

## Grazing Lawns in Terai Grasslands, Royal Bardia National Park, Nepal<sup>1</sup>

Jhamak Bahadur Karki

Department of National Parks and Wildlife Conservation, Babar Mahal, P.O. Box 860, Kathmandu, Nepal

Yadavendardev V. Jhala<sup>2</sup>

Wildlife Institute of India, Chandrabani, P.O. Box 18, Dehradun-248001, India

and

Param Pal Khanna

Wadia Institute of Himalayan Geology, Dehradun, India

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### ABSTRACT

We compared the community structure, nutritive quality, and aboveground biomass of grazing lawns (patches of shortgrass communities) to neighboring grasslands in the Terai of western Nepal. Grazing lawns differed from the adjacent grasslands in species composition and community structure. Species diversity and species richness were higher on grazing lawns ( $H = 1.60$ ,  $S = 20.93$ ) than the grasslands ( $H = 0.97$ ,  $S = 8.97$ ). Fencing that excluded grazers for 150 days made areas of grazing lawns indistinguishable from neighboring grasslands in terms of plant height and biomass. Growing shoots of forage from grazing lawns had higher digestibility, crude protein, and sodium than forage from the grasslands. Grazing lawns appear to be maintained by continuous grazing and are enriched by deposition of urine, dung, and by certain plant species not found in the adjacent grasslands.

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### SARANSHA

*Hamile nepalko paschimi terai chetrako grazing lawn (choto samudayik ghans bhayeko chetra) sanga cheuchauko ghanse maidan ko community structure, paustik matra ra aboveground biomass ko tulana garyou. Grazing lawn ko species composition ra community structure ghanse maidan bhanda pharak paiyo. Species diversity ra species richness ghanse maidan ( $H = 0.97$ ,  $S = 8.97$ ) bhanda grazing lawn ( $H = 1.60$ ,  $S = 20.93$ ) ma badi paiyo. Grazing lawn lai 150 din samma charicharan rokda ghansko uchhai ra sukha taul cheuchau ko ghanse maidan sanga pharak payiyena. Grazing lawn ka ghanska badirahaka munaharuma ghanse maidan ko danjoma badi pachya paustik padartha paiyo. Nun ko matra grazing lawn ma badi paiyo. Grazing lawn kayam rakhna lagatar charicharan ko pramukh bhumika paiyo. Grazing lawn lai ajhai paustiktako hisable prabhakari banauna mal nutra le ra kehi ghansharu payinule thap maddat purayeko dekhincha.*

*Key words:* aboveground biomass; community structure; forage; hot spot; mega-herbivores; Nepal; nutritive quality; species composition.

HERBIVORES CAN HAVE A PRONOUNCED EFFECT on plant establishment, growth, plant form, reproductive success, and plant community diversity (Janzen 1969; Huffaker 1971; McNaughton 1976, 1979a, b; Edroma 1981; Louda 1983; McNaughton 1983; Hartnett *et al.* 1996). Continuous grazing by a large congregation of herbivores results in activation of tillers and selection for ecotypes of more prostrate growth form (Vesey-Fitzgerald 1969, 1973, 1974; McNaughton 1976, 1979a, b, 1988; McNaughton & Banyikwa 1995). Areas in east Af-

rica where ungulates maintain shortgrasses during periods of high utilization have been referred to as grazing lawns (McNaughton 1984). Forage from grazing lawns can have higher nutritive values and digestibility, and provide more available biomass to ungulates (Olubajo *et al.* 1974; McNaughton 1979b, 1984; McNaughton *et al.* 1982; Rhodes & Sharrow 1990).

We observed small areas of shortgrass/forb communities (<0.5 ha) interspersed within the phantas (local name for grasslands) of several hundred hectares in size in the Royal Bardia National Park, Nepal. We hypothesized that these shortgrass patches were grazing lawns, *i.e.*, they were established and maintained through intensive utilization

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<sup>2</sup> Corresponding author.

by ungulates, which included chital (*Axis axis*), swamp deer (*Cervus duvauceli duvauceli*), hog deer (*Axis porcinus*), rhinoceros (*Rhinoceros unicornis*), elephant (*Elephas maximus*), and barking deer (*Muntiacus muntjac*). We quantified: (a) plant community structure on grazing lawns and neighboring grasslands; (b) plant growth within exclosures on grazing lawns; and (c) nutritive quality of forage from grazing lawns and grasslands. In support of our hypothesis, we expected: (1) grazing lawns to have a different physiognomic structure compared to grasslands. Individuals of the same forage species would take on a more prostrate, grazing-adapted form (ecotypes) when compared to neighboring grasslands. This would result in short canopy height with higher forage density per unit volume; (2) forage from grazing lawns would have higher nutritive content in comparison to forage from neighboring grasslands; and (3) exclusion of ungulate grazing would promote an increase in biomass and plant height on grazing lawns.

## METHODS

**STUDY AREA.**—We studied grazing lawns within *Imperata cylindrica* (L.) Beauv. dominated grasslands in the Baghaura phanta (28°30.56'N, 81°15.15'E; 165 m elev.) of Royal Bardia National Park (968 km<sup>2</sup>) located in the southwestern Terai of Nepal. The study area was situated in the floodplain of Karnali River, which consists of coarse sand and fresh deposits of alluvial soil, silt, and gravel. The climate is subtropical. The influence of monsoon is high and the region has three distinct seasons: hot-dry (February–mid-June), monsoon (mid-June–late September), and winter (late September–January). There is a distinct difference in the rainfall ( $\bar{x}$  = 1800 mm/yr, 1990–1994) and temperature among these seasons. The majority of the precipitation occurs between June and September, and some between January and February. The temperature ranges from a minimum of 4°C in winter to a maximum of 40°C in summer.

**EXCLOSURES AND SAMPLING.**—Six different grazing lawns were studied within Baghaura phanta. To prevent grazing by ungulates, 6- × 6-m areas within each grazing lawn were wire fenced to 2.5 m in height. Exclosures were established in early winter before the winter rains (December 1996). Quadrats (50 × 25 cm) were clipped at random within each grazing lawn and grassland prior to and after 150 days of fencing. During the second sampling phase, there were effectively three treatments: grazing

lawns without fencing, grazing-excluded grazing lawns (within exclosures), and neighboring grasslands. Six quadrats were clipped within each grazing lawn and fenced area. Six quadrats from neighboring grasslands (a few meters away) were clipped to permit paired statistical analyses. Additional quadrats also were clipped at random from the neighboring grassland (for another study) and are used here for the analysis of species biomass. Species numbers, percent cover, average height of each species, number of clumps and culms, and fresh weight were measured in the field with an accuracy to 0.5 g using a spring balance. All samples were oven-dried to determine dry biomass.

All data were tested for normality and appropriately transformed when necessary prior to conducting further statistical analysis. Shannon-Wiener diversity indices and jackknife estimates of species richness were computed for each of the grazing lawns and grasslands. The bootstrap procedure (Krebs 1989) was used to generate 90 percent confidence intervals for the diversity indices. To test the hypothesis that grazing lawns differed in plant community structure from neighboring grasslands, a discriminant function was developed based on plant species biomass, plant species numbers, and average plant species height. For the discriminant analysis, all dicot plants were pooled except *Oxalis* species, because *Oxalis* was observed to be heavily utilized and was likely to contribute substantially to herbivore grazing. A two-way ANOVA was used to test for differences in biomass of different plant species on grazing lawns and grasslands. The main effects of the model were species (*Imperata cylindrica*, *Saccharum spontaneum*, *Vetiveria zizanioides*, *Desmostachya bipinnata*, dicot species, and others) and grazing history (grazing lawns, grazing-excluded grazing lawns, and grasslands).

**NUTRIENT AND SOIL ANALYSIS.**—The proportional dry biomass contribution of all herbaceous species in each grazing lawn and associated grassland was computed. A composite plant sample was prepared by adding dry, ground young shoots of all individual plant species in proportion to their dry weight occurrence for each grazing lawn and neighboring grassland separately. Grass-blades and shoots of dominant species, such as *I. cylindrica*, *S. spontaneum*, and *V. zizanioides*, in the early growth phase were harvested by hand from grazing lawns and associated grasslands to simulate ungulate grazing. Crude protein (CP), acid detergent fiber (ADF), lignin, and acid-insoluble ash (AIA) were determined (Goering & Van Soest 1970) for the com-

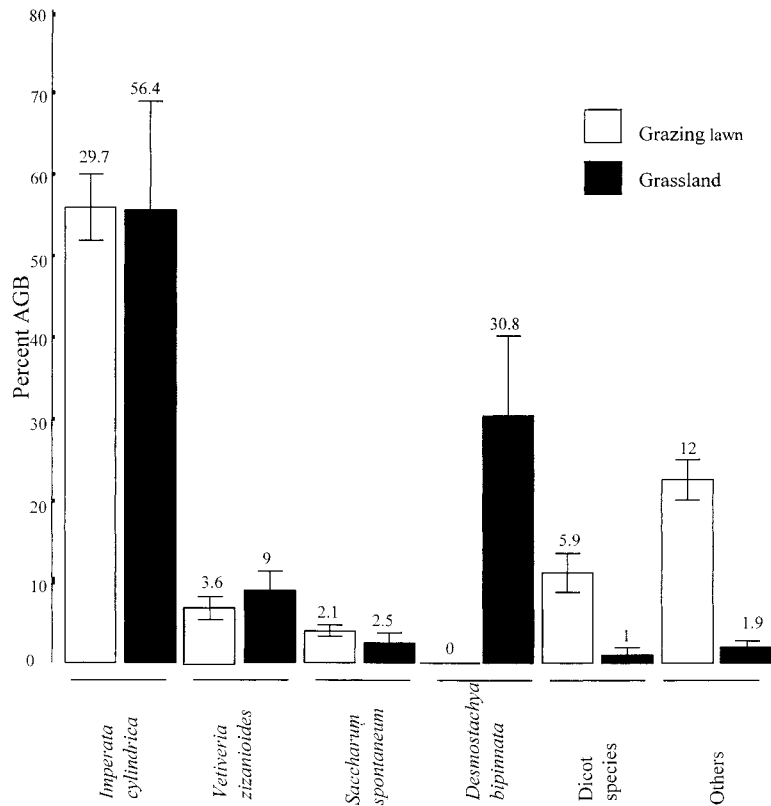


FIGURE 1. Percent aboveground biomass (AGB,  $\bar{x} \pm SE$ ) of species on grazing lawns and grasslands. Value above the bar is mean dry AGB g/m<sup>2</sup>.

posite and three dominant grasses (*I. cylindrica*, *S. spontaneum*, and *V. zizanioides*) from each grazing lawn and corresponding grassland. Major elements (Na, Ca, P, K, and Mg) and trace elements (Fe, Cu, Mn, and Zn) also were determined for the composite sample and dominant grass species from grazing lawn and grass communities by inductively coupled plasma atomic emission spectrometry space (ICP-AES; JY 70+) and flame photometer (Systronics Mediflame 127). Nutrient and mineral analyses were done only for forage samples from grasslands and grazing lawns. Samples from fenced areas of grazing lawns were not analyzed for their mineral and nutrient contents. Separate two-way ANOVAs were used for each nutrient (four ANOVAs) and mineral content (nine ANOVAs). Alpha levels for rejecting the null hypothesis of no difference were adjusted appropriately ( $P = 0.05/4$  for nutrients and  $P = 0.05/9$  for minerals) for each ANOVA so that the overall type I error rate remained at 0.05. The main effects of this model were species and grazing history (grazing lawn and

grassland). Paired composite forage samples and dominant grass species of grazing lawns and grasslands also were compared by paired *t*-tests (appropriately adjusted *P* values). This analysis helped in determining which species contributed to the difference detected by the ANOVA in nutrient (CP, ADF, AIA, and lignin) and mineral content between grazing lawns and grasslands.

Two 20-cm soil core samples were collected from each grazing lawn and corresponding grassland. These soil samples were composited for each grazing lawn and grassland separately and analyzed for the same nine elements, pH, nitrogen, and particle size. All statistical analyses were done using SPSS computer software (Norusis 1990).

## RESULTS

EFFECTS OF GRAZING LAWNS ON SPECIES COMPOSITION.—*Imperata cylindrica*, *V. zizanioides* (L.), and *S. spontaneum* (L.) dominated the grasslands and grazing lawns. Coarser grass species like *V. ziza-*

TABLE 1. Summary of results by two-way ANOVAs for biomass and nutrient content of forage samples from grazing lawns and neighboring grasslands. N = sample size.

	N	Effects	df	F	P
Dry biomass	432	Grazing history (G)	1	7.33	0.007
		Species (S)	5	18.1	0.001
		Interaction (G × S)	5	5.37	0.001
		Error	420		
Crude protein	46	Grazing history (G)	1	15.43	0.001
		Species (S)	3	14.46	0.001
		Interaction (G × S)	3	0.473	0.7
		Error	38		
ADF	45	Grazing history (G)	1	24.9	0.001
		Species (S)	3	5.89	0.09
		Interaction (G × S)	3	1.933	0.141
		Error	37		
Lignin	45	Grazing history (G)	1	6.314	0.016
		Species (S)	3	0.274	0.844
		Interaction (G × S)	3	0.3	0.83
		Error	37		

*nioides* and *D. bipinnata* occurred at low densities on grazing lawns. Dicots contributed > 11.1 percent of the biomass for grazing lawns compared to only 1.0 percent for grasslands (Fig. 1).

The bootstrap Shannon-Wiener diversity index for grazing lawns was 1.60 (90% ci: 1.26–1.97) while that of grasslands was 0.97 (90% ci: 0.66–1.25). The jackknife estimate of species richness for grazing lawns was 20.93 (90% ci: 16.52–25.34) while that of grasslands was 8.97 (90% ci: 7.33–10.61). Thus, grazing lawns had greater species richness and diversity compared to grasslands.

The quadrat samples from grasslands ( $N = 36$ ) and grazing lawns ( $N = 72$ ) were classified correctly at a 90 percent efficiency level (grassland, 97%; grazing lawn, 86%) by the discriminant function. Six plant community variables (dicot height and numbers, higher on grazing lawns; *Saccharum narenga* height, greater on grasslands; *Fimbristylis* sp. number, higher on grazing lawns; *Oxalis corniculata* number and height, greater on grazing lawns) contributed significantly ( $P < 0.0001$ ) to the discriminant function. A two-way ANOVA on dry aboveground biomass with species and grazing lawn/grassland as main effects showed a significant

interaction (Table 1), suggesting that certain species increased in biomass on grazing lawns while others decreased in biomass (Fig. 1). Thus, grazing lawns differed substantially in community structure from grasslands.

EFFECTS OF FENCING ON GRAZING LAWNS.—The relation of aboveground biomass ( $\text{g/m}^2$ ) from grazing lawns, grasslands, and grazing-excluded areas of grazing lawns (exclosures) after 150 days of grazing free environment was as follows: Grassland (87.12a) > Fenced grazing lawn (62.96ab) > Grazing lawn (53.44b; ANOVA:  $F_{(2,105)} = 6.2$ ; different letters indicate a significant difference of the means using Tukey's multiple range test at  $P < 0.05$ ). The heights of all three dominant grass species within fenced portions of the grazing lawns were not significantly different from grasslands after 150 days of protection from grazing (Table 2).

EFFECTS OF GRAZING LAWNS ON FORAGE QUALITY.—In general, growing tips of plants from grazing lawns had higher crude protein values, lower acid detergent fiber, and lower lignin than growing tips of plants from neighboring grasslands (Table 1; Fig.

TABLE 2. Comparison of heights (cm) for grass species after 150 days of ungulate-free growth on grazing lawns. A different letter after the mean indicates a difference in means using Tukey's multiple range test at  $P \leq 0.05$ .

Species	Ungrazed		Grassland	df (N, D)	F	P
	Grazing lawn	grazing lawn				
<i>Imperata cylindrica</i>	23.5a	57.33b	66.5b	2, 15	6.13	0.011
<i>Vetiveria zizanioides</i>	14.67a	82.4b	88.75b	2, 9	60.17	0.001
<i>Saccharum spontaneum</i>	35.67a	97.5b	110.5b	2, 8	8.67	0.01

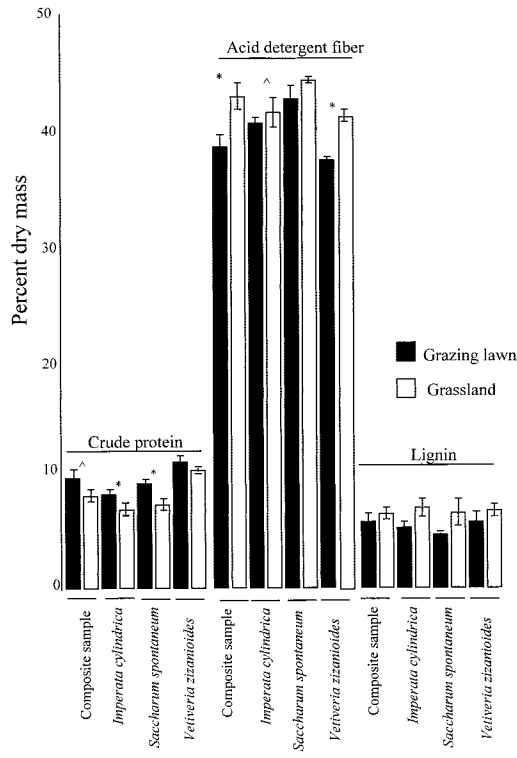


FIGURE 2. Comparison of nutrient content ( $\bar{x} \pm SE$ ) of growing shoots of dominant grass species on grazing lawns and grasslands. \* $P < 0.0125$  (adjusted  $\alpha$ ); ^  $P < 0.05$ .

2). Forage from grazing lawns did not differ significantly (at the adjusted  $P$  value  $0.05/9 = 0.0055$ ) in their mineral content compared to adjacent grasslands except for Na (which was higher on grazing lawns; two-way ANOVA:  $F = 7.3$ ,  $P = 0.007$ ; Table 3). Soils of grazing lawns and corresponding grasslands did not differ significantly in their mineral content, physical characteristics, pH, and moisture content.

**DISCUSSION**

**SOILS.**—Compared to grazing lawns described by McNaughton (1984) in the Serengeti ecosystem

(large areas measured in  $km^2$ ), the shortgrass patches observed in the Bardia grasslands were much smaller in area ( $<0.5$  ha.). Therefore, the scale of comparison between grazing lawns and neighboring grasslands was at a micro level compared to grazing lawns of the Serengeti. Due to this micro-scale, one would expect the underlying edaphic soil characteristics of grazing lawns to be similar to that of grasslands. Soil characteristics did not differ statistically between grazing lawns and adjacent grasslands; however, soils of grazing lawns tended to have higher soluble N content ( $\bar{x} = 1.96\%$ ,  $SE = 0.26$ ) and lower pH ( $\bar{x} = 8.2$ ,  $SE = 0.07$ ) in comparison to grassland soils (soluble N =  $1.5\%$ ,  $SE = 0.1$ ; pH =  $8.47$ ,  $SE = 0.17$ ). Analyses of more soil samples possibly could result in significant differences between grazing lawn and grassland soils for these parameters. These differences probably would be attributable to higher rates of dung and urine deposition on grazing lawns relative to grasslands (Day & Detling 1990, Archer & Smeins 1991).

**COMMUNITY STRUCTURE AND SPECIES COMPOSITION.**—Grazing reduces competition and promotes species richness and diversity within a community (Huffaker 1971, Edroma 1981, Green & Kauffman 1995, Noy-Meir 1995, Detling 1998). Grazing lawns had higher species richness and diversity in comparison to neighboring grasslands. Grasses growing on grazing lawns tended to have prostrate, grazing-adapted forms, forming a dense mat near the soil surface. The discriminant analysis function that correctly classified 90 percent of the quadrats to grazing lawns and grasslands, took into account species composition, biomass, number, and species height (attributes of plant community structure). Therefore, grazing lawns had a distinctly different plant community compared to grasslands, thus supporting our hypothesis.

**FORAGE QUALITY AND QUANTITY.**—New flush of vegetation growing on the grazing lawn had higher nutritive quality compared to new flush of grass-

TABLE 3. Mineral content of composite forage samples from grazing lawns and grasslands in Royal Bardia National Park, Nepal.

Mineral		P	Zn	Fe	Mn	Ca	Cu	Mg	Na	K
Grazing lawn	$\bar{x}$	1720	29.3	795	52	4992	35.8	1805	*289	118
	SE	103	2.29	186	4.34	481	7.39	169	24.3	7.5
Grassland	$\bar{x}$	2059	31.2	528	55.5	4307	34.7	1563	*230	103
	SE	232	2.35	185	4.36	263	8.98	99.7	29.2	5.4

All values are in ppm; SE = standard error; \* =  $P < 0.007$ .

land vegetation. All samples of grazing lawns had greater crude protein values and higher digestibility (lower fiber) than grassland samples. Mineral content of forage samples from grazing lawns (as well as grasslands) were well above the minimum requirements of ruminants, except for Na and were marginal for P, Ca, and Mg (McDowell 1985). Sodium especially was found in extremely low concentrations (Robbins 1983, Church 1984, Van Soest 1987). Thus, grazing lawns not only provided more digestible forage with higher crude protein (Rhodes & Sharrow 1990), but also provided higher concentrations of deficient minerals like Na. *Oxalis* spp. growing abundantly on grazing lawns had high concentrations of Na (>400 ppm), Mg (>3550 ppm), and P (>2200 ppm). McNaughton (1984) had found that areas of higher animal concentration had higher contents of Mg, Na, and P.

While the aboveground biomass was greater for grasslands compared to grazing lawns, very little of this biomass would be palatable food for selectively feeding ungulates (Sinclair 1974); however, almost all of the aboveground growth on grazing lawns would be palatable to ungulates. The foraging efficiency (*i.e.*, biomass intake and nutrient intake per bite) as well as the number of bites per unit time were likely to be higher on grazing lawns (Bailey *et al.* 1996; Bradbury *et al.* 1996). Grazing lawns thus provided highly nutritious forage in high density per unit volume in comparison to grasslands.

**DYNAMICS OF GRAZING LAWNS.**—Our study suggests that grazing lawns differ considerably from neighboring grasslands in their physiognomic structure. We only can speculate as to how these differences come about within the small areas that encompass both grazing lawns and grasslands. Data from grazing-excluded areas of grazing lawns suggests that differences in plant height and biomass between grazing lawns and grasslands were a direct consequence of intensive grazing (Smart *et al.* 1985). It seems likely that tall grassland areas are initially opened up by fire, floods, and/or grazing by mega-herbivores (elephants and rhinos). Chital and swamp deer, both capable of selective foraging due to their medium-sized mouths, dominate the ungulate community of Bardia grasslands. These un-

gulates then maintain grazing lawns by intensive utilization. Due to reduction in competition from tallgrasses, grazing lawns provide an environment for the establishment and maintenance of a more diverse plant community (Noy-Meir 1995, Detling 1998). This community is in turn sustained, and made more productive, by deposition of ungulate urine and dung (Day & Detling 1990, MacNaughton & Banyikwa 1995, Detling 1998). Overuse of grazing lawns would tend to increase unpalatable weeds and lower productivity (Dyer *et al.* 1991, 1993). Such grazing lawns would lead to disuse by ungulates and allow tallgrass species and ecotypes to recolonize (Allen *et al.* 1995). Thus, grazing lawns seem to be one state of a dynamic successional equilibrium for a different plant community initiated by effects of fire or mega-herbivore utilization, maintained by continuous grazing and enriched by animal manure.

The trends that emerge even with a limited sample size (six grazing lawns) are ecologically interesting, and merit a more detailed investigation. A long-term study with exclosures on 15 to 30 grazing lawns from different phantas would provide a better understanding on succession, the mechanism of nutrient and mineral enrichment, and equilibria of grazing lawn communities.

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