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RESEARCH ARTICLE

# DIVERSITY AND COMPOSITION OF TREE STANDS IN TROPICAL FORESTS OF THE DARJILING PART OF EASTERN HIMALAYA

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**ABSTRACT**

The present study quantifies the diversity and composition of tree species having girth size ≥ 15 cm in the tropical forests of Darjiling part of Eastern himalaya through nested quadrat sampling method. In total, 74 species under 64 genera and 36 families were recorded. The individual density varied from 25 to 88.89 individuals $ha^{-1}$. Shannon-Weaver Index ranged from 0.016 to 0.138 whereas the species richness varied from 0.074 to 0.894. The most dominant families were Lauraceae and Malvaceae, followed by Leguminosae and Phyllanthaceae. The abundance to frequency ratio ranged from 0.020 to 0.125 and the basal area ranged from 0.088 ±0.003 to 76.172 ±0.285$m^2$ $ha^{-1}$. The dominant species was *Shorea robusta* (IVI: 27.502) followed by co-dominant species *Tetrameles nudiflora* (IVI: 15.998) and *Tectona grandis* (IVI: 11.442). The study reveals that the favourable climatic condition is one of the reasons for the rich diversity and composition of the tree species in the area.



## INTRODUCTION

An important attribute of natural and organized forest community is diversity (Hairston, 1964) and a number of indices have been proposed to evaluate diversity (Simpson, 1949; Shannon and Weaver, 1963). Forests of the tropical belt are highly diverse due to niche variation and species interaction (Volkov *et al*., 2009). In tropical forests, the diversity of tree species is greatly influenced by topography, niche requirement and disturbances (Huang *et al.*, 2003). The Tropical forests of Eastern Himalaya are largely deciduous with markedly dry winter and wet summer (monsoon) (Grierson and Long, 1983). Several anthropogenic interferences have been occurring in the tropical forests through felling of trees, developing plantations with only very few selected species, poor farming and poaching (Ndah *et al*., 2012). Tree provides habitat and resources for almost all the living organisms inside the forest (Huston, 1994). In tropical forests, trees play a vital role as indicators of stresses and changes (Khan *et al.*, 1997) and are also important sources for carbon sequestration and energy cycle in the forest ecosystem (Singh, 2002). The Darjiling part of the sub-Himalayan region is well known for its pristine beauty and floristic richness. The lower hills of Darjiling are mainly covered by tropical and sub-tropical climatic zones exhibiting extremely diverse habitats (Rai *et al*., 2011).

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The micro-climatic differences have resulted into the development of mosaic of forest types where the species diversity is well known (Cowan and Cowan, 1929; Das, 1995, 2004). Champion and Seth, (1968) have provided the information on the vegetation of Darjiling by recognizing five forest types in tropical and sub-tropical belt categorized under Group 2B and Group 3C. Rai and Das, (2005) did some such preliminary works on the foothill forests of Darjiling Himalaya. However, for a long time, detailed work on the diversity and composition of tree stands have not been performed and therefore this investigation was carried out to evaluate the present scenario of diversity, richness and composition of tree stands in tropical forests of Darjiling part of the Eastern Himalaya.

## MATERIALS AND METHODS

### Study Area

Darjiling part of the Himalaya lies as a spur on the lap of Eastern Himalayan belt. Bhujel, (1996) have altitudinally divided the hills into five vegetation-zones starting from tropical to alpine, where the tropical belt extends upto 800 m amsl. The forests under study lie on the southern region of the Mahananda Wildlife Sanctuary on the western bank of the river Teesta (Fig.1). The study does not include the Terai part of Darjiling hills, rather it covers the forest lying within an altitudinal range of 135 – 800 m amsl and which is characterized by very moist condition and maintains a consistently higher ambient temperature than the rest of the upper regions of Darjiling Hills. The tropical zone remains warmer throughout the year with temperature ranging from 5.6º to 27º C and an average annual rainfall of about 325 cm. The mean annual relative humidity remains 71.4 % (Rai and Das, 2005). pH of the soil ranged from 4.96 – 5.33 comprising ultisols of the palehumults group with coarse texture (Lama, 2004).

distribution pattern of the species (Whitford, 1949). The ratio of <0.025 indicates regular distribution, 0.025 – 0.050 means random distribution and >0.050 indicates contiguous distribution (Curtis and Cottam, 1956). The recorded tree species was grouped into Raunkiaer's five frequency classes and a comparison between normal and observed frequency was noted (Raunkiaer, 1934). The basal area of the individual tree species was ascertained using the formula:

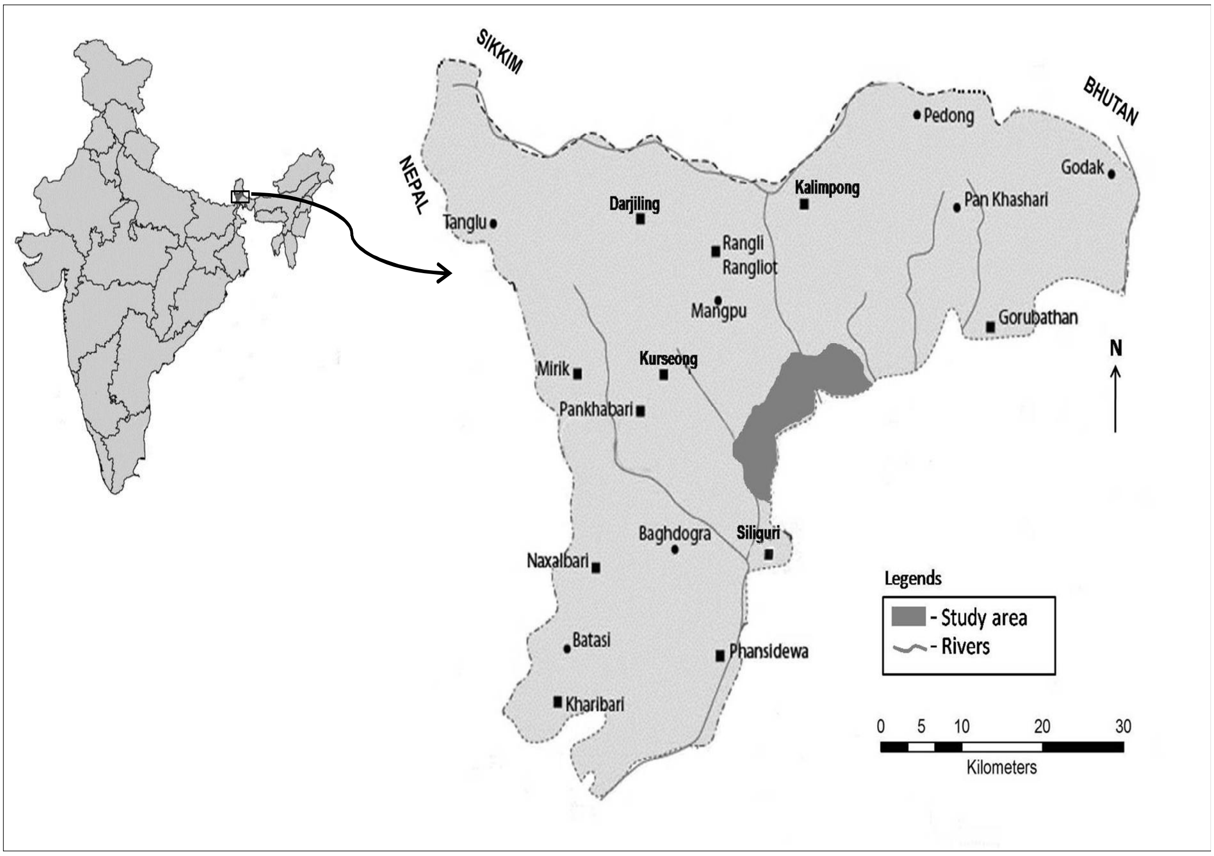


**Fig. 1. Location map of Darjiling showing study area**

**Phytosociological Analysis**

The composition of tree species was estimated by placing random quadrats of 20 x 20 m (400 $m^2$) in the study area. Individuals with girth size $\geq$ 15 cm at chest height (1.37 m above the ground) were considered as trees. For each species, voucher specimens were collected and processed using conventional methodology (Jain and Rao, 1977) and were identified with the help of floras including Prain (1903); Cowan and Cowan (1929); Hara (1966, 1971); Hara *et al.*, (1978); and Grierson and Long (1983, 1987, 1991, 1999, 2001) and confirmed by matching at CAL and NBU Herbaria. The voucher specimens collected for each species were deposited at NBU Herbarium after the work was over.

The vegetation data were quantitatively analysed for Frequency (F), Density (D) and Dominance (Dm) of recorded species of plants (Curtis and McIntosh, 1950; Phillips, 1959). The Importance Value Index (IVI) was ascertained as the sum of the Relative Frequency (RF), Relative Density (RD) and Relative Dominance (RDm) (Curtis, 1959). The abundance to frequency ratio (A/F) was studied to understand the spatial

$$BA = \frac{(CBH)^2}{4\pi}$$

where, *CBH* is the circumference of the tree trunk at breast height

For calculating the species diversity, Shannon-Weaver Index ($H'$) (Shannon and Weaver, 1963) was followed

$$H' = -\sum[(ni/N)\ln(ni/N)]$$

where, $ni$ is the number of individual of a species and $N$ is the sum total of all the individual species For Species Richness, Menhinick's Index ($D$) was followed (Menhinick, 1964)

$$D = S/\sqrt{N}$$

where, $S$ is the number of individual and $N$ is the sum total of all the individual species
Simpson's Index (Simpson, 1949) was used for calculating the concentration of dominance ($CD$)

$$CD = \sum (ni/N)^2$$

Where *ni/N* is the same as that of Shannon-Weaver values
The Species evenness was estimated by Pielou's Index (*J*) (Pielou, 1966)

$$J = H'/\ln S$$

where, $H'$ is the Shannon Index and $S$ is the number of individual

## RESULTS AND DISCUSSION

From the study area, a total representative of 74 species of trees belonging to 64 genera and 36 families were recorded (Table 1). Majority of the species belonged to the family Lauraceae and Malvaceae (7 species each) followed by Leguminosae and Phyllanthaceae (5 species each), Apocynaceae, Combretaceae, Lamiaceae and Meliaceae each with 4 species, Anacardiaceae (3 species), Bignoniaceae, Euphorbiaceae, Lythraceae and Moraceae (2 species each) and Achariaceae, Arecaceae, Burseraceae, Clusiaceae, Compositae, Cornaceae, Dilleniaceae, Dipterocarpaceae, Fagaceae, Magnoliaceae, Myrtaceae, Pandanaceae, Primulaceae, Rhamnaceae, Rubiaceae, Rutaceae. Sabiaceae, Salicaceae, Sapotaceae, Simaroubaceae, Styracaceae, Tetramelaceae and Theaceae (1 species each).

The density gives an idea about the strength of a species in the community. The total stem density estimated for tree stand was 2436.62 individuals $ha^{-1}$. The individual with highest density was of *Shorea robusta* (88.89 individuals $ha^{-1}$), followed by *Tectona grandis* (60 individuals $ha^{-1}$).

The lowest density of 25 individuals $ha^{-1}$ was shown by species like *Artocarpus lacucha, Casearia vareca, Kydia calycina, Gynocardia odorata, Litsea salicifolia, Mangifera sylvatica, Terminalia myriocarpa, Grewia serrulata* and *Stereospermum tetragonum.* The basal area is an important parameter for understanding the dominance of trees in an ecosystem (Srinivasa *et al.*, 2013). The total basal area for the tree species from the study site was 343.221 ±1.242$m^2$ $ha^{-1}$. The basal area ranged from 0.088 ±0.003 to 76.172 ±0.285$m^2$ $ha^{-1}$ showing highest for *Shorea robusta* (76.172 ±0.285$m^2$ $ha^{-1}$) followed by *Tetrameles nudiflora* (43.200 ±0.633$m^2$ $ha^{-1}$) and least for *Casearia vareca* (0.088 ±0.003$m^2$ $ha^{-1}$). The basal area for some important species like *Tectona grandis, Schima walichii, Gmelina arborea, Lagerstroemia parviflora* and *Toona ciliata* were 24.486 ±0.086, 22.518 ±0.213, 13.818 ±0.129, 6.595 ±0.038 and 2.834 ±0.071$m^2$ $ha^{-1}$ respectively.

Ecologically, abundance refers to the relative amount of species observed within a given area. The maximum abundance was recorded for *Shorea robusta* and *Tectona grandis.* The dominance of a species in a community is expressed through IVI that incorporates three parameters, RF, RD and RDm for measuring the productivity and diversity of each species (Rao *et al.*, 2013). The species with the highest index is the leading dominant species in the area. The IVI for the tree stand from the study site ranged from 1.484 to 27.502.

**Table 1. Quantitative characteristics of the Tree stand from the study area**

| Species | Family | $Dha^{-1}$ | RF | RDm | $BAm^{-2}$ | A/F | IVI |
|---|---|---|---|---|---|---|---|
| *Actinodaphne obovata* (Nees) Blume | Lauraceae | 37.50 | 0.738 | 0.425 | 1.460 ±0.082 | 0.094 | 2.702 |
| *Ailanthus integrifolia* Lamarck | Simaroubaceae | 33.33 | 2.214 | 1.732 | 5.944 ±0.070 | 0.028 | 5.314 |
| *Alangium chinense* (Loureiro) Harms | Cornaceae | 34.38 | 1.476 | 0.823 | 2.825 ±0.049 | 0.043 | 3.710 |
| *Albizia chinensis* (Osbeck) Merrill | Leguminosae | 35.71 | 1.292 | 2.120 | 7.278 ±0.115 | 0.051 | 4.878 |
| *Albizia lebbeck* (Linnaeus) Bentham | Leguminosae | 28.13 | 1.476 | 1.114 | 3.824 ±0.094 | 0.035 | 3.744 |
| *Albizia lucidior* (Steudel) Nielson | Leguminosae | 30.00 | 0.923 | 0.956 | 3.280 ±0.184 | 0.060 | 3.109 |
| *Albizia procera* (Roxburgh) Bentham | Leguminosae | 40.00 | 0.923 | 0.528 | 1.813 ±0.051 | 0.080 | 3.092 |
| *Alstonia scholaris* (Linnaeus) R. Brown | Apocynaceae | 28.13 | 1.476 | 0.521 | 1.788 ±0.040 | 0.035 | 3.151 |
| *Aphanamixis polystachya* (Wallich) R. Parker | Meliaceae | 33.33 | 1.107 | 0.268 | 0.921 ±0.021 | 0.056 | 2.743 |
| *Aporosa octandra* (Buchanan-Hamilton *ex* D.Don) Vickery | Phyllanthaceae | 32.14 | 1.292 | 0.498 | 1.710 ±0.053 | 0.046 | 3.109 |
| *Ardisia solanacea* (Poiret) Roxburgh | Primulaceae | 31.25 | 1.476 | 0.212 | 0.728 ±0.019 | 0.039 | 2.971 |
| *Artocarpus lacucha* Buchanan-Hamilton | Moraceae | 25.00 | 0.923 | 0.237 | 0.814 ±0.034 | 0.050 | 2.186 |
| *Bauhinia purpurea* Linnaeus | Leguminosae | 46.43 | 1.292 | 0.262 | 0.897 ±0.010 | 0.066 | 3.458 |
| *Bischofia javanica* Blume | Phyllanthaceae | 30.00 | 0.923 | 0.144 | 0.493 ±0.019 | 0.060 | 2.297 |
| *Bombax ceiba* Linnaeus | Malvaceae | 37.50 | 2.214 | 1.894 | 6.501 ±1.532 | 0.031 | 5.647 |
| *Bridelia retusa* (Linnaeus) A. Jussieu | Phyllanthaceae | 33.33 | 1.107 | 0.206 | 0.708 ±0.013 | 0.056 | 2.681 |
| *Callicarpa arborea* Roxburgh | Lamiaceae | 30.00 | 1.845 | 0.309 | 1.061 ±0.306 | 0.030 | 3.385 |
| *Callicarpa vestita* Wallich *ex* C.B. Clarke | Lamiaceae | 28.13 | 1.476 | 0.150 | 0.513 ±0.010 | 0.035 | 2.780 |
| *Calophyllum polyanthum* Wallich *ex* Planchon & Triana | Clusiaceae | 31.25 | 0.738 | 0.473 | 1.624 ±0.726 | 0.078 | 2.494 |
| *Casearia vareca* Roxburgh | Salicaceae | 25.00 | 0.554 | 0.026 | 0.088 ±0.003 | 0.083 | 1.605 |
| *Castanopsis lanceifolia* (Oersted) Hickel & Camus | Fagaceae | 29.55 | 2.030 | 1.730 | 5.937 ±1.646 | 0.027 | 4.972 |
| *Chisocheton cumingianus* (C.DC.) Harms | Meliaceae | 27.78 | 1.661 | 0.228 | 0.783 ±0.068 | 0.031 | 3.029 |
| *Chukrasia tabularis* A.Jussieu | Meliaceae | 30.36 | 2.583 | 1.209 | 4.148 ±0.033 | 0.022 | 5.038 |
| *Cinnamomum bejolghota* (Buchanan-Hamilton) Sweet | Lauraceae | 30.56 | 1.661 | 0.200 | 0.685 ±0.206 | 0.034 | 3.114 |
| *Cryptocarya amygdalina* Nees | Lauraceae | 32.14 | 1.292 | 0.482 | 1.655 ±0.042 | 0.046 | 3.093 |
| *Dillenia pentagyna* Roxburgh | Dilleniaceae | 33.33 | 2.214 | 0.978 | 3.355 ±0.035 | 0.028 | 4.560 |
| *Diploknema butyracea* (Roxburgh) H.J.Lam | Sapotaceae | 33.33 | 1.661 | 0.814 | 2.793 ±0.027 | 0.037 | 3.842 |
| *Drimycarpus racemosus* (Roxburgh) Hooker *f. ex* Merchand | Anacardiaceae | 28.57 | 1.292 | 0.166 | 0.569 ±0.018 | 0.041 | 2.630 |
| *Duabanga grandiflora* (DC.) Walpers | Lythraceae | 35.42 | 2.214 | 5.103 | 17.515 ±0.105 | 0.030 | 8.771 |
| *Ficus semicordata* Buchanan-Hamilton *ex* Smith | Moraceae | 31.25 | 0.738 | 0.075 | 0.257 ±0.015 | 0.078 | 2.095 |
| *Firmiana colorata* (Roxburgh) R. Brown | Malvaceae | 32.50 | 1.845 | 2.215 | 7.603 ±0.077 | 0.033 | 5.394 |
| *Garuga pinnata* Roxburgh | Burseraceae | 40.00 | 0.923 | 0.203 | 0.618 ±0.019 | 0.080 | 2.768 |
| *Glochidion daltonii* (Müeller Argoviensis) Kurz | Phyllanthaceae | 33.33 | 0.554 | 0.086 | 0.295 ±0.011 | 0.111 | 2.008 |
| *Gmelina arborea* Roxburgh | Lamiaceae | 28.85 | 2.399 | 4.026 | 13.818 ±0.129 | 0.022 | 7.609 |
| *Grewia serrulata* DC. | Malvaceae | 25.00 | 1.292 | 0.132 | 0.454 ±0.020 | 0.036 | 2.450 |

Continue……………….

**Table 1. Quantitative characteristics of the Tree stand from the study area**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Gynocardia odorata* R.Brown | Achariaceae | 25.00 | 0.923 | 0.286 | 0.982 ±0.052 | 0.050 | 2.235 |
| *Holarrhena pubescens* Wallich *ex*. G. Don | Apocynaceae | 50.00 | 1.476 | 0.447 | 1.533 ±0.015 | 0.063 | 3.975 |
| *Kydia calycina* Roxburgh | Malvaceae | 25.00 | 1.107 | 0.099 | 0.341 ±0.011 | 0.042 | 2.232 |
| *Lagerstroemia parviflora* Roxburgh | Lythraceae | 40.00 | 1.845 | 1.922 | 6.595 ±0.038 | 0.040 | 5.408 |
| *Litsea monopetala* (Roxburgh) Persoon | Lauraceae | 26.92 | 2.399 | 0.359 | 1.231±0.012 | 0.021 | 3.862 |
| *Litsea cubeba* (Loureiro) Persoon | Lauraceae | 33.33 | 1.107 | 0.271 | 0.929 ±0.039 | 0.056 | 2.746 |
| *Litsea salicifolia* (Roxburgh *ex* Nees) Hooker *f.* | Lauraceae | 25.00 | 0.923 | 0.107 | 0.367 ±0.022 | 0.050 | 2.056 |
| *Magnolia champaca* (Linnaeus) Baillon *ex* Pierre | Magnoliaceae | 33.33 | 1.107 | 0.567 | 1.947 ±0.038 | 0.056 | 3.042 |
| *Mallotus philippensis* (Lamarck) Müeller Argoviensis | Euphorbiaceae | 32.14 | 1.292 | 0.141 | 0.484 ±0.014 | 0.046 | 2.752 |
| *Mangifera sylvatica* Roxburgh | Anacardiaceae | 25.00 | 0.369 | 0.089 | 0.305 ±0.098 | 0.125 | 1.484 |
| *Meliosma pinnata* (Roxburgh) Maximowicz | Sabiaceae | 31.25 | 0.738 | 0.424 | 1.456 ±0.051 | 0.078 | 2.445 |
| *Micromelum integerrimum* (Buchanan-Hamilton *ex* DC.) Wight & Arnott *ex* Roemer | Rutaceae | 33.33 | 1.107 | 0.247 | 0.847 ±0.013 | 0.056 | 2.722 |
| *Neolamarckia cadamba* (Roxburgh) Bosser | Rubiaceae | 30.00 | 0.923 | 1.294 | 4.442 ±0.125 | 0.060 | 3.448 |
| *Oroxylum indicum* (Linnaeus) Kurz | Bignoniaceae | 32.14 | 1.292 | 0.185 | 0.635 ±0.012 | 0.046 | 2.796 |
| *Ostodes paniculata* Blume | Euphorbiaceae | 33.33 | 1.107 | 0.117 | 0.402 ±0.009 | 0.056 | 2.592 |
| *Pandanus furcatus* Roxburgh | Pandanaceae | 40.00 | 0.923 | 0.211 | 0.724 ±0.009 | 0.080 | 2.775 |
| *Persea gamblei* (King *ex* Hooker *f.*) Kosterman | Lauraceae | 30.00 | 0.923 | 0.135 | 0.463 ±0.016 | 0.060 | 2.289 |
| *Phoenix loureiroi* Kunth | Arecaceae | 29.17 | 1.107 | 0.457 | 1.567 ±0.038 | 0.049 | 2.761 |
| *Phyllanthus emblica* Linnaeus | Phyllanthaceae | 39.29 | 1.292 | 0.186 | 0.639 ±0.012 | 0.056 | 3.090 |
| *Pterospermum acerifolium* (Linnaeus) Willdenow | Malvaceae | 31.25 | 1.476 | 0.901 | 3.094 ±0.078 | 0.039 | 3.660 |
| *Pterygota alata* (Roxburgh) R. Brown | Malvaceae | 30.00 | 0.923 | 0.603 | 2.070 ±0.095 | 0.060 | 2.757 |
| *Rhus chinensis* Miller | Anacardiaceae | 29.17 | 1.107 | 0.146 | 0.501 ±0.011 | 0.049 | 2.450 |
| *Schima wallichii* Choisy | Theaceae | 30.00 | 2.768 | 6.561 | 22.518 ±0.213 | 0.020 | 10.560 |
| *Shorea robusta* Gaertner | Dipterocarpaceae | 88.89 | 1.661 | 22.193 | 76.172 ±0.285 | 0.099 | 27.502 |
| *Sterculia villosa* Roxburgh | Malvaceae | 29.55 | 2.030 | 0.876 | 3.006 ±0.062 | 0.027 | 4.118 |
| *Stereospermum tetragonum* DC. | Bignoniaceae | 25.00 | 1.292 | 0.211 | 0.645 ±0.013 | 0.036 | 2.528 |
| *Styrax serrulatus* Roxburgh | Styracaceae | 30.00 | 0.923 | 0.235 | 0.807 ±0.042 | 0.060 | 2.389 |
| *Syzygium cumini* (Linnaeus) Skeels | Myrtaceae | 27.78 | 1.661 | 0.726 | 2.493 ±0.062 | 0.031 | 3.527 |
| *Tectona grandis* Linnaeus *f.* | Lamiaceae | 60.00 | 1.845 | 7.134 | 24.486 ±0.086 | 0.060 | 11.442 |
| *Terminalia alata* Wallich | Combretaceae | 29.17 | 1.107 | 1.635 | 5.611 ±0.067 | 0.049 | 3.939 |
| *Terminalia chebula* Retzius | Combretaceae | 30.00 | 0.923 | 1.688 | 5.795 ±0.102 | 0.060 | 3.842 |
| *Terminalia bellirica* (Gaertner) Roxburgh | Combretaceae | 28.13 | 1.476 | 2.848 | 9.776 ±0.203 | 0.035 | 5.479 |
| *Terminalia myriocarpa* Van Heurck & Müeller Argoviensis | Combretaceae | 25.00 | 1.476 | 2.151 | 7.383 ±0.097 | 0.031 | 4.653 |
| *Tetrameles nudiflora* R. Brown | Tetramelaceae | 29.17 | 2.214 | 12.587 | 43.200 ±0.633 | 0.024 | 15.998 |
| *Toona ciliata* Roemer | Meliaceae | 32.14 | 1.292 | 0.826 | 2.834 ±0.071 | 0.046 | 3.436 |
| *Vernonia volkameriifolia* DC. | Compositae | 33.33 | 0.554 | 0.037 | 0.127 ±0.005 | 0.111 | 1.958 |
| *Wrightia sikkimensis* Gamble | Apocynaceae | 32.14 | 1.292 | 0.174 | 0.596 ±0.012 | 0.046 | 2.785 |
| *Wrightia arborea* (Dennstedt) Mabberley | Apocynaceae | 50.00 | 1.107 | 0.270 | 0.925 ±0.019 | 0.083 | 3.429 |
| *Ziziphus jujuba* Miller | Rhamnaceae | 29.17 | 1.107 | 0.107 | 0.368 ±0.017 | 0.049 | 2.411 |

[$Dha^{-1}$=Density per hectare, RF=Relative Frequency, RDm=Relative Dominance, $BAm^{-2}$=Basal Area per sq metre, A/F=Abundance/Frequency, IVI= Importance Value Index]

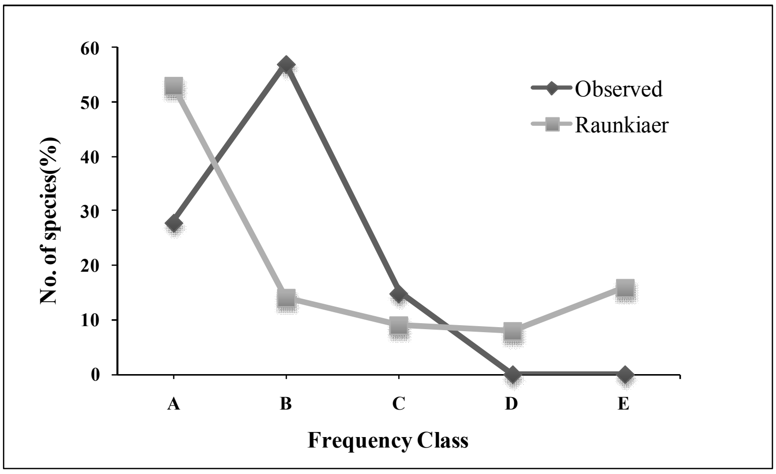


**Fig. 2. Comparison of Raunkiaer's frequency with observed frequency distribution**

The most dominant species was *Shorea robusta* (IVI: 27.502) followed by co-dominant *Tetrameles nudiflora* (IVI: 15.998). Other important tree species from the study area were *Tectona grandis* (IVI: 11.442), *Schima walichii* (IVI: 10.560), *Duabanga grandiflora* (IVI: 8.771) and *Gmelina arborea* (IVI: 7.609). The least dominant species was *Mangifera sylvatica* (IVI: 1.484). As per the Raunkiaer's frequency class, the forest represented only three classes A, B and C with species exhibiting 28 %, 57 % and 15 % respectively as compared to the normal Raunkiaer's frequency distribution of 53 %, 14 %, 9 %, 8 % and 16 % for respective classes A, B, C, D and E. Most of the species fell under class B, followed by A and C showing A<B>C pattern. (Fig. 2).

The abundance to frequency ratio expresses the pattern of species distribution. Among the recorded plants, only 5 species showed regular distribution pattern, but majority of the 38 species were found to be randomly distributed and 31 of them showed contiguous nature of distribution. The girth class for the species was established on the basis of different sizes of girth. The highest number of 214 individuals showed girth class above 75 cm followed by 190 individuals under the girth class of 15 – 30 cm. 158 individuals fell under the girth class of 30 – 45 cm, 90 individuals under the girth class 45 – 60 cm and least number of 69 individuals fell under the girth class of 60 – 75 cm (Fig. 3).

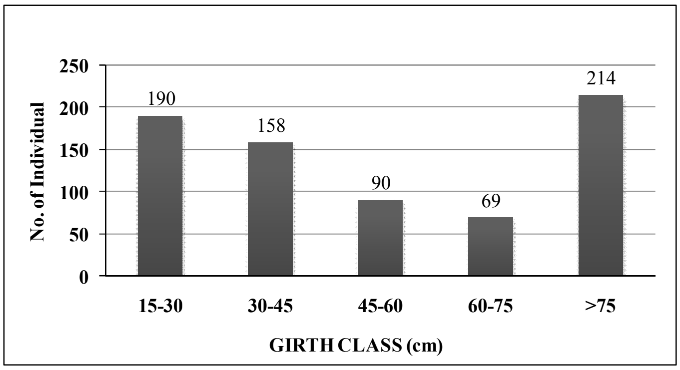


**Fig. 3. Girth class of recorded tree species**

The ecological diversity indices are important parameters to understand the structure of the forest ecosystem. The Shannon-Weaver diversity for the tree species was estimated to be 4.195, the species richness was 2.756, the concentration of dominance was ascertained as 0.017 and the species evenness was found to be 0.975. The Carl Pearson correlation coefficient between different diversity parameters showed a much positive relations among diversity, richness and dominance of the species, and a negative correlation with abundance to frequency ratio (Table 2).

**Table 2. Correlation between different diversity parameters**

| | Den | BA | A/F | *H'* | *D* | *CD* | *J* |
|---|---|---|---|---|---|---|---|
| Den | 1 | | | | | | |
| BA | 0.646 | 1 | | | | | |
| A/F | 0.362 | -0.001 | 1 | | | | |
| *H'* | 0.642 | 0.657 | -0.409 | 1 | | | |
| *D* | 0.690 | 0.712 | -0.334 | 0.994 | 1 | | |
| *CD* | 0.794 | 0.829 | -0.105 | 0.906 | 0.947 | 1 | |
| *J* | 0.642 | 0.657 | -0.409 | 1.000 | 0.994 | 0.906 | 1 |

*In bold, significant values at the level of significance alpha=0.050 (two-tailed test)*

The composition and diversity of tree species in the study area revealed quite a healthy status of tree stands expressing the richness of the forest vegetation.

The humid climate of the area provides a favourable condition for the species diversity and dominance. The richness of the tree stand is determined by its high individual density and basal area. The distribution of the species in frequency class showed that the species have only three classes depicting more or less pointed curve in contrast to the normal five classes with J-shaped Raunkiaer's curve. Number of tree species in the Himalayas shows various pattern of distribution (Sharma *et al*., 2009). In a homogeneous community, the distribution of individuals is same in all the parts of the area (Shukla *et al.*, 2014). The present study shows a heterogeneous behavior of individual distribution of tree stands. The random distribution is found in a homogenous environment and contiguous pattern is the most common (Odum, 1971). Majority of the species (51 %) were more randomly distributed and 7 % were regular. Contiguous distribution was expressed by 42 % of the species in the study area thereby depicting the structure of natural vegetation (Venna *et al.*, 1999). Species like *Tectona grandis* and *Gmelina arborea* expressed wider dominance as because of the plantation by the forest department in random patches inside the forest. The index of species diversity was higher as compared to the index of dominance showing inverse relationship with each other which is in accordance with Odum, (1971). The species diversity from the study area was found to be greater than that recorded by Rai and Das, (2005) for the foot hill forests. Some species showed lower importance value, whereas some showed higher values expressing more dominance in the area and thereby ecologically significant. Although the area covers some part of protected forests, small villages in and around happens to be the cause of some disturbances inside the forests as the people are dependent on the Non-Timber Forest Products including forest fuels.

## Conclusion

The present study highlights a good forest structure with well represented tree species in the tropical belt of Darjiling hills showing healthy individuals, high species diversity and richness. The dominant species are to be conserved and the less dominant species should be planted more by the forest department in participation with the local inhabitants in places where forest improvement program is being implemented. Moreover, the favorable climatic condition in this belt has always been a boon for the forests to grow and flourish thereby making the habitat dense and suitable for the faunal populations too.

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