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Research article

Phytosociological assessment & distribution patterns of tree species in the forests of Doon Valley, Shivalik hills of lower Himalaya

Mohommad Shahid* and Shambhu Prasad Joshi

Ecology Research Laboratory, Department of Botany, D.A-V. (P.G.) College, Dehra Dun, Uttarakhand, India
*****Corresponding Author: mdshahid07@yahoo.com [Accepted: 18 June 2016]

Abstract: Study was conducted in the three forest ranges (Barkot, Lachchiwala and Thano) of Dehra Dun forest division, Doon Valley, Uttarakhand, India. Phytosociological studies of the sites were conducted for tree species. Fifty quadrats of 10 × 10 m^2 size were laid on each site for studying the trees composition and structure. Diversity Indices were calculated for each site. Species richness ranged between six species in Thano to 15 species in Barkot. Two Way Indicator Species Analysis was performed and classified tree layer into eight groups depending on the eigen value.

Keywords: Dominance - Diversity - TWINSPAN - Classification.

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INTRODUCTION

Vegetation is an essential part of the ecosystem that interprets the effects of the total environment (Billings 1952). Vegetation complex fluctuates from one season to another season in a cyclic manner over the years in a successional way and the fluctuations suggest a response by each species population to prevailing heat, moisture and light as modified by the vegetation itself (Heady 1958). The development and deterioration of plant species alters the pattern of the species distribution in community (Watt1964). Vegetation emphasis on study of composition, development, geographic distribution and environmental relationships of plant communities (Legendre & Fortin 1989, Kolasa & Rollo 1991).

Plants growing together have mutual relationship among themselves and with the environment (Mishra *et al*. 1997). These interactions among different plants and between plants and their environment result in the outcome of different vegetation types in different areas. The quantitative relationship between rare and profusely growing species is a significant structural property of a community. Phytosociological analysis of a plant community is the first and foremost basis of the ecological study of any piece of vegetation and this study is important to understand the functioning of any community. Oosting (1956) suggested the importance of phytosociological parameters for spatial problems in sociological behaviour of plants.

The Sal (*Shorea robusta*) forests of Doon Valley are one of the most frequently studied vegetation tracts. The wooded communities have been described in detail, and studies on Sal regeneration are the standards in the ecological and forestry literature of India (Champion 1923, Bhatnagar 1960, Champion & Seth 1968). The ground layer has also received attention (Rajvanshi *et al.* 1983). The Doon Valley forests are however increasingly noted for their wildlife values and ecological and forestry studies.

Urbanization, a new sign of prosperity, and decrease in forest cover are altering the temperature and reducing the rainfall of Doon Valley (Negi & Chauhan 2002). The anthropogenic disturbances have created wide openings reducing the soil moisture of the forest floor and the Sal regeneration. Doon Valley is experiencing the wide range of anthropogenic disturbances like cattle grazing, fuel and fodder collection, increase in the population near the villages of the study sites. In recent years, after the inception of Uttarakhand in year 2000, Dehra Dun city (Doon Valley) is expanding exponentially. Other sources of disturbances in this region are the National Highway connecting Dehra Dun and the holy cities of Haridwar and Rishikesh, forest fires, collection of fodder and fuelwood, grazing of cattle, etc. The climate changes in the valley have forced the locals to go for cooler places like Lachchiwala, putting extra pressures on the nearby forest. All these

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perturbations have put impact on the dominance and diversity of the forests of Doon Valley. Therefore, the study is an attempt to address the following issues: (1) the current status of different plant species in the Doon Valley; (2) the frequency, distribution patterns, and abundance of tree species in the valley.

MATERIALS AND METHODS

Study Site

The Doon valley is situated in the Siwalik Himalayas, between latitudes 29°55' to 30°30' N and 77°35' to 78°24' E. It is saucer-shaped and *ca.* 20 km wide & 80 km long valley with 2100 km^2 geographical area (Fig. 1). In east the area is bounded by river Ganga and in West by river Yamuna. Mussoorie hills formed its northern boundary whereas the Shiwalik Mountains formed the southern boundary of the valley. The climate of the area is sub-tropical; the average maximum and minimum temperatures are 27.65ºC and 13.8ºC, respectively, and the average rainfall is 202.54 cm. The soils are developed on the deep alluvial deposits with the parent material derived from the Doon Alluvium. In these studied subtropical deciduous forests, dominant species is *Shorea robusta* (Sal), with associates such as *Anogeissus latifolia*, *Terminalia tomentosa*, *Adina cordifolia*,*Terminalia bellirica* etc.

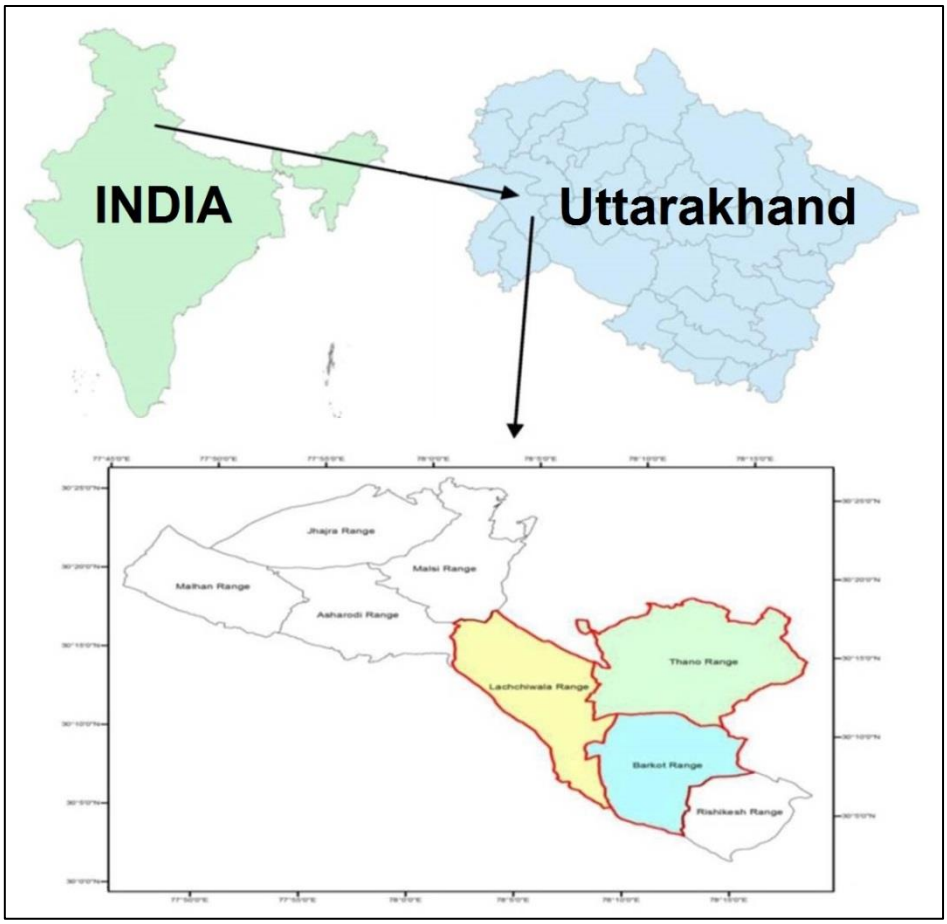

Figure 1. Location of Study Sites.

Methodology

The study was conducted in Barkot forest range, Lachchiwala forest range and Thano forest range of Dehra Dun forest division in Doon Valley. Forests of Doon Valley were thoroughly surveyed for its topography, microclimate and biotic stress conditions. Phytosociological studies of the selected sites were conducted once in the year 2010–11. The vegetation was analysed by means of random sampling to give most representative composition of vegetation. Fifty quadrats of 10 × 10 m^2 size were laid on each site for studying the trees composition. In each tree quadrat cbh (circumference at breast height *i.e.*, at 1.37 m above ground level) of each tree (>10 cm cbh) was measured. Vegetation composition was evaluated by analyzing the frequency, density, abundance and importance value index (IVI) according to Curtis & McIntosh (1951) and Mishra (1968) and as given below:

$$\textbf{Frequency} = \frac{\text{Total number of quadrats in which the species occurred}}{\text{Total numberof quadrats studied}} \times 100$$

$$\textbf{Relative Frequency}\ (\%) = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

$$\textbf{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}}$$

$$\textbf{Relative Density}\ (\%) = \frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}} \times 100$$

$$\textbf{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats in which the species occurred}} \times 100$$

$$\textbf{Relative Dominance}\ (\%) = \frac{\text{Basal area of a species}}{\text{Basal area of all species}} \times 100$$

Importance Value Index (IVI) = Relative Frequency + Relative Density + Relative Dominance

Diversity Indices and Evenness

The Shannon and Wiener diversity index (H′) was calculated using the formula (Shannon &Wiener 1963)

$$\mathbf{H'} = -\sum_{i=1}^{s} p_i \ln p_i$$

where, s = the number of species, p_i = the proportion of individuals or abundance of the i^{th} species expressed as a proportion of total cover, ln = log base n

Alpha diversity (α) is within area diversity, measured as the number of species occurring within an area of given size (Huston 1994). It is therefore a measure of richness of a potentially interactive assemblage of species.

Beta diversity (β) was introduced by Whittaker (1960) to designate the degree of species change along a given habitat as such it is a measure of between area diversity. It indicates rate of proportion and is normally represented in terms of similarity index or of a species turnover rate.

$$\textbf{Beta diversity}\ (\beta) = \frac{Sc}{S}$$

where, Sc is the total number of species encountered in all communities and S is the average number of species per community.

Concentration of dominance (Cd) was measured by Simpson's index (Simpson 1949)on the basis of their density.

$$\mathbf{Cd} = \sum_{i=1}^{s} (p_i)^2$$

where, p_i is the proportion of i^{th} species and s is the number of individuals of all the species.

Equitability or Evenness was calculated by as given by Pielou (1969).

$$\textbf{Equitability (J)} = \frac{H'}{H'_{max}} = \frac{\sum_{i=1}^{s} p_i \ln p_i}{\ln s}$$

where, s = the number of species, p_i = the proportion of individuals or abundance of the i^{th} species expressed as a proportion of total cover, ln = log base n.

Dominance-Diversity Curves (D – D curves)

Dominance-Diversity curves exhibit the community organization in terms of resource share (Saxena & Singh 1982, Pande *et al.* 2001). The logarithm values of IVI of the species have been ordinated against the species sequence to draw D-D curves (Dominance-Diversity curves) for different studied sites to interpret the community organization in terms of resource share and niche-space.

TWINSPAN

In the present study, TWINSPAN ordination, an indirect ordination was done. The classification of species was done according to their ecological preferences. The classifications were used together to obtain an ordered two-way table that expresses the synecological relations of species as succinctly as possible. TWISNPAN for Windows Version 2.3 (Hill & Smilauer 2005) was used for the analysis.

RESULTS

Dominance (Importance Value Index) of trees at Barkot range

Shorea robusta was the dominant species in the Barkot range, with the IVI value 141.32. The Co-dominant species are *Mallotus philippensis* and *Ehretia laevis* with IVI value 33.53 and 31.68 respectively. A total of 15 species are recorded from the Barkot range. 20% frequency was reported by the three species *viz. Bauhinia variegata, Syzygium cumini and Cassia fistula.* 30% frequency was recorded for the only one species *Adina cordifolia*. The minimum IVI value (3.60) was reported for the *Casearia tomentosa.* 10% frequency was observed by the eight species. *Shorea robusta* has the 47% share in the forest of the Barkot range. Density of 15 trees 100 m^{-2} was recorded in the Barkot range (Table 1).

Table 1. Distribution analysis of tree species in Barkot range.

Species	F	D	A	A/F	IVI
Shorea robusta Roxb. ex Gaertner f.	100	9.0	9.00	0.09	141.32
Mallotus philippensis (Lam.) Muell.-Arg	60	2.1	3.50	0.06	33.53
Ehretia laevis Roxb	70	1.8	2.57	0.04	31.68
Terminalia bellirica (Gaertner) Roxb.	10	0.2	2.00	0.20	14.40
Adina cordifolia (Roxb.) Hook.f. ex Brandis	30	0.4	1.33	0.04	11.56
Syzygium cumini (L.) Skeels	20	0.4	2.00	0.10	10.21
Cassia fistula L.	20	0.2	1.00	0.05	9.48
Ougeinia oojeinensis (Roxb.) Hochre.	10	0.1	1.00	0.10	9.04
Bauhinia variegate L.	20	0.2	1.00	0.05	8.34
Miliusa velutina (Dunal) Hook.f. & Thom	10	0.1	1.00	0.10	6.52
Terminalia alata Heyne	10	0.1	1.00	0.10	6.10
Anogeissus latifolia Wall.	10	0.1	1.00	0.10	5.35
Ficus benghalensis L.	10	0.1	1.00	0.10	4.56
Litsea glutinosa (Lour.) Robinson	10	0.1	1.00	0.10	4.30
Casearia tomentosa Roxb.	10	0.1	1.00	0.10	3.60

Note: F= Frequency (%), D=Density (tree $100m^{-2}$), A=Abundance, IVI= Importance Value Index.

Dominance (Importance Value Index) of trees at Lachchiwala range

The maximum IVI (126.36) was for the *Shorea robusta*. *Mallotus philippensis* and *Syzygium cumini* has the IVI value of 33.28 and 29.84 respectively. 100% Frequency was recorded for the *Shorea robusta*. 10 % Frequency was observed for the seven species. *Terminalia alata, Adina cordifolia* and *Anogeissus latifolia* had the frequency of 20% in the Lachchiwala range. A Density of 11.70 tree $100m^{-2}$ was recorded in the Lachchiwala range. The A/F ratio was in the range from 0.04 for the *Mallotus philippensis* to 0.20 for *Miliusa velutina.* The minimum IVI Value (4.02) was recorded for the *Caseaseria tomentosa* (Table 2).

Table 2. Distribution analysis of tree species in Lachchiwala range.

Species	F	D	A	A/F	IVI
Shorea robusta Roxb. ex Gaertner f.	100	6.5	6.50	0.07	126.36
Mallotus philippensis (Lam.) Muell.-Arg	60	1.6	2.67	0.04	33.28
Syzygium cumini (L.) Skeels	40	1.4	3.50	0.09	29.84
Terminalia bellirica (Gaertner) Roxb.	20	0.2	1.00	0.05	28.51
Ehretia laevis Roxb	30	0.8	2.67	0.09	17.18
Adina cordifolia (Roxb.) Hook.f. ex Brandis	20	0.2	1.00	0.05	9.63
Anogeissus latifolia Wall.	20	0.2	1.00	0.05	9.28
Miliusa velutina (Dunal) Hook.f. & Thomson	10	0.2	2.00	0.20	9.01
Cordia dichotoma G.Forst	10	0.1	1.00	0.10	7.67
Terminalia alata Heyne	10	0.1	1.00	0.10	7.67
Bauhinia variegate L.	10	0.1	1.00	0.10	6.57
Cassia fistula L.	10	0.1	1.00	0.10	6.57
Flacourtia indica (Burm.f.) Merrill	10	0.1	1.00	0.10	4.42
Caseaseria tomentosa Roxb.	10	0.1	1.00	0.10	4.02

Note: F= Frequency (%), D=Density (tree $100m^{-2}$), A=Abundance, IVI= Importance Value Index

Dominance (Importance Value Index) of trees at Thano range

The *Shorea robusta* has the maximum IVI (187) in the Thano range. The *Mallotus philippensis* and *Syzygium cumini* had the IVI value 38.97 and 25.36 respectively. A total of six species are recorded in the Thano range. The maximum share was by the *Shorea robusta*. 20 % Frequency was recorded for the three species *viz. Syzygium cumini, Tectona grandis and Terminalia alata.* The A/F ratio was in the range of 0.04 to 0.36. The minimum IVI Value (15.69) was of the *Terminalia alata* (Table 3).

Table 3. Distribution Analysis of Tree species in Thano range.

Species	F	D	A	A/F	IVI
Shorea robusta Roxb. ex Gaertner f.	100	10.7	10.70	0.11	187.00
Mallotus philippensis (Lam.) Muell.- Arg.	50	1.4	2.80	0.06	38.97
Syzygium cumini (L.) Skeels	20	0.2	1.00	0.05	25.36
Ehretia laevis Roxb	30	0.4	1.33	0.04	17.28
Tectona grandis L. f.	20	0.2	1.00	0.05	15.71
Terminalia alata (Gaertner) Roxb.	20	0.2	1.00	0.05	15.69

Note: F= Frequency (%), D=Density (tree $100m^{-2}$), A=Abundance, IVI= Importance Value Index.

Diversity Measurements

α-diversity (Species Richness) was the maximum 15 from the Barkot range. Lachchiwala and Thano ranges have reported the α-diversity (Species Richness) 14 and 06 respectively. (β) Beta Diversity 5.83 was recorded from Thano range. The highest Concentration of Dominance (Cd) (0.4213) was recorded from the Thano range while the lowest Concentration of Dominance (Cd) (0.2175) was recorded from the Lachchiwala range. The Barkot range has 0.255 Concentration of Dominance (Cd). The highest H' (2.023) was recorded in the Lachchiwala range while the lowest H' (1.242) was recorded in Thano range. 2.023 H' was recorded from Lachchiwala range. The maximum value of Evenness (J) (0.577) was recorded in the Thano range while the minimum (0.4683) was recorded in the Barkot range (Table 4).

Table 4. Diversity index of trees at various study sites.

Indices	Barkot range	Lachchiwala range	Thano range
Richness (α)	15	14	06
Diversity (β)	2.33	2.50	5.83
Dominance (Cd)	0.255	0.2175	0.4213
Shannon(H')	1.949	2.023	1.242
Evenness (J)	0.4683	0.5401	0.577

Dominance-Diversity (D-D) Curve

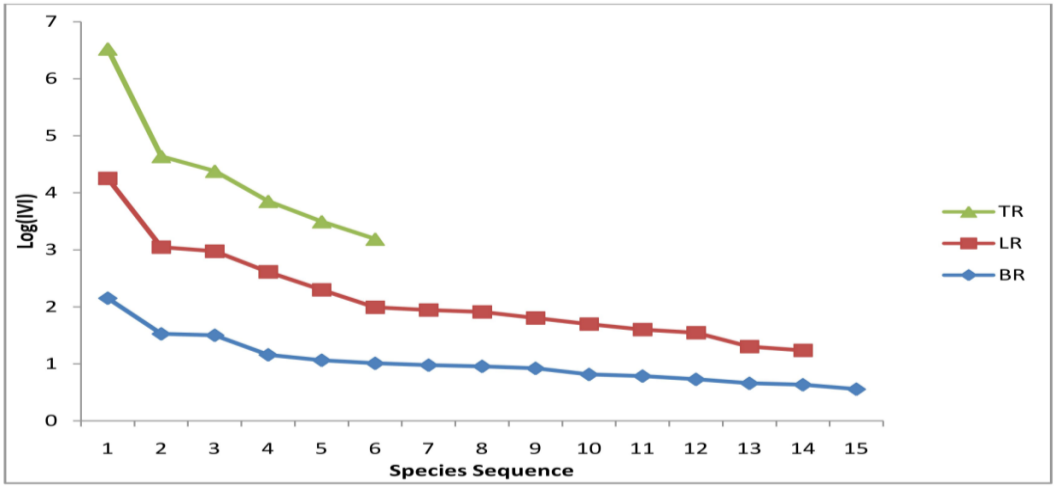

Figure 2. Dominance-Diversity curve of the tree species at various study sites. (BR- Barkot range, LR- Lachchiwala range, TR- Thano range)

Importance values of plants were plotted against the species sequence to draw the Dominance-Diversity curves (D-D curves) and interpret the community organization in terms of resource share and niche-space. A D-D curve for the tree layer is shown in figure 2. In the present study, all the sites represented either geometric or log normal distributions. Log normal series indicative of the highly mixed nature of vegetation. The geometric form is often shown by vascular plants having lower density (Whittaker 1975).

TWINSPAN- (Two-way Indicator Species Analysis)

Species Classification: A total of 18 tree species were analysed with TWINSPAN. Division number 1 classified the 18 species with an Eigen Value 0.364 into 12 species in the Left Hand side and 06 species in the Right Hand Side (RHS). A total of eight groups are formed after the classification with the TWINSPAN (Fig. 3).

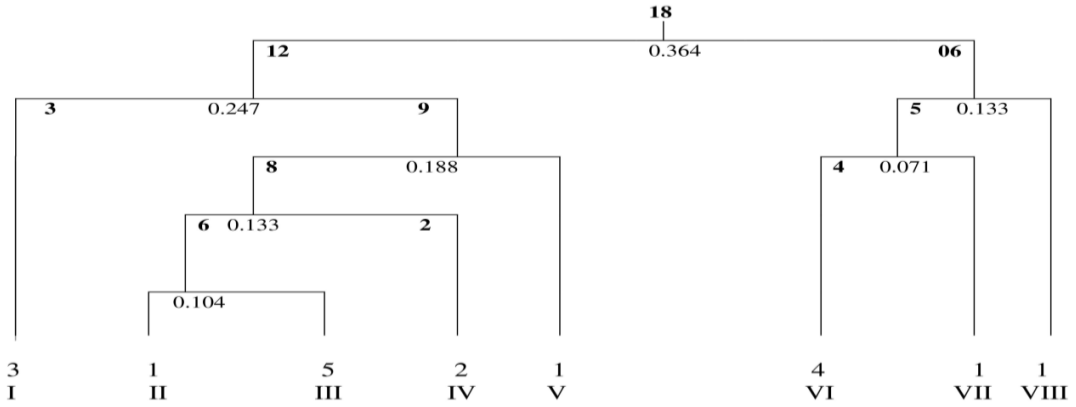

Figure 3. Classification of Tree Species on the basis of TWISNPAN.

Group III is the largest groups with five tree species *Anogeissus latifolia, Bauhinia variegata, Caseaseria tomentosa, Cassia fistula, Miliusa velutina.* One species each is present in the four groups (Group II, V, VII and VIII). Group I is having the three species namely *Ficus benghalensis, Litsea glutinosa, Ougeinia oojeinensis. Shorea robusta* along with *Ehretia laevis, Mallotus philippensis* and *Syzygium cumini* forms the group VI. Two species *Cordia dichotoma, Flacourtia indica* are present in the Group IV (Table 5).

Table 5. Clustering of Tree species at various study sites.

Group	No. of Species	Name of Species
I	03	*Ficus benghalensis, Litsea glutinosa, Ougeinia oojeinensis*
II	01	*Adina cordifolia*
III	05	*Anogeissus latifolia, Bauhinia variegata, Caseaseria tomentosa, Cassia fistula, Miliusa velutina*
IV	02	*Cordia dichotoma, Flacourtia indica*
V	01	*Terminalia alata*
VI	04	*Ehretia laevis, Mallotus philippensis, Shorea robusta, Syzygium cumini*
VII	01	*Terminalia bellirica*
VIII	01	*Tectona grandis*

DISCUSSION

The mosaics of species distribution in any forest are governed by various environmental factors (Bajpai *et al.* 2012). Bliss (1963), Douglas & Bliss (1977) and Billings (1973) have reported that vegetation of any place is the outcome interaction of many factors like meso-topographic gradients, the elevation, soil, species composition and biotic interferences. It is also reported that the regional patterns of species richness are consequences of many interacting factors, such as plant productivity, competition, geographical area, historical or evolutionary development, regional species dynamics, regional species pool, environmental variables and human activity (Woodward 1988, Palmer 1991, Eriksson 1996, Zobel 1997, Criddle *et al.* 2003). The values of vegetation parameters obtained for most of the sites in the present study fall within a comparable range of values reported for Western Himalaya (Kala & Uniyal 1999).

The site is a natural Sal forest and lopping of these trees for fuel and fodder, along with extraction of medicinal (*Zingiber roseum*) and ethanobotanical (*Pterospermum acerifolium, Calamus tenuis* etc.) plants are the major disturbances prevailing in the region. In addition to this, in the recent years, over mature Sal, and those infested by *Hoplocerambyx spinicornis* (Sal borers) were also removed by the forest department. All these disturbances have resulted in large canopy gaps and tampering of forest soils, which has made the forest floor vulnerable to runoff during rains. With the runoff of the top soil all the nutrients are washed away and the soil becomes oligotrophic. Evergreen species are better adapted to oligotrophic soils as they can amortilize the nutrients over a longer period of time (Grime 1973) with their greater tissue longevity (Hireman *et al.* 2002) and greater nutrient storage and recycling. Dominance of perennial grasses shows their competitive success under

stress conditions (Pandey &Singh 1987) as they have extremely large and complex root systems, which enables them to collect water and essential nutrients over a wide area.

The presence of some opportunistic species such as *Eupatorium adenophorum* in forest are taking advantage of canopy opening on the one hand and changing environmental conditions from mesic to xeric on the other hand. Distribution pattern analysis shows species dispersion across a span of time at any given site. The pattern of distribution depend both on physico-chemical natures of the environment as well as on the biological peculiarities of the organisms themselves. Among the sites, under present study, an overview of distribution patterns (A/F ratio) for tree layer shows that contiguous pattern was the most common followed by random pattern. Odum (1971) contiguous distribution is common in nature and formed due to small but significant variation in the ambient environmental conditions. Contiguous distribution of varying degree has been observed in tropical forests of India (Shanmughavel 1994). Similar findings have also been reported by Kumar *et al.* (2004) for tropical forest of Garhwal Himalaya. Variation in distribution pattern among sites and vegetation composition are associated with micro-environmental and biotic factors (Singhal & Soni 1989).

Importance value of Sal in tree layer ranged between 123.36 and 187.00, which is well within the limits of earlier studies (Rawat & Bhainsora 1999). Dominance of Sal depends upon the age, available resources, associate species, disturbance regime and successional changes. The Site (Thano range) in which the IVI exceeds more than 150.00 can be predicted that the Sal forest is progressing towards the climax stage, where as in other two sites (Barkot and Lachchiwala ranges), having IVI values are ranging between 100.00 and 150.00 denotes that these sites were under heavy disturbances.

The value of Concentration (Cd) for Tree species ranges between 0.2175 and 0.4213. The values of species diversity (H') reported in the present study are towards higher side, this may be due to the anthropogenic disturbances prevailing in these sites, which can increase species diversity by lowering the dominance of a few species, which make resources available to early successional species and by increasing environmental heterogeneity provides a basis for specialization and resource partitioning (Grubb 1977, Denslow 1980).

In tropical forests, values of species diversity (H') are generally high, between 5.06 and 5.40 (Knight 1975)as compared to Indian forests, between 0.00 and 4.21 (Agni *et al.* 2000). The value of H' reported in the present study are well within these limits. Species richness of species in Sal forests of Doon valley is generally low. This may be ascribed to false management practices adopted during the British rule to get the monoculture of Sal trees by the removal of 'Kokats'. Huge demand for wood during the two World Wars was catered to from Sal forests of the valley. In the recent years, wide canopy openings have resulted due to various anthropogenic reasons and infestation of *Hoplocerambyx spinicornis*. These canopy gaps have proven to be fruitful for the invasion of large number of opportunistic plants.

Sal forests of Doon Valley are characteristically homogenous in distribution due to various silvicultural operations carried out in the past, but the values of Cd in the present study are much less than the previous study (Chauhan *et al.* 2001). This concludes the moving of Sal forests of the valley towards heterogeneity and may be because of various disturbances prevailing in these forests *viz*. collection of fodder and fuel wood, grazing of cattle, tremendous increase in the population of the Doon Valley after becoming the Capital of the State Uttarakhand. The urbanization along the periphery of the forest has the great impacts on the forest structure. β-diversity for Trees varies from 2.33 to 5.83 in the Barkot and Thano respectively. Importance values of trees were plotted against the species sequence to draw the Dominance-Diversity curves (D-D) curves and interpret the community organization in terms of resource share and niche-space. D-D curves for tree species showed the log series and log normal distributions for Barkot, Thano and Lachchiwala ranges respectively. The log series distribution indicates that moderately common species reflect most closely the nature of environment and fluctuate violently from time to time than the most abundant species. On the other hand, log normal distribution gives the best distribution of species – abundant pattern (Preston 1948). The assumption being that individuals were distributed between species in accordance with Normal or Gaussian distribution and population growth is Geometric (William 1964).

The 18 Trees species are classified into VIII groups by the TWINSPAN. *Shorea robusta*, the main species of the Doon Valley is associated with the *Ehretia laevis, Mallotus philippensis, and Syzygium cumini* in the Group VI. The dichotomies are primarily based on the eigen values depicting overlapping of species in different sites. These results indicate the relationship among sites and among species on the basis of TWINSPAN and these relationships ranked the sites and species in the vegetation accordingly.

CONCLUSIONS

It can be concluded that species diversity is being regulated by factors like community stability and evolutionary time as heterogeneity of both micro and macro environment affects the diversification among different communities. Amongst major factors that influenced vegetation structure are human disturbance, extensive grazing, trampling, invasion of opportunistic species and soil erosion. Human disturbance, extensive grazing has resulted in the formation of highly fragmented vegetation type, which in turn has critical impact on community structure.

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