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DOMINANCE AND DIVERSITY RELATIONS OF WOODY VEGETATION STRUCTURE ALONG AN ALTITUDINAL GRADIENT IN A MONTANE FOREST OF GARHWAL HIMALAYA

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BHANDARI, B. S., MEHTA, J. P. & TIWARI, S. C. 2000. Dominance and diversity relations of woody vegetation structure along an altitudinal gradient in a montane forest of Garhwal Himalaya. Woody vegetation composition, dominance and diversity were studied along a southwest facing altitudinal gradient in a montane forest of Garhwal Himalaya. *Quercus leucotrichophora* (1800–2000m) and *Quercus-Rhododendron* (2000–2200 m) were the dominating species. Soils were acidic. Percentage organic carbon ranged from 2.1 ± 0.23 (upper) to 2 ± 0.25 (lower). C:N ratio assessed the steady state of litter decomposition in the soil. On lower slope *Quercus leucotrichophora* was the dominant species, and on upper slope, *Quercus leucotrichophora* and *Rhododendron arboreum* were the competing species. Invasion of *Pinus roxburghii* (chir-pine) is an indication of *Quercus leucotrichophora* (oak) replacement in the near future. Marked degree of dissimilarity between upper and lower slopes was due to variation in altitude. Decreasing diversity indices from seedling to tree strata reflected the poor regeneration potential of these forests. Across the strata, shrub layers had a specific niche approach owing to higher beta-diversity.

Key words: Altitude - diversity - niche approach - regeneration - succession - vegetation

BHANDARI, B. S., MEHTA, J. P. & TIWARI, S. C. 2000. Kaitan kedominanan dan kepelbagaian struktur tumbuhan berkayu di sepanjang cerun tinggi di sebuah hutan gunung di Garhwal Himalaya. Komposisi, kedominanan dan kepelbagaian bagi tumbuhan berkayu dikaji di sepanjang barat daya berhadapan dengan cerun altitud di sebuah hutan gunung di Garhwal Himalaya. *Quercus leucotrichophora* (1800–2000 m) dan *Quercus rhododendron* (2000–2200 m) merupakan spesies yang paling dominan. Tanah adalah berasid. Peratus karbon organik berjulat dari 2.1 ± 0.23 (atas) hingga 2 ± 0.25 (bawah). Nisbah C:N menaksirkan keadaan penguraian sarap yang mantap di dalam tanah. Di cerun yang lebih rendah, *Quercus leucotrichopora* merupakan spesies yang dominan, manakala di bahagian cerun yang lebih tinggi, *Quercus leucotrichophora* dan *Rhododendron arboreum* ialah spesies yang bersaing. Penyerbuan *Pinus roxburghii* (chir-pine) menunjukkan tanda-tanda penggantian bagi *Quercus leucotrichophora* (oak) pada masa hadapan. Darjah ketaksamaan yang ditanda antara cerun atas dan cerun bawah ialah akibat perbezaan altitud. Penurunan indeks kepelbagaian daripada anak benih kepada strata pokok menunjukkan potensi pemulihan yang lemah bagi hutan-hutan tersebut. Merentasi strata, lapisan pokok renik mempunyai pendekatan nic yang khusus bergantung kepada kepelbagaian beta yang lebih tinggi.

Introduction

The natural distribution of Himalayan forests from the outer hills to the inner higher zones of the Himalayas is determined primarily by altitude. However, geology, soils and other biotic and abiotic factors also exert influences to a great extent (Champion & Seth 1968). The elevational range of 300 to 2200 m in the Garhwal Himalaya reflects three vegetational regimes, viz. *Shorea robusta* in the submontane zone (up to 1000 m), *Quercus leucotrichophora* (>1500 m) in the low montane to mid-montane zone and *Pinus roxburghii* regime in between the first two regimes. Vegetation between 2200 and 2800 m exhibits a dense canopy of *Quercus floribunda* at moist situations and occupies an intermediate range between *Q. leucotrichophora* and *Q. semecarpifolia*. Above 2800 m oak-conifer association occurs where *Q. semecarpifolia, Abies pindrow, Rhododendron barbatum, Taxus wallichiana* and species of *Viburnum* are the dominant forms. In the inner region between 2200 and 3000 m, forests of *Cedrus deodara* dominate. The outer ranges, however, exhibit pure forests of *Abies spectabilis, Betula utilis* and *Cupressus torulosa* which occur either singly or mixed in various proportions extending up to 3000 m. In several localities, *Quercus semecarpifolia-Abies pindrow* forest lying south of the snows as well as the *Cedrus deodara* forests, merge into the above type of forests. *Betula* is associated with *Prunus cornuta, Rhododendron campanulatum* and *Sorbus* spp. at higher altitudes. In sub-alpine forests of *Betula-Rhododendron* as well as the shrubby areas of *Rhododendron anthopogon* and *Rhododendron lepidotum*, species of *Cotoneaster, Lonicera* and *Rosa* are better developed on the north exposed slopes. In moist and open localities, luxuriant meadows of herbaceous perennials occur with usual components represented by genera such as *Anemone, Epilobium, Gentiana, Geranium, Polygonum*, etc. Along the entire altitudinal range of Garhwal Himalaya, the overlaps among the above species regimes are broad and, therefore, transitional communities having mixtures of the species of more than one zone are often found. Though ecosystem level studies of diversified forests under different anthropogenic stresses, e.g. fire, grazing, are available (Tiwari & Paliwal 1982, Tiwari *et al.* 1989, Bhandari *et al.* 1995), yet studies along an altitudinal gradient are still wanting (Joshi & Tiwari 1990, Bhandari *et al.* 1997). The present study was, therefore, undertaken to analyse the structure of woody vegetation in terms of species composition, dominance and diversity along an altitudinal gradient in a montane forest of Garhwal Himalaya.

Materials and methods

Location

The study was carried out along an altitudinal gradient in the montane forest of Narainbagar (79°22' E, 30°8'N) in the Chamoli District of Garhwal Himalaya (Figure 1). This mountainous area with an elevation ranging from 1800 to 2200 m was selected for the vegetational analysis. A total of three sites were studied at differing altitudes to examine the impact of altitude on woody vegetation (Table 1).

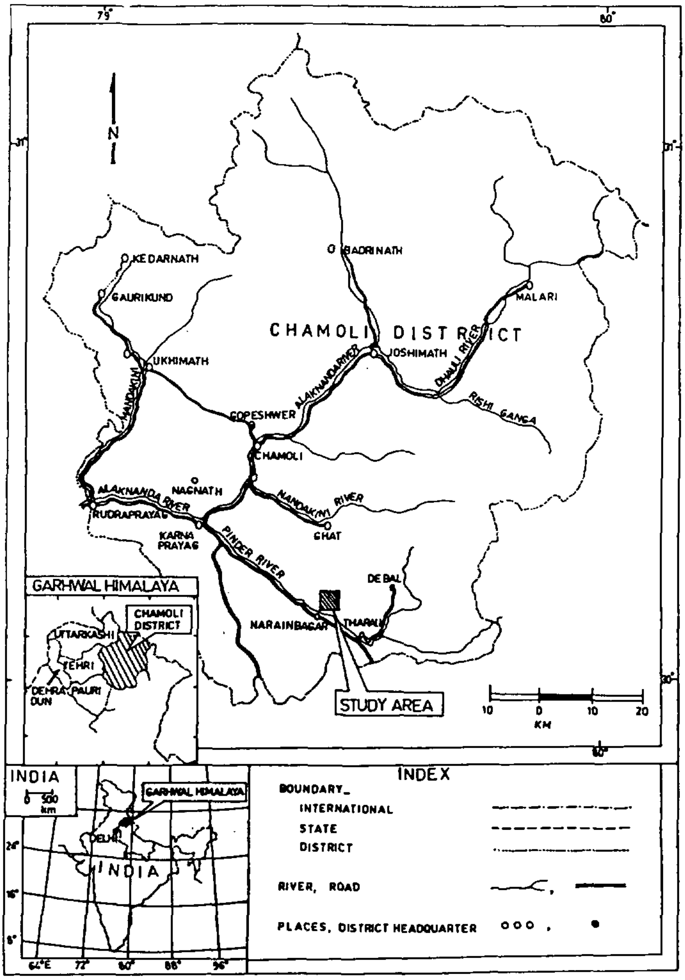

Figure 1. Map showing location of study area in Garhwal Himalaya

Table 1. Site characteristics

Site	Altitude (m)	Slope (°)	Forest type	Aspect
Upper slope	2200	45	*Quercus–Rhododendron* (Mixed)	Southwest
Middle slope	2000	49	*Quercus leucotrichophora*	Southwest
Lower slope	1800	52	-do-	Southwest

The climate is monsoonic and and divisible into three different seasons, viz. rainy (June–September), winter (October–February) and mild summer (March–mid June). Total rainfall during the study period (1996) was 1610 mm of which more than 75% occurred during the rainy season; a mean monthly maximum temperature of 13 °C and a mean monthly minimum temperature of 6 °C were recorded in the study area. Maximum and minimum temperatures reached were 28 °C and 3 °C respectively.

Methods

Vegetational analysis was carried out using 10 × 10 m quadrats. Fifteen quadrats were laid down at each altitudinal gradient of the flank. In each quadrat, all trees (≥31.5 cm cbh) and saplings (10.5–31.4 cm cbh) were individually measured at breast height, i.e. 1.37 m from the ground. The individuals of trees with ≤ 10 cm cbh were treated as seedlings. Shrubs were considered separately.

Field data were analysed for abundance, density and frequency. The importance value index (IVI) was determined as the sum of the relative values, viz. frequency, density and dominance. The ratio of abundance to frequency was used to interpret the distribution pattern of the species. The distribution pattern was regular if < 0.05 (Curtis & Cottam 1956). Similarity indices between different altitudinal gradients for tree, sapling, seedling and shrub layers were calculated following Jaccard (1912) on the basis of density.

Species diversity was determined using Shannon-Wiener Information Function (Shannon & Wiener 1963, Pielou 1977, Sugihara 1980):

$$\bar{H} = -\sum_{i=1}^{s} \left[\frac{Ni}{N}\right] \ln \left[\frac{Ni}{N}\right]$$

where $\bar{H}$ = Shannon-Wiener index of species diversity,
Ni = density of the species i,
and N = total density of all the species in a stand.

This index is a measure of information in a group of species which have different probabilities of being represented. Information is maximum when the probabilities (number of individuals) for all species are equal. Information is zero, if there is only one possibility.

Dominance concentration of species was calculated for observation of strongest control/cover of species over space at different stands within the forest (Simpson 1949):

$$C = -\sum_{i=1}^{s} \left[\frac{Ni}{N}\right]^2$$

where Ni and N are same as for the Shannon-Wiener Information Function.

Following Whittaker (1975), beta-diversity (β) was computed to measure the rate of species change across the stands. The expression is as given below:

$$\beta = \frac{Sc}{\bar{S}}$$

where *Sc* is the total number of species encountered in all stands and $\bar{S}$ is the average number of species per stand.

During the course of the study composite soil samples were taken from each study plot. All the collected soil samples were analysed for chemical attributes including pH, organic carbon, exchangeable phosphorus and potassium content as per the procedures described by Jackson (1958). Total nitrogen analysis was carried out using the Kjeldahl's method.

Results and discussion

Soil chemical properties

Analysis of soil samples revealed the acid nature of soils. Soil pH ranged from 5.1 to 5.8, 5.2 to 5.9 from 5.1 to 5.9, for the upper, middle and lower slopes respectively. Organic carbon (percentage) varied between 2.10 ± 0.23 and 2.50 ± 0.25 from upper to lower gradients (Table 2). In general, there was less variation in the organic carbon content at different altitudinal gradients. It might be associated with the identical vegetation and physiographic aspects of the gradients. These values are in the range reported for the oak and pine forests of Kumaun and Garhwal Himalaya (Singh & Singh 1987, Bhandari 1995).

Table 2. Chemical properties of soils from the study sites

Gradient	pH (Range)	Organic carbon (%)	N (%)	C : N	P (kg ha^{-1})	K (kg ha^{-1})
Upper	5.1–5.8	2.10 ± 0.23	0.25 ± 0.08	8.4	14.40 ± 1.70	170.8 ± 9.2
Middle	5.2–5.9	2.40 ± 0.25	0.30 ± 0.05	8.0	18.80 ± 1.48	210.6 ± 12.8
Lower	5.1–5.9	2.50 ± 0.25	0.31 ± 0.05	7.9	21.60 ± 0.63	295.4 ± 22.4

Phosphorus content varied between 14.40 ± 1.70 and 21.60 ± 0.63 and potassium between 170.8 ± 9.2 and 295.4 ± 22.4 kg ha^{-1} from the upper to the lower slopes. These are much higher than the ranges reported for temperate forests of Garhwal Himalaya dominated by *Cupressus torulosa* (Baduni & Sharma 1996). This is partly due to the slow decomposition of litter in these broad-leafed forest stands. Slow litter decomposition is also associated with the lower temperature due to thick canopy cover in these forests than in the gymnospermic forests which provide a relatively open under-canopy environment. The C:N ratio may reflect the potential for release of N in the soil by organic matter decomposition and, therefore, indicates the degree of decomposition of organic matter in the forest soils (Kononova 1966, Ulrich 1971, Rawat & Singh 1988). Kawahara and Tsutsumi (1972) reported that generally the soil of a forest stand attains the steady state only when this ratio falls to 10. In the present study, C:N ratio ranged between 7.9 and 8.4 (Table 2). Likewise, Pugh (1974) also pointed out that when C:N ratio approaches 10, an accelerated mineralisation process is indicated.

Dominance

On the basis of density, basal cover and importance value index (IVI), *Quercus leucotrichophora* and *Rhododendron arboreum* were the dominant species from the upper to the lower slopes (Tables 3, 4 and 5). On the basis of IVI values, competition was observed between *Quercus leucotrichophoro* and *Rhododendron arboreum* in the tree stratum on the upper slope. Changing dominance in the sapling and seedling layers reflects that if identical environmental conditions continue, the dominant species in the tree strata may be replaced by the emerging species like *Pyrus pashia, Myrica esculenta* and/or by *Pinus roxburghii.* The existance of *Pinus roxburghii* in the sapling stratum on the upper and lower slopes is attributed to peculiar bioedaphic factors prevailing in the Himalayan region. *Quercus,* being a multipurpose species with high demand, yields more to biotic stresses, and may be replaced by the invading species. And, if the biotic stresses are able to alter the vegetation cover, edaphic conditions in turn are also changed in due course of time. Further, the forests of *Quercus leucotrichophora,* a late successional species, when disturbed by various anthropogenic means, are invaded by the early successional species such as pine (*Pinus roxburghii*) due to changed microclimatic conditions (Semwal & Mehta 1996). It is a serious threat to the oak-rhododendron forests at these altitudes.

The total basal cover across the slopes ranged from 27.25 to 39.30 m^2 ha^{-1} and the total tree density from 650 to 1150 ha^{-1}. In earlier references, total basal area and density were reported in the ranges of 27–84 $m^2 ha^{-1}$ and 350–1640 plants ha^{-1} respectively, for various forest types in Kumaun Himalaya (Saxena & Singh 1982, Singh & Singh 1987). The values of density for the present study fall in this range. However, the values of basal cover are near to minimum suggesting that the present forest stands are younger than the forests of Kumaun Himalaya for which the above range is reported.

Berberis aristata, Ficus spp. and *Spiraea vaccinifolia* were the dominant shrub species. Comparatively higher density of the shrubs on the slopes indicates the progressive secondary succession to higher growth forms.

Table 3. Density (D), total basal cover (TBC) and importance value index (IVI) of different species on upper slope

Stratum/species	D (Plants ha^{-1})	TBC (m^2ha^{-1})	IVI
Tree			
Lyonia ovalifolia	190	3.56	55.88
Myrica esculenta	110	3.38	42.54
Pyrus pashia	10	0.10	3.09
Quercus leucotrichophora	310	12.80	99.73
Rhododendron arboreum	530	7.41	98.99
Sapling			
Lyonia ovalifolia	320	0.65	48.06
Myrica esculenta	290	0.77	49.13
Pinus roxburghii	30	0.03	8.08
Pyrus pashia	60	0.10	17.39
Quercus leucotrichophora	300	0.05	31.08
Rhododendron arboreum	1300	3.48	146.29
Seedling			
Lyonia ovalifolia	450	0.09	52.33
Myrica esculenta	280	0.06	38.69
Pyrus pashia	180	0.13	36.24
Quercus leucotichophora	430	0.82	113.81
Rhododendron arboreum	490	0.12	38.93
Shrub			
Berberis aristata	150	0.02	55.17
Ficus spp.	130	0.03	55.84
Litsea monopetala	40	0.005	13.06
Pyracantha crenulata	50	0.08	66.87
Rhus parviflora	20	0.001	7.98
Rubus niveus	20	0.003	8.44
Spiraea vaccinifolia	330	0.040	92.64

Distribution pattern and similarity indices

The distribution pattern of the species in the different strata and gradients is given in Table 6. Odum (1971) stated that in natural conditions, contagious distribution is most common. Preponderance of regular as well as random distribution reflects the magnitude of biotic interferences such as grazing and lopping in the present natural forest stands.

Tree strata were 38.91 to 86.66% similar among themselves (Table 7). The difference in similarity is due to differences in dominance at altitudinal gradients. It is interesting to note that the lower slope was 13.34% dissimilar to the middle slope while it was 61.09% dissimilar to the upper slope. It is due to variation in altitude which ultimately affected the configuration of species at different gradients. Less differences in the similarity indices between the lower and middle, and between the middle and upper slopes indicate the gradual change in species composition from the lower to the upper slopes.

Table 4. Density (D), total basal cover (TBC) and importance value index (IVI) of different species on middle slope

Stratum/species	D (Plants ha^{-1})	TBC (m^2ha^{-1})	IVI
Tree			
Lyonia ovalifolia	25	0.66	18.95
Myrica esculenta	25	6.13	32.76
Pyrus pashia	12.5	0.02	8.64
Quercus leucotrichophora	550.0	32.10	219.63
Rhododendron arboreum	37.05	0.39	20.10
Sapling			
Lyonia ovalifolia	75.0	0.13	23.48
Myrica esculenta	137.5	0.38	54.86
Pyrus pashia	137.5	0.20	47.55
Quercus leucotrichophora	75.0	0.17	25.18
Rhododendron arboreum	612.5	1.56	148.92
Seedling			
Lyonia ovalifolia	462.5	0.17	66.44
Myrica esculenta	137.5	0.26	53.25
Pyrus pashia	175.5	0.05	38.01
Quercus leucotrichophora	487.5	0.11	64.17
Rhododendron arboreum	387.5	0.25	78.10
Shrub			
Asparagus curillus	25.0	0.008	5.81
Berberis aristata	612.5	0.16	105.55
Ficus spp.	25.0	0.004	10.58
Leptodermis lanceolata	62.5	0.01	10.98
Pyracantha crenulata	175.0	0.13	63.13
Rhus parviflora	87.5	0.006	19.27
Spiraea vaccinifolia	537.5	0.12	87.07

Diversity and related measurements

Species diversity ($\bar{H}$) ranged from 0.361 to 1.89, 1.77 to 1.96, 1.86 to 2.25, and 1.86 to 2.20, for tree, sapling, seedling and shrub strata respectively (Table 8). These values are comparable with those generally reported for temperate forests (Singh & Singh 1987, Adhikari *et al.* 1991). The decreasing trend of diversity index from seedling to tree via sapling stratum reflects the poor regeneration potential of these forest stands. Alarmingly poor regeneration of *Quercus leucotrichophora* was also pointed out by Saxena and Singh (1984) and Bankoti *et al.* (1986).

Species diversity and concentration of dominance are generally inversely related (Table 8). Dominance concentration value varied across the stands and strata. However, the values are in the range reported for Himalayan forests (Ralhan *et al.* 1982, Saxena & Singh 1982, Bhandari *et al.* 1997).

Table 5. Density (D), total basal cover (TBC) and importance value index (IVI) of different species on lower slope

Stratum/species	D (Plants ha^{-1})	TBC (m^2ha^{-1})	IVI
Tree			
Myrica esculenta	30	3.51	25.74
Pyrus pashia	10	0.08	09.13
Quercus leucotrichophora	660	34.25	264.99
Sapling			
Lyonia ovalifolia	30	0.03	74.26
Myrica esculenta	90	0.16	73.09
Pinus roxburghii	20	0.04	15.48
Pyrus pashia	150	0.03	130.73
Rhododendron arboreum	40	1.13	49.09
Seedling			
Lyonia ovalifolia	160	0.02	57.11
Myrica esculenta	70	0.03	59.24
Pyrus pashia	450	0.02	105.32
Quercus leucotrichophora	70	0.004	27.73
Rhododendron arboreum	80	0.024	50.53
Shrub			
Asparagus curillus	80	0.012	16.31
Berberis aristata	550	0.08	80.71
Ficus spp.	10	0.0008	3.08
Pyracantha crenulata	240	0.12	69.24
Rhus parviflora	20	0.00063	4.20
Rubus niveus	50	0.01	8.26
Spiraea vaccinifolia	880	0.15	117.69

Table 6. Distribution pattern (percentage)

Site/stratum	Regular	Random	Contagious
Upper slope			
Tree	40	20	40
Sapling	16.7	66.7	16.7
Seedling	-	80	20
Shrub	28.57	-	71.43
Middle slope			
Tree	20	40	40
Sapling	40	-	60
Seedling	20	40	40
Shrub	28.57	-	71.43
Lower slope			
Tree	-	-	100
Sapling	-	60	40
Seedling	-	60	40
Shrub	-	28.57	71.43

Table 7. Similarity indices for different strata at different altitudinal gradients

Site/stratum	Upper slope	Middle slope	Lower slope
Upper slope			
Tree	100	45.27	38.91
Sapling	100	57.52	18.04
Seedling	100	90.80	42.10
Shrub	100	50.77	45.14
Middle slope			
Tree		100	86.66
Sapling		100	43.51
Seedling		100	44.80
Shrub		100	74.12

Table 8. Species diversity ($\bar{H}$) and dominance concentration (C)

Site	Stratum	Species diversity ($\bar{H}$)	Concentration of dominance (C)
Upper slope	Tree	1.888	0.3215
	Sapling	1.839	0.3725
	Seedling	2.249	0.2204
	Shrub	2.197	0.2797
Middle slope	Tree	0.9114	0.7226
	Sapling	1.768	0.3941
	Seedling	2.009	0.2392
	Shrub	2.034	0.3090
Lower slope	Tree	0.361	0.8910
	Sapling	1.956	0.3076
	Seedling	1.862	0.3546
	Shrub	1.861	0.3415

The dominance diversity (d-d) curves (based on IVI) approached a geometric series for all the strata except the seedling stratum where it reflected Preston's (1948) log normal model (Figures 2a, b, c, and d). The geometric form is often shown by vascular plants having low diversity (Whittaker 1975). The log normal distribution of seedling stratum is due to deep shade under-canopy environment which resulted in severe competition between species (Bhandari *et al.* 1997).

The values of β-diversity were 2.9, 3.2, 3.2 and 4.2 for tree, sapling, seedling and shrub layers respectively. These values are much lower than those reported for the oak forests of Kumaun Himalaya (Tewari & Singh 1985). The low values of β-diversity show that the species composition does not differ significantly across the slopes. Relatively greater β-diversity of shrub layer showed greater habitat specialisation by shrubs than the trees, saplings and seedlings.

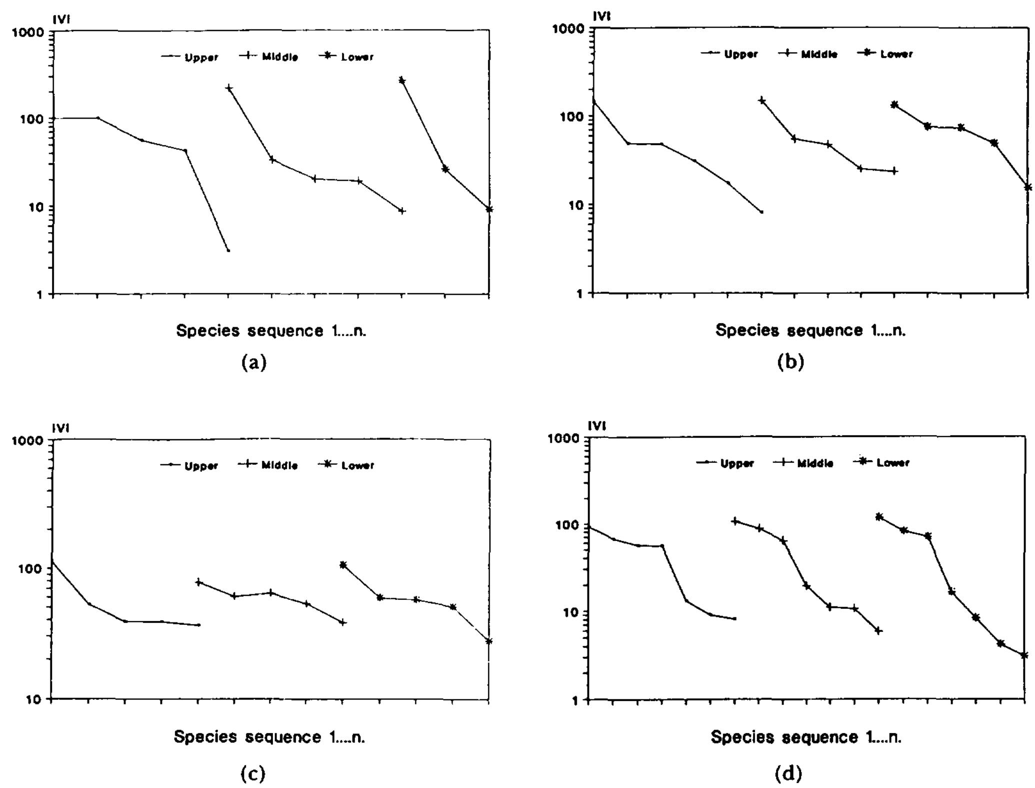

Figure 2. Dominance diversity (d-d) curves for different altitudes
a. Tree layers b. Sapling layers
c. Seedling layers d. Shrub layers

Conclusion

These broad-leaved forests exhibit low diversity with *Lyonia ovalifolia* and *Myrica esculenta* as the prominent associates with *Quercus leucotrichophora* and *Rhododendron arboreum*. *Quercus leucotrichophora*, the climax species of the montane flank, seems to be steadily replaced by *Pinus roxburghii*, since the former is in greater demand for fuel, fodder, agricultural implements, animal bedding, biomanuring, etc. than the latter. The increasing demand by the natives for forest products for their daily needs might be responsible for such a steep degradation of climax formations. Such a change in the ecological status of this climax forest is a cause for alarm to the forest managers and policy-makers who need to seek solutions to achieve a balanced environment in conserving the natural vegetational wealth of the Himalayas.

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