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Community structure and regeneration status of tree species in Eastern Himalaya: A case study from Neora Valley National Park, West Bengal, India

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ABSTRACT: The phytosociological attributes of temperate forests were investigated in the Upper Range, Neora Valley National Park (NVNP), Eastern Himalaya. The area was grouped into three altitudinal zones viz., lower, middle and upper temperate and tree species were sampled at three life stages (seedlings, saplings and mature trees). The average species richness of trees, saplings and seedlings per forest stands was 15.67 ± 4.04, 14.0 ± 3.61 and 14.67 ± 1.53 respectively which reflects a medium diversity status. The mean density of seedlings (32278.6 ± 3713.13 ha^{-1}) > saplings (840 ± 141.07 ha^{-1}) > trees (248.5 ± 22.79 ha^{-1}). Basal area ranged from 9.36 m^2 ha^{-1} to 29.95 m^2 ha^{-1} for trees, from 1.34 m^2 ha^{-1} to 2.07 m^2 ha^{-1} saplings and from 1.92 m^2 ha^{-1} to 5.75 m^2 ha^{-1} for seedlings at different study sites. It was observed that majority of the tree species at all life stage showed contiguous distribution pattern. Good regeneration status was recorded for maximum species at all the sites. Density-diameter distribution exhibited decrease in tree densities towards higher DBH classes. The present study has provided a baseline data for the long term monitoring of tree communities in the area that will help to assess the effect of present ecological consequences of ongoing and future climate changes.

KEY WORDS: Beta diversity, DBH classes, Dominance, Eastern Himalaya, India, Regeneration status, Species richness.

INTRODUCTION

The quantitative analysis of community composition and structure is prerequisite for the precise evaluation of biodiversity (Oosting, 1956; Singh *et al*., 2014). In a climax forest ecosystem, tree is fundamental component as it influence the resources and habitats for almost all other forest organisms. The sub-tropical and temperate forests of eastern Himalaya are having luxuriant vegetation rich in trees species due to its favorable climatic parameters. However assessment of tree communities are usually site specific and provides a reliable data on various ecological attributes such as composition, abundance, distribution and dominance which ultimately help in understanding the natural regeneration processes and dynamics (Logman and Jenik, 1987; Puhlick *et al*., 2012; Sarkar and Devi, 2014). Quantitative analysis is not only crucial for planning, carrying out management and conservation activities (Eilu and Obua, 2005; Mwavu and Witkowski, 2009; Mishra *et al*., 2013; Malik and Bhatt, 2015) but also known as key criterion for planning and interpreting long-term ecological research (Phillips *et al*., 2003; Condit, 1995). Various changes are appearing in the Himalayan forests in terms of their structure, density and composition due to global warming (Gaur, 1982; Malik *et al*., 2016) and on account of habitat destruction and over-exploitation of forest resources (Bargali *et al*., 1998; Kumar *et al*., 2004). Thus, conducting the detailed ecological study in Himalayan forest is necessary which will provide a baseline data for the long term monitoring processes and also to assess the different ecological consequences of ongoing and future climate changes. An insight to the stable natural regeneration of woody species and their population structure plays a key role in the promotion of their suitable management, utilization and conservation (Mwavu and Witkowski, 2009a). Several studies in temperate forests of western Himalaya demonstrate quantitative assessment of plant diversity and tree regeneration (Rao *et al*., 1990; Pande *et al*., 2001; Pant and Sammant, 2012; Raturi, 2012; Pala *et al.* 2013; Ballabha *et al.,* 2013). However, data on eastern Himalayan temperate forests are scanty. Therefore, in the present communication an attempt was made to assess the tree community structure and regeneration status of one of the important protected areas in eastern Himalayan landscape, i.e., Neora Valley National Park (NVNP).

MATERIALS AND METHODS

Study area

The Neora Valley National Park (NVNP) is situated in the eastern Himalayan landscape, between latitude 26º52' to 27º07'N and longitude 88º45' to 88º55'E

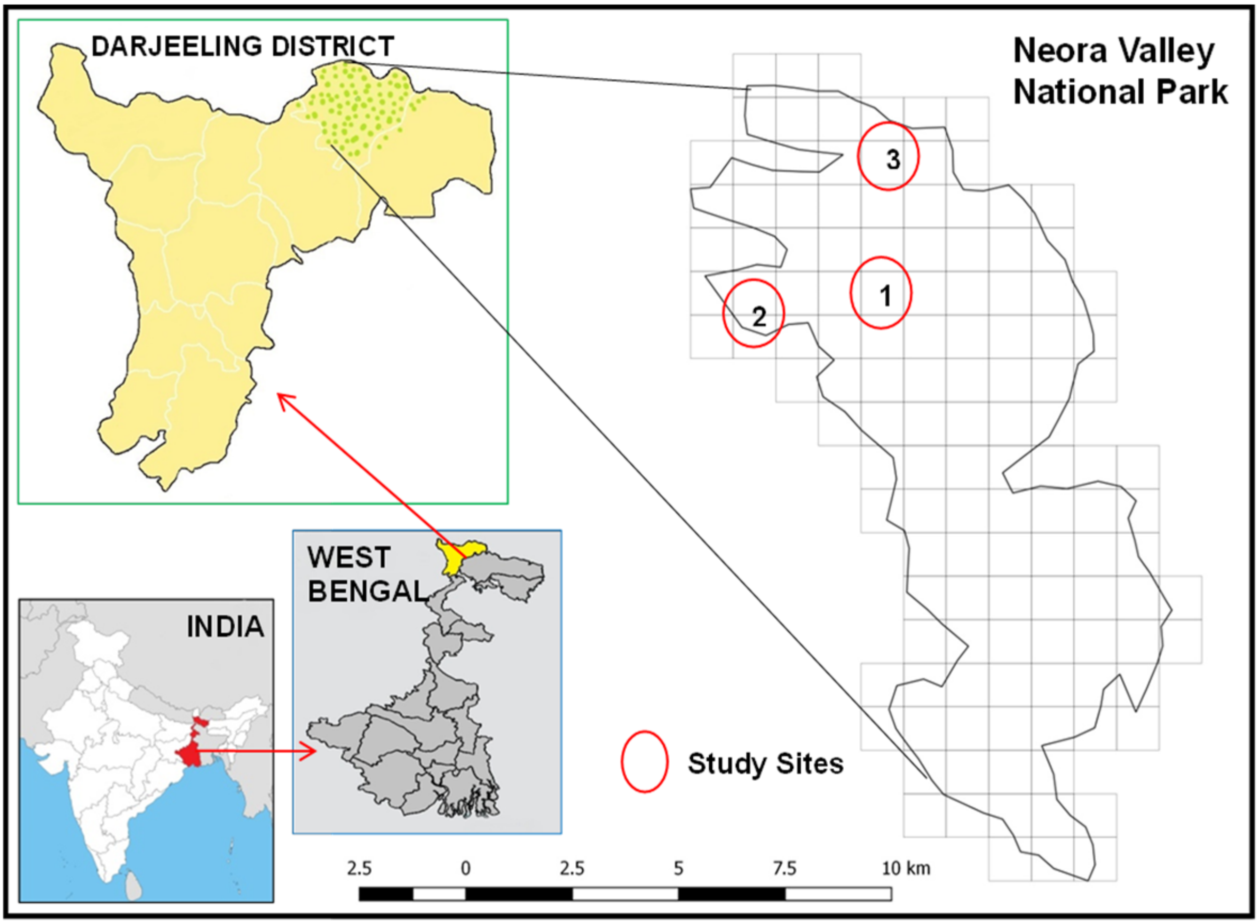

Fig. 1. Map showing study area (1=LT, 2=MT and 3=UT)

covering an area of 159.89 km^2 (**Fig. 1**). It is delimited by Sikkim, Bhutan and Jalpaiguri district (West Bengal) at its northern, north–eastern and southern boundaries respectively. The park covers a wide range of altitude (183–3200 m msl), habitats and climatic conditions. The park represents tropical, sub-tropical, temperate and sub-temperate forests which are a great wealth of biodiversity of eastern Himalayas (Mallick, 2010). Neora river with its numerous streams and offshoots provides a perennial drainage system for the park which is flowing from north to south direction. Administratively, the park was divided into two ranges, viz., Upper Neora Range (HQ Lava) and Lower Neora Range (HQ Samsing). The present study restricted to the temperate zone (Upper Neora Range, above 2100 m) of the park. The climate of the park is north east monsoonic. Rainy (mid-June to September), winter (October to February) and summer (March to mid-June) seasons are well marked due to fluctuation in weather conditions. The area is influenced by the norhthest monsoon with annual average precipitation of 635 cm (Indiatour, 2017). Mean monthly temperature fluctuates between 0 °C (in January) to 20 °C (in June). The average relative humidity varies from 40 % to 90 %.

Field survey and data collection

The Upper Neora Valley was grouped in the three altitudinal zones, i.e., lower (LT), middle (MT) and upper temperate (UT) for sampling during the field survey in year 2016. Characteristic features of these forest stands (study sites) are summarized in **Table 1.** Tree species compositions were assessed through quadrat method at three life stages, viz., seedlings, saplings and trees (adult). Circumference (C) was used to differentiate life stages into mature trees (C ≥30 cm, at 1.37 m above ground level), saplings (C = 10.5–31.4 cm) and seedlings (C < 10.5 cm) following Knight (1963). A total ten plots of 400 m^2 size were laid randomly in each stands for tree layer (10 plots × 3 sites = 30 plots), while four quadrats (25 m^2 size) for saplings (30 tree plots × 4 = 120 quadrats) and eight quadrats (1 m^2 size) for seedlings (30 tree plots × 8 = 240 quadrats) nested within each tree quadrat. The number of individuals of each species were counted within respective quadrats and recorded. Circumference measured with help of graduated tape in trees and by calipers in case of saplings and seedlings. Species occurred within each plots were collected and a particular code was given to each of unidentified

Table1. General details of the study sites in the Neora Valley National Park (NVNP).

Sl. No	Study sites (abbreviation)	Name of forest area	Altitude (m asl)	Coordination	Common tree species (IVI)
1.	Lower temperate (LT)	PHE Source	2156 – 2229	27º05'42.3" to 27º06'12.7"N & 88º43'21.5"–88º43'34.8"E	*Lithocarpus pachyphyllus* (168.49), *Machilus duthiei* (40.07), *Quercus lamellosa* (27.98) and *Lindera nacusua* (17.71).
2.	Middle temperate (MT)	Chaudapheri	2359 – 2474	27º05'25.8" to 27º05'42.2"N & 88º42'3.3"–88º42'26.2"E	*L. pachyphyllus* (59.97), *Quercus thomsoniana* (31.1), *Rhododendron arboretum* (26.29), *Pinus* sp. (22.52).
3.	Upper temperate (UT)	Alubari	2463 – 2845	27º07'27.9" – 27º08'1.9"N & 88º42'48.5" – 88º43'36.4"E	*L. pachyphyllus* (96.32), *Eurya acuminate* (34.44), *Magnolia globosa* (29.26), *Lyonia ovalifolia* (25.34), *R. arboreum* (24.69).

species (when vegetative stage) and processed for herbarium following standard botanical practice (Jain and Rao, 1977).

Data analysis

The collected plant specimens were identified with help of literature (Hooker 1872–97; Prain, 1963; Grierson and Long, 1987; Polunin and Stainton, 1984; Anonymous, 2016) and herbarium (CAL). The ecological data was computed for frequency (dispersion of species in a community), density (the number of individuals per unit area), abundance (the number of individuals per sampling unit of occurrence) and basal area (the area actually occupied by the stem near the ground surface) following Misra (1968) and Mueller-Dombois and Ellenberge (1974).

Importance value index (IVI) of each species was calculated by summing relative frequency, relative density and basal area as per Curtis (1959). Total species count in each site was taken as species richness (Phillips, 1959). Shannon-Wiener diversity index (Shannon and Wiener, 1963), concentration of dominance (Simpson, 1949) and beta diversity (Whittaker, 1972) were calculated for each site using following formula.

Shannon-Wiener diversity index $(\bar{H}) = -\sum_{i=1}^{s}\left(\frac{N_i}{N}\right)\log_2\left(\frac{N_i}{N}\right)$,
Where; Ni = importance value index of a species;
N = total importance value index of all the species.

Concentration of dominance (Cd) $= \sum_{i=1}^{s}\left(\frac{N_i}{N}\right)^2$,
where; Ni and N are similar as in Shannon-Wiener diversity index.

Beta diversity $(\beta - \text{Div}) = \frac{Sc}{S}$,
where, Sc = total number of species occurring in a set of samples counting each species only once whether or not it occurred more than once; S = average number of species per individual sample.

The regeneration status of tree species was determined on the basis of population size of seedlings and saplings following Shankar (2001). Good regeneration, i.e., if particular species is present in seedlings > saplings > trees; fair regeneration, i.e., if species present in seedlings > saplings ≤ trees; poor regeneration, i.e., if a species survives only in sapling stage, but not as seedling; if a species is present only in adult form it is considered as not regenerating. A species is considered as new if the species has no tree representatives, but only saplings and/or seedlings. Further, tree individuals were divided into six diameter classes at breast height (DBH), i.e., 10–20 cm, 21–30 cm, 31–40 cm, 41–50 cm, 51–60 cm and > 60 cm (Rao *et al.*, 1990). The density-diameter distribution of trees were calculated to understand the pattern of regeneration of each forest stand.

RESULTS

Species richness and density

A total of 28 species belongs to 21 genera and 15 families were recorded from three sampling sites. *Rhododendron* with 3 species revealed as most dominant genus followed by *Ilex*, *Lindera*, *Quercus* and *Viburnum* (2 species each). Among family, maximum species (5 species) belonged to Lauraceae followed by Ericaceae (4 species) and Fagaceae (3 species). The consolidated phytosociological attributes and diversity indices of studied forest stands are shown in **Table 2**. Ecological parameters like density, basal area (BA), importance value index (IVI) and distribution pattern have been calculated for each species of trees (**Appendix 1**), saplings (**Appendix 2**) and seedlings (**Appendix 3**) at each site. Species richness of trees varied from 12–20 (15.67±4.04), saplings 11–18 (14±3.61) and seedlings 13–16 (14.67±1.53) at different sites. Total tree density for study sites varied from 222.5–265 ha^{-1} (248.67±22.79), saplings 690–970 ha^{-1} (840.0±141.07) and seedlings 28000–34667 ha^{-1} (32278±3712.13). Tree basal area recorded maximum (29.95 m^2 ha^{-1}) at site LT and minimum (9.36 m^2 ha^{-1}) at UT. Average basal area per site for trees, saplings and seedlings found 18±7.54 m^2 ha^{-1}, 1.75±0.37 m^2 ha^{-1} and 3.53±1.99 m^2 ha^{-1} respectively. Basal area ranged between 9.36 m^2 ha^{-1} and 29.95 m^2 ha^{-1} for trees, 1.34 m^2 ha^{-1} and 2.07 m^2 ha^{-1} for saplings, whereas it varied from 1.92 m^2 ha^{-1} to 5.75 m^2 ha^{-1} for seedlings.

Distribution and dominance

It is observed that majority of the tree species at all life stage showed contiguous distribution pattern, while regular distribution pattern recorded for few species

Table 2. Phytosociological attributes and diversity indices of the study sites.

Variable	Trees			Saplings			Seedlings		
	LT	MT	UT	LT	MT	UT	LT	MT	UT
No. of plots	20	20	20	40	40	40	80	80	80
Size of plots (m^2)	400	400	400	25	25	25	01	01	01
Actual sampled area (ha)	0.80	0.80	0.80	0.10	0.10	0.10	0.008	0.008	0.008
No. of species	12	20	15	11	18	13	13	15	16
No. of genera	12	18	14	11	16	09	11	13	13
No. of families	10	14	12	08	12	08	09	09	10
Density ($ind.ha^{-1}$)	222.5	258.0	265.0	970	690	860	34167	28002	34667
Basal Area (m^2 ha^{-1})	29.95	9.36	14.69	2.07	1.34	1.85	1.92	2.92	5.75
Diversity index ($\bar{H}$)	1.58	2.78	2.27	3.01	2.08	2.52	2.07	2.27	2.38
Beta diversity (β - Div)	3.87	3.13	2.83	6.29	12.00	7.88	6.19	7.96	7.44
Concentration of dominance (Cd)	0.35	0.09	0.15	0.15	0.10	0.15	0.16	0.13	0.11

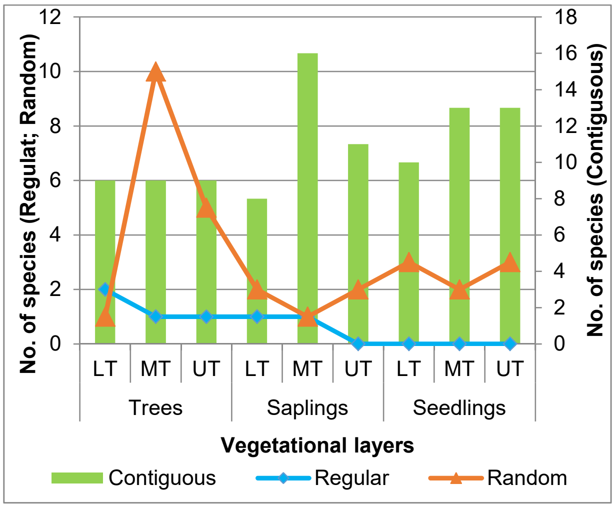

Fig. 2. Distributions trees, saplings and seedlings at different study sites.

among trees and saplings (**Fig. 2**). *Lithocarpus pachyphyllus* revealed as the most dominant tree species in the area represented IVI 168.49, 59.97 and 96.32 at site LT, MT and UT respectively. It was followed by *Machilus duthiei* (IVI 40.07) at LT, *Eurya acuminate* (IVI 34.44) at UT and *Quercus thomsoniana* (IVI 31.10) at MT. In saplings stratum, *Viburnum nervosum* revealed as most dominant species at UT (IVI 68.43) and MT (IVI 52.68), while *Symplocos* sp. (IVI 81.65) at LT. Among seedling, *Symplocos* sp. had maximum IVI (81.29) at LT, *V. nervosum* (IVI 77.90) at MT and *E. acuminate* (IVI 47.89) at UT respectively. The density-dominance curves (d-d curve) of trees and saplings were geometric or log series while in case of seedlings log normal were of common (**Fig. 3**).

Regeneration status

The regeneration status of each tree species at different study sites are shown in **Table 3.** Proportion of fair, good, new, not and poor regeneration statuses are shown in **Fig. 4**. Good regeneration status was recorded for maximum species at all the sites. Density-diameter distribution exhibited decrease in tree densities towards higher DBH classes **(Fig. 5)**.

Table 3. Regeneration status of tree species in study area.

Name of species	Study sites		
	LT	MT	UT
Acer campbellii Hook.f. & Thomson ex Hiern	Fair	Not	Fair
Betula alnoides Buch.-Ham. ex D.Don	–	Fair	–
Cryptomeria japonica (Thunb. ex L.f.) D.Don	–	Poor	–
Eurya acuminate DC.	Good	Good	Good
Evodia fraxinifolia (Hook.) Benth.	–	Good	–
Ilex dipyrena Wall.	New	–	Poor
Leucosceptrum canum Sm.	–	–	Good
Lindera sp.	–	New	New
Lindera nacusua (D.Don) Merr.	Good	Good	Good
Lithocarpus pachyphyllus (Kurz) Rehder	Fair	Good	Good
Litsea elongate (Nees) Hook.f.	Not	New	–
Lyonia ovalifolia (Wall.) Drude	–	Good	Good
Machilus duthiei King	Good	Poor	Fair
Magnolia globose Hook.f. & Thomson Hook.f. & Thomson	Not	–	Fair
Neolitsea umbrosa (Nees) Gamble	Fai	Fair	–
Pinus sp.	–	Good	–
Quercus lamellosa Sm.	Fair	Poor	Not
Quercus thomsoniana A.DC.	Fair	Good	–
Rhododendron arboretum Sm.	Good	Good	Good
Rhododendron falconeri Hook.f.	–	New	Good
Rhododendron grande Wight	–	Not	Not
Schefflera rhododendrifolia (Griff.) Frodin	New	Poor	Fair
Symplocos sp.	Good	Good	Good
Tsuga dumosa (D.Don) Eichler	–	Not	–
Sterculia sp.	–	Poor	–
Viburnum sp.	–	–	New
Viburnum nervosum D.Don	Good	Good	Good
Ilex crenata Thunb. var. *thomsoni* (Hook.f.) Loes	Good		New

Maximum tree individuals (50.7%) were observed in the lowest DBH class (10–20 cm) in the area, followed by 21–30 cm (21.28%), 31–40 cm (10.5%), while minimum (0.7%) in the class 61–70 cm. Lowest DBH class (10–20 cm) covered 65.71% of total individuals at UT, 57.01% at MT and 25.88 % at LT. Distribution of tree individuals at MT restricted to the DBH class 41–50 cm as none of the individuals occurred in higher DBH classes (above 41–50 cm).

DISCUSSION

The recorded values for various parameters viz., species richness, density, basal area, Shannon-Wiener

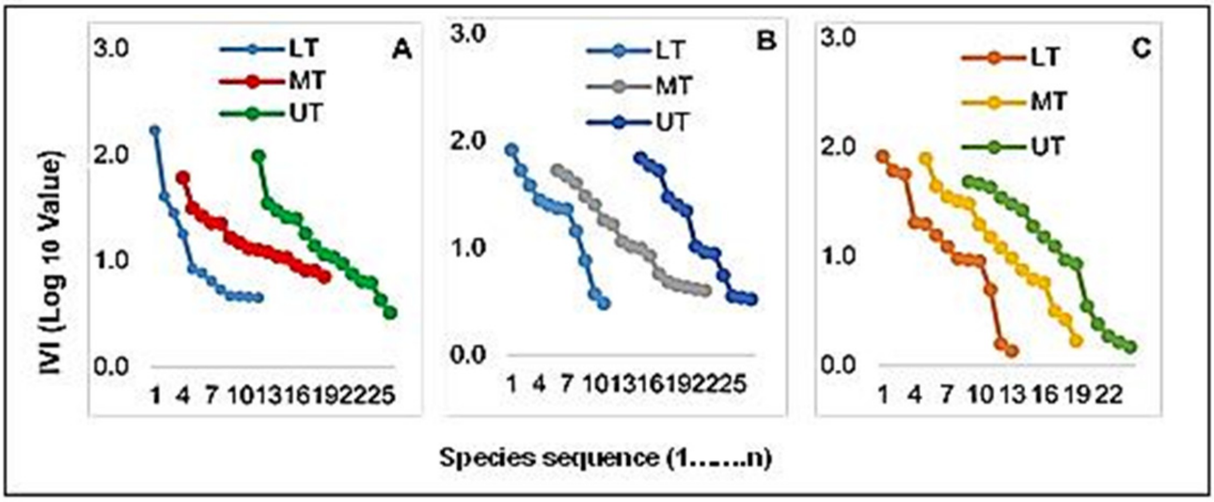

Fig. 3. Dominance-diversity curves (d-d curve): **A**. Trees, **B**. Saplings and **C**. Seedlings.

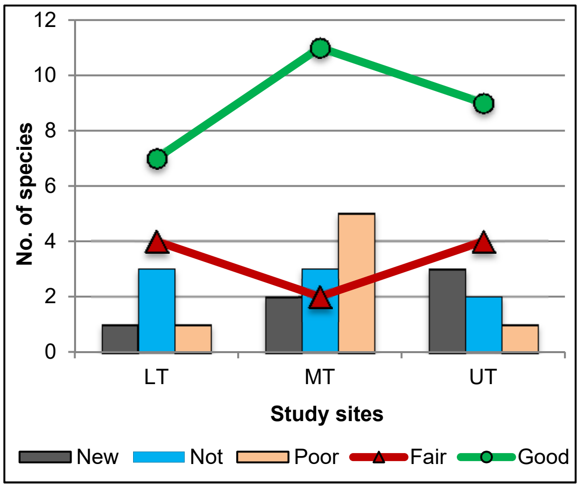

Fig. 4. Regeneration status of tree species at various study sites.

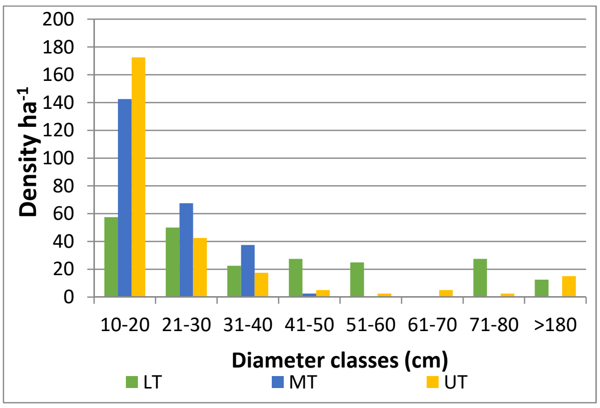

Fig. 5. Distributions of tree individuals in different diameter classes.

diversity index, concentration of dominance and beta diversity are compared to the earlier reported values from different Himalayan forests (**Table 4).** The variations in phytosociological attributes in temperate Himalayan forest could be influence by environmental variable (soil conditions, slope angle, species composition, elevation, regional climate and topography), biotic and anthropogenic interferences (Billings, 1952; Douglas and Bliss, 1977). Apart from this, the forest succession, are also responsible for both locality and landscape-level variations in forest attributes, thereby producing spatial heterogeneity (Timilsina *et al*., 2007). In the present study, species richness of trees and saplings recorded maximum at middle altitude (MT), intermediate at upper (UT) and minimum at lower altitude (LT). Tree density, seedlings species richness and seedlings basal area followed a trend of increasing (from LT–UT) with increased in altitude (LT–UT). Basal area of trees and saplings were recorded maximum at lower altitude (LT) and minimum at middle (MT) while intermediate at upper altitude (UT). Lower species richness and density at LT than MT and UT could be due to higher total basal area (TBA) of trees which is three time high (29.95 m^2 ha^{-1} trees) than the UT (9.36 m^2 ha^{-1}). At LT, *Lithocarpus pachyphyllus* (IVI 168.49) covered 77.78 % (23.30 m^2 ha^{-1}) of total tree basal area, thus, revealed as a sole dominant tree species. Sagar *et al*., (2008) also confirmed that the species richness decreases with an increased in species dominance.

The distribution of tree species in all life stages (seedlings, saplings and trees) revealed that contiguous distribution pattern which substantiate the hypothesis that contiguous distribution is common in nature, while random distribution is found only in uniform environments (Odum, 1971). The density-dominance curves (d-d curve) of trees showed geometric series curve. The steep gradient indicated low evenness in dominance (IVI) among the high ranking species (Odum, 1971). *Lithocarpus pachyphyllus* found the most dominant species at all three sites, have much higher IVI than the low ranking species. Saplings represented geometric or log series while seedlings log

Table 4. Comparison of earlier reported phytosociological attributes of Himalayan forest with the results of the present study.

Forest type (no. of stands studied)	Altitude range (m)	SR	Density (ind. ha^{-1})	Basal Area (m^2 ha^{-1})	H	B–div	Cd	Ep	Ref. **
Trees									
Temperate (03), NVNP	2156–2845	15.67±4.04	248.5±22.79	18±10.69	2.19±0.57	3.28±0.54	0.2±0.14	1.15±0.20	**Ref. 1**
Motane (06), Uttarakhand	1400–3000	13.83±3.31	848.33±268.88	37.63±14.66	3.13±0.35	3.31±0.51	0.17±0.04	1.20±0.05	Ref. 2
Temperate (03), Garhwal	900-2600	16.33±4.41	393.33±110.39	24.28±12.05	3.01±0.46	-	0.08±0.02	-	Ref. 3,4
Temperate (04), Garhwal	-	10.41±1.08	994±252	58.73±21.53	2.51±0.36	-	0.12±0.06	0.82±0.05	Ref. 5
Tropical (04), Manipur	300-360	3-4	685-920	-	0.11-1.18	-	0.56-0.97	-	Ref. 6
Temperate (09), Kashmir	-	7-10	685-921	-	0.97-1.62	3.98-4-85	0.26-0.56	0.39-0.78	Ref. 7
Saplings									
Temperate (03), NVNP	2156–2845	14±3.61	840±141.07	1.75±0.37	2.25±0.24	8.72±2.95	0.13±0.03	1.24±0.03	**Ref. 1**
Motane (06), Uttarakhand	1400–3000	12.0±2.76	628.33±291.92	1.93±1.16	3.09±0.40	2.72±0.47	0.15±0.05	1.25±0.11	Ref. 2
Temperate (03), Garhwal		18.0±5.06	3056±1396.69	1.94±0.46	2.98±0.46	5.09±0.68	0.13±0.07	1.03±0.10	Ref. 3,4
Tropical (04), Manipur	300-360	2-3	95-795	-	0.11-1.19	-	0.56-0.98	-	Ref. 6
Tropical (01), Assam		34	442±27	88.87±9.45	2.43	-	0.19	0.69	Ref. 8
Seedlings									
Temperate, NVNP	2156–2845	14.67±1.53	32278.6±3712.1	3.53±1.99	2.24±0.16	7.20±0.91	0.13±0.03	1.21±0.04	**Ref. 1**
Motane (6), Uttarakhand	1400–3000	14.67±2.875	1283.33±682.69	0.34±0.17	3.26±0.32	3.32±0.53	0.14±0.03	1.24±0.16	Ref. 2
Temperate (03), Garhwal		12.33±4.58	4310±2154.54	0.033±0.019	2.79±0.57	3.86±0.38	0.21±0.11	1.13±0.08	Ref. 3,4
Tropical (04), Manipur	300-360	3	7300-15500	-	0.63-.76	-	0.71-.73	-	Ref. 6

Ref.1= **Present study, Ref. 2= Singh (2016), Ref.3= Malik (2014), Ref. 4= Malik & Bhatt (2016), Ref. 5= Pala *et al.* (2016), Ref.6= Devi *et al.* (2006), Ref. 7= Raizada & Juyal (2012), Ref. 8= Dutta & Devi (2013).

normal due to the less difference in IVI of species, indicating the co-dominance among the species.

The future composition of a forest stands can be determined by the density of seedlings, saplings and mature trees within that particular community (Austin, 1977). In present study, good regeneration status (density of seedling > saplings > trees) was recorded for 7, 11 and 9 species at LT, Mt and UT respectively while few species showed fair, new, not and poor regeneration statuses. In general all three forests stands were regenerating, having good population of seedlings and saplings as this is a protected area where collections of fodder and fuel wood are not allowed. However, the virgin canopy cover (large and medium sized trees) of these evergreen broad leaved forests and abundant undergrowth of naturalized bamboo may be affecting the survival of seedlings (especially of poor, not regenerating species) in the area, because radiation intensity decrease exponentially with increasing amount of canopy cover at top and middle story. Further, the numbers of herbivore wild animals are always high in protected area.

In the present study, diversity index ranged from 1.58 (LT) to 2.27 (UT) for trees which are lower to those of reported from western himalayan temperate forests of Garhwal (Singh, 2016; Malik, 2014; Malik and Bhatt, 2016); higher to temperate forests of Kashmir Himalaya (Raizada and Juyal, 2012) and tropical forests of eastern Himalaya (Devi *et al*., 2006). Diversity index recorded from 2.08 (MT) to 3.03 (LT) for saplings and 2.07 (LT) to 2.38 (MT) for saplings, which are comparable to the earlier studies (Singh, 2016; Malik and Bhatt, 2016).

The beta diversity values for tree species reported from this study ranged from 2.13 (UT) to 3.87 (LT) for trees. These values are similar to those reported by earlier workers (Singh, 2016; Malik, 2014) for trees. Beta diversity varied from 6.29 (LT) and 12.00 (MT) for sapling and from 6.19 (LT) to 7.96 (MT) for seedling, which are higher to the earlier reported value by Singh (2016) and Malik (2014).

The concentration of dominance (Cd) ranged from 0.09 (MT) to 0.35 (LT) for trees, 0.10 (LT, UT) to 0.15 (MT) for samplings and from 0.11 to 0.16 for seedlings in present study. The values of diversity index and Cd were inversely related with each other in the study area, which is indicated that the higher species diversity negatively affect the Cd.

The diameter distribution of trees has often been used to represent the population structure of a forests stand (Saxena and Singh, 1984; Khan *et al*., 1987) and to predicted regeneration status of trees species by age and diameter structure (Vablen *et al*., 1979). It is evident from the **Fig. 3** that tree species possesses higher number of individuals in the lower DBH classes and decrease towards higher classes. The decrease in densities towards higher DBH class was abrupt at MT and UT is the indicatives of good regeneration potential. Higher densities of the trees in medium to lower girth classes suggests the forests are still in evolving stage (Campbell *et al*., 1992). However, the decreased in densities towards higher DBH class in not abrupt at LT, indicates that the forest is mature and old. *Lithocarpus pachyphyllus*, represented all diameters classes at LT and also covered maximum classes at MT and UT, revealed as most dominant species. Species represented by more individuals in higher DBH classes than the lower in any forest considered on the threshold of extinction from that particular forest (Kennedy and Swaine, 1991).

CONCLUSION

Assessment of diversity and regeneration status of tree species is important for their sustainable utilization, management, and conservation. The present study revealed that, all three forests stands of NVNP were contributing a good number of seedlings and saplings and also regenerating, with an overall regeneration status of "good". The overall future community structure may be sustained unless there is a major environmental or ecological stress. The reasons and significances of poor regeneration status of some tree species are need to be studied along with a systematic management plan which is required for their conservation and sustainable utilization.

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Appendix 1. Density (ind. ha^{-1}), basal area (m^2 ha^{-1}) and IVI of tree, sapling and seedling.

Name of species	Lower temperate				Middle temperate				Upper temperate			
	DEN.	COV.	IVI	DIST.	DEN.	COV.	IVI	DIST.	DEN.	COV.	IVI	DIST.
Trees												
Acer campbellii	2.5	0.07	4.59	Co	8	0.40	11.88	Ra	8	0.10	9.22	Ra
Betula alnoides	–	–	–	–	23	0.54	22.34	Ra	–	–	–	–
Cryptomeria japonica	–	–	–	–	10	0.41	12.94	Ra	–	–	–	–
Eurya acuminata	5	0.27	6.38	–	13	0.13	12.46	Ra	45	0.58	34.44	Ra
Evodia fraxinifolia	–	–	–	–	8	0.04	8.05	Ra	–	–	–	–
Leucosceptrum canum	–	–	–	–	–	–	–	–	5	0.06	4.21	Co
Lindera nacusua	15	0.39	17.71	Co	5	0.09	6.04	Co	5	0.09	6.32	Co
Lithocarpus pachyphyllus	130	23.30	168.49	Re	41	2.87	59.97	Ra	60	7.98	96.32	Re
Litsea elongata	7.5	0.52	8.33	Ra	–	–	–	–	–	–	–	–
Lyonia ovalifolia	–	–	–	–	20	0.37	16.44	Co	33	0.50	25.34	Co
Machilus duthiei	32.5	2.80	40.07	Co	8	0.13	8.98	Ra	18	0.52	17.84	Ra
Magnolia globosa	2.5	0.29	5.31	Co	–	–	–	–	13	2.48	29.26	Ra
Neolitsea umbrosa	–	–	–	–	3	0.02	2.75	Co	–	–	–	–
Pinus sp.	–	–	–	–	20	0.65	22.52	Ra	–	–	–	–
Quercus lamellosa	12.5	1.87	27.98	Re	8	0.42	10.52	Co	8	0.32	10.69	Ra
Q. thomsoniana	–	–	–	–	18	1.84	31.10	Co	–	–	–	–
Rhododendron arboreum	7.5	0.29	7.57	Co	28	0.73	26.29	Ra	23	1.25	24.69	Co
Rhododendron falconeri	–	–	–	–	–	–	–	–	8	0.12	7.44	Co
Rhododendron grande	–	–	–	–	3	0.06	3.17	Co	3	0.05	3.19	Co
Schefflera rhododendrifolia	–	–	–	–	5	0.18	7.03	Co	13	0.39	11.24	Co
Symplocos sp.	2.5	0.05	4.52	Co	13	0.18	14.63	Re	5	0.06	6.10	Co
Tsuga dumosa	–	–	–	–	3	0.13	3.96	Co	–	–	–	–
Ilex crenata var. *thomsoni*	2.5	0.02	4.43	Co	–	–	–	–	–	–	–	–
Sterculia sp.	–	–	–	–	8	0.04	8.00	Ra	–	–	–	–
Viburnum nervosum	2.5	0.08	4.63	Co	13	0.13	10.92	Co	18	0.19	13.70	Co
Saplings												
Betula alnoides	–	–	–	–	20	0.05	9.83	Co	–	–	–	–
Cryptomeria japonica	–	–	–	–	10	0.02	4.27	Co	–	–	–	–
Eurya acuminata	40	0.12	14.28	Co	80	0.09	30.21	Co	190	0.34	58.70	Co
Evodia fraxinifolia	–	–	–	–	20	0.07	11.41	Co	–	–	–	–
Ilex dipyrena	–	–	–	–	–	–	–	–	20	0.03	5.53	Co
Leucosceptrum canum	–	–	–	–	–	–	–	–	10	0.02	3.52	Co
Lindera sp.	–	–	–	–	30	0.03	10.22	Co	30	0.05	9.05	Co
Lindera nacusua	70	0.15	22.88	Co	20	0.03	8.37	Co	30	0.04	10.22	Co
Lithocarpus pachyphyllus	100	0.31	38.10	Ra	110	0.23	46.51	Co	130	0.38	52.37	Ra
Lyonia ovalifolia	–	–	–	–	40	0.08	16.44	Co	90	0.16	29.51	Co
Machilus duthiei	170	0.37	52.54	Ra	40	0.07	17.99	Co	–	–	–	–
Neolitsea umbrosa	10	0.01	3.02	Co	–	–	–	–	–	–	–	–
Pinus sp.	–	–	–	–	10	0.02	4.81	Co	–	–	–	–
Quercus lamellosa	–	–	–	–	10	0.02	4.44	Co	–	–	–	–
Q. thomsoniana	20	0.08	7.57	Co	10	0.01	3.96	Co	–	–	–	–
Rhododendron arboreum	70	0.19	25.20	Co	80	0.20	39.81	Re	60	0.14	22.03	Co
Rhododendron falconeri	–	–	–	–	10	0.04	5.71	Co	50	0.22	25.12	Co
Schefflera rhododendrifolia	10	0.03	3.71	Co	10	0.01	3.96	Co	–	–	–	–
Symplocos sp.	300	0.43	81.65	Re	50	0.13	25.27	Co	10	0.01	3.41	Co
Ilex crenata var. *thomsoni*	90	0.17	23.16	Co	–	–	–	–	10	0.01	3.30	Co
Sterculia sp.	–	–	–	–	10	0.01	4.11	Co	–	–	–	–
Viburnum sp.	–	–	–	–	–	–	–	–	20	0.06	8.80	Co
Viburnum nervosum	90	0.21	27.89	Co	130	0.23	52.68	Ra	210	0.39	68.43	Ra
Seedlings												
Acer campbellii	160	0	1.35	Co	–	–	–	–	177	0.02	1.63	Co
Betula alnoides	–	–	–	–	500	0.09	7.41	Co	–	–	–	–
Eurya acuminata	2167	0.13	19.47	Co	3000	0.34	34.93	Co	6333	0.72	47.89	Ra
Evodia fraxinifolia	–	–	–	–	167	0.01	1.66	Co	–	–	–	–
Ilex dipyrena	840	0.07	9.45	Co	–	–	–	–	1000	0.14	9.17	Co
Leucosceptrum canum	–	–	–	–	–	–	–	–	843	0.17	8.39	Co
Lithocarpus pachyphyllus	5500	0.43	56.05	Ra	3667	0.47	43.28	Ra	4333	0.91	42.33	Ra
Lindera sp.	–	–	–	–	3167	0.31	31.64	Co	1833	0.13	12.22	Co
Lindera nacusua	1000	0.04	9.15	Co	2333	0.17	19.38	Co	2167	0.31	18.65	Co
Litsea sp.	–	–	–	–	167	0.05	3.12	Co	–	–	–	–
Lyonia ovalifolia	–	–	–	–	2667	0.34	30.02	Co	4667	0.57	34.14	Co
Machilus duthiei	5833	0.44	60.03	Ra	–	–	–	–	2333	0.67	26.12	Co
Magnolia globosa	–	–	–	–	–	–	–	–	167	0.07	2.39	Co
Neolitsea umbrosa	–	–	–	–	500	0.04	5.67	Co	–	–	–	–
Pinus sp.	–	–	–	–	2000	0.04	14.85	Co	–	–	–	–
Quercus lamellosa	500	0.04	4.91	Co	–	–	–	–	–	–	–	–
Quercus thomsoniana	1667	0.07	15.51	Co	167	0.03	2.62	Co	–	–	–	–
Rhododendron falconeri	–	–	–	–	500	0.05	6.11	Co	3000	0.86	29.81	Co
Rhododendron arboreum	1000	0.04	8.99	Co	1000	0.07	9.57	Co	1500	0.34	14.89	Co
Schefflera rhododendrifolia	167	0.01	1.56	Co	–	–	–	–	167	0.01	1.46	Co
Symplocos sp.	11000	0.55	81.29	Ra	1000	0.11	11.84	Co	167	0.03	1.83	Co
Ilex crenata var. *thomsoni*	1500	0.03	12.14	Co	–	–	–	–	333	0.05	3.45	Co
Viburnum nervosum	2833	0.07	20.09	Co	7167	0.8	77.9	Ra	5667	0.75	45.63	Ra