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Community structure and species diversity of *Pinus merkusii* Jungh. & de Vriese forest along an altitudinal gradient in Eastern Himalaya, Arunachal Pradesh, India

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Abstract: *Pinus merkusii*, the only pine species naturally distributed to the south of equator with a wide altitudinal range of 30–1800 m a.s.l., is under threat due to habitat destruction and over exploitation for its timber and resin. In India, the species is restricted to Arunachal Pradesh. The community characteristics of *P. merkusii* dominated forests were studied in Anjaw District of Arunachal Pradesh at three elevations i.e. at Walong (900–1200 m a.s.l.), Namti (1200–1500 m a.s.l.) and Dong (1500–1800 m a.s.l.) during the years 2012–2014. Species richness was highest at low elevation site followed by medium elevation and lowest at high elevation site with 76, 50 and 35 species, respectively. Fagaceae, Poaceae, Lauraceae and Rosaceae were the most dominant families. Overall tree density decreased with the increase in elevation (1124 to 896 individuals ha^{-1}), whereas density of *P. merkusii* increased with the elevation (286 to 504 individuals ha^{-1}). Basal cover was largest at medium elevation site with 54.34 m^2 ha^{-1} and lowest at low elevation site with 32.8 m^2 ha^{-1}. *P. merkusii* contributed maximum to the total stand basal cover and IVI at all the three sites. The largest basal area of *P. merkusii* was recorded at medium elevation site. Shannon's diversity index and Menhinick's species richness index decreased with the increase in elevation. Conversely, Simpson's dominance index increased with elevation. Species similarity index was highest between medium and high elevation sites (59%) and lowest between low and high elevation sites (39%). Most of the plant species were distributed contagiously in all the three elevation sites. Present study revealed high plant species diversity at low elevation which decreased with the increase in elevation. Significant contribution of *P. merkusii* to density, basal cover and IVI depicted sheer domination by this vulnerable gymnosperm in these forests.

Key words: Community structure and dominance, *Pinus merkusii* forest, vulnerable.

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Introduction

Pinus L. is the largest genera with more than 110 species of the family Pinaceae which forms dominant vegetation in northern hemisphere viz. North America, Europe and Asia. Only *Pinus merkusii* Jungh. & de Vriese extends towards the southern hemisphere (Critchfield & Little 1966; Mirov 1967; Price *et al.* 1998; Richardson 1994). Distribution of *P. merkusii* in natural forests is reported from Arunachal Pradesh, Indo–Myanmar region, Thailand, Malaysia,

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Philippines and Sumatra within the altitudinal range of 30–1800 m a.s.l. (Choudhury 2003; Farjon 2013; FIPI 1996; Reungchai *et al.* 1986). In Northeast India, Pine forests are restricted to the subtropical and temperate regions where *Pinus roxburghii*, *Pinus kesiya*, *Pinus wallichiana* and *Pinus merkusii* dominate (Champion & Seth 1968). Existence of large natural forests of *P. merkusii* was reported from Myanmar, Thailand and Sumatra (APFORGEN 2013). Besides being a good timber species, the species produces high quality resin of commercial importance that has also anticancer properties (APFORGEN 2013; Cooling 1968; Dayal 1986; Orwa *et al.* 2009). Over-exploitation for diverse use, habitat destruction and change in land use pattern, frequent occurrence of forest fire and mining activities are threatening the species in its native habitats throughout the world (Farion 2013; Razal *et al.* 2005). Considering the ongoing threats and its declining population, this species has been classified as Vulnerable under the IUCN red data list (Farjon 2013). In Arunachal Pradesh, various developmental activities such as construction of roads and dams has been impacting the natural habitats of *P. merkusii* (Bharali *et al.* 2012; Deka *et al.* 2013).

Understanding the community structure is a pre–requisite to describe various ecological processes in a forest ecosystem (Elourard *et al.* 1997). Altitude is one of the most important determinants of habitat characteristics as it regulates conditions such as temperature and moisture (Korner 2000). Therefore, many researchers have studied community characteristics and explored distribution pattern of plants along altitudinal gradients and reported that altitude plays a key role in regulating species richness (Grytnes 2003; Kessler 2000; Oommen & Shanker 2005). In South East Asia, the studies on *P. merkusii* include, its anatomy, stand soil dynamics, and oil composition (Buckley *et al.* 2007; Coppen *et al.* 1998; Gunadi *et al.* 1998; Krave *et al.* 2002; Kurose *et al.* 2007; Pumijumnong & Wanyaphet 2006). However, information on plant community structure of *P. merkusii* dominated natural forests is very meager. Hence, the present study intends to provide an insight into the plant community structure and species diversity pattern along an altitudinal gradient in *P. merkusii* dominated forests in the Eastern Himalayan state of Arunachal Pradesh, India.

Materials and methods

Study Area

The study was conducted in *P. merkusii* forests of Anjaw district, Arunachal Pradesh, which lies in the range of Eastern Himalayas. Anjaw district is located between 26°55' and 28°40' N latitude and 92°40' and 94°21' E longitude with an altitudinal range from 300–5000 m a.s.l. (Fig. 1). The district is bound by China and Myanmar in the north and east, respectively, and Lower Dibang Valley and Lohit districts of the state in the west and south, respectively. Vegetation of Anjaw district is classified as Tropical semi evergreen forest, Subtropical broad–leaved forest, Subtropical pine forests and Sub alpine forests (Anonymous 2005). Despite very rich and unique flora and fauna, and with a range of threats, there is no protected area declared by the authority in the district for conservation purpose (Aiyadurai 2012). The district is dominated by Mishmi tribes and partly by Meyors towards the Indo-China borders. Lohit is the main river of the district with numerous tributaries such as Tidding, Krowti and Dichu that form the mighty Brahmaputra River. The climate is subtropical and humid in the lower elevations and the valleys, while it is cold and dry in the higher elevations. Annual rainfall in the district varies from 3500–5500 mm. The soil is sandy loam to loamy sand with highly acidic to mildly acidic in nature (Anonymous 2009).

Materials and methods

The study was carried out in the *P. merkusii* forests at three elevation ranges viz., low elevation site at Walong (900–1200 m a.s.l.), medium elevation site at Namti (1200–1500 m a.s.l.) and high elevation site at Dong (1500–1800 m a.s.l.). The elevation ranges were decided by considering the known global altitudinal distribution range of the species i.e. from a few meters to 1800 m (Cooling 1968). For community analysis, two rectangular plots of 300 m × 50 m size were established at each elevation range. Further in each plot, 25 quadrats of 10 m × 10 m were laid randomly to study the tree species composition. GBH of all individuals within these quadrats having ≥30 cm GBH was measured at 1.37 m from ground. To study the advance growth on forest floor, the densities of sapling (≤30 cm ≥10 GBH and more than 50 cm height) and seedling (<10 cm collar diameter and

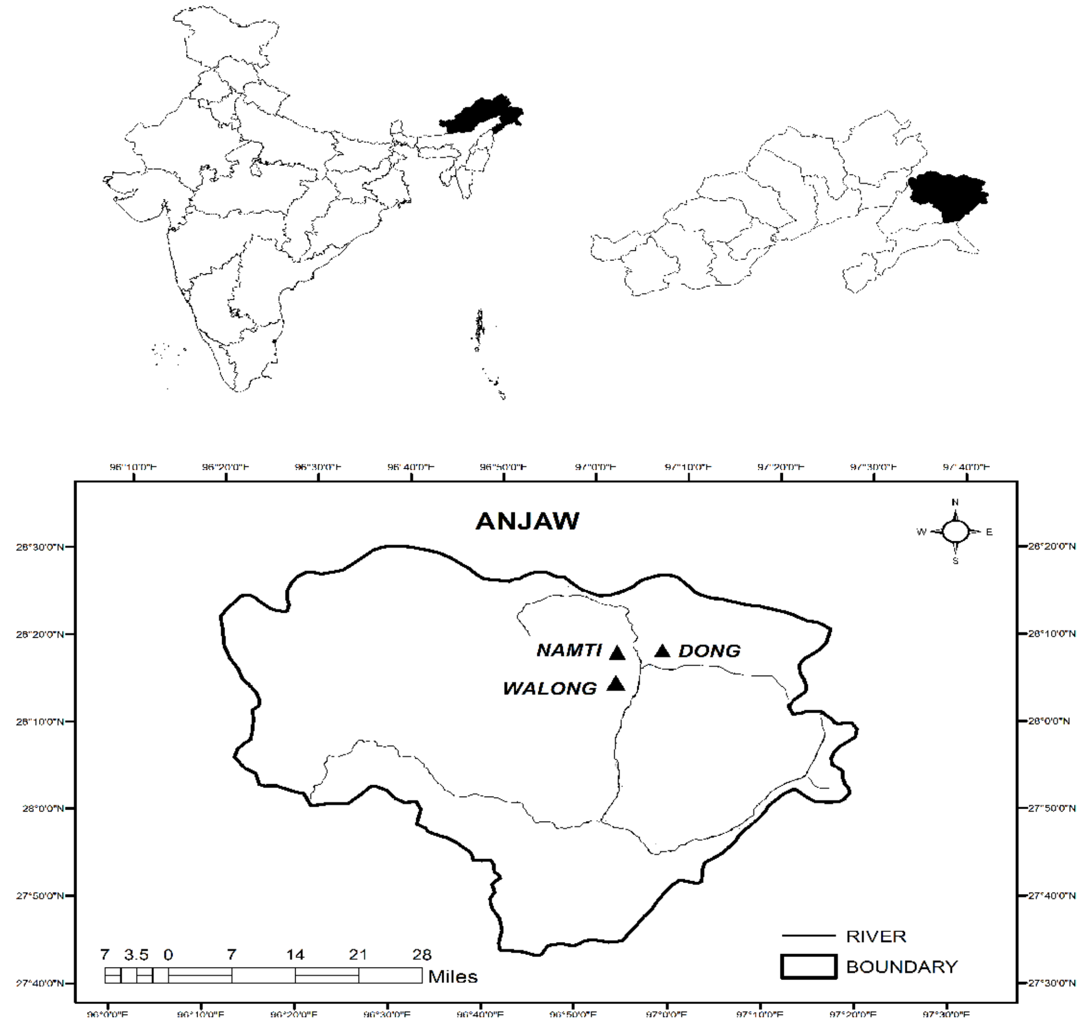

Fig. 1. Location of study area (Walong–Low elevation, Namti–Medium elevation and Dong–High elevation).

<50 cm height) of different tree species were determined following Uma Shankar (2001). Within the randomly selected quadrats for tree species, two 5 × 5 m quadrats for shrubs, saplings, seedlings and two 1m × 1m quadrats for herbs were laid for their detailed study. Specimens of all the plant species were collected and herbaria were prepared according to Jain & Rao (1977) and identification was done with the help of flora of Arunachal Pradesh, Flora of Assam (Kanjilal *et al.* 1934–1940), Flowers of Himalaya (Polunin & Stainton 1985) and consulting the regional Herbaria ARUN of the Botanical Survey of India.

Frequency, density, abundance, basal areas and importance value (IVI) of plant species were determined according to Misra (1968) and Mueller–Dombois & Ellenberg (1974). Species richness index (D_{mn}) was calculated following Menhinick (1964), α and β diversity were calculated by following the methods given by Whittaker (1960), Species diversity index (H') was calculated following Shannon & Weaver (1963), species dominance index (C_d) was calculated following Simpson (1949), Evenness index (E) was calculated following Pielou (1966), Indices of similarity was calculated by using formula given by Sorensen (1948). The distribution pattern was calculated according to Whitford (1949).

$$\text{Distribution Pattern} = \frac{\text{Abudance}}{\text{Frequency}}$$

If the ratio is <0.025, it indicates regular distribution; between 0.025 and 0.05, it indicates random distribution and >0.05 indicates contagious or clumped distribution.

Statistical analysis

Statistical analysis were carried out using SPSS v. 16.0. Shapiro–Wilk test was conducted

Table 1. Family wise genera and species enumerated in the study area.

Family	Genera	Species	Family	Genera	Species
Acanthaceae	1	1	Malvaceae	1	1
Actinidiaceae	1	4	Melastomaceae	3	4
Anacardiaceae	3	3	Meliaceae	1	2
Araliaceae	1	2	Moraceae	2	3
Aspleniaceae	1	1	Myrsinaceae	2	4
Asteraceae	4	6	Myrtaceae	1	1
Begoniaceae	1	1	Nephrolapidaceae	1	1
Berberidaceae	1	1	Ophioglossaceae	1	1
Betulaceae	2	2	Orchidaceae	1	1
Buddlegaceae	1	1	Pinaceae	1	1
Dryopteridaceae	1	1	Poaceae	9	9
Eleagnaceae	1	1	Pteridaceae	2	3
Ericaceae	1	1	Rosaceae	1	6
Euphorbiaceae	2	2	Rubiaceae	1	1
Fabaceae	3	5	Rutaceae	1	1
Fagaceae	2	8	Thelypteridaceae	1	1
Hydrangeaceae	1	1	Thymelaeaceae	1	1
Lamiaceae	3	3	Ulmaceae	1	1
Lauraceae	2	6	Urticaceae	3	5
			Verbenaceae	1	1

for the selected variables to determine their normality. The variables with normal distribution were considered for one-way ANOVA to determine their significant levels for the differences among the variables and indices across the three elevation gradients. Whereas, variables without normal distribution were considered for Kruskal–Wallis test for their significance at $P < 0.05$.

Results

Floristic diversity and species richness

Altogether 98 species under 67 genera belonging to 40 families were recorded from the three elevation ranges (Table 1). Among all the species recorded, 46 were tree species under 29 genera belonging to 21 families, 29 species were shrubs under 18 genera belonging to 13 families and 23 species were herbs under 22 genera belonging to 11 families (Table 2). Most dominating families were Fagaceae with 8 species, Poaceae with 9 species, Lauraceae and Rosaceae with 6 species each. In addition, Fabaceae, Urticaceae and Lamiaceae were among the other co-dominant families in the study sites (Table 1).

Species richness varied significantly among the sites, highest value being recorded from the low elevation site with 76 species followed by medium elevation site with 50 species and the lowest in high elevation site with 35 species ($F = 9.74$, $P < 0.01$) (Table 2). However, there was no significant difference in Menhinicks species richness index among the three sites ($\chi^2 = 5.135$, $P > 0.05$). In case of trees, the species richness index was highest in low elevation site followed by medium elevation site, and it was lowest in high elevation site with values of 1.43, 1.01 and 0.75, respectively. A similar trend of species richness index was recorded in shrubs and herbs as well (Table 3).

α diversity, Shannon diversity index, dominance index and IVI

α diversity recorded in the three elevation sites differed significantly and depicted a decreasing pattern with increase in elevation ($F = 9.69$, $P < 0.01$). In case of tree species, low elevation site showed highest α diversity followed by medium elevation site, and the lowest was recorded in high elevation site with values of 5.37, 3.57 and 2.62,

Table 2. Distribution of family, genera and species among trees, shrubs, herbs, saplings and seedlings in three study sites.

		Trees	Shrubs	Herbs	Saplings	Seedlings	Total
Walong (Low elevation)	Species	34	23	19	6	4	76
	Genus	28	14	19	6	4	58
	Family	20	9	10	5	4	34
Namti (Medium elevation)	Species	22	13	15	7	5	50
	Genus	16	11	15	7	5	41
	Family	14	8	9	6	5	25
Dong (High elevation)	Species	16	9	10	6	6	35
	Genus	12	7	10	4	6	27
	Family	10	7	6	4	6	20
Total	Species	46	29	23	11	7	98
	Genus	30	18	22	8	7	67
	Family	21	13	11	7	7	39

Table 3. Various phytosociolgical characteristics of tree (T), shrubs (SH), saplings (SP), herbs (H) and seedling (SD) in three study sites.

Parameters	Walong (Low elevation)					Namti (Mid elevation)					Dong (High elevation)				
	T	SH	H	SP	SD	T	SH	H	SP	SD	T	SH	H	SP	SD
Species richness (S)	34	23	19	6	4	22	13	15	7	5	16	9	11	6	6
No. of Genera	28	15	19	5	4	16	12	14	7	5	11	8	11	4	6
No. of Family	18	9	12	5	4	14	7	10	6	5	15	7	9	3	6
Menhinicks species richness index (D_{mn})	1.43	0.85	1.07	0.45	0.49	1.01	0.66	0.94	0.44	0.50	0.75	0.63	0.82	0.42	0.54
α Diversity	5.37	3.48	3.29	1.17	0.95	3.57	2.17	2.70	1.26	1.08	2.62	1.69	2.11	1.12	1.25
Shannon-Weiner diversity index (*H'*)	2.77	3.03	2.77	1.69	0.91	2.15	2.48	2.57	1.88	1.25	1.82	2.14	2.27	1.77	1.13
Simpson Index (D)	0.14	0.05	0.07	0.20	0.53	0.26	0.09	0.08	0.16	0.34	0.32	0.12	0.11	0.20	0.33
Species evenness index (E)	0.78	0.97	0.94	0.94	0.65	0.70	0.97	0.95	0.97	0.78	0.65	0.98	0.95	0.95	0.63
Density (individuals ha^{-1})	1124	2932	31700	684	268	942	1564	25700	1028	396	896	816	18200	836	488
Basal cover (m^2 ha^{-1})	32.8	–	–	–	–	54.34	–	–	–	–	41.92	–	–	–	–

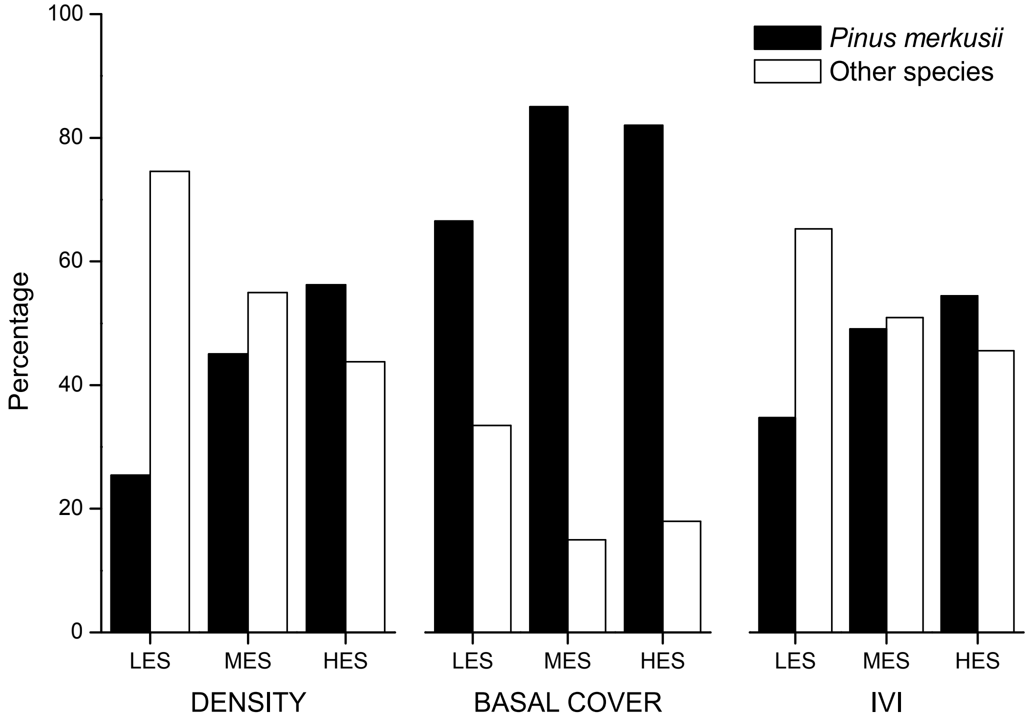

Fig. 2. Percentage contribution of *Pinus merkusii* and other tree species towards total density, basal cover and importance value index in three elevation site. (LES–Low elevation site, MES–Medium elevation site, HES–High elevation site).

respectively. A similar trend of α diversity for shrubs and herbs was recorded, where highest α diversity was recorded in low elevation and decreased with the increase in elevation (Table 3).

Shannon-Wiener index of species diversity (H') in the three elevation sites varied significantly, where diversity index of trees, shrubs and herbs was highest in low elevation site followed by medium elevation and lowest in high elevation site ($F = 26.094$, $P < 0.05$) (Table 4). There was no significant variation in dominance index (C_d) among the three elevation sites (Table 3).

Among the tree species, *Pinus merkusii* had the highest IVI in all the three study sites with values of 104.2 (35%), 147.2 (49%) and 163.3 (55%) at low, medium and high elevation sites, respectively (Fig. 2). *Castanopsis armata* and *Alnus nepalensis* had next highest IVI values (16.6 and 11, respectively) at low elevation site, whereas *Alnus nepalensis* (23.4), *Castanopsis indica* (18.5) and *C. lanceifolia* (10.1) were recoded with high IVI next to *P. merkusii* in medium elevation site. *Alnus nepalensis*, *Quercus acutissima* both have an IVI of 22.1 and *Ficus semicordata* (14.2) showed high IVI next to *P. merkusii* in high elevation site. *Rubus pectinaris* and *Artemisia indica* among the shrubs were the most dominant species with IVI of 18.9 and 17.5, respectively at low elevation site, whereas *Melastoma melabathricum* (34.9) and *Oxyspora paniculata* (23.6) were most dominant at medium elevation site, and *Lyonia ovalifolia* (40.8) and *Oxyspora cernua* (25.6) were the dominant shrub at high elevation site. Among the herbs, *Nephrolepis cordifolia*, *Gnaphalium pensylvancium* and *Setaria pumila* were dominant at low elevation site with IVI of 20.3, 18.9 and 17.3, respectively. In case of medium elevation site, *Phleum* sp. (27.2) *Pteris* sp. (23.3) and *Cyclosorus apendiculatum* (23.3) were dominant with high IVI whereas, *Pteris* sp. (32.3) and *Dryopteris sparsa* (28.4) were the dominant herbs in high elevation site with high IVI. In case of saplings, *P. merkusii* had highest IVI in all the three elevation sites followed by saplings of *Toona ciliata*, *Elaegnus* sp. and *Ficus semicordata*. Among the seedlings, *P. merkusii* was the most dominant species with highest IVI values at all the three elevation sites (Supplementary 1).

Distribution pattern, similarity index and β diversity

Whitford's Index revealed that most of the plant species in the three elevation sites had clumped

Table 4. Similarity Index (%) of tree (T), sapling (SP), shrub (SH), seedling (SD) and herb (H) in three study sites.

Sites		Walong (Low elevation)						Namti (Medium elevation)					
		A	T	SP	SH	SD	H	A	T	SP	SH	SD	H
Dong (High elevation)	A	39	–	–	–	–	–	59	–	–	–	–	–
	T		28	–	–	–	–	–	47	–	–	–	–
	SP			33	–	–	–	–	–	46	–	–	–
	SH				25	–	–	–	–	–	45	–	–
	SD					91	–	–	–	–	–	90	–
	H						53	–	–	–	–	–	76
Walong (Low elevation)	A							54	–	–	–	–	–
	T								50	–	–	–	–
	SP									31	–	–	–
	SH										55	–	–
	SD											100	–
	H												71

Table 5. Density (individuals ha^{-1}), basal cover ($m^2\ ha^{-1}$) and girth class distribution in three study sites.

Girth Class	Walong (Low elevation)		Namti (Medium elevation)		Dong (High elevation)	
	Density	Basal cover	Density	Basal cover	Density	Basal cover
30–60	866	9.95	610	5.99	528	7.27
60–90	138	5.99	130	7.87	176	8.28
90–120	72	6.59	82	7.52	114	10.26
120–150	30	3.78	58	8.24	52	6.73
150–180	2	0.38	20	4.48	2	0.38
180–210	10	2.96	22	7.07	14	4.23
>210	6	3.14	20	13.15	10	4.75
Total	1124	32.83	942	54.34	896	41.92

distribution pattern. At low elevation site, 93% of the total plant species exhibited clumped distribution and the remaining species showed random distribution. At medium elevation site, 95% of the total plant species showed clumped distribution, while 3% were distributed randomly and only 2% showed regular distribution. At high elevation site, 81% of the total plant species showed contagious distribution, whereas 17% were under random distribution and only 2% showed regular distribution.

Sorensen's similarity index revealed highest similarity of plant species composition between high and medium elevation sites with 59% similarity. There was 54% similarity between low elevation site and medium elevation site. There was very less similarity in plant composition between the low elevation site and high elevation site with an index of 39% (Table 4). Further, β diversity among the three study sites was highest between low elevation site and high elevation sites followed by medium elevation site and low elevation site with 0.71 and 0.46, respectively and lowest between medium and high elevation sites with 0.39.

Density, girth class and basal cover

Kruskal-Wallis test revealed that there was a significant difference in tree density among the three elevation sites ($\chi^2 = 12.72$, $P < 0.05$). The highest tree density was recorded at low elevation site (1124 ± 380 individuals ha^{-1}) followed by medium elevation site (942 ± 279 individuals ha^{-1}) and lowest at high elevation site (896 ± 264 individuals ha^{-1}) (Table 4). Though the density of other tree species decreased with increase in elevation, density of *P. merkusii* increased with increase in elevation (Figure 2). Tree basal cover in the three elevation sites also differed significantly, where highest basal cover was recorded at medium elevation site (54.34 $m^2\ ha^{-1}$)

followed by the high elevation site (41.92 m^2 ha^{-1}), and it was lowest at low elevation site (32.8 m^2 ha^{-1}) (χ^2 = 42.01, P < 0.05) (Table 4). Studies on girth class distribution pattern revealed decrease in number of individuals with increase in girth class at all the three elevation sites, whereas highest number of individuals was recorded between the girth classes of 30–60 cm. However, relative contribution of different girth classes to the total basal cover differed among the three elevation sites. At low elevation site, there was a significant contribution by the trees of 30–60 cm girth class to the total basal cover, whereas at medium elevation site, significant contribution to basal cover was made by the individuals having girth >210 cm. The individuals between 90–120 cm girth class contributed highest to the total basal cover at high elevation site (Table - 6). At all the three elevation sites, *P. merkusii* contributed maximum to the total basal cover (Fig. 2).

Discussion

The study revealed that highest number of plant species belonged to the family Fagaceae, Poaceae, Lauraceae and Rosaceae followed by Asteraceae, Urticaceae and Lamiaceae at all the three elevation sites. These families were also reported to be dominant in the Subtropical Karst Forests in South–West China (Zhang *et al.* 2002). The dominance of plants under Rosaceae, Pteridaceae, Lamiaceae, Pinaceae and Asteraceae families was also reported from the temperate forests of Pakistan (Raja *et al.* 2014). Gentry (1988) also reported the dominating character of the species under Fagaceae family in the North Temperate and South Temperate areas of the world along with gymnosperms. The findings of the present study was also supported by many reports, where plants belonging to Asteraceae, Poaceae, Ericaceae, Lauraceae and Rosaceae families showed dominating character in temperate forests of Arunachal Pradesh (Behera 2002; Bharali *et al.* 2011; Paul 2008).

Species richness recorded in this study with only 98 plant species at all the three study sites was poor. A total of 181 species were reported from Gharwal Himalaya (Semwal *et al.* 2010), 143 species in temperate forests of northwestern Ethiopia (Zegeye *et al.* 2011), 113 species in temperate forests of Subansiri district of Arunachal Pradesh, India (Behera & Khushwaha 2007), 112 species in Himalayan subtropical scrub forests and Himalayan subtropical pine forests of Kandi Siwaliks of Jammu and Kashmir (Sharma & Kant 2014) and 110 species in *Pine–Quercus* dominant forests of Nikya hills in Pakistan (Amjad *et al.* 2013). In contrary, species richness of the present study was higher than it was reported in temperate and subalpine coniferous forests of Subansiri district (Behera *et al.* 2002) and temperate forests in West Siang district of Arunachal Pradesh (Bharali *et al.* 2011). Frequent forest fire by local inhabitants for fodder production, hunting of wild animals and firewood collection, habitat destruction by defense personnel for regular surveillance at international borders may be the cause for poor species richness in all the study sites. Loss of forest cover and diversity due to forest fire was also reported by Negi *et al.* (2012). Similar findings on the reduction in species richness of smaller diameter class due to regular disturbance in the natural forest was also reported by Arthur and his coworkers (1998). Moreover, being fire hardy and drought tolerant, *P. merkusii* survived frequent fire with cold air and dry soil conditions during winter season. Whereas, most of its plant associates were removed due to such disturbances and harsh climate and soil conditions resulting at poor species richness in all the three sites.

There was a reduction in species richness index, α diversity index and Shannon-Weiner diversity index with increasing elevation. The species diversity reduced with increase in elevation and it is in conformity with the observations made by several workers (McCain & Grytnes 2010). In the present study we have also encountered similar pattern of decreased species richness index with the increase in elevation which is supported by the findings of many other workers (Bharali *et al.* 2011; Ghimire *et al.* 2008; Kharkwal *et al.* 2005; Wang *et al.* 2007). It is well established fact that, species richness index is dependent on multiple locality factors, such as, climatic factors, slope, temperature, solar radiation and soil (Lomolino 2001), where these factors might have also played a key role in resulting low species richness index in the present study sites. Barry (2008) reported that with 100 meter increase in elevation, air temperature decreases by approximately 0.6 °C. Such changes in abiotic factors might have created heterogeneous environmental conditions in each elevation site with the reduction in growing season and in turn determining the species composition of a forests (Korner 1998).

Pinus merkusii dominated at all the three study sites. Similar findings in *Pinus roxburghii* forests in Garhwal Himalaya was reported by

Khali & Bhatt (2014) and in *Pinus wallichiana* forests in Western Himalaya of Jammu and Kashmir was reported by Sharma & Raina (2013).

This study also revealed that most of the plant species were under contagiously distributed whereas a very few were under random distribution. Similar type of distribution pattern in natural forests was reported by many workers (Kumar & Bhatt 2006; Mehta *et al.* 1997; Singh *et al.* 2009). It is a well-established fact that in natural forests, most of the plant species are distributed contagiously. The random distribution indicates stable habitats and the regular distribution pattern indicates the existence of severe compe-tition among the species (Odum 1971).

There was a reduction in tree density with the increase in elevation and it was within the range of the findings in temperate *Rhododendron* forests of Arunachal Pradesh (Paul 2008) and temperate forest of Kumaun Himalaya (Saxena & Singh 1982). In spite of highest density of trees, lowest basal cover was recorded at low elevation site. It could be due to the occurrence of large number of individuals in lower girth class of 30–60 cm with less number of individuals in high girth class compared to the other two sites. Except *P. merkusii,* the remaining tree species did not have individuals with larger girth class, thus *P. merkusii* dominated in all the three elevations. Overall tree density decreased with increase in elevation, although, density of *P. merkusii* increased with the increase in elevation. This has contributed significantly to the total basal cover of the species, which also increased with the increase in elevation. However, the less number of seedling and saplings of *P. merkusii* in the study area is a matter of concern for its perpetuation. As such, out of the 46 recorded tree species, seedlings of only six tree species and saplings of only 11 tree species were record from all the three elevation sites. This indicates the impact of prevailing anthropogenic disturbances on natural habitats of these species.

The ecological data gathered in the present study on the natural pine forest dominated by *Pinus merkusii* should be helpful in framing conservation strategies for protecting this unique but vulnerable forest type.

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Table S1. Structure and composition of trees, saplings, shrubs, seedlings and herbs in the three studied sites (Density in ha^{-1} and basal area in $m^2\ ha^{-1}$).