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Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broad-leaved forest along an altitudinal gradient in Garhwal Himalaya

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Abstract: The focus of the study is to characterize the structure, composition and diversity of Banj Oak (*Quercus leucotrichophora*) forests at different altitudes and slopes in Mandal-Chopta area of Garhwal Himalaya. Competing co-dominant tree layers comprised of *Persea duthiei* and *D. himalense* at the higher altitude (2100m a.s.l.) and steeper slope (45°); *D. himalense* and *Betula alnoides* at the middle altitude (1700m a.s.l.) and moderate slope (38°); and *Lyonia ovalifolia* and *Myrica esculenta* at lower altitude (1550m a.s.l.) and gentles slope (30°) were observed in these forests. Community diversity was highest (3.140) at the higher altitude (site-1) whereas the concentration of dominance followed the opposite trend of the diversity. Physico-chemical properties of soils have revealed that availability of higher average total nitrogen and moisture contents might have given birth to higher total basal cover values at middle altitude. The tree density was positively correlated with the tree diversity and tree richness (P< 0.001). The vegetational parameters A/F ratio, Shanon-wiener index, Species richness, Margalef index and soil parameters especially pH and available phosphate (kg/ha) were significant (P<0.05%) among the forest sites.
Keywords: Banj Oak community, Himalaya, species evenness, vegetation analysis.

Introduction

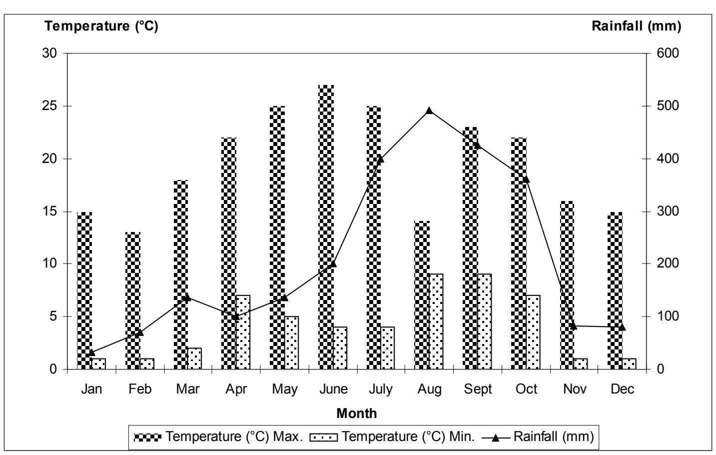
The Himalayan moist temperate forests are characterized by extensive oak and coniferous forests extending from 1500 to 3000m asl. In the Western and Central Himalayas, the three main Oaks provide a simple and convenient basis for subdivision into three altitudinal zones each *i.e.*, *Quercus semecarpifolia* Sm. (Fagaceae) Kharsu oak in the upper altitudinal zone (2500m), *Q. floribunda* Lindl. ex Royle. (Fagaceae) Moru oak in the middle zone (2250m) and *Q. leucotirchophora* A. Camus. (Fagaceae) Banj oak in the lower altitudinal zone (2000m). These oak forests are usually composed of mainly single species depending on the altitude. Puri (1960) and Champion and Seth (1968) considered that these forests represent climatic climax of one or the other species.

Banj oak (*Q. leucotroichophora*) forests (Forest Sub-Type 12/C1a as per Champion & Seth, 1968) are evergreen high forests of trees of large girth but medium height, rarely over 25m and usually with large branching crowns festooned with mosses, ferns, aroids and other epiphytes. In damp ravines and other favourable sites, there may be an appreciable mixture of deciduous trees contributing to the main canopy. The banj oak forests are exposed to damage or destruction through human agencies, being at a favourable altitude for settlement and cultivation. The species is coppiced regularly near habitations for getting young shoots for quality fodder, which gives a decidedly different appearance from the original undisturbed form. Lopping is extremely prevalent and combined with fuel and a charcoal demand has led to the disappearance of the forests over large areas (Sharma & Gairola, 2007). These forests are not themselves inflammable, but in many localities suffer a good deal from fires spreading up from the pine zone below.

A plant community is the collection of plant species growing together in a particular location that show a definite association with each other (Muller-Dombois & Ellengberg, 1974). The most common method of defining this diversity at the ecosystem level is the species. Species diversity is considered as a spatial form of textural diversity and treated both in structure and dynamics of the plant community (Maarel, 1988). However, the concept of diversity is generally concerned with the representation of variability involved in the natural communities. The comparative analysis of species abundance distributions based on species abundance models with associated diversity indices can provide valuable information on the diversity of a community (Magurran, 1988).

Another important biodiversity indicator is the relative (proportional) abundance or degree of dominance of individuals among different species. This is usually referred to as evenness or equitability and measures the extent to which species are equally represented in a community. There exists a strong correlation between structural diversity and species diversity (Sahu *et al.*, 2008). An increase in spatial-structural heterogeneity and habitat complexity is

Fig. 1. Climatic data for Mandal-Chopta forest (Source: Forest Dept. of Uttarakhand)



equivalent to provision of niches and resources, which usually leads to an enrichment of species (Begon *et al*. 1990). Conceptual approaches, which distinguish different spatial levels with regard to species diversity and structural diversity have a major disadvantage (Bastian,1990), because they fail to integrate or even mention ecological processes and thereby ignore the functional dimension of biodiversity (Noss,1990). Although some studies have analyzed the altitudinal and latitudinal forest zones in Himalayas and the surrounding mountains (Tang & Ohsawa 1997; Wang & Ohsawa 2006 a, b, c) but there are very few studies available as far as middle temperate zone of Garhwal Himalaya is concerned. According to Franklin (1988) and Noss (1990), three main components of biodiversity can be identified as: (i) composition, (ii) structure, and (iii) function. In the present study therefore, the pattern of community structure, composition and diversity of ecologically distinct Mandal-Chopta forest of Garhwal Himalaya, which receives the full force of monsoon and hitherto form peculiar climate for banj oak growth have been studied along an altitudinal gradient for establishing priorities of conservation for this species.

Materials and Methods

Study area

The Mandal-Chopta forest of Garhwal Himalaya is located at 30° 27.560' N latitude and 79° 15.234' E longitude. The banj oak forests in the area are distributed between 1550 to 2100 m a.s.l (Table 1). The climate of the area is influenced by monsoon pattern of rainfall. The average annual rainfall ranges between 1900 – 2600 mm in these forests, most of which occurs in the monsoon season. The mean monthly minimum temperature ranges between 2.0°C (January) and 12.0°C (August), whereas mean maximum temperature between 13.0° (February) and 26.0°C (June), with moderate to heavy snowfall in winter season during December to March (Fig. 1).

Sampling

After reconnaissance survey, three sites i.e., (i) Upper (2100m asl with 45° slope and on North-East facing aspect), (ii) Middle (1700m asl with 38° slope and on North facing aspect) and (iii) Lower (1500m asl with 30° slope and on East facing aspect) of the temperate mixed broad-leaved forest growth were chosen for the determination of structure and composition of vegetation. The sampling was done by establishing ten plots of 10m X 10m size randomly on each site. The woody vegetation was analyzed for species richness, density and diversity at all the three altitudes, following standard methods (Curtis & McIntosh 1950; Phillips, 1959; Whittaker, 1972). Species richness was simply the species related diversity, which is the number of species per specified number of individuals (Margalef, 1958). The ratio of abundance to frequency indicated the distribution pattern, which was calculated as per Whitford (1949) and reflected regular (<0.025), random (between 0.025 – 0.05) and contagious (>0.05) distributions (Curtis & Cottam, 1956). The circumference at breast height (cbh) was taken for determination of tree basal area and calculated as πr^2, where r is the radius measured at 1.37m height. The basal area of a species was calculated by multiplying the mean tree basal area with density. Total basal area was the sum of basal area of all species present in the site. Tree basal area was used to determine the relative dominance of a species. Importance value index (IVI) was the sum of the values of relative frequency, relative density and relative dominance (Phillips, 1959).

Several species diversity indices incorporate properties, species richness and evenness of the vegetation. Both an

Fig. 2. Density wise diameter classes of different tree species at: (a) Upper, (b) Middle and (c) Lower altitudes

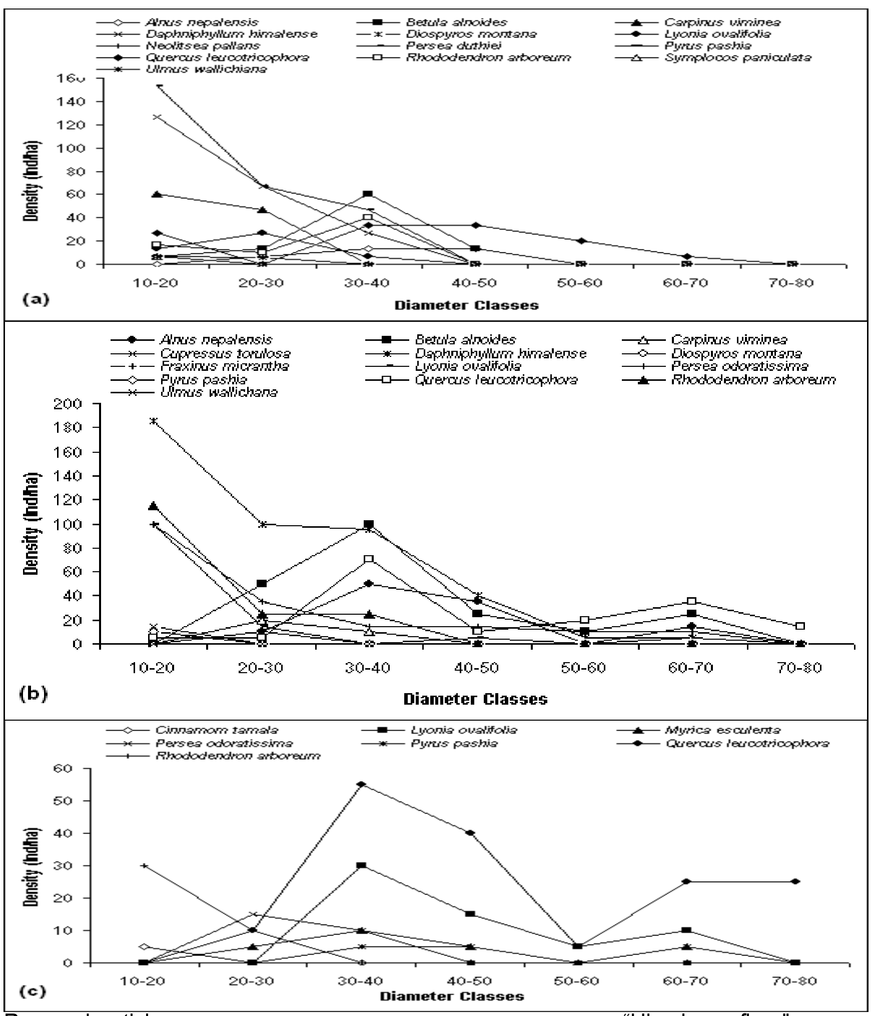


Table 1. Site characteristics in the Mandal-Chopta forest area of Garhwal Himalaya

Location/site	Altitude (m.a.s.l)	Slope (°)	Forest type	Aspect
Upper site (Gharsaari)	2100	45	Mixed Broad-leaved	North-East facing
Middle site (Bammana)	1700	38	Mixed Broad-leaved	North facing
Lower site (Khalla)	1550	30	*Quercus-Lyonia* forest	East facing

increase in richness and evenness lead to higher numerical values of such diversity indices. A prominent species diversity index is the Shannon-Wiener information index. This index requires the total number of individuals in the sample and the number of individuals of each species for calculating proportional abundance as input variables. The Shannon-Wiener index is relatively independent of sample size and has a tendency towards stressing rare species (Odum, 1983). The species diversity was therefore calculated using Shannon-Wiener index (Shannon & Weaver, 1963) as: $H' = - \sum n_i /n \log_2 n_i /n$, Where n_i was the IVI value of a species and n was the sum of total IVI values of all species in that forest/site. The $\log_2$ was converted into $\log_{10}$ as: $H' = 3.322 \log_{10} n - 1/n \sum n_i \log_{10} n_i$. Another well-known dominance indicator is Simpson's index (Simpson, 1949). This index is heavily weighted towards the most abundant species in the sample but less sensitive to species richness. The index of similarity (IS) between forest sites was calculated following Sorenson (1948), basing on the existing species richness of all the sites as: IS = 2C / A + B X 100, Where C is the common number of species in two comparable sites, and A and B are the total number of species in site A and B respectively.

Soil Sampling and analysis

Soil samples were collected during March to April 2006, from the top (0-10 cm), middle (11-30 cm) and lower (31-60 cm) layers of all the sites. The moisture percentage was determined as per Mishra (1968) and the soil pH by standard paste technique using pH meter (Rhodes, 1982). The organic carbon percentage was measured using potassium dichromate method by reduction of organic carbon and subsequently by spectrophotometer. Extractable phosphate was known using sodium bicarbonate extracts (Oleson *et al*., 1954). Total nitrogen was measured by the standard Kjeldhal procedure (Bremner & Mulvaney, 1982). Data were analysed for single factor using analysis of variance (ANOVA) (Steel & Torrie, 1981). Correlation was developed between different vegetational and soil parameters across different sites.

Results

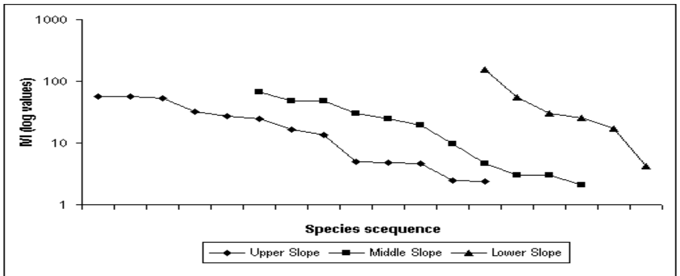
The number of species in a particular forest type varies markedly along the altitudinal range of its growth, which depends on the complex suit of factors that characterize the habitat of individual species. Ecological function of the species involves all kinds of processes, which are inevitably associated with some changes over space, and composition and structure are affected at species level. The fundamental capability of ecosystems to evolve, change and recognize themselves is a prerequisite for the sustainability of viable system (Ashby, 1974). The species in a community grow together in a particular environment because they have a similar requirement for existence in terms of environmental factors (Ter Baak, 1987).

Table 2. Structure and Composition of woody species

Species (altitude m. a.s.l)	Density (ind ha^{-1})	T.B.C. (m^2 ha^{-1})	IVI
Upper altitude **(2100)**			
Alnus nepalensis	33	2.54	16.57
Betula alnoides	93	5.45	31.93
Carpinus viminea	107	2.08	27.47
Daphniphyllum himalense	220	5.28	53.71
Diospyros montana	13	0.06	4.70
Lyonia ovalifolia	47	1.58	13.71
Neolitsea pallans	13	0.14	4.93
Persea duthiei	267	6.22	56.04
Pyrus pashia	13	0.08	4.77
Quercus leucotrichophora	120	10.02	56.47
Rhododendron arboreum	67	3.81	24.89
Symplocos paniculata	7	0.06	2.44
Ulmus wallichiana	7	0.05	2.41
Total	**1005**	**37.39**	**300.04**
Middle altitude **(1700)**			
Alnus nepalensis	110	11.02	30.55
Betula alnoides	210	17.23	48 .06
Carpinus viminea	35	2.43	9.72
Cupressus torulosa	10	0.26	2.10
Daphniphyllum himalense	430	17.47	66.64
Diospyros montana	10	0.08	3.00
Fraxinus micrantha	10	0.11	3.03
Lyonia ovalifolia	120	2.22	19.68
Persea odoratissima	185	8.60	37.24
Pyrus pashia	10	0.11	3.03
Quercus leucotrichophora	160	21.00	48.02
Rhododendron arboreum	165	3.56	24.33
Ulmus wallichiana	15	0.21	4.60
Total	**1470**	**84.29**	**300.00**
Lower altitude **(1550)**			
Cinnamom tamala	5	0.08	4.23
Lyonia ovalifolia	60	6.32	55.58
Myrica esculenta	25	3.67	30.19
Persea odoratissima	25	1.17	13.30
Pyrus pashia	15	1.79	16.98
Quercus leucotrichophora	160	22.06	154.23
Rhododendron arboreum	40	1.22	25.48
Total	**330**	**36.32**	**299.99**

At upper altitude (2100m) higher tree density of *Persea duthiei* King ex Hook. f. (Lauraceae) (267 trees/ha) and *Daphniphyllum himalense* Benth. (Daphniphyllaceae) (220 trees/ha) was recorded. But most of the individuals of these species were confined to lower diameter classes (10-20cm and 20-30cm), and therefore contributed lower TBC values. Although the density of *Quescus leucotrichophora* was 120 trees/ha,

Fig. 3. Dominance diversity curves (d-d curves) for woody species at different altitudinal gradients

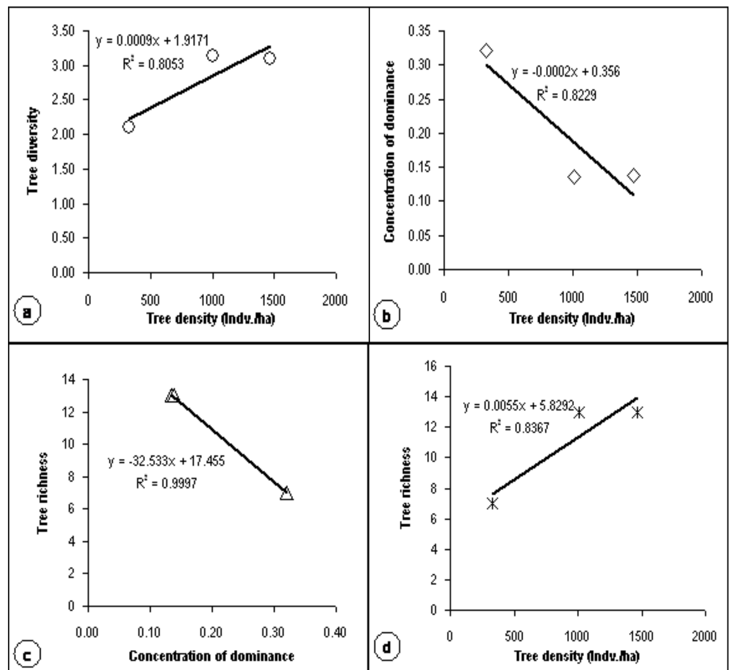


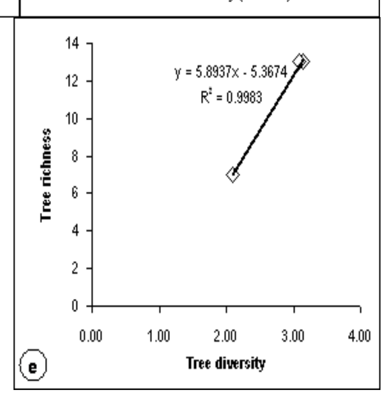
but the TBC value was comparatively high (10.02m^2/ha) and the individuals were uniformly distributed in lower, middle and higher dbh classes (Fig. 2a). Similarly at middle altitude (1700m), the maximum density of *D. himalense* (430 trees/ha) was recorded, but most of them (185 trees/ha in 10-20cm and 100 trees/ha in 20-30cm dbh classes) were in lower diameter classes. However, the distribution of *Betula alnoides* Buch.-Ham. ex D. Don (Betulaceae) was recorded in all diameter classes. The *Q. leucotrichophora* forest was comparatively established with more density (160 trees/ha) and TBC (21.00m^2/ha) values at this altitude. The individuals of banj oak were more in middle (70 trees/ha in 30-40cm dbh class) and higher (35 trees/ha in 60-70cm dbh class) diameter classes. The number of trees in lower diameter classes was lesser (Figure 2b). A normal forest of banj oak was observed at lower altitude (1550m), where highest density (160 trees/ha) and TBC (22.06m^2/ha) values of *Q. leucotrichophora* were noticed. Moreover, the banj oak individuals were found distributed in nearly all the dbh classes (55 trees/ha in 30-40cm class; 40 trees/ha in 40-50cm class; and 25 trees/ha each in 60-70cm and 70-80cm classes). This may be attributed to the less density and diversity of associated species at this altitude (Fig. 2c).

The tree diversity was highest (3.14) at the higher altitude, while it was 3.09 and 2.10 respectively at middle and lower altitudes (Table 3). At higher altitude the maximum diversity and concentration of dominance (0.45 and 0.0354) values were recorded for *Q. leucotrichophora*, followed by *P. duthiei* (0.45 and 0.0349) and *D. himalense* (0.44 and 0.0321), and minimum for *Symplocos paniculata* Thumb. (Symlocaceae) and *Ulmus wallichiana* Planchon (Ulmaceae). On the other hand the highest diversity and concentration of dominance values (0.48 and 0.0493) were recorded for *D. himalense* and minimum (0.05 and 0.0000) for *Cupressus torulosa* D. Don (Cupressaceae) at middle altitude. At lower altitude the maximum diversity and concentration of dominance values (0.49 and 0.2643) were observed for *Q. leucotrichophora* and minimum for *Cinnamom tamala* Buch.-Han. (Lauraceae) (Table 3). Beta diversity (β) values were 3.15, 2.89 and 3.50 respectively, for upper, middle and lower altitudes. The value of species evenness, species richness and Margalef index were minimum (0.75, 7.0 and 1.19) at lower altitude and maximum (0.85, 13.0 and 1.80) at higher altitude (Table 3). The dominance diversity curve approached a geometric series along all altitudinal gradients (Fig. 3). It is evident that the total actual area occupied by woody plants was 236.88 m^2/ha (2.36%).

The soils in the *Q. leucotrichophora* forests, extending from 1550 to 2100m elevations were slightly acidic to almost neutral in reaction with a pH range of 5.7 to 6.6, which was assumed to be the favourable range for nutrients availability of this species. The moisture

Fig.4. Correlation between various vegetational parameters on different altitudes





percentage in the soils varied from 14.53 to 17.05 %. The total nitrogen and organic carbon percentage values at all the altitudes ranged between 0.11 % to 0.65% and 1.02% to 7.74%. The presence of higher average moisture contents (15.57% at higher and 16.01% at middle altitudes), availability of higher average organic carbon (3.91% at higher and 3.61% at middle altitudes) and nitrogen contents (0.36% at higher and 0.38% at middle altitudes) in the soils of 2100m and 1700m altitudes respectively

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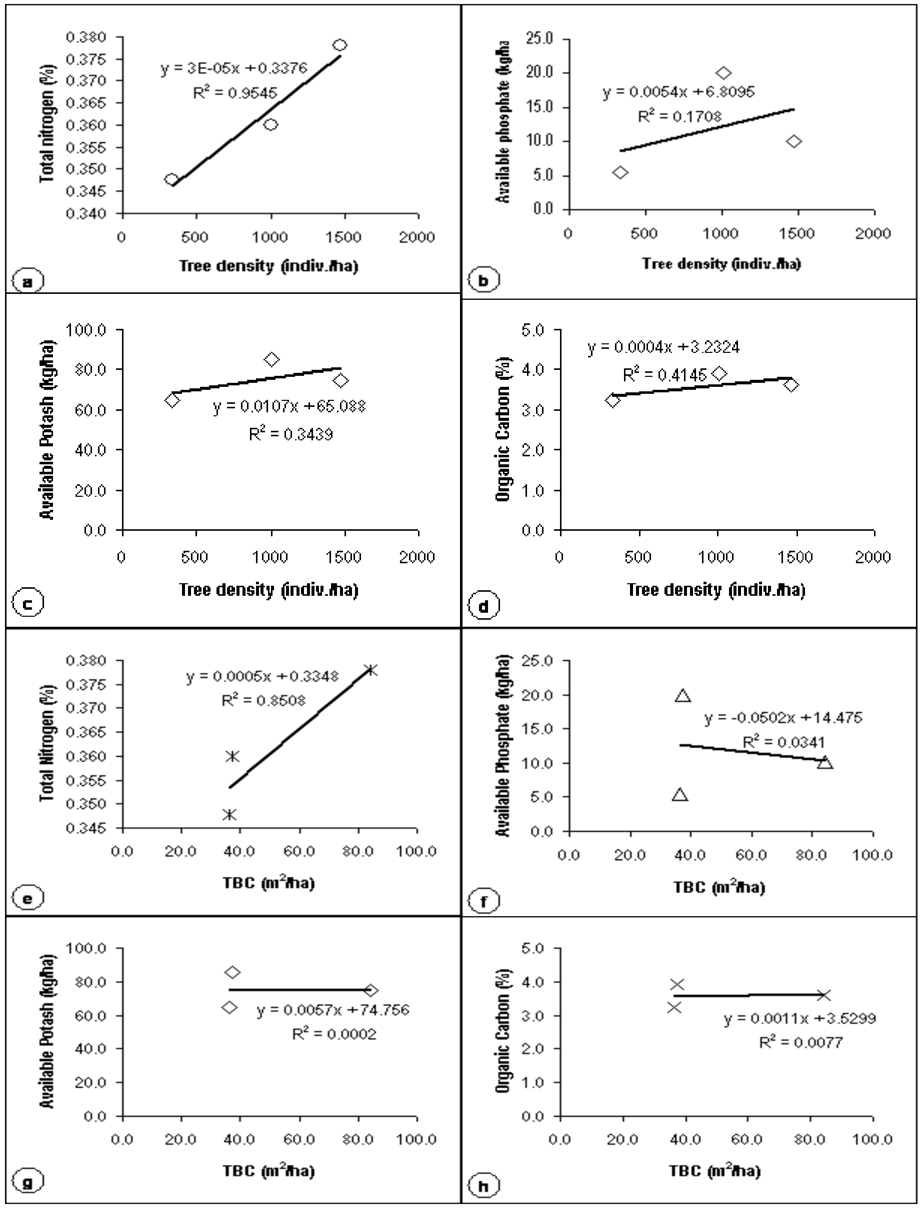
might have given birth to higher diversity (3.140 and 3.092) and total basal cover values (37.39m^2/ha at higher altitudes and 84.29m^2/ ha at middle altitudes) (Table 2, 4) on these altitudes. The maximum (91.50 kg/ha) and minimum (44.0 kg/ha) potassium values were recorded for higher and lower altitudes respectively. The presence of higher diversity at higher altitudes is believed to be related with higher potassium release (Sharpe *et al.*, 1992).

The correlation between different vegetational parameters along altitudinal gradient is given in Fig. 4a-4e. The tree density was positively correlated with the tree diversity and tree richness (P< 0.001) and negatively with tree concentration of dominance at P< 0.001. The cd was negatively correlated with tree richness and tree diversity was positively correlated with tree richness. On the other hand the correlation between vegetational parameters (tree density and Total Basal Cover) *vs* soil parameters (total nitrogen, available phosphate, available potash and organic carbon) were positively correlated (Fig. 5a- 5h).

Fig.5. Correlation between vegetational and soil parameters across different altitudinal gradients



Discussion

The results revealed that the total basal cover (36.32 to 84.29m^2/ha) and the total tree density (330 to 1470 individuals/ha) values were comparable to the moist temperate forests of other parts of Himalaya (Table 2). Earlier several workers like Baduni (1996), Ghildiyal *et al.* (1998), Sharma and Baduni (2000), Ram *et al.* (2004) have reported the values of TBC and density from 17.9 to 180.1 m^2/ha and 270 to 1670 individuals/ha respectively, for temperate forests. The total diversity values were comparable with those reported for the temperate forests by Monk (1967), Singh and Singh (1987). The concentration of domination (cd) values (0.135 at higher altitude, 0.139 at middle altitude and 0.321 at lower altitude) were more or less similar to those reported by Risser and Rice (1971) for certain temperate vegetation. Tiwari and Singh (1985) also observed concentration of dominance (cd) values between 0.11 and 0.93 for tree layer in the temperate forests of Kumaon Himalaya.

Table 3. Structure and composition of woody species at various altitudes

Components	*Upper altitude* (2100 m asl)	*Middle altitude* (1700 m asl)	*Lower altitude* (1550 m asl)
H'	3.14	3.09	2.10
Cd	0.1350	0.1389	0.3213
Simpson's Diversity	12.865	12.861	6.679
Beta diversity	3.15	2.89	3.50
Equitability	0.85	0.84	0.75
Species Richness	13.0	13.0	7.0
Margalef Index	1.80	1.67	1.19

The rural habitations in Garhwal Himalaya are mostly situated up to 2000 m a.s.l, which is also the preferred zone of banj oak forest in this area. At some places, due to summer nomadic settlements, the

Table 4. Physico-chemical characteristics of the soil at different altitudes

Location/ Altitude (m a.s.l.)	Soil layer	Depth (cm)	Moisture (%)	pH	Total Nitrogen (%)	Available Phosphate (kg/ha)	Available Potash (kg/ha)	Organic Carbon (%)
Upper altitude (2100)	Top layer	0-10	15.92	5.90	0.62	21.00	91.50	7.74
	Middle layer	11-30	15.85	5.85	0.28	20.00	91.50	2.43
	Lower layer	31-60	14.95	5.70	0.18	19.00	73.50	1.56
Average			**15.57**	**5.82**	**0.36**	**20.00**	**85.50**	**3.91**
Middle altitude (1700)	Top layer	0-10	17.05	6.60	0.52	12.32	84.00	5.02
	Middle layer	11-30	15.94	6.35	0.34	10.24	72.00	3.18
	Lower layer	31-60	15.05	6.10	0.27	7.68	69.00	2.64
Average			**16.01**	**6.35**	**0.38**	**10.08**	**75.00**	**3.61**
Lower altitude (1550)	Top layer	0-10	15.67	5.85	0.65	6.25	84.00	6.01
	Middle layer	11-30	15.05	5.90	0.28	5.00	66.00	2.69
	Lower layer	31-60	14.53	5.90	0.11	5.00	44.00	1.02
Average			**15.08**	**5.88**	**0.35**	**5.42**	**64.67**	**3.24**

exploitation of the oak forests extends up to 2500 m a.s.l. The oaks are treated traditionally as the most common and easy accessible multipurpose trees by the inhabitants. The *Q. leucotrichophora* forests, when exposed to adverse influences, the exceptionally hard oak itself persists in the form of scrubs and all other associates except *Rhododendron arboretum* and *Lyonia ovalifolia* Wall (Ericaceae) (which are not eaten by cattle and are of very poor fuel value) are killed out. In the extreme case, even oak may succumb leaving an open pure stand of *Rhododendron arboretum* Smith (Ericaceae). Therefore, the protection of oak species is essential for maintaining the stability, species richness and vigour of temperate forests in Garhwal Himalaya.

The study points out an urgent need for the conservation of biodiversity of the banj oak forests of Garhwal Himalaya. Strict protection and regulatory measures are required for its conservation, however, such measures will fail unless fuel and fodder requirements of the local inhabitants are met. It was estimated that the wood extracted from these forests meets 81-100% energy needs of the local populations, and as much as 38% of the total wood extracted is marketed for buying food grain and other requirements. These forests also support 80-95% of the fodder needs (Singh & Singh 1992). Therefore systematic fuel-wood plantations of fast growing trees on the village commons should be encouraged by setting aside selected forest compartments for raising high density short rotation energy plantations. Contrivances for developing village pastures with a mixture of grasses and legumes with scattered native fodder trees (such as *Grewia oppositifolia* Roxb. ex Mast (Tiliaceae), *Celtis australis* Hook. f. (Ulmaceae), *Ficus gibbosa* Blume. (Moraceae), etc.), could be a viable strategy for easing the anthropogenic pressure on these forests. Further, there is a need to integrate the livelihood of local human populations with conservation measures through participatory forest management in such a way so that the local inhabitants are able to draw a large share of benefits from conservation of these forests.

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