Research Article

The Influence of Protection From Grazing on Cholistan Desert Vegetation, Pakistan

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On the Ground

- The information from this study is important for helping promote a more sustainable use of resources, such as grasses and shrubs, and in increasing an understanding of the utilization dynamics and their impact on potential recovery in the study area and beyond.
- This study contributes insight toward ensuring the achievement of conservation measures outside protected areas to restore biodiversity in degraded habitats, through comparing the plant characteristics between a protected and unprotected site.
- This study substantiates other findings, which suggest that using protected areas is one of several strategies that need to be adopted for recovering lost biodiversity and ensure their effective management.
- This study improves our understanding of how shifts in vegetation characteristics resulting from land use change and management can modify the recovery of, in the case of Cholistan, previously grazed vegetation.

Keywords: rangeland rehabilitation, vegetation growth, biodiversity, species composition.

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The growing population and the increasing demand for agricultural products are putting pressure on limited grazing and rangeland resources.[1] Under such scenarios, and especially so in resource challenged ecosystems, much of the biodiversity and production levels are unlikely to be utilized sustainably without effective management.[2] Because biomass production is usually low in resource-challenged ecosystems, the rate of degradation, and eventual desertification, is accelerating because of overutilization.[1] In such ecosystems, effective management is needed for sustainable plant growth and survival, as rainfall availability is unreliable, uncontrolled grazing is high, and soil nutrient status is poor.[2,3] Therefore, strategies that promote sustainable management of biodiversity are needed, for instance, by establishing and maintaining protected areas.[2]

In arid and semiarid areas, animal production is influenced by the quality and quantity of available feed resources.[4] In these areas, overgrazing has reduced the nutritional and productivity levels of many rangelands by up to 25%.[3] Plants grazed by animals, or used for supplementary forage in rangelands, are often generally low in nitrogen, digestible energy, and mineral content.[5] This deficiency reduces overall animal performance and productivity, thus reducing the smallholder farmers' livelihoods and source of income.[6] The current productivity of the Cholistan rangelands in Pakistan, their plant nutrition in relation to livestock grazing, and the trends since independence are largely understudied.[6] Limited nationwide studies on the composition and production changes of grasses and shrubs in the Cholistan area have been carried out,[7] but with less focus toward factors such as the effects of management and herbivory on the composition and production levels of the vegetation. Instead, in semiarid environments such as the Cholistan Desert, conservation approaches and studies have focused on species and growth characteristics, which are considered valuable for certain specific uses (e.g., medicinal properties), overlooking the importance of vegetation structure and ecosystem stability.[8]

Because conservation and management approaches in semiarid environments rarely include measures for examining the value of plant growth contributing significantly to improving pastoralists' livelihood, the outcome is a decrease in species' distribution, resulting in abundance of unpalatable species.[6] In unprotected grazing areas, the overexploitation of resources is of particular concern because these are ecosystems with low resilience.[6,8] In publicly owned areas, unlike in protected areas which are regulated and managed, there are no fences or official delineations for controlling grazing pressure, thus exposing vegetation to overexploitation by pastoralists.[9] Thus, it is essential to understand how differences in vegetation characteristics are adapted toward recovery in previously grazed rangelands as a result of a change in land use and management approaches.

Evaluating the effects of different land use management approaches on vegetation characteristics is important when conserving degraded areas, which potentially require protection in order to aid their recovery.[2] Once the effects of different land uses are evaluated, there will be an understanding of how protecting overutilized areas improves ecosystem stability, and the livelihood of pastoralists, through improving plant community growth and production.[10] Therefore, the objectives of the present study were to assess and compare the effect of protecting an area from grazing for 2 years on changes in standing crop biomass, plant density, plant cover, and frequency in the Cholistan Desert.

Materials and Methods

Site Description

Cholistan is one of the four major deserts of Pakistan in the South of Bahawalpur District, and it extends through the Nara and Thar Deserts of Sindh between 27°42′N and 29°45′N latitude and 69°52′E and 75°24′E longitude, at an altitude of about 112 m (367 ft) above sea level (Fig. 1).[6,7] The climate of the Cholistan Desert is subtropical, arid, and semiarid, with monsoon rainfall influenced by occasional long droughts.[11] The relative humidity is very low with a high rate of evaporation, whereas mean annual rainfall varies between 100 mm (4 in) and 255 mm (10 in). The mean summer temperature ranges between 34 to 38°C (93–100°F), and the winter temperature between 15 and 20°C (59–68°F).[6] Topographically, the area is divided into two geomorphic regions based on parent material, soil, and vegetation.[12] The soil of the Cholistan Desert is very poor in organic matter concentration, and the pH ranges between 8.6 and 10.0 saline and saline-sodic soils, respectively.[7]

The selected study area of 200 ha (494 ac) is located in Din Garh (latitude 28°56'33"N and longitude 71°50'13"E). It is found in the Lesser Desert of Cholistan, managed by the Pakistan Council of Research in Water Resources (PCRWR), and has been fenced since December 2013.[13] The mean yearly precipitation ranges from under 100 mm (4 in for the west) to 200 mm (8 in for the east), falling mostly during the monsoon season (July to September).[13] The rainfall is exceptionally variable in amount and duration, and long droughts are a relatively common feature (at least one event every 10 years). The total amount of rainfall received during the study period was higher than the usual annual amounts received in previous years (Fig. 2).

Mean temperatures are very high in summer (May through August is 34°C [93°F], with highs of 51°C [124°F]

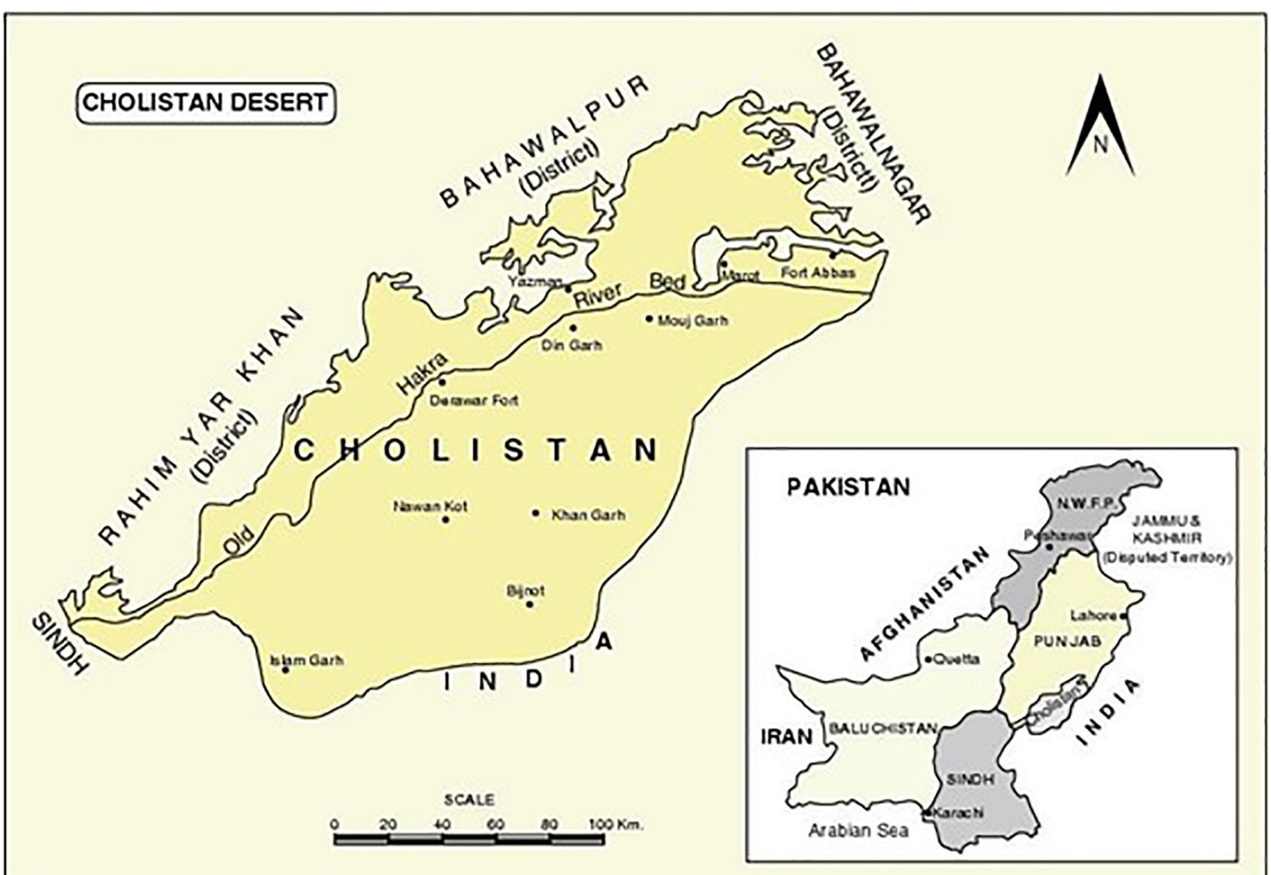

Figure 1. Map of the location of the Cholistan Desert in Pakistan. Source: Akhter and Arshad (2006).

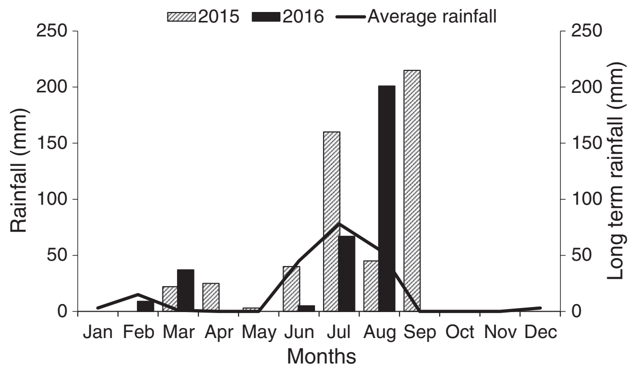

Figure 2. Monthly average rainfall recorded at Din Garh (Cholistan Desert) Bahawalpur (incorporating months during the study period), January 2015 to December 2016, and the average long-term rainfall average for the study area.

occasionally recorded in July and August) and are low in winter, with low incidences of frost. The soil is classified as either saline or saline-sodic, with pH ranges between 8.8 to 9.6.[13] The subsoil water in most places of Cholistan is brackish and unfit for normal plant growth, with underground water at a depth of 30 to 50 m (98–164 ft). The vegetation in the Cholistan Desert is xeromorphic, which is tolerant to environmental stresses such as extreme aridity, high salinity, high temperature, and low nutrient availability.[13]

The dominant plant species of the Lesser Cholistan Desert include the following: *Suaeda fruticosa* (L.) Forssk. (shrubby sea-blite), *Heliotropium strigosum* (Wall.) Kazmi (bristly heliotrope), *Heliotropium crispum* Desf. Fl. Atlant., *Sonchus arvensis* L. (perennial sowthistle), *Salsola baryosma* Forssk. Fl. (saltwort), *Salsola imbricate*, Forssk. (saltwort), *Aristida adscensionis* L. (sixweeks threeawn), *Dipterygium glancum* Boiss (alqa), and *Citrullus colocynthis* (Linn.) Schrad. (bitter apple) (Table 1).[13]

Study Design

The study consisted of the following two treatments: 1) an area fenced off from grazing 2 years before commencing the study (hereafter called "protected"), and 2) an area not fenced off from grazing before commencing the study and also during the study (hereafter called "unprotected"). These two treatments were compared on four 20-ha (49.4 ac) plots for each treatment adjacent to each other, and sampled during fall (November 2015) and spring (April 2016).

Sampling Methodology and Measurements

The study used three transects, 100 m (328 ft) long, parallel to each other and spaced 6 m (20 ft) apart laid out on each of both the protected and unprotected plots. Every 10 m (32.8 ft) within each transect, 1-m^2 (10.8 ft^2) quadrats were laid for monitoring standing crop production, plant

Table 1. List of plant species of Cholistan desert with common or local name, habit, lifecycle, palatability, and preference by grazing or browsing animals

Species	Common/local name	Habit	Life cycle	Palatability		
				S	G	C
Ochthochloa compressa (Forssk.) Chimber	Wire grass	Grass	Perennial	+++	+++	++
Lasiurus scindicus Henr	Sewan grass	Grass	Perennial	+++	+++	+++
Cenchrus ciliaris Linn	Buffelgrass	Grass	Perennial	+++	+++	+++
Cynodon intemedius	Couch grass	Grass	Perennial	+++	++	+
Aristida adscensionis Linn	Sixweeks threeawn	Grass	Perennial	+++	+++	+
Dactyloctenium aegyptium Linn.	Egyptian grass	Grass	Annual	+++	+++	+
Heliotropium strigosum Desf.	Bristly Heliotrope	Shrub	Perennial	Unpalatable		
Salsola baryosma Linn	Saltwort	Shrub	Perennial	++	++	+++
Salsola imbricata Forssk.	Saltwort	Shrub	Perennial	++	++	+++
Haloxylon salicornicum (Moq.)	Saxaul	Shrub	Perennial	++	++	+++
Withania somnifera (Linn.)	Winter cherry	Shrub	Perennial	++	++	++
Calotropis procera Ali	Apple of sodom	Shrub	Perennial	+	+	+
Neurada procumbens Linn.	Creeping thorn rose	Herb	Annual	+++	++	++
Dipterygium glaucum Decne	Alqa	Herb	Annual	++	++	+
Tribulus ochroleucus (Maire)	Bhakhra	Herb	Annual	++	++	+
Heliotropium strigosum Willd	Heliotrope	Herb	Annual	++	++	++
Citrullus colocynthis (Linn.)	Bitter apple	Herb	Perennial	+	-	-

+++ indicates palatable; ++, moderate palatability; +, low palatability; S, sheep; G, goat; C, camel.

frequency, and density. Inside the quadrats, standing crop was clipped at ground level and weighed before oven drying at 85°C (185°F) for 24 hours, to estimate dry-matter (DM) content. The average standing crop was calculated in kg/ha (lbs/ac). To determine plant species cover, species were recorded along each transect using the line intercept method as described by Barabesi,[14] whereas plant density was estimated by counting the number of individuals and dividing by the quadrat's area. Similarly, species frequency was estimated by counting the number of times a plant species occurred in a given number of quadrats. Plant density, measured as plants/m^2 (plants/ft^2), plant species coverage (%), and plant species frequency (%) were calculated based on Louhaichi et al.[10]

During the standing crop determination and species identification procedures, the common plant species in both the protected and unprotected areas were also collected and identified. The oven-dried subsamples of these species were then used for chemical analysis. Plant material was analyzed for nitrogen (N) and phosphorus (P) through digesting the samples in sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2). The N value obtained was used to calculate the crude protein (CP) content of the plant material.[15] Neutral detergent fiber, acid detergent fiber (ADF), and the in vitro organic matter digestibility were determined.[16,17]

The canopy cover of the Cholistan rangeland area was measured using the digital vegetation charting technique,[18] which is based on the use of a high-resolution digital camera to take vertical photographs pointed downward at the time of standing crop sample collection. The camera height was maintained at 1.5 m (4.92 ft) above the ground to ensure that all images had an almost equal surface area. Captured images (125 images in each treatment) were analyzed using an image processing software called VegMeasure software©.[19]

Statistical Analysis

A general linear model, with plant species frequency, plant species cover, and density as continuous variables, was used to evaluate the effects of exposing one area to continuous grazing and another area to protection over a 2-year period on plant characteristics. To factor in the effect of season (time) on biomass, density, species cover, and frequency between the protected and unprotected plots, a repeated measures analysis of variance (ANOVA) was used, with the transects within each plot treated as the replicates. An independent *t* test was used to test for the effects of protecting the area on changes in chemical composition of the sampled species. The data were analyzed using Statistica 8.1.[20] The differences among the means were compared using Turkey's post hoc least significant difference at $P < 0.05$.

Results and Discussion

Effect of Land Use Type on Standing Crop

After the monsoon in 2015, total aboveground standing crop was significantly higher ($P < 0.05$) in the protected area at 597 kg/ha (532.63 lbs/ac), compared with the unprotected area at 170 kg/ha (151.67 lbs/ac), with the same pattern observed in the spring of 2016 (359 kg/ha [320.29 lbs/ac] in the protected area; and 52 kg/ha [46.39 lbs/ac] in the unprotected area) (Fig. 3). Protecting the area from grazing resulted, as expected, in an increase in standing crop compared with the continuous grazing of the unprotected area.

In both protected and unprotected plots, the plant community was comprised and dominated by perennial shrubs and grasses. After monsoon, four species of annual herbs and grasses appeared for a short period: *Tribulus* L. (bhakhra), *Portulaca oleracea* L. (common purslane), *Neurada procumbens* (creeping thorn rose), and *Aristida adscensionis* L. (sixweeks threeawn). In the two seasons under investigation, the dominant grasses were *Dactyloctenium aegyptium* (L.) Willd. (Egyptian grass), *Lasiurus scindicus* Henrard (sewan grass), and *Pennisetum ciliare* (L.) Link (buffelgrass), contributing at least 90% of the total standing crop in the

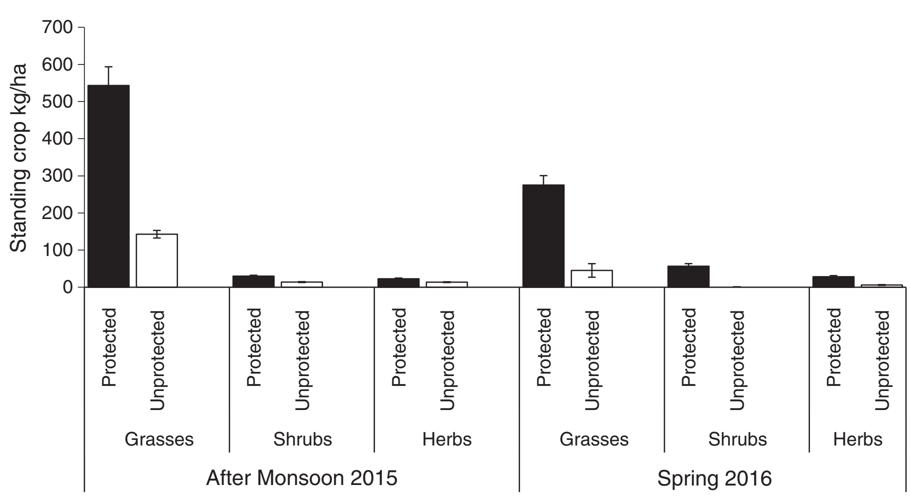

Figure 3. Total aboveground biomass in protected and unprotected plots of Din Ghar after monsoon (2015) and spring (2016) rainfall. Means for grass, shrub, and herb biomass are represented with standard error bars.

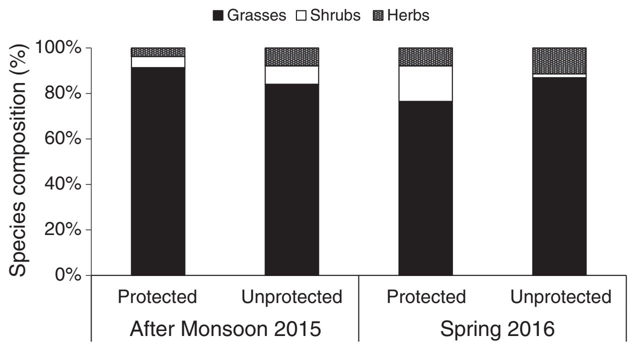

Figure 4. Plant species composition (%) in the protected and unprotected plots after monsoon 2015 and spring 2016.

protected area, especially after the monsoon (Fig. 4). The dominant shrubs were *Salsola imbricate*, Forssk and *Haloxylon recurvum* (saxaul), contributing 4% of the total standing crop composition in the protected area. The unprotected area was also dominated by grasses, contributing at least 80% of the standing crop after the monsoon. In the unprotected area, shrubs, such as saxaul and saltwort, contributed about 7% of the total standing crop measured after the monsoon (Fig. 4).

In spring, the same trend was observed in both areas, with protected and unprotected areas dominated by grass species more than shrubs and herbs. Such growth characteristics reflect the persistence of the grasses compared with shrubs, especially in the unprotected areas. The expectation was that the grass component would be significantly reduced from the standing crop composition, especially in the 2016 sampling period when rainfall levels were lower than those measured in 2015.

Effect of Protection From Grazing on Vegetation Responses

Plant density. Plant density (plants/m^2; plants/ft^2) of grasses after the monsoon season was significantly higher ($P < 0.05$; 90%) in the protected area compared with the unprotected area (82%). However, in spring, the unprotected area recorded higher ($P < 0.05$) grass density (80%) compared with the protected area (71%). The results also indicate that the highest plant density was found in grasses, rather than shrubs and herbs in the protected area (results not shown). Somewhat similar to this study's findings after the monsoon, Belgacem[9] found that plant species density, composition, and plant growth characteristics, such as stem basal area, were higher in protected savanna habitats compared with unprotected savannas in the northwestern part of Benin. These results suggest that protecting a part of an ecosystem to allow a period of recovery is effective in improving vegetation growth characteristics such as biomass, plant density, and species composition. The differences in plant density between the protected and unprotected plots may be explained mostly by a combined effect of animal movement and livestock grazing after the monsoon. Continued livestock browsing, grazing, and trampling effects in unprotected plots reduced seed availability, which impacted the recruitment potential of existing vegetation in the unprotected area. The higher plant density in the unprotected area in spring may be explained by the possible robust regeneration strategy of the plants in the unprotected compared with the protected area. This possibly resulted in higher plant density in the unprotected area compared with the protected area.

Of the grass species found in both the protected and unprotected sites after the monsoon in 2015, sixweeks threeawn (which recorded the highest grass CP content and lower ADF, Table 2) was higher ($P < 0.05$) in density in the

Table 2. Concentrations of total CP, NDF, ADF, ash, and IVDOMD (g/kg DM; oz/st DM) of some of the foliage growing in Cholistan, Pakistan

Lifeform	Species	Family	CP	NDF	ADF	Ash	IVDOMD
Shrubs	Shrubby sea-blite	Chenopodiaceae	119	365	253	235	496
	Winter cherry	Solanaceae	93	389	225	115	547
	Field milk thistle	Asteraceae	85	464	213	135	494
	Saltwort	Amaranthaceae	118	384	203	220	529
	Saxaul	Amaranthaceae	103	375	271	252	548
	Alqa	Capparaceae	94	551	365	113	412
	Sixweeks threeawn	Poaceae	109	710	257	98	388
Grasses	Couch grass	Poaceae	79	659	425	86	452
	Couch grass	Poaceae	92	661	374	65	383
	Egyptian grass	Poaceae	88	701	447	102	386
	Buffelgrass	Poaceae	97	751	466	91	430
	Wire grass	Poaceae	76	654	435	64	386

CP indicates crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; DM, dry matter; IVDOMD, in vitro digestibility of organic matter in dry matter.

Table 3. Effect of growth seasons on plant species density, cover, and frequency during the period extended from fall 2015 to spring 2016 in the protected and unprotected areas

Species	Year	Density (plants/m^2)		Cover (%)		Frequency (%)	
		Unprotected area	Protected area	Unprotected area	Protected area	Unprotected area	Protected area
	2015						
Wire grass *(O. compressa)*		0.66^{a}	0.73^{b}	2.14^{a}	0.05^{b}	5.00^{a}	1.18^{b}
Sixweeks threeawn *(A. adscensionis)*		0.06^{a}	0.02^{a}	22.61^{b}	2.73^{b}	12.51^{a}	9.41^{a}
Saltwort *(S. baryosma)*		0.06^{a}	0.02^{a}	6.27^{a}	0.11^{b}	7.50^{a}	1.18^{b}
Alqa *(D. glancum)*		0.20^{a}	0.13^{a}	3.65^{a}	0.53^{b}	7.50^{a}	1.18^{b}
Saltwort *(S. imbricate)*		-	0.71	-	1.79	-	4.70
Saxaul *(H. salicornicum)*		0.06^{a}	0.17^{b}	0.28^{a}	0.68^{b}	2.50^{a}	4.70^{a}
Bhakhra *(T. ochroleucus)*		5.37^{a}	18.53^{b}	45.14^{a}	61.69^{b}	25.00^{a}	40.01^{b}
	2016						
Wire grass *(O. compressa)*		1.06^{a}	1.06^{a}	-	-	-	-
Sixweeks threeawn *(A. adscensionis)*		-	-	29.44^{a}	29.44^{a}	30^{a}	30^{a}
Saltwort *(S. baryosma)*		0.08^{a}	0.08^{a}	14.59	14.59	10	10
Alqa *(D. glancum)*		0.02	0.02	-	-	-	-
Saltwort *(S. imbricate)*		-	-	14.59^{a}	14.59^{a}	-	-
Saxaul *(H. salicornicum)*		0.02^{a}	0.02^{a}	-	-	-	-
Bhakhra *(T. ochroleucus)*		-	-	83.26^{b}	83.26^{b}	61.03^{b}	61.03^{b}

Note: The means of species density, species cover, species frequency, means within the same row followed by different lowercase letter(s) differ significantly ($P < 0.05$).
* The density, cover, and frequency in the unprotected area were compared with those in the protected area.

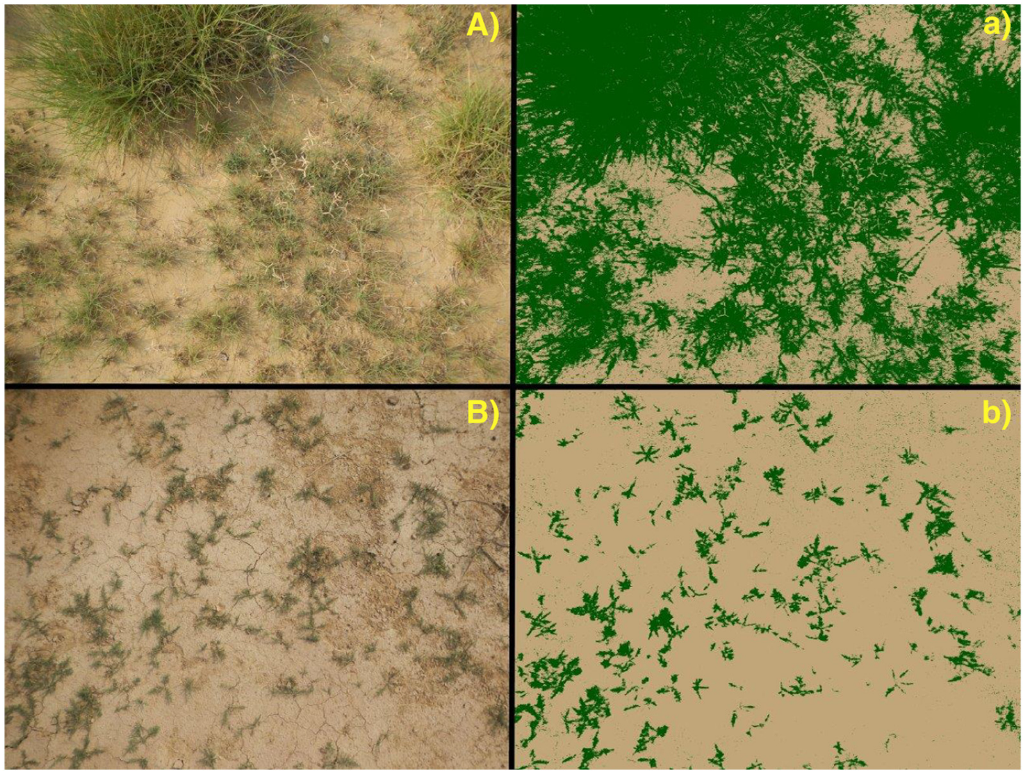

Figure 5. The unprocessed and processed images from the unprotected and protected plots used to monitor vegetation change. **A**, The original/unprocessed image from the protected plot, whereas **a** represents the same image after processing. **B,** The original/unprocessed image from the unprotected plot, whereas **b** represents the same image after processing, after the monsoon (2015) at the Cholistan site. The images were processed using VegMeasure software and interpreted for percent vegetation cover and bare ground after monsoon 2015.

unprotected area (0.06 plants/m^2 [0.67 plants/ft^2]) compared with the protected area (0.02 plants/m^2 [0.22 plants/ft^2]). Its cover and frequency were also higher (P < 0.05) in the unprotected area compared with the protected area (Table 3). During the spring of 2016, sixweeks threeawn recorded no values for the monitored parameters. Of the shrubs found in both sites in 2015, the species density of saltwort (which recorded the highest shrub CP and lowest ADF compared with the other shrubs) was not different (P > 0.05) when comparing both the unprotected and protected sites. For saltwort density in spring 2016, no significant results were observed between the protected and unprotected areas (Table 3).

The abundance of sixweeks threeawn in the unprotected site was surprising considering that this species recorded high crude protein and other nutrition values. The high CP reflects high nutritive value of a particular species to animals that utilize it, whereas a low ADF value of a particular species suggests a high digestible energy of that particular species.[21] Therefore, the expectation was that because of its high CP levels (109 g/kg DM) and low ADF (257 g/kg DM; 57.568 oz/st DM), animals would readily graze it and reduce its density. The same could be suggested for saltwort CP (118 g/kg DM; 26.432 oz/st DM) and ADF (203 g/kg DM; 45.472 oz/st DM), in terms of its growth response after the monsoon and in spring. This higher density of both sixweeks threeawn and saltwort (especially in 2016) in the unprotected sites could be attributed to a robust regeneration strategy of these species after grazing. Grass and shrub species such as sixweeks threeawn and saltwort are equally actively productive during the winter and summer seasons, suggesting an advantage over other grass species (e.g., wire grass) in terms of growth characteristics and abundance.[22]

Vegetation cover, species cover and frequency characteristics. As expected, vegetation cover and bare ground percentages differed significantly (P < 0.05) between the unprotected and protected areas. Vegetation cover was significantly higher in the protected compared with unprotected areas after the monsoon (Fig. 5; Table 4). The same trend was observed in spring 2016, with the protected area showing higher vegetation cover than the unprotected area (Fig. 6; Table 4). Such vegetation cover was likely due to high animal numbers trampling and grazing on the vegetation in the unprotected compared with the protected sites. Of the plants common in both sites in 2015, saltwort and sixweeks threeawn cover were significantly higher in the unprotected (6.27% and 22.6%) compared with the protected area (0.11% and 2.73%).

Sixweeks threeawn and saltwort also recorded higher frequency (P < 0.05) in the unprotected compared with the protected area in

Table 4. Plant and soil % cover in the protected and unprotected areas of Cholistan Desert (values are a mean of 125 pictures)			
Sampling time	**Vegetation cover (%)**	**Soil cover (%)**	**Unclassified**
2015			
Monsoon Protected	53.3	46.5	0.2
Monsoon unprotected	7.3	92.6	0.1
2016			
Spring protected	33.5	66.5	0
Spring unprotected	7.3	92.7	0

* The images were processed using VegMeasure software© and interpreted for percent vegetation cover and bare ground after **monsoon** 2015 and spring 2016 in both the protected and unprotected areas.

2015 (Table 3). No significant differences were observed between the two sites for the two species in terms of species frequency in 2016. Because vegetation measurements were conducted after the monsoon in 2015, the seasonal effect of high rainfall after the monsoon, interacting with herbivory, sparked a positive response by both shrubs and grasses compared with spring, which had low rainfall availability. This resulted in high values of the measured plant characteristics in the unprotected area, which were disturbed through herbivory, compared with the undisturbed protected area. Therefore, it is within reason to suggest that the disturbance in terms of herbivory, interacting with high resource availability in the form of rainfall, sparked an increase in growth response through changes in patterns of carbon allocation in the remaining unbrowsed/ungrazed plant parts, as suggested by Reich et al.,[23] resulting in high species frequency and species cover of the palatable species.

A shrub species common in the two sites, which was present in 2015 but absent in 2016 and which showed different growth

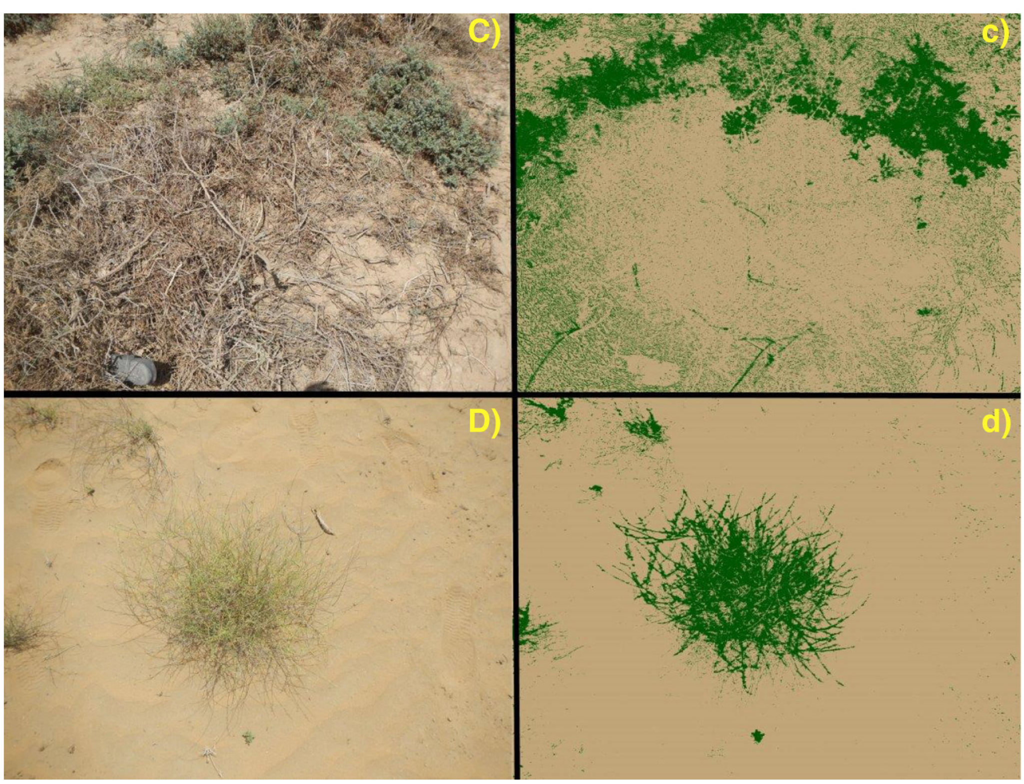

Figure 6. The unprocessed and processed images from the unprotected and protected plot used to monitor vegetation change. **C,** The original/unprocessed image from the protected plot, whereas **c** represents the same image after processing. **D,** The original/unprocessed image from the unprotected plot, whereas **d** represents the same image after processing, after spring (2016) at the Cholistan site. The images were processed using VegMeasure software and interpreted for percent vegetation cover and bare ground after spring 2016

characteristics compared with the grass species, was saxaul. Saxaul recorded high CP content (Table 2), suggesting that it was ideal for browsing by livestock in the area. However, saxaul showed higher cover (0.67% in the protected and 0.28% in the unprotected area) and frequency (4.7% in the protected and 2.5% in unprotected area) in 2015. In 2016, saxaul recorded no values for the monitored parameters, except for low density in both the unprotected and protected areas. Using the CP content of both saxaul and saltwort, it is suggested that the higher CP of saltwort increased its browsing compared with saxaul in unprotected areas, reducing its species frequency cover compared with saxaul. These results also suggest that the higher rainfall in the 2015 sampling period compared with 2016 caused a positive response in terms of growth characteristics of the species monitored. Because of higher rainfall, grasses and shrubs were able to recover well after herbivory, as compared with the spring period in 2016.

Conclusion

In the current study, 2 years of protection from continuous livestock grazing resulted in higher standing crop, plant density, vegetation cover, and species frequency compared with the unprotected area. The most abundant and highly nutritious grass and, in some instances, shrub species responded positively to both grazing exclusion and the availability of resources (rainfall), showing higher density, cover, and frequency in the unprotected compared with the protected area. These results reflect a significant effect of disturbances, through browsing and grazing, on vegetation characteristics in the unprotected area compared with the protected area. As a result, the current study substantiates other findings which suggest that using protected areas is one of several strategies that need to be adopted in order to facilitate and restore lost biodiversity.[21,24] For the study site, the results contribute insight toward ensuring the achievement of conservation measures outside the protected areas and to rehabilitate degraded habitats. Findings are also critical in improving our understanding of grazing effects on vegetation, and how continuous grazing impacts potential vegetation recovery in the study area and beyond.

Generalization of our results should be limited because of the lack of replications of investigated ecosystems in this study site and other areas. In addition, the duration of protection needs further examination as long-term rest may cause negative ecological effects. It is suggested that, in collaboration with local communities, further studies on sound management practices and approaches are required for the improvement of this ecosystem and for reducing the potential of further degradation.

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