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Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India

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Abstract: More than two third tree species were in early succession and similarly, the higher number of shrubs and herbs were in early and mid-succession indicates the successional nature of the community. A comparatively higher number of trees and shrubs were recorded on the western aspect where low erosion and greater anthropogenic pressure were present. The total tree density was higher at hilltop of eastern aspect and hill slope of western aspect. Total tree basal area varied from 4.5 m^2ha^{-1} (hill base) to 11.9 m^2ha^{-1} (hilltop) on the eastern aspect and from 9.3 m^2ha^{-1} (hilltop) to 16.8 m^2ha^{-1} (hill base) on the western aspect. The sapling and seedling density was lower on western aspect because higher anthropogenic disturbances may lead the removal of seedlings of most of the tree species. The shrub and herb diversity was higher on both the aspects as compared to tree diversity because opening of canopy provides greater opportunity for the recruitment of shrubs and herbs. There were few individuals of important species in older girth classes and higher numbers in younger girths indicate the forest is regenerating. The significant presence of *Coriaria nepalensis*, non-leguminous nitrogen fixing species, at all the sites seems to help in the restoration of the ecosystem.

Resumen: Más de dos terceras parte de las especies de árboles estaban en sucesión primaria lo cual, igual que el hecho de que el mayor número de arbustos y hierbas estaba en sucesión temprana y media, indica la naturaleza sucesional de la comunidad. Se registró un número comparativamente más alto de árboles y arbustos en el flanco occidental. La densidad total de árboles fue más alta en el flanco oriental de la cima y en la ladera occidental. El área basal total de los árboles varió entre 4.5 m^2ha^{-1} (base del cerro) y 11.9 m^2ha^{-1} (cima) sobre la ladera oriental y entre 9.3 m^2ha^{-1} (cima) y 16.8 m^2ha^{-1} (base) en la ladera occidental. La densidad de plántulas y juveniles fue más baja en la ladera occidental, ya que una mayor incidencia de disturbios antropogénicos puede conducir a la remoción de plántulas de la mayoría de las especies arbóreas. La diversidad de arbustos y hierbas fue más alta en las laderas con ambas orientaciones en comparación con la diversidad de árboles, y que cuando el dosel se abre se presentan mayors oportunidades para el reclutamiento de arbustos y hierbas. Hubo pocos invididuos de especies importantes en las clases perimétricas más viejas y los altos números en clases de diámetros más jóvenes indican que el bosque se está regenerando. La significativa presencia de *Coriaria nepalensis*, una especie fijadora de nitrógeno no leguminosa, en todos los sitios parece contribuir a la restauración del ecosistema.

Resumo: A presença de mais de dois terços de espécies arbóreas na fase inicial da sucessão e de modo semelhante de arbustos e as ervas na fase intermédia indicavam a sucessão natural da comunidade. Um número comparativamente mais alto de árvores e arbustos foram registados no vertente ocidental onde a erosão baixa e a mais alta pressão antropogénica estavam presentes. A densidade total das árvores era mais elevada no topo das colinas na orientação oriental e na encosta de orientação ocidental. A área basal das árvores variou entre os 4,5 $m^2.ha^{-1}$ (na base da colina) e os 11,9 $m^2.ha^{-1}$ (no topo) na zona oriental e de 9,3 $m^2.ha^{-1}$

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topo) a 16,8 $m^2.ha^{-1}$ na base da colina na vertente ocidental. A densidade do movedio e nascedio era menor na orientação ocidental por causa da mais elevada intervenção antropogénica o que poderá levar à desaparição do renovo da maior parte das espécies arbóreas. A diversidade dos arbustos e ervas era mais elevada nas duas orientações quando comparada com a diversidade das árvores porquanto a abertura do copado proporciona uma maior oportunidade para a emergência dos arbustos e das ervas. Verificou-se haver poucos exemplares de espécies importantes nas classes diamétricas mais velhas e um maior número de pequenos diâmetros, o que indica que a floresta está em regeneração. A presença significativa da *Coriaria nepalensis*, uma espécie não leguminosa fixadora de azoto, em todas as estações, parece ajudar na restauração do ecossistema.

Key words: Forest, regeneration, soil, species richness, succession, vegetation analysis.

Introduction

One of the foundation for conservation of biological diversity in forest landscapes is understanding and managing the disturbances regimes of a landscape under past natural and semi-natural conditions (Spies & Turner 1999). Only a few decades ago disturbances were viewed as extraordinary events, unnatural deviation from the normal successional development of equilibrium communities (Oliver & Larson 1990; Pickett & White 1985). Biodiversity is the totality of genes, species and ecosystem in a region. Conservation biologists warn that 25 percent of all species could become extinct during the next twenty to thirty years. The cause for the loss of species are numerous but the most important is the loss and fragmentation of natural habitats. In the Himalayan region, the chronic form of disturbances are found in which people remove only a small fraction of forest biomass in the form of grazing, lopping, surface burning and litter removal at a given time. The problem with the chronic form of forest disturbance is that plants or ecosystems often do not get time to recover adequately because the human onslaught never stops (Singh 1998). This does not only affect the ecosystem but also arrest the succession of the communities.

Species composition of major forest types of Central Himalaya is described by Ralhan *et al.* (1982); Saxena & Singh (1982); Sexena *et al.* (1984); Singh & Singh (1987); Tewari & Singh (1981) and Upreti *et al.* (1985). Singh & Singh (1992) have summarized the information on the structure and functioning of the Himalayan forest ecosystems. Singh *et al.* (1994) have made detailed studies on biomass productivity, leaf longevity and forest structure from low elevation to high altitude forests of Central Himalaya. The present study deals with plant bio-diversity, vegetation composition and regeneration pattern of Central Himalaya forests in relation to natural and anthropogenic disturbances.

Materials and methods

The study area Nainital is located between 29° 21′-29° 24′ N latitude and 79° 25′-79° 29′ E longitude between 1300-2000 m elevation in the Central Himalaya. The disturbances occur either in the form of recurring soil erosion (natural) or anthropogenic disturbances, like grazing, lopping, litter removal and surface burning. For the detailed study of plant biodiversity and other vegetational parameters, the area was divided into three sites each on eastern and western aspects along the elevational gradient i.e., hill base (1300-1500 m), hill slope (1500-1800 m) and hilltop (1800-2000 m). A heavy landslide that occurred approximately 60-70 years ago (based on personal inventory with the locals) characterized the sites on eastern aspect. The complete absence of large sized trees at the site located between 1300-1500 m elevation on eastern aspect whereas the presence of large sized trees of *Pinus roxburghii, Quercus leucotrichophora* and *Acer oblongum* was characteristic feature of the western aspect. On the eastern aspect, the site located between 1500-1800 m showed almost a complete absence of large sized trees, while on the western aspect, only *Pinus roxburghii* had large sized trees. On the site located between 1800-2000 m, the characteristic features were recurring erosion, anthropogenic disturbances and absence of large sized trees on both eastern and western aspects.

The climate of the study area is influenced by monsoon pattern of rainfall. The annual rainfall was 2821 mm of which three fourth occurred in rainy season (mid-June to mid-September). The mean monthly maximum temperature ranged between 16.8°C (January) and 29°C (May), and mean minimum temperature ranged between 1.2°C (January) and 14°C (June).

The study was conducted during the years 1996-97. From each site, the composite soil samples were collected from 0-10 cm, 10-20 cm and 20-30 cm depths, packed in polythene bags and brought to the laboratory for analysis of physical and chemical properties. Moisture content was determined on dry weight basis. Soil texture was determined using the sieves of different size. Soil pH was measured by glass electrodes using 1:5 proportion of soil and water (Jackson 1958). Organic carbon was determined by wet oxidation method (Piper 1944), and the factor 1.724 was used to convert the organic carbon into soil organic matter. The total nitrogen was analysed by Kjel auto N analyzer. Available phosphorus was determined colorimetrically through Chloro-stannous molybdo-phosphoric blue method (Jackson 1958). Vegetation analysis was made for all the three layers of the forest i.e., trees, shrubs and herbs. The plants were identified with the help of a plant taxonomist and the Forest Flora of Kumaun (Osmaston 1926) and Flora Simlensis (Collet 1971) were also consulted. The total species encountered for different forest layers were assigned to early, mid and late successional species following Reddy (1989), Chaudhary (1989) and through personal field experiences. Tree layer was analysed by sampling ten quadrats of 10 x 10 m size in each site. The size and number of samples was determined following Saxena & Singh (1982). The vegetation data were quantitatively analysed for abundance, density and frequency (Curtis & McIntosh 1950). The Importance Value Index (IVI) for the tree layer was determined as the sum of the relative frequency, relative density and relative dominance (Curtis 1959). The distribution pattern of different species was studied using the ratio of abundance to frequency (Whitford 1949). Trees were considered to be individuals >30 cm cbh (circumference at breast height), saplings, 10-30 cm cbh and seedlings, <10 cm, circumference (Saxena *et al.* 1984). The shrub layer was analysed by sampling ten quadrats of 5 x 5 m randomly on each site. The herbs were analysed by placing ten quadrats of 1 x 1 m randomly on each site during rainy season (Peak growth period). The diversity index for all the three layers at each site was computed by using Shannon-Wiener Information Index (Shannon-Weaver 1963) and concentration of dominance was computed by Simpson's index (Simpson 1949). The dominance-diversity curve was drawn by a co-ordinate point of its relative importance index (IVI) on the y-axis and its position in the sequence of species from highest to lowest IVI on the x-axis (Whittaker 1975) for tree layer and density for shrubs and herbs.

Results

Soil

There was little variation in sand, silt and clay percent on both the aspects. Percent sand ranged between 90.7 and 92.7, silt 3.1 and 4.8%, and clay 3.9 and 4.9%. Bulk density ranged between 1.0 g cm^{-3} and 1.3 g cm^{-3} and it was comparatively higher on the western aspect. Soil porosity ranged between 51.1% and 61.5% and the higher values were observed on the eastern aspect. Soil moisture content was comparatively higher on the eastern aspect and it ranged between 4.6% and 15.4% on all the sites. The pH of the soil was neutral to basic and it ranged between 7.0 and 8.4. The carbon content ranged between 0.8% and 2.3%, nitrogen 0.04% and 0.11%, available phosphorus 13.4 and 24.7 ppm, and C: N ratio 7.3 and 42.0 (Table 1).

Plant biodiversity

A total of 92 species of plants were reported from the study area, out of which 15 were trees, 31 shrubs and 46 herbs. The successional status of trees, shrubs and herbs are given in Fig. 1. More than two- third tree species were early successional on both the aspects whereas the high number of shrubs and herbs were in early and mid-succession.

Tree layer

On the eastern aspect at hill base, the lowest tree density was reported for *Rhus wallichii* (10 ind ha^{-1}) and highest for *Pinus roxburghii* (70 ind ha^{-1}). At hill slope, the lowest density was rported

Table 1. Physicochemical properties of soil of the study sites at elevational (m) gradient.

Parameters	1300-1500 m		1500-1800 m		1800-2000 m	
	East	West	East	West	East	West
Sand (%)	91.3	90.9	92.7	91.3	90.7	91.9
Silt (%)	3.8	4.3	3.1	4.2	4.8	4.1
Clay (%)	4.9	4.8	4.1	4.5	4.5	3.9
Bulk density (g cm^{-3})	1.0	1.2	1.0	1.2	1.1	1.3
Porosity (%)	60.4	53.4	61.5	53.8	57.3	51.1
Moisture content (%)	12.2	5.5	15.4	8.5	6.2	4.6
Water holding capacity (%)	43.7	29.8	37.0	40.0	25.1	28.3
Soil pH	7.2	8.0	7.0	7.9	8.4	8.4
Carbon (%)	1.1	0.9	2.1	2.3	1.5	0.8
Total Organic matter (%)	1.9	1.6	3.6	4.0	2.6	1.4
Nitrogen (%)	0.04	0.06	0.05	0.08	0.08	0.11
Available Phosphorus (ppm)	22.7	22.7	14.0	20.0	24.7	13.4
C:N Ratio	27.5	15.0	42.0	28.7	18.8	7.3

for *Cedrus deodara* (10 ind ha^{-1}) and highest for *Pinus roxburghii* (280 ind ha^{-1}), whereas at hilltop, the lowest density was reported for *Acer oblongum* (10 ind ha^{-1}) and highest for *Pinus roxburghii* (390 ind ha^{-1}). It was the dominant species on all sites (IVI = 71.1-175.9) of the eastern aspect followed by *Coriaria nepalensis* at hill slope (IVI = 88.3) and hilltop (IVI = 71.0), and *Quercus leucotrichophora* at hill base (IVI = 55.2). On the western aspect, the tree density ranged between 10 ind ha^{-1}, each for *Grewia optiva* and *Zanthoxylum alatum* (the species had large girth, therefore it was considered as tree (Osmaston 1926) and 160 ind ha^{-1} for *Coriaria nepalensis* at hill base. Density at hill slope ranged between 20 ind ha^{-1} each for *Melia azedarach* and *Sapium insigne* and 270 ind ha^{-1} for *Coriaria nepalensis* whereas it ranged between 20 ind ha^{-1} for *S. insigne* and 210 for *C. nepalensis* at hilltop. The maximum IVI at hill base was shown by *Pinus roxburghii* (IVI = 66.6) followed by *Coriaria nepalensis* (IVI = 54.9) and *Quercus leucotrichophora* (IVI = 47.4). At hill slope and hilltop, *Coriaria nepalensis* was the dominant species (IVI = 97.7 and 98.4, respectively) followed by *Pinus roxburghii* (Table 2).

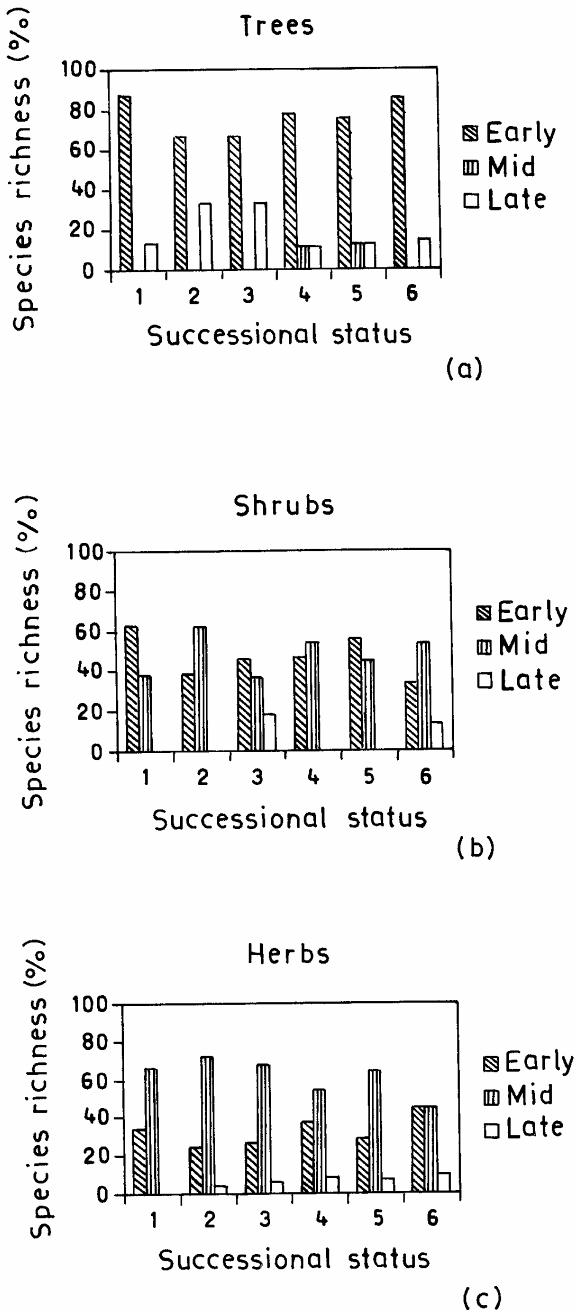

Fig. 1. Species richness (%) in different successional stages.

The mean basal area ranged between 81.5 cm^2 $tree^{-1}$ for *Acer oblongum* and 594.3 cm^2 $tree^{-1}$ for *Pinus roxburghii* whereas, the total basal area was minimum each for *Rhus wallichii* and *Zanthoxylum alatum* (0.1 m^2ha^{-1}) and maximum for *Pinus roxburghii* (8.2 m^2ha^{-1}) on all the sites. The total basal area increased from hill base (4.5 m^2ha^{-1}) to hilltop (11.9 m^2ha^{-1}) on eastern aspect while it decreased from hill base (16.8 m^2ha^{-1}) to hilltop (9.3 m^2ha^{-1}) on western aspect (Table 2).

Sapling and seedlings

The total sapling density varied from 160 ind ha^{-1} at hill base (western aspect) to 690 ind ha^{-1} at hill slope (eastern aspect). The sapling density was more than twice (370-690 ind ha^{-1}) on eastern aspect as compared to western aspect (160-200 ind ha^{-1}). Similar pattern was observed for the total basal area. Saplings of *Pinus roxburghii* and *Coriaria nepalensis* established their dominance on eastern aspect at all the sites while on western aspect, saplings of *Acer oblongum* and *Coriaria nepalensis* were dominant at hill base, *Coriaria nepalensis* and *Pinus roxburghii* at hill slope and *Cupressus torulosa* and *Pinus roxburghii* at hilltop (Table 3).

The seedling density ranged between 40 ind ha^{-1} at hill slope of the western aspect and 430 ind ha^{-1} at hilltop of the eastern aspect. It was higher on the eastern aspect (190-430 ind ha^{-1}) as compared to the western aspect (40-170 ind ha^{-1}) (Table 3).

Shrubs

Total density of shrubs varied from 3720-7200 ind ha^{-1}. It was comparatively higher on the western aspect (4520-7200 ind ha^{-1}) and decreased from hill base to hilltop. The maximum individual shrub density was observed for *Rumex hastatus* (2160 ind ha^{-1}) at hill slope and minimum for *Trema politoria, Hamiltonia suaveolens* and *Rhus cotinus* (40 ind ha^{-1} for each) at hill base of the western aspect (Table 4).

Herbs

Total herbs density ranged between 15.9 and 33.3 ind m^{-2}. Both the maximum and minimum values were observed on the eastern aspect at hill base and hilltop, respectively. It increased from hill base to hilltop on the eastern aspect while maximum density was on hill slope of the western aspect. The maximum individual herb density (5.2 ind m^{-2}) was reported for *Bidens pilosa* at hilltop and minimum was 0.2 ind m^{-2} both on the eastern aspect (Table 5).

Species diversity

The species richness, species diversity and concentration of dominance of different layers are given in Table 6. Both the species richness and diversity for tree layer decreased from hill base to hilltop on both the aspects. The shrub diversity was maximum on hill slope of eastern aspect but it increased from hill base to hilltop on western aspect. The herb species richness and diversity also increased from hill base to hilltop on both the aspects.

Dominance diversity curve

The dominance diversity curves were drawn for each site. The curves for all layers (i.e., trees, shrubs and herbs) fit for the lognormal situation (Fig. 2a, b).

Regeneration

The regeneration of some important species is given in Figs. 3 and 4. The seedlings and saplings of *Pinus roxburghii, Quercus leucotrichophora* and *Coriaria nepalensis* were present on the hill base of eastern aspect. In this site, the trees of *P. roxburghii* were young and in the girth class of 30-60 cm (Figs. 3a). On the western aspect, the seedlings and saplings *of Pinus roxburghii, Quercus leucotrichophora* and *Coriaria nepalensis* were present. At this site, trees of *P. roxburghii* and *Q. leucotrichophora* were present in the higher girth classes (Fig. 4a). At the hill slope, the seedlings and saplings were present for *Pinus roxburghii, Quercus leucotrichophora* and *Coriaria nepalensis* on both the aspects (Fig. 3b and 4b). At hilltop of both the aspect, seedlings and saplings of *Pinus roxburghii, Coriaria nepalensis* and *Q. leucotrichophora* were present except at hill slope of western aspect where seedlings of *Q. leucotrichophora* were absent (Figs. 3c and 4c).

Discussion

The presence of some old oak trees in the study area indicates the presence of original oak forest in the area. The hilltop and hill slope witnessed recurrent soil erosion whereas, the hill base showed deposition of debris on the eastern aspect and the anthropogenic disturbances were present on the western aspect. In the complex Himalayan forest ecosystem chronic form of disturbances exists in

Table 4. Shrub density (ind ha^{-1}) in different sites in mid-elevational forests in Central Himalaya.

Species	Eastern Aspect			Western Aspect		
	Hill Base	Hill Slope	Hill Top	Hill Base	Hill Slope	Hill Top
Aerva scandens	-	-	-	80	80	-
Agave americana	160	-	-	680	520	320
Asparagus racemosus	-	280	240	-	360	120
Berberis asiatica	880	920	720	520	600	520
Buddleia asiatica	-	-	-	80	80	-
Caryopteris wallichiana	-	-	-	-	440	-
Copquhounia coccinea	-	200	-	200	-	-
Cornus oblonga	-	-	-	-	-	160
Desmodium elegans	120	320	-	-	-	-
Desbregeasia longifolia	-	80	120	160	-	280
Flemingia bracteata	-	80	-	-	-	-
Girardinia heterophylla	-	-	-	-	-	80
Hypericum oblongifolium	440	-	400	-	520	-
Hamiltonia suaveolens	-	-	-	80	40	-
Inula cuspidata	-	-	80	-	-	-
Indigofera heterantha	-	240	-	-	-	240
Lantana camara	920	200	-	1360	120	80
Lespdeza eriocarpa	-	400	-	240	240	360
Mahonia nepalensis	-	-	120	-	-	-
Osyris arborea	-	-	-	80	80	-
Pyracanthus crenulata	840	960	480	280	600	360
Pogostemone plectranthoides	-	-	-	320	160	-
Reinwardtia indica	-	-	-	120	-	-
Rhus cotinus	-	-	-	120	40	-
Rubus ellipticus	400	720	680	720	440	280
Rubus lasiocarpus	-	240	400	-	-	80
Rumex hastatus	560	400	400	2160	1880	1040
Spiraea canescens	-	-	-	-	200	280
Trema politoria	-	-	-	-	40	-
Viburnum cotinifolium	-	-	80	-	-	320
Woodfordia fruticosa	-	-	-	-	80	-
Total	4320	5040	3720	7200	6520	4520

which people remove only a small fraction of forest biomass in the form of grazing, lopping, surface burning and litter removal at a given time. These disturbances are affecting the stability of the ecosystem and retarding the successional process in the area. Both natural and human caused disturbances are considered since vegetation responses do not distinguish between natural and human activities. A comparison of the physical properties of soil at the elevational range of 1300-2000 m covering the complete study area, the fine soil content decreased with increasing elevation. Chaudhary (1989) has reported an increase in the fine soil contents with decreasing elevation on the damaged area and Singh & Singh (1991) have reported that the fine soil contents increased significantly with

Table 5. Herb density (ind ha^{-1}) in different sites in mid-elevational forests in Central Himalaya.

Species	Eastern Aspect			Western Aspect		
	Hill Base	Hill Slope	Hill Top	Hill Base	Hill Slope	Hill Top
Alternanthera sessilis	0.5	0.8	0.2	0.7	0.4	1.0
Ageratum canyzoides	-	-	-	1.1	-	-
Agrimonia eupatorium	-	-	-	-	-	0.4
Anaphalis busua	0.5	0.6	0.2	0.4	0.4	-
Anaphalis cinnamonea	-	-	-	-	0.5	0.6
Anaphalis contorta	1.4	1.5	1.1	2.7	2.9	1.7
Apluda mutica	-	0.5	0.4	0.4	-	0.8
Artemisia nilagarica	1.8	2.4	1.2	1.3	1.3	1.0
Bidens biternata	0.7	-	3.5	1.3	1.2	1.0
Bidens pilosa	0.6	0.9	5.2	1.2	1.0	1.9
Bothriochloa pertusa	-	0.5	0.4	1.1	0.7	-
Bupleurum hamiltonii	-	-	0.5	-	-	-
Campanula colorata	-	-	-	0.6	-	0.5
Conyza stricta	-	0.7	-	1.7	3.0	-
Carum anathifolium	-	0.2	0.8	-	0.5	-
Chrysopogon gryllus	-	-	-	-	0.8	-
Chrysopogon serrulatus	0.9	1.2	1.1	0.9	0.8	0.9
Crotolaria albida	0.6	0.5	0.4	-	-	0.6
Cymbopogon distans	-	0.3	0.3	-	-	-
Cynodon dactylon	-	0.8	1.1	0.9	0.8	0.9
Cynoglossum lanceolarum	0.3	0.9	0.6	0.9	-	-
Dicliptera bupleoroides	-	-	1.8	0.6	1.0	1.6
Drymaria cordata	-	1.7	2.2	-	-	-
Erigeron bonariensis	0.8	1.3	0.4	-	1.1	0.3
Erigeron karvinskianus	2.2	2.0	1.9	2.6	3.4	3.0
Eriophorum canescens	-	-	-	-	-	0.6
Eriophorum comosum	-	0.3	0.5	0.7	1.1	1.1
Galium aparine	-	1.0	-	-	0.7	0.8
Galium rotundifolium	-	1.0	-	-	1.1	1.3
Geranium ocellatum	0.2	-	-	-	-	-
Gerbera gossypina	-	0.4	0.6	-	0.5	-
Goldfusia dalhousenia	-	-	0.4	1.0	1.2	0.5
Leucus lanata	1.6	1.4	0.5	-	1.4	1.8
Micromeria biflora	0.6	1.8	0.9	1.2	1.3	1.5
Nepeta leucophylla	1.0	1.9	1.2	1.8	2.0	2.0
Oenothera rosea	-	-	0.4	-	-	0.6
Oplismenus undulatifolium	-	1.0	1.2	-	-	-
Origanum vulgare	0.7	-	0.2	0.4	-	0.9
Ranunculus diffusus	-	-	0.4	-	-	0.4
Rubia cordifolia	-	-	0.5	-	0.3	0.5
Scutellaria angulosa	-	1.0	0.5	-	-	0.6
Seigesbeckia orientolis	-	-	0.6	1.6	1.1	1.3
Swertia cordata	-	1.3	-	0.4	-	-
Swertia purpurascens	0.9	1.0	-	-	1.2	1.1
Swetia chirata	0.6	0.6	1.6	-	-	-
Thalictrum foliolosum	-	-	0.5	1.1	0.6	0.7
Total	15.9	29.5	33.3	26.6	32.3	31.9

Table 6. Species diversity of different forest strata in Central Himalayan forests.

Aspect	Altitude	Parameters	Vegetation layer				
			Tree	Sapling	Seedling	Shrub	Herb
East	1300-1500 m	SR	8	5	4	9	18
		SD	2.80	1.45	1.74	2.40	3.94
		CD	0.15	0.26	0.32	0.14	0.07
	1500-1800 m	SR	6	6	5	13	29
		SD	1.87	1.87	1.96	3.34	4.65
		CD	0.34	0.47	0.29	0.12	0.04
	1800-2000 m	SR	6	7	7	12	34
		SD	1.60	2.64	2.59	3.29	4.74
		CD	0.43	0.18	0.19	0.11	0.04
West	1300-1500 m	SR	9	5	5	16	24
		SD	2.46	2.14	2.15	3.20	4.39
		CD	0.16	0.24	0.25	0.15	0.05
	1500-1800 m	SR	7	4	2	19	28
		SD	2.31	1.85	0.81	3.46	4.54
		CD	0.25	0.30	0.63	0.13	0.05
	1800-2000 m	SR	6	4	2	15	31
		SD	1.85	1.80	0.54	3.55	4.56
		CD	0.27	0.58	0.78	0.15	0.06

SR = Species richness, SD = Species diversity, CD = Concentration of dominance

increasing elevation on the undamaged area. The bulk density was comparatively higher on the western aspect whereas, the moisture content and porosity were higher on the eastern aspect. The soil pH and C:N ratio in the present study were found to be quite high. The high pH may be due to weathering of rocks, which contain basic compounds or importation of basic salts. The hill slope of eastern aspect was highly eroded with high sand content may be the reason for higher C:N ratio. Robertson & Vitousek (1981) have also reported high soil pH in disturbed ecosystems and high C:N ratio (31.8) in sand stage soil.

A total of 92 species of plants were recorded in the present study area, out of which 15 were tree, 31 shrubs and 46 herbs. The saplings and seedling density were higher on eastern aspect as compared to western aspect because of higher anthropogenic disturbances on the western aspect, which leads the removal of seedlings of most of the species. The tree and shrub diversity had weak negative relation while tree and herbs (r^2 = -0.82, p>0.01) were highly negatively correlated. This indicates that the open canopy provides opportunity for the recruitment of shrubs and herbs. Species diversity in tree layer declined with increasing elevation on both aspects. This may be due to recurrent soil erosion in the hill slope and hilltop, which influence the regeneration of late successional species. The presence of few late successional tree, shrub and herb species and higher number of early and mid-successional species indicates the successional nature of the community. Tilman (1988) reported that late succession are not absent from early succession environment. Shade tolerant species colonise early succession environment if seed sources are nearby, suitable germination sites are present, and climate conditions suitable for growth. The greater number of early and mid-successional shrub and herb in the community were due to anthropogenic disturbances that arrest further succession. The diversity was higher in the present study compared to Singh & Singh (1991) reported for tree layers in an undamaged oak forest of Kumaun Himalaya. Pandey & Singh (1985) have also reported an increase in species diversity in disturbed ecosystems of Kumaun Himalaya. FEMAT (1993) and Essen *et al.* (1992) have reported that

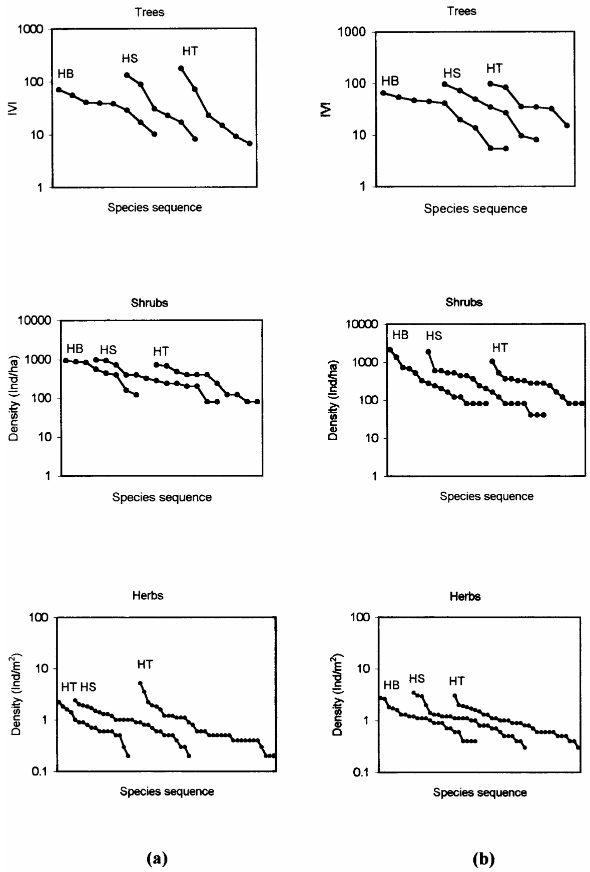

Fig. 2. Dominance-diversity curves for different vegetational layers; (a) Eastern aspect, (b) Western aspect.

the changes from late to early stages of forest development are more drastic and may account for the greatest alterations of biological diversity, changes in the quality and diversity of mid to late successional forests through management for wood production can also alter biological diversity and threatened the viability of species and ecosystem. The probable causes of maximum herbaceous diversity can be cited to the varied heterogeneous conditions, which appears to the result of hectic disturbances in the ecosystem.

The d-d curves for all the vegetational layers (i.e., trees, shrubs and herbs) fit for the lognormal situation. The lognormal series describes the partitioning of realized niche space among various species and it is the consequence of the evolution of diversity in the species along the niche parameters that it exploits (Whittaker 1965).

In the present study, there was almost a complete absence of trees in higher girth classes, indi-

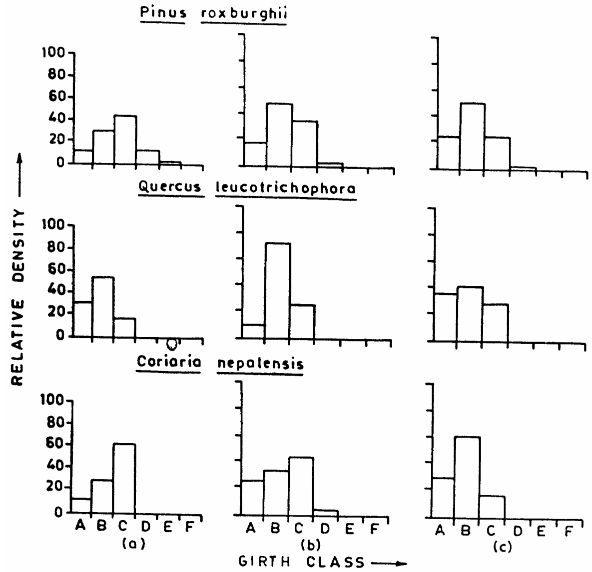

Fig. 3. Population structures of three important species on eastern aspect; (a) Hill base (b) Hill slope (c) Hill top; the relative density is on y-axis and the size classes on x-axis; A = Seedlings, B = Saplings, C = Trees, 30-60 cm, D = 60-90 cm, E = 90-120 cm, F = 120-150 cm, G = 150-180 cm, H = 180-210 cm.

cating the successional trend of the community. *Coriaria nepalensis*, a non leguminous nitrogen fixing species, was present on all the sites. This species may help in the restoration of soil and in the re-conversion of original pine-oak forests. The presence of seedlings and sapling of *Pinus roxbughii* and *Coriaria nepalensis* on all the six sites indicate that these species are profusely regenerating in the area. Presence of sufficient number of seedlings on the eastern aspect indicate better survival of all the three species i.e., *Pinus roxburghii, Quercus leucotrichophora* and C*oriaria nepalensis*. Whereas, the western aspect was characterized by low number of seedlings and saplings indicate the higher anthropogenic pressure on this aspect. The complete absence of seedlings of *Quercus leucotrichophora*, in its natural elevational range, on the hilltop of western aspect shows heavy anthropogenic pressure on this species. On the eastern aspect, *Rhododendraon arboreum* was a new entrant and showed relatively high presence of seedlings and saplings along with *Cornus macrophylla* and *Acer oblongum*. The proportion of different age classes or seral across a landscape and over time is one of the fundamental characteristics of the vegetation mosaic (Spies & Turner 1999). Turner *et al.*

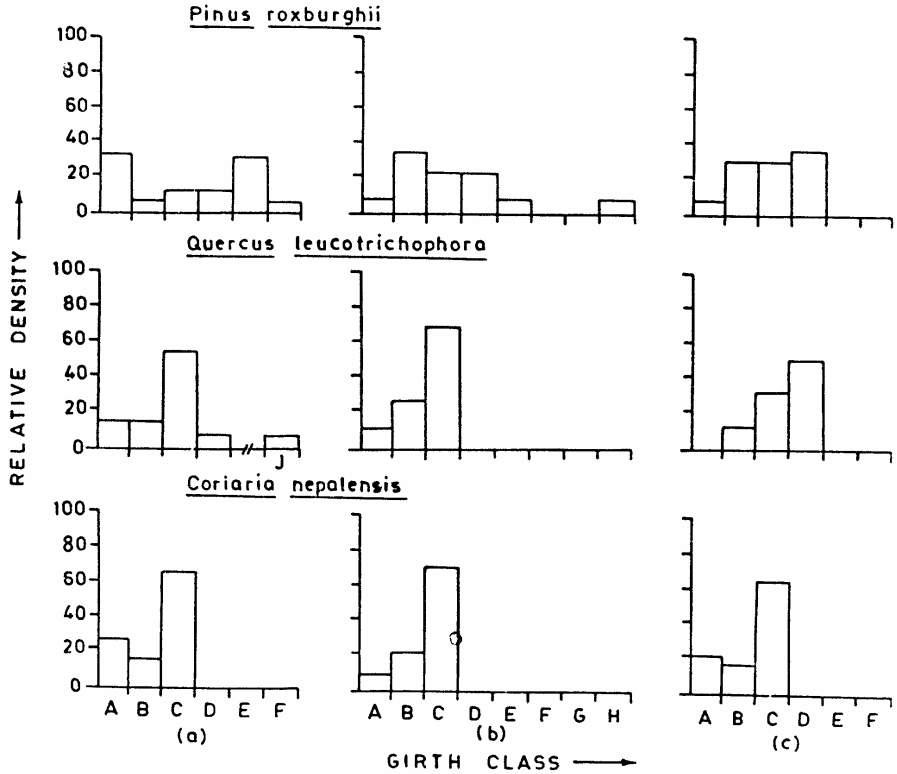

Fig. 4. Population structures of three important species on western aspect; (a) Hill base (b) Hill slope (c) Hill top; the relative density is on y-axis and the size classes on x-axis; A = Seedlings, B = Saplings, C = Trees, 30-60 cm, D = 60-90 cm, E = 90-120 cm, F = 120-150 cm, G = 150-180 cm, H = 180-210 cm.

(1993) have reported that the variability increased as the ratio of the disturbance interval to the recovery interval decreased and landscapes were relatively small, variability in older age classes was high. The differences in vegetation structure and species composition between early successional forest conditions and later stages when tree canopies close and increased height have been documented by Haila *et al.* (1994).

Conclusion

Anthropogenic pressure was major factor arresting succession as was evident by a complete absence of trees in the higher girth classes and relatively low recruitment of seedlings, indicates the successional trend of the community. *Coriaria nepalensis*, a non-leguminous nitrogen fixing species, was present on all the sites. This species may help in the restoration of soil and in the reconversion of original pine-oak forests.

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