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Phytosociological Investigation and Life Form Pattern of Grazinglands under Pine Canopy in Temperate Zone, Northwest Himalaya, India

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Abstract: In temperate region of Northwest Himalaya, drier slopes are dominated by *Pinus roxburghii* and are known for rich ground herbaceous flora predominated by grasses. These regions serve as grazingland for livestock and cattle. Present study deals with vegetation analysis, phytosociology and life form pattern of such grazingland between 1100-1400 m a.s.l. across the altitudinal gradient and varying slopes. *Capillipedium parviflorum* is identified as dominant species based on Importance value index, although the area is exhibited by large number of herbs in comparison to grasses and sedges. Vegetation of the area is contagiously distributed and predominantely represented by therophytes and geophytes indicating the degree of anthropogenic activities. The native vegetation is disturbed by overgrazing and life forms of the flora of each of the association are maintained by the intensity of grazing. In the sites under observations, besides grazing, fire was main detrimental factor for dominating the flora by therophytes. Codominance of geophytes may be assigned to its propagation through underground perennating organs as the fire type in these ecosystems is crown fire type. The study describe all these features.

Key words: Pine canopy, temperate grazinglands, Garhwal Himalaya, India

INTRODUCTION

Vegetation is a key factor in determining the structure of an ecosystem. It determines many ecological parameters within a plant community such as microclimate, energy budget, photosynthesis, water regimes, surface runoff and soil temperature (Tappeiner and Cernusca, 1996). Vegetation of an area varies from place to place according to habitat heterogeneity of the area itself. The description and classification of the plant community in an ecosystem is known as phytosociology (Braun-Blanquet, 1932; Odum, 1971). The number of species reflects the gene pool and adaptation potential of the community (Odum, 1963). Quantitative analysis of vegetation helps in understanding the structure, composition and tropic

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organization of any community. Species composition and diversity vary from habitat to habitat within the communities exposing identical physiognomic characteristics (Nautiyal *et al*., 1999). Likewise, the life forms of species represent the adjustment of perennating organs and plant life history to environmental conditions (Nautiyal *et al*., 2001). It is an important characteristic in describing vegetation that offers a preliminary picture of the ecological character of the vegetation (Kershaw, 1973).

Plant species diversity in the under storey strata is an important component in ecosystem functioning (Host and Register, 1991; Arsenault and Bradfield, 1995; Brakenhielm and Lui, 1998). In general, plant species diversity in the under storey is sensitive to ecosystem conditions (Pregitzer and Barnes, 1982; Strong *et al*., 1991; Mitchell *et al*., 1998) as well as to disturbance such as canopy removal (Duffy and Meier, 1992) and grazing (Hadar *et al*., 1999). The characterization of community response to any given disturbance, in terms of functional response types, appears to be a promising tool for analyzing the effects of disturbances on plant species diversity and community structure (McIntyre *et al*., 1999; Lavorel *et al*., 1999).

Pine forests in temperate Himalaya are responsible to replace broad-leaf association and shrub layer under these forests is very poor. However, ground vegetation is rich particularly after fire, which provides more isolation from the ground resulting in dense herbaceous elements and thus, exhibits maximum herbaceous diversity than any other forests of Garhwal Himalaya (Rawat and Bhandari, 2006). *Capillipedium parviflorum* is dominant grass under pine in temperate Himalaya between 8000-1200 m a.s.l. and therefore, they serve as pasture land in Garhwal Himalaya for successful practices of animal husbandry (Anthwal *et al*., 2008). A great deal of work has been done on the temperate grazinglands in Garhwal Himalaya (Tewari *et al*., 1989; Pant and Tiwari, 1992; Sah *et al*., 1994; Khera *et al*., 2001; Sharma *et al*., 2001; Rawat and Bhandari, 2006; Anthwal *et al*., 2008). However, there are no reports on vegetation composition and life form pattern of *Capillipedium parviflorum* dominated grazinglands since earlier focus was given on *Pinus* forest. This study reports phytosociological features and life form pattern of *Capillipedium parviflorum* grazingland across the altitudinal gradient and slope aspects.

MATERIALS AND METHODS

Study Site

The study was conducted during the years 2005-2006. The area of study i.e., Badiyargarh is located in district Tehri Garhwal (Latitudes 30° 22'-30° 14' and Longitudes 78° 56'-78° 47'), 20 km north of Srinagar Garhwal, Uttarakhand, India extending from 1000-1500 m above mean sea level. The region comprises temperate zone of Himalaya with *Pinus* as dominant tree species with graminoides as predominant under canopy vegetation and therefore, used as grazing land by local inhabitants. The livestock of these inhabitants mainly include cow, sheep, goat and rarely buffalo. Generally, each household owns 2-5 cattle. However, sheep and goats are owned by few households as a self employment option. The climate of the area is warm-temperate with moderate summers and severe winters with an annual precipitation of 240 cm, most of which commences during the rainy season. Details of meteorological parameters are shown in Fig. 1 and 2.

For phytosociological investigation and life form pattern of under canopy vegetation of *Pinus* forest in the study area, 4 sites of 100 m^2 were selected along an altitudinal gradient having different slope aspects and angles. These sites were named as site A (Nagdev I), site B (Nagdev II), located at an elevation of 1400 m with South-East and North-East facing,

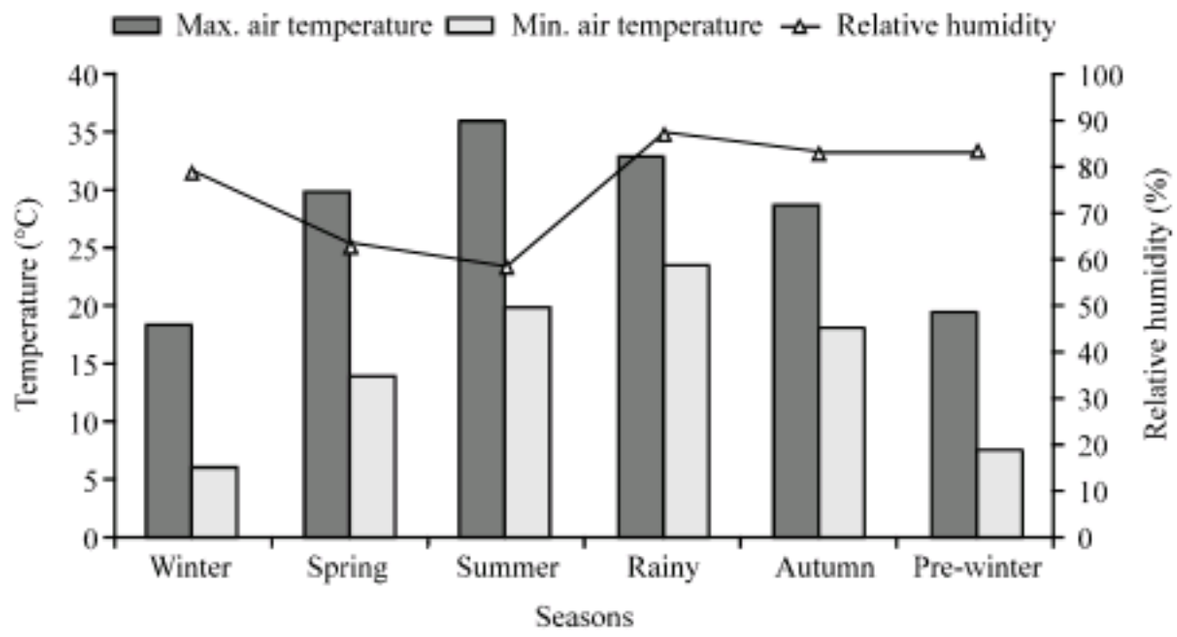

Fig. 1: Seasonal fluctuation in humidity (%), mean minimum and maximum air temperature during study period

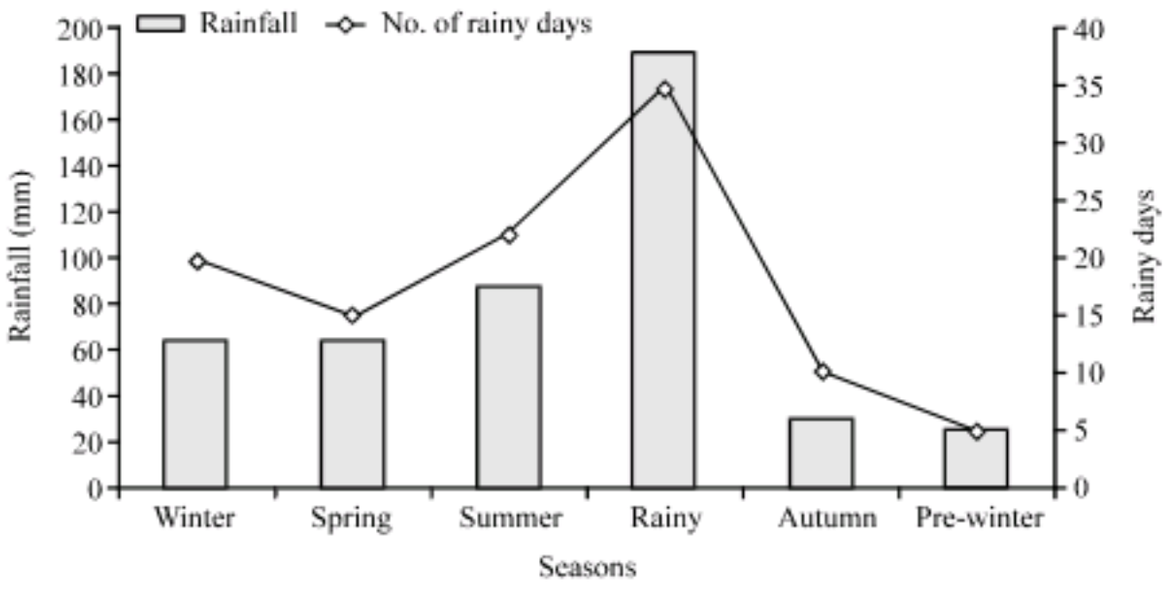

Fig. 2: Seasonal variation in rainfall and number of rainy days at study period

Table 1: Geographical parameters and its status in all study sites

	Sites			
Parameters	A	B	C	D
Place	Nagdev I	Nagdev II	Sendri I	Sendri II
Latitude	30°-22'-30°-14'	30°-22'-30°-14'	30°-22'-30°-14'	30°-22'-30°-14'
Longitude	78°56-78°-47	78°56-78°-47	78°56-78°-47	78°56-78°-47
Altitude (m a.s.l.)	1400	1400	1100	1100
Slope	Moderate	Moderate	Moderate	Moderate
Angle	25-40°	25-40°	25-40°	25-40°
Aspect	South-East	North-East	North-West	North-East

respectively with 25-40° slope angle. Site C (Sendri 1) and site D (Sendri 2) extends a little below at an elevation of 1100 m facing North-West and North-East face, respectively. Details of the sites are shown in Table 1.

Methodology

During the course of this study, region under observations was surveyed for floristic composition throughout the year 2005-06. All the species were collected followed by herbarium preparation. Identification of the specimens was done with the help of regional floras (Naithani, 1984, 1985; Gaur, 1999) and were crossed checked with Garhwal University

Herbarium (GUH) and Botanical Survey of India (BSI), Northern circle herbarium at Dehradun. The collected plants were observed keenly for perenating organs and their positions and were assigned to various life form classes as per Raunkier's biological spectrum (Raunkiaer, 1934).

To understand the vegetation structure and phytosociological features of under canopy vegetation, an area of 10 m^2 was marked on each site and random sampling was done by laying 10 quadrats of 50×50 cm size. In the temperate region of Himalaya, 6 seasons are identified viz., Winter, Spring, Summer, Rainy, Autumn and Pre-winter and therefore, sampling was done for 6 times at each site at 2 month intervals, hence no replicate plots were used. The size and number of quadrat was determined on the basis of species area curves method (Cain, 1938). Quantitative parameters such as percentage of frequency, density, abundance and Total Basal Cover (TBC) of each species present in quadrats were recorded and analyzed as per the methods of Misra (1968), Kershaw (1973) and Tiwari (2005). The concept of Importance Value Index (IVI) has been developed to express the dominance and ecological success of any species (Curtis and McIntosh, 1950). The index was calculated by summing the three relative values, viz., relative frequency, relative density and relative dominance as per the methods of Curtis (1959) and Phillips (1959). The ratio of abundance to frequency (A/F) is a relative measure to present the distribution of species in a community and was calculated as per the method of Curtis and Cottam (1956) as: A/F<0.025 (regular); between 0.025 and 0.05 (Random) and >0.05 (contagious) distribution.

RESULTS

An observation on floristic composition is one of the basic requirements to estimate the current status of the forest resources or to effectively plan and conserve the existing forest covers. Out of 36 families recorded for the representative genera and species, Asteraceae, Poaceae, Fabaceae and Lamiaceae families were observed to be dominant at all sites. They occupied maximum habitat and enjoy better niche diversity. These families were represented by 114 genera and 137 species with 23 genus and 25 species of family Asteraceae and 16 species of same number of genus of family Poaceae. Of the 137 species recorded, 67 were herbs/prostrate herbs, 17 grasses/sedges, 8 climbers, 40 under shrubs/shrubs and remaining were trees. Details of vegetational features are shown in Fig. 3. Life form analysis revealed

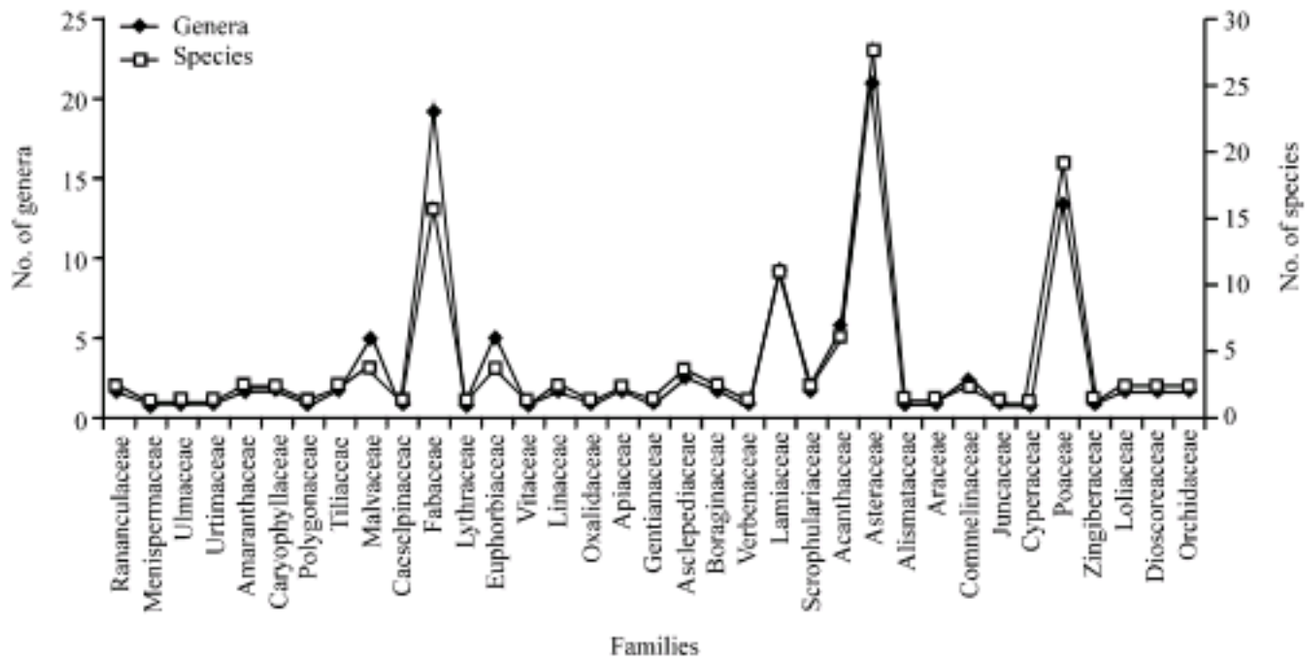

Fig. 3: Vegetation features of the study area

that phanerophytes (PH), chamaephytes (Ch), hemicrypotophytes/ hemigeophytes (He), cryptophytes/geophytes (Cr) and therophytes (Th) were represented by 18, 18, 30, 21 and 50 species, respectively.

Capillipedium parviflorum possessed maximum frequency, density. TBC and IVI at all sites, only *Cyperus niveus* is found as the sedge at all study sites (Appendix I, II). Among forbs, *Desmodium diffusum*, *Desmodium gangeticum*, *Pogostemon benghalense*, *Aechmanthera gossypina*, *Oxalis corniculata*, *Reinwardtia indica*, *Inula cappa*, *Leucas lanata*, *Ageratum conyzoides* etc. responded differently as they had maximum density, frequency, TBC and IVI at one or other sites. Higher frequency indicated more frequent distribution at the sites due to optimum soil and environmental conditions. *Capillipedium parviflorum* showed 100% frequency at all the sites. *Capillipedium parviflorum* emerged as having maximum Total Basal Cover (TBC) and density in all sites. The higher value of IVI indicates that all the available resources are being utilised by that species and left over are being trapped by another species as the competitors and associate. The high IVI of a species indicated its dominance and ecological success, in the form of its better regeneration and greater ecological amplitude. *Capillipedium parviflorum* showed maximum IVI values at all sites indicating its dominance due to environmental suitability and ability of the species as well against grazing and forest fire as Pine forest faces severe fire during Winter months.

DISCUSSION

The composition of grazingland varies greatly with the altitude, soil moisture and intensity of biotic factors. In the complex Himalayan forest ecosystem, chronic form of disturbances exists in which people remove a small fraction of forest biomass in the form of grazing, lopping, surface burning and litter removal at a given time. These disturbances affect the stability of the ecosystem and retard the successional process in this area. The majority of grasslands arising on different altitudes are created due to various anthropogenic disturbances or some other factors. In addition, variation in topography, elevation, soil, rainfall and other climatic conditions are responsible for sustaining specific type of plants, peculiar to Himalaya (Gaur *et al*., 1995). Maximum number of species indicates the tendency of each species to emerge, grow and establish with the onset of favourable conditions. However, this is ultimately determined by the prevailing environmental conditions and also through the range of tolerance and adaptation of a particular species (Bhandari *et al*., 1999). Seasonal fires opening gaps in this forest facilitate high light intensity and space for the growth of herbaceous species and therefore, increased diversity (Bhandari *et al*., 1997). Similar observations were reported by Semwal *et al*. (2008) in moist temperate forests in Northwest Himalayas.

For a particular species, higher frequency indicates its more frequent distribution at sites due to optimum soil and environmental conditions. *Capillipedium parviflorum* showed 100% frequency at all sites. However, moderate level of grazing, moist condition, better soil condition and geomorphology favour's the forb's growth (Gaur *et al*., 2003). The higher value of IVI indicates that all the available resources are being utilised by that species and left over are being trapped by another species as the competitors and associates. Lower importance value of species is an index of low grazing pressure by herbivores on the study sites, as vegetation is a reflex of interactions between the plants, animals, soils and climate. Moreover, each species of a community plays specific role and there is a definite quantitative relationship between abundant and rare species (Bhandari *et al*., 1999). The high IVI of a

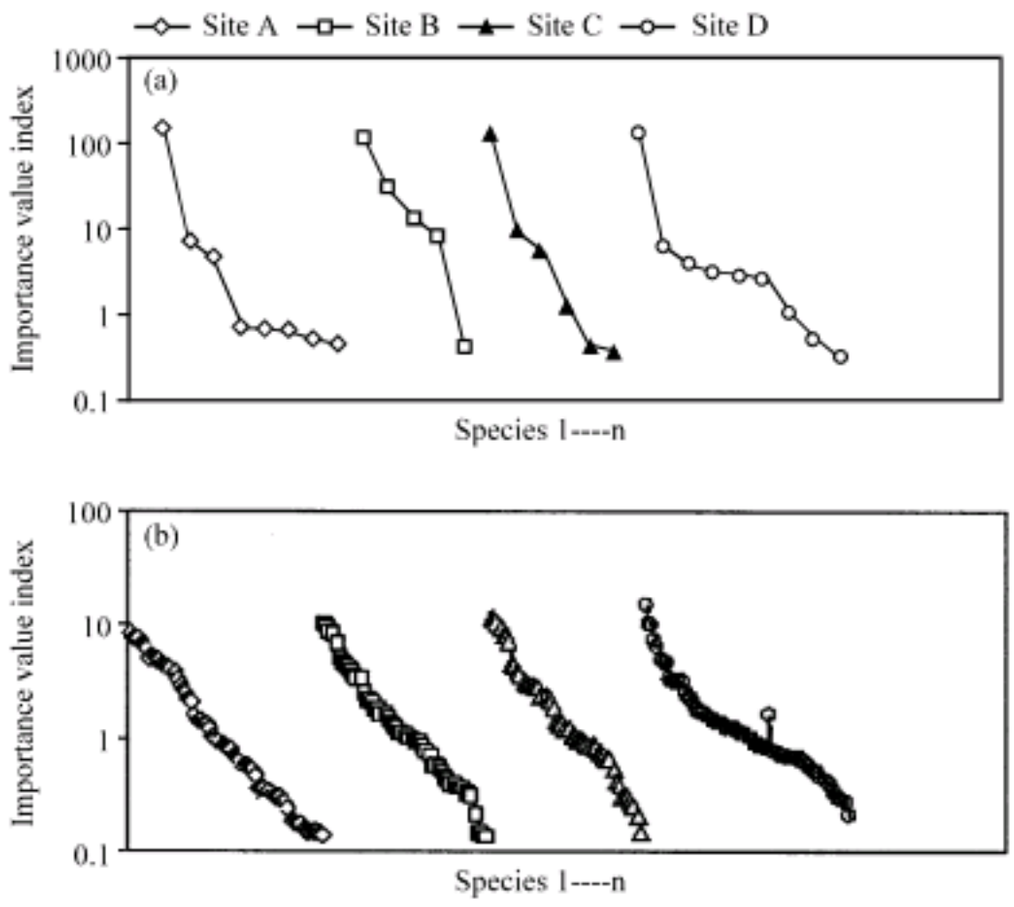

Fig. 4: Grasses and forbs species showing dominance-diversity curves, (a) grasses and (b) forbs

species indicated its dominance and ecological success, its good power of regeneration and greater ecological amplitude. *Capillipedium parviflorum* showed maximum IVI values at all sites and therefore, emerged as dominant species of the ecosystem.

Two broad approaches are used to analyse diversity i.e., diversity indices and dominance diversity curve. The dominance diversity curve (Fig. 4a, b) is often used to interpret the community organization in terms of resource share and niche space (Nautiyal *et al*., 2000). The dominance-diversity curves approached towards log-normal series distribution for herbaceous layer, however few dominating species took over the major share of resource and left over resource is divided among the remaining counterpart species. The log series indicates that moderately common species reflect most closely the nature of the environment and abundant species fluctuate less violently from time to time. A log series would however result if the intervals between the arrivals of these species were random rather than regular (Boswell and Patil, 1971). It is applicable in the situations where one or few factors dominate the ecology of the community as in present sites where fire along with altitudes and aspect determine community structure.

Abundance and frequency (A/F) ratio reveals that regular distribution of the species was totally absent and most of the species were contagiously distributed in all sites during all seasons (Fig. 5a-d). This is in conformity with the observation of several workers that grasslands or grazinglands, exhibit the dominance of aggregation due to tussock forms of grasses (Singh and Yadava, 1974) and specific microclimate preference of many forbs. Heavy grazing caused the disturbance of natural vegetation and allowed introduction of weeds and seral vegetation which appears as randomly distributed. The contiguous distribution pattern is a characteristic pattern of nature (Odum, 1971) and was also reported for the other grazinglands of Garhwal Himalaya (Joshi and Tiwari, 1990; Bhandari *et al*., 1995; Pande *et al*., 1996; Bhandari *et al*., 1997) and for other ecosystems as well (Kershaw, 1973; Singh and Yadava, 1974; Kunhikannan *et al*., 1998). Random distribution found in very uniform environment only and regular distribution occurs where severe competition exists between

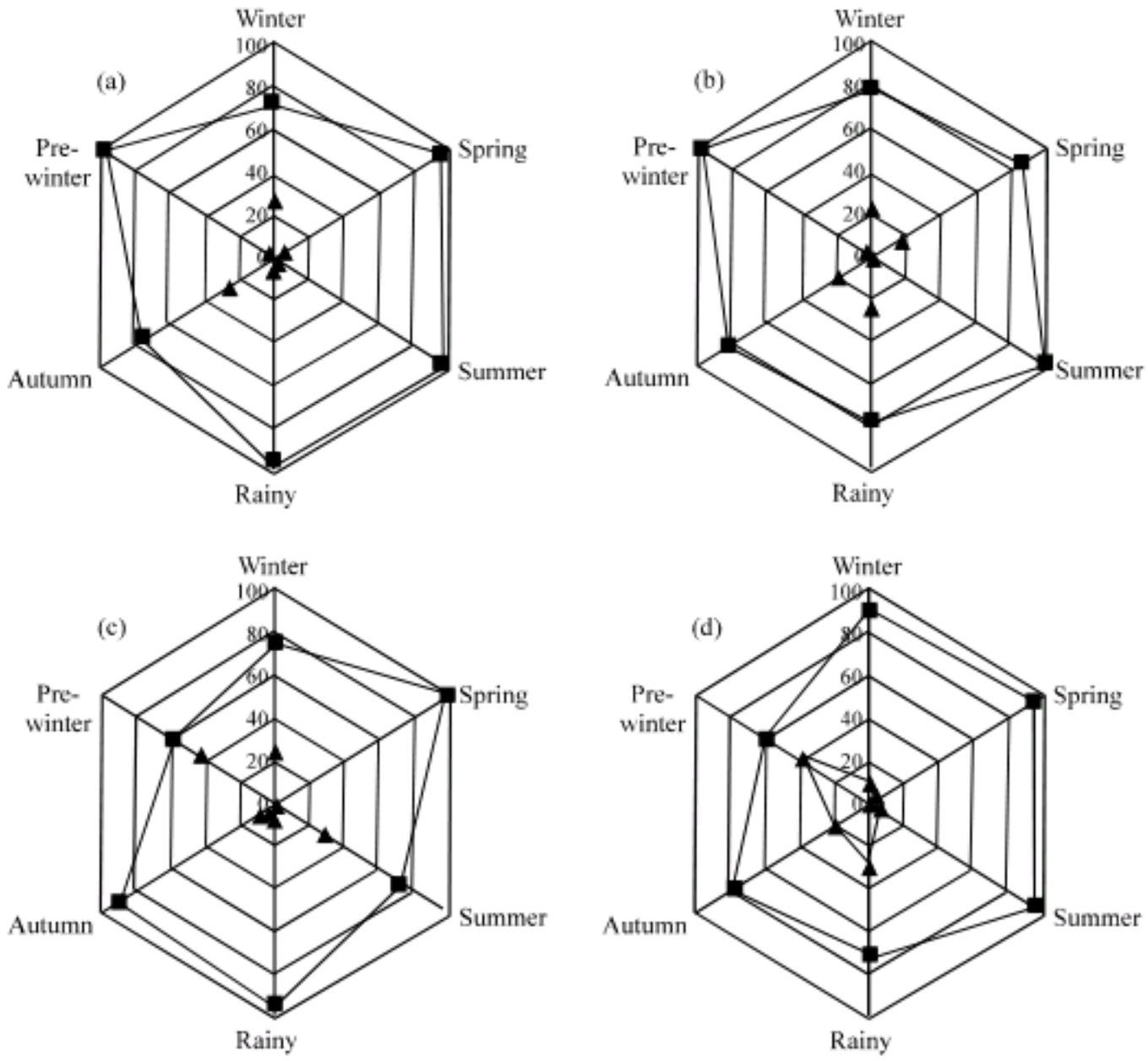

Fig. 5: Distribution pattern of vegetation in all sites during different seasons, (a) site A, (b) site B, (c) site C and (d) site D

individuals. The dominance of contagious distribution may also be due to the fact that the majority of herb species reproduce vegetatively in addition to their sexuality. However, observations indicated that contagious distribution in vegetation was due to multitude of factors and the vegetative reproduction may not be the only reason (Kershaw, 1973; Saxena and Singh, 1982).

The life forms are taken as indicator of climate and assumed to have evolved in direct response to the environment (Pandit and Pahurkar, 1998). The observations made for life-form pattern showed higher number of therophytes (50). This was followed by hemi-cryptophytes (30). Presence of these showed heavy biotic stress in the sites. Therophytes are the indicators of the amount of biotic influence on the habitat as most of them are annual. Singh and Ambasht (1975) found that therophytes develop especially in an area where the native vegetation has been disturbed by overgrazing and life forms of the flora of each of the association are maintained by the intensity of grazing. In the sites under observations, besides grazing, fire was main detrimental factor for dominating the flora by therophytes. The life form pattern for chamaephytes was recorded to be low due to high palatability and high grazing intensity by the livestock and cattles. Firing in these ecosystems is of crown type thus co-dominance of Hemigeophytes may be assigned to its propagation through underground perennating organs as the organs below soil are not damaged by this type of fire. The present result confirm the finding of Bharucha and Dave (1944), who stressed that

higher therophytes are the indicators of the magnitude of influence of man and animals on the habitat. Saxena and Singh (1982) gave the biological spectra for Himalayan vegetation across the altitudes including the pine forests. The therophyte nature of the flora in the pine forests may be attributed to recurring fires, relative xericness and broken canopy which permits the abundant herbaceous growth during rainy season.

It may be inferred from the findings that *Capillipedium parviflorum* was a dominant species among the under canopy vegetation in *Pinus* forest of temperate Himalaya irrespective of altitudinal gradient and aspect. However, co-dominance species were different in most of the site because of specific microclimatic requirements by these species. This also leads into a dominance of aggregation due to tussock forms of grasses and microhabitat preference by other species as well. Similarly, dominance by therophytes life forms is the indicator of intensity of grazing and fire in these ecosystems of Himalaya.

ACKNOWLEDGMENT

The first author is thankful to G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) Kosi Katarmal, Almora for providing financial support.

Appendix I: Frequency (%) and Density (plant m^{-2}) of species at different stands

	Frequency (%)				Density (plant m^{-2})			
Grasses	A	B	C	D	A	B	C	D
*Arundinella nepalensis*Trinius	6.67	16.67			10.07	91.9		
Avena sterelis Bor			3.33	15.00			1.20	8.2
Racharia distachya (L.) Stapf	5.00				2.67			
Capillipedium parviflorum (R.Br.) Stapf	95.00	85.00	91.67	93.33	364.72	358.6	364.70	248.6
Chloris dolichostachya Lagasca				3.33				0.8
Cynodon dactylon (L.) Persoon				8.33				4.2
Echinochloa crus-galli (L.) P. Beauv				1.67				0.2
Eulaliopsis binata (Retz.) Hubbard		13.33	10.00			39.7	30.33	
Hemarthria compressa (L.f.) R.Br.	5.00			6.67	2.73			2.0
Heteropogon contortus (L.) P. Beauv.			3.33				1.80	
Oplismenus composites (L.) P. Beauv.	31.67	25.00	45.00	31.67	12.80	21.1	18.30	11.7
Saccharum officinale L.	1.67				2.00			
Setaria viridis (L.) P. Beauv.	3.33		3.33	11.67	3.07		0.67	7.5
Sedges								
Cyperus niveus Retz.	3.33	3.33	15.00	10.00	1.67	6.9	26.77	11.1
Forbs								
Abelmoschus crinitus Wallich				1.67				0.1
Abutilon indicum (L.) Sweet				3.33				0.4
Aechmanthera gossypina (Nees) Nees	35.00	36.67	18.33		4.60	5.8	1.20	
Aeschynemone indica L.	26.67	13.33	3.33	21.67	3.20	1.4	0.33	1.8
Ageratum conyzoides L.	1.67				0.07			
Ajuga bracteosa L.	30.00	45.00	21.67	20.00	1.73	4.0	1.35	1.5
Ajuga macrosperma Wallich ex Benth.			3.33				0.33	
Alternanthera sessilis (L.) Dc.			11.67	18.33			5.00	0.5
Alysicarpus monoliformis				10.00				1.0
Alysicarpus rugosus(Willd) DC.				6.67				0.5
Anagallis arvensis L.	5.00				0.40			
Anaphalis triplinervis (Sims) C.B. Clarke		5.00		8.33		0.4		0.5
Androsace rotundifolia Hardwicke			6.67				0.53	
Androsace umbellate (Lour.) Merrill.				6.67				0.9
Arachne cordifolia (Decne.) Hurusawa			3.33				0.33	
Arisaema flavum (Forsk.) Schott			1.67				0.13	
Arisaema tortuosum (Wallich) Schott	6.67				0.67			
Artemesia japonica Thunb	6.67			36.67	0.67			4.7
Artemisia nilagirica (C.B.Clarke) Pampanini	43.33			13.33	4.67			0.9

Appendix I: Continued

Grasses	Frequency (%)				Density (plant m^{-2})			
	A	B	C	D	A	B	C	D
Asparagus racemosus Willd.	5.00	6.67		3.33	3.07	0.3		0.2
Atylosia crassa Prain andKing	1.67	1.67			0.67	1.0		
Atylosia mollis sensuBaker	5.00				0.40			
Atylosia scrabaeoides (L.) Benth.		5.00	20.00	16.67		0.5	1.93	1.7
Barlaria cristata L.	10.00	13.33	8.33	10.00	0.27		1.60	
Barlaria pectinata	5.00		5.00		1.07	1.1	0.33	1.0
Barlaria prinoites L.				6.67				0.5
Bauhunia vahlii Wight andArn.		5.00		3.33		0.5		0.3
Bidens tripartite L.	3.33				0.13			
Bignonia picta			6.67				1.07	
Blepharis maderaspatensis (L.) Roth.		6.67	8.33			0.8	2.33	
Blumea mollis (D.Don) Merrill				18.33				0.7
Borreria pusilla (Wallich) DC.	1.67				0.07			
Buchnera hispida Buch-Ham. Ex D.Don.				6.67				1.9
Campanula sylvatica				1.67				0.2
Campylotropis speciosa (Royle ex Schindler) Schindler	23.33	25.00	16.67		3.33	3.8	2.87	
Carssia absus			6.67				1.13	
Caryopteris odorata (D.Don.) B.L.Robinson	11.67				0.33			
Cayrotia auriculata	5.00				0.07			
Celtis australis L.	1.67				0.07			
Cissampelos pareira L.	31.67	33.33	25.00	33.33	2.60	2.7	2.27	2.7
Clematis gouriana Roxb.ex DC		1.67				0.2		
Coccinia grandis (L) Voigt				1.67				1.0
Commelina benghalense L.				1.67				0.1
Commelina kurzii C.B. Clarke	1.67	1.67	3.33	10.00	0.33	0.1	0.27	0.1
Cotoneaster microphyllus Wallich ex Lindley.				1.67				2.7
Crotalaria alata Buch-Ham.ex D.Don.	6.67		6.67	10.00	1.00		3.13	0.1
Crotalaria albida Heyne ex Roth.	8.33				0.07			
Crotalaria humifosa graham ex Benth.		31.67				3.0		
Crotalaria mysorensis Roth.		3.33				0.3		
Crotalaria prostrate Rottler ex Willd.	3.33	10.00			0.53	1.2		
Curcuma angustifolia Roxb.				8.33				0.7
Cyanotis axillaris (L.) D.Don.			6.67				1.87	
Cynoglossum glochidiatum Wallich ex Benth.		3.33		1.67		0.4		0.2
Desmodium diffusum DC.	43.33	63.33	41.67	23.33	3.00	3.3	2.18	5.0
Desmodium floribundum (D.Don) Sweet. Ex G.Don	5.00			8.33	7.13	11.7	8.67	2.1
Desmodium gangeticum (L.) DC	38.33	23.33	28.33	8.33	0.13			0.5
Desmodium microphyllum (Thunb.) DC	13.33			3.33	1.33			0.3
Desmodium trifolium (L.)DC			5.00	30.00			1.00	2.6
Dicliptera bupleuroides Nees	6.67				0.13			
Dioscorea bulbata	5.00	1.67	11.67	8.33	0.73	0.7	0.73	0.8
Dioscorea bulbiferal (L.)			3.33				0.13	
Duchesnea indica (Andrews) Focke.			6.67				1.00	
Echinops cornigerus DC				6.67				0.5
Eclipta alba (L.)Hasskari			3.33				0.27	
Euphorbia hirta L.			3.33	18.33			0.53	2.7
Fagopyrum esculentum (L.) Moench			3.33				0.27	
Flemingia fruticulosa Wallich ex Benth.		1.67				0.1		
Galium aparine L.	8.33				0.27			
Gentiana aprica Decne.		1.67				0.1		
Geranium ocellatum Cambess.		1.67	8.33			0.1	1.83	
Gnaphalium affine D.Don.				3.33				0.1
Gnaphalium luteoalbum L.	1.67			10.00	0.07			1.5
Gonostegia hirta(Blume) Miq.	1.67	1.67			0.13	2.1		
Habenaria latilabris (Lindley) Hook	1.67	6.67			0.13	0.5		
Hemeclea sp.	8.33				0.6			
Hypoxis aurea Lour.			5.00				0.53	

Appendix I: Continued

	Frequency (%)				Density (plant m^{-2})			
Grasses	A	B	C	D	A	B	C	D
Indigofera glandulosa Willd	6.67				0.53			
Inula cappa (Buch-Ham ex D.Don) DC	33.33	48.33	50.00	20.00	0.13	7.2	6.35	2.5
Ipomoea indica				5.00				0.4
Ipomoea nil (L.) Roth				3.33				0.3
Ixeris polycephala Cassini	3.33		11.67		3.87		0.80	
Laggera alata (D.Don) Schultz-bipontinus ex Oliver	13.33				1.20			
Lathyrus aphaca L.				1.67				0.1
Lespedeza gerardiana Graham ex Maxim	35.00	25.00	25.00		7.47	4.1	4.63	
Leucas aspera			5.00	15.00			0.40	0.8
Leucas lanata Benth.	1.67	18.33	60.00	15.00	0.47	1.7	7.63	1.3
Lindenbergia grandiflora (Buch-Ham.ex D.Don) Benth.				8.33				0.8
Linum cotymblosum		5.00				0.5		
Melilotus indica (L.) Allioni.		5.00				0.4		
Micromeria biflora (Buch-Ham.ex D.Don) Benth.	43.33	1.67	31.67	23.33	5.60	0.9	8.33	1.9
Monocera sp.	31.67	21.67			3.67	2.4		
Nepeta graciliiflora Benth.	5.00	6.67		10.00	1.07	0.5		2.3
Nervillea prainiana (King andPantling) Seidenfaden and Smitin			3.33	6.67			1.00	1.67
Oligomeris linifolia		1.67				0.1		
Oxalis corniculata L.	35.00	51.67	41.67	25.00	2.67	6.2	2.47	3.2
Parthenium hysterophorus L.	5.00			6.67	0.40			0.5
Parthenocissus semicordata (Wallich) Planchon	0.10				1.67			
Pentanema indicum (L.) Ling.	16.67			8.33	4.87			0.7
Phyllanthus maderaspatensis L.			3.33				0.33	
Pimpinella microphylla	5.00				0.27			
Pluchea lanceolata (D.C) C.B.Clarke.				6.67				1.0
Pogostemone benghalense (Burm.f.) Kuntze.	28.33	38.33	30.00	3.33	4.80	4.6	3.78	0.3
Polygala chinensis L.	5.00			5.00	0.40			0.3
Reinwardtia indica Dumotier	36.67	30.00	21.67	3.33	3.40	3.9	6.20	0.7
Rungia pectinata (L.) Nees.		20.00				3.5		
Rungia repens (L.) Nees.	13.33	15.00			0.93	3.0		
Salvia lanata Roxb.	13.33		13.33		3.33		0.43	
Senecio graciliflorus DC.			10.00	3.33			2.33	0.3
Sida rhombifolia L.				1.67				0.2
Sida acuta Burm.f.				55.00				15.0
Sida spinosa L.				8.33				1.5
Sonchus asper (L.) Hill.	31.67	1.67	36.67		2.80	0.5	3.15	
Stellaria media (L.)Villars.		1.67				0.1		
Swertia angustifolia Buch- Ham ex D.Don.	16.67			5.00	2.00			0.4
Tagetes minuta L.				50.00				6.8
Tephrosia pumila (Lam.) Persoon.		5.00		3.33		1.2		0.3
Tephrosia purpurea (L.) Persoon.		1.67				0.2		
Teucrium quadrifarium Buch- Ham ex D.Don.	31.67	10.00	21.67		6.00	1.1	1.67	
Thalictrum javanecum Blume		1.67				0.5		
Trichodesma indicum (L.) R.Br.				5.00				0.4
Trigonella corniculata (L.) L.	6.67				0.53			
Triumfetta pilosa Roth.				5.00				0.8
Urginia indica (Roxb.) Kunth.		11.67		8.33		0.9		0.5
Vaccaria pyramidata Medikus.		3.33				1.3		
Verbaria chinensis		6.67				0.5		
Vernonia cinera/(L.) Lessing.	5.00		8.33	1.67	1.73		0.80	0.3
Vicoa indica (L.) DC.	5.00	6.67			1.87	2.0		
Vigna vexillata (L.) A. Richard.				6.67				0.8
Viola pilosa Blume.		10.00				3.9		
Viola serpens Wallich ex Gingins.	11.67	36.67	30.00		0.73	5.2	2.92	
Woodfordia floribunda Salisbury.				5.00				0.5
Zornia gibbosa Spanoghe	1.67		5.00		0.13		1.20	

Appendix II: Total Basal Cover (TBC) and Importance value Index (IVI) of species at different stands

	TBC (cm^2 m^{-2})				IVI			
Grasses	A	B	C	D	A	B	C	D
*Arundinella nepalensis*Trinius	0.15	2.15					0.40	3.06
*Avena sterelis*Bor			0.0	0.029	4.75	29.69		
racharia distachya(L.) Stapf	0.00				0.63			
Capillipedium parviflorum (R.Br.) Stapf	10.02	7.82	11.0	7.003	150.69	120.45	139.00	124.28
Chloris dolichostachya Lagasca				0.004				0.45
Cynodon dactylon (L.) Persoon				1.635				3.99
Echinochloa crusalli (L.) P.Beauv				0.002				0.31
Eulaliopsis binata (Retz.) Hubbard		0.69	0.4			12.38	2.24	
Hemarthria compressa (L.f.) R.Br.	0.01			0.06	0.69			1.00
Heteropogon contortus (L.) P. Beauv.			0.0				1.28	
Oplismenus composites (L.) P. Beauv.	1.78	0.25	0.2	0.067	6.97	8.06	10.01	6.18
Saccharum officinale L.	0.01				0.41			
Setaria viridis (L.) P. Beauv.	0.01		0.0	0.008	0.63		0.37	2.80
Sedges								
Cyperus niveus Retz.	0.01	0.03	0.1	0.153	0.50	0.40	5.65	2.57
Forbs								
Abelmoschus crinitus Wallich				5.00E-04				0.21
Abutilon indicum (L.) Sweet				0.006				0.65
Aechmanthera gossypina (Nees) Nees	0.19	0.21	0.0		7.62	8.08	3.64	
Aeschynemone indica L.	0.03	0.01	0.0	0.026	2.65	1.21	0.30	2.31
Ageratum conyzoides L.	0.00				0.17			
Ajuga bracteosa L.	0.34	0.40	0.0	0.138	7.87	9.88	0.69	6.37
Ajuga macrosperma Wallich ex Benth.			0.1				2.96	
Alternanthera sessilis (L.) DC.			0.0	0.008			1.44	1.75
Alysicarpus monoliformis				0.018				1.23
Alysicarpus rugosus (Willd) DC.				0.025				3.25
Anagallis arvensis L.	0.00				0.47			
Anaphalis triplinervis (Sims) C.B. Clarke		0.00		0.001	2.10	0.92		1.03
Androsace rotundifolia Hardwicke			0.0				0.52	
Androsace umbellate (Lour.) Merrill.				0.013				0.65
Arachne cordifolia (Decne.) Hurusawa			0.0				0.31	
Arisaema flavum (Forsk.) Schott			0.0				0.15	
Arisaema tortuosum (Wallich) Schott	0.02				0.69			
Artemesia japonica Thunb	0.01	0.00		0.171	0.56	1.07		10.43
Artemisia nilagirica (C.B.Clarke) Pampanini	0.34			0.007	8.76			1.23
Asparagus racemosus Willd.	0.02	0.00		0.005	0.90	0.51		0.74
Atylosia crassa Prain and King	0.00	0.01			0.15	0.69		
Atylosia mollis sensuBaker	0.00				0.30			
Atylosia scrabaeoides (L.) Benth.		0.00	0.0	0.072		0.39	2.88	4.60
Barlaria cristata L.	0.00		0.0		1.48	0.93		1.45
Barlaria pectinata	0.03	0.03	0.0	0.005	0.18		1.03	
Barlaria prinoites L.				0.005				0.55
Bauhunia vahlii Wight andArn.		0.02		0.003		0.14		0.51
Bidens tripartite L.	0.00				0.32			
Bignonia picta			0.0				0.82	
Blepharis maderaspatensis (L.) Roth.		0.00	0.0			1.79	0.90	
Blumea mollis (D.Don) Merrill				0.003				1.72
Borreria pusilla (Wallich) DC.	0.01				0.25			
Buchnera hispida Buch-Ham. Ex D.Don.				0.007				0.77
Campanula sylvatica				0.010				0.51
Campylotropis speciosa (Royle ex Schindler) Schindler		0.06	0.03	0.000		2.94	0.54	1.95
Carssia absus			0.00				0.76	
Caryopteris odorata (D.Don.) B.L.Robinson	0.04				1.01			
Cayrotia auriculata	0.00				0.17			
Celtis australis L.	0.00				0.14			
Cissampelos pareira L.	0.04	0.03	0.00	0.03	3.87	1.46	2.34	5.04
Clematis gouriana Roxb.ex DC		0.00				0.00		
Coccinia grandis (L) Voigt				0.025		0.84		0.65

Appendix II: Continued

Grasses	TBC (cm^2 m^{-2})				IVI			
	A	B	C	D	A	B	C	D
Commelina benghalense L.				0.003				0.62
Commelina kurzii C.B. Clarke	0.02	0.00	0.0	0.007	0.54	0.13	0.26	1.10
Cotoneaster microphyllus Wallich ex Lindley.				0.003				0.43
Crotalaria alata Buch-Ham.ex D.Don.	0.01		0.1	0.022	0.64		4.33	1.25
Crotalaria albida Heyne ex Roth.	0.01				0.37			
Crotalaria humifosa graham ex Benth.		0.04				4.19		
Crotalaria mysorensis Roth.		0.03				0.30		
Crotalaria prostrate Rottler ex Willd.	0.01	0.01			0.78	0.00		
Curcuma angustifolia Roxb.				0.027				1.61
Cyanotis axillaris (L.) D.Don.			0.0				0.93	
Cynoglossum glochidiatum Wallich ex Benth.		0.01		0.001		0.00		0.29
Desmodium diffusum DC.	0.19	0.26	0.2	0.030	7.53	8.61	8.00	4.70
Desmodium floribundum (D.Don) Sweet. Ex G.Don	0.00			0.002	0.16			0.65
Desmodium gangeticum (L.) DC	0.17	0.07	0.0	0.018	5.05	3.58	2.91	2.07
Desmodium microphyllum (Thunb.) DC	0.01			0.002	1.22			0.28
Desmodium trifolium (L.)DC			0.0	0.017			0.99	3.09
Dicliptera bupleuroides Nees	0.00				0.15			
Dioscorea bulbata	0.00	0.01	0.0	0.003	0.99	1.06	1.03	1.34
Dioscorea bulbiferal L.			0.0				0.21	
Duchesnea indica (Andrews) Focke.			0.0				0.90	
Echinops cornigerus DC				0.000				1.43
Eclipta alba (L.) Hasskari			0.1				1.25	
Euphorbia hirta L.			0.0	0.038			0.39	2.59
Fagopyrum esculentum (L.) Moench			0.0				0.3	
Flemingia fruticulosa Wallich ex Benth.		0.00				0.32		
Galium aparine L.	0.00				0.37			
Gentiana aprica Decne.		0.00				0.13		
Geranium ocellatum Cambess.		0.01	0.1			0.21	1.39	
Gnaphalium affine D.Don.				0.022				0.88
Gnaphalium luteoalbum L.	0.00			0.023	0.27			0.99
Gonostegia hirta(Blume) Miq.	0.00	0.02			0.15	2.19		
Habenaria latilabris (Lindley) Hook	0.00	0.01			0.15	0.56		
Hemeclea sp.	0.04				1.35			
Hypoxis aurea Lour.			0.0				0.43	
Indigofera glandulosa Willd	0.02				0.67			
Inula cappa (Buch-Ham ex D.Don) DC	0.17	0.32	0.5	0.08	5.08	10.13	11.35	2.25
Ipomoea indica				0.003				0.41
Ipomoea nil (L.) Roth				0.015				0.33
Ixeris polycephala Cassini	0.01		0.1		0.59		2.77	
Laggera alata (D.Don) Schultz-bipontinus ex Oliver	0.04				1.44			
Lathyrus aphaca L.				0.003				0.35
Lespedeza gerardiana Graham ex Maxim	0.19	0.08	0.1		6.39	3.34	3.2	
Leucas aspera			0.0	0.012			0.67	1.35
Leucas lanata Benth.	0.01	0.03	0.2	0.015	0.31	3.35	9.57	1.83
Lindenbergia grandiflora. (Buch-Ham.ex D.Don) Benth			0.0				0.68	
Linum cotymblosum		0.00				0.42		
Melilotus indica (L.) Allioni.		0.00				0.39		
Micromeria biflora (Buch-Ham.ex D.Don) Benth.	0.12	0.01	0.2	0.019	6.84	1.10	10.62	3.14
Monocera sp.	0.03	0.06			4.40	3.89		
Nepeta graciliiflora Benth.	0.01	0.01		0.021	0.82	0.57		1.22
Nervillea prainiana (King andPantling) Seidenfaden and Smitin		0.04	0.0			0.98	1.23	
Oligomeris linifolia		0.00				0.14		
Oxalis corniculata L.	0.04	0.07	0.0	0.046	4.44	7.06	4.62	3.09
Parthenium hysterophorus L.	0.00			0.02	0.37			0.61

Appendix II: Continued

	TBC (cm^2 m^{-2})				IVI			
Grasses	A	B	C	D	A	B	C	D
Parthenocissus semicordata (Wallich) Planchon				0.004				0.86
Pentanema indicum (L.) Ling.	0.17			0.002	4.59			1.08
Phyllanthus maderaspatensis L.			0.0				0.27	
Pimpinella microphylla	0.01				0.30			
Pluchea lanceolata (D.C) C.B.Clarke.				0.015				0.67
Pogostemone benghalense (Burm.f.) Kuntze.	0.04	0.00	0.1	0.008	3.32	5.29	4.0	0.71
Polygala chinensis L.	0.00			0.003	0.34	0.00		0.39
Reinwardtia indica Dumotier	0.06	0.07	0.1	0.008	5.08	4.59	7.1	1.07
Rungia pectinata (L.) Nees.		0.01				2.07		
Rungia repens (L.) Nees.	0.05	0.03			2.27	1.77		
Salvia lanata Roxb.	0.24		0.1		4.18		2.46	
Senecio graciliflorus DC.			0.1	0.013			2.28	0.83
Sida rhombifolia L.				0.237				0.29
Sida acuta Burm.f.				0.001				14.73
Sida spinosa L.				0.009				0.83
Sonchus asper (L.) Hill.	0.27	0.01	0.3		6.01	1.31	8.1	
Stellaria media (L.)Villars.		0.01				0.33		
Swertia angustifolia Buch- Ham ex D.Don.	0.02			0.003	1.61			0.71
Tagetes minuta L.				0.04				10.14
Tephrosia pumila (Lam.) Persoon.		0.08		0.015		1.60		0.90
Tephrosia purpurea (L.) Persoon.		0.01				0.36		
Teucrium quadrifarium Buch- Ham ex D.Don.	0.17	0.02	0.0		4.99	1.65	2.14	
Thalictrum javanecum Blume		0				0.36		
Trichodesma indicum (L.) R.Br.				0.011				0.44
Trigonella corniculata (L.)	0.03				1.40			
Triumfetta pilosa Roth.				0.02				0.54
Urginia indica (Roxb.) Kunth.		0.18		0.143		0.94		7.19
Vaccaria pyramidata Medikus.		0.03				1.38		
Verbaria chinensis		0.01				0.76		
Vernonia cinera/(L.) Lessing.	0.03		0.0	0.021	2.51		0.73	1.66
Vicoa indica (L.) DC.	0.02	0.02			0.80	0.97		
Vigna vexillata (L.) A. Richard.			0.0	0.032			0.96	3.29
Viola pilosa Blume.		0.05				2.49		
Viola serpens Wallich ex Gingins.	0.01	0.06	0.0		0.91	4.42	3.03	
Woodfordia floribunda Salisbury.				0.025				1.53
Zornia gibbosa Spanoghe	0.00		0.0		0.15		1.40	

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