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Original Article

Impact of rangeland enclosure and seasonal grazing on protected and unprotected rangelands in Chakwal region, Pakistan

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Abstract: Scrub rangelands support livestock grazing and provide ecosystem services to their inhabitants. The present study was conducted in Chakwal, an important tract of the Pothwar Plateau, which sustains herds of small domestic and nomadic ruminants. Urbanization and uncontrolled grazing practices have reduced rangeland productivity and increased soil erosion and resulted in poor land conditions. This study assessed the influence of two years of rangeland protection on aboveground vegetation biomass and the chemical composition of plants and aimed to determine the influence of seasonal grazing on the live-weight gain of small ewes. Using the line intercept method, vegetation data from protected and unprotected plots in 2015 and 2016 were collected at two sites, Dhulli and Begal. Vegetation cover was assessed from images using VegMeasure. Results showed that protected study sites displayed higher vegetation biomass (834 and 690 kg ha^{-1}) compared to the unprotected study site

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(477 and 326 kg ha^{-1}) during April and August of both years. In the seasonal grazing trial, the experimental ewes that grazed on protected rangelands showed higher live-weight gain (33–63 g day^{-1}) compared to live weight of ewes (17–21 g day^{-1}) that grazed on unprotected rangelands during the experimental period of 127 days at both sites. The results suggest that the Chakwal rangeland has tremendous potential to improve vegetation productivity but modern livestock management and seasonal grazing practices are needed to improve carrying capacity and livestock productivity.

Keywords: Seasonal grazing; Climate change; Productivity; Rangeland; Protected area

1 Introduction

In arid and semi-arid areas, timing and the amount of rainfall are the key factors determining the diversity of vegetation, nutritive quality and higher productivity of usable forage in rangelands (Chauvin et al. 2014). However, the variability in precipitation, and fluctuation in temperatures make most rangelands vulnerable to degradation (Reynolds et al. 2007). The effects of climate change in dry areas are reflected in biodiversity losses and reduced net primary productivity of rangelands under poor management practices. These effects can only be reversed through improved conservation management practices such as controlled grazing (Poyry et al. 2004). In rangelands, when the forage is low in quantity and quality, shrubs and trees provide more nutrients than grasses to grazing animals such as crude protein (Bowman et al. 1991). However, in dry seasons, forage quantity and quality become more critical and seriously impacts growth and productivity of grazing animals (John 2001).

In rangelands in developing countries, unmanaged anthropogenic activities coincident with persistent drought have resulted in land degradation and desertification (FAO 2010). The literature in south Asia, especially Pakistan, indicates that rangeland rehabilitation in most of these regions has not been successful (Mansoor et al. 2018). These failures have been attributed, in part, to donor preferences, which tend to have a physical and technical focus rather than a focus on the socioeconomic and cultural needs of the local people (Mureithi et al. 2010). According to Verdoodt et al. (2010), social enclosures by local communities remained successful in combating land degradation in rangelands. However, few scientists have recommended closing off areas from grazing for specific periods as an option to restore degraded rangelands and maintaining the socioeconomic wellbeing of local communities (Wernersson 2013). Increasing anthropogenic activities in the recent past have overburdened rangeland resources (Mansoor et al. 2018). Large herds are over-grazing grasses and an increasing human population is exploiting already sparse trees for fuel and timber resulting in severe degradation (Ulziibaatar and Matsui 2021). This degradation has affected ecosystem productivity and hampered the growth of both livestock and human populations dependent on these resources (Shah et al. 2015; Mansoor et al. 2018). Various scientific methods have been applied to conserve and restore rangelands vegetation diversity and biomass production but the most efficient and effective method is exclosure from unmanaged grazing on vegetation biomass and vegetation composition (Ullah et al. 2015; Qasim et al. 2017). Similar studies incorporating this strategy experienced significant increases by as much as 74% in aboveground plant biomass in protected sites (Qasim et al. 2017). An arid steppe rangeland in El Gono, Tunisia protected for 12 years resulted in a 29% increase in plant biomass and better animal health (Jeddi and Chaieb 2010). A similar study conducted in the desert steppes of China showed a 65% increase in a biomass production of protected rangeland as compared to free grazing (Rong et al. 2014).

In Pakistan, Pothwar scrub rangelands occupy an area of 1.68 million ha. This region is the most productive rangeland in the country (Mansoor et al. 2020). However, in recent times, the productivity of these rangelands has shown a significant downward trend (Munawar et al. 2018) mostly due to the lack of proper grazing systems, over exploitation of resources and urbanization (Hussain et al. 2009). Nomadic grazing is the most prevalent grazing system in these rangelands and is responsible for rapid degradation of range resource in terms of biomass production and palatable range species (Shah et al. 2015) and the number of livestock is continuously on the rise, leading to a shortage of feed and forage resource, especially in the winter months (Ahmad et al. 2012; Mansoor et al. 2018). Uncontrolled grazing and irregular distribution of rainfall has negatively affected the livelihoods of poor livestock keepers (Amir and Gillani 2019). There is, therefore, a need for more effective measures to prevent further degradation without affecting the livelihoods of local people.

Husbandry systems are nomadic or settled. Nomad stock owners come from Punjab and Khyber Pakhtunkhwa Provinces in Pakistan (Amir and Gillani 2019). They have large herds and often practice full pastoralism, while local farmers are settled agro-pastoralist with small to medium herds. The aim of the Agriculture Innovation Program was to protect degraded rangeland areas and measure biomass productivity over time. A second aim was to develop a model for local communities to assess the amount of forage at the time of monitoring after spring and monsoon rainfall as a basis to estimate the optimal stocking rate and evaluate the impact of seasonal grazing on their livestock productivity.

The objective of the present study was to assess the impact of seasons on the biomass and nutritional quality of range vegetation in protected and unprotected sites and consequently on livestock performance. Ewes were allocated according to calculations based on stocking rate (head ha^{-1}). In this way, 18 and 12 ewes were allowed in protected and unprotected grazing areas for two consecutive years (2015–2016).

2 Materials and Methods

2.1 Study sites

Chakwal District is in the Pothwar Plateau where settled agro-pastoralists graze their livestock and nomadic pastoralists came from the Punjab and Khyber Pakhtunkhwa Provinces of Pakistan and pass through Chakwal in the winter months. The study areas are Begal and Dhulli villages in Chakwal District, (33°02'48.77" N 72°39'01.12" E) and Dhulli (33°02'48.77" N 72°39' 01.12" E), North Punjab, Pakistan in a hilly region of the Pothwar Plateau. The soils have developed from a wide range of parent material consisting of loess, piedmont alluvial, river alluvium deposits, mountain outwash and stream valley deposits. The study areas also experience heavy soil erosion. The average high air temperature is 38°C in summer and 1°C in winter. Annual precipitation in Begal is approximately 500 mm and of Dhulli is approximately 300 mm. At both sites, about 80% of annual precipitation occurs in summer season from July to September.

The dominant plant species at both sites are: *Cenchrus ciliaris* (L.), *Bothriochloa pertusa* (L.) A.Camus, *Cymbopogon jwarancusa* (Jones) Schult., *Saccharum spontaneum* L., *Aristida depressa* Retz., *Desmostachya bipinnata* (L.) Stapf, *Poa annua* L., *Saccharum munja* Roxb., *Heteropogon contortus* (L.) P.Beauv. ex Roem.& Schult., *Dichanthium annulatum* (Forssk.) Stapf, *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult. *Cymbopogon jwarancusa* (Jones) Schult. and *Panicum antidotale* Retz. The dominant tree and shrub species at both sites are *Acacia modesta* Wall., *Acacia nilotica* (L.) Willd. ex Delile, *Tamarix aphylla* (L.) Karst., *Grewia oppositifolia* Buch.-Ham. ex D. Don, *Acacia farnesiana* (L.) Willd., *Ziziphus mauritiana* Lam., *Tecomella undulata* (Sm.) Seem., *Calligonum polygonoides* L., *Carissa opaca* Stapf, *Gymnosporia royleana* Wall. ex M.A. Lawson, *Prosopis cineraria* (L.) Druce., *Periploca aphylla* Decne.

2.2 Sampling design and aboveground vegetation biomass estimation

In September 2014, after discussion with the local authorities, 50 ha at each site were designated to be protected. Protected sites were further divided into three blocks, and three blocks of the same size were marked outside the protected sites. Hence, study comprised two treatments 1) area was fenced off from grazing and protected for two years before the commencement of the study and 2), a similar area was not fenced and unprotected. During 2015 and 2016, data on aboveground vegetation biomass production were collected twice every year, once after the spring and once after the summer monsoon rains. This period was selected because the peak biomass could be achieved, especially after the rainy months of April and July every year. The first sampling for vegetation characteristics was carried out in April 2015 using the line intercept method of Herrick et al. (2015). The same procedure was repeated in August 2015, April 2016 and in August 2016. Three transects of 100-meters each were laid out in three directions parallel to each other in each block. A one-meter square quadrate was used at 10 m intervals along transect lines and standing forage was clipped at 3–4 cm above ground level to allow for plant regeneration (Ahmad 2011). The collected aboveground plant biomass was oven-dried at 60°C for 48 hours and weighed to measure dry plant biomass production. A total of thirty quadrates were collected from each block.

2.3 Vegetation canopy cover

The canopy cover of the Begal and Dhulli rangeland vegetation in protected and unprotected grazing sites was estimated using a high-resolution Nikon digital camera 134 following a digital vegetation charting technique protocol (Louhaichi et al. 2017). The camera height was maintained at 1.5 m so that images were comparable. Captured Images were analyzed using VegMeasure software to estimate percent vegetation versus percent bare soil. VegMeasure® is a computerized vegetation measurement program developed by the Department of Rangeland Ecology and Management at Oregon State University (Louhaichi et al. 2010).

2.4 Chemical composition of plants

The oven-dried sub-samples of all species were used for chemical analysis. Plants were digested using the Kjeldahl method (Estefan et al. 2013). The digested aliquot was analyzed for total nitrogen (N), phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg) in plant samples. For crude protein estimation, the concentration of total N in plant samples was multiplied by 6.25 (Estefan et al. 2013). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to AOAC (1990).

2.5 Stocking rates of small ruminants

After a preliminary survey of rangeland productivity and community composition, stocking rates were calculated using the methodology of Holechek et al. (2003). In 2015, the stocking rate in the protected areas was set at 6 and 4 animals ha^{-1} month^{-1} and 4 and 4 animals ha^{-1} month^{-1} in unprotected plots at Dhulli and Begal sites. After the monsoon rainfall, the stocking rate in the control area was set at 6 animals ha^{-1} month^{-1} and 4 animals ha^{-1} month^{-1} at the Dhulli and Begal sites. The selection of 6 animals means the calculated stocking rate based allowed for grazing on a 1 ha area. In 2016, the stocking rate in the protected area was set at 2.7 and 2 animals ha^{-1} month^{-1} and 1.4 and 1.3 animals ha^{-1} month^{-1} in unprotected plots at Dhulli and Begal sites. After the monsoon rainfall, the stocking rate in the protected area was set at 5.8 and 6 animals ha^{-1} month^{-1} and 2 and 2.3 animals ha^{-1} month^{-1} in the control plots at Dhulli and Begal sites.

The experimental ewes were allowed to grazing 6 to 8 hours daily before the monsoon (May 23, 2015 to July 20, 2015) and after the monsoon seasons (August 21, 2015 to October 27, 2015). All the ewes were ear-tagged and drenched in anthelmintic (Nilzan Plus @ 1ml/kg body weight) before the start of the experiment. The live-weight gain data were collected on the first day, followed by 15 day intervals until the end of the experiment.

2.6 Statistical analysis

The yearly biomass production, nutritive quality and live-weight gain were analyzed using *t-test* to compare protected and unprotected rangeland sites using Statistix 8.1. A one-way ANOVA was used for analysis of data belonging to proximate composition of the native vegetation of Chakwal (CP, ADF, NDF, P, Ca, Mg and K) within each season (spring and summer). However, a two-way ANOVA was used to analyze the grazing data in two seasons of a year and for protected and unprotected sites. The threshold used for determining statistical significance was $p<0.05$.

3 Results

3.1 Rainfall pattern during study period

The long-term average annual rainfall for the Begal and Dhulli sites are 550 and 350 mm, while annual rainfall recorded during 2015 and 2016 was 748 and 419 mm at Begal and 425 and 218 mm at Dhulli. The rainfall amount and pattern during rainy seasons in 2015 was higher and in 2016 lower than the long-term annual average. Precipitation deficits were seen in the summer of 2016 (June-August) and some spring quarters (March-May). In 2016, Dhulli and Begal area received 70% and 48% less rainfall from January to the end of April 2016 compared to 2015 (Fig. 1a and 1b).

3.2 Aboveground vegetation biomass production

In the summer of 2015, the rangeland was more productive due to high monsoon rains along with continuous low rainfalls in the following months. In 2016, both sites received low monsoon rains, followed by a dry spell from September to December. In the summer of 2016, Dhulli and Begal received 50% and 70% less rainfall compared to 2015.

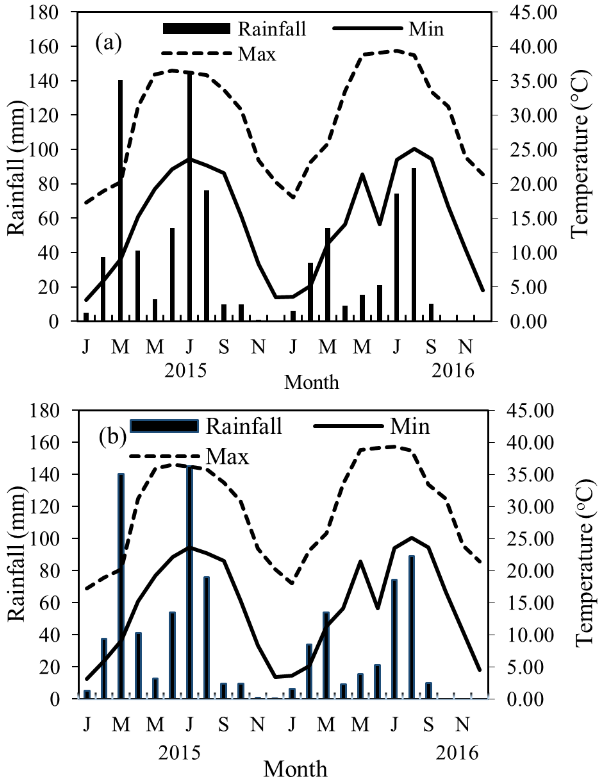

Fig. 1 Rainfall (Bars) and maximum and minimum temperature at Begal (a) and Dhulli (b) during 2015 and 2016.

The average biomass production differed significantly between study sites. The results showed that in May 2015 after the winter rains, total biomass in the protected area was higher (834 and 690 kg ha⁻¹ at Begal and Dhulli sites respectively) than in the unprotected area where it was only 477 and 326 kg ha⁻¹ at Begal and Dhulli sites respectively (Fig. 2a and b). During the monsoon in August, total biomass in the protected area was higher (1,100 and 745 kg ha⁻¹ at Begal and Dhulli sites respectively) compared to the unprotected area where it was 534 and 423 kg ha⁻¹ at Begal and Dhulli sites (Fig. 2a and b).

After a five month rest period in the protected areas (November 2015 to March 2016), vegetation sampling was performed again after the spring rains in April 2016 in the protected and unprotected plots. The total aboveground biomass in the protected sites was 300 and 228 kg ha⁻¹ which was higher compared to the unprotected sites (176 and 137 kg ha⁻¹) (Fig. 2a and b). After the monsoon, the vegetation sampling was repeated in August 2016 at both sites. In the second season of the study, biomass values were 827 and 600 kg ha⁻¹ which were far more compared to the unprotected sites with values of 302 and 214 kg ha⁻¹ (Fig. 2a and b).

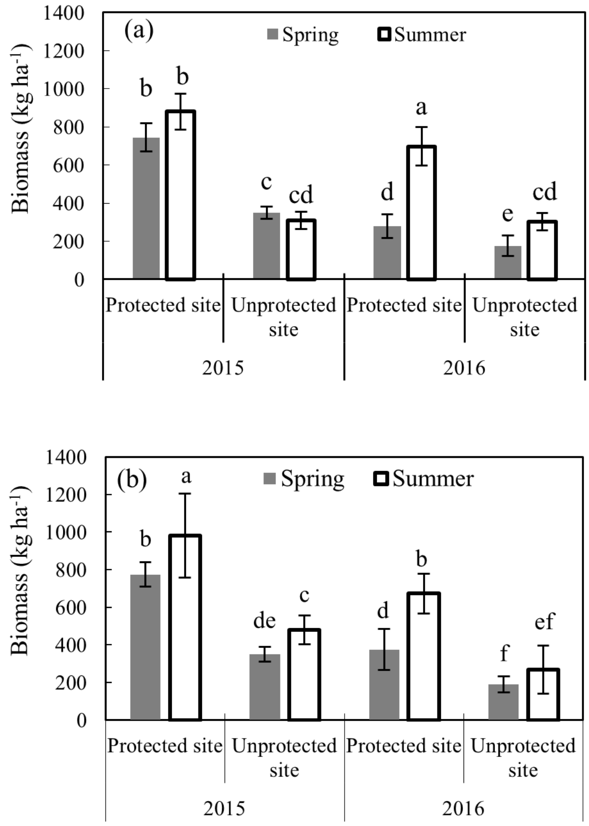

Fig. 2 Mean ± SD of total aboveground dry-matter production at Begal (a) and Dhulli (b) in protected and unprotected plots in spring and summer during 2015 and 2016. Bars of a given site with different letters are significantly different at $p<0.05$.

The increase in biomass was 43% and 41% in Begal after spring rainfalls in 2015 and 2016 respectively compared to the unprotected site. Similarly, at the Dhulli site, increases in biomass were 53% and 40% in 2015 and 2016 compared to the unprotected site. Compared to the unprotected site, an increase in biomass was also observed after the summer monsoon rains in both sites. The increase at Begal site was 51% and 63% in 2015 and 2016. At the Dhulli site, this increase was 53% and 64% in 2015 and 2016.

3.3 Vegetation canopy cover

The photographs taken in April 2015 and August 2015 were used to assess the difference in percent cover of vegetation and bare soil (Fig. 3). The plant cover was higher in the protected grazing sites at both study locations (Fig. 3). In 2015 at Begal, plant cover was 82% and 18% in the protected and unprotected sites after the winter rains. After the monsoon, plant cover was 61.6% and 38.2% in the protected and unprotected grazing site (Fig. 3). In the same year, after the winter rains at the Dhulli site, plant cover was 21.7% and 78.3% in the unprotected and protected grazing sites; whereas after the monsoon, plant cover was 26.3% and 73.7% in the unprotected and protected sites (Fig. 3).

At both sites, grasses accounted for approximately 60% of the total biomass of the area, of which 25% of these grasses were unpalatable (Table 1). The low rainfall did not affect the biomass production or unpalatable invasive grass species such as *Desmostachya bipinnata*, *Saccharum munja*, *Saccharum spontaneum* and shrubs *Carrissa opaca*, and *Gymnosporia royleana*, which became dominant and reduced the potential stocking rate. *Desmostachya bipinnata* grass patchers were larger than other species in areas near watering points due to its invasive nature.

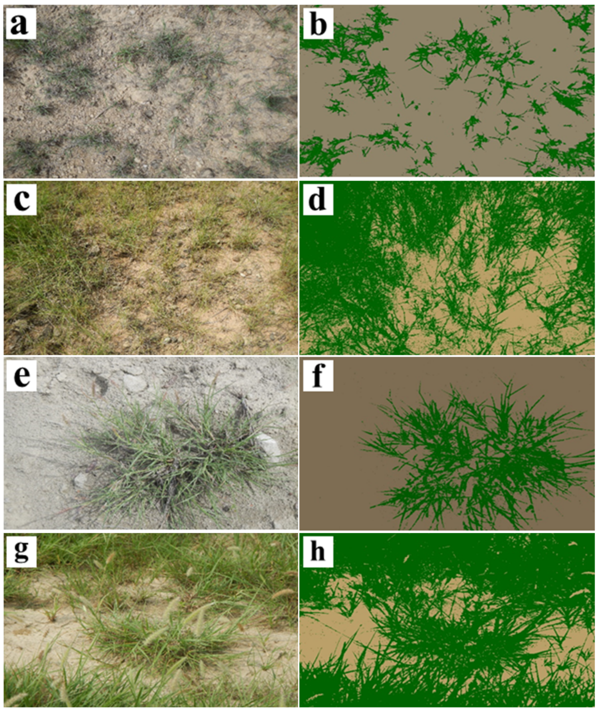

Fig. 3 Original and processed digital images using VegMeasure software Begal (a-d) and Dhulli (e-h) during 2015. a, b, e and f are from unprotected sites while c, d, g and h are from protected sites.

3.4 Chemical composition of plants

The concentration of nutrients in foliar biomass varied by season. Higher concentrations of all nutrients were found in foliar biomass in the spring (Table 2). Significant differences were observed in

Table 1 Plant species of Chakwal with local names, habit, lifecycle, palatability and preference by grazing animals.

Species	Common Name	Habit	Life Cycle	PALATABILITY	
				Sheep	Goat
Panicum antidotale Retz	Blue panic	Grass	Perennial	+++	++
Cenchrus ciliaris Linn	Dhaman	Grass	Perennial	+++	++
Poa annua Linn	Blue grass	Grass	Annual	+++	++
Bothriochloa pertusa Linn	Palwan	Grass	Perennial	+++	+++
Dichanthium annulatum Forssk	Murgha	Grass	Annual	+++	++
Cymbopogon jwarancusa Boiss	Khavi	Grass	Perennial	+++	++
Desmostachya bipinnata (L.) Stapf	Grass	Grass	Perennial	Unpalatable	
Heteropogon contortus Linn	Sariala	Grass	Perennial	++	++
Crysopogon aucheri Sdapf	Bari grass	Grass	Perennial	+++	++
Artistida depressa Retz	Lomb	Grass	Perennial	++	++
Saccharum munja Linn	Kana	Grass	Perennial	Unpalatable	
Grewia oppositifolia Parker	Falsa	Shrub	Perennial	+	++
Calligonum poligonoides Linnaeus	Phog	Shrub	Perennial	+	++
Zizyphys mauritiana Lam	Mala ber	Shrub	Perennial	++	+++
Carissa opaca Linn	Grinda	Shrub	Perennial	-	+
Gymnosporia royleana Wall	Pataki	Shrub	Perennial	-	+
Tecomella undulatata Roxb	karir	Shrub	Perennial	+	++
Acacia modesta Wall	Phulai	Tree	Perennial	++	+++
Acacia nilotica Linn	Kikar	Tree	Perennial	++	+++
Tamarix aphylla (L)Karst	Frash	Tree	Perennial	Unpalatable	
Acacia farnesiana Linn	needle bush	Tree	Perennial	+	++
Periploca aphylla Dcne	Bata	Tree	Perennial	Unpalatable	
Zizyphus nummularia	Ber	Tree	Perennial	+++	+++

Note: +++ Palatable ++Moderate Palatable +Low palatable, Farrukh and Mufakhirah (2009), Holm et al. (1979).

concentrations of nutrients among grasses, shrubs and trees. Species and time influenced the content of CP, ADF, NDF and Ash (Table 2). As expected, plants became more fibrous as they matured. The ADF and NDF values did not change throughout the season but temporal changes in CP were more marked. The CP values were near 3.6%–9.8% in grasses, 10.4%–18.4% in shrubs and 14.5%–16.9% in trees in the spring. As the season advanced, all plants lost protein content and ended the season with CP values from 3.1%–7.6% in grasses, 0.1%–15.1% in shrubs and 12.1%–14.3% in trees at seed set. In general, shrubs and trees have moderate fiber levels compared to grasses. Mineral content was influenced by species and season.

The concentration of P was higher in the spring, ranging from 0.05% in *Desmostachya bipinnata* to 2.3% in *Carissa opaca* and declining with the plant maturity, while concentrations of Ca were lower during the plant vegetative stage ranging from 1% in *Gymnosporia* royleana to 5.5% in *Desmostachya bipinnata* but increased with the maturity of plant. K content was highest in the spring and declined as the season progressed, while Mg content increased gradually over the grazing season.

3.5 Weight gain of ewes

In the seasonal grazing trial, ewes that grazed on the protected sites showed higher live-weight gains compared to those on the unprotected sites during the experimental period of 127 days during the two years at the Begal site (protected: 33–63 g day^{-1}; unprotected 17–21 g day^{-1}). The live-weight gain during the first year (2015) was higher than that in the second year (2016). Similarly, the weight gains were higher before the monsoon rains compared with post- monsoon weights. The statistical analysis showed significance differences among groups, seasons and years. The average live-weight gain (kg) per hectare also increased in a similar trend (Table 3). The total live-weight gain of the entire group (kg) per hectare showed a similar trend with higher gains on protected and lower gains in unprotected sites during the two years (Table 3).

In the seasonal grazing trial, ewes that grazed on protected sites showed higher live-weight gains compared to live-weight gains of ewes on unprotected sites during the experimental period of 127 days, during two years at Dhulli site (protected: 48–80 gram day^{-1}; unprotected: 19–24 g day^{-1}). The live-weight gain during the first year (2015) was higher in the two groups than in the second year (2016). Similarly, the weight gains were higher before the monsoon rains compared to the post-monsoon period. The statistical analysis showed significance differences among groups, seasons and years. The average live-weight gains (kg) per hectare also increased in a similar trend (Table 4). The total live-weight gains of the entire group (kg) per hectare showed a similar trend, with higher gains on protected sites and lower gains on unprotected sties during the two years (Table 4).

4 Discussion

4.1 Aboveground vegetation biomass, canopy cover and nutritional composition

Protection from unmanaged grazing at both sites resulted in greater aboveground vegetation biomass both during spring rainfall and summer monsoon. The protected site in Begal and Dhulli displayed higher biomass after the spring rainfalls compared to the unprotected sites. An increase in biomass was also observed after the summer monsoon rains at both sites. These results are consistent with our previous research on the cold, semi-arid rangelands in Ahmadun Ziarat, Pakistan (Islam et al. 2018) and the warm desert rangelands in Cholistan, Pakistan (Zubair et al. 2018). In these rangelands, protection from unmanaged grazing also increased vegetation biomass compared to unprotected sites.

Overall at both sites, inter-annual variations in spring and monsoon rainfalls resulted in large variability in the amount of moisture penetrating the soil. This has a negative impact on primary biomass production, which further affects animal productivity as discussed in (Wullschleger et al. 2010). In the Pothwar region, winter rainfall is an important factor in controlling the composition and new growth of plant communities while summer rainfall is important for increasing the biomass production of existing plant species needed to sustain animals when other fodders are scarce (Shehzadi et al. 2021). It has been observed that reductions in winter rainfall reduce germination and then establishment of plants, whereas summer drought is responsible for reducing grassland productivity (Bittencourt et al. 2013). This study shows that both factors have a definite influence on rangeland productivity and factors involved in maintaining livestock in the area.

Table 2 Proximate composition crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and phosphorus (P), calcium (Ca), magnesium (Mg) and potassium (K) in the native vegetation of Chakwal consumed by livestock. All values are percentages. Data show mean values ± standard deviations

Season	Name of Grasses	CP	Ash	ADF	NDF	P	Ca	Mg	K
	Panicum antidotale Retz	9.8±0.1^{jk}	7.8±0.1^{i}	40.5±0.2^{f}	64.3±0.3^{i}	0.9±0.0^{klm}	4.2±0.1^{e}	2.9±2.0^{hijkl}	1.6±0.0^{cd}
	Cenchrus ciliaris Linn	6.9±0.2^{l}	8.2±0.1^{fgh}	44.2±0.3^{de}	62.3±0.1^{j}	1.2±0.0^{hij}	2.6±0.0^{k}	1.2±0.0^{mn}	1.8±0.0^{bc}
	Poa annua Linn	5.2±0.1^{m}	11.2±0.1^{c}	36.2±0.1^{klm}	66.4±0.2^{f}	1.5±0.0^{efg}	2.8±0.0^{ijk}	1.8±0.0^{jklmn}	1.4±0.0^{def}
	Bothriochloa pertusa Linn	4.9±0.0^{mn}	8.4±0.1^{eg}	44.9±0.3^{cde}	72.4±0.2^{c}	0.9±0.0^{klm}	3.1±0.0^{hi}	1±0.05^{n}	1.2±0.0^{fgh}
	Dichanthium annulatum Forssk	5.5±0.0^{m}	9.6±0.2^{e}	45.6±0.4^{cd}	72.1±0.1^{c}	0.8±0.0^{lmn}	3.5±0.0g	2.3±0.0^{hijkl}	1.6±0.0^{cd}
	Cymbopogon jwarancusa Boiss	5.3±0.1^{m}	8.1±0.0^{ghi}	35.7±0.1^{klmn}	61.9±0.6^{j}	1.2±0.1^{hij}	2.9±0.0^{ij}	1.6±0.0^{klmn}	1.2±0.0^{fgh}
	Desmostachya bipinnata (L.) Stapf	4.8±0.2^{mn}	11.5±0.2^{b}	38.8±0.6^{fgh}	62.4±0.3^{j}	0.5±0.0^{op}	5.5±0.0^{b}	1.4±0.0^{lmn}	1.5±0.0^{de}
	Heteropogon contortus Linn	3.6±0.1^{op}	4.3±0.1^{p}	46.5±0.2^{bc}	60.1±0.1^{k}	0.7±0.0^{mno}	1.8±0.0^{m}	1.4±0.0^{lmn}	1.6±0.0^{cd}
Spring	*Crysopogon aucheri* Sdapf	5.4±0.1^{m}	7.3±0.1^{j}	36.9±0.3^{ijkl}	57.4±0.4^{m}	1.1±0.0^{ijk}	2.1±0.0^{l}	1.4±0.0^{lmn}	1.1±0.0^{ghi}
	Grewia oppositifolia Wight	14.2±0.1^{ef}	12.4±0.2^{a}	34.5±0.2^{mno}	38.6±0.3^{s}	1.5±0.0^{efg}	3.3±0.0^{gh}	1.6±0.0^{klmn}	1.1±0.0^{gh}
	Calligonum poligonoides Boiss	18.4±0.3^{a}	7.2±0.1^{jk}	36.7±0.1^{ijkl}	40.1±0.4^{r}	1.5±0.0^{efg}	1.8±0.0^{m}	4.1±0.3^{abcd}	1.7±0.0^{c}
	Zizyphys mauritiana Lam	13.2±0.1^{g}	6.4±0.2^{l}	24.3±0.1^{s}	34.6±0.1^{u}	1.8±0.0^{bcd}	3.4±0.0^{g}	3.4±0.0^{cdefgh}	1.3±0.0^{efg}
	Carissa opaca Linn	10.4±0.3^{ij}	5.2±0.1^{n}	23.7±3.3st	32±0.2^{v}	2.3±0.0^{a}	1±0.05^{o}	3.7±0.0^{bcde}	2±0.0^{ab}
	Gymnosporia royleana Wall	14.2±0.2^{ef}	3.4±0.1^{r}	29.4±0.2^{q}	36.8±0.4^{t}	1.9±0.0^{bc}	1.4±0.0^{n}	4.3±0.0^{abc}	1.5±0.0^{de}
	Acacia modesta Wall	16.9±1.1^{b}	10.2±0.1^{d}	27.3±0.1^{r}	39.8±0.1^{r}	2±0.05^{b}	1.8±0.0l^{m}	3.5±0.0^{bcdef}	2.2±0.0^{a}
	Acacia nilotica Linn	15.3±0.4^{c}	9.4±0.1^{e}	22.4±0.2^{t}	28.8±0.2^{x}	1.7±0.1^{cde}	1.5±0.0l^{n}	4.5±0.0^{ab}	2.1±0.0^{a}
	Zizyphus nummularia Burm.f.	14.5±0.5^{de}	8.5±0.1^{f}	34.2±0.1^{nop}	51.2±0.1^{o}	1.4±0.0^{efg}	1.9±0.0^{lm}	3.5±0.0^{bcdefg}	1.8±0.1^{bc}
	Panicum antidotale Retz	7.6±0.0l^{op}	5.6±0.0^{m}	43.4±0.^{1e}	67.2±0.1^{e}	0.6±0.0^{no}	5.3±0.0^{bc}	2.1±0.0^{ijklm}	1.1±0.1^{ghi}
	Cenchrus ciliaris Linn	5.4±0.0^{m}	6.3±0.0^{l}	46.4±0.1^{bc}	64.4±0.2^{hi}	0.9±0.0^{klm}	3.9±0.0^{f}	0.9±0.1^{n}	1.3±0.0^{efg}
	Poa annua Linn	3.6±0.1^{op}	7.2±0.0^{jk}	38.5±0.2^{ghi}	68.3±0.1^{d}	1.1±0.0^{ijk}	4.2±0.0^{e}	1.1±0.0^{mn}	1.1±0.0^{ghi}
	Bothriochloa pertusa Linn	3.2±0.0^{p}	6.2±0.1^{l}	46.3±0.1^{bc}	74.6±0.0^{b}	0.7±0.0^{mno}	4.9±0.0^{d}	0.8±0.1	0.9±0.0^{ij}
	Dichanthium annulatum Forssk	4.3±0.0^{no}	5.4±0.0^{mn}	48.7±0.0^{a}	75.7±0.0a	0.6±0.1^{no}	5.2±0.1^{c}	1.8±0.1^{jklmn}	1.2±0.1^{fgh}
	Cymbopogon jwarancusa Boiss	4.8±0.0^{mn}	6.4±0.1^{l}	37.4±0.2^{hijk}	64.9±0.0^{ghi}	1±0.0^{jkl}	3.8±0.0^{f}	1.1±0.1^{mn}	0.8±0.1^{j}
	Desmostachya bipinnata Linn	3.9±0.0^{op}	7.9±0.0^{hi}	40.1±0.1^{fg}	65.1±0.1^{gh}	0.3±0.0^{p}	6.3±0.1^{a}	0.9±0.0^{n}	0.9±0.0^{ij}
	Heteropogon contortus Linn	3.1±0.1^{p}	3.1±0.0^{rs}	47.5±0.2^{ab}	65.5±0.2^{g}	0.6±0.0^{no}	3.5±0.0^{g}	0.8±0.0^{n}	1.2±0.0^{fgh}
Summer	*Crysopogon aucheri* Sdapf	4.3±0.1^{no}	5.4±0.0^{mn}	36.8±0.0^{ijkl}	59.2±0.1^{l}	0.9±0.0^{klm}	2.9±0.0^{ij}	1±0.05^{n}	0.8±0.0^{j}
	Grewia oppositifolia Wight	12.2±0.1^{h}	8.5±0.0^{f}	36.5±0.0^{jkl}	41.3±0.3^{q}	1.1±0.0^{ijk}	4.2±0.2^{e}	1.2±0.0^{mn}	0.9±0.0^{ij}
	Calligonum poligonoides Boiss	15.1±0.1^{cd}	5.6±0.0^{m}	38.2±0.1^{hij}	43.2±0.2^{p}	0.9±0.0^{kl}	2.9±0.0^{ij}	3.1±0.1^{efghi}	1.2±0.1^{fgh}
	Zizyphys mauritiana Lam	10.3±0.3^{j}	4.8±0.0^{o}	26.6±0.1^{r}	36.5±0.2t	1.2±0.0^{hij}	4.2±0.2^{e}	2.8±0.1^{efghij}	1±0.05^{hij}
	Carissa opaca Linn	9.1±0.1^{k}	3.9±0.0^{q}	29.3±0.0^{q}	34.8±0.1^{u}	1.6±0.0^{ef}	2.8±0.1^{jk}	2.4±0.2^{hijkl}	1.4±0.0^{def}
	Gymnosporia royleana Wall	11.2±0.2^{i}	2.8±0.0^{s}	32.6±0.0^{p}	38.7±0.0^{s}	1.3±0.1^{ghi}	3.1±0.1^{hi}	3.1±0.1^{efghi}	1.1±0.0^{ghi}
	Acacia modesta Wall	14.3±0.1^{def}	7.8±0.0^{i}	33.1±0.1^{op}	41.4±0.2^{q}	1.6±0.0^{def}	3.6±0.2^{fg}	2.6±0.0^{fghij}	1.6±0.0^{cd}
	Acacia nilotica Linn	13.6±0.0^{fg}	6.9±0.0^{k}	26.6±0.0^{r}	31.2±0.2^{w}	1.2±0.1^{hij}	2.8±0.1^{jk}	3.2±0.1^{defgh}	1.8±0.1^{bc}
	Zizyphus nummularia Burm.f.	12.1±0.0^{h}	7.1±0.0^{jk}	35.4±0.0l^{mn}	54.6±0.3^{n}	0.9±0.0^{klm}	3±0.1^{ij}	2.4±0.0^{ghijk}	1.2±0.0^{fgh}
P Value		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Within column, values with different uppercase letters are significantly different ($P \leq 0.05$).

Table 3 Impact of seasonal grazing on live-weight (kg) gain of ewes at Begal, Pakistan

Parameters	2015				2016			
	Phase-1		Phase-2		Phase-1		Phase-2	
	P	UP	P	UP	P	UP	P	UP
Total area (ha)	24	8	24	8	24	8	24	8
Numbers of plots	3	1	3	1	3	1	3	1
Hectares per plot	8	8	8	8	8	8	8	8
Stocking rate (head ha^{-1})	6	4	6	4	2	1.3	6	2.3
Day grazing/plot	30	30	30	30	30	30	114	114
Days rest period /plot	60	0	60	0	60	0	60	0
Total days on pasture	58	58	69	69	58	58	69	69
Number of heads	18	12	18	12	18	12	18	12
Mean initial weight (kg/head)	51	52.33	54.66	53.5	41.5	41.1	44.4	42.2
Mean final weight (kg/head)	54.66	53.5	58	55	44.4	42.2	46.7	43.4
Mean daily gain (g)	63.10	20.17	48.41	21.74	50.00	18.97	33.33	17.39
Difference of wt. gain (kg)	3.66	1.17	3.34	1.50	2.90	1.10	2.30	1.20
Total weight gain (kg ha^{-1})	8.23	1.76	7.52	2.25	6.53	1.65	5.18	1.80

Table 4 Impact of seasonal grazing on live-weight gain (kg) of sheep in Dhulli, Pakistan

Parameters	2015				2016			
	Phase-1		Phase-2		Phase-1		Phase-2	
	P	UP	P	UP	P	UP	P	UP
Total area (ha)	24	8	24	8	24	8	24	8
Numbers of plots	3	1	3	1	3	1	3	1
Hectares per plot	8	8	8	8	8	8	8	8
Stocking rate (head ha^{-1})	6	4	6	4	2.7	1.4	5.8	2
Day grazing/plot	30	30	30	30	30	30	30	30
Days rest period /plot	60	0	60	0	60	0	60	0
Total days on pasture	58	69	58	69	58	69	58	69
Number of heads	18	12	18	12	18	12	18	12
Mean initial weight (kg/head)	62.5	61.66	67.16	63	40.84	40.72	44	42
Mean final weight (kg/head)	67.16	63	70.5	64.7	44	42	46.8	43.3
Mean daily gain (g)	80.34	19.42	57.59	24.64	54.48	18.55	48.28	18.84
Difference of wt. gain (kg)	4.66	1.34	3.34	1.70	3.16	1.28	2.80	1.30
Total weight gain (kg ha^{-1})	10.49	2.01	7.52	2.55	7.11	1.92	6.30	1.95

Note: P; protected site, UP; unprotected site.

Vegetation canopy cover in the protected sites displayed higher percentages compared to unprotected grazing areas. A number of studies conducted in similar climatic conditions have shown similar results in which the vegetation cover tends to increase with the extent of protection from grazing (Merdas et al. 2017; Qasim et al. 2017; Bröder et al. 2019). Zubair et al. (2018) found that as protective activities ceased, the cover and biomass of vegetation suddenly decreased. Numerous studies have shown that sites with greater vegetation cover had more aa stable soil structure and the dangers of soil erosion decreased substantially (Islam et al. 2018). Many studies have documented a positive correlation between rainfall and semi-arid and arid rangeland vegetation (Hamada et al. 2011; Byrne et al. 2011). Similar results were obtained in the current study as the canopy cover of the vegetation was highest after rainfalls and lowest before rainfall episodes. This effect was directly related to biomass production as well, which is also supported by studies conducted in similar conditions (Saugier et al. 2001; Williams et al. 2005; Hernández et al. 2011).

In arid and semi-arid regions, rangeland livestock systems suffer from forage quality and availability, resulting in food insecurity and resource conflicts (FAO 2009). According to Zampaligre et al. (2013), domestic livestock adapt their feeding behaviors according to the available feed resources. Analysis of foliar nutrients showed high variability among species. In the Pothwar region, the share of grasses in the diet of small ruminants was higher throughout the year but in the dry season the quantity and quality of these grasses became more critical, imposing more serious constraints to the development and productivity of these animals. At this time, shrubs and leguminous tree leaves and pods had high crude protein and phosphorus and low fiber and lignin. This factor plays an important role in fulfilling nutritional requirements, particularly during the dry season (Habib 2016). Our results suggest that the leaves of these trees can be used for supplemental CP to the existing low-quality forage-based diets either by lopping the branches or by direct browsing.

4.2 Weight gain of ewes

In the Pothwar region, small ruminants are vital to the livelihood of resource-poor farmers who rear them for their own consumption, income generation, cultural uses, manure and as an investment. During the monsoon months, prolonged exposure to air temperatures above 30°C and humidity higher than 80% prevent lactating ewes from maintaining their thermal balance, thus inducing heat stress conditions (Sevi et al. 2001). In this situation, sheep activate a number of compensatory physiological mechanism such as reducing their feed intake and changes in the metabolism of water, protein, energy, and mineral balances, enzymatic reactions and hormonal secretions (Marai et al. 2007). The results on body weight show that the weight increase was higher after the spring rains when the fresh biomass of shrubs and grasses was more nutritious and highly palatable and the body weight slightly increased after the summer rains when seasonal changes in the quality and availability of feed resources were observed due to warm (40°C–50°C), moist conditions (Devendra Leng 2011). Heat stress accompanied with low-quality feed impaired growth and maximized the chances of disease (Nardone 2010). Due to the stress animals face in the summer, good management with better feeding regimes become critical factors in flock performance.

Besides unmanaged grazing, climatic fluctuations have impacts on biomass production, particularly in ecosystems of high inter- and intra-annual rain variability. This may be the reason that after the summer rains in 2015, despite having good vegetation biomass, two factors mainly affected small ruminant's productivity i) structural carbohydrates and ii) the presence of unpalatable species. Sheep generally prefer grasses and forbs to shrubs, while goats prefer shrubs and trees (Hemen 2015). The high lignin content in grasses during this season reduces the intake of grasses because grasses are high in structural carbohydrates and low in protein. The presence of unpalatable species (*Saccharum spontaneum, Aristida depressa, Desmostachya bipinnata* and *Saccharum munja*) in the area decreased grazing pressure and caused palatable plants to be eliminated from high grazing pressure. This further promoted unpalatable species to grow in their place, especially near newly constructed dams. Our results are in agreement with previous studies (Noy-Meir and Walker 1986; Westoby et al. 1989; Moretto and Distel 1999) that reduction or elimination of grazing from rangelands provides a competitive advantage to unpalatable species invading the area. Despite resting the area (no grazing) for one year followed by seasonal grazing, the unpalatable grasses attained dominance and it is extremely difficult to reverse this situation.

5 Conclusion

Since livestock productivity is vital for the inhabitants of Pothwar plateau region, this study demonstrated that protected grazing provided these rangelands with significantly higher vegetation cover and biomass. This factor in turn increased the live weight of ewes, which can help the local community increase premiums and better livelihoods. Nevertheless, exclosures remained instrumental in increasing the vegetation diversity, proper reseeding techniques and grazing methods especially after rainfall season may play an important role in improving the productivity of these rangelands. This phenomenon merits further investigation.

These results can inform efforts by rangeland managers, including nomadic and settled pastoralists, to improve the quantity and nutritional quality of rangeland vegetation and thereby sustain and improve livestock performance.

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