Journal of Arid Environments 82 (2012) 106–114

Contents lists available at SciVerse ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Plant species composition and soil characteristics around Iranian piospheres

E. Shahriary[a,c,*], M.W. Palmer[a], D.J. Tongway[b], H. Azarnivand[c], M. Jafari[c], M. Mohseni Saravi[c]

[a] Department of Botany, Oklahoma State University, Stillwater, OK 74078, USA
[b] CSIRO Sustainable Ecosystems, GPO Box 284, Canberra, A.C.T. 2601, Australia
[c] Colleges of Natural Resources, University of Tehran, 31585-4314 Karaj, Iran

ARTICLE INFO

Article history:
Received 26 September 2009
Received in revised form
23 November 2011
Accepted 12 February 2012
Available online 23 March 2012

Keywords:
Arid and semi-arid rangeland
Gradient analysis
Grazing gradient
Iran
Transhumant
Watering point

ABSTRACT

Most of Iran's land area consists of arid and semi-arid rangelands, and because of this grazers depend on watering points. In the vicinity of the watering points, grazers generate areas of altered soils and vegetation known as *piospheres*. These rangelands are managed by three systems: Nomadic, Transhumant and Sedentary. To study the effect of grazing on piospheres, we sampled plant species composition, vegetation cover, height, soil nitrogen (N), soil organic matter (OM), soil pH and electrical conductivity (EC) over a two year period along 5000m-long transects radiating outward from watering points within desert-steppe (Lajaneh), steppe (Mojen) and mountain-steppe (Abr) ecosystems in Shahrood, Iran. Both univariate and multivariate methods were used to examine the influence of grazing on plant species and soil. One-way analysis of variance (ANOVA) was used to determine if differences existed among different distances. Soil N, OM, pH, EC and height of palatable species were the response variables. After using detrended correspondence analysis (DCA), an indirect gradient analysis technique, we used Canonical Correspondence Analysis (CCA), a direct gradient analysis technique, to examine the influence of grazing on plant species composition. Significance of species-environments correlations were tested by distribution-free Monte Carlo tests (999 permutations). Distance from the watering point, which we assumed to be inversely related to grazing pressures, was significantly related to species composition, cover and height of palatable species. Distance from water was also negatively correlated with N, pH, OM and EC. Livestock influenced species composition through defoliation and trampling. The most evident impact of overgrazing is the reduction of palatable species around watering points. Our results suggest that livestock may affect species composition along watering points by nutrient enrichment through voiding urine and feces. Our result demonstrates marked zonation in species composition along watering point (invaders, increasers and decreasers respectively). We argue here that, in studied areas, range managers should provide new water sources and reduce grazing pressure before the rangeland is damaged to a critical level. We suggest that piospheres deserve more researches and understanding their characteristics help us to manage arid and semi-arid rangelands.

1. Introduction

Water limits the survival and growth of livestock and wildlife especially in arid environments, since water is usually available at only a few scattered point sources; livestock cannot get sufficient water, resulting in some areas (watering points) being overutilized. A pioneering study (Osborn et al., 1932) found a grazing intensity gradient emanating from watering points in Australia. Valentine (1947) reported a forage usage gradient associated with water sources in the Chihuahuan desert. Location of water influences the distribution of livestock and wildlife, and as a consequence, a radial gradient of plant cover and dung density. The provision of water in arid and semi-arid rangeland thus changes the spatial distribution of livestock. The result is an ecological unit composed of livestock, watering point and rangeland: the zone is called a piosphere, coined from the Greek 'pios' meaning 'drink' (Lange, 1969).

Grazing is one of the most important factors impacting vegetation (Hulme, 1996). Grazers may alter grassland vegetation through fertilization from feces (Baadshaug, 1983) and urine (Steinauer and Collins, 1995) and by acting as dispersal agents (Fischer et al., 1996; Rosas et al., 2008). Grazing impacts plants by increasing mortality of palatable species, thus reducing ability of grazed palatable species to compete with less palatable exotic species, and also reducing seed production and seedling establishment (Assaeed and Al-Doss, 2001; Hunt, 2001). Grazing

* Corresponding author. Department of Botany, Oklahoma State University, 104 Life Science East, Stillwater, OK 74078, USA. Tel.: +1 4053851789.
E-mail addresses: eahsanshahriary@yahoo.es, eshahriary@gmail.com (E. Shahriary).

0140-1963/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jaridenv.2012.02.004

intensity and vegetation degradation around stockposts and natural and artificial watering point have been studied (Andrew and Lange, 1986; Fusco et al., 1995; James et al., 1999; Riginos and Hoffman, 2003; VanRooyen et al., 1994; Thomas et al., 2000). Fernandez-Gimenez and Allen-Diaz (2001) studied how a grazing gradient along watering points changed species composition in Mongolian grasslands. McIntyre and Lavorel (1994) found significant associations between individual plant species and various environmental and grazing-related factors in Australian rangeland. In the light of these findings, management practices should consider the impact of grazing on vegetation relative to other sources of variation like climatic factors (de Bello et al., 2006, 2007). Lange (1969) suggested sampling along watering points to determine the effects of piosphere in arid and semi-arid rangeland including drier and less palatable forage and more walking for drinking. Lange stressed that interactions (grazing capacity, water point, climate…) define the piosphere, not spatial and temporal limits. He showed that piosphere patterns and interactions are more complicated than they appear first. Valuable information for range management can be achieved by an extension of Lange's work.

Traditional range management adjusts stocking rate to manage vegetation condition. Overgrazing of Iranian rangelands causes soil degradation (Moghadam, 1998) and decrease in productivity (Mesdaghi, 1996). However, only a few rigorous studies of the effects of grazing on vegetation and soils in Iran exist; examples include Javadi et al. (2005) and Sanadgol (2006). The purpose of this paper is to describe the vegetation of a poorly-studied rangeland community in the north-eastern Iran while simultaneously quantifying the local impact of intense sheep grazing. In particular, we aim 1) to describe species composition along grazing gradients from watering point in three different ecological zones in Iran: the desert-steppe, steppe and mountain-steppe, and 2) to assess the relationship between the plant species and measured environmental variables including soil variables and distance from watering point.

2. Materials and methods

Approximately 85% of Iran has an arid, semi-arid or hyper-arid environment. Due to low precipitation most of Iran's land surface is not suitable for cultivation (Moghadam, 1998). About 55% of the total land area of Iran is suitable for range management (Moghadam, 1998). Three main types of rangeland management systems can be found in Iran include 1) Nomadic: in this system herders adapt management to severe climatic conditions (drought, irregular rainfall), by moving their livestock to search for water and forage (FAO, 1992), 2) Transhumant: herders move their livestock between summer rangelands and winter rangelands yearly (FAO, 1992) and 3) Sedentary: a system of mixed farming (to produce forage crops) and animal husbandry by farmers. These systems differ in key characteristics (Table 1). Traditional range managers (in all three systems) use traditional methods without formal training in rangeland management, animal production, or soil conservation that causes rangeland degradation.

2.1. Study area

The data were collected from the southern, central and northern parts of Shahrood, Semnan Province, Iran. A 2-year study was initiated in 2005; we selected three watering points as a surrogate of grazing gradient in desert-steppe zone Lajaneh, steppe zone Mojen and mountain-steppe Abr under nomadic, transhumant and sedentary management system. In the selected watering points of Shahrood, sheep follow daily grazing cycle (grazing, resting, walking to water and walking from water). Watering points were exploited for 180 yr in desert-steppe zone Lajaneh, 140 yr in steppe zone Mojen and 160 yr in mountain-steppe Abr. The three studied zones are located along a precipitation gradient from 340 mm in Abr, 216 mm in Mojen and 97.3 mm in Lajaneh. Minimum temperatures recorded in December are −8.4 °C in Lajaneh, −17.6 °C in Mojen and −21.8 °C in Abr, while maximum temperatures recorded in June are 42 °C in Lajaneh, 32.6 °C in Mojen and 30 °C in Abr (Table 2).

2.2. Vegetation and soil sampling

Following discussions with natural resource agencies and herders, we selected one watering point in each zone. We located three 5000 m transects starting from each watering point.

The first transect were oriented between 0° (true North) and 120°, the second between 120°–240° and the third between 240°–360°.

We located 1 m × 1 m plot in every 50 m along transects from 0 m up to 5000 m. In each plot, we determined the cover, plant height, abundance and number of all plants. To show the differences among grazing intensities at three different distances (100, 1000 and 10,000 m), height of five palatable individuals of *Dactylis glomerata* (mountain-steppe Abr), *Artemisia aucheri* (steppe zone Mojen) and *Zygophyllum eurypterum* (desert-steppe zone) were measured and soil samples collected.

Three soil samples were collected from each plot center, 1 m right and left of each plot to a depth of 20 cm. The three samples were mixed into one sample. Soil samples were air-dried and sieved through a 2 mm sieve prior to chemical analyses. Laboratory analyses of soil samples were carried out at the soil laboratory of the Faculty of Natural Resources, University of Tehran. Soil organic matter was assessed using the Walkley–Black method (Nelson and Sommers, 1996), soil nitrogen was determined using the Kjeldahl method (Bremner and Mulvaney, 1982), electrical conductivity (EC) was determined using a conductivity meter, and pH in saturation extract (determined using conductivity meter).

Table 1
Three livestock management systems in Iran, their characteristics and productions.

Management system	Livestock diversity	Herder	Grazing management	Products (dairy and meat)
Nomadic	Diverse (Sheep, goat, camel and cattle)	Many	Multiple grazing systems (rotational grazing, deferred grazing and continuous grazing)	High quality High diversity National use
Transhumant	Less diverse (sheep and goat)	One	Multiple grazing systems (rotational grazing, deferred grazing and continuous grazing)	High quality High diversity National use
Sedentary	Less diverse (sheep and goat)	One	Continuous grazing	Low quality Low diversity Personal use

Table 2
Geographical locations, vegetation types, precipitations and temperatures of studied areas.

Region	Geographical position	Vegetation type	Common plant species	Precipitation (mm)	Maximum temperature (°C)	Minimum temperature (°C)
Desert-steppe Lajaneh	(55°01′30″E, 36°10′30″N)	Desert shrubland	*Zygophyllum eurypterum*	97.3	42	−8.4
Steppe Mojen	(54°45′21″E, 36°30′18″N)	Shrubland	*Artemisia aucheri*	216	32.6	−17.6
Mountain-steppe Abr	(55°03′70″E, 36°42′31″N)	Grassland	*Dactylis glomerata*	340	30	−21.8

2.3. Statistical analysis

2.3.1. Univariate analysis

We analyzed the data of soil nitrogen (N), soil organic matter (OM), soil pH, electrical conductivity (EC) and height of palatable species of three different distances from watering points. All data met distributional assumptions of ANOVA, One-way ANOVA was used and means were compared using Tukey test (Zar, 2009). All analysis performed with the software SAS 9.2 (SAS Institute Inc, Cary, NC, USA, 2008).

2.3.2. Multivariate analysis

We implemented indirect and direct gradient analyses with CANOCO 4.5 (Ter Braak and Šmilauer, 1998). To decide about using direct gradient analysis based on linear or unimodal methods, we performed Detrended Correspondence Analysis (DCA) to assess gradient length (Hill and Gauch, 1980). The beta diversity was larger than 4.0, and therefore unimodal methods such as Canonical Correspondence Analysis (CCA) are recommended (Lepš and Šmilauer, 2003). We used CCA to assess species variation explained by measured variables in relation to distance from watering point. We used square root and log transformation for distance from watering point and soil parameters respectively. CCA relates species composition to environmental variables (Palmer, 1993). In CCA biplots arrows show variable in direction of maximum variation and rate of change in species distribution (Ter Braak, 1986; ter Braak and Prentice, 1988).

Canonical axes show variation in plant species matrix that explained by environmental variable matrix. We can show the highest amount of explained variance by first canonical axis. We calculated *F*-statistics from original data and tested the null model assumption. Significance of explained variation by variables tested with Monte Carlo permutation with 999 permutations of the constraining variables (Legendre and Legendre, 1998; Lepš and Šmilauer, 2003). Significance was tested at $\alpha = 0.01$ level.

3. Results

3.1. Univariate analysis

3.1.1. Height of palatable species

Distance from watering point has a significant effect on height of all palatable species. (One-way ANOVA: a) *Dactylis glomerata*, F: 570.64, df = 2,12, $P = 0.0001$, b) *Artemisia aucheri*, F: 158.55, df = 2,12, $P = 0.0001$, c) *Zygophyllum eurypterum*, F: 281.39, df = 2,12, $P = 0.0001$). Height of all palatable species was low around watering points and increased beyond 100 m from watering points (Fig. 1a).

3.1.2. Soil nitrogen

There is a significant effect of distance from watering point on soil N (One-way ANOVA: a) the mountain-steppe zone Abr, F: 240.13, df = 2,12, $P = 0.0001$, b) the steppe zone Mojen, F: 547.90, df = 2,12, $P = 0.0001$, c) the desert-steppe zone Lajaneh, F: 7.43, df = 2,12, $P = 0.024$) in three different zones. Soil around watering points (100 m) had higher soil nitrogen than farther distances. However, there is no significant difference in the effects of farther distances on soil N in different regions (Fig. 1b).

3.1.3. Soil OM

Distance from watering point has a significant effect on soil OM (One-way ANOVA: a) the mountain-steppe zone Abr, F: 452.40, df = 2,12, $P = 0.0001$, b) the steppe zone Mojen, F: 8.63, df = 2,12, $P = 0.017$, c) the desert-steppe zone Lajaneh F: 87.89, df = 2,12, $P = 0.0001$). Soil OM was high around watering points and decreased beyond 100 m from watering points (Fig. 1c).

3.1.4. Soil pH

Soil pH was affected by distance from watering point (One-way ANOVA: a) the mountain-steppe zone Abr, F: 135.74, df = 2,12, $P = 0.0001$, b) the steppe zone Mojen F: 324.73, df = 2,12, $P = 0.0001$, c) the desert-steppe zone Lajaneh F: 7.84, df = 2,12, $P = 0.021$). However, there was no significant difference of farther distances on soil pH in different regions (Fig. 1d).

3.1.5. Soil EC

Distance from watering point has a significant effect on soil EC. (One-way ANOVA: a) the mountain-steppe zone Abr, F: 264.37, df = 2,12, $P = 0.0001$, b) the steppe zone Mojen, F: 6.41, df = 2,12, $P = 0.032$, c) the desert-steppe zone Lajaneh, F: 390.95, df = 2,12, $P = 0.0001$). Soil EC was high around watering points and decreased beyond 100 m from watering points. No more changes were obtained exceeding 100 m from watering points (Fig. 1e).

3.2. Multivariate analysis

3.2.1. Indirect gradient analysis

For all three study sites, DCA revealed species composition to be strongly related to grazing intensity (Fig. 2). In the mountain-steppe Abr (Fig. 2a), palatable species *Dactylis glomerata* and *Artemisia aucheri* located on the right side of first axis. The spiny species *Astragalus gossypinus* and *Onobrychis cornuta* are located in the center of first axis after palatable species; they only grazed in the absence of palatable species (Fig. 2a). The invader species *Peganum harmala*, *Perovskia abrotanoides*, *Hulthemia persica* and *Verbascum gossypium* located at the left side of first axis. They are commonly found in overgrazed areas. In the steppe zone Mojen (Fig. 2b), there is a transition from most palatable species left side of the side of the first axis, i.e. *A. aucheri*, to non-palatable species *Eryngium billardieri*, *P. abrotanoides*, *V. gossypium* and *H. persica* in the middle, and the poisonous species *Peganum harmala* located far to the right (Fig. 2b). In the desert-steppe zone Lajaneh (Fig. 2c), palatable species *Zygophyllum eurypterum*, *Salsola vermiculata* and *Tamarix aphylla* are located on the right side of first axis (Fig. 2c). The spiny species *Alhagi camelorum* and *Atraphaxis spinosa* are located in the center of first axis after palatable species; they only grazed in the absence of palatable species.

The poisonous species *P. harmala* is located on the left side of the first axis. In all three sites, plots closest to the watering point were associated with non-palatable or poisonous species including: *P. harmala*, *H. persica*, *P. abrotanoides*, *Alhagi camelorum* and those furthest from the watering point were associated with palatable

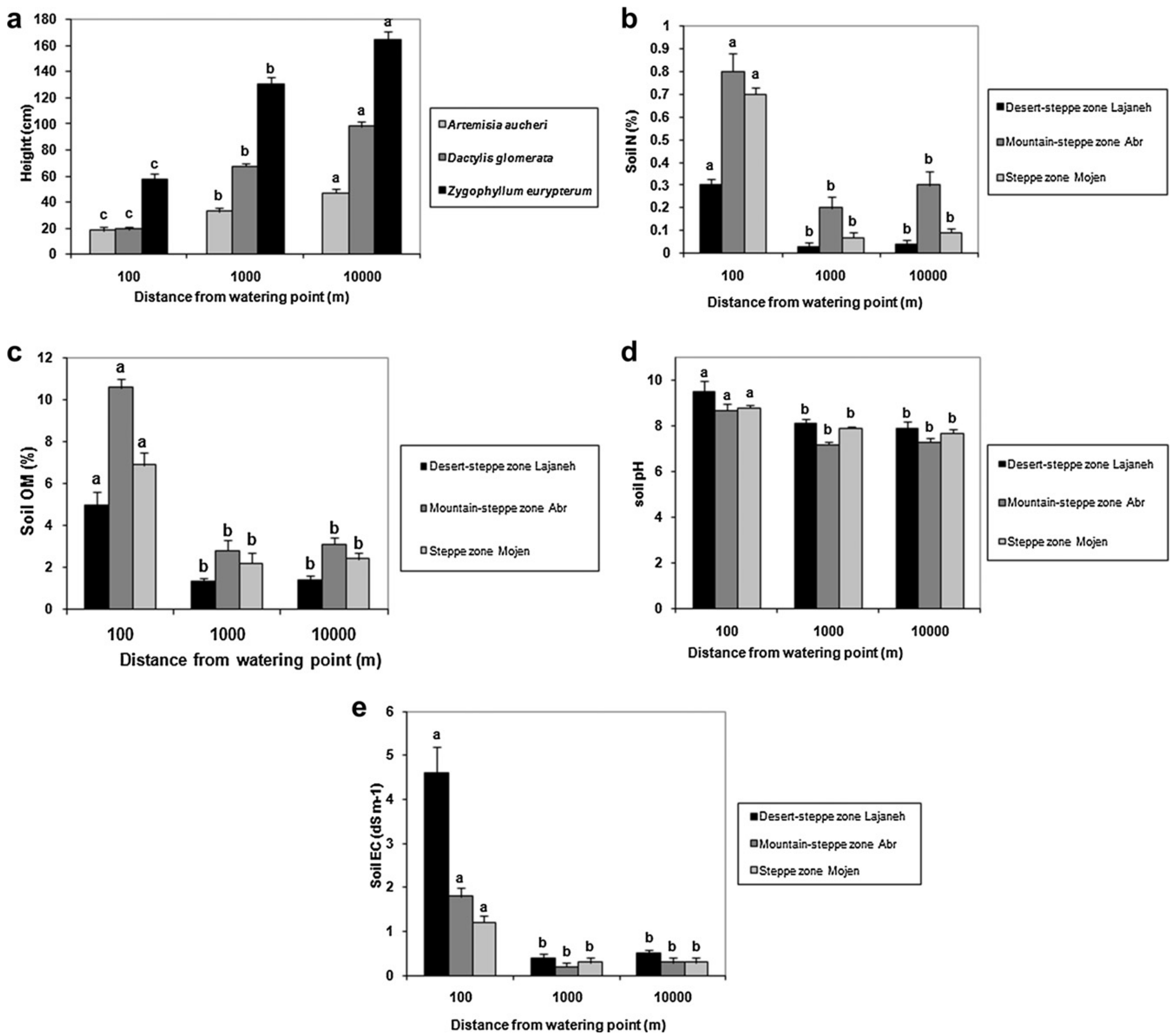

Fig. 1. Height of all palatable species (a) (five replications), soil N (b) (five replications), soil OM (c) (five replications), soil pH (d) (five replications), and Soil EC (e) (five replications) along three different distances(100, 1000 and 10,000 m) along watering points in the mountain-steppe zone Abr, the steppe zone Mojen and the desert-steppe zone Lajaneh (mean ± SE).

species. This supports the view that distance from the watering hole is a useful proxy for grazing.

3.2.2. Direct gradient analysis

CCA reconfirmed a strong relationship between distance from the watering point and species composition (Fig. 3). The test of the first canonical axis and also all canonical axes is significant ($P = 0.002$). In the desert-steppe zone Lajaneh (Fig. 3a), palatable species *Zygophyllum eurypterum*, *Salsola vermiculata* located on the left side of first axis. *Atraphaxis spinosa* and *Tamarix aphylla* located on the center of first axis commonly found in transition from overgrazing area to low grazed area. The invasive species *Peganum harmala* and *Alhagi camelorum* were located on the right side of first axis (Fig. 3a). *Peganum harmala* and *Alhagi camelorum* were correlated to area in the vicinity of watering point. In the steppe zone Mojen (Fig. 3b), *Peganum harmala*, *H. persica*, *Verbascum gossypium* and *Peroveskia abrotanoides* located on the right side of first axis. *Peganum harmala*, *H. persica*, *Verbascum gossypium* and *Peroveskia abrotanoides* were correlated to area in the vicinity of watering point. Less palatable species, *Eryngium billardieri*, *Bromus tectorum* and *Atragalus gossypinus* located on the center of first axis, commonly found in transition from overgrazing area to low grazed area (Fig. 3b). *Artemisia aucheri* were located on the left side of first axis and related to distance from watering point. In the mountain-steppe Abr (Fig. 3c), palatable species *Dactylis glomerata* located on the left side of first axis. *P. abrotanoides*, *Astragalus gossypinus*, *Onobrychis cornuta* and *Artemisia aucheri* located on the center of first axis, commonly found in transition from overgrazing area to low grazed area. *P. harmala*, *H. persica* and *V. gossypium* located on the right side of first axis, associated with the watering point (Fig. 3c).

4. Discussion

4.1. Soil

In all three zones, concentrations of OM, N, EC and pH were usually greatest on the plots closest to water. Since distance from

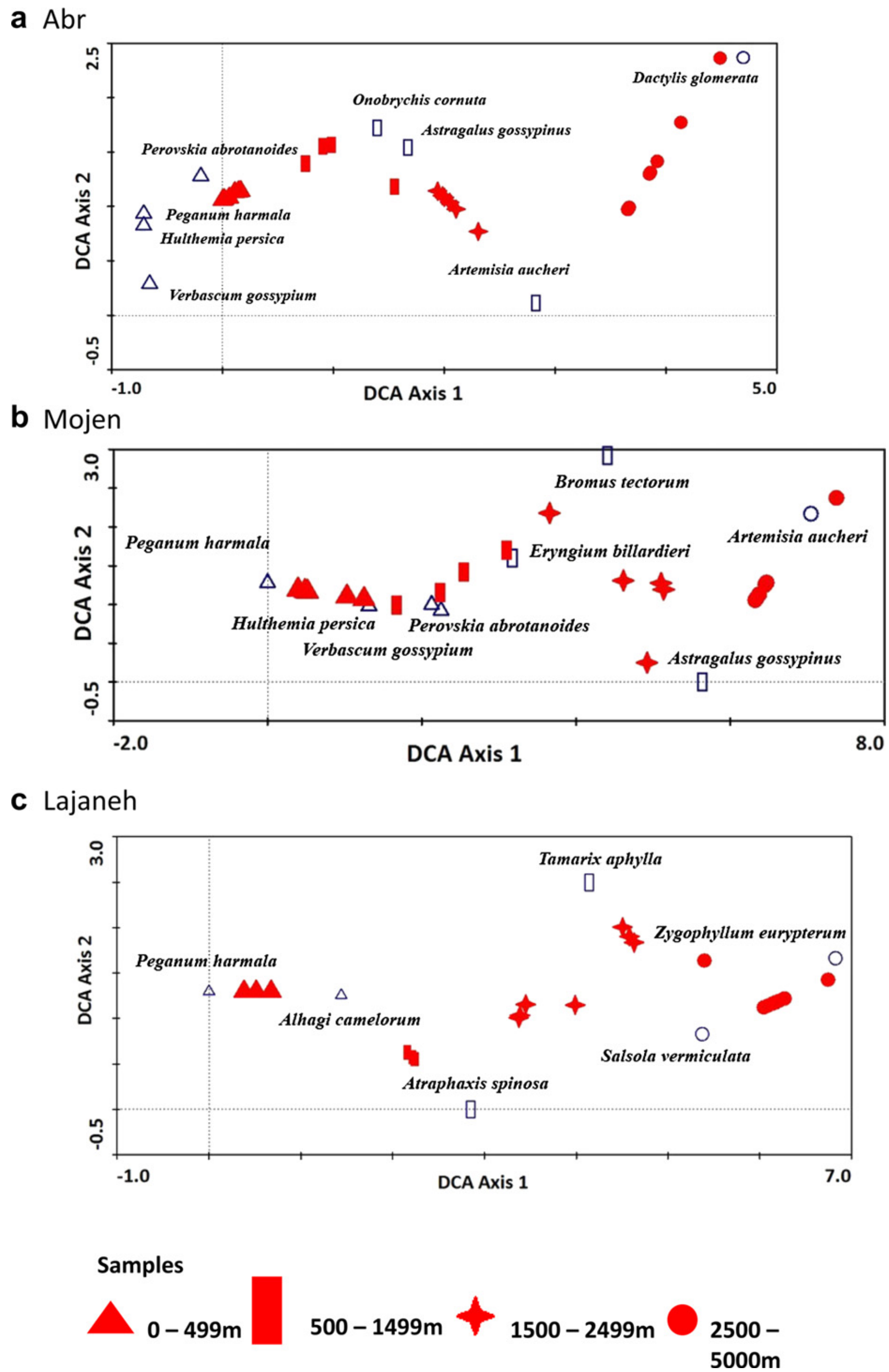

Fig. 2. DCA biplot of first and second axes for vegetation data in a) the mountain-steppe Abr (Length of gradient: 5.189), b) the steppe zone Mojen (Length of gradient: 5.926) and c) the desert-steppe zone Lajaneh (Length of gradient: 5.332) (not-filled symbols represent plant species).

water and concentrations of OM, N, EC and pH were negatively correlated; it is possible that livestock redistributed nutrients along watering points. Change in soil properties and nutrients generally occurred within 100 m of the watering points (Fig. 1b–e). Similar ranges have been recorded by other studies, and other investigators (Fernandez-Gimenez and Allen-Diaz, 2001; Moleele and Perkins, 1998; Smet and Ward, 2006; Tolsma et al., 1987; Turner, 1998; Hao and Chang, 2003) have observed similar patterns of nutrient redistribution around water points. For example, Tolsma et al. (1987) found soil nutrient enrichment to a distance of 100m from the water-point. Soil nutrients can be affected by herbivore activities like grazing, trampling, urination, and defecation; they affect soil pH (Killham, 1994; Smet and Ward, 2006) and N (Smet and Ward, 2006; Whitehead, 2000). Our findings suggest a strong effect of herbivore activity on soil properties and nutrients near the watering point. Fernandez-Gimenez and Allen-Diaz (2001) and Smet and Ward (2006) observed elevated N concentrations near water points.

Livestock overgrazing triggers invasion process by changing soil properties through voiding urine and feces around watering points (Brooks, 2003). Tolsma et al. (1987) and Moleele and Perkins (1998) found that particular species associated with intensive grazing

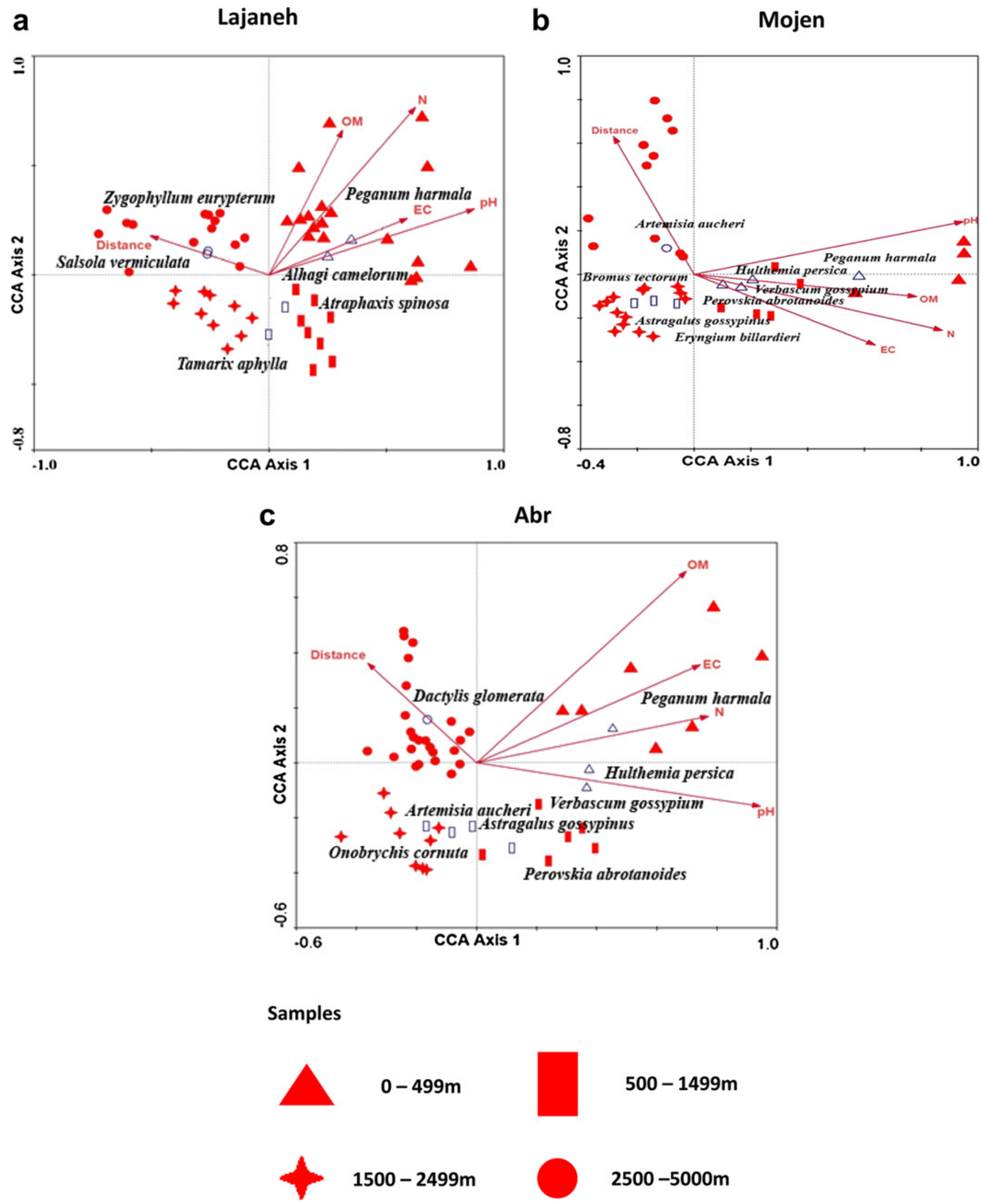

Fig. 3. CCA species triplot of first and second axes for vegetation, distance and soil data in relation to soil chemical attributes, and distance to watering-points in a) the desert-steppe zone Lajaneh (Eigenvalues: Axis 1 = 0.779, Axis 2 = 0.525, Total inertia = 1.924, The test of the first canonical axis: *F*-ratio = 24.622, *P* = 0.002, The test of all canonical axes: *F*-ratio = 11.289, *P* = 0.002), b) The steppe zone Mojen (Eigenvalues: Axis 1 = 0.764, Axis 2 = 0.429, Total inertia = 1.744, The test of the first canonical axis: *F*-ratio = 16.480; *P* = 0.002, The test of all canonical axes: *F*-ratio = 11.803; *P* = 0.002) and c) the mountain-steppe Abr (Eigenvalues: Axis 1 = 0.747, Axis 2 = 0.473, Total inertia = 1.878, The test of the first canonical axis: *F*-ratio = 22.095; *P* = 0.002, The test of all canonical axes: *F*-ratio = 10.647; *P* = 0.002) (not-filled symbols represent plant species).

pressure and near water points may also be favored by elevated N concentrations in these areas.

4.2. Plant species height

Height of palatable species increased significantly with distance from watering points (Fig. 1a).

Heavy grazing caused decreases photosynthesis, reduced root growth and reduced reproduction (Coughenour, 1985; Proffitt et al., 1993). Overgrazing (Intensity, frequency and season) decreases root size and plants lose their ability to absorb water and nutrients, so plant use carbohydrate reserves to survive in expense of their growth and reproduction (Holechek et al., 2003). They produce smaller leaves in size and number, smaller height and smaller seed size. Finally, palatable plants die and replace by exotic invader species (Holechek et al., 2003; Landsberg et al., 1999).

4.3. Plant species composition

In the desert-steppe, steppe and mountain-steppe zones, plant species composition changes along gradients from watering point. We interpret these changes as a response to increasing grazing pressure near the watering point. Grazing-tolerant species and species of marginal palatability were more abundant near water and at intermediate distances from water in desert-steppe, steppe and mountain-steppe zones (Fig. 2).

Cover of palatable species increased significantly with distance from watering points (Fig. 3). Grazing pressure along watering point changed species composition of steppe, desert-steppe and mountain-steppe zones. The species composition along the gradient from these watering points corresponds to findings by Fernandez-Gimenez and Allen-Diaz (2001) that showed heavy grazing around water points in Mongolian ecosystem led to selective removal of perennial grass species, promoting the growth of unpalatable species. Previous studies showed that provision of water reduces livestock movement resulting in constant heavy grazing pressure on palatable species and increases vegetation degradation (James et al., 1999; Klintenberg and Christiansson, 2005; Klintenberg et al., 2007; Klintenberg and Verlinden, 2008; Smet and Ward, 2005; Thrash, 1998a).

Similar cases of heavy grazing around watering points have been reported from South Africa (Smet and Ward, 2005), Australia (James et al., 1999), Ethiopia (Tefera et al., 2007) and Kruger National Park (Thrash et al., 1993). In central northern Namibia, Klintenberg and Verlinden (2008) observed changes in vegetation species composition from perennial to unpalatable annual grasses. In our study, perennial and more palatable species were shown to have their maximum as far as 4–10 km from the watering point in the three zones (personal observation). Overgrazing and trampling kill palatable species, thus increasing open space for exotic invasion. On the other hand, livestock overgrazing reduces the competitive ability of native plants, although numerous researchers indicated that the abundance of exotic species could increase around watering points (Andrew and Lange, 1986; Landsberg et al., 2003).

Our findings show that herbivory by livestock has changed the plant species composition in the Lajaneh, Mojen and Abr rangeland, palatable species replaced by less palatable species around water points.

We can classify species according to their appearance along grazing gradient from watering point in studied areas. Sensitive species to grazing are eliminated around watering point, they are “Decreasers” (*sensu* Dyksterhuis, 1949); their densities decrease in direct proportion to grazing intensity. In our study, decreasers (*Dactylis glomerata*, *Salsola vermiculata*, *Artemisia aucheri* and *Zygophyllum eurypterum*) are perennial and have tall shoots. ”Increasers” (*sensu* Dyksterhuis, 1949) are native species increasing in density toward the center of grazing gradient and taking advantage of the decreaser’s disappearance. They occupy both grazed and ungrazed part of grazing gradient. Some species that show up only after the introduction of grazing; are termed “invaders” (*sensu* Dyksterhuis, 1949). Increasers (*Astragalus gossypinus*, *Atraphaxis spinosa*, *Onobrychis cornuta*, *Bromus tectorum*, *Eryngium billardieri*) and invaders (*Peganum harmala*, *H. persica*, *Verbascum gossypium*, *Alhagi camelorum*) have short growing season and low palatability due to spines, small leaves and secondary metabolites (Díaz et al., 2001; Gibson, 2009; Ward, 2006).

Overgrazing changes species composition, cover and reduce suitable site for seedling establishment. In our study, the differences in plant species composition along watering points provide a basis for understanding the effect of grazing on species growth, establishment and mortality. The first zone in the vicinity of watering point is a sacrifice area (*sensu* Valentine, 1947) characterized by high soil disturbance and exposure of soil surface. It is considered a ‘sacrifice’ because all useful forage is essentially lost. In the second zone, grazing effects decrease along distance from watering point. The palatable species are replaced by unpalatable, spiny poisonous species in the second zone. The third layer is undergrazed and dominated by decreasers.

As we expected, soil enrichment is associated with overgrazing and therefore found on the location of *Peganum harmala* (Fig. 3). The high frequency of poisonous species, like *Peganum harmala* (African rue) around watering points in comparison with the low abundance of the majority of palatable species, e.g. *Zygophyllum eurypterum*, *Artemisia aucheri* and *Dactylis glomerata* shows overgrazing impact. *Peganum harmala* is a perennial herb or shrub in the Zygophyllaceae (Gintzburger et al., 2003). *Peganum* produces a variety of alkaloids (harmin and harmalin) and is poisonous for livestock (Faskhutdibov et al., 2000; Gintzburger et al., 2003). Severe poisoning can result in death; livestock are not likely to consume this plant when alternative forage is available (Cory, 1949; McDaniel and Duncan, 2006). *Peganum harmala* generally populates areas that typically show soil disturbances, like livestock tracks and watering points (Kaul and Thalen, 1979; Michelmore, 1997; Thalen, 1979). We consider the fact that poisonous species such as *Peganum harmala* and spiny species like *H. persica* and *Alhagi camelorum* is a consequence of a history of overgrazing.

5. Conclusions

Results presented here imply that livestock grazing may have affected plant community composition, both directly and indirectly through decreasing proportion of highly palatable species (decreasers), increasing proportion of grazing-tolerant species (increasers and invaders), more soil disturbance through trampling and higher nutrient concentrations (pH, N, OM, and EC) by voiding urine and feces close to watering points.

Plant community composition in all of our sites was largely determined by distance from watering point (grazing pressure) and soil nutrient (pH, N, OM, and EC). In studied areas, we found several composition layers around watering points. The available area decreases around watering point and it increases livestock intensity there, so overgrazing around watering point is severe. The evidences of overgrazing can be found along 100–1000 m from these watering points.

Soil chemical gradients around watering point can be a useful indicator to monitor rangeland health (Whitford et al., 1998). Thus when studying the ecological impact of livestock on species composition, it can be more appropriate to sample along key resources like watering points. The result of livestock overgrazing around studied watering points, may reflect the similar condition around thousands of watering points in arid and semi-arid zones of the world. This information is very important in understanding and managing of arid and semi-arid rangelands. Invader and exotic species affect herders’ income by diminishing forage quality, livestock poisoning and increasing cost of rangeland improvement and development. They also affect wildlife habitats by depleting soil nutrient and water content. Palatable and native species decline around watering point, so control efforts for exotic species and restoration should optimally focus on grazing gradient along watering points.

One cause of overgrazing and inefficient distribution of livestock can be insufficient number and unsuitable distribution of watering points. Herders should consider water provision and monitoring of their piosphere to develop better rangeland management strategies. Provision of new watering points gives the opportunity to overgrazed area to be rehabilitated. Negligence of grazing intensity and frequency leads to extinction of palatable decreaser species. We suggest to herders to re-open their watering points at regular intervals, to remove grazing pressure from overgrazed areas.

The grazing gradient along watering points provides an opportunity to understand ecological processes in many ecological fields. We need to optimize grazing pressure, determination of watering point locations and to do more research to understand the success of improvement program after closing watering points and moving livestock to other patches.

If range managers plan to maintain their livestock by moving them to available rich resources (forage and water), exploited watering points can recover and grazing pressure does not affect biodiversity and rangeland health. Rangers should include watering point development and extension in their plans. On the other hand, provision of new watering point without grazing management result in more degradation. Grazing management, training of herders by natural resources and environmental agencies are needed to control piosphere negative effects.

Acknowledgements

This research was funded by the University of Tehran. Thanks to the fine staff of the university of Tehran and Oklahoma State University for the use of their facilities and support of the project. We are grateful to Dr. Daniel McGlinn for his help that improved the quality of the manuscript.

References

Andrew, M.H., Lange, R.T., 1986. Development of a new piosphere in arid chenopod shrubland grazed by sheep. 2. Changes to the vegetation. Australian Journal of Ecology 11, 411–424.

Assaeed, A.M., Al-Doss, A.A., 2001. Seedling competition of *Lasiurus scindicus* and *Rhazya stricta* in response to water stress. Journal of Arid Environments 49, 315–320.

Baadshaug, O.H., 1983. Fertilization and liming of mountain pasture. III. Effects on botanical composition. Research in Norwegian Agriculture 34, 259–268.

Bremner, J.M., Mulvaney, C.S., 1982. Nitrogen—total. In: Page, A.L. (Ed.), Methods of Soil Analysis, Part 2, Chemical and Microbial Properties. American Society of Agronomy, Madison, WI, pp. 599–611.

Brooks, M.L., 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. Journal of Applied Ecology 40, 344–353.

Cory, V.L., 1949. African rue (*Peganum harmala* L.) in the United States. Field and Laboratory 17, 20–23.

Coughenour, M.B., 1985. Graminoid responses to grazing by large herbivores: adaptations, exaptations, and interacting processes. Annals of the Missouri Botanical Garden 72 (4), 852–863.

de Bello, F., Lepš, J., Sebastià, M.T., 2006. Variations in species and functional plant diversity along climatic and grazing gradients. Ecography 29, 801–810.

de Bello, F., Lepš, J., Sebastià, M.T., 2007. Grazing effects on the species-area relationship: variation along a climatic gradient in NE Spain. Journal of Vegetation Science 18, 25–34.

Díaz, S., Noy-Meir, I., Cabido, M., 2001. Can grazing response of herbaceous plants be predicted from simple vegetative traits? Journal of Applied Ecology 38, 497–508.

Dyksterhuis, E.J., 1949. Condition and management of range land based on quantitative ecology. Journal of Range Management 2, 104–115.

Faskhutdibov, M.F., Telezhenettskaya, M.V., lekovich, M.G., Abdullaev, N.D., 2000. Alkaloids of Peganum harmala. Chemistry of Natural Compounds 36, 602–605.

FAO, 1992. Report on the round table on pastoralism. FAO Technical Cooperation Programme, Project TCP/IRA/2255, Rome.

Fernandez-Gimenez, M., Allen-Diaz, B., 2001. Vegetation change along gradients from water sources in three grazed Mongolian ecosystems. Plant Ecology 157, 101–118.

Fischer, S., Poschlod, P., Beinlich, B., 1996. Experimental studies on the dispersal of plants and animals by sheep in calcareous grasslands. Journal of Applied Ecology 33, 1206–1222.

Fusco, M., Holechek, J., Tembo, A., Daniel, A., Cardenas, M., 1995. Grazing influences on watering point vegetation in the Chihuahuan desert. Journal of Range Management 48, 32–38.

Gibson, J.D., 2009. Grasses and Grassland Ecology. Oxford University Press, 320 p.

Gintzburger, G., Toderich, N.K., Mardonov, K.B., Mahmudov, M.M., 2003. Rangelands of the Arid and Semi-arid Zones in Uzbekistan. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

Hao, X., Chang, C., 2003. Does long-term heavy cattle manure application increase salinity of a clay loam soil in semi-arid southern Alberta? Agriculture, Ecosystems and Environment 94, 89–103.

Hill, M.O., Gauch, H.G., 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 42, 47–58.

Holechek, J.L., Pieper, R.D., Herbel, C.H., 2003. Range Management, Principles and Practices. Prentice-Hall, Upper Saddle River, NJ. 587p.

Hulme, P.E., 1996. Herbivory, plant regeneration, and species coexistence. Journal of Applied Ecology 84, 609–615.

Hunt, L.P., 2001. Heterogeneous grazing causes local extinction of edible perennial shrubs: a matrix analysis. Journal of Applied Ecology 38, 238–252.

James, C.D., Landsberg, J., Morton, S.R., 1999. Provision of watering points in the Australian arid zone: a review of effects on biota. Journal of Arid Environments 41, 87–121.

Javadi, S.A., Jafari, M., Azarnivand, H., Alavi, S.A., 2005. Effect of grazing intensity on soil nitrogen and organic matter of Lar Rangeland. Iranian Journal of Natural Resources 3, 711–725 (in Persian).

Kaul, R.N., Thalen, D.C.P., 1979. South-west Asia. In: Goodall, D.W., Perry, R.A. (Eds.), Arid-land Ecosystems: Structure, Functioning and Management, vol. 1. Cambridge University Press, Cambridge, United Kingdom, pp. 213–271.

Killham, K., 1994. Soil ecology. Cambridge University Press, Cambridge, England.

Klintenberg, P., Christiansson, C., 2005. Improved Access to Water: An Enemy in Disguise? Drainage Basin Management – Hard and Soft Solutions in Regional Development. Stockholm International Water Institute, Stockholm.

Klintenberg, P., Seely, M.K., Christiansson, C., 2007. Local and national perceptions of environmental change in central northern Namibia: do they correspond? Journal of Arid Environments 69, 506–525.

Klintenberg, P., Verlinden, A., 2008. Water points and their influence on grazing resources in central northern Namibia. Land Degradation & Development 19, 1–20.

Landsberg, J., Lavorel, S., Stol, J., 1999. Grazing response groups among understorey plants in arid rangelands. Journal of Vegetation Science 10, 683–696.

Landsberg, J., James, C.D., Morton, S.R., Muller, W.J., Stol, J., 2003. Abundance and composition of plant species along grazing gradients in Australian rangelands. Journal of Applied Ecology 40, 1008–1024.

Lange, R.T., 1969. The piosphere: sheep track and dung patterns. Journal of Range Management 22, 396–400.

Lepš, J., Šmilauer, P., 2003. Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press, Cambridge.

Legendre, P., Legendre, L., 1998. Numerical Ecology. Elsevier Science BV, Amsterdam.

McDaniel, K., Duncan, K., 2006. African Rue Control: Ground Applications. New Mexico Cooperative Extension Service Publication BC-6. New Mexico State University College of Agriculture and Home Economics Cooperative Extension Service, Las Cruces.

McIntyre, S., Lavorel, S., 1994. How environmental and disturbance factors influence species composition in temperate Australian grasslands. Journal of Vegetation Science 5, 373–384.

Mesdaghi, M., 1996. Rangeland Management in Iran. Emam Reza University Press, Mashhad.

Michelmore, M., 1997. African Rue Management, Distribution, Biology, Impact, and Control Strategies for *Peganum harmala* L. (Zygophyllaceae) in South Australia. Primary Industries, SA, Port Augusta, South Australia.

Moleele, N.M., Perkins, J.S., 1998. Encroaching woody plant species and boreholes: is cattle density the main driving factor in the Olifants Drift communal grazing lands, south-eastern Botswana? Journal of Arid Environments 40, 245–253.

Moghadam, M.R., 1998. Rangeland and Rangeland Management. University of Tehran Press, Tehran.

Nelson, D.W., Sommers, L.E., 1996. Total carbon, organic carbon, and organic matter. In: Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnson, C.T., Sumner, M.E. (Eds.), Methods of Soil Analysis. Part 3, Chemical Methods. Soil Science Society of America (SSSA) and American Society of Agronomy (ASA), Madison.

Osborn, T.G., Wood, J.G., Paltridge, T.B., 1932. On the growth and reaction to grazing of the perennial saltbush (*Atriplex vesicarium*). An ecological study of the biotic factor. Proceedings of the Linnaean Society of New South Wales 57, 377–402.

Palmer, M.W., 1993. Putting things in even better order: the advantage of canonical correspondence analysis. Ecology 74, 2215–2230.

Proffitt, A.P.B., Bendotti, S., Howell, M.R., Eastham, J., 1993. The effect of sheep trampling and grazing on soil physical properties and pasture growth for a red-brown earth. Australian Journal of Agricultural Research 44, 317–331.

Riginos, C., Hoffman, M.T., 2003. Changes in population biology of two succulent shrubs along a grazing gradient. Journal of Applied Ecology 40, 615–625.

Rosas, C.A., Engle, D.M., Shaw, J.H., Palmer, M.W., 2008. Seed dispersal by *Bison bison* in a tallgrass prairie. Journal of Vegetation Science 19, 769–778.

Sanadgol, A.A., 2006. How different grazing intensities affect soil moisture in *Bromus tomentellus* grassland. Pajouhesh va Sazandegi 73, 49–55 (in Persian).

SAS Institute, 2008. SAS Version 9.2 for Windows. SAS Institute Inc., Cary, NC, USA.

Smet, M., Ward, D., 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure using grazing gradients around waterpoints in a semi-arid savanna. African Journal of Range and Forage Science 22, 59–71.

Smet, M., Ward, D., 2006. Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. Journal of Arid Environments, 64,251–64,269.

Steinauer, E.M., Collins, S.L., 1995. Effects of urine deposition on small-scale patch structure in prairie vegetation. Ecology 76, 1195–1205.

Tefera, S., Snyman, H.A., Smit, G.N., 2007. Rangeland dynamics of Southern Ethiopia: (2). Assessment of woody vegetation structure in relation to land use and distance from water in semi-arid Borana rangelands. Journal of Environmental Management 85, 443–452.

Ter Braak, C.J.F., 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67, 1167–1179.

Ter Braak, C.J.F., Prentice, I.C., 1988. A theory of gradient analysis. Advances in ecological research 18, 271–317.

Ter Braak, C.J.F., Šmilauer, P., 1998. CANOCO Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (Version 4). Microcomputer Power, Ithaca, NY.

Thalen, D.C.P., 1979. Ecology and Utilization of Desert Shrub Rangelands in Iraq. Dr. W. Junk B.V. Publishers, The Hague.

Thrash, I., Theron, G.K., Bothma, J.D.P., 1993. Impact of water provision on herbaceous plant community composition in the Kruger National Park. African Journal of Range & Forage Science 10, 31–35.

Thrash, I., 1998a. Impact of large herbivores at artificial watering points compared to that at natural watering points in Kruger National Park, South Africa. Journal of Arid Environments 38, 315–324.

Thomas, D.S.G., Sporton, D., Perkins, J.S., 2000. The environmental impact of livestock ranches in the Kalahari, Botswana: natural resource use, ecological change and human response in a dynamic dryland system. Land Degradation & Development 11, 327–341.

Tolsma, D.J., Ernst, W.H.O., Verwey, R.A., 1987. Nutrients in soil and vegetation around two artificial waterpoints in eastern Botswana. Journal of Applied Ecology 24, 991–1000.

Turner, M.D., 1998. Long-term effects of daily grazing orbits on nutrient availability in Sahelian West Africa: I. Gradients in the chemical composition of rangeland soils and vegetation. Journal of Biogeography 5, 669–682.

Valentine, K.A., 1947. Distance from water as a factor in grazing capacity of rangelands. Journal of Forestry 45, 449–454.

VanRooyen, N., Bredenkamp, G.J., Theron, G.K., Bothma, J., du, P., le Riche, E.A.N., 1994. Vegetational gradients around artificial watering points in the Kalahari Gemsbok National Park. Journal of Arid Environments 26, 349–362.

Ward, D., 2006. Long-term effects of herbivory on plant diversity and functional types in arid ecosystems. In: Danell, K., Duncan, P., Bergström, R., Pastor, J. (Eds.), Large Herbivore Ecology, Ecosystem Dynamics and Conservation. Cambridge University Press, pp. 142–170.

Whitehead, D.C., 2000. Nutrient Elements in Grassland: Soil–Plant–Animal Relationships. CAB International, Oxon.

Whitford, W.G., de Soyza, A.G., Van Zee, J.W., Herrick, J.E., Havstad, K.M., 1998. Vegetation, soil, and animal indicators of rangeland health. Environmental Monitoring Assessment 51, 179–220.

Zar, J.H., 2009. Biostatistical Analysis. Prentice Hall, New Jersey, USA. 960p.