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Foraging behaviour of cattle and goats in the grazing-lands of forested zone of Indian Central Himalaya

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Abstract. Data on plant species foraged, foraging hours, bite rate, bite size and species drymatter (DM) removed per bite were collected in a grazingland of forested zone of Indian Central Himalaya to describe foraging behaviour of cattle and goats. Cattle and goats together foraged 31 plant species, of which 29 plant species (26 herbs and 3 woody) were foraged by cattle and 21 (16 herbs and 5 woody) by goats. The average foraging period was similar for cattle and goats (10 h for each), bite rate (19 - 46 bites min^{-1}), and bite size (58 -199 mg $bite^{-1}$) were significantly different for adult cattle, calves and goats in different months ($P < 0.01$). The average DM intake (kg dry matter) was 3.2 kg for adult cattle, 1.1 kg for calves and 1.0 kg for goats. The foraging search cost, reckoned as distance walked per unit DM intake (km kg^{-1}), of calves (10) was far the greatest, followed by goats (8) and adult cattle (3). Response breadth (in terms of species foraged) of goat was significantly narrower in species-rich site (0.22) than in species-poor site (0.46) while cattle showed similar response breadths in the two sites (0.38 - 0.42).

Key-words: bite rate and size, dry matter intake, foraging search cost, diet breadth, selection ratio

Introduction

All the major landuse categories of the Central Himalaya viz., close-canopied forest, forest with partial tree cutting and clear-felled forest occupied by grasses or converted into scrubs and cropfields and natural alpine grasslands (between 3,000-4,000 m elevation or more) are subject to free-grazing of livestock. Within the Himalaya (below 2,500 m elevations) the relationship between man and forests through his livestock has been very intimate since time immemorial. Most of the grazinglands of this zone are subject to free grazing with little regulation often beyond their carrying capacities (Singh *et al.* 1988). The grazingland typically consists of forest and its varying forms of conversion, such as forest with partly cut tree stock and treeless grasslands or scrubs with a dense network of grazing trails of livestock and severely disturbed soil. Both cattle and goats share these grazinglands, often with little herding and thus provide with an opportunity to compare their foraging behaviour in a least managed situation. So far, we have no information on the foraging characters of these livestock, which is required not only to develop practices for managing the Central Himalayan grazinglands (Singh 1991), but also as part of the aspects of ecology of these foragers and the ecosystems they occupy.

This study is an attempt to describe the seasonal foraging patterns of cattle and goats in a grazingland of the forested zone of the Central Himalaya, where they forage throughout the year.

Material and methods

Study site. The study was conducted at a site located between 1,600 - 2,000 m elevations (29°27' to 29°29' N lat. and 79°23' to 79°25'E long.). The study site located within the banj oak (*Quercus leucotrichophora* A. Camus) forest zone consisted of a series of forested (oak forest), partly deforested and completely deforested plots located one after another. The total area was about 15 ha. In the partly deforested site a number of chir pine (*Pinus roxburghii* Sarg.) trees had established subsequent to cutting of oak trees. The deforested site was treeless grassland. A small part of it (about one hectare) was planted by State Forest Department with *Cupressus torulosa* Don (density; 310 individuals ha^{-1}) about eight years ago.

The total tree basal cover (54 m^2 ha^{-1}) of the forested site was comparable with that of the other similar forests of the region (Singh and Singh 1987), while in the partly deforested site it was slightly more than half of the forested site (Table 1). The major shrub

Site	Forested	Partly deforested	Deforested
Area (ha)	4.1	4.7	5.7
Total tree basal area (m^2 ha^{-1})	54	30	-
Herb biomass (g d.w. m^{-2})			
- September (rainy)	62.5	114.8	144.8
- December (winter)	12.7	4.1	5.2
- April (summer)	13.5	8.0	6.7
Total herb species	25	31	12
Soil texture (%) - sand	57 (4.1)	66 (2.6)	76 (4.8)
- silt	28 (2.0)	22 (1.2)	14 (0.7)
- clay	15 (0.9)	12 (0.8)	10 (0.6)
Bulk density (gcm^{-3})	0.89(0.03)	1(0.04)	1.21(0.02)
Water hold. capacity (%)	54(3.8)	46(2.7)	40(1.8)
Total nitrogen (%)	0.28(0.09)	0.2(0.04)	0.16(0.03)
Organic carbon (%)	4.29(0.87)	2.7(0.46)	1.99(0.45)
C:N ratio	15.32	14.32	12.44

Table 1. Certain features of the grazing sites - mean values (standard error).

species were *Daphne cannabina*, *Randia tetrasperma*, *Rubus ellipticus* and *Berberis asiatica* in the forested site, and *R. ellipticus*, *R. tetrasperma*, *Lantana camara* and *B. asiatica* in the partly deforested site (Joshi 1991).

Among the different growth forms of the herbs viz., tall forbs (> 30 cm tall plants with scattered leaves all along the erect stems), (ii) grass like plants including sedges, (iii) short forbs (≤ 30 cm tall plants with leaves arranged in short umbrella-like structures with or without arching stems, (iv) cushion and spreading forbs includes cushion or rossette forming and prostrate forms, short forbs were dominant in forested site, while in partly deforested site and deforested site grasses and sedges predominated. The herb biomass increased markedly from forested to deforested site and it was much larger in rainy season than in summer and winter (Table 1). In each site, the species number was markedly higher in september (12 in deforested site to 31 in partly deforested site) than in December (10-16) and April (7-12). The total species number was highest in the partly deforested site, followed by forested site, and in the deforested site it was lowest (Table 1).

All the three sites had similar exposure and degree of slopes (slope angle, 40-45°). Subsequent to deforestation proportion of coarse particles in soil increased, while water holding capacity of soil, and nitrogen and organic matter in soil declined, and soil bulk density increased (Table 1).

The rocks of the study area are commonly black carbonaceous and pyritous, locally oxidized to an ash-grey colour, with characteristic oxidization rings on primary planes. Light green and grey banded slates intercalated with thin layer of silt stone is another typical element of lithology (Valdiya 1980).

Of the annual rainfall of 2,488 mm, more than 75% occurs during the latter part of summer, from mid-June to mid-September. The mean maximum temperature varies from 12.1°C (January) to 27.4°C (May), and the mean minimum from 3.5°C (January) to 6.9°C (July). Depending on climatic variations, the year is divisible into (1) a dry and warm summer season (March to mid-June), (2) a wet and warm rainy season (mid-June to mid-September), and (3) a dry and cold winter season (mid-September to February). The ratio of potential evaporation to precipitation indicated perhumid condition on annual basis, as described by Holdridge (1967), but in March, April, May, November and December potential evaporation exceeds precipitation (Fig. 1).

Measurements. Two mixed cattle (bullocks, cows and calves) - goat herds of similar size and composition, were observed for the foraging behaviour. Herd I consisted of 6 bullocks, 18 cows, 8 calves and 17 goats (49 in total). It foraged daily only in the deforested site. The herd II consisted of 4 bullocks, 24 cows, 5 calves and 12 goats (45 in total). It divided foraging period each day between the partly deforested site and forested site. In the herd II goats kept their foraging restricted to partly deforested site. The cattle of this herd visited first partly deforested site and then the forested site each day. No other animal herd visited the study site.

Since our objective was to characterize the natural grazing behaviour of cattle and goats, we allowed them to graze freely with no herding. Consequently,

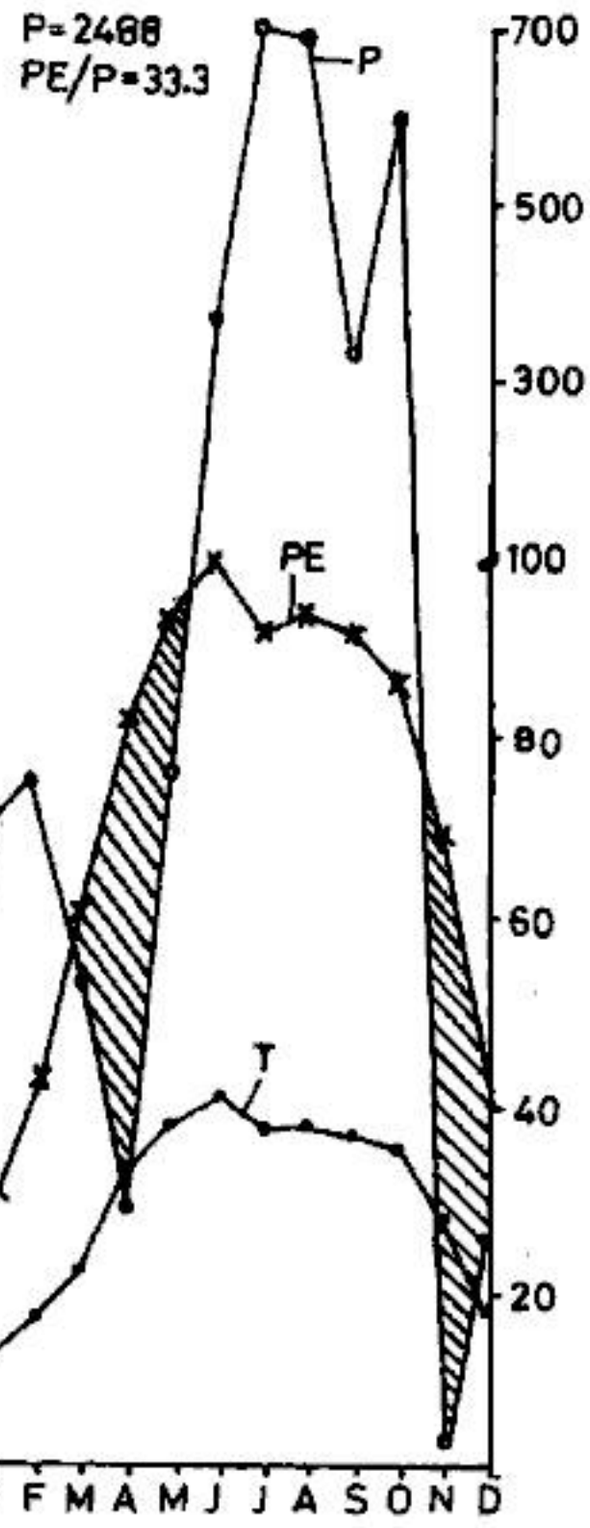

Fig.1. Climate in study area, P - precipitation, PE - potential evaporation (both in mm), T - temperature (°C).

it was not possible to desinging models of spatial interspersion and segregation (such as, completely randomized, randomized block and systematic desing types). But this approach is liable to the problem of "simple pseudoreplication" (Hurlbert 1984). However, the lack of replication in this case (replication of plots within each plant community) was unavoidable given the objective of this study. According to Hurlbert (1984) replication is often impossible or undesirable and in a situation like this, experiments involging unreplicated treatments may also be the only or best option.

In each of the sites the following foraging variables were observed: plant species and plant parts grazed/browsed (hereafter generally referred to as foraged), time devoted to different activities i.e., actual foraging, walking within the sites, day time temporary camping for taking rest and rumination and other activities performed each day; length of foraging track; bite rate (number of bites per min); bite size (average dry mass of plant material removed per incidence of bite); and species selection.

To investigate above mentioned foraging variables, three similar individuals (average-sized and non-reproductive) were marked and observed closely from < 1 m distance throughout the stay (from arrival at the sites in the morning to departure in the evening) on each sampling date (once a month) from September 1988 to September 1989. Animals were accustomed to all the communities involved before the experiment was begun. The methods are summarized in Table 2.

Variables	Observations	Incidence of observations
Total stay period (h)	Stay period of animals in different communities	Observation was made on alternative days throughout the year (about 180 days). Mean stay period was separately calculated for each month. Based on entire herds
Distance covered (km)	Average distance travelled while walking an animal per minute x time spent by the animal on walking	Individuals observed throughout the stay period of a day on each sampling date (three days of a month for each animal category)
Bite rate (bite min $^{-1}$)	Number of bites over one minute duration in each site observed from < 1 m distance	Observation repeated at every 10 min. interval (Hodgson 1982a) throughout the period of actual foraging (giving generally 45 to 50 replicates for cattle and 25 to 40 for goats per day)
Bite size (mg)	Amount of plant mass removed per 100 bites in different plant communities	900 bites per individual in each community each month. 900 bites were evenly distributed across different sessions of a day such as morning, noon and evening. Attempt was made to determine diurnal changes in bite size but after finding no significant change it was stopped

Table 2. Summary of the methods followed to determine certain foraging variables for grazing animals. Observations were made on three average-sized individuals of each animal species in each month from September 1988 to September 1989 between departure from and return to overnight camp.

	Herd - I				Herd - II			
Months	Bullocks	Cows	Calves	Goats	Bullocks	Cows	Calves	Goats
9 - 12 DFT	7.6''	8.7'''	8.1''	13.3'''	11.7'''	9.5'''	8.5'''	10.8'''
SC	9.6'''	9.2'''	11.9'''	11.2'''	10.1'''	11.5'''	10.5'''	16.1'''
9 - 4 DFT	6.3''	6.1''	5.8''	9.1'''	8.1'''	7.7''	7.5''	6.2''
SC	11.5'''	12.4'''	14.1'''	10.9'''	13.4'''	10.4'''	11.2'''	12.6'''
12 - 4 DFT	2.3 ns	4.5'	0.9 ns	1.7 ns	3.7'	3.3'	3.0'	1.7 ns
SC	4.9''	5.7''	8.2''	3.3'	5.3''	5.8''	4.5'	6.5''

Table 3. Seasonal differences in daily foraging track (DFT) and search cost (SC) of the animals of the herd - I and herd - II. '/' measure significantly larger/smaller for first named month. '/' $P < 0.05$, ''/'' $P < 0.01$, '''/''' $P < 0.001$, ns - not signicant.

The time spent by the marked individuals of each animal for various activities during the total stay period of a day was noted with a stop watch. The activities were actual foraging, that is the time when animals forage with a head-down posture, walking i.e., animal movement from one place to another in search of better site for foraging with head-high posture, day time temporary camping for taking rest and rumination, and other activities such as fighting, playing, rubbing and thrusting horns into tree trunks and ground surface.

To determine the bite size, bites were converted to ovendry weight via hand-clipped simulated bites (Neff 1974). Attempts to remove the plant material eaten by animals from their mouth in a bite failed, therefore validation of this method was not possible. That is why we have used the term "apparent bite size" in place of "bite size". However, in order to increase precision the replication number was kept high for simulation of bites (Table 2), and plants were clipped at what was apparently the same height from a similar patch immediately adjacent to grazed plants. The plant materials were separated species-wise and oven dried at 60°C till constant weight and weighed. We derived in average bite size per community for each of the animals and average contribution of the different plant species to the animal diet. The experience and observation from very close proximity enabled to identify plant species eaten in each bite incidence.

The shoot biomass was harvested as close to the ground as possible, from ten randomly selected 1 x 1 m quadrats at monthly intervals during the study period from each of the three sites. The harvested samples were separated into live shoots and dead shoots. The samples were dried at 60°C till constant weight and weighed.

Data syntheses (derived grazing parameters). We used following equations to characterize and compare grazing behaviour of the animals:

1) The daily intake (I) of animals was calculated as: I = AFD, where, A = bite rate (number of bites/minute), F = actual foraging hours, D = apparent bite size (amount of plant material clipped per bite)

2) Selection ratio (SR) of an animal for a plant species was expressed as given in Crawley (1983):

SR = Proportion of the plant species in animal's diet/ Proportion of total biomass accounted for by this species.

The selection ratio was calculated using the values of biomass of September, December and April. Since selection ratio for a plant species, depends in part on availability of alternative forages present in the community (Fitz Gerald *et al.* 1986), it does not give an assessment of selection level which is universally valid.

3) Diet breadth (B) of the animal's foraging across the plant species present in the community was calculated as for Levins' (1968) response breadth (B). In detail see Bargali (1992).

4) Proportional similarity between any two animals in terms of species grazed. The degree of similarity between animal species was calculated using the expression of Schoener (1970; see in Zangerl and Bazzaz 1983 or Bargali 1992).

Statistical analyses. t-tests (Snedecor and Cochran 1968) were used to compare animals (cow-bullock, cow-calf and cow-goat) for following observations: bite rate, bite size, foraging period and length of foraging track, the comparisons being made within each site in different months/seasons and averaged across the site. In significance test, the animal species represented the treatment while individuals represented experimental units. For above parameters comparisons between-months/seasons for each animal were made.

In order to estimate the effect of forage availability on different foraging variables (e.g. actual foraging time, bite rate, bite size, search cost etc.), the community herb biomass (average across the site) was considered as independent variable (X) and foraging variable as dependent variable (Y) to develop a a linear regression equation and to evaluate the correlation coefficient (r) between these two measures. The data of foraging variables of different animals in different months at different sites, were compared by ANOVA.

For simplicity, data averaged across the months for the measure studied, are given in table to compare the animal species. Standard errors are presented also but tests for significance were not applied, to avoid sacrificial pseudoreplication (Hurlbert 1984).

Results

Foraging track and species number. Generally, cattle and goats foraged in separated groups, and of the two, goats formed a relatively loose group. Goats were quick to change direction of movement while foraging, resulting in a zig-zag tracking pattern. In comparison, cattle were very slow to change direction. Goats easily reached moderate to steep slopes (30-70°), while cattle avoided slopes above 45°.

The length of daily foraging track did not vary significantly between the two animal species both within a herd as well as between the herds. However, it showed significant seasonal variation (Table 3), the track length being much longer during dry seasons (winter and summer) than during the wet season. This reflected the effect of herb biomass, to which the length of foraging track (average across the animals of the two herds) was negatively correlated ($Y = 9.5 - 0.07 X$, $r = -0.85$, $P < 0.01$).

The numbers of plant species foraged upon by the animals are given in Table 4. Cattle's diet consisted of more species than the goat's diet. Cattle avoided some woody species which were important constituents of goat's diet. In most of the species, leaves and flowers or inflorescence were eaten along with succulent stems. Since grazing limited the setting of fruits and seeds, they formed only a small fraction of animal diets (Table 5).

Growth form	Sp	Sf		
		A	Cattle	Goats
Tall forbs	10	4	4	2
Short forbs	15	12	12	5
Cushion and spreading forbs	6	1	1	1
Grasses and sedges	13	9	9	8
Total herb species	44	26	26	16
Woody species	13	5	3	5
Total herb + wood species	57	31	29	21

Table 4. Number of plant species of different growth-form eaten by cattle and goats (September 1988 - September 1989). Sp - species present in all three sites, Sf - species foraged from all three sites, A - all animals.

	Cattle	Goats
Woody plants		
Berberis asiatica Roxb. ex EC	LIF	LIF
Cupressus torulosa Don	-	L
Pinus roxburghii Sarg.	L	L
Randia tetrasperma Benth. and Hook	-	LIF
Rubus ellipticus	LIF	LIF
Tall forbs		
Craniotome furcata (Link.) O. Kuntze	LIS	LIS
Goldfusia dalhousiana Nees	LIS	-
Hedychium spicatum Buck.Ham.ex Smith	LIS	-
Scutellaria angulosa Benth.	LIS	LIS
Short forbs		
Cyanotis vaga (Laur.) Schult.F.	LIS	-
Dipsacus mittis Linn.	LIS	-
Dicliptera roxburghiana Nees.	LIS	LIS
Galium aparine Linn.	LIS	-
Nepta leucophylla Benth	LIS	LIS
Oldlandia diffusa (Willd.) Roxb.	LIS	-
Pedicularis pectinata Wall ex Benth.	LIS	LIS
Polygonum nepalense (Meissn.) Hook. f.	LIS	LIS
Reinwardtia indica Dumort.	LIS	-
Roscoea procera Wall	LIS	-
Rumex hastatus Don	LIS	-
Teucrium royleanum Wall. ex Benth.	LIS	LIS
Cushion and spreading forbs		
Parietaria debilis Forst. f.	LIS	LIS
Grasses and sedges		
Arthraxon lanceolatus (Roxb.) Hochst.	LI	LI
Arundinella nepalensis Trin	LI	LI
Carex cruciata Wahlenb.	LI	LI
Chrysopogon serrulatus	LIF	LIF
Cynodon dactylon	LI	LI
Cyperus compressus Linn.	LIF	LIF
Mondo intermedium (D. Don) Baily	LI	-
Setaria glauca P. Beauv.	LIF	LIF

Table 5. List of species and their parts eaten by cattle and goats in the study sites. L - leafs, I - flowers/inflorescence, F - fruits, S - stems.

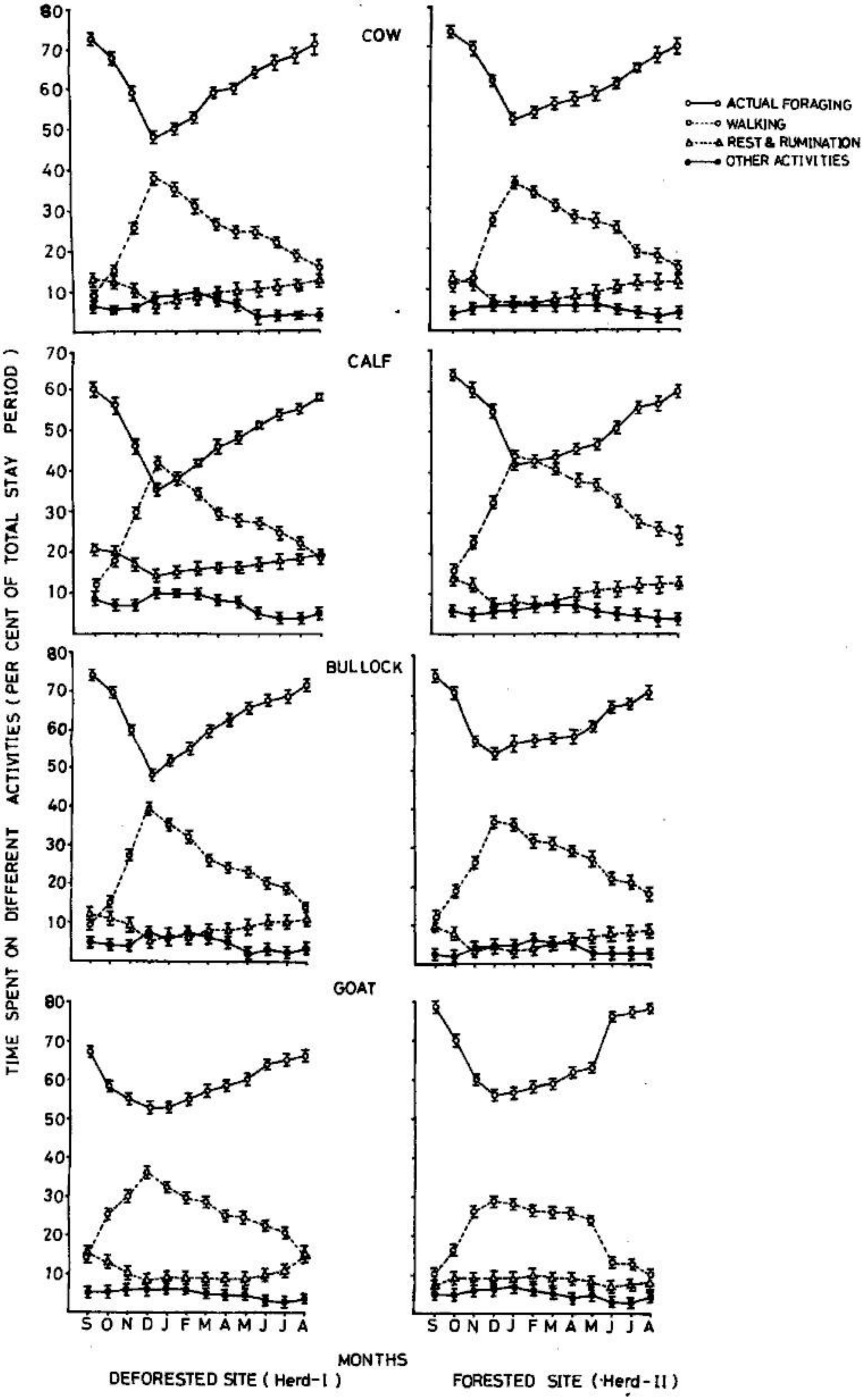

Fig. 2. Time spent by grazing animals (percent of total stay period) of herd - I and herd - II on different activities during the study period.

Time allocation to different activities. The average daily stay period of animals, across the two herds and twelve months was similar for cattle and goats (10 h for each), but it varied significantly ($P < 0.01$) between cattle and goats in difirent months. The stay period of both the animals was significantly longer ($P < 0.01$) during rainy season (9.6-11.5 h) than during winter and summer seasons (8.3-10.5 h).

The average of actual foraging hours (across the study period and two herds, Table 6), were similar for adult cattle (6.2 h day^{-1}) and goats and significantly ($P < 0.05$) shorter for calves. ANOVA indicated that the actual foraging periods were significantly ($P < 0.01$) different for different months, but between-herd difference was not significant. Across the seasons, actual foraging hours and proportion of the total stay period devoted to it, were maximum during rainy season and minimum during winter season for all animals (Fig 2). The actual foraging time (across the two herds, h day^{-1}) was positively related to monthly herb biomass (across the sites, g m^{-2}), which could be described by a single equation for cattle and goats: $Y = 4.9 + 0.02 X$ ($r = 0.9$, $P < 0.01$).

The time spent on walking (h day^{-1}, across the two herds) was inversely related to the amount of herb biomass (g m^{-2}) for all the animals: $Y = 3.04 - 0.013 X$ ($r = -0.94$, $P < 0.01$), while the time spent on resting and rumination was positively related to the herb biomass: $Y = 0.77 + 0.005 X$ ($r = 0.9$, $P < 0.01$).

The average time spent by animals on walking, resting, rumination and other activities were similar for adult cattle and goats, and were significantly ($P < 0.01$) shorter than those for calves, rumination showed a reverse pattern (Fig. 2).

Bite rate and bite size. ANOVA indicated that bite rate (number of bites, per min) varied significantly across different animals (adult cattle, calves and goats), sites and seasons ($P < 0.01$). The average bite rate across the months and herds was highest for goats, followed by adult cattle and calves (Table 6). Bite rates of animal pairs (adult cattle-calf and adult cattle-goat) were significantly ($P < 0.05$ to $P < 0.01$) different in different seasons (Table 7). Seasonal pattern (Table 6) showed that the bite rate was significantly greater ($P < 0.05$ to $P < 0.001$, Table 8) during wet season than during dry seasons. Thus the bite rate for each animal (average across the two herds) was positively related to monthly herb biomass (average across the sites), which could be described by a single equation for both cattle and goats: $Y = 26.91 + 0.14 X$ ($r = 0.93$, $P < 0.01$).

The average apparent bite size (across the months and sites) of goats was nearly 70 % smaller than that of the cattle (Table 6). ANOVA indicated that the bite size was significantly different across the sites and months. For cattle, it was much larger during rainy season than during either of the dry seasons (Table 8). Contrary to this, for goats the bite size was larger during dry seasons, as they shifted their foraging to shrubs. This also shows that goats bite size is greater when it is browser than when it is grazer.

The bite size on herbs and monthly herb biomass (g m^{-2}) indicates a significant positive relationship ($P < 0.01$) for both cattle and goats according to following eguations, respectively: $Y = 145.6 + 0.57X$ ($r = 0.96$, $P < 0.01$), and $Y = 33.03 + 0.1X$ ($r = 0.83$, $P < 0.01$).

Daily intake. The daily dry matter intake (DMI) of all the animals followed the pattern of the herb biomass. The daily DMI decreased sharply after rainy season, the decline (relative to the maximum DMI in September) being significantly greater ($P < 0.01$) for cattle than for goats. For example, the December's DMI was 75 to 88 % lower than that of the September for cattle, compared to 36-37 % lower for goats. Similarly the April's DMI was 62 to 80 % lower than that of September for cattle and 15 to 27 % lower for goats. ANOVA showed significant differences ($P < 0.01$) in daily DMI by animals in different months, but the difference between the animals of the two herds was not significant. The average DMI per day (average across the months and two herds) was 3.4 kg for bullock, 3 kg for cow, 1.1 kg for calf and 1 kg for goat. In Indian plains, an adult cattle is considered to be aqual to four goats (Pandey 1981), while in the present study in terms of intake it comes to three goats. Goats in hills are not different from goats of plains, but cows are smaller.

The monthly mean search cost, expressed as distance walked per unit DMI (km kg^{-1}) was 8 for goats, 3 for adult cattle and about 10 for calves. ANOVA indicated that the herd-to-herd difference was not significant for the search cost. It increased as herb biomass decreased according to:
$Y = 9.5 - 0.07X$ ($r = -0.848$, $p < 0.01$).

The average value of search cost, across the months and animals of two herds, was 2.5, 10.4 and 6.7 km kg^{-1} during rainy season, winter season and summer season, respectively.

Diet composition. During rainy season both goats and cattle avoided dead plant parts. During dry seasons cattle consumed a substantial amount of dead plant parts, while goats generally avoided them (Fig. 3). Cattle consumed leaves of woody plants only during winters and summers, while goats browsed upon them throughout the year, the proportion being especially higher during dry seasons (Fig . 3).

Response breadth. Levins's response breadth in present case is a measure of equitability, the greater the response breadth, the lower the selectivity, and *vice-versa*. In the forested and partly deforested sites the average response breadth (across the months) was significantly narrower ($P < 0.01$) for goats (0.22) than for cattle (0.41-0.42), while in the deforested site difference between the animals' response breadths was not significant. The plant species selectivity by animals increased ($P < 0.01$) with increasing monthly species richness and biomass of the vegetation. The goats maintained significantly narrower response breadth in the species-rich forested site (herd II) than in the species-poor deforested site (herd I),while cattle showed similar response breaths in the two sites.

When only the foraged species were considered (not all the species of grazinglands) the response breadths became much broader. The average response breadths for cattle and goats (0.62-0.64) indicate that both the animals divided the plant species intake with similar degree of evenness or unevenness. However, in the deforested site, goats (response breadth, 0.92) were far less selective than cattle (response breadth, 0.55-0.69) among the plant species they foraged.

	Bullocks	Cows	Calves	Goats	Bullocks	Cows	Calves	Goats	Bullocks	Cows	Calves	Goats
F R	3.5	3.5	3.0	-	45	42	25	-	234	210	176	-
W	3.0	2.4	1.9	-	32	29	15	-	168	147	123	-
S	2.2	2.1	1.7	-	36	33	17	-	156	138	112	-
P R	4.4	4.3	3.7	8.2	40	38	22	50	232	219	166	49
W	2.7	3.1	2.5	5.4	28	24	12	38	217	200	157	61
S	4.0	3.9	3.2	6.2	32	28	14	42	195	172	134	53
D R	7.1	6.9	5.6	7.0	46	44	26	54	211	199	171	58
W	4.7	4.5	3.5	4.6	34	30	16	42	163	147	104	62
S	5.8	5.6	4.4	5.3	37	33	18	45	184	167	137	60
Mean	6.3	6.2	5.1	6.1	37	34	19	46	199	183	146	58

Table 6. Actual foraging hours (hours day^{-1}), bite rate (bite min. $^{-1}$), and apparent bite size (mg dry wt. bite^{-1}) of animals in different plant communities averaged across sampling dates. F - forested site, P - partly deforested site - herd I, D - deforested site - herd II, Mean - average across the two herds and twelve months, R - rainy, W - winter, S - summer.

Animal pair (n = 3 for each animal)	Herd - I Deforested site			Herd - II Forested site			Herd - II Partly deforested site		
	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer
				Bite rate					
Cows-Bullocks	0.27 ns	1.72 ns	1.48 ns	0.42 ns	1.14 ns	0.94 ns	0.52 ns	1.38 ns	1.57ns
Cows-Calves	5.97''	2.96'	6.59''	4.23''	6.61''	7.44''	4.63'	3.91'	6.29''
Cows-Goats	3.57'	5.38''	5.63''	-	-	-	3.56'	8.40''	5.02''
				Bite size					
Cows-Bullocks	0.32 ns	1.51 ns	1.08 ns	1.04 ns	1.38 ns	1.48 ns	0.53 ns	0.75 ns	1.35ns
Cows-Calves	3.05'	4.72'	2.91'	2.99'	8.72'''	3.16'	3.26'	3.15'	3.11'
Cows-Goats	11.46'''	10.49'''	11.77'''	-	-	-	11.26'''	12.16'''	10.53'''

Table 7. Comparisons of bite rate and bite size (t - tests) in rainy (September), winter (December), and summer (April) seasons. For statistical explanations see Table 3.

Months	Deforested site - Herd-I Bullocks	Cows	Calves	Goats	Forested site - Herd-II Bullocks	Cows	Calves	Goats	Partly deforested site - Herd-II Bullocks	Cows	Calves	Goats
9 - 12 BR	4.7''	8.1''	7.5''	8.5''	5.7''	5.1''	9.8'''	-	6.5''	6.6''	5.9''	7.6''
BS	2.8'	5.3''	9.6'''	1.9 ns	5.7''	5.3''	9.4'''	-	3.4'	3.5'	3.5'	4.1'
9 - 4 BR	3.5'	4.9''	5.3''	4.0''	3.2'	3.1'	7.1''	-	3.4'	4.3'	7.6''	4.6''
BS	2.9'	4.3'	5.2''	1.6 ns	6.5''	5.8''	11.6'''	-	3.1'	3.3'	4.9''	3.9'
12 - 4 BR	1.9 ns	2.9'	2.8'	3.9'	2.7 ns	2.8'	3.7'	-	2.6 ns	2.6 ns	1.5 ns	2.2 ns
BS	0.4 ns	1.4 ns	2.6 ns	0	0.6 ns	0.9 ns	1.7 ns	-	1.3 ns	2.2 ns	3.5'	1.0 ns

Table 8. Seasonal differences (t -tests) in bite rate (BR) and bite size (BS). For statistical explanations see Table 3.

Month	Herd - I Deforested site Bullocks - Cows	Bullocks - Calves	Cows - Calves	Cows - Goats	Herd - II Forested site Bullocks - Cows	Bullocks - Calves	Cows - Calves	Cows - Goats
September	0.84	0.72	0.87	0.67	0.89	0.80	0.86	0.41
December	0.92	0.87	0.95	0.39	0.97	0.86	0.89	0.55
April	0.95	0.79	0.83	0.47	0.91	0.90	0.84	0.48
Average	0.90	0.79	0.88	0.51	0.92	0.85	0.86	0.48

Table 9. Proportional similarity between the animals in different months. This pertains to plant species composition of animal diet.

In the proportional similarity in species composition of diet (Table 9) cattle were distinctly more similar among themselves, than they were to goat. Proportional contribution of different growth forms in animal diet in terms of dry mass is given in Table 10. Bullock and calf did not differ significantly from cow, therefore only cow's diet composition was considered as representative of cattle diet. The patterns emerging from the data of September i.e., at the end of rainy season when herb biomass and species richness were maximum and December and April representing winter and summer seasons, when herb biomass was minimal are described below. In September the food intake of goat was more or less evenly distributed among the various growth forms, while cow's intake had significantly greater proportion of grasses and sedges (31 to 81 % across the sites) than of the forbs. In December most of the cow's intake was from herbaceous dead individuals in the deforested site

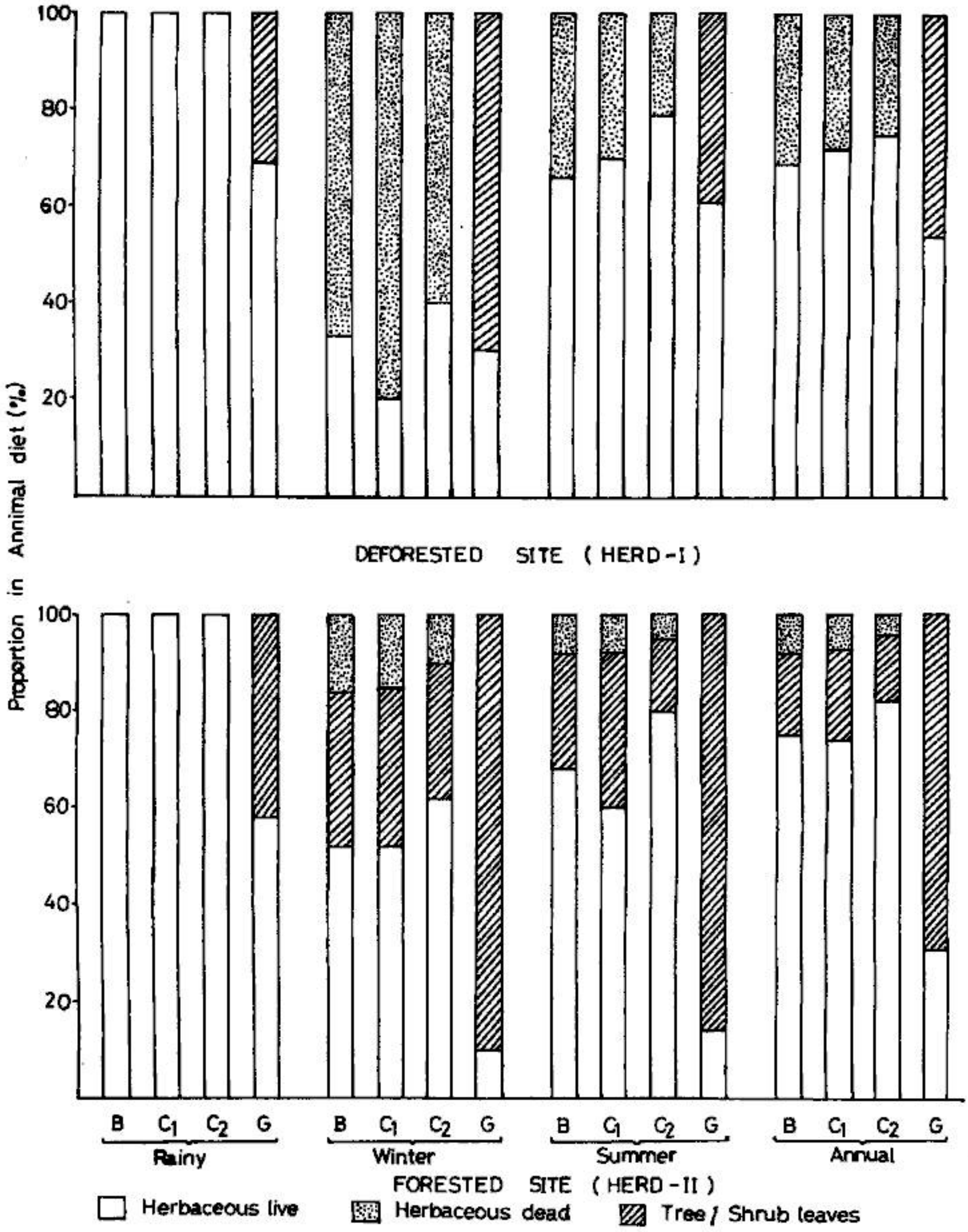

Fig.3. Proportion of tree/shrub leaves and herbaceous dead in animal diet during rainy, winter, and summer seasons. B - bullocks, C_1 - cows, C_2 - calves, G - goats.

(70 %) and from woody plants leaves (tree saplings and shrubs) in forested site (41 %), while goat's intake was predominantly by the leaves of woody plants in both the sites (Table 10). In April the cow's intake was mixed one, while goat's intake was clearly dominated by leaves of woody plants in the forested site (Table 10).

Selection ratio (SR, Table 10) indicated that in the forested site (herd II), grasses and sedges were the most preferred plants for cow. Among the forbs of this site the cow's selection ratio was generally higher for short forbs than for either tall or cushion-spreading forbs. In the deforested site cow's SR was greater for short forbs than for other forms. In this site they avoided tree saplings and cushion and spreading forbs. For goats, tall forbs and tree saplings were generally the most preferred forms in forested site and in deforested site, respectively (Table 10).

Discussion

In spite of taking large number of replicates by closely following the animals, the value of our data on diet composition of animals is limited, as it was difficult to simulate herbivore's bite. However, some patterns of foraging behaviour of the study animals are identifiable (Table 11).

Time allocation and search cost. In the present study the total stay period of animals in the sites varied across the seasons and it was directly related to the day-length. Animals spent proportionally greater time on foraging and rumination as herb biomass of the sites increased. Cowan and O'Grady (1976), Chacon and Stobbs (1976), Cowan *et al.* (1986) have also reported that grazing time is reduced when the yield of pasture is very low.

Being more mobile (Table 11) and capable of reaching steep slopes inaccessible to cattle, goats had wider foraging areas than cattle. Related to this was the markedly higher search cost for goats compared to that for cattle (Table 11). The low requirement to move while foraging may indicate that cattle are able to cope with poor quality food. This should result in more concentrated foraging by cattle than by goats, especially when day-to-day variations in foraging tracks are also low. Since moderate grazing pressure often promotes species richness and diversity of communities (Mc Naughton 1985), we may expect that the cattle would reduce it within the area of their influence and goats would increase diversity in the grazinglands.

Bite rate, bite size and dry matter intake. The bite rate for all the animals was maximum during rainy season when the plant biomass was highest and it declined with the sharp decline in herb biomass during the dry seasons. This is consistent with the reports of Pandey (1981) for cattle and goats of Indian plains. The bite rate of goat was significantly higher than that of cattle. The selection from larger number of species might have caused low bite rate in the relatively more species-rich partly deforested site.

A greater shift from herbs to woody plants resulted in a greater bite size of goat during winter season than the other seasons. The goats bite size was significantly greater on woody species (77 mg bite^{-1}) than on herbs (41 mg bite^{-1}), while cattle's bite size did not vary significantly from woody species to herbs. The average bite size on herbs was positively related to herb biomass for both cattle and goats. Allden and Whittaker (1970), Hodgson (1981), Forbes (1982) and Penning (1986) have also reported that in temperate swards, as swards surface height increases, bite size linearly increases. Forbes and Coleman (1987) found that although there was a close relationship between mass and height, consistently better results were obtained with herbage mass rather than with height.

The daily dry matter intake a product of grazing time, bite rate and herbage intake per bite was maximum during rainy season. In dry months the lower values of these variables resulted in low dry matter intake. However, goats, in part compensated for low bite rate during winter and summer seasons by increasing the bite size. Consequently, easonal decline in intake of goats was far less than that of cattle. Hodgson (1977,1982a,b) and Dougherty *et al.* (1988) have reported that grazing time, bite rate and bite size are the variables which animals use to compensate for low rates of intake. Obviously, in this region of ever-degrading grazinglands, survival of goats is likely to be better. In recent years goats population has increased, and that of cattle stabilized (Singh and Singh 1991).

Diet composition. Cattle consumed dead plant parts in dry months when plant cover was sparse. A higher proportion of dead biomass in the diet of cattle in dry months is understandable, since at higher stocking rate where the rate of herbage consumption exceeds the rate of forage regrowth, the animals are forced to use all the available forage (Forbes 1988). This results in a decline in digestibility of the diet as the animal graze into lower horizons of the swards (Hodgson 1981). Being well adapted to browsing (Cory 1927), goats preferred browsing on woody species rather than foraging close to ground surface on dead herbal biomass during dry seasons. Several workers have

Months	Growth form	Herd- I Deforested site				Herd II Forested and partly deforested site			
		Cows		Goats		Cows		Goats	
		PC	SR	PC	SR	PC	SR	PC	SR
September	Woody plants	0.0	0.0	23.1	25.7	0.0	0.0	24.1	4.3
(Rainy)	Tall forbs	7.4	3.7	31.4	15.9	18.7	10.2	17.7	10.2
	Grasses and sedges	11.6	2.8	30.2	0.5	30.9	36.8	18.1	2.9
	Short forbs	11.0	5.0	15.3	7.0	19.7	19.6	35.5	3.8
	Cushion and spreading forbs	0.0	A	0.0	A	24.3	14.8	4.6	2.8
	Dead biomass	0.0		0.0		0.0		0.0	
December	Woody plants	0.0	0.0	72.9	52.1	41.9	5.0	95.5	11.4
(Winter)	Tall forbs	8.7	17.4	8.9	17.8	9.4	22.9	0.7	1.7
	Grasses and sedges	A	A	A	A	5.9	31.1	0.7	3.7
	Short forbs	20.9	6.7	18.2	5.9	26.0	8.3	3.1	1.0
	Cushion and spreading forbs	A	A	A	A	0.0	0.0	0.0	0.0
	Dead biomass	70.4		0.0		16.8		0.0	
April	Woody plants	0.0	0.0	37.5	16.3	29.9	2.5	86.9	7.3
(Summer)	Tall forbs	2.2	0.0	0.0	0.0	5.4	1.4	0.0	0.0
	Grasses and sedges	55.5	11.1	51.4	10.3	43.0	103.1	11.4	38.3
	Short forbs	14.8	49.3	11.2	33.9	12.7	26.1	1.8	3.5
	Cushion and spreading forbs	A	A	A	A	0.0	0.0	0.0	0.0
	Dead biomass	27.5		0.0		9.0		0.0	

Table 10. Proportional contribution (PC in %) of different growth forms to daily dry mater intake, and the selection ratio (SR) of the forms foraged by cow and goat in different seasons. A - absent.

Foraging character	Ad. cattle	Calves	Goats
Foraging area	Restricted to gentle slopes	Same as for cattle	Widely spread including steepest slopes
Actual foraging period (h\day)	1	0.84	1
Time spent on walking (h\day)	1	1.25	0.92
Resting and rumination (h\day)	1	1.58	0.73
Other activities (h\day)	1	1.42	1.10
Daily for. track length and course		less zig-zag	zig-zag
Search cost (distance needed per unit food intake)	1	2.95	2.47
Mobility rate(km\h)	1	0.84	1.10
Bite rate (number of bites\ min.)	1	0.54	1.31
Bite size (mg\bite)	1	0.76	0.31
		increasing with the vegetation size	
Daily food intake (kg dry matter\day)	1	0.34	0.31
RDFI (%) - winter	1	1.1	0.47
- summer	1	1.14	0.32
Variation in temporal forag. pattern	less	intermediate	more
Response breadth of foraging across species			
- species rich site (forested)	1	1	0.53
-species-poor site (deforested)	1	1	1.27

Table 11. Summary of foraging characters of animals in the grazing land. All the values are averaged and relative to those of adult cattle which have been standardized to 1. RDFI - reduction in daily food intake relative to maximum dry matter intake in September.

reported that goats have an ability to improve the quality of food by selecting from the available vegetation (Malechek and Leinweber 1972, Coblentz 1978). Because of the relatively small digestive tract, the selective browsing has advantages to goats over other ruminants.

The animals diet composition may also be analysed in terms of plant forms. It varied markedly across the seasons and sites. A pronounced shift from berbaceous vegetation (rainy) to woody vegetation shows that goat is opportunistic, and thus more successful in meeting out its food requirement in this system of sharp changes of vegetation.

The use of selection ratios (proportion of plant species or species group in the diet divided by the corresponding proportion in the stand) is recommended as the best way to express diet selection (Van Dyne *et al.* 1980). However, Hodgson and Grant (1981) have pointed out that such rations are purely relative and have their limitations. Selection ratio in relation to growth forms varied across the seasons and sites. In response to greater availability, cows showed high preference for grasses and sedges in the deforested site, while goat preferred taller forms (tree/shrubs and tall forbs) in both the sites (SR, 10.2. and 4.3 in forested site, and 15.9 and 25.7 in deforested site, respectively for tall forbs and tree/shrubs). Thus preference seems to be directly related to the morphology of plants and foraging mechanics of the animal. Cattle are grazers (Bell 1978, Arnold 1980), they usually use their tongues to gather vegetation into mouth before biting and tearing it off (Arnold 1980, 1985, 1987; Hodgson 1981). It seems that cushion and spreading forbs were too small to be easily foraged upon while tall forbs were less preferred by cow in the periods of abundance of food. Grasses and sedges with well-spread tillers and short forbs with umbrellalike form (Givnish 1987) are easy to to gathering into the mouth of cattle. Higher selection ratio of goats for taller forms is understandable since goats are basically browsers (Bell 1978, Arnold 1980, 1985, 1987; Upadhyay 1988) and are capable of removing individual leaves from a plant (Arnold 1985, Hodgson 1981). A high thereshold for strong teste in goats enables them to consume large guantities of browse material which has a large number of secondary compounds (Upadhyay 1988). Shrubs and tree leaves are main feed of goats which are not very much acceptable by other animals and such they do not compete with other livestock (Upadhyay 1988).

Generally, only small differences have been found in the diets selected by the animals of same breed but differing in age. Hodge and Doyle (1967) compared 10 week old lambs and yearlings on two types of pasture and found that they selected similar amounts of grass and clover. Similar results have been found in the diet selected by lambs and older sheep (Langlands 1969, Jamison and Hodgson 1979), calves and cows (Pandey 1981). Among calves, cows and bullocks we did not find significant difference in diet composition.

In the present study proportional similarity in species composition of diet between cow (representative of cattle) and goat varied with changes in season and site. During rainy season when herbaceous biomass was at its peak cows and goats showed maximum similarity in species composition of their diets. The higher proportion of dead tissues and that of woody plants in the diets of cow and goat, respectively decreased similarity between them during the dry periods of winter and summer when herbaceous cover was far sparse.

In response to the lower number of plant species, significantly higher proportional similarity (Table 9) between cow and goat occurred in the deforested site (0.67) than in the more species-rich forested site (0.41). Dudzinski and Arnold (1973) and Langlands and Sanson (1976) have also reported that cattle and goat differ in food preference when grazing species-rich swards, but not when grazing simple swards (Le Du and Baker 1981).

Levins's B and other commonly used measures of niche breadth are often estimates of response equitability than of response breadth, but in case of animals certain array of utilizable items defines their response breadths neatly, and therefore B is more useful for them than for plants (Zanged and Bazzaz 1983). Levins's response breadth of goat was

significantly narrower than that of cattle when plant species richness and biomass were high, indicating its more selective behaviour in foraging than that of cattle. But the difference between goats and cows became non-significant as goat's response breadths widened when plant species and plant biomass declined. This suggests that goat is an "opportunistic" in its foraging behaviour, utilizing only a few species when species richness is high and plant biomass is abundant, but resorting to forage upon most species in the condition of paucity of plant material.

The higher food search cost and narrower response breadth of goat in the alpine meadows where potential quantity and quality never restricted animals selectivity (Negi *et al.* 1993) than in the present study (Table 12) also highlights its opportunistic foraging character.

Variables	Alpine meadows	Present study
Bite rate (bites $min.^{-1}$)	23.0	45.8
Bite size (mg $bite^{-1}$)	59.0	58.0
Daily intake (kg dry matter)	0.7	1.0
Foraging track (km day^{-1})	8.0	7.6
Search cost (km kg^{-1} food)	15.4	8.2
Response breadth	0.49	0.77

Table 13. Foraging variables of goat in alpine meadows (Negi *et al.* 1993) and in the present study.

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