BLUE PINE (*PINUS WALLICHIANA*) FOREST STANDS OF GARHWAL HIMALAYA: COMPOSITION, POPULATION STRUCTURE AND DIVERSITY

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BHANDARI, B. S. 2003. Blue pine (*Pinus wallichiana*) forest stands of Garhwal Himalaya: composition, population structure and diversity. The study reports the composition, population structure and diversity of blue pine (*Pinus wallichiana*) forest stands of Garhwal Himalaya with special reference to altitude and aspect. A total of four sites were studied, of which two were on the southeast and the other two on the northwest facing slopes. *Pinus wallichiana* was the dominant tree species; however, competition was observed on the northwest upper slope. Higher species richness was noticed in the sapling and seedling layers. *Berberis aristata, Cotoneaster affinis, Pyracrantha crenulata* and *Pyrus pashia* were the dominant shrub species. Tree layers had a similarity of 43.30 to 82.92%. The higher degree of dissimilarity between the lower gradients of opposite aspects indicated a significant change in the community structure due to variation in aspect conditions. Species diversity ($\bar{H}$) ranged from 0.73 to 1.60, 1.71 to 2.53, 1.83 to 2.47 and 1.87 to 2.33 for tree, sapling, seedling and shrub layers respectively. Among the different strata, within the present study area, the tree stratum showed comparatively greater habitat specialization owing to the higher value of beta-diversity than the saplings, seedlings and/or shrubs.

Key words: Altitude - aspect - structure - dominance - diversity - similarity - Garhwal Himalaya

BHANDARI, B. S. 2003. Dirian hutan pain biru (*Pinus wallichiana*) di Garhwal Himalaya: komposisi, struktur populasi dan kepelbagaian. Kajian melaporkan tentang komposisi, struktur populasi dan kepelbagaian dirian hutan pain biru (*Pinus wallichiana*) di Garhwal Himalaya dengan rujukan khusus kepada altitud dan hala. Sejumlah empat tapak dikaji; dua daripadanya menghadap cerun tenggara dan dua lagi menghadap cerun barat laut. *Pinus wallichiana* merupakan spesies pokok yang dominan; bagaimanapun, persaingan dicerap di bahagian yang lebih tinggi di cerun barat laut. Kekayaan spesies lebih tinggi dalam lapisan anak pokok dan anak benih. *Berberis aristata, Cotoneaster affinis, Pyracantha crenulata* dan *Pyrus pashia* adalah spesies pokok renek yang dominan. Lapisan pokok mempunyai persamaan sebanyak 43.30 hingga 82.92%. Darjah ketaksamaan yang lebih tinggi antara gradien rendah bagi hala bertentangan menunjukkan bahawa terdapat perubahan yang bererti dalam struktur komuniti akibat perubahan hala. Kepelbagaian spesies ($\bar{H}$) berjulat daripada 0.73 hingga 1.60, 1.7 hingga 2.53, 1.83 hingga 2.47, dan 1.87 hingga 2.33 masing-masing bagi lapisan pokok, anak pokok, anak benih dan pokok renek. Di kalangan strata yang berbeza di kawasan kajian, strata pokok menunjukkan pengkhususan habitat yang lebih besar secara perbandingan akibat daripada nilai beta-kepelbagaian yang lebih tinggi berbanding anak pokok, anak benih dan/atau pokok renek.

Introduction

Forests account for 45% of the total geographical area of the Garhwal Himalaya (Anonymous 1993). Garhwal Himalaya exhibits submontane to alpine climate with distinct physiography, altitudes and aspects which harbour a variety of forest types. Owing to the varied topography and altitudes, diverse forest and alpine pasture communities may occur within a distance of 300–500 km (Singh 1992). In general, the distribution of different forest types is primarily governed by the altitude and secondarily by the factors such as geology, soils, orientation of valleys and other biotic and abiotic stresses (Champion & Seth 1968).

The elevational range of 300 to 2200 m in the Garhwal Himalaya reflects three vegetational regimes, viz. *Shorea robusta* and associated species 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. However, along the entire altitudinal range of Garhwal Himalaya, the overlaps among species regimes are broad; therefore, transitional communities having mixtures of species of more than one zone are often found.

Although a number of studies on the structure and composition of Himalayan forests are available (Saxena & Singh 1982, Tewari & Singh 1985, Bankoti *et al.* 1986, Singh & Singh 1987, Joshi & Tiwari 1990, Adhikari *et al.* 1991, Bhandari *et al.* 1995, 1997, Mehta *et al.* 1997), quantitative studies on forest dominated by blue pine (*Pinus wallichiana*) are completely lacking. The objective of the present study was to analyse the structure, composition and dominance/diversity of *P. wallichiana* forest stands on different altitudes and aspects.

Materials and methods

Location

The study was carried out in a mountain flank of Jakholi (78°53'E, 30°23'N) in the Rudraprayag District of Garhwal Himalaya. Two stands at an elevation of 1800 m (one on the southeast aspect and other on the northwest aspect) and two at 2100 m within the slope range of 36 to 42° were selected.

Climate

The climate is subtropical montane with distinct rainy (June–September), winter (October–February) and mild summer (March–mid June) seasons. The total rainfall during the study period was 1660 mm, of which more than 60% occurred during the rainy season. A mean monthly temperature of 12 °C and minimum temperature of 7 °C were recorded. Winter is characterized by one or two snowfalls in a year.

Methods

Vegetation analysis was carried out using twenty 10 × 10 m randomly placed quadrats at each of the study sites. In each quadrat, the circumference of 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 level. Tree individuals with <10.4 cm cbh were treated as seedlings and shrubs were considered separately.

Frequency, density, abundance, basal area and importance value index (IVI) were calculated for each species at each locality (Curtis & McIntosh 1950). Total basal cover (TBC) was calculated to reflect the area occupied by different species of the community.

All individuals of the dominant species (*P. wallichiana*) were categorised into five 30 cm cbh classes starting with 31.5–61.5 cm and ending with one >183 cm class for the analysis of population structure.

Similarity indices between different stands for tree, sapling, seedling and shrub layers were calculated following Jaccard (1912) on the basis of density.

Species diversity ($\overline{H}$) was determined with Shannon-Wiener information function (Shannon & Wiener 1963, Pielou 1977, Sugihara 1980):

$$\overline{H} = -\sum_{i=1}^{s}\left(\frac{N_i}{N}\right)\log_2\left(\frac{N_i}{N}\right)$$

where,

$\overline{H}$ = Shannon-Wiener index of species diversity
N_i = density of the species i

and

N = total density of all the species in a stand.

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

$$C = -\sum_{i=1}^{s}\left(\frac{N_i}{N}\right)^2$$

where,

N_i 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.

Results and discussion

Dominance and population structure

Pinus wallichiana was the most important species on all the sites. The maximum density, total basal cover (TBC) and importance value index (IVI) values of this species were obtained for the southeast (SE) facing slopes. These depict the favourable growth of *P. wallichiana* on the eastern faces (Table 1). On the basis of the above phytosociological attributes, competition was observed between *Quercus leucotrichophora* and *P. wallichiana* in the tree layer on the northwest (NW) upper slope indicating that *P. wallichiana* prefers the SE slopes which are comparatively drier than the NW slopes. On the other hand, relatively wet and moist habitats are much more suitable for the growth and development of *Q. leucotrichophora* and associated species. This concurs with earlier reports that eastern faces provide a more congenial environment for the luxuriant growth of gymnosperms than for broad-leaved species at this altitudinal range. This is due to the relatively drier climatic and hence the microclimatic conditions on the eastern faces than the western faces of Garhwal Himalaya which favour the growth of broad-leaved species (Bhandari & Tiwari 1997, Bhandari *et al.* 2000).

Although the dominance, in general, was shared by common species in all the strata, *Symplocos paniculata* emerged as a dominant species, whereas *Myrica esculenta* and *P. wallichiana* were found competing with each other in the seedling stratum on the southeast lower (SEL) site. *Pinus roxburghii* was noticed on the SEL site in the sapling stratum with the lowest values of density, TBC and IVI. The presence of *P. roxburghii* on the lower gradient of the eastern slope reflects the invasion by this species from lower altitudes of the eastern face. It is a serious threat to the broad-leaved forests of Central Himalaya. If *P. roxburghii* encroaches on the broad-leaved forests of this altitudinal range, it may create problems to the healthy environment of these forests, which ultimately may lead to a monoculture development.

In addition, *P. roxburghii* is a light-demanding, fire-adapted but fire-promoting species. The surface fires averaging once every two or three years cause substantial nitrogen losses (Singh *et al.* 1984). Nitrogen depletion is one of the major causes for the monoculture development of chir pine (*P. roxburghii*) in this altitudinal range.

Tree density ranged from 160 to 550 plants ha^{-1} for *P. wallichiana* and from 20 to 260 plants ha^{-1} for *Q. leucotrichophora*. Greater species richness was reported in the sapling and seedling layers on both the aspects and altitudes. Only a few species were able to reach maturity due to various biotic factors operating thereupon. *Quercus leucotrichophora* and most of the associated species are multipurpose species and are exploited for fodder, fuel, agricultural implements, animal bedding, biomanuring, etc. *Berberis aristata, Cotoneaster affinis, Pyracrantha crenulata* and *Pyrus pashia* were the dominant shrub species on all the stands. Competition between various shrub and seedling species is due to the deep shade in the under-canopy environment. Whittaker (1972) also suggested that the dominance of one stratum may affect the dominance and diversity of another stratum.

The total basal area across the stands ranged from 8.86 to 67.40 m^2 ha^{-1} and the total tree density varied between 320 and 670 plants ha^{-1} (Table 1). On the other hand, Bhandari and Tiwari (1997) reported values of total basal area and density to be in the range of 41.17–73.55 m^2 ha^{-1} and 1570–1787.5 plants ha^{-1} respectively, for the *Q. leucotrichophora* forests of Garhwal Himalaya. The present values of basal cover and density are much lower suggesting that these stands are either much younger or bear greater biotic stresses than the montane oak forests of Garhwal Himalaya. It was revealed during field observations as well as from information collected from villagers that these forest stands in the vicinity of some villages provide fuel and fodder to natives. Thus, with the changing scenario of these forest stands, efforts are being made by the forest officials and inhabitants around to check the steep degradation of these natural resources.

Table 1 Density (D, plants ha^{-1}), basal cover (BC, m^2 ha^{-1}) and importance value index (IVI) of woody species on the study sites

Stratum/species	SEU			SEL			NWU			NWL		
	D	BC	IVI	D	BC	IVI	D	BC	IVI	D	BC	IVI
Tree												
Lyonia ovalifolia	-	-	-	80	1.43	28.96	-	-	-	30	0.28	36.58
Myrica esculenta	-	-	-	-	-	-	40	0.92	23.79	-	-	-
Pinus wallichiana	420	30.40	200.70	550	58.40	253.3	320	9.36	150.00	160	2.52	130.23
Quercus leucotrichophora	210	2.43	81.38	20	0.21	17.35	260	0.47	150.30	110	1.59	102.62
Rhododendron arboreum	-	-	-	-	-	-	20	0.96	20.89	20	0.49	30.52
Symplocos paniculata	40	0.96	18.33	-	-	-	-	-	-	-	-	-
Sapling												
L. ovalifolia	150	0.41	32.74	350	0.41	43.04	250	0.81	32.10	-	-	-
M. esculenta	230	0.46	35.54	150	0.31	30.09	250	0.41	28.42	100	0.24	36.53
P. roxburghii	-	-	-	10	0.51	2.98	-	-	-	-	-	-
P. wallichiana	1050	3.85	146.94	380	1.31	70.51	960	0.94	3.68	440	1.41	135.83
Q. leucotrichophora	24	0.10	22.95	420	0.26	69.11	450	0.99	123.58	320	0.96	89.65
R. arboreum	70	0.19	17.15	190	0.51	34.29	40	0.06	52.56	-	-	-
S. paniculata	340	0.65	44.65	330	0.47	50.04	210	0.55	30.81	90	0.19	37.93
Seedling												
L. ovalifolia	320	0.15	31.69	530	0.18	50.38	280	0.12	36.06	-	-	-
M. esculenta	550	0.13	41.54	250	0.12	32.81	130	0.22	39.15	170	0.06	45.16
P. wallichiana	1730	0.93	125.99	260	0.26	59.91	710	0.30	107.17	440	0.23	129.67
Q. leucotrichophora	310	0.22	35.81	530	0.17	47.35	200	0.14	41.93	120	0.08	49.84
R. arboreum	170	0.11	23.09	230	0.10	29.39	-	-	-	-	-	-
S. paniculata	760	0.09	41.84	710	0.42	80.15	540	0.13	75.76	250	0.07	75.27
Shrub												
Berberis aristata	1240	0.18	57.81	1110	0.28	66.14	1570	0.28	72.15	750	0.16	81.54
Cotoneaster affinis	420	0.17	27.76	1220	0.79	91.11	1010	0.23	44.29	-	-	-
Lonicera quinquelocularis	40	0.03	5.00	-	-	-	-	-	-	-	-	-
Pyracantha crenulata	1470	1.11	97.04	720	0.60	63.48	1170	0.60	77.14	580	0.23	77.63
Pyrus pashia	670	1.98	70.90	750	0.65	75.80	1620	0.38	79.55	960	0.32	112.25
Rosa brunonii	400	0.06	28.47	-	-	-	250	0.04	18.79	260	0.03	28.25
Rubus ellipticus	170	0.02	12.96	10	0.01	3.39	50	0.02	8.03	-	-	-

SEU = southeast upper slope, SEL = southeast lower slope, NWU = northwest upper slope, NWL = northwest lower slope

The population structure of *P. wallichiana* was analysed by examining the size class data in all the stands. The presence of small and large individuals indicates frequent regeneration as well as dominance at maturity (Figures 1 a & b). The relatively large percentages of young individuals and a few old ones do not indicate frequent regeneration (Knight 1975) (Figure 1c). The absence of a certain girth class, E, (Figure 1d) may indicate an interruption in the regeneration due to different microclimatic conditions, the interruption resulting from the changing stand conditions (Bankoti *et al.* 1986).

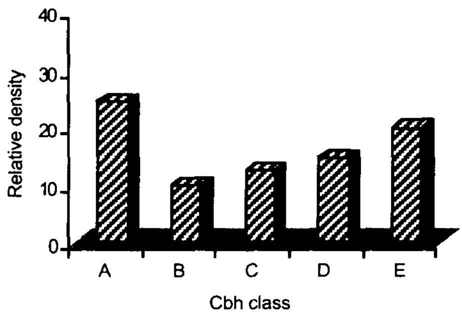


Figure 1a Population structure of *Pinus wallichiana* on southeast upper (SEU) slope

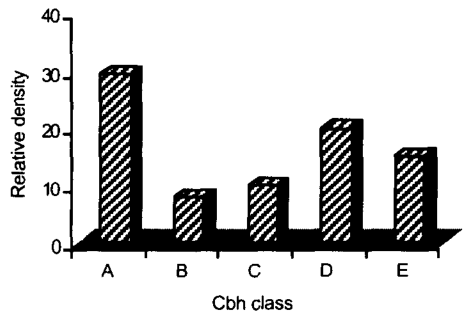


Figure 1b Population structure of *Pinus wallichiana* on southeast lower (SEL) slope

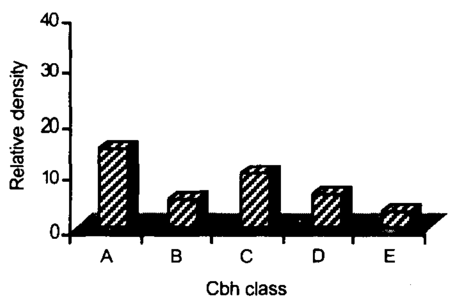


Figure 1c Population structure of *Pinus wallichiana* on northwest upper (NWU) slope

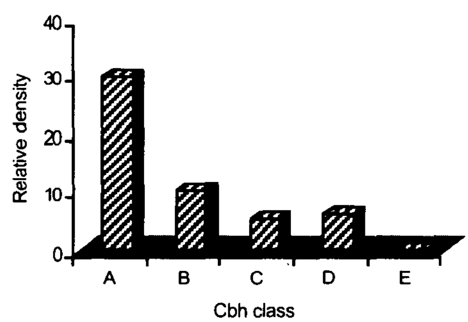


Figure 1d Population structure of *Pinus wallichiana* on northwest lower (NWL) slope

Similarity indices

On the basis of similarity indices, tree layers had a similarity of 43.30 to 80.92% (Table 2). The major difference between the lower and upper ranges indicates a significant change in community structure due to variation in altitude and aspect. Moreover, the higher similarity between the west- and east-facing upper slopes is an indication of identical vegetation due to relatively open habitats at mountains with increasing altitude. On the other hand, the higher degree of dissimilarity between the lower altitudes of different aspects is due to the striking change in the habitat conditions owing to variations in microclimatic and other associated factors.

Table 2 Similarity indices between different sites and strata

Site/stratum	NWU	NWL	SEU	SEL
SEU				
Tree			100	66.77
Sapling			100	59.93
Seedling			100	69.77
Shrub			100	71.29
SEL				
Tree				100
Sapling				100
Seedling				100
Shrub				100
NWU				
Tree	100	58.33	80.92	52.71
Sapling	100	69.90	80.02	72.68
Seedling	100	69.01	65.26	73.23
Shrub	100	61.80	75.40	75.95
NWL				
Tree		100	54.64	43.30
Sapling		100	46.48	64.26
Seedling		100	40.66	51.71
Shrub		100	64.94	65.41

SEU = southeast upper slope SEL = southeast lower slope
NWU = northwest upper slope NWL = northwest lower slope

Diversity and related measurements

Species diversity ($\bar{H}$) ranged from 0.73 to 1.60, 1.71 to 2.53, 1.83 to 2.47, and 1.87 to 2.33 respectively, for tree, sapling, seedling and shrub strata (Table 3). These values are comparable with those reported for the temperate forests of Kumaun and Garhwal Himalaya (Singh & Singh 1987, Bhandari & Tiwari 1997). The lower diversity in the temperate (montane) forests could be due to the lower rate of evolution and diversification of communities (Simpson 1949, Fischer 1960) and severity in the environment (Connell & Oris 1964).

Species diversity and dominance concentration are generally inversely related. The values of concentration of dominance (C) ranged from 0.3807 to 0.7319 for trees, 0.1843 to 0.3738 for saplings, 0.1982 to 0.3118 for seedlings, and 0.2322 to 0.2903 for shrubs. These findings support the ranges reported by Risser and Rice (1971) for temperate forests.

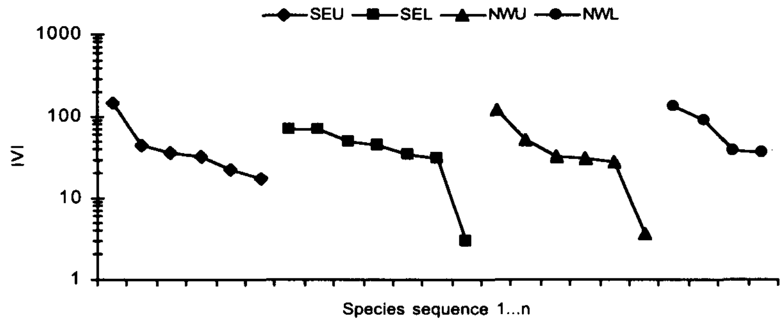
Table 3 Species diversity ($\bar{H}$) and dominance concentration (C) of woody species on different sites

Site/stratum	$\bar{H}$	C
SEU		
Tree	1.19	0.4947
Sapling	1.84	0.3738
Seedling	2.17	0.2778
Shrub	2.33	0.2322
SEL		
Tree	0.73	0.7319
Sapling	2.53	0.1843
Seedling	2.47	0.1982
Shrub	1.98	0.2617
NWU		
Tree	1.43	0.4198
Sapling	2.14	0.2774
Seedling	2.07	0.2692
Shrub	2.19	0.2345
NWL		
Tree	1.60	0.3807
Sapling	1.71	0.3477
Seedling	1.83	0.3118
Shrub	1.87	0.2903

SEU = southeast upper slope SEL = southeast lower slope
NWU = northwest upper slope NWL = northwest lower slope

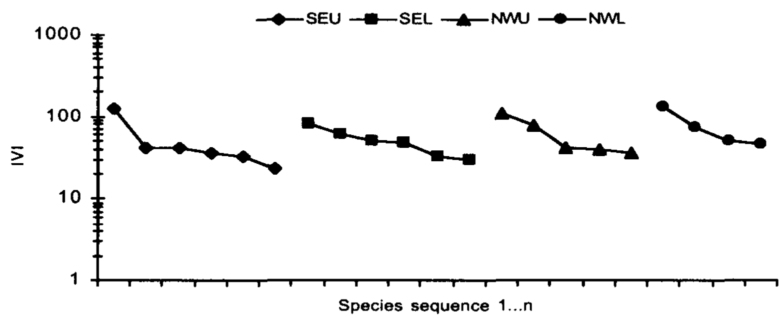
Within the present study sites, the values of beta-diversity were 1.71, 1.21, 1.14 and 1.27 for tree, sapling, seedling and shrub layers respectively. These values are lower than those reported for Central Himalayan forests (Bankoti *et al.* 1986). Low values of beta-diversity indicate that the growth forms respond in similar fashion (Adhikari *et al.* 1991). This index has often been used to indicate the variation in species composition between habitats and it is suggested that the finer the divisions of a habitat, the greater would be the values of beta-diversity (Whittaker 1975). Therefore, among the different strata, within the present study area, trees showed relatively greater habitat specialization than saplings, seedlings or shrubs.

The dominance diversity (d-d) curves for sapling, seedling and shrub layers based on IVI approached mostly a geometric series except in a few cases where they reflected Preston's (1948) log normal model (Figures 2a, b & c). The geometric form is often shown by vascular plants having low diversity (Whittaker 1975). On the other hand, log normal distribution in the seedling and shrub layers on the southeast lower (SEL) and northwest upper (NWU) sites is due to deep shade under-canopy environment, which resulted in severe competition between species (Bhandari & Tiwari 1997).



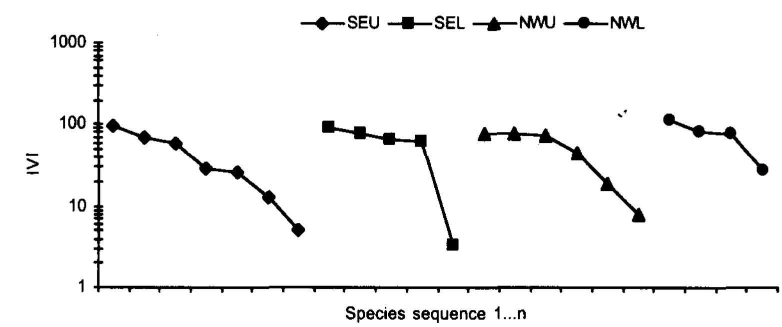
SEU = southeast upper slope SEL = southeast lower slope
NWU = northwest upper slope NWL = northwest lower slope

Figure 2a Dominance diversity curves for sapling layers



SEU = southeast upper slope SEL = southeast lower slope
NWU = northwest upper slope NWL = northwest lower slope

Figure 2b Dominance diversity curves for seedling layers



SEU = southeast upper slope SEL = southeast lower slope
NWU = northwest upper slope NWL = northwest lower slope

Figure 2c Dominance diversity curves for shrub layers

The study clearly shows that unlike chir pine (*P. roxburghii*) blue pine (*P. wallichiana*) has the tendency to share common habitats with *Q. leucotrichophora* and other associated species like *Lyonia ovalifolia, M. esculenta, Rhododendron arboreum* and *S. paniculata.* In spite of the visible competition between *P. wallichiana* and *Q. leucotrichophora* in tree (northwest lower, NWL) and sapling layers (southeast lower, SEL), *P. wallichiana* has been found to have dominated the other species in all the study sites. The reason may be due to the over-exploitation of *Q. leucotrichophora,* a multiple-use species (Bhandari & Tiwari 1997). On the other hand, *P. wallichiana* is known as a low quality fuelwood and the branches are oftenly used in the protection of domestic climbers. It is thus concluded that if the extent of the various biotic stresses is reduced to a considerable limit, the diversity of *P. wallichiana – Q. leucotrichophora* and associated species may be maintained in a healthy state. However, the invasion of *P. roxburghii* in these forest stands should be regarded as a possible threat to the co-existence of these forest species. Therefore, proper management practices along with public awareness may be an important tool for the conservation and management of the biological diversity of these forests at this altitudinal range.

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