutrients provides suitable sites for vegetation establishment, and causes the heterogeneous pattern characteristic of vegetation and plant populations (Ludwig and Tongway, 1995; Al-
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2. Materials and methods
2.1. Study area

The study area, the National Wildlife Research Center (NWRC), is located at about 30 km from Taif city, Saudi Arabia (21° 14’ 50” N, 40° 42’ 30” E, 1400 m altitude) (Fig. 1). Topography is flat with undulating plateau. The area is subject to continuous livestock grazing by sheep and camels which represent the only human activity that impacts vegetation. An area of about 35 km² was fenced in 1986 to prevent livestock grazing. Thirty-five years after fencing, vegetation and flora was surveyed in both the fenced site and in the surrounding open site subject to continuous overgrazing. Unfortunately there are no historical records on the levels of grazing with different animals and their effects on plant community attributes. Uncontrolled numbers of free-ranging camels, sheep and goats continuously grazed in the open site and there was no grazing by either domestic or wildlife animals in the fenced site (M.Z. Islam, personal communication).

The climate is arid with the 30 year average annual rainfall of 180.7 mm (Fig. 2). The rainy season falls between October and May while the summer months remain dry. The mean annual temperature is 22.8 °C, with the coldest mean temperatures (15.4 °C) in January and warmest (29 °C) in August. The study site’s soil characteristics are relatively homogeneous with a high proportion of sand (80%) and low organic matter content amounting to 0.44% (Al-Bakre, 2008).

2.2. Field survey and data analysis

A total of 30 sampling stands (20 m × 20 m) were selected to represent the prevailing habitat and community variations inside and outside the exclosure (15 stands for each). Within each stand, five (5 m × 5 m) plots were randomly distributed to estimate plant frequency and density. However, line intercept method (Canfield, 1941) was applied for measuring cover of species using 5 lines of 20 m each, within each stand. The importance value index was calculated as the sum of relative values of density, frequency and cover. Nomenclature of species was according to using Chaudhary (1989, 2000), and Chaudhary and Akram (1987).

We classified the plant community into six functional groups according to their growth forms: annuals, grasses, perennial forbs, shrubs, trees and weeds. The weedy species were defined as those noxious species that are enhanced by large herbivores, in particular, has been adopted as a defense against overgrazing and has become a method used to implement conservation objectives. Comparison of vegetation composition and diversity including species richness and abundance, and plant functional groups in open and fenced areas could reflect the system stability and resilience of the rangelands (Metzger et al., 2005). Such approach can help to guide sustainable management strategies for conserving natural resources and ecosystem goods and services.

Following this management approach, the objectives of this study were to investigate the changes in plant diversity and abundance, floristic composition and plant groups of the major life forms in response to thirty-five years of grazing exclusion in western Saudi Arabia.
overgrazing (Chaudhary and Le Houérou, 2006). Cover and plant density were calculated as means for each plant functional group. Species diversity was calculated for each functional group as total species number and mean species richness per unit area (100 m$^2$). Huston (1994) argued these as a simple and easily interpretable indicator of biological diversity. We further calculated the proportion of restricted species that were found only in either the fenced site or in continuous overgrazed site. The recorded species were rated to three palatability classes (1 = unpalatable, 2 = moderately palatable, 3 = highly palatable) based on field observation, available literature and expert knowledge (local herders and rangers). The similarity between the fenced and open sites as based on the presence/absence data was estimated by Jaccard and Sorensen similarity indices (Kent, 2010) by the following equations:

Jaccard index: $C_J = j/(a + b - j)$

Sorensen index: $C_S = 2j/(a + b)$

where $a$ = number of species in the fenced site, $b$ = number of species in the open site, and $j$ = number of species common to both sites.

Diversity attributes, cover and density were compared among the five functional groups using one-way ANOVA, followed by Tukey’s test (Zar, 1999). A paired Wilcoxon sign-ranks test was used to test for significant differences in vegetation attributes and palatability classes between fenced and grazed sites. All data analyses were carried out with the SPSS software (SPSS for Windows, Version 16.0, Chicago, IL, USA).

3. Results

3.1. Effect on floristic composition

Covers and density of annuals, grasses, perennial forbs, shrubs and trees were significantly greater in the exclosure than in the overgrazed site (Fig. 3a and b). The results showed that grasses were the most sensitive growth form to overgrazing as they were absent from the overgrazed sites. However, weed species were the more tolerant species to overgrazing as they were not recorded in the protected site. The cover of annuals, perennial forbs and trees was increased by about 3 times, and shrubs by 2.1 times in exclosure stands compared with overgrazed ones. Similarly, the density of annuals, shrubs, trees

![Figure 1] Study site (NWRC) in Makkah Region, Saudi Arabia.

![Figure 2] Average rainfall and temperature in Taif city (source: Presidency of Meteorology and Environment, Saudi Arabia).
and perennial forbs was greater by 3.38, 2.83, 3.69 and 4.58 times in protected site, respectively, than in the overgrazed site.

Results in Table 1 show that livestock exclusion influenced the structural characteristics of the plant community. Tree species of Acacia (A. ehrenbergiana, A. gerrardii and A. tortilis), shrubs (Indigofera spinosa, Lycium shawii and Ochradenus bac-catus) and perennial forbs (Echinops viscosus and Fagonia indica) were more abundant with higher importance values in the excluded than in the overgrazed plots (Table 1). Five grass species (Panicum turgidum, Stipagrostis ciliata, Stipagrostis obtusa and Stipagrostis plumosa), perennial forbs (Blepharis ciliaris, Boerhavia repens, Farsetia longisiliqua, Felicia abyssinica and Salsola spinifera) and shrubs (Psidiadu punctulata and Salsola spinifera) were not recorded in the overgrazed plots. However, the weedy and noxious species (Calotropis procera, Citrullus colocynthis, Pergularia tomentosa, Senna italica and Solanum incanum) were not found in the fenced plots.

3.2. Effect on floristic diversity

Livestock exclusion has influenced different measured diversity attributes (Table 2). The diversity of plants showed differences between open and fenced sites at the levels of species, genera and families (Table 2; Fig. 4). The most common families in the protected site were Asteraceae, Fabaceae and Poaceae compared with Apocynaceae, Capparaceae, Euphorbiaceae and Fabaceae in the grazed site (Fig. 4).

Table 1  Variation in relative importance values of perennials at excluded and grazed sites. The last column shows the index of change (differences between excluded and grazed sets). Bold type indicates differences that are significantly different ($P < 0.05$, paired Wilcoxon sign-ranks test).

| Species                  | Excluded site | Grazed site | Index of change |
|-------------------------|---------------|-------------|-----------------|
| Acacia ehrenbergiana    | 47.68         | 19.95       | 27.73           |
| Acacia gerrardii        | 56.65         | 24.79       | 31.86           |
| Acacia tortilis         | 38.18         | 16.38       | 21.80           |
| Aerva javanica          | 0.00          | 22.08       | –22.08          |
| Blepharis ciliaris      | 28.25         | 0.00        | 28.25           |
| Boerhavia repens       | 19.30         | 0.00        | 19.30           |
| Calotropis procera      | 0.00          | 44.69       | –44.69          |
| Citrullus colocynthis   | 0.00          | 38.13       | –38.13          |
| Echinops viscosus       | 23.66         | 17.25       | 6.41            |
| Fagonia indica          | 61.97         | 48.22       | 13.75           |
| Farsetia longisiliqua   | 16.89         | 0.00        | 16.89           |
| Felicia abyssinica      | 24.17         | 0.00        | 24.17           |
| Indigisfera spinosa     | 52.80         | 32.33       | 20.47           |
| Lycium shawii           | 50.52         | 19.95       | 30.57           |
| Ochradenus              | 27.79         | 16.32       | 11.47           |
| Polycarpaea repens      | 45.09         | 0.00        | 45.09           |
| Panicum turgidum        | 21.54         | 0.00        | 21.54           |
| Pergularia tomentosa    | 0.00          | 40.63       | –40.63          |
| Salsola spinifera       | 34.12         | 0.00        | 34.12           |
| Senoa italica           | 0.00          | 41.74       | –41.74          |
| Solanum incanum         | 0.00          | 32.43       | –32.43          |
| Stipagrostis ciliata    | 20.79         | 0.00        | 20.79           |
| Stipagrostis obtusa     | 63.24         | 0.00        | 63.24           |
| Stipagrostis plumosa    | 28.23         | 0.00        | 28.23           |

The similarity between fenced and open sites (beta-diversity) showed that, in contrast to alpha-diversity, beta-diversity attained the lowest values at species level, i.e., 0.21 and 0.35 for Jaccard and Sorenson indices, respectively (Table 3). The beta-diversity attained the highest values of 0.40 and 0.58 at genus level for Jaccard and Sorenson indices, respectively.

Exclusion from grazing had a positive effect on the total number of species and species richness of annuals, grasses, perennial forbs, shrubs and trees groups (Fig. 5a and b). However, overgrazing had a positive effect on total number and richness of weedy species. The restricted species in the...
fenced site for annuals, grasses, perennial forbs, shrubs and trees were 62.7%, 100%, 54.5%, 59.6% and 66.7%, respectively (Fig. 5c).

3.3. Effect on palatability

Highly palatable species was significantly higher in the fenced plots than in the grazed ones (Fig. 6). About 66.7% of the recorded species at the excluded site were highly palatable compared to 34.5% at the grazed site. In contrary, about 55.2% unpalatable species were found in the grazed site compared to 25.8% in the protected site.

4. Discussion

Livestock exclusion has been suggested as a simple and effective method for restoring and conserving vegetation productivity and diversity in degraded rangelands (Shaltout et al., 1999; El-Keblawy et al., 2009; Todd and Hoffman, 2009; Rutherford and Powrie, 2010). The results of the present study in degraded rangelands of the western Saudi Arabia indicated that establishing exclosures had a positive effect on vegetation cover and density as well as on improvement of vegetation diversity in terms of increasing species richness and diverse functional groups.

Our results showed that the dissimilarity in community composition between the excluded and grazed sites was maintained at the different taxonomic levels (families, genus and species) and even within different plant functional groups. Livestock exclusion increased cover, density and richness of

| Taxonomic level | Jaccard index | Sorensen index |
|-----------------|---------------|----------------|
| Family          | 0.39          | 0.56           |
| Genus           | 0.40          | 0.58           |
| Species         | 0.21          | 0.35           |

Figure 4  Variation in frequency of recorded species representing the different families at excluded and grazed sites of the study area.

Figure 5  Total number of species (a), species richness (b), and the proportion of species found exclusively in excluded site or grazed site (c) for the different plant functional groups. Bars are averages ±SE of 15 stands. Significant difference between excluded and grazed sites are indicated by symbols, ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$ (paired Wilcoxon sign-ranks test), while similar letters on bars are not significantly different between plant functional groups (Tukey’s studentized range test). Capital letters are used for excluded site and lower-case letters for grazed site.
annuals, perennial forbs, and woody shrubs and trees. Annual plants are considered as a main component of vegetation in the rangelands of Saudi Arabia (Shaltout et al., 1996; Al-Rowaily et al., 2012). They are a highly variable fodder resource especially for goat and sheep during the rainy periods (Chaudhary and Le Houérou, 2006). This may explain the reduction in its cover, density and richness at the grazed site. Although heavy grazing is known to promote the abundance of annuals and forbs (Noy-Meir et al., 1989; Landsberg et al., 2002; Brooks et al., 2006), this does not appear to be an important effect in the study area. Our results showed that the exclusion of animals enhances the cover, density and richness of woody shrubs and trees which facilitate the establishment and growth of herbaceous and annual species under their canopies (El-Bana et al., 2007; Abdallah et al., 2008; Al-Rowaily et al., 2012). In addition, field observations made during sampling indicated that Acacia species in the excluded site had dense cover of annuals and forbs under their canopies, suggesting that they are probably key factors in promoting floristic productivity and diversity, especially for annuals and forbs (Munzbergova and Ward, 2002; Abdallah et al., 2008). This could clarify the higher abundances of annuals and perennial forbs compared to other functional groups in the excluded site.

The abundance of spiny Acacia species (A. ehrenbergiana, A. gerrardii, and A. tortilis) and spiny shrubs (I. spinosa and L. shawii) was reduced in the grazed site, indicating that these species are tolerant of heavy grazing pressure. The twigs, leaves and pods of these species are considered as an appealing forage source for browsers, such as camels and goats, during drought (Keya, 1997; Skarpe et al., 2000; Chaudhary and Le Houérou, 2006). The spiny nature of these species is noted as a mechanical defense against heavy grazing, making them tolerant to grazing pressure (Gowda, 1996; Keya, 1997). On the other hand, the higher abundance of such palatable species at the excluded site, suggesting that current grazing pressure has a negative impact on vegetation composition. It has been shown that heavy browsing of the above-ground plant parts of Acacia species is the most likely mechanism leading to a decline in their canopy cover and density, and may be prone them to severe impact (Noumi et al., 2010; Al-Rowaily et al., 2012).

The remarkable difference between the grazed site and excluded site was the disappearance of grasses and weeds, respectively. Grasses such as P. turgidum, S. ciliata and S. obtusa are described as sensitive and intolerant grazing, and consequently they are dominant under protected conditions (Le Houérou, 2002; Chaudhary and Le Houérou, 2006). Oatham et al. (1995) found that overgrazing resulted in a significant reduction in the abundance and cover of the palatable grass, S. plumosa in the rangelands of UAE. With intense grazing pressure and drought there may be a reduction in, or complete loss of these grasses. Al-Rowaily et al. (2012) noted a deterioration of perennial grasses under heavy grazing in the rangelands of central Saudi Arabia, and such deterioration accelerates erosion and desertification (Barth, 1999).

The current results (Tables 1 and 3 and Fig. 6) demonstrated dissimilarity between grazed and excluded sites, and a shift in species composition from palatable species to unpalatable ones under continuous grazing. The dominant weedy species in the grazed site were C. procera, C. coloecynthia, P. tomentosa, S. italicca and S. incanum which are all widespread unpalatable species (Chaudhary and Le Houérou, 2006; Gallacher and Hill, 2006). It seems that these species have replaced the highly palatable grasses and intolerant grazing species as a result of heavy grazing (Briske, 1991; Gallacher and Hill, 2006; Al-Rowaily et al., 2012). Li et al. (2005) stated that overgrazing in the Inner Mongolian desert steppe has led to a significant reduction in palatable species. This could be attributed to the selective grazing of highly palatable species.
that are not tolerant to heavy grazing and trampling (Milton et al., 1994; Ksiksi et al., 2007).

In the exclosure, the higher richness and restriction of many palatable and rare species such as *B. repens*, *Maerua crassifolia*, *Ostestegia fruticosa*, *P. crispa*, *P. punctulata* and *S. plumosa* confirmed the positive effect of establishing fencing. From a viewpoint of ecological restoration and land use as well as conservation of plant diversity, a sustainable option for natural resources management in arid regions should be directed toward establishing fencing in different habitats for restoring vegetation and preventing rangeland degradation. In this respect, more research are needed to assess the effect of animal exclusion on ecosystem process and function at different time scale in degraded rangelands of arid regions.

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