

Grasslands in the Damodar Kunda Region of Upper Mustang, Nepal

Rita Arjel Koirala

Tribhuvan University, Nepal

Rinjan Shrestha

King Mahendra Trust for Nature Conservation, Nepal

and Per Wegge

Department of Biology and Nature Conservation, Agricultural University of Norway

Abstract

This study was carried out in a 117 sq.km area in the Damodar Kunda region of upper Mustang in Nepal during the summer of 1996. Stratified quadrat sampling was used to describe the floristic composition of five vegetation types distributed in three different zones inhabited almost exclusively by three different herbivores, the Tibetan argali (*Ovis ammon hodgsonii*), the naur or blue sheep (*Pseudois nayaur*), and the domestic goat (*Capra hircus*).

The spatial arrangement, species' composition, and relative coverage of the five vegetation types varied with landscape pattern, aspect, and altitude. Dry Grassland was distributed in all three habitat zones. Lonicera Community and Wet Meadow vegetation types were found in both the naur and goat zones. Desert Steppe and Dry Meadow were restricted to the argali zone.

Forage availability and species' richness were lowest in the argali zone, situated between 5,140 and 5,250 masl, and graminoids were more abundant than forbs—with *Saussurea graminifolia* the most abundant species of the latter. The naur zone, between 4,950 and 5,050 masl, was richest in forage with graminoids the most abundant forage category, although the shrub *Potentilla fruticosa* was the most abundant species. The goat zone, between 4,800 and 4,900 masl, was moderately rich in forage and the richest in terms of species. The most abundant forage category here was shrubs, particularly the species *Lonicera rupicola*. Because the three ungulates were spatially separated with distinct differences in summer diet (Koirala and Shrestha 1997), resource competition is probably minimal during summer at current animal densities. Domestic stock grazing by goats could probably be increased without negative effects on the rare and endangered Tibetan argali, provided animals are only herded within the Namta watershed. Domestic stock grazing should not be extended into the Tehchang watershed of the argali zone until the seasonal habitats of Tibetan argali are better known, as increased summer grazing by goats might have a negative effect on the winter pastures of this wild sheep species.

Introduction

More than 48% of the land area in the Himalayan region of Nepal along its northern border with Tibet is occupied by natural grassland vegetation (LRMP

1986). Himalayan region grasslands are complex with a mosaic of vegetation communities along a steep altitudinal gradient combined with a myriad of topographical features. The region thus has a comparative ecological advantage over the plains by providing habitats for a unique assemblage of large wild ungulates (Schaller 1977). Naur (or blue sheep)-*Pseudois nayaur*- and argali, *Ovis ammon hodgsonii*, are the main wild ungulates in these grasslands (Schaller 1977; Miller 1993; Jackson *et al.* 1994; Wegge and Oli 1997).

The grasslands not only support a large number of plant and animal species, they also provide a livelihood for mountain people. Because they are low in primary production, they are generally unsuitable for growing crops. Hence, livestock grazing presents the only way at present to convert primary production to secondary products, such as meat and milk products, and non-food products, such as fibre, hide, and manure - all important products for the subsistence livelihood in this region (Miller 1993, 1995).

So far, only a few studies have been carried out in this part of the country (Richard 1994, Ale 1993). Information on the floristic composition and other habitat features is a prerequisite for land-use planning and management. The study described here was carried out in the Damodar Kunda region of Upper Mustang, near the Tibetan Autonomous Region (TAR) of China. The objectives of the study were to describe and compare the different plant communities in and the habitats used by three coexisting ungulates: two wild ungulates - the rare Tibetan argali and the more common naur - and domestic goats.

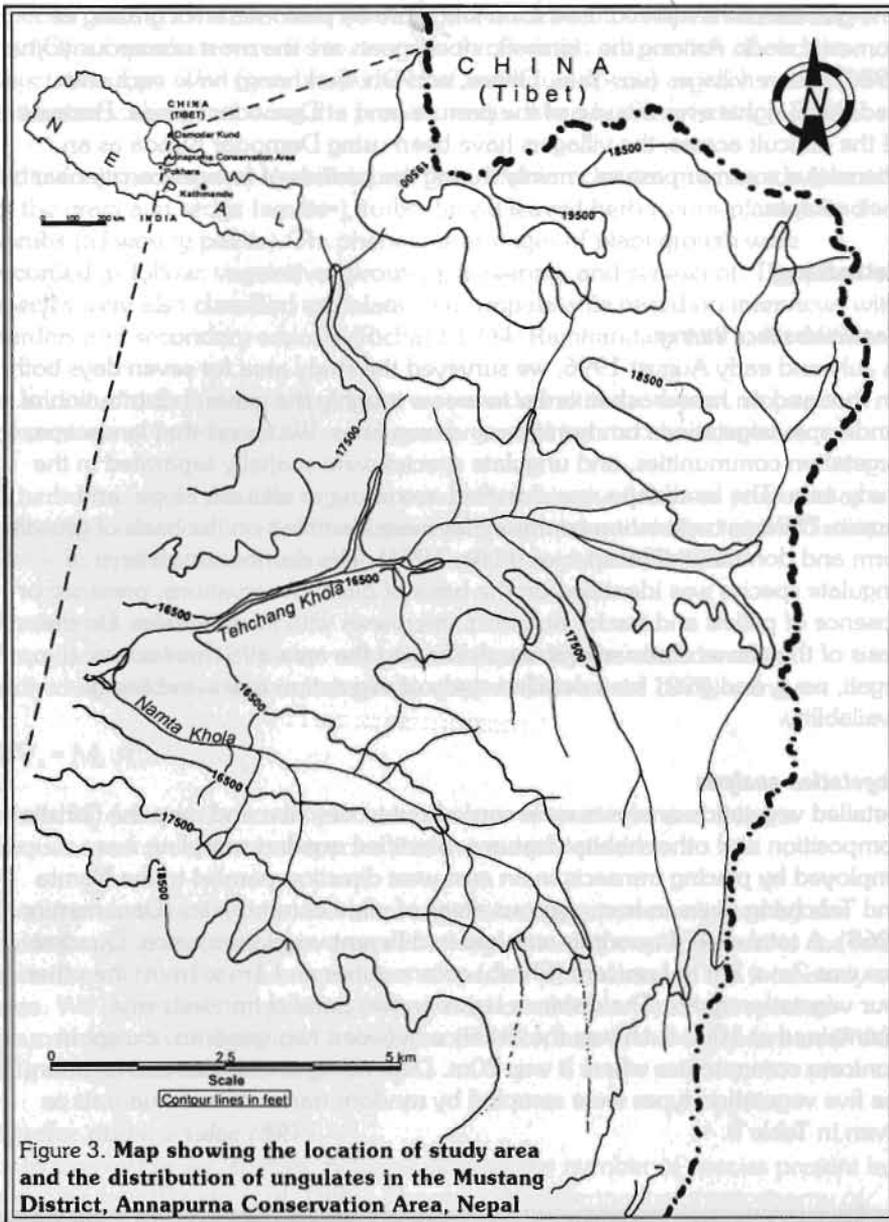
Study Area

The Damodar Kunda region of upper Mustang is located in the north-eastern part of Mustang District at an altitudinal range of 4,700m to 5,900m (Figure 3). It is bordered by the TAR of China to the north and east and by peaks reaching more than 6,000m in altitude to the south and west. The study area covered approximately 117 sq.km.

The Damodar Kunda is regarded as a highly sacred site by both Hindus and Buddhists. The area is traversed by the Techang and Namta rivers, the latter being one of the headwaters of the Kali Gandaki River. The landscape in the north of Techang is open, undulating, gently sloped terrain with interspersed round-topped hills, small lakes, and gullies, whereas the terrain in the south of the Namta is more rugged and precipitous.

The climate is controlled by the rain shadow effect created by the Himalayas. The general physiognomy can be described as high elevation cold desert (Ojha 1986; Brown 1982), similar to that of the Tibetan Plateau (Miller 1994). Total annual rainfall is less than 200 mm and more than half of the total precipitation occurs as snow during the winter. The minimum temperature remains below zero from early October to the middle of April. The snow and frozen land start to thaw at the beginning of April.

In general, the vegetation represents high altitude grasslands that are Tibetan in character (Stainton 1972). Plant cover is sparse, with a clear gradient related to substrate moisture. Plant communities vary from xeric to mesic type depending



upon the micro-climate. This has led to the formation of five distinct plant communities in the study area.

The Damodar Kunda region is an important area of faunal diversity. Wolf (*Canis lupus*), snow leopard (*Uncia uncia*), and brown bear (*Ursus arctos*) have been reported (BCDP 1994), and the Tibetan lynx (*Felis lynx isobellina*) and red fox (*Vulpes vulpes*) are also suspected to exist. Naur and argali are the only wild ungulates known to the area (Koirala and Shrestha 1997). Other mammalian species include marmot (*Marmotta himalayana*), pika (*Ochotona* sp.), and woolly hare (*Lepus* sp.).

The grasslands have been used for a long time by pastoralists for grazing of domestic stock. Among the domestic stock, goats are the most numerous (Ojha 1986). Three villages (viz. Yara, Ghara, and Dhi/Surkhang) have exclusive traditional rights over the use of the pasture land at Damodar Kunda. Because of the difficult access, the villagers have been using Damodar Kunda as an alternative summer pasture, mainly during the periods of forage scarcity near their villages.

Methodology

Reconnaissance survey

In July and early August 1996, we surveyed the study area for seven days both on foot and on horseback in order to assess roughly the general distribution of landscape, vegetation communities, and ungulates. We found that landscape, vegetation communities, and ungulate species were spatially separated in the study area. The landscape was classified according to altitude, slope, and terrain. Different vegetation communities were identified on the basis of growth-form and dominant plant species (Miller 1994). The distribution pattern of ungulate species was identified on the basis of direct observations, presence or absence of pellets and tracks, and from interviews with local herders. On the basis of the above observations, we delineated the area into three zones (i.e., argali, naur, and goat) for a detailed study of vegetation types and forage availability.

Vegetation analysis

Detailed vegetation analyses were carried out to describe and map the floristic composition and other habitat features. Stratified quadrat sampling was employed by placing transects in an east-west direction parallel to the Namta and Tehchang rivers in homogenous areas of plant communities (Daubenmire 1968). A total of 474 quadrats was laid in different vegetation types. Quadrat size was 2m x 2m in *Lonicera* (Shrub) communities and 1m x 1m in the other four vegetation types. The distance between two parallel transects was maintained at 10m, such was the distance between two quadrats, except in *Lonicera* communities where it was 20m. Depending on the size and location, the five vegetation types were sampled by random transects and quadrats as given in Table 5.

Table 5. The distribution of transects and quadrats in the different vegetation types present in three ungulate zones

Vegetation Types	Goat zone		Naur zone		Argali zone		Total / vegetation type	
	N	T	N	T	N	T	N	T
Lonicera Community	60	(3)	25	(2)	A		85	(5)
Wet Meadow	60	(12)	10	(2)	A		70	(14)
Dry Grassland	60	(6)	92	(12)	20	(2)	172	(20)
Dessert Steppe	A		A		120	(10)	100	(10)
Dry Meadow	A		A		27	(6)	27	(6)
Total sample / zone	120	(21)	127	(16)	167	(18)	N=47 4	(55)

N = total number of quadrats, T = total number of transects, and A = absent

Species' area curves (Daubenmire 1968) were drawn to check the minimum number of quadrats required to describe the floristic composition of each vegetation type. The percentage cover of individual species in each quadrat was estimated visually following the procedure described by Smart *et al.* (1976).

Individual species were classified into three lifeform classes: graminoids (plants of the grass and sedge families), forbs (broad leaved herbaceous plants), and shrubs (all woody plants). The phenological stages of plant growth were recorded as follow: vegetative/sprouting, flowering, and senescent. The plant species were also classified as palatable or unpalatable based on interviews with herders and secondary sources (Richard 1994; Rajbhandary 1991; Ale 1993).

In addition to the vegetation survey, we recorded altitude, aspect, slope, and percentage of bare ground/scree to assess general habitat characteristics.

A herbarium of all the plant species encountered in the field was prepared as a reference collection. Unidentified specimens were later identified at the National Herbarium in Kathmandu and by the range ecologist at ICIMOD.

Prominence value (PV)

Prominence values (PV) were calculated to quantify the abundance of individual species in different vegetation types (Dinerstein 1979) using

$$PV_x = M_x \sqrt{f_x}$$

where M_x denotes the mean percentage cover of species x , and f_x is the frequency of occurrence of species x in the sample quadrats.

Prominence values within individual vegetation types were weighted by the corresponding proportionate area of the vegetation type with respect to the total area in order to obtain an expression of species' abundance in the total study area. We estimated forage availability based on abundance. Plant species' abundance was categorised as very rare ($PV < 1$), rare ($PV 1-5$), common ($PV 5-40$), and abundant ($PV > 40$).

Species richness value (SRV)

In its simplest sense, species' richness denotes the number of species present in a community (Begon *et al.* 1996). However, considering the physiognomy of the study area, we calculated the species' richness value by weighting the total number of species present with the corresponding proportionate area of the vegetation community as shown by the following equation:

$$SRV_a = \sum_{i=1}^s N_i \times A_i$$

where SRV_a is the species' richness value for habitat a ; N_i is the total number of species in vegetation community i ; A_i is the proportionate area of vegetation community i with respect to the total area of habitat a , and s is the total number of vegetation communities.

Results and Discussion

The three zones differed in landscape pattern, spatial arrangement of vegetation types, and distribution of ungulates (Figure 4). The southern side of the Namta River was mostly covered by steep topography and inhabited by naur, while the argali were found in the more flat and open terrain on the northern side of the Tehchang River. The goats were herded along the northern side of Namta River where the topography was moderate and vegetation was luxuriant. The naur and goat habitats in Namta Valley shared many landform characteristics except aspect. Both differed clearly from the argali habitat. Table 6 illustrates the general habitat characteristics of the three ungulate species.

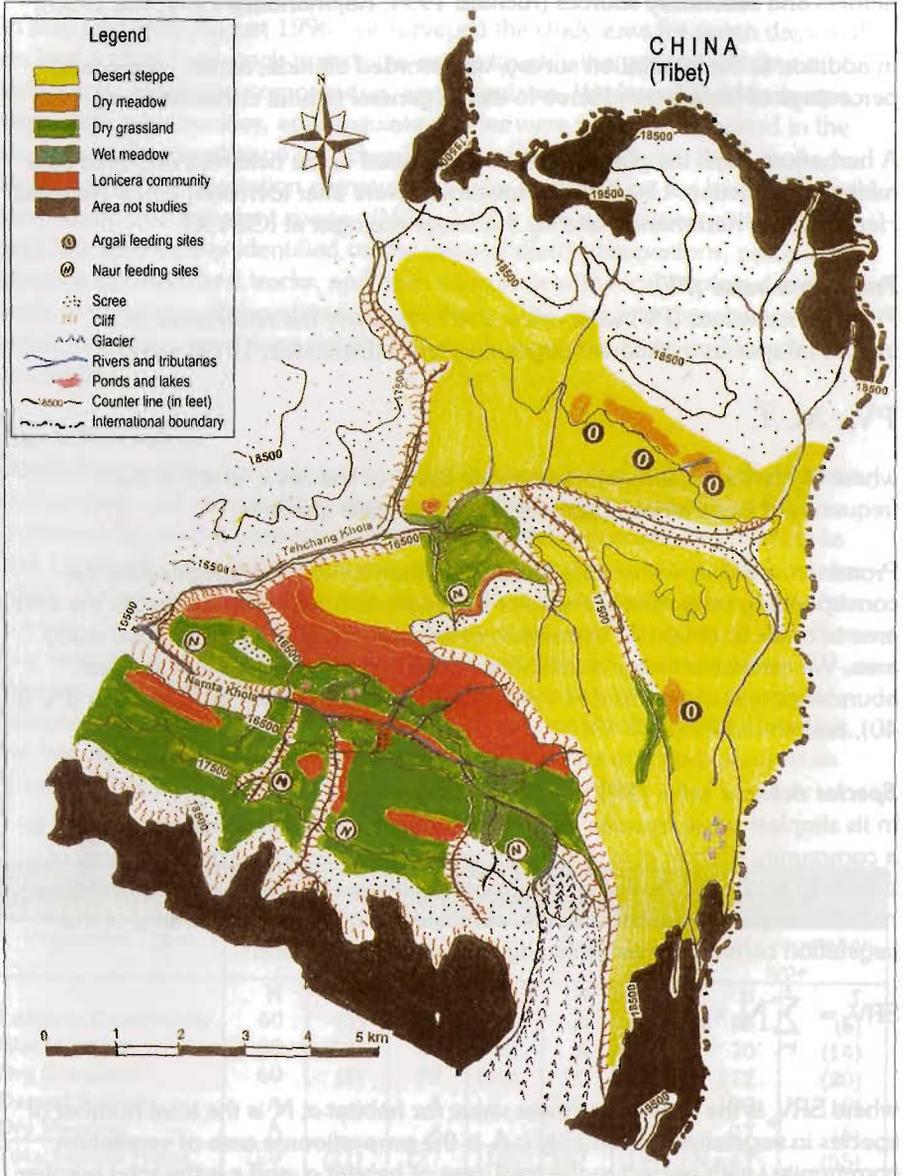


Figure 4. **Map of the study area showing vegetation types, feeding sites and other habitat features of the ungulates**

Table 6. General habitat features of the argali, naur, and goat zones in the study area

Features	Argali zone	Naur zone	Goat zone
Ungulate species	Argali	Naur	Goat
Approximate area (sq.km)	81.8	33.2	13.0
Altitude (m)	5140-5270	4950-5050	4800-4900
Aspect	SW	NE	SW
Slope (degrees)	0-5	5-45	5-25
*Bare ground coverage	69%	27%	37%
Total plant species	33	56	57
Vegetation type	Desert Steppe (90%) Dry Meadow (5%) Dry Grassland (5%)	Dry Grassland (70%) Lonicera Comm. (25%) Wet Meadow (5%)	Dry Grassland (30%) Lonicera Comm. (60%) Wet Meadow (10%)
*Ecological density/sq.km	1.3	5.5	30.1
**Crude density/sq.km.	0.9	1.6	3.3

* Based on vegetation quadrats, which did not include the completely unvegetated scree

** Rough estimates as no systematic population censuses were carried out

The Argali Zone

The argali zone was situated at the highest altitudinal range (5,140-5,250m). It covered approximately 88.9 sq.km or 70% of the study area. The general topography was flat and open. Scree covered more than half of the zone. The major drainage was formed by the Tehchang River. Vegetation cover was very low (ca 30%) and the bare ground coverage would have been higher if unvegetated scree had been included (Figure 4). The zone contained three vegetation types in which a total of 33 plant species was recorded: Desert Steppe, Dry Meadow, and Dry Grassland.

Desert Steppe—Desert Steppe was the most extensive vegetation type, covering almost 90% of the area of the argali zone. Bare ground coverage was >70%, the highest among the three vegetation types (Table 7). We identified a total of 18 different species: 6 graminoids, 11 forbs, and one shrub. Forbs and graminoids dominated the vegetation with the forb *Saussurea graminifolia* as the most abundant species. *Kobresia pygmaea*, *Kobresia* sp., and *Carex ustulata* were common graminoids. *Potentilla fruticosa* was the only shrub found in this community.

Dry Meadow—Dry Meadow vegetation was patchily distributed and located in relatively moist pockets within the Desert Steppe type; covered only 5% of the area of the argali zone. Bare ground coverage (49%) was lower than that of Desert Steppe. The vegetation type contained a total of 25 species: 6 graminoids, 18 forbs, and 1 shrub. Graminoids dominated the vegetation (Table 7). The most abundant species in Dry Meadow was the graminoid *Kobresia pygmaea* followed by the shrub *Potentilla fruticosa*. Common forbs were *Saussurea graminifolia* and *Arenaria glanduligera*.

Dry Grassland—Dry Grassland was distributed patchily along the banks of the Tehchang River and its south-east tributaries (Figure 4). This vegetation type covered approximately 5% of the area of the argali zone, and had nearly 50%

Table 7. Argali zone - Mean Coverage (c%), Frequency (f) and Prominence Values (PV) of the three most abundant species within each lifeform category in each vegetation type. The approximate proportionate area (A) of each vegetation type is shown in parentheses

Species	Desert Steppe (A=90%)			Dry Meadow (A=5%)			Dry Grassland (A=5%)			Total PV*
	c %	f	PV	c %	f	PV	c %	f	PV	
Graminoids	12.7	-	106.0	28.3	-	228.1	33.1	-	317.1	122.7
<i>Kobresia pygmaea</i>	4.2	70	35.1	14.5	78.2	128.2	-	-	-	38.0
<i>Kobresia</i> sp.	3.5	74	29.9	5.0	57.5	38.0	-	-	-	28.8
<i>Carex ustulata</i>	3.0	89	28.1	-	-	-	-	-	-	25.8
<i>Stipa</i> sp.	-	-	-	4.1	55.0	30.1	18.4	100	183.8	21.3
<i>Carex</i> sp.	-	-	-	-	-	-	9.3	100	92.5	4.6
<i>Agrostis</i> sp.	-	-	-	-	-	-	2.9	65	23.2	2.9
Other graminoids	2.0	69	12.9	4.7	138.6	31.9	2.5	50	17.7	-
Forbs	13.2	-	107.0	10.4	-	58.5	6.8	-	41.6	101.3
<i>Saussurea graminifolia</i>	4.4	91	42.0	2.2	49.6	15.4	-	-	-	38.5
<i>Arenaria glanduligera</i>	4.0	93	38.1	1.3	53.9	9.9	-	-	-	34.8
<i>Saxifraga hemispherica</i>	1.7	59	13.3	-	-	-	-	-	-	12.2
<i>Saussurea eriostemon</i>	-	-	-	-	-	-	1.4	55	10.2	1.7
<i>Sedum</i> sp.	-	-	-	1.1	42.9	7.0	-	-	-	1.0
<i>Dracocephalum heterophyllum</i>	-	-	-	-	-	-	2.0	55	14.8	0.7
<i>Potentilla anserina</i>	-	-	-	-	-	-	1.0	40	6.3	0.3
Other forbs	3.1	108	13.7	5.8	220.0	26.2	2.4	95	10.2	-
Shrubs	2.8	-	22.2	12.8	-	124.5	11.1	-	86.2	30.5
<i>Potentilla fruticosa</i>	2.8	65	22.2	12.8	95.0	124.5	11.1	60	86.2	30.5
Mean vegetation cover	29%	-	-	52%	-	-	51%	-	-	-
Mean bare ground	71%	-	-	48%	-	-	49%	-	-	-

*Weighted on the basis of proportionate area of each vegetation type.

bare ground. A total of 14 plant species was recorded, consisting of 4 graminoids, 9 forbs, and 1 shrub. Vegetation composition was dominated strongly by graminoids, particularly by *Stipa* sp. Other abundant species were *Carex* sp. and *Potentilla fruticosa*. Among the forbs, *Dracocephalum heterophyllum* and *Saussurea eriostemon* were the common species. We could not find *Saussurea graminifolia*, *Arenaria glanduligera*, or *Kobresia pygmaea*, the most common species of Desert Steppe and Dry Meadow, in this type of grassland.

Forage Availability—*Saussurea graminifolia* (total PV = 38.5) and *Kobresia pygmaea* (total PV = 38.0) were the most available plants at the species' level (Table 7). The former was more abundant in Desert Steppe than in Dry Meadow, whereas *Kobresia pygmaea* had the highest prominence value in Dry Meadow. *Potentilla fruticosa* (Total PV = 30.5) was the only available woody species in the habitat.

The most available forage category at the life form level graminoids (total PV = 122.7), followed by the forbs (total PV = 101.3), and shrubs (total PV = 30.5) (Table 7). But the availability of each category varied with vegetation type: both

graminoids and forbs were almost equally available in Desert Steppe, whereas graminoids were more available than forbs in Dry Meadow and Dry Grassland (Figure 5).

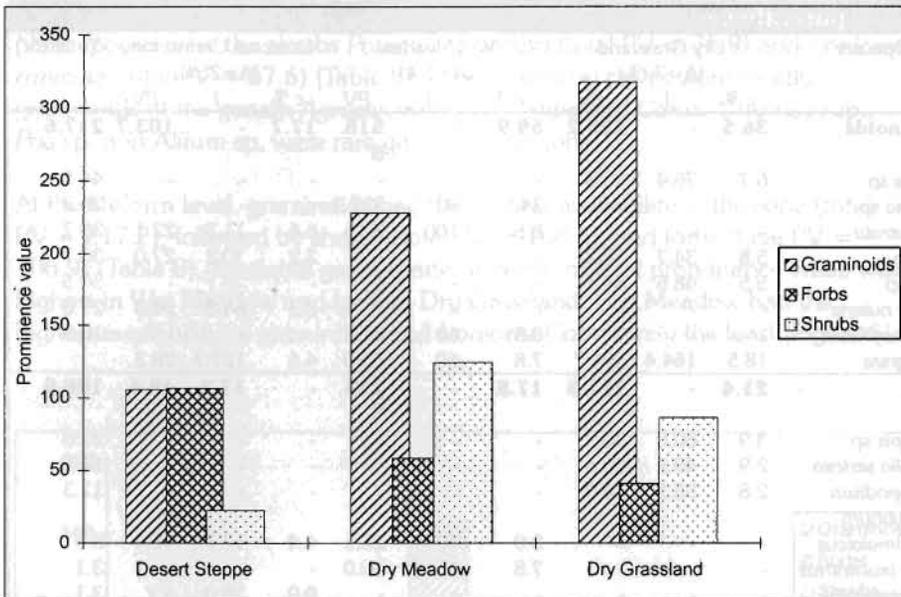


Figure 5. **Composition of available vegetation by lifeform in the different vegetation types in the argali zone**

Species' Richness Value (SRV)—SRV was highest in Desert Steppe (SRV=18.2) followed by Dry Meadow (SRV=1.3) and Dry Grassland (SRV=0.8). The total Species' Richness Value was the lowest (SRV=18.2) among the three zones.

The Naur Zone

The naur zone was located on the south side of the Namta River at a lower altitude (4,950-5,050m) than the argali zone (Figure 4). It covered approximately 28% of the study area and had a more rugged topography than the argali zone. Vegetation was more patchily distributed, with a bare ground coverage of 27%, the lowest among the three zones. The naur zone comprised three vegetation types in which a total of 56 plant species was recorded.

Dry Grassland—Dry Grassland was the dominant vegetation type, covering approximately 70% of the zone. It was more or less continuously distributed in the habitat with little more than 30% bare ground (Table 8). We identified 47 species: 10 graminoids, 33 forbs, and 4 shrubs. Although graminoids dominated the vegetation, the shrub *Potentilla fruticosa* was the most abundant plant species. Graminoids, such as *Agrostis* sp., *Carex* spp., and *Stipa* sp., and the forbs *Oxytropis* sp., *Leontopodium himalayanaum*, and *Potentilla serecia* were also common plant species.

Table 8. Naur Zone: Mean coverage (c%), frequency (f) and prominence values (PV) of the three most abundant plant species within each lifeform category in each vegetation type. The approximate proportionate area (A) of each vegetation type is shown in parentheses

Species	Dry Grassland (A=70%)			Wet Meadow (A=5%)			Lonicera Community (A=25%)			Total PV*
	c %	f	PV	c %	f	PV	c %	f	PV	
Graminoids	36.5	-	236.2	59.9	-	518.5	17.7	-	103.7	217.6
<i>Agrostis</i> sp.	6.7	76.4	58.8	-	-	-	-	-	-	44.5
<i>Kobresia</i> sp.	-	-	-	34.5	90	327.3	-	-	-	36.3
<i>Carex atrata</i>	-	-	-	8.8	100	87.5	6.6	11.3	22.1	30.7
<i>Stipa</i> sp.	5.8	34.7	34.2	-	-	-	3.2	70.2	27.0	30.7
<i>Carex</i> sp.	5.5	48.6	38.4	-	-	-	-	-	-	30.5
<i>Elymus nutans</i>	-	-	-	-	-	-	3.3	64.8	26.3	27.6
<i>Kobresia filicina</i>	-	-	-	8.8	60	67.8	-	-	-	10.5
Other grass	18.5	164.4	104.7	7.8	60	36.0	4.6	127.7	28.3	
Forbs	21.4	-	121.3	17.8	-	198.9	-	11.3	48.4	106.9
<i>Oxytropis</i> sp.	3.9	60.0	30.2	-	-	-	-	-	-	21.6
<i>Potentilla sericea</i>	2.9	49.2	20.3	-	-	-	-	-	-	14.5
<i>Leontopodium himalayanum</i>	2.8	33.1	16.0	-	-	-	-	-	-	11.3
<i>Aster himalaicus</i>	-	-	-	3.0	70	25.1	4.4	17.7	18.4	5.9
<i>Juncus leucanthus</i>	-	-	-	7.8	60	60.0	-	-	-	3.1
<i>Dracocephalum heterophyllum</i>	-	-	-	-	-	-	0.9	38.0	5.7	3.1
<i>Ranunculus chaerophyllum</i>	-	-	-	7.0	40	44.3	-	-	-	2.2
<i>Artemisia</i> sp.	-	-	-	-	-	-	1.2	50.7	8.8	2.2
Other forbs	11.8	314.7	54.8	12.0	330	69.4	4.8	150.1	15.6	-
Shrubs	11.2	-	95.9	2.3	-	14.2	49.8	-	403.3	168.6
<i>Potentilla fruticosa</i>	11.0	75.0	95.6	2.3	40	14.2	5.8	41.0	37.3	76.9
<i>Lonicera rupicola</i>	0.2	3.1	0.3	-	-	-	28.6	88.7	269.5	67.6
<i>Hippophae tibetana</i>	-	-	-	-	-	-	13.2	49.3	92.6	23.2
<i>Cotoneaster</i> sp.	-	-	-	-	-	-	2.2	2.5	3.5	0.9
Mean vegetation cover	69%	-	-	92%	-	-	79%	-	-	-
Mean bare ground	31%	-	-	8%	-	-	21%	-	-	-

* Weighted on the basis of proportionate area of each vegetation type.

Lonicera Community—Lonicera Community type vegetation had a patchy distribution. It covered approximately 25% of the area with 79% vegetation cover (Table 8). A total of 28 species was recorded: 7 graminoids, 17 forbs, and 4 shrubs. Shrubs dominated the vegetation with *Lonicera rupicola* as the most abundant species followed by *Hippophae tibetana*. Among graminoids, *Stipa* sp. and *Elymus nutans* were the most common species.

Wet Meadow—Wet Meadow vegetation was found along rivulets in poorly drained pockets; it constituted only 5% of the zone (Table 8). Within the community, vegetation cover was more than 90%. It was characterised by a thick sod layer and dominated by sedges. A total of 21 plant species was recorded: 6 graminoids, 14 forbs, and one shrub. The vegetation was dominated by graminoids. *Kobresia* sp. was the most abundant species followed

by other *Carex* sp. and the forbs *Juncus leucanthus* and *Ranunculus chaerophyllus*.

Forage availability

Although the naur zone was dominated by Dry Grassland, the most abundant plant species were the shrubs *Potentilla fruticosa* (total PV = 76.9) and *Lonicera rupicola* (total PV = 67.6) (Table 8). Other common plants were mostly graminoids of the genera *Agrostis*, *Kobresia*., *Stipa* and *Carex*. *Chesneya* sp., *Poa* sp. and *Allium* sp. were rare genera in this zone.

At the lifeform level, graminoids had the highest availability in the zone (total PV = 217.2), followed by shrubs (total PV = 168.6), and forbs (total PV = 106.9) (Table 8). Available green matter in terms of total prominence value was highest in Wet Meadow and least in Dry Grassland. Wet Meadow had the highest availability of graminoids and Lonicera Community the least (Figure 6).

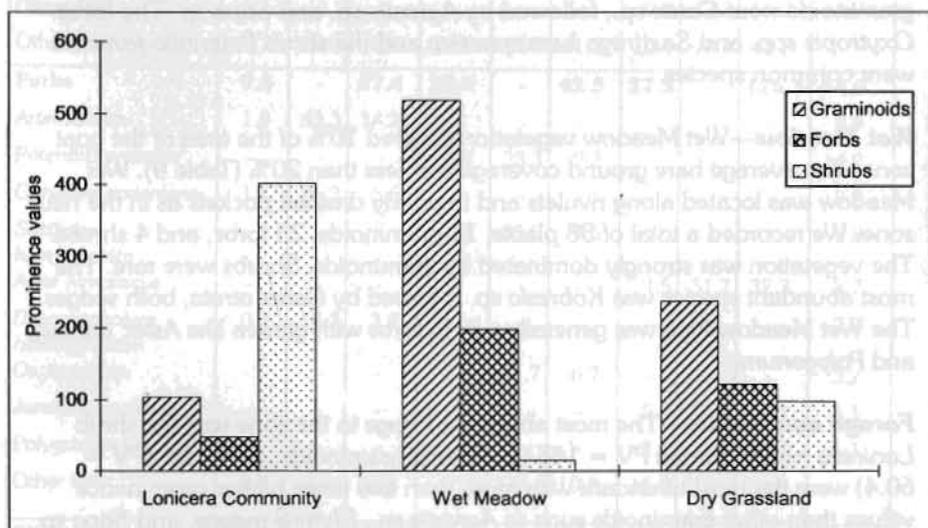


Figure 6. Composition of available vegetation by lifeform in the different vegetation types in the naur zone

Species' Richness Value (SRV)—Among the three zones, the naur zone had the highest species' richness (SRV=40.1). Among the vegetation types, SRV was highest in Dry Grassland (SRV=32.9) followed by Lonicera Community (SRV=7) and Wet Meadow (SRV=1.1).

The goat zone

The goat zone was located along the north side of Namta River and had a moderate topography and luxuriant vegetation. It was the smallest zone in terms of area (approximately 13.0 sq.km or 11% of the study area) and lay between 4,800 and 4,900m. The zone was drained by the Namta River and its northern tributaries. The slope ranged between 5 and 25°. Total bare ground (37%) was

higher than in the naur zone, but less than in the argali zone. The goat zone contained three vegetation types, dominated by *Lonicera* Community which formed a continuous belt along the Namta River (Figure 4). A total of 57 plant species was recorded in this zone.

***Lonicera* Community**—This was the dominant vegetation type and covered almost 70% of the total goat zone. It had a continuous distribution on the southern aspect of Namta Valley along the river and half way up the slopes. We recorded a total of 34 plants: 7 graminoids, 22 forbs, and 5 shrubs. Shrubs strongly dominated the vegetation composition. *Lonicera rupicola* was the most abundant species followed by *Caragana brevifolia* (Table 9).

Dry Grassland—Dry Grassland vegetation was found in saddle-like basins and on less steep slopes ($<15^\circ$). It covered approximately 30% of the zone and had a little over 35% bare ground. A total of 42 plants was recorded: 9 graminoids, 29 forbs, and 4 shrubs. PVs of graminoids were more than eight times higher than those of forbs or shrubs (Table 9). The most abundant graminoids were *Carex* sp., followed by *Agrostis* sp. and *Stipa* sp. The forbs *Oxytropis* spp. and *Saxifraga hemispherica* and the shrub *Potentilla fruticosa* were common species.

Wet Meadow—Wet Meadow vegetation covered 10% of the area of the goat zone. The average bare ground coverage was less than 20% (Table 9). Wet Meadow was located along rivulets and in poorly drained pockets as in the naur zone. We recorded a total of 38 plants: 11 graminoids, 23 forbs, and 4 shrubs. The vegetation was strongly dominated by graminoids. Shrubs were rare. The most abundant species was *Kobresia* sp. followed by *Carex atrata*, both sedges. The Wet Meadow type was generally rich in forbs with genera like *Aster*, *Juncus*, and *Polygonum*.

Forage availability—The most abundant forage in the zone was the shrub *Lonicera rupicola* (total PV = 148.0). Among graminoids, *Carex* sp. (PV = 60.4) were the most abundant with more than two times higher prominence values than other graminoids such as *Agrostis* sp., *Elymus nutans*, and *Stipa* sp. (Table 9). *Chesneya* sp., *Kobresia filicina*, and *Poa* sp. were rare plants in the zone and had very low total prominence values.

At the life form level, shrubs (total PV = 223.1) were the most available and forbs (Total PV = 54.0) the least available forage categories. Availability of shrubs in Wet Meadow was negligible (Figure 7).

Species' Richness Value (SRV)—The Species' Richness Value for the zone was 36.8. It was highest in *Lonicera* Community (SRV=20.4) followed by Wet Meadow (SRV=3.8) and Dry Grassland (SRV=12.6).

Comparison of the three zones

Vegetation types—Of the five different vegetation communities, only Dry Grassland was present in all three zones (Table 6). Desert Steppe and Dry Meadow vegetation types were only found in the argali zone, whereas Wet Meadow and *Lonicera* types were found in both the naur and goat zones.

Table 9. Goat zone: Mean coverage (c%) Frequency (f) and Prominence Value (PV) of the three most abundant plant species within each lifeform in each vegetation type. The approximate proportionate area (A) of each vegetation type is shown in parentheses

Species	Lonicera Community (A=60%)			Dry Grassland (A=30%)			Wet Meadow (A=10%)			Total PV*
	c %	f	PV	c %	f	PV	c %	f	PV	
Graminoids	7.6	-	53.0	45.6	-	353.3	55	-	398.3	177.6
<i>Carex</i> sp.	-	-	-	19.2	93.3	185.2	-	-	-	60.4
<i>Agrostis</i> sp.	2.1	68.3	17.6	7.2	70.0	60.0	-	-	-	30.5
<i>Elymus nutans</i>	2.2	55.0	16.4	-	-	-	-	-	-	21.3
<i>Stipa</i> sp.	1.6	40.0	10.3	7.0	45.0	47.0	-	-	-	20.3
<i>Kobresia</i> sp.	-	-	-	-	-	-	22.0	71.7	186.2	19.1
<i>Carex atrata</i>	-	-	-	-	-	-	13.6	65.0	109.5	11.0
<i>Carex ustulata</i>	-	-	-	-	-	-	9.0	43.3	59.2	5.9
Other graminoids	1.7	50.0	8.8	12.2	80.0	61.2	10.4	78.3	43.3	-
Forbs	9.6	-	47.4	10.0	-	42.9	27.3	-	126.3	54.0
<i>Artemisia</i> sp.	1.8	63.3	14.3	-	-	-	-	-	-	8.9
<i>Potentilla anserina</i>	-	-	-	1.8	28.3	9.3	-	-	-	4.2
<i>Corydalis gowaniana</i>	1.1	26.7	5.6	-	-	-	-	-	-	3.8
<i>Saxifraga hemispherica</i>	-	-	-	1.3	35.0	7.6	-	-	-	3.8
<i>Aster himalaicus</i>	-	-	-	-	-	-	4.5	51.7	32.3	3.7
<i>Dracocephalum heterophyllum</i>	0.9	18.3	3.7	-	-	-	-	-	-	3.2
<i>Oxytropis</i> sp.	-	-	-	1.0	41.7	6.7	-	-	-	3.2
<i>Juncus leucanthus</i>	-	-	-	-	-	-	5.3	35.0	31.1	3.1
<i>Polygonum sibiricum</i>	-	-	-	-	-	-	2.2	23.3	10.7	1.1
Other forbs	5.8	233.3	23.8	5.9	178.3	19.2	15.3	213.3	52.8	-
Shrubs	42.2	-	348.7	8.3	-	44.8	1.3	-	4.3	223.1
<i>Lonicera rupicola</i>	26.7	85.0	246.2	0.3	5.0	0.7	0.0	1.7	0.1	148.0
<i>Caragana brevifolia</i>	11.5	51.7	82.7	1.2	13.3	4.3	0.1	5.0	0.3	50.9
<i>Potentilla fruticosa</i>	1.8	25.0	9.2	5.0	45.0	33.3	0.1	3.3	0.2	15.5
<i>Hippophae tibetana</i>	2.2	23.3	10.7	1.8	13.3	6.5	1.1	11.7	3.8	8.7
Mean vegetation cover	72%	-	-	74%	-	-	84%	-	-	-
Mean bare ground	28%	-	-	26%	-	-	16%	-	-	-

* Weighted on the basis of proportionate area of each vegetation type.

Phenology—In all three zones, most of the plants were at the flowering stage (70% in the argali and naur zones and 63.2% in the goat zone). Some plants (up to 19%) were in the early growing stage and a few grass species (>15%) were already in senescence.

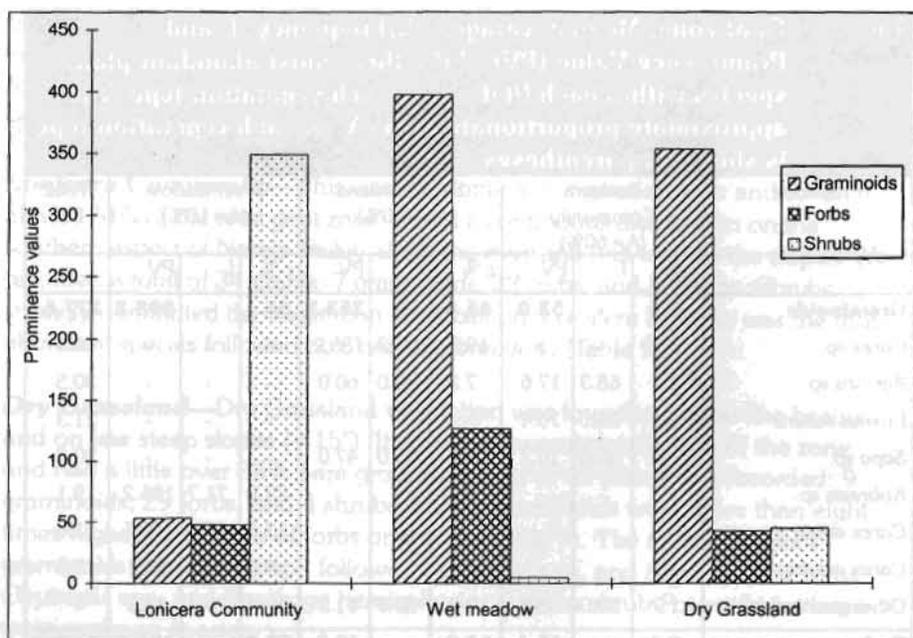


Figure 7. **Composition of available vegetation by lifeform in the different vegetation types in the goat zone**

Palatability—Only two unpalatable species, *Meconopsis horridula* and *Carex* sp., were recorded in the argali zone. Important palatable species widely distributed in the argali zone included *Kobresia pygmaea*, *Kobresia* sp., *Saussuria graminifolia*, *Stipa*, and *Elymus nutans*.

The unpalatable species in the naur zone included such species as *Cotoneaster*, *Primula*, *Anaphalis contorta*, *Carex* sp., *Bistorta*, and *Meconopsis horridula*. The common palatable species recorded in this zone were *Kobresia* sp., *Stipa* spp., and *Lonicera rupicola*.

Unpalatable species were common in the goat zone. Notable among them were *Caragana*, *Primula*, *Anaphalis contorta*, *Carex* sp., *Bistorta*, *Elsholtzia eryostyachia*, and *Meconopsis horridula*, among which *Caragana* was the most abundant. The common palatable plants in the goat zone were *Lonicera rupicola*, *Stipa*, *Kobresia*, and *Elymus nutans*.

Species' Richness Value (SRV)

We recorded a total of 33, 56, and 57 plant species in the argali, naur, and goat zones, respectively. Hence, species' richness in terms of total number of species was higher in the goat and naur zones than in the argali zone.

The Dry Grassland in the naur and goat zones had three times more species (47 and 42 species respectively) than the Dry Grassland of the argali zone (14 species). *Lonicera* Community and Wet Meadow had more species in the goat zone than in the naur zone. Within the argali zone, Dry Meadow (25 species)

was the most and Dry Grassland (14 species) the least species-rich vegetation types

When species' richness was adjusted to the proportionate area of vegetation types, SRV was found to be highest in the naur zone (SRV=40.1) and lowest in the argali zone (SRV=18.2). A closer look at the vegetation types in the individual zones revealed that the Dry Grassland (SRV=32.9) of the naur zone, Lonicera Community (SRV=20.4) of the goat zone, and Desert Steppe (SRV=18.2) of the argali zone had the highest species' richness values.

Forage availability

Total available forage was lowest in the argali zone (total PV=254.0) and highest in the naur zone (total PV=493.1) (Table 10). Both graminoids (total PV=217.6) and forbs (total PV=168.6) were most available in the naur zone, whereas shrubs (total PV=223.1) were most available in the goat zone. Thus, the argali zone, which covered the largest area, was poorest in total available forage.

Table 10. Total prominence values of plant species by lifeform in each ungulate zone calculated using weighted averages of all vegetation types with the amount of barren ground included in the estimates

Life form	Argali zone	Naur zone	Goat zone
Graminoids	122.7	217.6	177.6
Forbs	101.3	106.9	54.0
Shrubs	30.0	168.6	223.1
Total	254.0	493.1	454.7

Conclusion

The argali zone, at the highest altitude among the three habitat zones, was marginal in terms of available forage with highest bare ground coverage (69%). Vegetation was almost equally dominated by forbs and graminoids. Of the 33 different plant species recorded in the zone, only 9 species were common (PV>5)—the other 24 species were rare. The forb *Saussurea graminifolia* was the most abundant species.

The naur zone was found mainly on moderate to steep slopes with a northern aspect near scree and rock outcrops. Bare ground coverage was the lowest and species richness value the highest among the three ungulate zones. The vegetation was dominated by different species of graminoids. Of the 56 species recorded, 17 were common (PV>5) and 39 rare. The shrub *Potentilla fruticosa* was the most abundant species.

The goat zone was located at a lower altitude in the Namta Valley. Plant species' richness (57 species) was the highest among the three zones. Vegetation was dominated by shrubs. Of the 57 plant species recorded, only 13 species were common (PV>5) — the other 44 were rare. The shrub *Lonicera rupicola* was the most abundant species. Forage availability was higher than in the argali zone but lower than in the naur zone.

Management Implications

The Damodar Kunda region provides a mosaic of habitats with a unique aggregation of rare and endangered wild animal species. Hence, the region can appropriately be termed a biodiversity 'hot spot' of the country, and hence requires special management programmes to support conservation of the asset.

Damodar Kunda also has good quality pasture with relatively abundant palatable forage resources such as *Kobresia* spp., *Stipa* sp., *Lonicera* sp., *Elymus* sp., *Agrostis* sp., and *Saussurea* sp., for both livestock and wild herbivores (argali and naur). The good condition of the pastures is also indicated by the presence of breeding populations of argali and naur and the relatively few and low coverage of unpalatable species.

Excessive grazing by domestic stock during the summer may limit forage availability for wild ungulates during winter if they do not move out of the area. It is not yet known whether the rare and endangered argali remain in Damodar during winter, but naur traditionally move down to lower elevations during and after the rutting season in December. Studies of the seasonal habitat use by argali, of the pasture condition and, in particular of the impact of summer grazing by livestock on forage quality and availability during winter, are required to assess the possibility of promoting animal husbandry in the region.

Acknowledgements

This study was made possible by co-operation between the Department of Biology and Nature Conservation at the University of Norway (AUN), the King Mahendra Trust for Nature Conservation (KMTNC) and the Tri-chandra Multiple Campus of the Tribhuvan University (TU), Nepal. The generous support of these institutions was very much appreciated.

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