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RESEARCH

EFFECT OF GRAZING SYSTEMS ON RANGE CONDITION IN PABBI HILLS RESERVE FOREST, KHARIAN, PUNJAB, PAKISTAN

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Grazing management of rangeland systems has not been well researched in Pakistan; grazing system the most sustainable is not known. In order to evaluate various grazing systems, a study was performed at Pabbi Hills Reserve Forest, Kharian, Punjab. Four simulated grazing treatments, viz. ungrazed control, continuous grazing, seasonal deferred grazing, and rotational deferred grazing, were tested in a randomized complete block design with four replicates. Response variables included species composition, fresh herbage yield, dry herbage yield of grasses and forbs, basal cover, and ground cover. Of the three grazing systems, the six-month seasonal deferred grazing system resulted in a marked increase in basal cover, but had no changes in relative species composition. A significant increase in grass cover and herbage production were also observed in this grazing system, suggesting that the 6-mo seasonal deferred grazing system is the most sustainable rangeland system.

Key words: Sustainable rangeland system, basal cover, species composition, herbage production, ground cover, six-month seasonal deferred grazing system.

Past experience indicates that to make rangeland systems sustainable, and in some cases to recover their condition, strategic rest periods are often necessary. Unfortunately, grazing management of rangeland systems has not been well researched in Pakistan, and it is not known when resting should be used. Pabbi Hills Reserve Forest, about 5 km from the city of Kharian, is an important grazing resource for local village communities, but it is deteriorating, which is a typical condition of many similar areas. It has a rangeland vegetation type that includes the *Acacia modesta* Wall., *Prosopis juliflora* (Sw.) DC., and *Grewia tenax* (Forssk.) Fiori browse plants, and the *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult., *Cymbopogon jwarancusa* (Jones) Schult., *Cenchrus ciliaris* L., and *Cynodon dactylon* (L.) Pers. grasses (Arshadullah *et al*., 2007). The area is badly dissected by erosion and soil fertility is very poor with only 0.53% organic matter (Nizami *et al*., 2004). Mean annual rainfall is 774 mm, mainly concentrated in July and August; the mean daily temperature is 12 ºC in January and 33 ºC in June (Meteorological report 2000 to 2004; through personal communication with Pakistan Meteorological Department, Government of Pakistan). Rainfall for each of the trial years is shown in Figure 1.

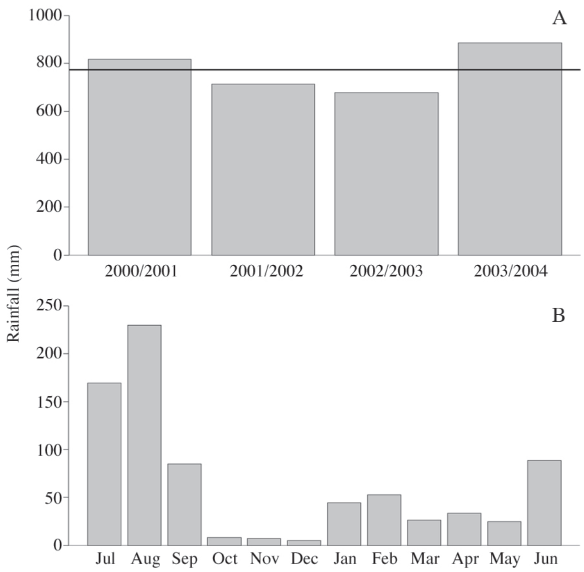

Figure 1. (a) Total annual rainfall at Pabbi Hills Reserve Forest, Kharian, 2000 to 2004. Kharian Meteorological Report (2000-2004), National Agromet Centre, Pakistan Meteorological Department, Government of Pakistan, Islamabad (Personal communication vide Govt. of Pakistan letter no. Agr-2(2) III/2008/04). The thick horizontal line at 774 mm shows the long-term mean rainfall. (b) Distribution of mean monthly rainfall over trial years 2000 to 2004.

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The seasons differed with respect to rainfall, 2001-2002 and 2002-2003 were dry as compared to 2000-2001 and 2003-2004. The 2003-2004 season was the wettest during the grazing trial.

In order to allow long rest periods, the areas at Pabbi Hills Reserve Forest could be rested either from the start of January to the end of June (winter to spring) or from the start of July to the end of December (summer to autumn). Thus, if implemented, this will lead to seasonal aspects of growth and actual plant composition depending on their flowering time. It is proposed that this seasonal aspect be avoided by rotating the rest period in each plot between the first and second halves of the year. The impact of this rotational resting method needs to be tested against continuous open grazing (without resting during the whole grazing season), the proposed 6-mo resting (spring and autumn aspect), and total resting in order to determine which system is likely to give the most sustainable results.

MATERIALS AND METHODS

Experimental design and treatments

To simulate the different types of grazing procedure treatments, the trial was set up in the summer of 2000 with funds from the World Bank for the Punjab Forest Development Project in Pabbi Hills Reserve Forest. The trial ran for 4 yr until 2004. Treatments were implemented at four sites in the grazing area of the Reserve Forest (each site was treated as one replicate). Fencing was fixed or removed from corner posts to prevent or allow, respectively, animal access to the different deferred grazing areas; animals had free access to the unfenced continuous grazing areas. The size of each paddock was 25 × 25 m. Stocking rates were found to be similar among treatments across the four replicates, but it was observed that they would have been high for the range type and its condition.

The experiment was laid out in natural vegetation conditions of Pabbi Hills Reserve Forest in a randomized complete block design with four replicates. The following four simulated grazing treatments were tested: T1: ungrazed control, a single ungrazed plot (protected with total resting for the 4 yr); T2: continuous grazing, a single continuously grazed plot (unprotected with open grazing and no rest period in the year); T3: 6-mo seasonal deferred grazing, two plots to simulate the two 6-mo seasons (January to June winter/spring grazing and July to December summer/autumn grazing); and T4: rotational deferred grazing, with four plots sequentially grazed throughout the year as indicated in Table 1.

Table 1. Grazing schedule of four camps in a simulated four-camp rotational deferred grazing system (Treatment T4). R = resting, G = grazing.

		Camp number			
Year	Season	1	2	3	4
1	January-March	G	G	R	R
	April-June	G	R	G	R
	July-September	R	R	G	G
	October-December	R	G	R	G
2	January-March	G	R	G	R
	April-June	R	R	G	G
	July-September	R	G	R	G
	October-December	G	G	R	R
3	January-March	R	R	G	G
	April-June	R	G	R	G
	July-September	G	G	R	R
	October-December	G	R	G	R
4	January-March	R	G	R	G
	April-June	G	G	R	R
	July-September	G	R	G	R
	October-December	R	R	G	G

Measurements and data collection

Soil surface cover. A pin-bridge with five pins 10 cm apart was used. It was placed over the herbage and the pins were allowed to fall through the plant canopy. Pins touching the base of a tiller contributed to basal cover, while those hitting litter contributed to litter cover. Pins falling to the soil surface contributed to bare ground. The pin-bridge was placed over 20 random points in each plot of each replicate and percentage basal cover, litter cover, and bare ground were determined.

Species composition. A square quadrant with an area of 0.25 m^2 (0.5 m × 0.5 m) was placed at 25 randomly selected points in each plot and all species found within the quadrant were recorded. Species composition of each species was expressed as a percentage of all the species present.

Ground cover. Visual estimates of ground cover were made in each of 10 randomly placed quadrants in each plot. The proportion of ground cover occupied by each of the following parameters was recorded: live green grass, green forbs, dead attached leaf, dead detached leaves, loose on the ground as litter, twigs and rocks, and bare ground. Observations of each parameter were recorded and expressed as a percentage.

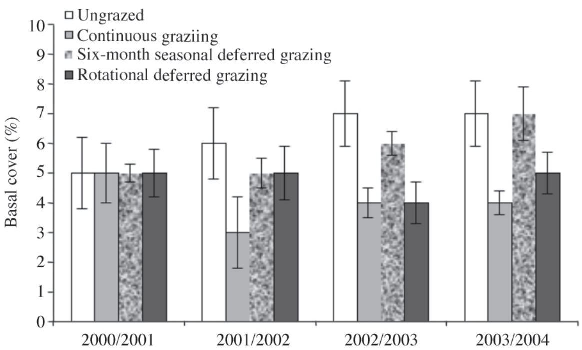
Herbage yield. After observing ground cover, vegetation in the 0.25 m^2 quadrants was cut with a sickle at 30 mm above ground and weighed to determine fresh weight. Each sample was dried to a constant weight in a drying oven at 65 °C. Resulting yields were expressed as kilograms of fresh and dry matter per hectare (kg FM ha^{-1} and kg DM ha^{-1}).

Statistical analysis

Data were collected four times a year during July, October, January, and April. Values were averaged across the year. ANOVA was carried out on the data. Least significant difference (LSD) tests were employed to establish significant differences between treatment means.

RESULTS AND DISCUSSION

Of the three grazing systems, the 6-mo seasonal deferred grazing resulted in a significant increase ($P < 0.05$) in basal cover (Figure 2). Basal cover increased steadily over the 4 yr in the 6-mo seasonal deferred grazing treatment, while the relative change in basal cover was significant only in the fourth year, which can be attributed to the more favorable rainfall in that year. Although litter cover decreased in all the grazing treatments, including the control, a significant decrease ($P < 0.05$) was observed in the 6-mo seasonal deferred grazing system (data not shown). This decrease in litter cover accompanied by the increase in basal cover suggests that litter cover does not play a role in establishing vegetation. This observation does not support the view by Evans and Young (1970), who mention that plant litter covering the soil surface acts as a layer of insulation which moderates temperature and moisture, and creates a more favorable environment for germination and establishment of grass species in rangeland communities. A large area of bare ground was observed at the study site, indicative of past prolonged high grazing pressure, leading to the recommendation that land improvement activities be initiated at the Pabbi Hills Reserve Forest. There were no significant changes observed in the bare ground in none of the grazing treatments during the study period.



SEM: Standard error of mean.

Figure 2. Effect of grazing systems on basal cover of Pabbi Hills Reserve Forest, Kharian. Values are the mean of data averaged across different months of each year; *n* = 4 replicates; error bars indicate ± SEM.

Species composition

The effect of the grazing system on species composition is shown in Table 2 for preferred and palatable species and in Table 3 for non-preferred and less palatable species.

After the 4-yr study, the species composition of the study site was largely maintained. The main grass contributors were separated into 'preferred and palatable' and 'non-preferred and less palatable' species according to Kenney and Black (1984), Fourie *et al*. (1985), Laca *et al*. (2001), Sultan *et al*. (2007), Guru *et al*. (2008); Rahim *et al*. (2008); Sultan *et al*. (2008), Ali *et al*. (2009), Arshadullah *et al*. (2009), and Chaudhry *et al*. (2010). The incidence of these grasses is shown in Tables 2 and 3. *Aristida adscensionis* L. and *Digitaria adscendens* (Kunth) Henrard were annuals, whereas all the others were perennials.

The grasses that were present in trace amounts were *Digitaria sanguinalis* (L.) Scop., *Panicum antidotale* Retz., *Panicum atrosanguineum* A. Rich., *Paspalum distichum* L., *Echinochloa colona* (L.) Link, *Dichanthium foveolatum* (Delile) Roberty, *Brachiaria reptans* (L.)

Table 2. Effect of grazing systems on species composition (%) of preferred/palatable grasses of Pabbi Hills Reserve Forest, Kharian. Data are means of four replicates over a 4-yr period (2000 to 2004).

	2000-2001		2001-2002		2002-2003		2003-2004	
Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
A) Ungrazed (control)								
Bothriochloa pertusa (L.) A. Camus	2	0.8	2	0.2	2	0.2	1	0.3
Cenchrus ciliaris L.	14	2.6	13	2.1	13	2.7	13	2.2
Cenchrus setiger Vahl	1	0.6	1	0.3	1	0.3	1	0.1
Chrysopogon serrulatus Trin.	3	1.4	4	1.7	2	0.2	4	0.6
Digitaria adscendens (Kunth) Henrard	2	1.1	2	0.7	2	0.5	2	0.5
B) Continuous grazing								
Bothriochloa pertusa (L.) A. Camus	1b	0.8	3a	0.3	3a	0.3	4a	0.4
Cenchrus ciliaris L.	14	2.7	14	1.6	13	2.0	14	1.9
Cenchrus setigerus Vahl	1	0.1	2	0.3	1	0.3	2	0.4
Chrysopogon serrulatus Trin.	4	2.2	3	1.2	2	0.7	3	0.7
Digitaria adscendens (Kunth) Henrard	2	1.3	2	0.5	1	0.2	2	0.4
C) Six-month seasonal deferred grazing								
Bothriochloa pertusa (L.) A. Camus	1	0.3	2	0.3	2	0.2	1	0.1
Cenchrus ciliaris L.	15	6.3	14	6.3	15	4.4	15	6.1
Cenchrus setigerus Vahl	1	0.2	2	0.2	1	0.3	2	0.3
Chrysopogon serrulatus Trin.	2	0.9	3	1.3	3	0.8	3	0.8
Digitaria adscendens (Kunth) Henrard	4	2.1	4	1.2	3	1.0	4	1.5
D) Rotational deferred grazing								
Bothriochloa pertusa (L.) A. Camus	1	0.6	1	0.4	1	0.3	2	0.3
Cenchrus ciliaris L.	14	3.5	15	2.5	13	3.4	15	4.6
Cenchrus setigerus Vahl	1	0.5	2	0.3	1	0.2	2	0.3
Chrysopogon serrulatus Trin.	4	1.4	4	1.1	4	1.1	5	0.8
Digitaria adscendens (Kunth) Henrard	3	1.7	3	1.2	2	1.0	2	0.7

Means in a row with different letter differ significantly ($P < 0.05$); SE: standard error.

Table 3. Effect of grazing systems on species composition (%) of non-preferred/less palatable grasses of Pabbi Hills Reserve Forest, Kharian. Data shown are the means of four replicates over a 4-yr period (2000 to 2004).

	2000-2001		2001-2002		2002-2003		2003-2004	
Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
A) Ungrazed (control)								
Aristida adscensionis L.	7	3.1	9	2.8	8	2.4	11	2.5
Cymbopogon jwarancusa (Jones) Schult.	13	0.9	12	0.9	13	0.6	13	1.0
Ochthochloa compressa (Forssk.) Hilu	19	3.2	18	3.5	17	3.3	19	1.4
Heteropogon contortus (L.) P. Beauv.	18	4.3	19	4.3	18	4.9	19	4.8
Sporobolus airoides (Torr.)	24	3.9	23	4.0	23	3.7	22	4.6
B) Continuous grazing								
Aristida adscensionis L.	6	2.6	7	2.8	5	2.3	6	2.0
Cymbopogon jwarancusa (Jones) Schult.	13	2.4	13	2.3	12	1.9	14	2.4
Ochthochloa compressa (Forssk.) Hilu	18	2.4	17	2.2	17	1.8	19	1.3
Heteropogon contortus (L.) P. Beauv.	19a	3.2	18ab	4.1	16ab	3.8	15b	3.3
Sporobolus airoides (Torr.)	23	2.5	22	2.7	20	3.3	18	3.1
C) Six-month seasonal deferred grazing								
Aristida adscensionis L.	6	3.2	8	3.2	6	2.3	6	2.0
Cymbopogon jwarancusa (Jones) Schult.	14	0.7	12	0.6	14	1.1	14	1.2
Ochthochloa compressa (Forssk.) Hilu	19	0.5	20	0.6	19	0.5	18	0.8
Heteropogon contortus (L.) P. Beauv.	17	5.2	19	3.2	18	3.0	20	3.5
Sporobolus airoides (Torr.)	22	1.3	22	1.3	23	1.2	22	1.4
D) Rotational deferred grazing								
Aristida adscensionis L.	6	2.2	7	2.6	6	1.8	8	2.5
Cymbopogon jwarancusa (Jones) Schult.	13ab	0.8	14a	0.3	12b	0.5	13ab	0.6
Ochthochloa compressa (Forssk.) Hilu	18	3.8	18	4.2	17	4.0	18	2.8
Heteropogon contortus (L.) P. Beauv.	17	5.1	16	5.1	15	4.6	16	4.8
Sporobolus airoides (Torr.)	23	1.5	22	1.2	21	1.4	23	1.5

Means in a row with different letter differ significantly ($P < 0.05$); SE: standard error.

C.A. Gardner & C.E. Hubb., *Paspalidium flavidum* (Retz.) A. Camus, *Dactyloctenium aegyptium* (L.) Willd., *Dactyloctenium scindicum* Boiss., *Chloris incompleta* Roth, and *Cynodon dactylon* (L.) Pers. The major forbs/herbs of the study area were *Tribulus terrestris* L., *Trianthema portulacastrum* L., *Euphorbia prostrata* Aiton, *Artemisia ludoviciana* Nutt., *Heliotropium europaeum* L., *Cardiospermum grandiflorum* Sw., *Abutilon indicum* (L.) Sweet, *Evolvulus alsinoides* (L.) L., *Malvastrum coromandelianum* (L.) Garcke, *Cyperus niveus* Retz., and *Cyperus rotundus* L. The major shrubs and trees were *Grewia tenax* (Forssk.) Fiori, *Prosopis juliflora* (Sw.) DC., and *Acacia modesta* Wall.

There was no significant effect of the grazing system on the change in composition of most of the grass species. This is in line with Dormaar *et al*. (1997), who studied a rotational grazing system with an ungrazed control and reported that the species distribution was unchanged between the two treatments. Whereas significant increases in species composition and forage production were observed with the protection of Margala National Park and the Lohiber Range area in the sub-tropical sub-humid zone (Mohammad and Naz, 1985), *H. contortus* decreased significantly (Table 3) after 4 yr of continuous grazing in this trial; this might be due to the fact that it does not develop sharp awns if it is consistently grazed (Kika de la Garza, 1999) and its population tends to decrease under heavy grazing (Hatch *et al*., 1999). *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult. is considered to be a nutritious palatable grass (Chaudhry *et al*., 2001). In free grazing rangeland, Rahim *et al*. (2008) suggested that the potential intake rate (PIR) was a useful preference indicator. In a trial reported by Sultan *et al*. (2008), the highest PIR was observed for *H. contortus*. However, despite its high PIR values, the results of the study by Sultan *et al*. (2008) also showed a relatively lower preference for *H. contortus*. This decrease in the preference for *H. contortus* might be due to the presence of awns that make it less palatable. The decrease in *H. contortus* under continuous grazing was accompanied by a significant increase in *B. pertusa* ($P < 0.05$) (Table 2) due to its creeping habit that makes it difficult for stock to graze. *Bothriochloa pertusa* (L.) A. Camus has been reported as turning out to be dominant in heavily grazed pastures (Hussain *et al*., 1982; Truong and McDowell, 1985).

Ground cover

Perennial grasses mainly contributed towards cover and composition, whereas forb contribution was minimal. There was no significant effect of rotational deferred grazing on the study site's ground cover. The results of the present study revealed that grass cover was significantly decreased in continuous grazing ($P < 0.05$), whereas a highly significant increase in grass cover was observed in the ungrazed control and in the 6-mo seasonal deferred grazing system (Figure 3). The increase in grass cover of ungrazed areas was also mentioned by Mohammad and Naz (1985), who observed a significant improvement in average percentage cover of major forage species after a 1-yr protection at Khawarmung (Kashmir) in the sub-tropical sub-humid zone. In the 6-mo seasonal deferred grazing, an increase in grass cover can be associated with a decrease in forbs and detached litter since a significant

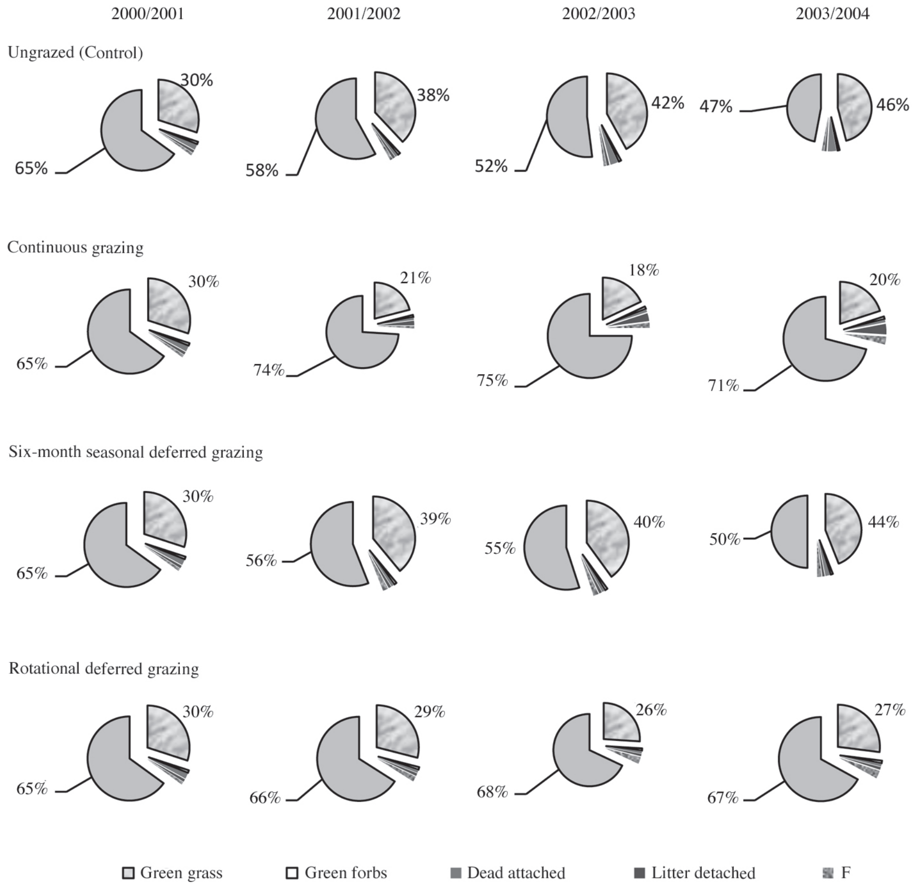
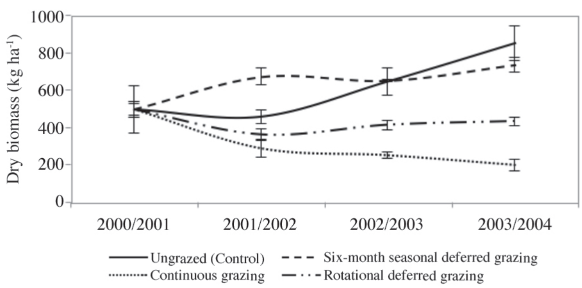


Figure 3. Effect of grazing systems on ground cover (%) of Pabbi Hills Reserve Forest, Kharian. Data shown are means of four replicates over a 4-yr period (2000 to 2004).

decrease (P < 0.05) in green forbs, detached litter, and bare ground was also observed. With the significant decrease in green grass under continuous grazing of the area, detached litter increased significantly over the 4-yr study. This increase in detached litter was probably due to the fact that the area remained totally unprotected from grazing animals.

Herbage yield

Plant life forms of perennial grasses, annual grasses, and forbs were included in the herbage production calculation. A significant increase (P < 0.05) in fresh and dry herbage yield of 6-mo seasonal deferred grazing was observed over the 4-yr study. This increase in herbage yield was comparable to the ungrazed control treatment in which a significant increase in herbage yield was recorded. These results are in line with Mohammad and Naz (1985), who observed five times more forage production in the protected area than the open area in the sub-tropical sub-humid zone (which covers Pothwar tract and Salt Range). On the other hand, there was a significant decrease (P < 0.05) in herbage production during 4 yr of continuous grazing. In rotational deferred grazing, the decrease in dry biomass was not significant (Figure 4; P < 0.05). The dynamics of herbage production is considered to be influenced by grazing severity attributable to the destruction of shoot apices resulting in a lower growth rate as shown in *Cenchrus ciliaris* L. and *C. setiger* Vahl grasslands (Shankarnarayan, 1977). However, with grazing deferment, herbage production during the main growing season could be maintained even under heavy grazing pressure (Gutman *et al.*, 1999).



Values are the mean of data averaged across different months of each year; *n* = 4 replicates; error bars indicate ± Standard Error of Mean

Figure 4. Effect on dry biomass of ungrazed (control), continuous grazing, six-month seasonal deferred grazing, and rotational deferred grazing.

CONCLUSIONS

The present study concludes that 6-mo seasonal deferred grazing performed better than other grazing treatments during the 4-yr study. Although there was no significant change in species composition, the significant increase in basal cover, ground cover of green grass and forbs, and increase in herbage yield were comparable to that of the ungrazed control, making it the most suitable grazing system for the area.

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Efecto de los sistemas de pastoreo en la condición del pastizal en la Reserva Forestal Pabbi Hills, Kharian, Punjab, Pakistán. El manejo del pastoreo de sistemas de praderas no ha sido bien estudiado en Pakistán y no se sabe cuál sistema de pastoreo es más sustentable. Con el fin de evaluar los diferentes sistemas de pastoreo se realizó un estudio en la Reserva Forestal Pabbi Hills, Kharian, Punjab. Se probaron cuatro tratamientos de pastoreo simulado: control sin pastoreo, pastoreo continuo, pastoreo estacional diferido, y rotación de pastoreo diferido, en un diseño en bloques completos al azar con cuatro repeticiones. Las variables de respuesta fueron: la composición de especies vegetales, rendimiento de forraje fresco y de forraje seco de gramíneas y herbáceas, rendimiento de forraje basal y la cobertura del suelo. De los tres sistemas de pastoreo, el sistema de pastoreo estacional diferido 6 meses resultó en un marcado aumento en la cobertura basal, pero no cambios en la composición relativa de las especies. Un aumento significativo en la cobertura de pastos y la producción de forraje se observaron también en este sistema de pastoreo, lo que sugirió que el sistema de pastoreo diferido por 6 meses en la temporada fue el sistema más sustentable de los pastizales.

Palabras clave: sistema de pastoreo sostenible, cobertura basal, composición de especies forrajeras, producción forrajera, cobertura de suelo, sistema de pastoreo diferido estacional de 6 meses.

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