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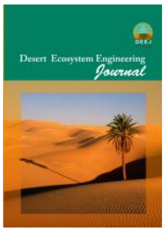

Effects of Semi- Circular Bunds on Composition, Biodiversity and Biomass changes of Vegetation in Semi-arid Rangelands of Bushehr Province

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Abstract

Semi-circular bunds are one of the useful rainwaters harvesting methods in arid and semi-arid areas for restoration and reclamation of rangelands. The aim of the present study was to evaluate the effects of semi-circular bunds on vegetation indices in semi-arid rangelands of Dashtestan county in Bushehr province. For this purpose, a systematic-randomized sampling method was conducted in the restoration (semi-circular bunds) area and control area. In each plot, the vegetation cover percentage was estimated. To compare the different indices such as species composition, biomass, diversity, and species richness between two areas, a t-test was used. The results showed a significant difference between the two areas in terms of all indices ($P<0.05$). The mean comparison showed that these practices had a significant effect on 31 plant species. In addition, comparing the means of indices including the number of species, Simpson and Shannon-Wiener diversity indices and Margalef richness indices showed that the restoration practices led to a significant increase in these indices. However, the Pielou evenness index increased significantly in the control area. Generally, in the semi-circular bunds area, the biomass of grasses, forbs, and total biomass was significantly higher than those of the control area. The RDA analysis showed that valuable species such as *Atriplex leucoclada*, *Hippocrepis unisiliquosa*, *Medicago polymorpha*, *Medicago rigidula*, and *Medicago raditaa* were more present in the semi-circular bund's areas. The results showed that constructing semi-circular bunds had a positive effect on the vegetation indices of semi-arid rangelands in Bushehr province.

Keywords: Margalef richness, rainwater harvesting, restoration, Dashtestan, Bushehr province.

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1. Introduction

In the recent two decades, Iran has experienced extensive or regional drought. Moreover, population growth, uncontrolled urban development, and inappropriate management of water distribution and consumption lead to an increase in the vulnerability of Iran against drought and water crisis. In the very dry climate with low soil moisture content, which is not enough to produce crops and vegetation, performing some water storage practices is of central importance (Khadem et al., 2015). In the rangeland ecosystems, for vegetation reclamation and strengthening its quality and quantity, it is necessary to change the soil moisture regime positively, so that with increasing soil moisture, it is possible to establish and grow the best plant species that were present before the degradation (Holechek et al., 2003). To do so, performing a series of biomechanical practices on the ground surface seems necessary to increase the permeability of water in soil and prevent the formation of runoff and wasting some parts of rainwater. Finally, these practices provide conditions for plant germination and establishment as well as rangeland reclamation through the quantitative and qualitative increase in vegetation (Oweis and Hashem, 2004).

Construction the structures such as contour furrow, terracing, pitting, flood spreading, semi-circular bunds, and Turkey nest are among the methods of collecting and controlling runoff in rangelands. In recent years, the semi-circular bunds systems have been used as an improvement and restoration method in arid and semi-arid rangelands of Iran (Jankju, 2009).

Semi-circular bunds are the curved pits with at least a 1.4 m radius, 30-40 cm depth, 50 cm height, and 40-50 cm thickness. The pond volume of each semi-circular bund is 0.7-1 m^3, which is constructed by labor force or machinery such as tractor and excavator along contours and perpendicular to the slope direction. The factors affecting the designing of semi-circular bunds are runoff volume, the precipitation intensity, the slope of the location, vegetation, type and texture of soil (Saghari et al., 2019).

Considering that such mechanical systems lose their initial efficiency after several years, and also considering the necessity of forage production for arid and semi-arid regions as well as biodiversity conservation, the biological methods are usually used combined with mechanical practices. The biological method is used to create vegetation through seeding, drill-seeding, and planting of high-quality and palatable species or providing proper conditions to grow plants by reducing the competition of low-quality and invasive species (Moghim, 2014).

Some studies performed in other semi-arid and arid regions of Iran indicated the positive effects of semi-circular bunds on production, diversity, and richness of species, as well as increasing the vegetation cover percentage of palatable species, and improving the rangeland condition (Delavari et al., 2014; Rigi et al., 2015; Mahmoudi Mogadam et al., 2016; Abdollahi et al., 2016; Bahmandi and Shahriary, 2017; Khosravi et al., 2016; Saghari et al., 2019).

For many years, the construction of semi-circular bunds has been performed as restoration practices in a large number of rangelands in Bushehr province, especially Dashtestan. Therefore, the aim of the present study was to investigate the effect of semi-circular bunds on vegetation indices in semi-arid rangelands of Bushehr province.

2. Material and methods

The study area is located in Tang-e Eram region of Dashtestan between the latitudes 28° 53’ 24’’ N to 28° 54’ 15’’ N and longitudes 51° 44’ 8’’ to 16° 43’ 7’’E in a mountainous area of Bushehr province. The two trees *Ziziphus spina*-christi and *Ziziphus nummularia* are found in the study rangelands. According to data available for the period of 2006-2018 at the study site from the National Meteorological Information Center of Iran, the mean annual rainfall is 335 mm. The mean annual temperature is 20.5°C. The mean altitude of the study area is 680 m above sea level. Generally, the climate of the study area is semi-arid based on Domarten method. The soils are mainly silt loam in texture.

The vegetation sampling was performed in the three sites, where restoration practices of semi-circular bunds were constructed. In each site, the reclamation practices area (20-hectare), in which semi-circular bunds were constructed, and the control area (19-hectare), where no reclamation practices were performed were selected. The ecology and topography of the control area and reclamation area were similar. Semi-circular bunds 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. 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).

Accordingly, in each of the reclamation practices area (semi-circular bunds) and control area, five transects of 150-m were established and 10 plots of 2-m2 were randomly studied along each transect. In each plot, the vegetation data such as the density of plant species and vegetation percentage were estimated. It is of note that, the minimal area method was used to determine the number of plots required (sample size) (Mesdaghi, 2003). The rangeland production was also estimated in both treatment and control areas using the clipping and weighting method. The samples were correctly identified using the common methods and identification keys with the aid of flora and botanists of the province. Vegetation in the area has changed considerably over the past several decades, primarily due to overgrazing. But the area was under enclosure.

The collected data were analyzed using statistical and ecological software. The effect of semi-circular bunds on vegetation was evaluated as the individual response of species and the response of all species. To evaluate the individual response of available species and the species diversity and richness in two areas, T-test was used in a completely randomized design. The statistical analysis was done in R software. The multivariate analysis methods were used to evaluate the effects of these reclamation practices on vegetation using the CANOCO 5 software (Leps and Smilauer, 2014).

3. Results

3.1. Species composition changes

In the area under the restoration practices of semi-circular bunds, 45 species were identified. In the control area, 45 species were also recorded. *Onobrychis crista-gallii* was only found in the reclamation area and *Bromus tectorum* only in the control area. In the semi-circular bunds, *Medicago rigidula*, *Zygophyllum eurypetrum*, *Capparis spinosa*, *Salsola ntricate* and *Ducrosia anethifolia*, respectively showed the highest canopy cover percentage (Table 1). However, in the control area, *Cressa cretica*, *Centaurea bruguieriana*, *Bromus tectorum*, *Onoprodon leptolepis*, and *Onosma dasytrichum* had the highest canopy cover percentage, respectively (Table 1).

3.2. The individual response of species

Comparing the mean values of canopy cover percentage of 45 common species in both semi-circular bunds and control areas was done using t-test. The results showed the significant effect of restoration practices on 32 plant species (Table 1). The mean values also indicated that in the semi-circular bunds area, the canopy cover percentage of 21 species was significantly higher than that of control (Table 1). Besides, in the control area, the canopy cover percentage of nine species significantly was higher than that of semi-circular bunds (Table 1).

Table (1): Comparing the mean values of canopy cover percentage of common species in both semi-circular bunds (SCB) and control areas in semi-arid rangeland of Bushehr province (the significant t values are bold)

Species	Control	SCB	t-value	P-value
Achillea eriophora	0.06	0.52	**2.69**	0.009
Aegilops umbellulata	0.33	0.36	0.12	0.9
Alhagi mannifera	0.52	0.15	-1.79	0.07
Anabasis setifera	0.16	0.89	**2.45**	0.01
Artemisia aucheri	0.12	0.43	1.07	0.09
Atriplex halimus	0.24	0.68	1.54	0.12
Atriplex leucoclada	0.1	0.55	**2.55**	0.013
Bromus danthonia	0.2	1.2	**3.39**	0.001
Bromus tectorum	1.4	-	-	-
Calotropis procera	0.08	0.47	1.72	0.09
Capparis spinosa	0.25	1.64	**3.07**	0.003
Capsella bursa- pastoris	1.8	0.15	**-4.99**	< 0.001
Carthamus oxyacantha	0.6	0.06	**-2.63**	0.01
Centaurea bruguieriana	1.82	0.09	**-5.09**	< 0.001
Centaurea intricata	0.27	0.3	0.09	0.92
Cichorium intybus	0.18	0.52	1.62	0.1
Citrullus colocynthis	0.32	1.58	**2.77**	0.001
Convolvulus acanthocladus	0.15	0.8	**2.57**	0.01
Cressa cretica	1.89	0.19	**-2.65**	0.01
Ducrosia anethifolia	0.25	1.13	**2.72**	0.008
Echinops dichrous	0.44	0.55	0.35	0.72
Erodium gruinum	0.19	0.89	**2.54**	0.013
Erysimum oleifolium	0.39	0.75	1.25	0.22
Fagonia bruguieri	0.13	0.85	**3.07**	< 0.001
Gundelia tournefortii	0.11	0.32	1.24	0.22
Gypsophila obconica	0.2	0.39	0.96	0.35
Heliotropium ramosissimum	0.09	0.66	**2.65**	0.01
Heteranthelium piliferum	0.58	0.09	**-2.6**	0.01
Hippocrepis unisiliquosa	0.04	0.58	**2.8**	0.007
Hordeum glaucum	0.36	0.02	-2.28	0.13
Hyparrhenia hirta	0.19	0.53	1.52	0.55
Malva parviflora	0.37	0.09	-1.64	0.1
Medicago polymorpha	0.03	1.2	**4.09**	< 0.001
Medicago radiata	0.14	0.94	**3.03**	0.003
Medicago rigidula	0.21	2.47	**4.29**	< 0.001
Oliveria decumbens	0.09	0.6	**2.62**	< 0.01
Onobrychis crista- gallii	-	0.46	**2.79**	0.007
Onoprodon leptolepis	1.01	0.04	**-3.64**	< 0.001
Onosma dasytrichum	1.01	0.06	1.8	0.07
Phalaris minor	0.7	0.14	**-2.59**	0.01
Plantago ovata	0.5	0.09	**-2.03**	0.04
Reseda aucheri	0.67	0.09	**-2.92**	0.004
Salsola imbricata	0.09	1.33	**3.95**	< 0.001
Scabiosa calocephala	0.04	0.45	**2.62**	< 0.001
Teucrium polium	0.07	0.59	**2.87**	0.005
Zygophyllum eurypetrum	0.19	2.05	**4.09**	< 0.001

3.3. Species diversity, richness, and evenness indices changes

The results of t-test for species diversity, richness, and evenness indices in both semi-circular bunds and control areas indicated that all indices, except Menhinick richness, had significant response toward restoration practices of semi-circular bunds. The comparison of the species number and diversity indices (Simpson, Shannon-Weiner) showed that restoration practices of semi-circular bunds resulted in a significant increase in species diversity. Moreover, comparing the mean values of Margalef richness index indicated a significant increase in species richness in the semi-circular bunds area (Table 2). However, the Pielo evenness index showed a significant increase in the control area (Table 2).

Table 2: Comparing the mean values of species diversity and richness indices in both semi-circular bunds (SCB) and control areas in semi-arid rangeland of Bushehr province (the significant t values are bold)

Indices	SCB	control	t-value	P-value
The number of species	9.25	6.5	5.02	< 0.001
Simpson diversity	0.85	0.77	4.03	< 0.001
Shannon-Weiner diversity	2.03	1.67	4.68	< 0.001
Margalef richness	1.87	1.43	3.72	< 0.001
Menhinick richness	1.02	0.96	0.96	0.35
Pielo evenness	0.85	0.89	-2.94	0.004

3.4. Rangeland biomass changes

The ANOVA results for the biomass of grasses and forbs showed that the biomass had a significant response toward the reclamation practices of semi-circular bunds (Table 3). The results of comparing the mean values of biomass indicated that in the semi-circular bunds area, the biomass of grasses, forbs, and total biomass were significantly higher than those of the control area (Table 3).

Table (3): Comparing the mean values of biomass (gr/m2) under restoration practices of semi-circular bunds (SCB) in semi-arid rangelands of Bushehr province (the significant t values are bold)

Biomass	**SCB**	**Control**	t-value	P-value
Grasses	33.85	12.16	**3.4**	0.001
Forbs	125.75	22.31	**16.65**	< 0.001
Overall biomass	159.6	34.47	**21.23**	< 0.001

3.5. Species group response to the restoration

To evaluate the group response of plant species in the study area to two environmental factors (semi-circular bunds and control), the redundancy analysis (RDA) analysis was used, in which the obtained model was significant (F=8.15 and P=0.001). The two-dimension diagram obtained from RDA analysis showed the circles of both semi-circular bunds and control areas, affecting the first axis in two completely opposite directions. The plant species are affected by two environmental factors as big as the length of arrows (Fig. 1). Species including *Atriplex leucoclada*, *Atriplex halibut*, *Aegilops umbellulata*, *Anabas setifera*, *Achillea eriophora*, *Bromus Danthonia*, *Calotropis procera*, *Capparis spinosa*, *Citrullus colocynthis*, *Echinops dichrous*, *Erodium gruinum*, *Fagonia bruguieri*, *Gypsophila obconica*, *Gundelia tournefortii*, *Hippocrepis unisiliquosa*, *Medicago polymorpha*, *Medicago rigidula* , *Medicago radita*, *Onobrychis crista gallii*, *Oliveria decumbens*, *Salsola imbricata*, *Teucrium polium* and *Zygophyllum eurypetrum* were dominant in the reclamation area of semi-circular bunds (Fig. 1). However, species such as *Bromus tectorum*, *Capsella bursa- pastoris*, *Heteranthelium piliferum*, *Cressa cretica*, *Hordeum glaucum*, *Malva parviflora*, *Phalaris minor*, *Plantago ovate*, and *Reseda aucheri* were observed in the control area (Fig. 1). Moreover, species like *Centaurea ontricate* were not affected by the reclamation practices of semi-circular bunds and the control treatment (Fig. 1).

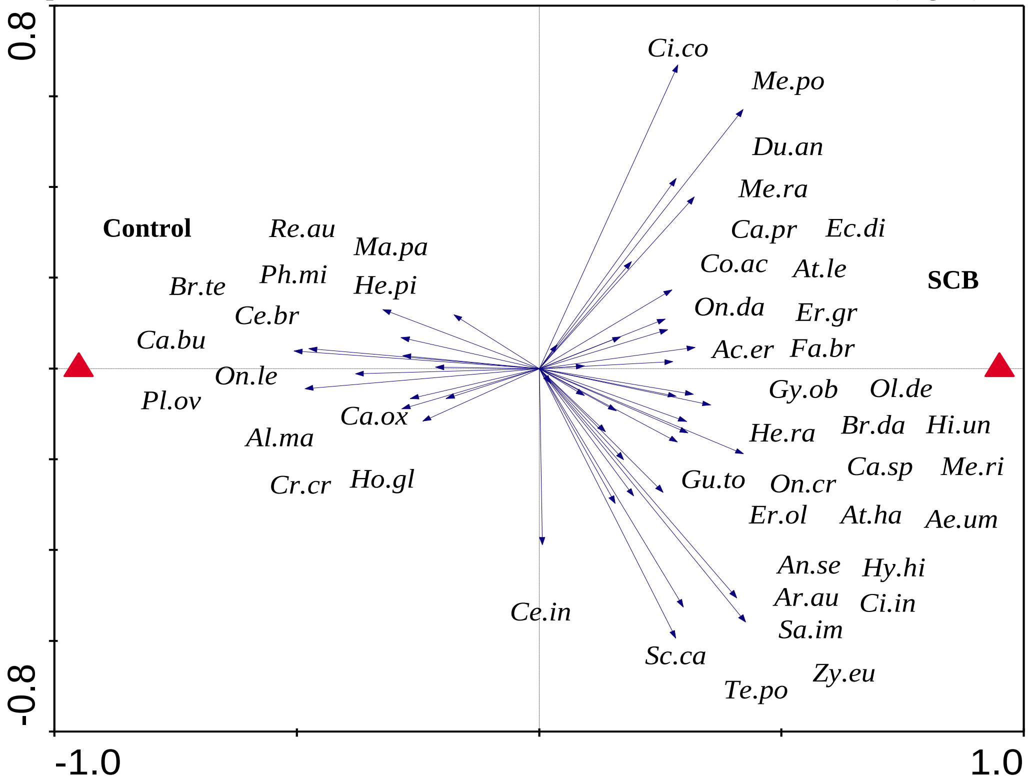

Figure (1): The RDA analysis diagram to evaluate the group response of plant species to the restoration practices (SCB). The full name of species is listed in Table 1.

4. Discussion and conclusion

The lack of soil moisture content in the rangelands of the country is one of the important stresses affecting the life of rangeland plants. When the soil of rangelands loses its permeability to absorb rainwater, mechanical methods are employed in the area to provide infiltration (Jankju, 2009). In arid and semi-arid regions, soil moisture is the most important factor limiting germination and plant growth. Mechanical or biomechanical practices such as pitting, furrowing, contour furrow, and semi-circular bunds are among the rangeland improvement and reclamation methods. Therefore, the construction of semi-circular bunds can provide better moisture condition for plant growth, thereby increasing canopy cover percentage in the area (Moghim, 2014; Al-Rowaily et al., 2015).

The results of the present study indicated that performing semi-circular bund systems in the study area significantly increased the vegetation cover percentage, consequently leading to an increase in the species biomass, diversity, and richness. According to the increased vegetation cover percentage and biomass, it can be stated that the higher moisture content in deep soils naturally helps the establishment of perennials with deep roots (Maestre et al., 2003; Amici et al., 2012). The results of the numerous pieces of research showed that harvesting rainwater methods in rangelands including pitting and contour furrow increased the infiltration rate, thereby increasing species diversity, richness, composition, and biomass (Abdollahi et al., 2015; Khosravi et al., 2016; Saghari et al., 2019).

The results demonstrated that in the restoration area the spices diversity indices were higher than those of the control area, so that Simpson and Shannon-Weiner indices showed significant difference with the control area. Besides, the Margalef richness index of in the reclamation area was higher than that of the control area. The Simpson diversity index is varied between zero and one, showing the possibility of selecting two individuals from one species. Therefore, the closer the index to zero, the lower the diversity is (Delavary et al. 2017). Accordingly, in the semi-circular bunds and control area, Simpson diversity index was calculated to be 0.85 and 0.77, respectively.

These values indicate that both regions have good diversity, but the reclamation area has higher diversity than the control area. The values of the Shannon index usually varies from 1.5 to 3.5, and in exceptional cases, it can be less than 1.5 or more than 3.5. In this study, the value of the Shannon index was estimated to be 2.03 and 1.67 in the restoration and control areas, respectively, indicating a higher diversity in the restoration area. Some scholars also pointed to changes in diversity and richness indices during biomechanical restoration practices, especially semi-circular bunds (Khosravi et al., 2016). It should be noted that since in the study area, many ranchers live and their livestock grazes on the rangeland, grazing affects the diversity of the area, which is in agreement with other studies (Zhao el at., 2011).

In the restoration area, the humidity, and management condition is getting better and results in more uniform vegetation (the vegetation spots are distributed uniformly in the area) and frequency, thereby increasing species diversity compared to the control area (Heshmati et al., 2018). However, the high species diversity and richness in the semi-circular bunds area can be attributed to the seed collection and transfer by wind and water into the pits and formation of a more powerful seed bank compared to the control areas (Rathore et al., 2015). In addition, the cultivation of plant species by seeding and drill seeding such as *Capparis spinose*, *Zygophyllum eurypetrum* and some other rangeland species, as well as shrub planting of *Atriplex halimus* can be explained as a reason for higher diversity and richness of the semi-circular bunds area compared to the control area (Bahmandi and Shahriary, 2016; Saghari et al., 2019).

In the control area, due to the high grazing pressure and the imbalance between livestock and rangeland capacity, the canopy cover and consequently the density was decreased. Grazing pressure initially affects the canopy cover of species, and if the pressure continues for several seasons, it changes the species composition and ultimately reduces species diversity and richness (Rigi et al. 2014; Khosravi et al. 2016). Not only is the effect of grazing on the species composition, density, diversity, and richness of central importance but also the effect of reclamation practices and environmental factors on species diversity and richness, which should be paid attention by natural resources managers.

The results of multivariate analysis showed that the species composition resulted from the restoration practices (semi- circular bunds) is inclined to valuable and palatable species, which is quite clear in the two-dimensional RDA analysis diagram. The changes are also evident in Table 1, which both confirm each other.

In general, the results indicate the positive effect of semi-circular bunds on the reclamation of the study area. If this method is performed with respect to the technical principles together with biological practices, it could be considered as one of the most suitable solutions for optimal use of moisture in arid and semi-arid regions. Therefore, semi-circular bunds lead to an increase in the canopy cover percentage and biomass for livestock use and water storage. Finally, it is suggested that the biological practices in the semi-circular bunds should not be limited to planting trees and shrubs. The use of native shrub species, forbs, and grasses such as *Zygophyllum eurypetrum*, *Medicago sp*. and *Vicia sp*. as well as planting of medicinal plants such as *Capparis spinosa* and other valuable plants should be prioritized. It is necessary to continue the present research in the following years and evaluate the efficiency of reclamation practices in other parts of Bushehr province.

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