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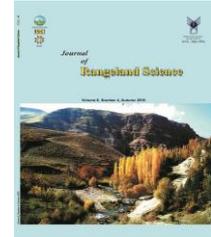
Research and Full Length Article:

Semi-Circular Bunds Effect on Restoration of Plant Vegetation and Soil Properties in Koteh Rangeland, Sistan and Baloochestan Province, Iran

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Abstract. In dry lands, semi-circular bund has been considered as a management practice used to restore the ecological revival in terms of vegetation enrichment and soil amelioration. This study was conducted to investigate the effects of semi-circular bunds on vegetation cover and some soil properties in Koteh rangeland, Sistan and Baloochestan province, Iran (2014). Adjacent to the semi-circular bund area, a rangeland area without semi-circular bunds was selected as the control site. Vegetation sampling was done using 5×5 m^2 plots and soil samples were taken from the depth of 0–30 cm. Vegetation and soil data were analyzed using T test. In total, 16 species from 7 families and 13 genera were observed. Results showed that semi-circular bunds exhibited more vegetation cover, plant production and density. The minimum values of production and vegetation cover were related to the control site. The highest and lowest richness and diversity of species were measured in the semi-circular bunds area and the control site, respectively. The pH level was significantly higher in the soils of semi-circular bunds area as compared to the control site ($P<0.05$). However, the level of soil EC followed an opposite pattern. Results showed that the amounts of organic carbon, nitrogen, potassium, phosphorus and calcium carbonate increased significantly in the semi-circular bunds as compared to the control site ($P<0.05$). The semi-circular bunds area had more amounts of clay and silt and the least values were measured in the control site. In total, the results of the study showed that building the semi-circular bund had positive effects on vegetation cover and soil properties in the rangelands of study area.

Key words: Species richness, Water harvesting, Arid rangelands, Soil fertility

Introduction

Natural ecosystems such as rangelands provide benefits to human society, which are of great ecological, socio-cultural and economic values (de Groot *et al.*, 2002). 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 provide forage for herbivores and offer the opportunity for outdoor recreational activities and enjoyment of nature. In addition, they play a great ecological role in conserving the biodiversity (Amiri, 2009). Considering ecology, the evaluations of ecosystem play significant roles in recognizing the ecosystems' structure and function (Abedi and Arzani, 2004). Correct programming for suitable utilization of water, soil and plant resources not only decreases the rangeland degradation but also leads to their conservation and improvement (Ariapour *et al.*, 2013).

Some changes in rangelands are regarded as natural ecosystem ones; however, if these changes go over the habitat's protective threshold, they are to destroy the rangeland (Sabeti, 1975). The increase in intensity of management practices over recent decades has had a strong impact on the landscape while affecting the quality of natural or semi–natural habitats (José–María *et al.*, 2010). The direct effect of management on vegetation cover and soil properties can vary depending on the practices (Bassa *et al.*, 2011). Evaluation of rangelands in response to management is important for land managers ranging from individuals to governments, especially when the output has a direct relevance for management decision making (Ata Rezaei *et al.*, 2006). It may be seeking to look for the evidence of landscape degradation or rehabilitation and the procedure needs to have equal facilities in dealing with these scenarios.

In recent decades, semi–circular bund (semi–circular bund height is primarily dependent on the prevailing ground slope and the selected size of the semi–circular bund). It is recommended to construct semi–circular bund with a height of at least 25 cm in order to avoid the risk of over–topping and subsequent damage. Where the ground slope exceeds 2.0%, the semi–circular bund height near the infiltration pit must be increased (Armas and Pugnaire, 2005). Semi–circular bund is one of the effective management practices that aim to increase soil fertility, vegetation cover and diversity in rangelands, which have been highly relevant as a potential practice for the conservation objectives. However, semi–circular bund effects on vegetation cover and soil properties had not been conclusive. In some cases, vegetation cover and soil fertility were increased (Jafari *et al.*, 2009; Arab, 2013) whereas in the others, there were either decreases (Khosravi, 2014). Comparison of vegetation composition and diversity along with species richness and abundance, and plant functional groups in the improved rangelands could reflect the system stability and resilience of the rangelands (Yari *et al.*, 2012). Such approach can help to guide sustainable management strategies for conserving natural ecosystem (Al-Rowaily *et al.*, 2015). The semi–circular bund has encouraged the infiltration and reduced runoff and erosion, leading to the retention of surface water resources and recharge of ground waters. Numerous studies have confirmed that semi–circular bund affects the biodiversity conservation because it is expected to promote secondary succession in rangeland ecosystems (Delavari *et al.*, 2014). The other effects of semi–circular bund used in the arid rangelands include the increases in the number of plant species, soil microorganisms and nutrient content of the soil (Rigi *et al.*, 2012; Arab, 2013; Khosravi, 2014).

In this paper, the semi–circular bund treatment was contrasted to address the following questions: a) how does semi-circular bund affect the vascular plant richness and diversity in the arid region of eastern Sistan and Baloochestan, Iran? And b) do the soil properties respond to the semi–circular bund? Our hypotheses suggest that 1) The semi–circular bund helps the establishment of plant species and 2) physico-chemical properties of soil in the semi-circular bund differ from control treatment (without semi–circular bund).

Materials and Methods
Study area
Koteh rangeland is located in Sistan and Baloochestan province, Taftan city in Iran between 28° 23′ 41′′–28° 39′ 00′′ N latitude and 60° 47′ 04′′–28° 23′ 09′′E longitude (Fig. 1). The experimental area is characterized by dry summer, warm autumn and cool winter. According to

data available for the period of 2006–2014 at the study site from the National Meteorological Information Center of Iran, the mean annual rainfall is 160 mm. The mean annual temperature is 19.7°C. The minimum and maximum elevations are 1400 m in the south to 3000 m in the north. The area represents a common arid landscape characterized by steep slopes covered by a mosaic of bush-forb. The bush-forb type covered 35% vegetation. The dominated vegetation types are *Artemisia santolina*, *Hammada salicornia* and *Salsola tomentosa*. Vegetation in the area has changed considerably over the past several decades, primarily due to overgrazing by goats. The soils are mainly silt loam in texture. We selected the area that was underwent semi–circular bund project for 7 years (Report of Range Improvement-Water Harvesting, Koteh, Sistan and Baloochestan, 2010).
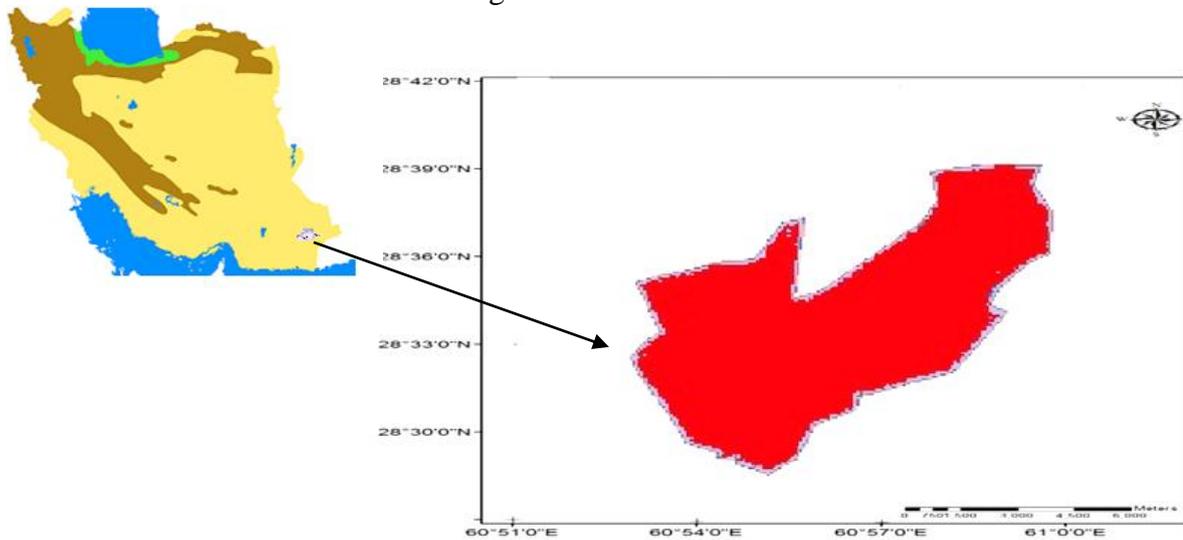
Fig.1. Study area in Sistan and Baloochestan province

Sampling Method
We selected the semi-circular bund site that underwent the succession for 8 years. A site without semi–circular bund was selected as a control site. There were no differences between topography, soil type, and spatial heterogeneity among the selected sites. The semi-circular bund site

covered a total area of about 12 ha. The data were collected in 2014. At each site, we conducted a comprehensive investigation of vegetation types.

A total of 10 sampling stands (50×50 m) were selected to represent the prevailing habitat and community variations in the sites (5 stands for each site). Within each stand, vegetation

properties were measured using the simple transects line (100 m) method within quadrates (5 m × 5 m) with a systematically–randomized method. In total, 30 transects were sampled in the sites. Species identification and nomenclature were carried out in the herbarium of University of Zabol, Iran.

Data on vegetation/canopy cover were 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 quadrate estimation methods. Plant species were classified as classes I (High), II (Medium) and III (Low) according to their palatability. Palatability is a plant characteristic that refers to the relish with which plants or its parts or feed are consumed as stimulated by the sensory impulses of grazing animal (Heath et al., 2003). In the present study, palatability was determined using reference texts (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):

$$IV = \frac{RD + RC + RF}{3}$$

RD =the relative density (the ratio of number of individuals of a species to the total number of individuals of all species, %);

RC =the relative cover (the ratio of cover of a species to the total cover of all species, %); and

RF =the relative frequency (the ratio of frequency percent of a species to the total frequency of all species, %) (Jiang et al., 2006).

In total, 120 vegetation plots were sampled in each site. Shannon species diversity index [H'=−∑ pi. lnpi] (Magurran, 1988) was 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.

Soil samples (silt loam texture) were taken at three points along transects in each stand (within quadrates at three points) using a soil auger from the surface layers (0–30 cm). Then, the soil samples in each quadrat were mixed together to make one composite sample. A total of 30 soil samples were selected (15 soil samples at each site). The soil samples were put in plastic bags and then, labeled; they were thereafter air dried and taken to the laboratory at the Department of Range and Watershed Management, University of Zabol in order to analyze the physical and chemical properties of soil. The soil texture was determined using laser diffractometry (Wang et al., 2012); the soil pH was determined in a 1:5 soil to distilled water slurry after one hour of agitation using a digital pH–meter (Thomas, 1996); electrical conductivity of saturated soil paste extract (ECe) using an EC–meter (Rhoades, 1996); total soil N (N_{tot}) was analyzed calorimetrically with a continuous flow ion analyzer following wet digestion in sulfuric acid (Bremner, 1996); Calcium carbonate ($CaCO_3$) was determined volumetrically by a calcimeter (Allison and Moodie, 1965). Organic carbon content (OC) was determined using the methods described by Lo et al. (2011). Available phosphorus (P) was determined by the method of Bray and Kurtz (1954). Available potassium (K) was measured by flame photometry method (Knudsen et al., 1982).

Statistical Analysis
Statistical analyses of the experimental data were performed using the SPSS 18.0. All the reported results are the means of five replicates and the deviations were calculated as the standard

error of mean (SEM). The statistical processing was mainly done by T–test (after testing for homogeneity of variance and confirming a normal distribution). A probability of 0.05 or lower was considered as significant.

Results

Effects on Floristic Composition

We collected a total of 16 plant species in the study area (Table 1) from 7 families and 13 genera. The semi–circular bund significantly affected the community composition for species, (P=0.01), genera (P=0.05), and families (P=0.05, Table 2). The number of species (16 species), genera (13 genera), and families (7 families) reached their maximum value in the semi–circular bund whereas the minimum number of species (8 species), genera (9 genera), and families (5 families) was observed in the control site (Table 2). The number of species and the proportion of annual (P=0.05) and perennial species were significantly affected by the semi–circular bund (P=0.00).

The semi–circular bund showed the highest number of plant species, of which approximately 75% were perennials. The areas were dominated by species in the Compositae (34%) followed by the Papilionaceae (20%), and Graminae (11%) (Table 2). There were three dominant species in the semi–circular bund based on the importance value: *Ar. santolina*, *H. salicornia* and *S. tomentosa*. Results in Table 2 show that semi–circular bund influenced the structural characteristics of the plant communities. The plant species of *Ar. santolina*, *H. salicornia* and *S. tomentosa* were more abundant with higher importance values in the semi–circular bund than the control

treatment. Chorological study (Table 1) showed that the largest proportion of the flora belongs to the Irano–Turanian elements (92.13%) followed by Europe–Siberian (6.14%) (Table 1).

Effects on Vegetation Cover, Species Diversity and Richness

The plant density of classes I and II was 9.27 (P=0.01) and 5.73 (P=0.03) m^{-2}, respectively in the semi–circular bund area, and was significantly greater than those in the control site at the peak growing season harvest (P<0.05; Table 3). The plant density of class III decreased from 3.02 plant m^{-2} in the control site to 2.27 plant m^{-2} in semi–circular bund area. However, there was no significant difference between the plant density of class III in semi–circular bund area and the control site (P=0.1; Table 3). The litter (31.13%) and canopy cover (54.67%) were also notably higher in the semi–circular bund area than the control site. Accordingly, the bare soil decreased from 49.73% in the control site to 8.23% in the semi–circular bund area (P <0.00, Table 3).

The diversity of plant species and richness were significantly affected by the semi–circular bund (P=0.00, Table 3). Both Shannon diversity index (H') and richness of the rangeland community increased in the semi–circular bund whereas the control site had the minimum diversity and richness of plant species. Results indicated that there were no significant differences in the plant species evenness of the sites (Table 3). Totally, the results of the present study showed that the semi–circular bund in the arid rangelands significantly altered the vegetation properties, which supports our first hypothesis.

Table 1. The dynamics of plant species at semi–circular bund and control areas

Species	Family	Growth form	Life history	Chorotype	Semi–circular bund area			Control area		
					Presence/ Absence	IV (%)	Frequency (%)	Presence/ absence	IV (%)	Frequency (%)
Bromus tectorum L.	*Graminae*	G	A	IT	1	18.98	11	1	27.21	20
Cardaria draba (L.) Desv.	*Brassicaceae*	F	A	Cosm	1	17.50	11	1	21.13	17
Cicer spiroceras Jaub. & Spach	*Papilionaceae*	F	P	IT	1	8.76	9	0	0	0
Cousinia gedrosiaca Bornm. & Gauba	*Compositae*	F	A	IT	1	10.43	8.5	1	21.19	15
Descurainia sophia (L.)Webb. ex Prantl.	*Brassicaceae*	F	A	IT	1	8.21	9	0	0	0
Zygophyllum eurypterum Boiss.& Buhse.	*Zygophyllaceae*	Sh	P	IT-ES	1	53.11	90	1	21	13
Hammada salicornia (Moq.) Iljin	*Amaranthaceae*	Sh	P	IT-SA	1	56.19	90	1	14.21	11
Artemisia santolina Schrenk.	*Compositae*	B	P	IT	1	70.28	100	0	0	0
Salsola tomentosa (Moq.)	*Amaranthaceae*	F	P	IT	1	54.32	90	0	0	0
Artemisia lehmanniana Bunge.	*Compositae*	B	P	IT	1	42.76	67	1	24.20	14
Artemisia sieberi Besser.	*Compositae*	B	P	IT	1	39.68	52	1	26.48	12
Amygdalus lycioides Spach.	*Rosaceae*	Sh	P	IT-ES	1	11.22	9	0	0	0
Cymbopogon olivieri (Boiss) Bor.	*Graminae*	F	P	IT	1	19.04	12	0	0	0
Astragalus mucronifolius Boiss.	*Papilionaceae*	B	P	IT	1	9.21	10	0	0	0
Amygdalus scoparia L.	*Papilionaceae*	Sh	P	IT	1	9.65	10	0	0	0
Cousinia stocksil C.Winkl.	*Graminae*	B	P	IT	1	8.42	9	1	32.09	12

Sh: Shrub, F: Forb, G: Grass, B: Bush, P: Perennial, A: Annual

1: Presence of species, 0: Absence of species. Chorotype: Cosm: Cosmopolitan, IT: Irano–Turanian, ES: Europe–Siberian, SA: Saharo–Arabian

Table 2. Number of plant families, genera, species, annuals and perennial plant sampled at semi–circular bund and control areas

Sites	No. Species	No. Genera	No. Families	Annuals	Proportion of total (%)	Perennials	Proportion of total (%)
Semi–circular bund area	16.00±1.44[a]	13.00±0.20[a]	7.00±0.01[a]	4.00±0.01[a]	18.61±0.1[b]	14.00±0.30[a]	86.12±5.10[a]
Control area	8.00±0.14[b]	9.01±0.20[b]	5.00±0.01[b]	3.00±0.01[b]	61.24±3.21[a]	4.00±0.10[b]	11.42±4.02[b]
T test Sig.	0.01**	0.05*	0.05*	0.05*	0.00**	0.00**	0.00**

*Values shown are the means± SE. Values within a column followed by different letters are significantly different (p<0.05).

Table 3. Plant properties in the semi–circular bund and control areas

Site	Density (n m⁻²)			Canopy cover (%)	Litter (%)	Bare soil (%)	Diversity (H′)	Richness	Evenness
	I	II	III						
Treatment	9.27±1.50[a]	5.73±1.35[a]	2.27±0.20[a]	54.67±3.21[a]	31.13±0.50[a]	8.23±0.50[b]	3.18±0.10[a]	16.00±0.11[a]	0.50±0.10[a]
Control	4.11±1.30[b]	2.11±1.00[b]	3.02±0.30[a]	14.54±2.02[b]	10.03±3.43[b]	49.73±3.43[a]	0.21±0.00[b]	8.00±0.10[b]	0.50±0.10[a]
T test Sig	0.01**	0.03*	0.1ns	0.00**	0.00**	0.00**	0.00**	0.00**	0.08ns

*Values shown are the means± SE. Values within a column followed by different letters are significantly different (p<0.05).

Effects on Soil Properties

The physical and chemical characteristics of soils are shown in Table 4. Results showed that the soils under the semi–circular bund had significantly lower pH values in the 0–30 cm soil layer (P<0.05) as compared with the control site. Compared with pH, the level of EC followed an opposite pattern. The EC level increased in the soil surface layer under the semi–circular bund treatment in comparison with the control site (Table 4). The semi–circular bund resulted in notable enrichment of organic carbon, nitrogen, potassium, and phosphorus

reserves in the 0–30 cm soil layer (Table 4).

In comparison with the control site, organic carbon levels were 2.57 time higher in the semi–circular bund area. The levels of nitrogen, potassium, and phosphorus followed the same pattern. Semi–circular bund resulted in the increased calcium carbonate content of the investigated soil layer (Table 4). The particle size distribution showed more clay and less sand in the soils of semi–circular bund area compared with the soils of control site. The silt was not significantly changed after building semi–circular bunds (Table 4).

Table 4. Characteristics of soil sampled in the semi–circular bund and control areas

Soil properties	Semi–circular bund	Control	Sig
pH	8.00±0.20[b]	8.90±0.20[a]	0.05*
ECe (dS m^{-1})	4.20±0.01[a]	3.00±0.01[b]	0.05*
Organic carbon (%)	3.17±0.01[a]	0.60±0.01[b]	0.00**
Nitrogen (%)	1.53±0.01[a]	0.02±0.01[b]	0.00**
Potassium (ppm)	435.12± 9.00[a]	109.50± 5.00[b]	0.00**
Phosphorus (ppm)	14.02±0.50[a]	2.12±0.10[b]	0.00**
CaCO$_3$ (%)	37.50±3.30[a]	30.86±3.50[b]	0.05*
Silt (%)	57.50±1.50[a]	50.20±1.10[a]	0.20n.s
Sand (%)	17.50±1.00[b]	42.20±2.00[a]	0.01**
Clay (%)	25.00±0.70[a]	7.60±0.70[b]	0.04*
Soil texture	Silt loam	Silt loam	-

*Values shown are the means± SE. Values within a row followed by different letters are significantly different (p<0.05).

Discussion

The results of the present study showed that the semi–circular bund had influenced different measured diversity attributes. The diversity of plants showed differences between the semi–circular bund and the control site at the levels of species, genera and families. Semi–circular bund had a positive effect on the total number of species and species richness. The results showed that the semi–circular bund enhances the cover, density and richness of perennial plants which facilitate the establishment and growth of herbaceous and annual species under their canopies (Al-Rowaily *et al*., 2015). Semi–circular bund in arid rangeland was shown to be good alternatives to recover vegetation and attenuate soil loss by the wind erosion in

these erodible rangelands (Jafari *et al*., 2009; Delavari *et al*., 2014).

Changes in the plant community in ecological processes likely provide a high diversity of niches, attract the seed dispersers and as a consequence, facilitate the colonization by new plant species (Jules *et al*., 2008; Suganuma *et al*., 2014), thereby facilitating the establishment of desirable species (Liu *et al*., 2015). Plant establishment provides suitable micro–habitats for the growth of plant species in arid lands (Amici *et al*., 2012; Khosravi, 2014). The habitat–modifying capacity of a plant can alter its environment, both above and below–ground. Understory microclimate is characterized by lower irradiance, air temperature and consequently, lower evapotranspiration demands than the

areas without vegetation (Maestre *et al*., 2003; Khosravi, 2014; Mohammadi, 2014). In addition, plant establishment can help the vegetation communities in the arid lands by trapping seeds (Rathore *et al*., 2015). In this way, perennials act as seed accumulators by shielding wind–dispersed seeds on the plant species, thereby enhancing possibilities for recruitment. Seedling establishment is often possible under the shade of existing perennials while allowing for the colonization and long–term persistence of herbaceous species (Shumway, 2000). Finally, the reduced soil erosion and improved soil properties associated with shrub development create a nutrient–rich, water–retaining substrate, and thus provide a better environment for germination, seedling growth, and productivity in water and nutrient poor environments (Su *et al*., 2002; Khosravi, 2014; Mohammadi, 2014).

The semi–circular had the lowest proportions of the bare soil probably because the dominant plants grow in large clumps and hinder the erosive processes (Ninot *et al*., 2007; Jafari *et al*., 2009; Khosravi, 2014). The reason might explain the greater canopy cover observed in the area. Many reports have confirmed that the positive effects of semi–circular bunds used in the arid lands include an increase in the number of plant species and biodiversity (Yari *et al*., 2012; Arab, 2013). For example, Khosravi (2014) in an investigation of the effects of semi–circular on the restoration of vegetation and properties in Naroon rangeland of Taftan area, Iran concluded that semi–circular bunds significantly increased plant biomass and diversity. Jafari *et al*. (2009) in the study of the effect of semi–circular bunds in a degraded arid environment of Sirjan, Iran reported that the semi–circular bunds greatly altered vegetation cover and soil properties in the degraded arid lands.

Species composition and diversity are fundamental characteristics of ecosystems and vegetation diversity should be considered in the course of vegetation restoration (Rodrigues *et al*., 2009). Results of the present study showed that the semi–circular bund helped the vegetation enrichment. The semi–circular bund increased the diversity and abundance of plant species. In the present study, the population of perennial species generally increased and up to the maximum value at the area where semi–circular bunds were performed. The semi–circular bund can be of benefits to landscape composition by increasing the ecotone density and landscape diversity (Arab, 2013). Therefore, the establishment of shrubs and trees during rangeland reclamation may cause an accumulation of mineral nutrients and water, leading to a local increase in soil fertility (El-Keblawy and Ksiksi, 2005), and may protect the understory species against high irradiance and temperature (Vetaas, 1992). Favorable soil and micro–climatic conditions underneath plant canopies act as "resource islands" for understory herbaceous plants (Stinca *et al*., 2015). These "resource islands" are critical to arid land rehabilitation because they may spur natural succession by facilitating the growth of other plants (Gómez–Aparicio *et al*., 2004; Khosravi, 2014).

Results showed that the semi–circular bund area had significant lower pH in comparison with the control site. The phenomenon was probably related to the plant coverage and soil organic carbon content because extensive secretion of organic acids from the roots of plants and amounts of CO_2 released from roots and microorganisms could lead to the decreased pH (Yong–Zhong *et al*., 2005). The results may be related to several mechanisms that release H^+ ions such as cation uptake by biomass, decomposition of organic matter to organic acids and CO_2 and root respiration. These processes are counter balanced to some extent by several sinks for H^+, the weathering of

soil minerals, anion uptake by biomass, and release of cation from soil organic matter (Li *et al*., 2008). Results showed that the EC value increased in the semi–circular bund area as compared to the control site. Higher EC value in the area may be the consequence of accumulation of soluble salts in the litter material (Zehtabian *et al*., 2006; Rathore *et al*., 2015).

The result revealed that in the semi–circular bund area, soil amelioration was increased whereas the control treatment showed less vegetation cover and very low soil enrichment. In the control treatment, the accelerated wind erosion due to the decreased vegetation cover and litter accumulation resulted in soil coarsening and loss of soil organic matter (Yong–Zhong *et al*., 2005). Soil organic carbon and total nitrogen concentrations in the semi–circular bund showed a significant increase as compared to the control site. Khosravi (2014) noted that the semi–circular bund area in Naroon rangeland of Taftan area contained more organic carbon than the areas without the semi–circular bunds. A similar increase in soil organic carbon concentrations following the building of semi–circular bund was reported in Sirjan rangelands by Jafari *et al*. (2009). The amount of soil organic carbon was associated with silt and clay due to their higher capacity for holding water and nutrients as compared to sand (Lu *et al*., 2015). Thus, soil particle size distributions play an important role in regulating the capacity of soil to preserve the organic matter. Khosravi (2014) showed that soil organic carbon content significantly increased in the semi–circular bund area with both higher clay and silt contents and lower sand content in Taftan rangelands of Iran. The increase in organic carbon and total nitrogen concentrations resulted mostly from the increase in organic matter returned to the soil and reduced wind erosion due to vegetation recovery and litter accumulation. Also, changes in

species composition could also affect organic matter and nutrient contents (Yong–Zhong *et al*., 2005). The greater species diversity and abundance of the perennial plants in the semi–circular bund area could be attributed partly to higher fertility of the soil. Increases in the soil nutrient levels reflect the accumulation of litter and roots, soil aggregates, and high root activity (Rathore *et al*., 2015). This mechanism occurs in response to two factors .I): the improved vegetation cover is likely to reduce soil erosion while trapping wind–blown, nutrient–enriched, fine materials from surrounding open areas (Wezel *et al*., 2000). II): nutrient enhancement is largely attributable to the plant litter and root mass additions to the soil (Zhang *et al*., 2006). The amounts of nitrogen, phosphorous and potassium increased in the semi–circular bund area; it supports the second hypothesis of this study that we have followed in the introduction section. Higher soil nutrition in the semi–circular bund area can be partially explained by the fact that the canopy cover of a plant is positively correlated with the amount of litter accumulation under its canopy (Li *et al*., 2008; Jafari *et al*., 2009). More canopy cover of the plants may have trapped more nutrients than the lower canopy cover. Lower radiation under plant species reduce soil temperature and evaporative water losses whereas higher organic matter content improves soil water retention, thereby causing soil moisture and rates of litter decomposition to be higher under plant canopies than in the areas without vegetation (Aguilera *et al*., 1999). Thus, more litter accumulation for a longer time may have contributed to higher fertility of the soils.

The values of silt and clay were found to be greater in the semi–circular bund area as compared to the control site. Higher concentrations of branches and denser canopies may have trapped more transported soil, which may have caused more significant changes in soil physical

properties. Singh *et al.* (2005) reported that denser canopies show the strongest positive correlation with soil deposition levels beneath shrub canopies and the distance over which the soil surface materials are transported by the wind decreases. Moreover, large quantities of wind–blown, fine–soil materials are collected in the vicinity of plants by stem–flow and through–fall processes of dust entrapment and deposition (Wezel *et al.*, 2000).

Conclusion

Results showed that semi–circular bund affected the ecologic rangeland properties through direct influences involving soil properties and vegetation cover. There was a significant difference between the area with the semi–circular bund and control. The result of present study showed that this operation greatly affected the habitat characteristics and resulted in vegetation enrichment in the arid rangeland of Taftan. The number of species increased in semi–circular bund area. Species richness was increased as well as plant diversity in the semi–circular bund area. The results indicate that the semi–circular bunds can alter physical soil traits and enhance soil nutrients. In conclusion, semi–circular bund can be an effective tool to enhance diversity and improve soil quality. However, more studies are needed to assess the effect of improvement operations on the reclamation of rangelands in the arid ecosystems.

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چکیده. در مناطق خشک، هلالی آبگیر به‌عنوان یکی از عملیلات اصلاحی مورد توجه می‌باشد که به‌منظور احیاء اکولوژیک پوشش گیاهی و حاصلخیزی خاک استفاده می‌شود. مطالعه حاضر به‌منظور بررسی اثرات هلالی‌های آبگیر بر خصوصیات پوشش گیاهی و برخی خصوصیات خاک در مرتع کوته در استان سیستان و بلوچستان انجام گرفت (سال ۱۳۹۴). در کنار منطقه هلالی‌های آبگیر، یک مرتع بدون هلالی‌های آبگیر به‌عنوان شاهد انتخاب گردید. نمونه‌برداری پوشش گیاهی در پلات‌های ۵ در ۵ مترمربعی و نمونه‌برداری خاک از عمق ۰-۳۰ سانتی‌متر انجام شد. داده‌های پوشش گیاهی و خصوصیات خاک دو سایت با استفاده از آزمون تی جفتی مورد مقایسه قرار گرفتند. در مجموع ۱۶ گونه گیاهی فهرست‌برداری شد که مربوط به ۷ خانواده و ۱۳جنس بودند. نتایج نشان داد که منطقه هلالی‌های آبگیر باعت افزایش حداکثری پوشش، تولید، تراکم گیاهان گردید. کمترین تولید و پوشش گیاهی مربوط به شاهد بود. بیشترین و کمترین غنا و تنوع گونه‌ای به‌ترتیب در منطقه هلالی‌های آبگیر و شاهد اندازه‌گیری شد. pH خاک در منطقه هلالی‌های آبگیر افزایش معنی‌داری در مقایسه با منطقه شاهد داشت. اما هدایت الکتریکی روند مخالفی داشت. نتایج نشان داد که میزان کربن آلی، نیتروژن، پتاسیم، فسفر و کربنات کلسیم در منطقه هلالی‌های آبگیر به‌طور معنی‌داری در مقایسه با منطقه شاهد افزایش داشت (P<۰/۰۵). منطقه هلالی‌های آبگیر میزان رس و سیلت بیشتری در مقایسه با منطقه شاهد داشت. به‌طورکلی نتایج نشان داد که احداث هلالی آبگیر اثر مثبت بر روی خصوصیات خاک و پوشش گیاهی مرتع مورد مطالعه داشت.

کلمات کلیدی: غنای گونه‌ای، جمع‌آوری آب، مراتع خشک، حاصلخیزی خاک