Effects of grazing on plant species diversity and above ground biomass in a Trans- Himalayan Rangeland

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Limited information is available on the species compositon, above ground biomass and its realations to grazing in a trans-himalayan rangeland. Its assessment is essential for long term conservation and management. In the present study, we compared species composition, phenology, diversity index and biomass between controlled (without grazing) and open (free grazing) plots to assess the effects of grazing in the selected experimental sites of Upper Mustang during July and November 2005. Species encountered were classified as high, medium, low and non palatable and in three lifeform categories-grasses, shrubs and forbs. The experimental sites are dominated by forbs (80%) followed by grasses (15%) and shrubs (5%). Disturbance caused by grazing affects the phenological characteristics of the plant community. Result also reveals that species diversity, maximum possible diversity, evenness and species richness was higher in the grazed plots during July and November. A comparison of the aboveground biomass in July showed that mean percentage biomass of high, medium and low palatable species is higher in ungrazed plots. In November, the percentage biomass of only medium palatable species was higher in ungrazed plots and rest of the category is higher in grazed plots. Significant difference in July, a peak growing seasons for most of the plant species in the region reveals that the pasture has impact of livestock grazing.

Keywords: Biomass, diversity, grazing effect, rangeland, species

Limited grazing land is available in Upper Mustang (28°47'- 29°19' N and 83°28'- 84°15' E) where species such as cattle, yaks, dzos, sheep, goats, horses, mules and donkey are dependent on it. According to Pokharel (2006a), grazing land comprises of 55.65% of the total area of Upper Mustang. High speed wind continuously blows which has eroded most of the top soil leading to sparse vegetation. The rangeland is unique in the sense that despite being very dry, fragile and most part being barren; it harbours a large number of Transhimalayan flora and fauna. Vegetation such as *Caragana* spp., *Lonicera* spp., *Stipa* spp., *Carex* spp. and *Kobresia* spp. dominate most of the the pasture land. These rangelands support unique assemblage of rare and endangered species – Snow leopard *(Uncia uncia)*, Lynx *(Lynx lynx isabellinus)*, Himalayan brown bear (*Ursus arctos)* and Grey wolf *(Canis lupus)*. Himalayan wooly hare (*Lepus oiostolus*) and Himalayan Marmot (*Marmota bobak*) are the common species that are dependent on rangeland. Birds like golden eagle and lammageier are commonly seen. Economically majority of the population of Mustang rely on agro pastoral system. However agricultural production is limited due to lack of sufficient water for irrigation and harsh climatic conditions leading to one crop per year. Forage production in the agriculture land is limited and very little forage is conserved as hay for winter feeds which only sustains for one or two months or even less in some of the areas. In the pasture grazing takes place throughout the year following traditional rotational system existing in the area. Information regarding the pastures in rangeland of Upper Mustang is very limited. Till date very limited research has been conducted on the species composition and its relations with the impact of grazing (Miller, 2002). Researchers have identified that overgrazing in the rangelands is the main factor causing deterioration of rangelands (Miller, 1996; Schaller and Gu, 1994; Wang *et al.*, 2002). Similarly it was also found that species diversity and productivity are maintained by livestock and wildlife grazing in many highland pastures (Carpenter and Klein, 1995). Grazers alter landscape heterogeneity (Belsky, 1992; McNaughton, 1985), rates of nutrient cycling (Frank *et al.*, 1998; Ritchie and Tilman, 1995), vegetation composition, and productivity (Dahlberg, 2000; Eccard *et al.*, 2000; Shackleton, 2000). Plant diversity increases with

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grazing in productive systems and decreases in nutrient poor areas (Huston, 2004). Modifications in natural grazing regimes and land use change often lead to changes in biodiversity (Chapin III *et al.*, 1997; Mooney *et al.*, 1996; Vitousek *et al.*, 1997) and vegetation structure (Eckert and Spencer, 1987; Noy-Meir, 1979, 1993; Walker and Noy-Meir, 1982). This paper describes how regularly grazed and totally ungrazed plots vary in species composition, phenology, diversity and above ground biomass. This work is a part of the broader ongoing research on rangelands conducted during 2005 in Upper Mustang.

Materials and Methods

Study site

The research was conducted in the Panga pasture of Lomanthang Village Development Committee (VDC) of Upper Mustang. Lomanthang VDC has forty four pasture units with a total area of 257.753 sq kms (Pokharel, 2006b). The altitudinal range of Panga pasture is 4,000 – 5,100 m. The climate of the area can be characterized as cold desert, desiccated by strong winds and high solar radiation. The climate is sub-alpine, and had a maximum and minimum temperature of 26.8°C and 9.9°C in July and 10.7°C and - 5.8 °C in November of 2005. The whole area remains under snow for 4 – 5 months from November to March. Total annual rainfall is less than 200 mm. More than half of the total precipitation occurs as snow during the winter months. The area is grazed every year by a flock of about 7000 including horse, lulu cow, yak, dzos, sheep, goat, mule and donkey. In addition to this, four nomads family reside in this pasture for four months during the summer season to graze yaks, sheep and goats.

Vegetation sampling

For assessment of the plant communities three ungrazed (controlled) plots, each of size1 m x 1m, were studied which were established during 2003 and 2004 by National Trust for Nature Conservation - Upper Mustang Biodiversity Conservation Project. For comparative assessment between ungrazed and grazed plots, each open plot (1m x 1m) are spaced at 100m towards the north of controlled plot with the help of GPS. From each main plot, a sub plot one in north and one in south direction of size 20x20 cm were taken for study. Altogether, six subplots of ungrazed and six of grazed were studied during July and in November 2005.

Floristic compositon, phenelogy, Indices of species diversity, richness and evenness

The floristic components in the controlled and open plots were studied and types of species were identified and categorized as high, medium, low and non palatable species based on previous records (Chetri and Gurung, 2004). Phenological characteristics of the species encountered were recorded.

The Shannon diversity index (H´; Shannon and Weiner's, 1963),

$$H' = 3.3219 \left\{ \frac{N \log N - \Sigma ni \log ni}{N} \right\}$$

was used to measure diversity between controlled and open plots, where N = total number of individuals of all species, and ni = total number of individuals of a species.

Richness was calculated as the number of species recorded (Stirling and Wilsey, 2001). For measuring evenness there are several indices available (Ricotta and Avena, 2000). In the present study, the most frequently used one; the Pielou index (J´; Pielou, 1975) is used. The Pielou index is described as J´ = H´/H max, where H´ is the Shannon diversity index and H´max is the maximum value of H´ (maximum possible diversity) in the community, if all the plant species are equally frequent. H max = 3.3219 logk, where k is the total number of type of species recorded.

Index of similarity gives the degree of similarity in terms of which species are present. It was calculated by applying formula given by Jaccard (Zobel *et al.*,1987):

$$IS_J = (C/A+B-C) \times 100$$

Where IS_J = Jaccard's Index of Similarity, A = total number of species in one sample, B = total number of species in another sample and C = total number of common species in both samples.

Biomass - controlled vs. open plots

Plant species were cut close to the ground surface, separated on the basis of palatability and collected in plastic zipper bag. Fresh weight of the species based on palatability was measured on the spot with the help of Digital Balance (Denver Instrument No: 98648-012-35). Unidentified species were clipped separately. A herbarium of the unidentified plant species was prepared for later identification. In order to reduce the moisture contents, the collected samples were air dried for 48 hrs and transported to Institute of Forestry, Pokhara for dry weight measurement. The samples were oven dried at 70°C for 24 hrs for dry weight measurement and the dry biomass percentage was calculated using the formula given by Zobel *et al.*1987

% dry Biomass = Dry weight/Fresh weight x 100

Independent sample t-test was used at $p<0.05$ in order to test the differences in biomass between the controlled and the open plots based on palatability. SPSS version 13.1 was used to analyze the data.

Results and Discussion

In the experimental plots of Panga Pasture of Lomanthang twenty species (17 belonging to 14 families: high-7, medium- 2, low – 6 and non palatable – 2 and 3 unidentified species) were recorded. According to lifeform, forbs is dominating (80%) the experimental plot site followed by grasses (15%) and shrubs (5%) (Annex 1). During July majority of the species were in green stage (55%) followed by dry (19%) in controlled plots and in open 78% were green followed by 8% in flowering stage. The same pasture had 99 % and 100% species in dry condition in controlled and open plots respectively in November. The findings of the present study reveal that grazing also affect the phenelogical conditions of the species in the experimental sites. July is the peak flowering season for most of the species in Upper Mustang (Chetri *et al.*, 2006). During July in the controlled plot majority of the species has already reach maturity during the time of data collection whereas in the open plot species are encountered in the flowering stage. In November, observations are severely hampered by early snowfall. Table 1 represents plant species diversity (H´ diversity, maximum possible diversity, and evenness and species richness) in the controlled and open plots in July and November. In the open plots during July and November, H´ diversity, maximum possible diversity, evenness and species richness was higher in comparison to controlled plots. The species richness based on palatability of the species is also different; higher numbers of palatability types are in open plots (Figure1). The findings of the present study are in agreement with the generalization made by McIntyre *et al.* (2003) and Sternberg *et al.* (2000) that grazing increases the species diversity at small scale. But Pyeyo *et al.* (2006) reported that the plant community structure analysis is more sensitive than the diversity indices to grazing treatments. The overlap of species in the controlled and the open as measured by Jaccard's index was 44% in July and 71% in November. The high degree of overlap indicates that the controlled and open plots share many of the same species.

Biomass - controlled vs. open plots

In July mean percentage biomass of high (74.36 ± 11.31), medium (59.38 ± 15.05) and low (73.72 ± 6.08) palatable species is higher in controlled than in open plots: high (69.35 ± 5.67), medium (35.00±7.07), low (46.25±30.16) and non palatable species (25.00±23.75) (Table 2). In July, non palatable species was recorded only in open plots. However in November the percentage biomass of only medium palatable species (62.17 ± 44.07) was higher in controlled plots where as the case is just reverse for high and low palatable species. A large standard deviation shows that the measurements of the biomass are widely spread out from the mean. Independent sample t-test showed a significant difference in dry biomass between the controlled and open plots in July ($t = 2.681$, $p<0.05$) but no significant difference was found in November ($t = -1.067$, $p>0.05$) (Table 3). The unexpected heavy snowfall during October has affected the vegetation composition of the pastures. Samples were taken after twenty one days when snow melted from the experimental sites. Thus actual biomass is underestimated as majority of the forbs which are in dormant stage are decayed by the melting snow and t-test failed to detect the differences between the compared plots. Compared to July less number of species are encountered in the plots (see Table 1 and Annex 1). Heaving grazing reduces aboveground biomass, which in turn decreases rainfall interception and increases infiltration and bare soil evaporation (Aguiar and Sala, 1999; Klausmeier, 1999). Another possibility is that changes in the aboveground litter inputs cause changes in the belowground flora and fauna, which have been shown to affect plant growth (Hooper *et al.*, 2000). Changes in species distribution, compositon and structure have also possible implications for wildlife due to reduced forage bimass and higher relative abundances of unpalatable species (Metzger *et al.*, 2005). Local people claim that rainfall is in decreasing trend since last two decades and snowfall does not occur on the right time of the year i.e November to February (Pokharel, 2006b). These factors along with weak traditional rotational grazing practices have affected most of the pastures in Upper Mustang. As majority of the pastures in Upper Mustang are dominated by annual plants, forbs and sedges timely rainfall and snowfall are the critical factors for the growth of the good quality vegetation in the rangeland.

Conclusion

In the Panga pasture of Lomanthang, species diversity, maximum possible diversity, evenness and species richness were higher in the grazed plots during July and November. Percentage biomass of high, medium and low palatable species is greater in controlled plots. Significant difference in July, a peak growing seasons for most of the plant species in the region reveals that the pasture has impact of livestock grazing. In addition, climate also played a critical role for maintaining good quality vegetations in the rangeland. In future similar type of studies is thought essential; experimental plots sites need to be distributed at different altitude and data need to correlate with other parameters such as soil and climate in order to draw a holistic conclusion. Such type of research will give a wide picture on how range productivity and plant communities respond to soil and climate properties and also the affects or benefits from livestock grazing. These informations will be helpful for the managemet and conservation of Trans-himalayan rangeland.

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References

Aguiar, M. R. and Sala, O. E. 1999. Patch structure, dynamics and implications for the functioning of arid ecosystems. *Trends in Ecology & Evolution* **14 (7)**: 273-277.

Belsky, A. J. 1995. Spatial and temporal landscape patterns in arid and semi-arid African savannas. *In Mosaic Landscapes and Ecological Processes* (ed), Chapman & Hall, New York, 31–56.

Carpenter, C. and Klein, J. 1995. Plant species diversity in relation to grazing pressure in three alpine pastures, Shey Phoksumdo National Parks, Dolpa District Nepal. Field Report. Wildlife Studies Program, San Francisco State University.

Chapin III, F. S., Walker, B. H., Hobbs, R. J., Hooper, D. U., Lawton, J. H. and Sala, O. E. 1997. Biotic control over the functioning of ecosystems. *Science* **277 (5325)**: 500–504.

Chetri, M. and Gurung, C. R. 2004. Vegetation Composition, species performance and its relationship among livestock and wildlife in the grassland of Upper Mustang, Nepal. In *Yak Production in Central Asian Highlands, the Fourth International Congress on Yak* (ed) Sichuan Publising Group, Sichuan Publication House of Science and Technology, 235-244.

Chetri, M., Chapagain, N. and Neupane, B. D. 2006. Flowers of Mustang-A pictorial Guidebook. National Trust for Nature Conservation, Kathmandu, Nepal.

Dahlberg, A. C. 2000. Vegetation diversity and change in relation to land use, soil and rainfall: a case studyfrom North–East District, Botswana. *Journal of Arid Environments* **44 (1)**: 19–40.

Eccard, J. A., Walther, R. B. and Milton, S. J. 2000. How livestock grazing affects vegetation structures and small mammal distributions in the semi-arid Karoo. *Journal of Arid Environments* **46 (2)**: 103–106.

Eckert, Jr. R. E. and Spencer, J. S. 1987. Growth and reproduction of grasses heavilygrazed under restrotation management. *Journal of Range Management* **40 (2)**: 156–159.

Frank, D. A., McNaughton, S. J. and Tracy, B. F. 1998. The ecology of the Earth's grazing ecosystems. *Bioscience* **48 (7)**: 513–521.

Hooper, D. U., Bignell, D. E., Brown, V. K., Brussard, L., Dangerfield, J. M., Wall, D. H. *et al.* 2000. Interactions between aboveground and belowground biodiversity in terrestrial ecosystems: patterns, mechanisms and feedback. *Bioscience* **50 (12)**: 1049-1061.

Huston, M. A. 2004. Management strategies for plant invasions: manipulating productivity, disturbance and competition. *Diversity and Distributions* **10**: 167-178.

Klausmeier, C. A. 1999. Regular and irregular patterns in semiarid vegetation. *Science* **284 (5421)**: 1826-1828.

McIntyre, S., Heard, K. M. and Martin, T. G. 2003. The relative importance of cattle grazing in subtropical grasslands: does it reduce or enhance plant biodiversity?. *Journal of Applied Ecology* **40 (3)**: 445-457.

McNaughton, S. J. 1985. Ecologyof a grazing system: the Serengeti. *Ecological Monographs* 5**5 (3)**: 259–294.

Metzger, K. L., Coughenour, M. B., Reich, R. M. and Boone, R.B. 2005. Effects of seasonal grazing on plant species diversity and vegetation structure in a semi-arid ecosystem. *Journal of Arid Environment* **61 (1)**: 147-160.

Miller, D. J. 1996. New Perspectives on Range Management, Pastoralism, and their implications for HKH-Tibetan Plateau Rangelands. *In Rangelands and Pastoral Development in the Hindu Kush – Himalayas* (ed), Regional Expert's meeting, ICIMOD, Kathmandu, Nepal, 7-12

Miller, D. J. 2002. Impacts of Livestock Grazing in Himalayn and Tibetan Plateau Rangelands. Northern Plain Associates.

Mooney, H. A., Cushman, J. H., Medina, E., Sala, O. E. and Schulze, E. D. 1996. Functional Roles of Biodiversity: A Global Perspective. Wiley, Chichester, UK.

Noy-Meir, I. 1979. Structure and function of desert ecosystems. *Israel Journal of Botany* 28: 1–19.

Noy-Meir, I. 1993. Compensating growth of grazed plants and its relevance to the use of rangelands. *Ecological Applications* 3 (1): 32–34.

Pielou, E. C. 1975. Ecological Diversity. Wiley, New York.

Pokharel, A. 2006a. Pasture Mapping of Upper Mustang, Nepal. A Project report submitted to National Trust for Nature Conservation-Annapurna Conservation Area Project/Upper Mustang Biodiversity Conservation Project, 183p.

Pokharel, A. 2006b. An Assessment of Rangelands and Pastoral production systems in Upper Mustang, Nepal. A Project report submitted to King Mahendra Trust for Nature Conservation-Annapurna Conservation Area Project/Upper Mustang Biodiversity Conservation Project, 85 p.

Pyeyo, Y., Alados, C. L. and Ferrer-Benimeli, C. 2006. Is the análisis of plant community structure better than common species-diversity indices for assessing the effects of livestock grazing on a Mediterranean arid ecosystem. *Journal of Arid Environments* **64 (4)**: 698-712.

Ricotta, C. and Avena, G. 2000. A parametric index of community eveness. *Ecoscience* **7 (4)**: 511-515.

Ritchie, M. E. and Tilman, D. 1995. Responses of legumes to herbivores and nutrients during succession on a nitrogen-poor soil. *Ecology* **76 (8)**: 2648–2655.

Schaller, G. B. and Gu Binyuan. 1994. Comparative ecology of ungulates in the Aru Basin of Northwest Tibet. *National Geographic Research and Exploration* **10 (3)**: 266-293.

Shackleton, C. M. 2000. Comparison of plant diversityin protected and communal lands in the Bushbuckridge lowveld savanna, South Africa. *Biological Conservation* **94 (3)**: 273–285.

Shanon, C. Z. and Wiener, W. 1963. The Mathematical theory of communication. Urbana: University of Illinois Press.

Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, E.D. and Kigel, J. 2000. Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. *Journal of Applied Ecology* **37 (2)**: 224-237.

Stirling, G. and Wilsey, B. 2001. Empirical relationships between species richness, evenness, and proportional diversity. *American Naturalist* **158 (2001)**: 286–297.

Vitousek, P. M., Mooney, H. A., Lubchenco, J. and Melillo, J. M. 1997. Human domination of Earth's ecosystems. *Science* **277 (5325)**: 494–499.

Walker, B. H. and Noy-Meir, I. 1982. Aspects of the stability and resilience of savanna ecosystems. *In Ecology of Tropical Savannas* (ed), Springer, Berlin, 556–590.

Wang, Y., Shiyomi, M., Tsuiki, M., Yu, X. and Yi, R. 2002. Spatial heterogeneity of vegetation under different grazing intensities in the Northwest Heilongjiang Steppe of China. Agriculture, *Ecosystems and Environment* **90 (3)**: 217-229.

Zobel, D. B., Jha, P. K., Yadav, U. K. R. and Behan, M. J. 1987. A Practical Manual for Ecology. Ratna Book Distributors, Kathmandu, Nepal.

Table 1: Diversity index, species richness and index of similarity, Panga Pasture, Lo Manthang

Plot type	July					November				
	H´	Hmax	SR	J´	IS_J	H	Hmax	J´	SR	IS_J
Controlled	2.01	3.17	9	0.63	44%	2.01	3.46	0.58	11	71%
Open	2.79	4.09	17	0.68		2.49	3.70	0.67	13	

Note: H´= Shannon diversity index; Hmax = Maximum possible diversity; SR=Species Richness; J´ = Pielou index and IS_J = Jaccard index of similarity

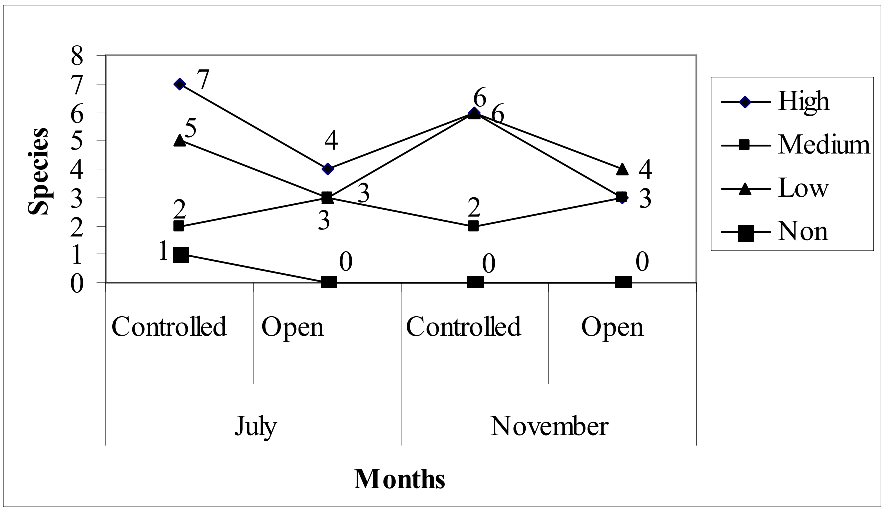

Figure1: Species richness based on palatability, Panga Pasture, Lomanthang

Table 2: Mean percentage of dry biomass (gms) in the controlled and open plots based on palatability, Panga Pasture, Lomanthang (Numbers in parenthesis indicate Standard Deviations)

Palatability	July		November	
	Controlled	Open	Controlled	Open
High	74.36 (11.31)	69.35 (5.67)	66.88 (14.07)	79.76 (9.54)
Medium	59.38 (15.05)	35.00 (7.07)	62.17 (44.07)	62.00 (11.31)
Low	73.72 (6.08)	46.25 (30.16)	59.37 (10.99)	64.7 (16.23)
Non	-	25.00 (23.75)	-	-
Mean Total	75.11 (5.21)	64.09 (9.77)	67.10 (12.37)	74.90 (5.87)

Table 3: Result of Independent sample t-test – biomass controlled vs. open, Panga Pasture, Lomanthang

Months	F	Sig.	t	df	Sig. (2 tailed)
July	**11.697**	**0.002**	**2.681**	**22**	***0.014**
November	**0.772**	**0.389**	**-1.067**	**22**	**0.298**

Note: * Significant difference, $p<0.05$

Annex 1. List of species recorded according to life forms, palatability and phenelogy in controlled and open plots, Panga Pasture, Lo Manthang, during July and November 2005 (Numbers in parenthesis indicate frequency percentage)

S.N.	Species	Palatability	July 2005		November 2005	
			Controlled	Open	Controlled	Open
Grass						
1	*Carex* spp.	High	Green/Fruiting (12.90)	Green/Fruiting (12.20)	Dry (13.89)	Dry (11.76)
2	*Kobresia* spp.	High	Dry/Fruiting (6.45), Green (12.90)	Dry (4.88), Green (9.76)	Dry (16.67)	Dry (17.65)
3	*Pennisetum* spp.	High	Green/Fruiting (12.90)	Green (4.88)	Dry (16.67)	Dry (2.94)
Shrubs						
4	*Potentilla* spp.	High	Flowering (3.23), Green (6.45)	Flowering (2.44), Green (2.44), Budding (2.44)	Dry (5.56), Green (2.78)	Dry (8.82)
Forbs						
5	*Anaphalis* spp.	High	-	Flowering (4.88), Green (4.88)	Dry (2.78)	Dry (8.82)
6	*Anaphalis triplinervis* (Sims) C.B. Clarke	High	-	Flowering (2.44), Green (2.44)	-	-
7	*Androsace* spp.	Low	-	Flowering (2.44), Fruiting (2.44)	Dry (2.78)	-
8	*Bistorta* spp.	Low	-	Green (2.44)	-	Dry (2.94)
9	*Cortia depressa* (D. Don) Norman	Low	-	Green (2.44)	-	-
10	*Euphorbia stracheyi* Boiss.	Non	-	Fruiting (2.44)	-	-
11	*Gentiana ornata* (G. Don) Griseb.	Medium	Flowering (6.45)	-	-	-
12	*Lancea tibetica* Hook. f. & Thoms.	Low	Flowering (3.23), Green (9.68)	Green (12.20)	Dry (11.11)	Dry (11.76)
13	*Pedicularis* spp.	Non	-	Green (2.44)	-	-
14	*Potentilla plurijuga* Hand. - Mazz.	High	Flowering (6.45), Fruiting (3.23)	Flowering (2.44)	Dry (8.33)	Dry (5.88)
15	*Saussurea nepalensis* Sprengel	Medium	Green (6.45)	Green (4.88)	Dry (5.56)	Dry (5.88)
16	*Saxifraga* spp.	Low	Fruiting (3.23), Green (6.45)	Green (4.88)	Dry (2.78), Green (5.56)	Dry (5.88)
17	*Thalictrum* spp.	Low	-	-		Dry (2.94)
18	Unidentified spp.	Low	-	-	Dry (5.56)	Dry (11.76)
19	Unidentified spp. I	Low	-	Green (4.88)	-	Dry (2.94)
20	Unidentified spp. II	Low	-	Flowering (2.44)	-	-