COMMUNAL PELLET DEPOSITION SITES OF HIMALAYAN MUSK DEER (*Moschus chrysogaster*) AND ASSOCIATED VEGETATION COMPOSITION.

BHAKTA BAHADUR SHRESTHA

Norwegian University of Life Sciences
Department of Ecology and Natural Resources Management (INA)
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Sincerely,

Bhakta Bahadur Shrestha

Ås, Norway

ABSTRACT

The Himalayan musk deer *(Moschus chrysogaster),* found in the sub-alpine and alpine vegetation of the Himalayan region, is one of the endangered deer species of Nepal. This study conducted in the Langtang National Park, Nepal analyzed how the musk deer select their communal pellet deposition sites, compared vegetation at the pellet deposition sites with adjacent sites (5-10m from a pellet site) and control sites (30 m from pellet site without pellet groups) and explored the potential role of musk deer as an agent of seed dispersal. The results depicted that altitude, cattle grazing, rock cover and distance to settlements influenced on selecting communal pellet deposition sites by the musk deer. The pellet deposition sites had lower mean richness of forbs and seedlings species. The evenness and mean density of forbs species were also lower but graminoid diversity and evenness of shrubs and seedlings were higher at the pellet sites compared to control sites. No unique plant species were dependent on musk deer for the dispersal of seeds. This study suggested that human and their domestic cattle disturbances should be minimized in order to conserve musk deer and its habitats.

Key words: Dispersal, diversity, evenness, Langtang National Park pellet, Nepal, richness,

1. INTRODUCTION

Herbivores can have a profound effect on terrestrial ecosystems (Harrison & Bardgett 2008). Their interaction with the landscape and vegetation may have either beneficial or adverse effect on both vegetation and other herbivores (Barnes et al. 2007). They directly affect plants by removal and trampling of the soil and vegetation (Frank & Groffman 1998; Ruess & McNaughton 1987) and indirectly by the changing the nutrient availability and cycling to the plants (Floate 1970). Many studies have revealed that dung and urine deposition affect the nutrient cycling and availability in a small scale (Buschbacher 1987; Floate 1970; Harrison & Bardgett 2008; McGregor & Brown 2010; Willot et al. 2000). Animal excreta may increase soil microbial activity, C & N cycling and eventually the plant production (Dai 2000; Williams & Haynes 1995). Dung and urine deposition have a substantial effect on the vegetation both within natural communities (Day & Detling 1990; McNaughton 1983) and domestic pasture systems (Lovell & Jarvis 1996; Sakadevan et al. 1993). Herbivore grazing and browsing is also influenced by the deposition of their excreta (Day & Detling 1990). Herbivores may facilitate the dispersal of seeds via their dung (Malo & Suarez 1995; Malo & Suarez 1998). They act as seed dispersers either by passing seeds through their digestive tract or seeds attaching to their outer body parts (Dinerstein 1989; Mason & Middleton 1992). Previous studies have documented that a large number of herbivores such as roe deer (*Capreolus capreolus),* red deer (*Cervus elaphus*), sika deer *(Cervus nippon),* fallow deer *(Dama dama),* white tailed deer *(Odocoileus virginianus),* wild boar *(Sus scrofa*) and rabbits *(Oryctolagus cuniculus)* play a crucial role in transporting a large number of seeds (Malo & Suarez 1998; Mason & Middleton 1992; Miller et al. 1992; Mousissie et al. 2005; Pakeman 2001; Rooney & Waller 2003; Schmidt et al. 2004; Vellend et al. 2003; Williams et al. 2008; Yamashiro & Yamashiro 2006). Diet preference is the most important factor for the dispersal of plants (Bartuszebige & Endress 2008). Edible foliage and small hard seeded species which are highly preferred by the herbivores have a higher chance of getting dispersed (Janzen 1984). Seed dispersal may have significant contribution in the demographic and genetic structure of plant communities (Myers et al. 2004).

Though a large number of herbivores are responsible for long distance dispersal of native and exotic plants (Myers et al. 2004; Vellend et al. 2003), the role of musk deer *(Moschus* *chrysogaster)* in seed dispersal has not been explored. Musk deer use communal pellet deposition sites for defecation (Green 1987b). Their pellet groups may contain seeds and help in the dispersal of plants. In addition, their pellet groups and urine deposition may affect the growth of seedlings, shrubs, forbs and graminoids. Along with grazing, their communal defecation can have effects on the species composition, richness, diversity and density of plants in the Himalayan ecosystem. Due to excessive hunting and habitat degradation, population of musk deer has been declining dramatically, which lead them to be endangered or even extinct in some areas (Zhou et al. 2004). Though Himalayan musk deer is classified as Endangered (EN) in IUCN (International Union for Conservation of Nature) Red List of threatened species; appendix I of CITES (Convention on International Trade of Endangered flora and fauna) (IUCN 2011), only few studies have been done on this species. These studies have only focused on the status, ecology and distribution. It is also necessary to understand the interaction of musk deer and vegetation. This study aims to analyze how the musk deer select their site for defecation and assess if plant species composition, density, richness, diversity and evenness differ among communal pellet sites, adjacent sites (5-10m from a pellet site) and control sites (30 m from pellet site without pellet groups) and finally evaluate the potential role of musk deer in plant seed dispersal.

2. MATERIALS AND METHODS

2.1 Study area

Langtang National Park is located in the central Himalaya of Nepal covering an area of 1710 km^2 of the three districts Rasuwa, Nuwakot and Sindhupalchok (Chalise 2003; Kharel 1997). The climate varies with altitude and aspect. Temperature ranges from -14 °C to 14 °C whereas rainfall varies from 804 mm to 3336 mm depending upon aspect, altitude and rain shadow effect (Durham University Himalayan Expedition 1977). Due to high variation in the climate and altitude, the park harbors a wide range of flora and fauna. Langtang National Park comprises the forest types from sub-tropical forest to alpine scrub (Sayers & Norconk 2008). This national park is considered as the habitat of rare wild animals such as wild dog *(Cuon alpinus),* wolf *(Canis lupus),* red panda *(Ailurus fulgens),* clouded leopard *(Neofelis lupus)* and snow leopard *(Panthera uncia).* Besides, the park is well known for one of the prime habitats of Himalayan musk deer (Kharel 1997). This study included the surrounding areas of Kanjala Himal from Mundu to Kigurchin which encompasses an elevation range of 3400-4300m and lies between 28° 12′ 32″ and 28° 11′ 34″ N latitude and 85° 31′ 26″ and 85°34′ 58″ E longitude (Fig. 1). This site comprised of three types of vegetation. Betula forest is solely dominated by *Betula utilies*, mixed forest consisted of mixed species of *Betula utilies, Abies spectabilies, Sorbus microphyalla, Rhodondendron campanulatum* and *Acer caesium* and alpine scrub which is mostly dominated with rhododendron shrubby species like *Rhododendron nivale, Rhododendron setosum* and *Rhododendron anthopogan.*

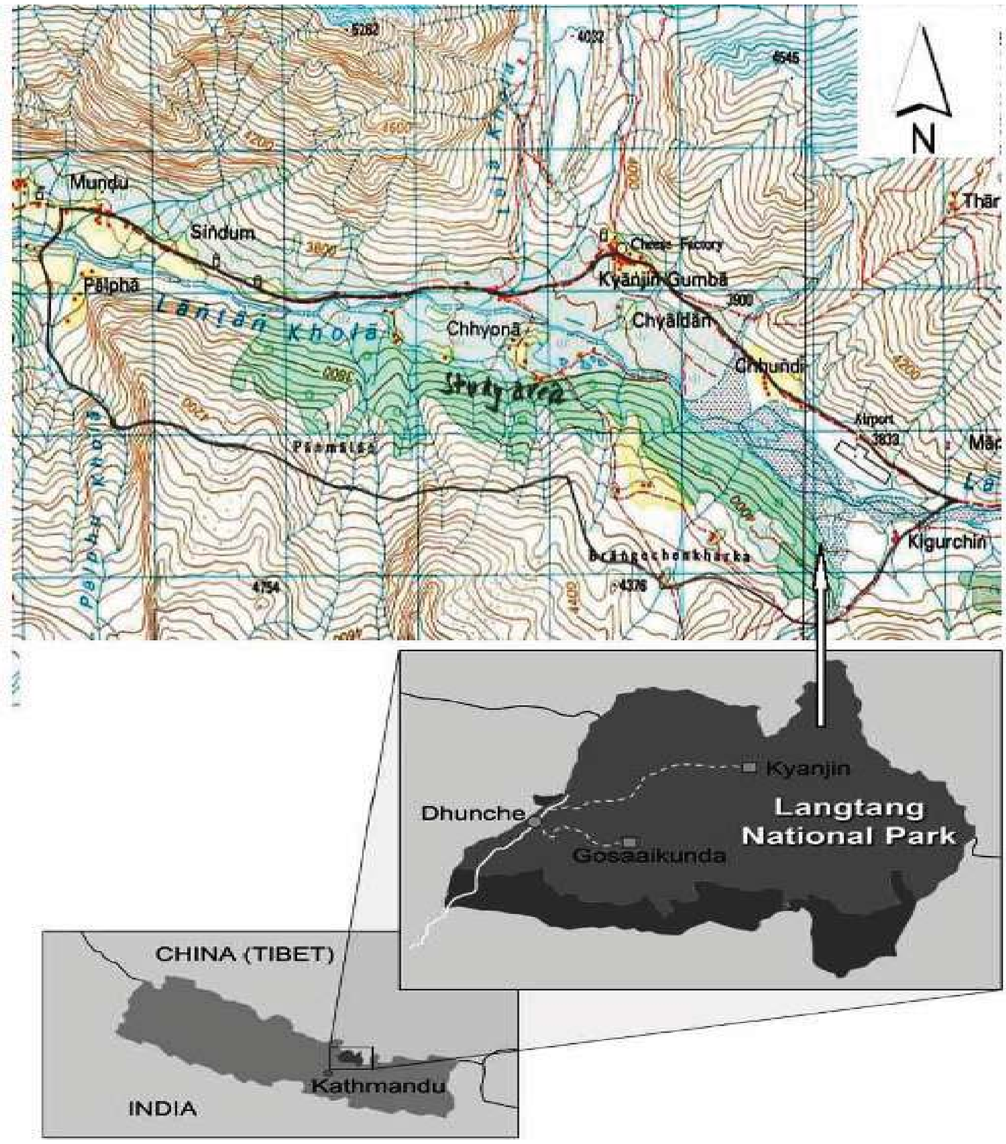

Fig.1. Map showing the study area.

2.2 Study species

The Himalayan musk deer, a native and protected deer species of Nepal, belongs to the order Artiodactyla of Moschidae family (Aryal et al. 2010; Whitehead 1972). They are distributed throughout the forested and mountainous parts of Asia from north of the Arctic circle southward to the northern edge of Mongolia and to Korea. Further south, avoiding the Gobi desert, the musk deer occurs in China, Burma, Northern India, Northern Vietnam and the Himalayan region. In central Asia, musk deer are found in Kazakhstan, possibly in Kyrgyzstan and the south of

Russia (Flerov 1952; Green 1986; Yang et al. 2003). They inhabit in the betula *(Betual utilies)* and rhododendron *(Rhododendron spp.)* forests of the Himalayan region at an altitude of 2500 to 4500 m (Kattel 1992). They are shy, solitary, territorial and crepuscular in habit and have a gestation period of 178-198 days, giving birth of a young in May-June (Green 1986). They are true concentrate feeders and feed on forbs and woody plants, leaves, flowers, twigs, lichens, moss, shoots and grass (Green 1987a; Kattel 1992). However, their diet varied seasonably. In autumn and winter, their main diet comprises high proportion of forbs and woody plants leaves whereas forbs and lichen in spring and summer. They have ability to adapt with poor quality diet when high quality diet is in acute shortage in winter (Green 1987a). Musk deer mainly use moderate slope with low forest cover, moderate to high shrub cover and high rock cover in the sub-alpine and alpine areas (Vinod & Sathyakumar 1999). Elongated dewclaws and low weight adapt them to climb trees and move in snow for feeding and other daily activities (Kattel 1992; Shrestha 1998). Musk deer use communal pellet deposition sites which are used by both sexes for defecation (Green 1987b; Shrestha 1998). They cover the fresh pellet by earth, old pellets, leaf litter and any other available debris to make them moist and smelly during dry autumn (Green 1987b).

2.3 Field sampling

A preliminary field investigation was conducted to assess vegetation types, physiographic condition, bio-physical features and the potential areas occupied by musk deer. The field study was carried out in June-July of 2011. Following the preliminary survey, a total of 149 sites of size 10 x 10 m^2 were randomly positioned in the study area where musk deer signs had been located. Inside the 10 x 10 m^2 sites, one 5 x5 m^2 plot was laid out randomly. In addition, three 1x1 m^2 subplots were randomly laid, one inside and two outside of 5 x 5 m^2 plot (Fig. 2). But when pellet groups were detected in the site, two 1x1m^2 subplots were laid in the centre of pellet groups inside 5x5 m^2 plot and two 1x1 m^2 subplots as adjacent sites were laid randomly outside 5x5 m^2 within 10x10 m^2 sites. Furthermore, control sites of 10x10 m^2 without pellet groups were randomly located at 30 m within the same habitat type (Fig. 3). Trees (girth breast height > 25 cm) were identified and measured in 10x10 m^2 sites. Shrubs (woody plant other than tree species) and saplings (tree species > 1 m in height and/or < 25 cm girth breast height) were recorded in 5x5 m^2 plots. Graminoids, forbs (flowering herbs which dies out at the end of each growing season), and seedlings (tree species < 1 m in height) were identified and recorded in 1x1 m^2 subplots. Slope, aspect, latitude, longitude, altitude, cattle grazing intensity, firewood and timber cutting, rock cover, litter cover, distance to settlements, edge distance, distance to water and rock cover were also recorded. All coverage data were taken in percentage. Distance from water, edge and settlements were calculated using topographical map and field measurement. Cattle grazing intensity and firewood and timber cutting were separately assessed in the ordinal scale from 0 to 4. (For cattle grazing, 0= no cattle dung (no grazing), 1= cattle dung in one of four 5x5m^2 in a site, 2= cattle dung in two of four 5x5m^2 in a site, 3= cattle dung in three of four 5x5m^2 in a site, 4= cattle dung in all 5x5m^2 in a site. Likewise for firewood and timber cutting, 0= no firewood and timber cutting, 1= firewood and timber cutting scars in one of four 5x5m^2 in a site, 2= firewood and timber cutting scars in two of four 5x5m^2 in a site, 3= firewood and timber cutting scars in three of four 5x5m^2 in a site, 4= firewood and timber cutting scars in all 5x5m^2 in a site).

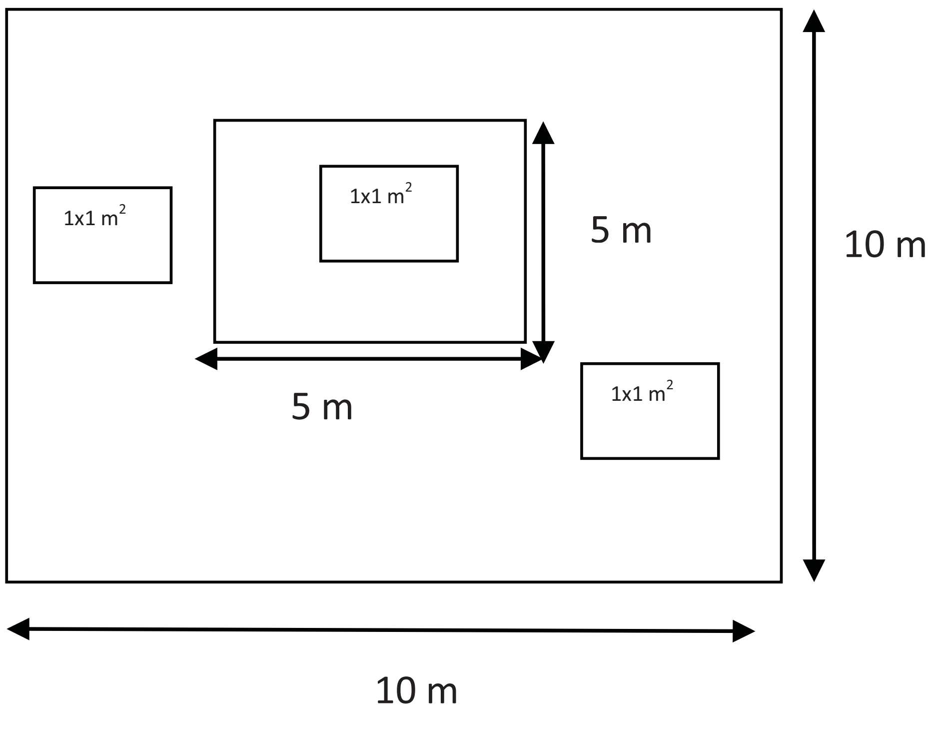

Fig. 2. Sampling design showing a site (10x10m^2), plot (5x5m^2) and subplots (1x1m^2).

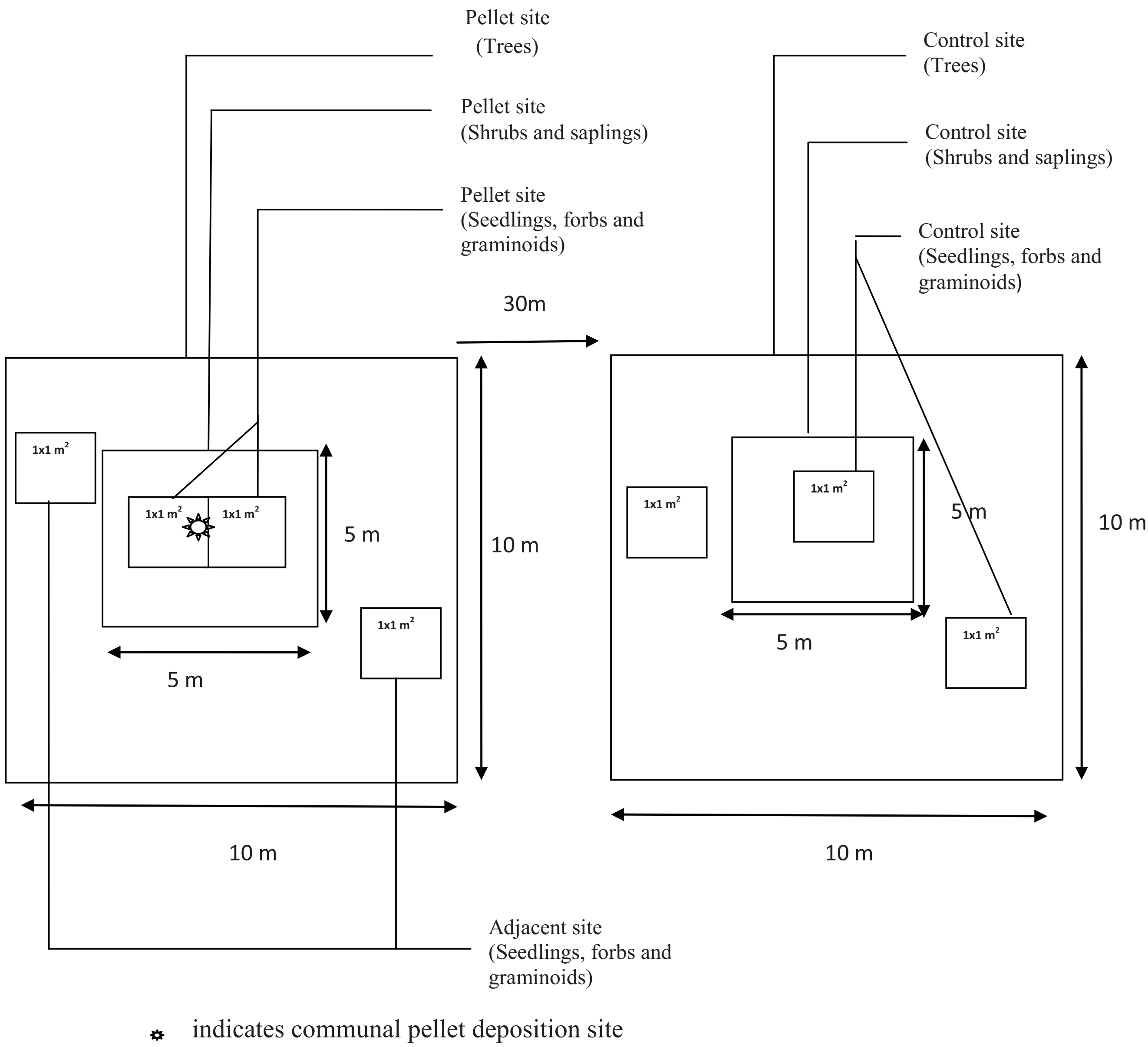

Fig. 3. Sampling design showing pellet site, adjacent site and control site.

2.4 Statistical analysis

Generalized linear model (GLM) was used to analyze the relationship between the response variable (pellet groups) and explanatory variables (slope, distance to water, distance to human settlements, rock cover, litter cover, relative radiation index (RRI), altitude, cattle grazing intensity, firewood and timber cutting, edge distance and tree density) by statistical software R 2.14.0 (R Developement Core Team 2011). All the variables were checked for collinearity and none of the variables were found having correlation coefficient higher than 0.5 (Annex 1). Pellet groups were treated as a binomial variable (presence or absence) which follows binomial distribution and requires a logit link (Guisan et al. 1999). The best fitted model was selected based on Akaike Information Criterion (AIC) by automatic “step-wise” model selection approach from both directions. The best fitted model was chosen based on the lowest AIC value. Tree density was calculated as the total number of all individual of tree species within 0.01 ha whereas the relative radiation index was calculated by using formula $\{\cos(180° - \Omega)*\sin\beta*\sin Ø\} + \{\cos\beta*\cos Ø\}$ where Ω is aspect, β is the slope and Ø is the latitude of each site (Shrestha & Jha 2010).

Using CANOCO 4.5 software package, a canonical correspondence analysis (CCA) was performed to evaluate the variability in species composition in trees, forbs, shrubs, graminoids, seedlings and saplings respectively in relation to explanatory variables (pellet groups, slope, distance to water, distance to human settlement, rock cover, litter cover, relative radiation index, altitude, cattle grazing intensity, firewood and timber cutting). After forward selection by Monte Carlo permutation tests, only the significant variables ($p<0.05$) were included in the analysis showing their importance in explaining the total variability in the species composition. Only species with the highest weight (the most frequent ones) were selected in forbs biplot display (Leps & Smilauer 2003).

Cumulative richness of each treatment sites was computed and compared among them based on 999 permutations using the rich package of function *c2cv* in R (Rossi 2011). Trees (100 m^2), shrubs and saplings (25 m^2) at the pellet sites were compared separately with vegetation of control sites (30 m from pellet sites without pellet groups) but in forbs, graminoids and seedlings, 2 m^2 subplots at pellet site were compared with 2 m^2 subplots at adjacent sites (5-10m from pellet sites) and randomly chosen 2 m^2 subplots at control sites (30m from pellet sites without pellet groups). Besides, species accumulation curve of each treatment sites in all communities were constructed with the *accumcomp* function from BiodiversityR (Kindt & Coe 2005). Mean richness of each treatment sites was calculated and compared among treatment sites based on 99 permutation using rich package of function *c2m* in R (Rossi 2011). In addition, mean densities were calculated for each treatment sites in all communities and one way ANOVA with tukey's pair-wise test in three treatment sites and two sample t-test in two treatment sites were used to test significant difference at 5 % level of significance among the treatment sites by using R 2.14.0 (R Developement Core Team 2011).

Renyi diversity ordering technique was used to compare diversity and evenness of treatment sites in each community with the function *renyicomp* from BiodiversityR package in R. Each value of the renyi diversity profile is based on parameter alpha which is scaled at 0, 0.25, 0.5, 1, 2, 4, 8 and infinity. Diversity ordering values are compared based on their effectiveness in graphically displaying the differences of profile (diversity or evenness) in treatment sites. The curve that starts at higher profile indicates the higher diversity or evenness but similar when the curves intersect (Kindt & Coe 2005; Tothmeresz 1995).

3. RESULTS

I recorded 67 plant species of which 67% were forbs, 10% trees, 15 % shrubs and 7 % graminoids. Out of 149 sampling sites, 42 sites had communal pellet groups which were found in betula forest, mixed forest and alpine scrub (Fig. 4). There was no significant difference in the distribution of communal pellet group deposition sites among the vegetation types (Fisher's exact test, p=0.62).

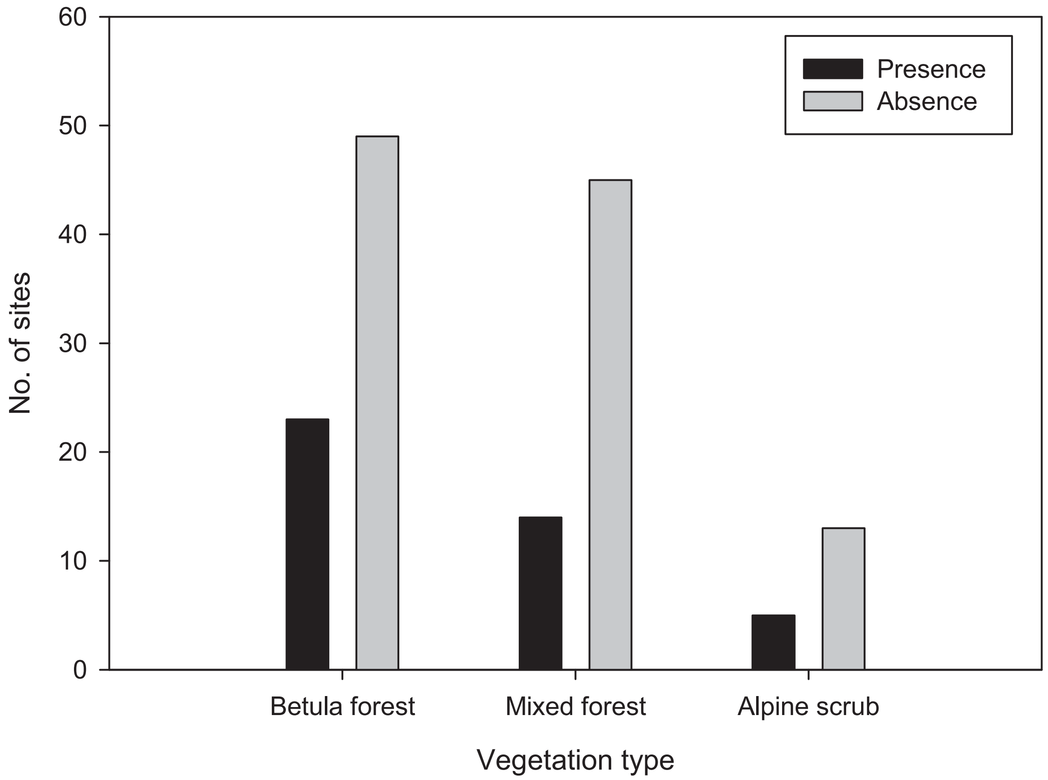

Fig. 4. The distribution of communal pellet group among vegetation types

3.1 Effect of biophysical variables on the communal pellet deposition

Altitude, cattle grazing, rock cover and distance to settlements affected the communal pellet deposition of musk deer where altitude and cattle grazing were the main variables influencing the pellet deposition (Table 1).

Table 1. The results of reduced model of GLM selected based on AIC criterion, showing the effect of altitude, cattle grazing, rock cover and distance to settlements on the pellet deposition.

Variables	Estimate	Std. Error	Z value	p value
(Intercept)	20.86	9.31	2.24	<0.05
Altitude	-0.005	0.002	-2.21	<0.05
Cattle grazing	-1.39	0.35	-3.91	<0.001
Rock cover	0.02	0.01	1.76	0.07
Distance to settlements	-0.001	0.0006	-1.58	0.11

Pellet group deposition had no significant effect on species composition of trees, shrubs, forbs, graminoids, seedlings and saplings (Table 2). Rock cover, altitude, firewood and timber cutting, distance to settlements, litter cover and distance to water were the variables significantly influencing the tree species composition as shown in canonical correspondence analysis (CCA) biplot diagram (Fig. 5a). The tree species associated with the first gradient were *Sorbus mycrophylla*, *Salix sikkemensis* and *Abies spectabilies*. The second gradient was caused by the rock cover, distance to water, firewood and timber cutting and litter cover which had association with *Betula utilis*, *Lyonia ovalifolia* and *Rhodondendron campanulatum.* Cattle grazing, firewood and timber cutting, litter cover, distance to water and altitude were the variables affecting the species composition of shrub community where the *Salix calyculata, Rhododendron setosum* and *Rhododendron anthopogon* influenced by distance to water, *Rhododendron nival* influenced by cattle grazing and *Cotonester rotundifolius* and *Ribes grifithii* influenced by the litter cover (Fig. 5b). In forb community, firewood and timber cutting, cattle grazing, slope and altitude had affected the species composition (Fig. 5c). *Carex spp* was associated with altitude whereas unidentified graminoid and *Poa spp.* were associated with the firewood and timber cutting in graminoid community (Fig. 5d). Rock cover and slope were the only variables influencing on the seedling species composition (Fig. 5e) whereas firewood and timber cutting, rock cover, slope and altitude were the variables influencing the sapling species composition (Fig. 5f).

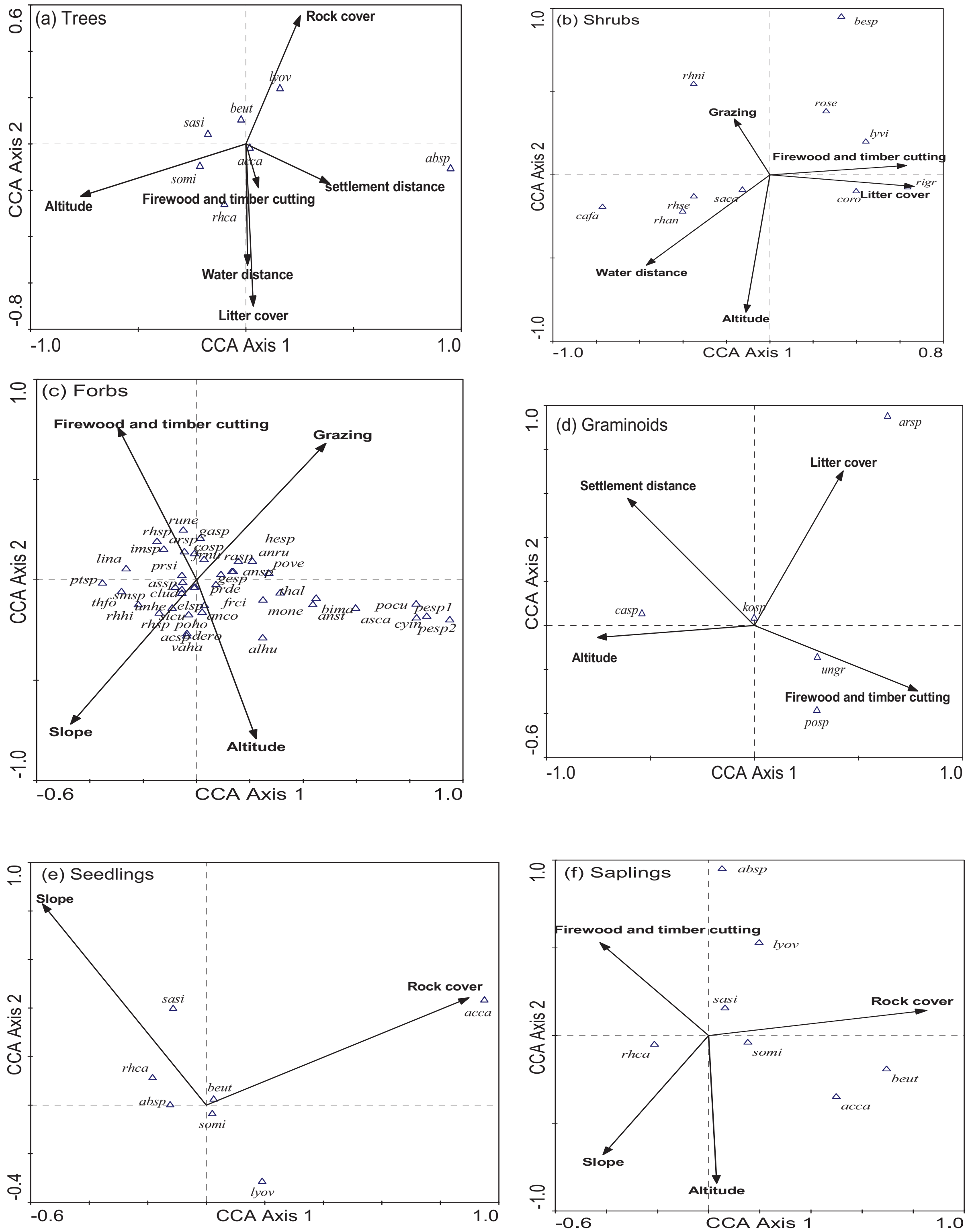

Fig. 5. The species-environmental variables biplot of CCA showing the effect of environmental variables on the species composition with environmental variables selected by the Monte Carlo permutation tests in (a) Trees, (b) Shrubs, (c) Forbs, (d) Graminoids, (e) Seedlings and (f) Saplings. The arrows indicated the environmental variables, triangle indicated species and species code as in annex 2.

Table 2. Summary statistics of Monte Carlo permutation tests including all the environmental variables in relation to species composition in trees, shrubs, forbs, graminoids, seedlings and saplings. Results are based on 499 permutations.

Variables	Plant community											
	Trees		Shrubs		Forbs		Graminoids		Seedlings		Saplings	
	F ratio	P value	F ratio	P value	F ratio	P value	F ratio	P value	F ratio	P value	F ratio	P value
Rock cover	2.42	<0.05	1.72	0.08	0.79	0.52	1.69	0.13	4.45	<0.05	6.80	<0.01
Altitude	10.78	<0.01	3.57	<0.01	2.27	<0.05	7.15	<0.01	1.05	0.39	4.06	<0.01
Slope	0.16	0.99	1.82	0.07	3.71	<0.01	0.99	0.39	2.77	<0.05	2.87	<0.01
Firewood and timber cutting	2.66	<0.05	3.17	<0.01	3.31	<0.05	11.7	<0.01	0.59	0.65	2.25	<0.05
Distance to settlements	7.18	<0.01	1.32	0.19	1.73	0.08	3.36	<0.01	0.72	0.59	1.4	0.23
Cattle grazing	1.27	0.25	3.04	<0.01	3.83	<0.05	1.63	0.16	0.77	0.49	1.27	0.21
Litter cover	3.69	<0.05	5.09	<0.01	2.09	0.05	7.78	<0.01	1.07	0.34	1.27	0.21
Distance to water	2.36	<0.05	4.44	<0.01	1.33	0.16	1.07	0.35	1.22	0.30	1.08	0.38
Relative radiation index	1.44	0.18	0.75	0.64	0.23	1.00	2.26	0.07	0.83	0.51	0.86	0.47
Pellet groups	0.73	0.63	0.70	0.71	1.12	0.32	1.13	0.35	0.63	0.66	0.64	0.67

3.2 Cumulative richness

A total of 51 and 48 plant species including trees, shrubs, forbs and graminoids were detected in the pellet sites and control sites respectively. 32 species comprising only forbs and graminoids were recorded in adjacent sites. Sapling of all the species of trees were found in both pellet sites and control sites whereas 4, 5 and 6 seedling species were observed at pellet sites, adjacent sites and control sites, respectively. There was no significant difference in cumulative richness of trees between the pellet sites and control sites (Table 3 and Fig. 6a). Cumulative richness of shrubs did not differ significantly between pellet sites and control sites (Table 3 and Fig. 6b). Cumulative richness of forbs at pellet sites did not differ with both adjacent sites and control sites (Table 3 and Fig. 6c). Cumulative richness of graminoids at pellet sites did not differ significantly with both adjacent sites and control sites (Table 3 and Fig 6d). Cumulative richness of seedling species did not differ significantly among treatment sites (Table 3 and Fig. 6e). Similarly, cumulative richness of sapling species between pellet sites and control sites was not significantly different (Table 3 and Fig. 6f).

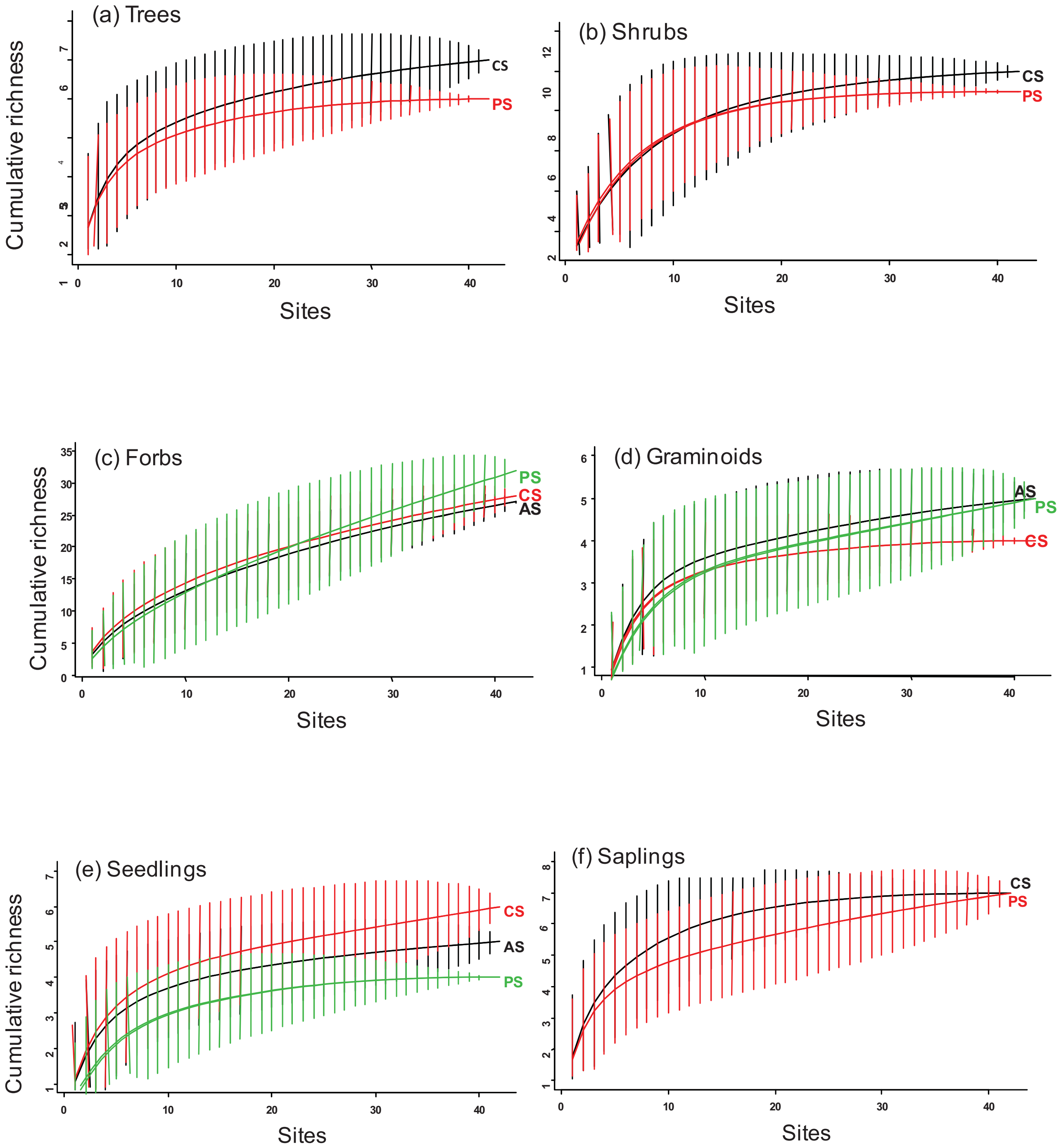

Fig. 6. Species accumulation curves for (a) Trees, (b) Shrubs, (c) Forbs, (d) Graminoids, (e) Seedlings and (f) Saplings for the treatment sites (PS- pellet sites, AS- adjacent sites and CS- control sites). The bars indicate 95 % confidence interval.

Table 3. Cumulative richness in seedlings, forbs, graminoids, saplings, shrubs and trees. The estimated cumulative number and p-values are from the rich package in R. The results are based on 999 randomizations. NC means not comparable.

Treatments		No of species	
Richness community-1	Richness community-2	Com1-com2	P value
1. Seedlings			
Pellet sites (4)	Adjacent sites (5)	-1	0.47
Pellet sites (4)	Control sites (6)	-2	0.23
Control sites (6)	Adjacent sites (5)	1	0.51
2. Forbs			
Pellet sites (32)	Adjacent sites (27)	5	0.26
Pellet sites (32)	Control sites (28)	4	0.27
Control sites (28)	Adjacent sites (27)	1	0.47
3. Graminoids			
Pellet sites (5)	Adjacent sites (5)	0	NC
Pellet sites (5)	Control sites (4)	1	0.43
Control sites (4)	Adjacent sites (5)	-1	0.44
4. Saplings			
Pellet sites (7)	Control sites (7)	0	NC
5. Shrubs			
Pellet sites (9)	Control sites (10)	-1	0.46
6. Trees			
Pellet sites (5)	Control sites (6)	-1	0.45

3.3 Mean richness and density

Mean richness and density of tree species at pellet sites did not differ significantly with control sites (Table 4 and $p=0.58$, Fig. 7a). Mean shrub richness and coverage did not differ between pellet sites and control sites (Table 4 and $p=0.33$, respectively, Fig. 7b). Mean richness and density of forbs species were lower at pellet sites than control sites (Table 4 and $p<0.05$, respectively). However, mean richness and density did not significantly differ between pellet sites and adjacent sites (Table 4 and $p=0.27$, respectively) and similarly did not differ between adjacent sites and control sites (Table 4 and $p=0.54$, respectively, Fig. 7c). Mean coverage of graminoid species did not differ significantly among the pellet sites, adjacent sites and control sites (ANOVA, $p=0.10$, Fig. 7d) and likewise, mean richness between these treatment sites did not differ (Table 4). Mean richness of seedling species was lower at pellet sites than both adjacent sites and control sites (Table 4) however mean density of seedlings did not differ among these treatment sites (ANOVA, $p=0.13$, Fig. 7e). Likewise, there was no significant difference in mean richness of sapling species between pellet sites and control sites (Table 4) and neither was the difference in mean density between these two treatment sites (Two sample t-test $p=0.85$, and Fig. 7f).

Table 4. Mean richness in seedlings, forbs, graminoids, saplings, shrubs and trees. The estimated mean and p-values are from the rich package in R. The results are based on 99 randomizations. NC means not comparable.

Treatments		No of species	
Richness community-1	Richness community-2	Com1-com2	P value
1. Seedlings			
Pellet sites (0.61)	Adjacent sites (1.07)	-0.45	**<0.05**
Pellet sites (0.61)	Control sites (1.14)	-0.52	**<0.05**
Control sites (1.14)	Adjacent sites (1.07)	0.07	0.46
2. Forbs			
Pellet sites (2.57)	Adjacent sites (3.07)	-0.5	0.15
Pellet sites (2.57)	Control sites (3.57)	-1.00	**<0.05**
Control sites (3.57)	Adjacent sites (3.07)	0.50	0.12
3. Graminoids			
Pellet sites (0.71)	Adjacent sites (0.95)	-0.23	0.11
Pellet sites (0.71)	Control sites (0.95)	-0.23	0.09
Control sites (0.95)	Adjacent sites (0.95)	0	NC
4. Saplings			
Pellet sites (1.66)	Control sites (1.71)	-0.04	0.47
5. Shrubs			
Pellet sites (1.40)	Control sites (1.28)	0.11	0.38
6. Trees			
Pellet sites (1.71)	Control sites (1.73)	-0.02	0.53

Bold figures indicate significant at the 5% level of significance.

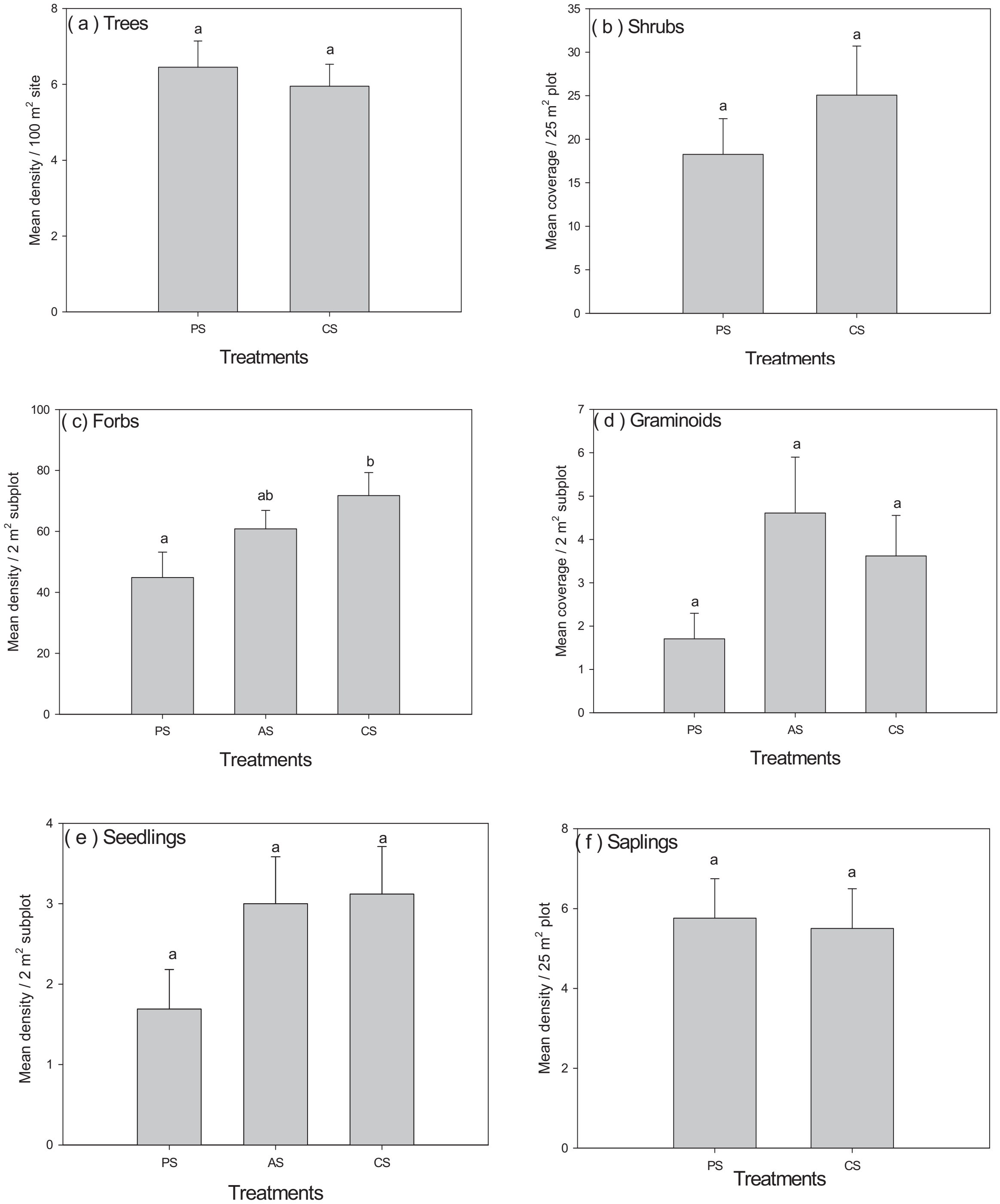

Fig. 7. Mean density and standard errors of pellet sites (n=42), adjacent sites (n=42) and control sites (n=42) in (a) Trees, (b) Shrubs (c) Forbs (d) Graminoids, (e) Seedlings and (f) Saplings. The bars indicate standard error. The p-values are from one way ANOVA with tukey's pairwise comparison test in three treatment sites and two sample t-test in two treatment sites. Different letters above bars indicate a significant difference between treatments; same letters indicate no difference at 5% level of significance.

3.4 Renyi diversity profile

Pellet sites had lower diversity of trees than control sites whereas they are similar in evenness due to intersecting their evenness profile (Fig. 8). Diversity of shrubs at pellet sites was similar with control sites but pellet site had higher evenness of shrubs than control sites (Fig. 9). Adjacent sites was the least diverse in forbs among treatment sites where pellet sites and control sites were similar and control sites had higher evenness of forbs than both adjacent and pellet sites (Fig. 10). Pellet sites had higher diversity of the graminoid species than both adjacent and control sites while adjacent sites had lower evenness of graminoids than both pellet sites and control sites (Fig. 11). Pellet sites had lower diversity of seedling species than adjacent sites and control sites but pellet sites had the highest evenness in seedling species followed by adjacent sites and control sites respectively (Fig. 12). Both diversity and evenness in sapling species between pellet sites and control sites were identical (Fig. 13).

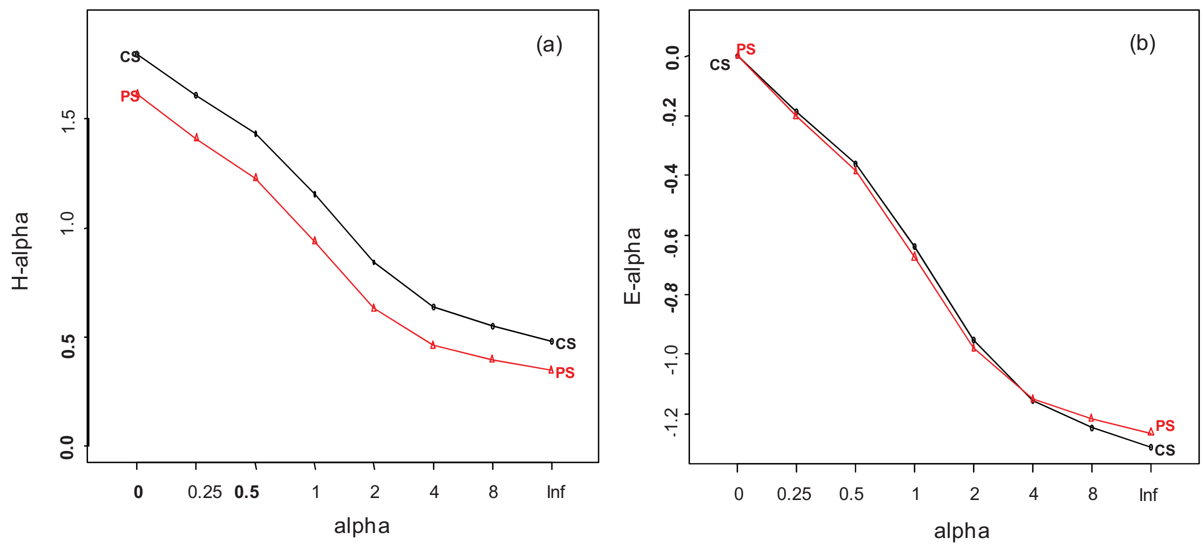

Fig. 8. Comparison of tree (a) diversity and (b) evenness between pellet sites and control sites. Results are based on 100 randomizations.

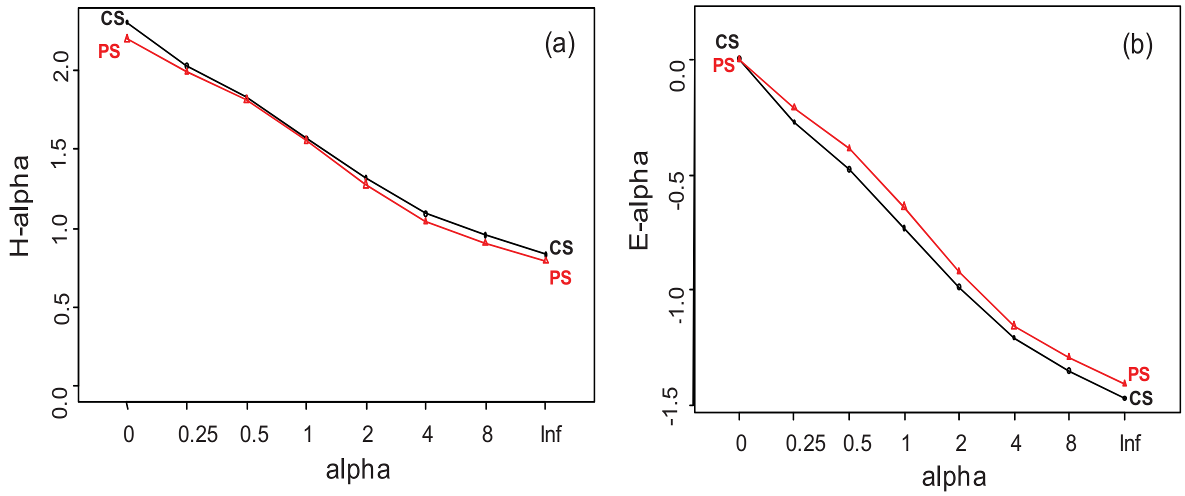

Fig. 9. Comparison of shrub (a) diversity and (b) evenness between pellet sites and control sites. Results are based on 100 randomizations.

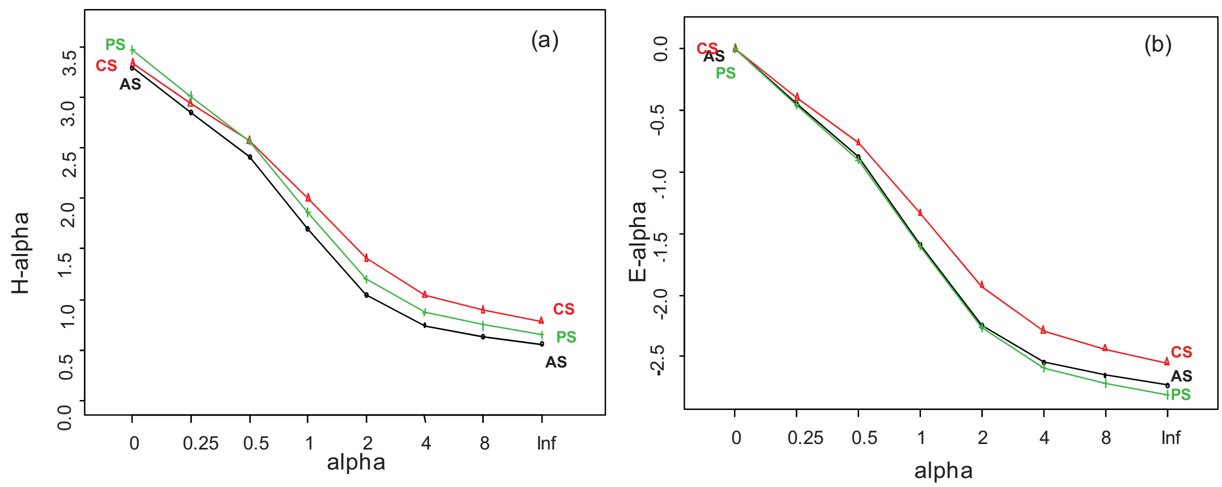

Fig. 10. Comparison of forb (a) diversity and (b) evenness among pellet sites, adjacent sites and control sites. Results are based on 100 randomizations

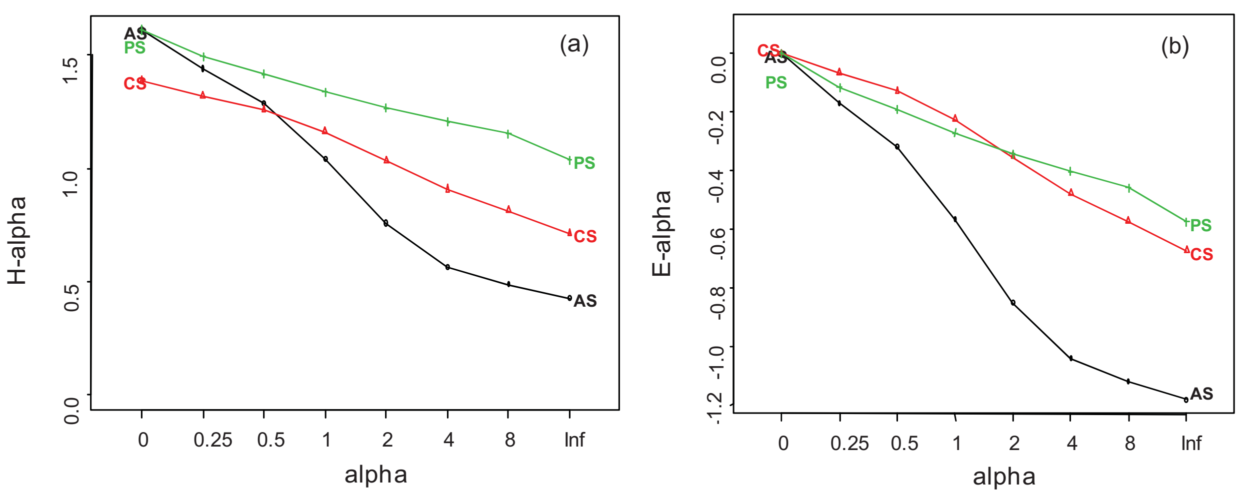

Fig. 11. Comparison of graminoid (a) diversity and (b) evenness among pellet sites, adjacent sites and control sites. Results are based on 100 randomizations.

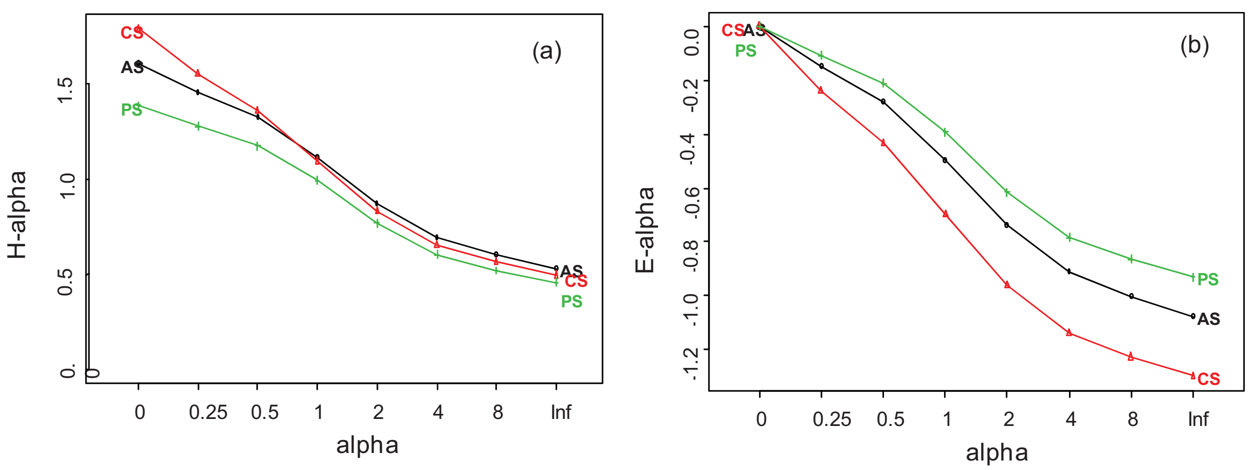

Fig. 12. Comparison of seedling (a) diversity and (b) evenness among pellet sites, adjacent sites and control sites. Results are based on 100 randomizations.

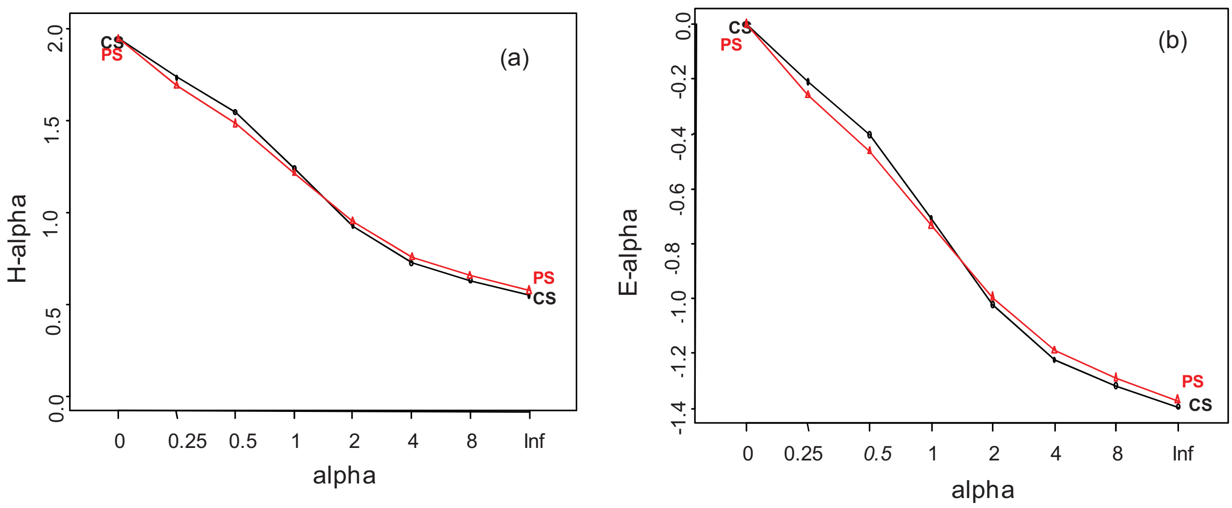

Fig. 13. Comparison of sapling (a) diversity and (b) evenness between pellet sites and control sites. Results are based on 100 randomizations.

3.5 Occurrence of unique species at communal pellet deposition sites

Unique seedlings were not found at pellet sites while *Sibbaldia cuneata and Elsholtzia spp* were the unique forb species detected at pellet sites. *Thalictum foliolusum and Cynanthus incanus & Saxifraga spp* were unique forbs found at adjacent sites and control sites respectively *(*Table 5). These unique forb species did not differ significantly among pellet sites, adjacent sites and control sites (Pearson's Chi-squared = 0.23, df = 2, p=0.89).

Table 5. The unique forbs species, their frequency and total abundance at pellet sites (n=42), adjacent sites (n=42) and control sites (n=42).

Treatment sites	Name of species	Frequency	Total abundance
Pellet sites	*Sibbaldia cuneata*	0.02	3
	Elsholtzia spp	0.02	12
Adjacent sites	*Thalictum folioliosum*	0.02	5
Control sites	*Cyananthus incanus*	0.02	15
	Saxifraga spp	0.02	4

4. DISCUSSION

4.1 Selection of communal pellet defecation sites

Though musk deer were distributed up to 4500 m altitude (Kattel 1992), they selected their defecation site in lower altitude with higher rock cover. Fewer pellet deposition sites were found with increasing altitude, distance to settlements and cattle grazing. Cattle and human disturbances are major habitat degradation factors of musk deer (Yang et al. 2003). The alarming declining of musk deer in Pakistan, China and Nepal is due to habitat degradation and poaching (Basnet 1992; Qamar et al. 2008; Zhou et al. 2004). Musk deer habitats are converting for agriculture and human settlement owing to population growth (Zhou et al. 2004). Population growth has forced the people of Himalayan region to exploit forest resource to fulfill their forest basic needs such as fuel wood, timber, fodder. Unsustainable forest harvesting practices in Himalaya region alter the subalpine and alpine vegetation in degradable condition (Eckholm 1975). Habitat destruction due to increasing human and livestock populations in Nepal limit the distribution of musk deer to smaller and fragmented area (Green 1986). Similarly, dramatic timber harvesting and conversion of musk deer habitat to pasture land, used by the domestic cattle lead to the competition of food and space between domestic cattle and musk deer in China. (Yang et al. 2003). Domestic cattle grazing and increasing use of betula and rhododendron forest for fuelwood by a local cheese factory, inhabitant and tourist in the habitat of musk deer were common practices in this areas. If these trends of habitat degradation continue, musk deer will be further threatened. Thus, the park and the conservation biologist, who are working with the musk deer conservation, should focus the conservation strategies prioritizing on these areas.

4.2 Vegetation at pellet deposition sites

There was no significant effect of pellet deposition on the species composition of forbs, shrubs, graminoids, trees, seedlings and saplings but effects of other variables such as altitude, rock cover, distance to settlements, firewood and timber cutting, distance to water sources, litter cover, cattle grazing and slope were detected. Rock cover, altitude, firewood and timber cutting, distance to water, litter cover and distance to settlements affected the tree species composition. The first ordination axis of trees accounted for 62.5% of the variance of species and environmental relation, whereas the second axis accounted for 83.2 % (Annex 3). Variables influencing the species composition vary with the plant community. Altitude, firewood and timber cutting affected the species composition of all the community, expect seedlings. Rock cover affected on the species composition of seedlings, saplings and trees species such as *Betula utilis*, *Lyonia ovalifolia, Acer caesium*. *Sorbus microphylla* and *Salix sikkimensis*. Distance from settlements affected the species composition of trees and graminoids whereas shrubs and forbs were affected by cattle grazing. Cattle grazing mostly affected *Rhododendron nivale* of shrub species and *Corydallis spp*, *Galium spp*, *Heracleum spp*, *Anaphalis spp*, *Polygonatum verticillatum*, *Fragaria nubicola*, *Geranium spp*, *Anemone rupicola* and *Ranunculus spp* of the forb species. This study depicted that the species composition of all the community were highly influenced by firewood and timber cutting, distance to settlements, and cattle grazing. This study is partially supported by Hayes & Holl (2003) which showed that cattle grazing had a significant effect on the species composition of native annual forbs in California coastal prairie. Grazing changes the species composition by the selective removal of species (Collins 1987). On the other hand, urine and fecal deposition may increase the nutrient cycling and alter species composition (Day & Detling 1990). But this study did not show any such effect in species composition. This may be due to a variable effect of pellet deposition on the nutrient concentration (Williams & Haynes 1995). Besides, the plant composition changes with response to many abiotic and biotic factors (White 1979). Altitude and slope affect on the soil temperature ultimately influence in the length of growing season (Bennie et al. 2006). Due to higher altitude, snowing is common in the Himalayan regions. The pellets probably have a little or no effect on the species composition due to preservation of pellet groups on the snow. Besides, the area covered by pellet groups is small and hence overall effect might be negligible.

Fecal and urine deposition of herbivores often increase nutrients in soil (Dai 2000; Floate 1981; Woodmansee 1978). Diversity shows a curvilinear relationship to soil fertility because nutrient addition lead to the competitive exclusion of subordinate species (Goldberg & Miller 1990). Several studies conducted in North America and Europe has also revealed that increase in nutrients cause a decrease in species richness and diversity (DiTommaso & Aarssen 1989; Marrs 1993). Similarly, a study carried out in chalk grassland nature reserve, Netherlands showed that the number of forbs and graminoid species decreased in the N and NPK treated plots compared to control plots whereas diversity and evenness also significantly decreased in N treated plots (Bobbink 1991). Both forb richness and density were significantly reduced by nitrogen enrichment due to inhibition of forb seedling establishment (Foster & Gross 1998). The results of this study is consistent with the above mentioned studies in forbs and seedling species where the evenness, mean richness and density of forbs species and mean richness of seedling species were lower at the pellet sites than control sites. Diversity of trees and seedling was also lower in pellet sites than control sites. On the other hand, pellet sites have higher diversity of graminoids and evenness of shrubs than control sites. This may be due to variation in disturbance level and nutrients enrichment by the addition of pellet groups. Moderate level of disturbance may increase diversity by providing early and late succession plant species (Connell 1978) and domestic cattle avoid grazing in fecal contaminated diet (Colman et al. 2003). There may have a little or no effect of nutrient enrichment on diversity of graminoids by addition of pellets. Musk deer diet is also varied seasonably and not only depends on graminoids. Besides, this study was carried out in pre-monsoon period where there were abundant graminoids, forbs, leaves, flowers, lichens and mosses for their diet. Herbivores and cattle have less pressure on the graminoids in this season compared to winter seasons.

This study also showed that there was no difference in the species richness except forb and seedling species. Diversity of shrubs, forbs and sapling at pellet sites was not significantly different with control sites. In the contrast with this study, Gillet et al. (2010) depicted that species richness was higher at cattle dung sites than control sites during initial observations while evenness was higher at final observations in a mesotrophic grassland in the pasture of Swiss Jura Mountain. Edward and Hollis (1982) also found that density of grass and forbs species were higher at latrine site of cattle, ponies and fallow deer compared to control sites though species richness did not differ between these sites. But this study did not show a higher diversity of forbs, shrubs, seedlings, saplings and trees at pellet sites than control sites. This may be due to nutrient response, colonizing species and herbivores effect. Diversity is not affected when colonized species are equivalent competitor and no response to nutrient enrichment (Carsen & Barrett 1988). Herbivore effect on diversity varies with environment. For example diversity in arid or saline environment does not change or even decrease whereas it increases in temperate grassland (Hobbs & Huenneke 1992; Milchunas et al. 1988). However, this study did not consider the herbivores effect, they may have effect on the diversity of plants species with respect to various environment.

4.3 Seed dispersal

Zheng and Pi (1979) revealed that Musk deer's diet consist the seeds of shrubs, forbs and grasses. Though they consumed seeds in their diet, this study did not find any unique species frequently on their pellet sites. The unique species like *Sibbaldia cuneata* and *Elsholtzia spp* occurred only once at the pellet deposition sites. In addition, there were not any unique seedling species occurred at pellet sites; instead they were lower mean richness in seedling species than both adjacent sites and control sites. Bartuszevige and Endress (2008) reported that cattle, elk *(Cervus elaphus)* and deer *(Odocoileus spp)* act as an agent of dispersal for many species whereas seedling density and richness are higher at pellet deposition sites compared to control sites. Malo and Saurez (1998) also showed that the red deer disperse the seeds of *Cistus ladanifer* in Mediterrenean ecosystem. On the contrary, this study depicted that any particular plant species are not dependent on musk deer for seed dispersal. This might be due to small size of pellet, lack of hard coat in the seeds and lack of morphological adaptation of seeds while passing through the gut of musk deer. Deer generally dispersed low amount of seeds due to small fecal size and lack of hard coat in the seeds (Wisdom 2005) and seeds damaged by digestive process (Yamashiro & Yamashiro 2006).

5. CONCLUSIONS

Low stature vegetation associated with musk deer pellet deposition was significantly different compared to control sites in a small scale. Forb richness and density at pellet sites were lower than control sites. Similarly, seedlings richness and graminoid diversity also differed at pellet site compared to control sites. But richness and density of trees, shrubs and saplings did not differ between pellet sites and control sites though their diversity and evenness were different. Neither any particular seeds remain viable passing through the digestive tract of musk deer for the germination. Musk deer was influenced by the human and cattle disturbances. Thus, firewood cutting, timber cutting, fodder cutting, litter collection and cattle herding should be minimized at the habitat of musk deer for its conservation.

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ANNEXES

Annex. 1. Table showing the collinearity among variables.

Variables	Altitude	Slope	Rock cover	Litter cover	Distance to water	Distance to settlements	RRI	Tree density
Altitude	1.00	0.25	-0.08	0.13	0.31	0.25	-0.09	0.12
Slope	0.25	1.00	-0.21	0.14	0.28	0.04	-0.52	0.22
Rock cover	-0.08	-0.21	1.00	-0.11	-0.02	0.07	0.20	-0.19
Litter cover	0.13	0.14	-0.11	1.00	0.06	0.09	0.01	0.33
Distance to water	0.31	0.28	-0.02	0.06	1.00	0.34	-0.18	0.01
Distance to settlements	0.25	0.04	0.07	0.09	0.34	1.00	-0.04	-0.07
RRI	-0.09	-0.52	0.20	0.01	-0.18	-0.04	1.00	-0.15
Tree density	0.12	0.22	-0.19	0.33	0.01	-0.07	-0.15	1.00

Annex 2. Table showing the species and their code, family and community

Name of species	Family	Code	Plant community
Betula utilis	Betulaceae	beut	Tree
Sorbus microphylla	Rosaceae	somi	Tree
Salix sikkimensis	Salicaceae	sasi	Tree
Lyonia ovalifolia	Ericaceae	lyov	Tree
Rhododendron campanulatum	Ericaceae	rhca	Tree
Abies spectabilies	Pinaceae	absp	Tree
Acer caesium	Aceraceae	acca	Tree
Lyonia villosa	Ericaceae	lyvi	Shrub
Rhododendron anthopogan	Ericaceae	rhan	Shrub
Rhododendron nivale	Ericaceae	rhni	Shrub
Rhododendron setosum	Ericaceae	rhse	Shrub
Ribes griffithii	Grossulariaceae	rigr	Shrub
Salix calyculata	Salicaceae	saca	Shrub
Cotonester rotundifolius	Rosaceae	coro	Shrub
Cassiope fastigiata	Ericaceae	cafa	Shrub
Berberis spp	Berberidaceae	besp	Shrub
Rosa sericea	Rosaceae	rose	Shrub
Corydalis spp	Papaveraceae	cosp	Forb
Primula denticulata	Primulaceae	prde	Forb
Bistorta macrophylla	Polygonaceae	bima	Forb
Rhodiola himalensis	Crassulaceae	rhhi	Forb
Artimisia spp	Asteraceae	arsp	Forb
Anaphalis contorta	Asteraceae	anco	Forb
Rumex nepalensis	Polygonaceae	rune	Forb
Androsace strigillosa	Primulaceae	anst	Forb
Sibbaldia cuneata	Rosaceae	sicu	Forb
Asplenium spp	Aspleniaceae	assp	Forb
Delphinium roylei	Ranunculaceae	dero	Forb

Galium spp	Rubiaceae	gasp	Forb
Smilacina spp	Smilacaceae	smsp	Forb
Morina nepalensis	Dypsacaceae	mone	Forb
Heracleum spp	Apiaceae	hesp	Forb
Cyananthus incanus	Campanulaceae	cyin	Forb
Thalictrum alpinum	Ranunculaceae	thal	Forb
Thalictrum foliolosum	Ranunculaceae	thfo	Forb
Potentilla cuneata	Rosaceae	pocu	Forb
Pedicularis spp1	Scrophularaceae	pesp1	Forb
Pedicuaris spp2	Scrophularaceae	pesp2	Forb
Impatiens spp	Balsaminaceae	imsp	Forb
Clintonia udensis	Liliaceae	clud	Forb
Anaphalis spp2	Asteraceae	ansp	Forb
Elsholtzia spp	Lamiaceae	elsp	Forb
Polygonatum verticillatum	Liliaceae	pove	Forb
Rhodiola spp	Crassulaceae	rhsp	Forb
Fritillaria cirrhosa	Liliaceae	frci	Forb
Viola rupestris	Violaceae	viru	Forb
Fragaria nubicola	Rosaceae	frnu	Forb
Primula sikkimensis	Primulaceae	prsi	Forb
Geranium spp	Geraniaceae	gesp	Forb
Pteris spp	Pteridaceae	ptsp	Forb
Anemone rupicola	Ranunculaceae	anru	Forb
Polygonatum hookeri	Liliaceae	poho	Forb
Allium humile	Amarylliidaceae	alhu	Forb
Lilium nanum	Liliaceae	lina	Forb
Rheum spp	Polygonaceae	rhsp	Forb
Aconitum spp	Ranunculaceae	acsp	Forb
Ranunculus spp	Ranunculaceae	rasp	Forb
Saxifraga spp	Saxifragaceae	sasp	Forb

Euphorbia spp	Euphorbiaceae	eusp	Forb
Valeriana hardwickii	Valerianaceae	vaha	Forb
Unidentified forb	???	unhe	Forb
Astragalus candolleanus	Leguminoceae	asca	Forb
Kopresia spp	Cyperaceae	kosp	Grass
Carex spp	Cyperaceae	casp	Graminoid
Poa spp	Poaceae	posp	Graminoid
Arundanaria spp	Poaceae	arsp	Graminoid
Unidentified graminoid	???	ungr	Graminoid

Annex 3. Summary of CCA axes showing the eigenvalue, species-environmental correlation, cumulative percentage variation of species and cumulative percentage variation of species and environmental relation in trees, shrubs, forbs, graminoids, seedlings and saplings.

Community	Axis	Eigen value	Species-environment correlation	Cumulative % variation of species data only	Cumulative % variation in species+environmental relation
Trees	1	0.28	0.64	12.1	62.5
	2	0.09	0.46	16.2	83.2
	3	0.05	0.39	18.5	95.3
	4	0.02	0.29	19.4	99.7
Shrubs	1	0.41	0.70	9.7	56.1
	2	0.14	0.54	12.9	75.1
	3	0.09	0.48	15.2	88.0
	4	0.05	0.29	16.5	95.8
Forbs	1	0.30	0.68	5.5	63.2
	2	0.12	0.49	7.7	89.1
	3	0.02	0.31	8.2	94.9
	4	0.02	0.33	8.7	100
Graminoids	1	0.32	0.67	13.4	62.5
	2	0.13	0.44	19.1	88.9
	3	0.05	0.32	21.4	99.7
	4	0.002	0.05	21.5	100
Seedlings	1	0.13	0.55	5.1	69.9
	2	0.05	0.38	7.4	100
	3	0.51	0.00	27.2	0.0
	4	0.49	0.00	46.4	0.0
Saplings	1	0.19	0.58	6.5	56.9
	2	0.11	0.45	10.2	88.7
	3	0.03	0.25	11.2	98.0
	4	0.007	0.12	11.5	100