Diversity of Trees in the Darjeeling Foothill Region of Eastern Himalaya

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Abstract

Phytosociological investigation using 20 x 20 m quadrats has been made on seven major forest types of Darjiling foothill region within an altitudinal range of 135 m to 1200 m leading to the record of 215 species of trees, 11 species of liana and three species of palms. Analysis of data revealed that the East Himalayan Sal forest showed highest species diversity but have moderate species richness and concentration of dominance. High species diversity and species richness were recorded from Semi Evergreen Mixed forest, Wet Mixed Deciduous Forest & Lower Bhabar Sal Forest with correspondingly low concentration of dominance. Bamboo brake had the lowest species diversity with high concentration of dominance. Computation of similarity index showed a poor relation between different forest types and reflected the developing nature of vegetation. Also, these forests have a high regeneration status with a good species composition. It has also been predicted that the anthropogenic interferences may cause the abrupt change in the structure of these vegetation types.

Keywords: Concentration of dominance, Darjiling forests, Phytosociology, Regeneration potential, Species diversity, Species richness, Tree diversity.

Introduction

Eastern Himalaya is well known for its extremely rich biodiversity and has attracted the attention of many plant and animal scientists from different corners of the world at least during the last three centuries (Das 1995). The Himalayan region has favoured the development of extremely rich vegetation and it ranges from tropical to subalpine and evergreen forests to coniferous stands (Champion & Seth 1968, Bhujel 1996). Various climatic factors, soil characteristics, diversified landforms, aspects and altitudinal variation in the region played important roles in determining the species composition and consequently the forest structure. Classification of Indian forests by Champion & Seth (1968) has undergone tremendous change with time and much is needed to understand the dynamics of forest and their community composition (Rai & Das 2003). Tropical and Subtropical regions are more diverse with respect to the species composition with great number of tree species occurring in this belt (Grierson & Long 1983; Spur & Burnes 1980). At the same time, future composition of forest is very much dependent on the regenerating power of the existing population which is determined by the differences in micro-climatic condition, inter-specific competition and available space (Pandey *et al* 2002). However, survivability of seedlings and saplings depends on the cumulative interaction of different components of the ecosystems and the age of the community.

The present investigation was carried out to find out the vegetation composition of different forest types as recognized by Champion & Seth (1968), similarity between different forests, their regeneration power, possible future compositional change, to assess the pattern of forest

growth and overall biological richness.

Study Area

Study was carried out in different reserve forests, national parks and wildlife sanctuaries along the low altitude hills (foothills) of Darjiling, Kurseong and Kalimpong sub-divisions in the Darjiling District of West Bengal, India. Entire horizontal stretch of Darjiling hills extending from foothills up to 1200 m was selected for the study. However, the rolling plains of Terai and Duars of the district have been excluded in the present study. The region is well represented by seven forest types as recognized by Champion and Seth (1968), under tropical and subtropical vegetation and is categorized under *Group 2B* and *Group 3C*. The overall climate of the area is subtropical with relatively warm days except a brief cold spell during December to February. The average day temperature ranges from 5.6 – 23° C. The area receives heavy rainfall due to monsoon for four months, June – September with an average of 325.5 cm per annum of which only 0.3 cm is received during January and a maximum of 149.4 cm during July. The mean Relative Humidity of the area is 71.4%.

Methods

The present study was carried during January 2001 to March 2003. Seven forest types were identified from the foothill region of the Darjiling part of Eastern Himalaya based on the phenological conditions and association of dominant species. These forest types are:

Type I: **Eastern Himalayan Sal Forest:** dominated by sal, distributed along the foothills, from Panighata to Teesta Valley.

Type II: **Bamboo Brakes:** dominated by *Dendrocalamus hamiltonii* which are sporadic in occurrence and invading natural forests as it is found at places in Balasun Valley.

Type III: **Riverine Forests:** along the low lying river valleys of Balasun, Nandi and Teesta.

Type IV: **Semi-evergreen Mixed Forests:** occurring along the steep slopes in the Mahananda Wildlife Sanctuary and Najoek of Kalimpong sub-division.

Type V: **Wet Mixed Deciduous Forests:** occurring in Rung Dung valley of Darjiling sub-division and Shivkhola of Kurseong sub-division.

Type VI: **Lower Bhabar Sal Forests:** occurring along the lower valley of river Teesta.

Type VII: **Upper Bhabar Sal Forests:** distributed along the upper reaches of river Teesta, Relli and Najoek in Kalimpong sub-division.

Random samplings were made taking at least 6 quadrates for each forest type to get a representative picture. Modification of methods as worked out by Mishra 1966; Malhotra 1973; Das & Lahiri, 1997 was adopted with 20 x 20 m as the size of the quadrat so that variability / homogeneity of species against small areas are taken care of. The girth at breast height (GBH) above 15 cm are treated as trees; 5 – 15 cm as saplings and below 5 cm as seedlings. Lianas with girth exceeding 10 cm are also recognized in the present analysis as trees.

Data compilation and analysis was carried out as per the standard procedures (Mishra, 1966) to determine the Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDm) and Importance Value Index (IVI) for different species of trees. Species Diversity using Shanon-Weaver Index (Shannon & Weaver 1963), Concentration of Dominance (Simpson 1949) and Species Richness by Menhinick's Index (Menhinick 1964) for these forest types were determined. Similarity Index (community coefficient) among different types was calculated as per Sorenson (1948) and Kadir (2001). To asses the uniformity of vegetation, frequency distribution pattern of Raunkiaer (1934) was followed.

The entire tree stand was grouped according to GBH with an interval of 25 cm to understand the dynamics of the forest growth. Number of seedlings and saplings calculated for five dominant species in each forest type to predict the future compositional change of vegetation.

Results and Discussion

Arboreal Diversity

A total of 215 species including 11 lianas and 3 palms having over 15 cm GBH have been recorded from the study area. Highest number of 96 species has been recorded from Type-IV (*Semi-evergreen Mixed Forests*) and with minimum number of 28 species from Type-VII (*Upper Bhabar Sal Forests*). Other forest types also showed high diversity for matured trees. Type–I (*Eastern Himalayan Sal Forest*) 66 species; Type – II (*Bamboo Breaks*) 54 species; Type – III (*Riverine Forests*) 42 species; Type – V (*Wet Mixed Deciduous Forests*) 42 species and Type – VI (*Lower Bhabar Sal Forests*) 63 species [Tables 1 – 7].

Girth Class Distribution Pattern

Girth class distribution pattern of different forest types shows relatively higher number of population in lower girth class for all the forest types (Figure 1). The middle canopy species are relatively lesser in number and shall not affect the interpretative quality. Thus, suggesting that either these forests are on the seral stage or the secondary forests coming up after the elimination of the primary structure. The proportion of different age classes across a landscape and over time is one of the fundamental characteristics of the vegetation mosaic (Spies & Turner 1999). There is a relatively higher number of species in seedling and sapling class, which is indicative of the disturbed ecosystem and is in confirmation with the observation by Pandey and Singh (1985). Moreover, higher number of seedlings and saplings along with the good number of species in these forests are also indicative of its rapidly developing vegetation rather than climax. Distribution pattern among different species in the same interval of the GBH shows a gradual decreasing pattern with increase in the girth class for all the forest types. Sites I, II & VI are well marked with tree-species of lower girth class, which shows an excellent adaptation of these species in this area. However, Sites I, III, IV & VI showed more or less stable population in higher girth class and hence is less disturbed as is expected for a protected area. Site II shows much skewed pattern with a much less number of population in the middle girth class indicating a heavy interference of forest by different factors. With lower population in higher girth class and low number of seedling and sapling with lesser number of species occurrence in Site II & V is indicative of matured forest and also appears to be disturbed.

Table 1. Phytosociological attributes in Eastern Himalayan Sal Forest (Type I)

Sl No.	Names of Plants	Density $400m^{-2}$	TBA $400m^2$ (cm^2)	RF	RD	RDm	IVI
1	*Shorea robusta*	106.67	33.99	13.043	46.57	66.37	125.983
2	*Pinus roxburghii*	10.48	8.413	3.106	4.574	10.49	18.17
3	*Schima wallichii*	5.71	123.26	3.727	2.495	5.243	11.465
4	*Terminalia bellirica*	7.14	701.826	4.348	3.119	1.688	9.155
5	*Phoenix loureiri*	10	1842.87	2.484	4.366	0.666	7.516
6	*Lagerstroemia parviflora*	5.24	9.722	4.969	2.287	0.181	7.437
7	*Syzygium cumini*	4.76	157.05	4.969	2.079	0.209	7.257
8	*Sterculia villosa*	7.14	24.754	3.106	3.119	1.017	7.242
9	*Bauhinia purpurea*	6.19	33.654	1.863	2.703	2.02	6.586
10	*Grewia optiva*	5.71	287.445	3.106	2.495	0.425	6.026
11	*Mallotus philippensis*	4.76	21.781	3.106	2.079	0.392	5.577
12	*Terminalia alata*	3.33	20.485	2.484	1.455	1.194	5.133
13	*Aporosa octandra*	4.76	45.81	1.863	2.079	0.849	4.791
14	*Bridelia retusa*	2.86	62.86	2.484	1.247	0.066	3.797
15	*Michelia champaca*	0.48	1421.86	0.621	0.208	2.406	3.235
16	*Terminalia chebula*	2.38	45.806	1.863	1.04	0.041	2.944
17	*Stereospermum colais*	1.43	113.113	1.863	0.624	0.413	2.9
18	*Actinodaphne sikkimensis*	1.43	154.152	1.863	0.624	0.2	2.687
19	*Phyllanthus emblica*	1.43	51.191	1.863	0.624	0.072	2.559
20	*Heynea trijuga*	2.38	8.413	1.242	1.04	0.219	2.501
21	*Mucuna macrocarpa*	1.9	65.737	1.242	0.832	0.06	2.134
22	*Dillenia pentagyna*	1.43	26.717	1.242	0.624	0.189	2.055
23	*Lannea coromendalica*	1.43	116.572	1.242	0.624	0.173	2.039
24	*Tectona grandis*	1.9	8.413	0.621	0.832	0.571	2.024
25	*Anthocephalus cadamba*	0.48	143.738	0.621	0.208	0.996	1.825
26	*Castanopsis hystrix*	0.95	6.319	1.242	0.416	0.167	1.825
27	*Litsea monopetala*	0.95	130.164	1.242	0.416	0.121	1.779
28	*Wrightia arborea*	0.95	46.909	1.242	0.416	0.104	1.762
29	*Grewia disperma*	0.95	65.568	1.242	0.416	0.051	1.709
30	*Acacia pennata*	0.95	80.993	1.242	0.416	0.037	1.695
31	*Bauhinia vahlii*	0.95	33.654	1.242	0.416	0.024	1.682
32	*Careya arborea*	0.48	51.191	0.621	0.208	0.769	1.598
33	*Dalbergia stipulacea*	1.43	117.264	0.621	0.624	0.107	1.352
34	*Archidendron clypearia*	1.43	30.363	0.621	0.624	0.04	1.285
35	*Oroxylum indicum*	0.95	106.832	0.621	0.416	0.214	1.251
36	*Aglaia chittagonga*	0.48	112.066	0.621	0.208	0.379	1.208
37	*Syzygium balsameum*	0.48	23.371	0.621	0.208	0.291	1.12
38	*Myrsine semiserrata*	0.95	72.43	0.621	0.416	0.069	1.106
39	*Dillenia indica*	0.95	4450.685	0.621	0.416	0.029	1.066
40	*Quercus sp*	0.48	45.806	0.621	0.208	0.236	1.065
41	*Sarcosperma arboreum*	0.48	27.951	0.621	0.208	0.179	1.008
42	*Syzygium sp*	0.48	63.568	0.621	0.208	0.171	1
43	*Ficus oligodon*	0.48	198.182	0.621	0.208	0.078	0.907
44	*Gmelina arborea*	0.48	48.461	0.621	0.208	0.07	0.899
45	*Ixora undulata*	0.48	58.696	0.621	0.208	0.063	0.892
46	*Casearia vareca*	0.48	44.547	0.621	0.208	0.061	0.89
47	*Pterospermum acerifolium*	0.48	881.890	0.621	0.208	0.043	0.872
48	*Buchanania lanazan*	0.48	79.123	0.621	0.208	0.034	0.863
49	*Cordia obliqua*	0.48	436.15	0.621	0.208	0.028	0.857
50	*Holmskoildia sanguinea*	0.48	330.403	0.621	0.208	0.028	0.857

Table 1 (contd.). Phytosociological attributes in Eastern Himalayan Sal Forest (Type I)

Sl No	Names of Plants	Density $400m^{-2}$	TBA $400m^{-2}$ (cm^2)	RF	RD	RDm	IVI
51	*Persea sp*	0.48	808.034	0.621	0.208	0.026	0.855
52	*Terminalia arjuna*	0.48	547.987	0.621	0.208	0.026	0.855
53	*Bridelia sikkimensis*	0.48	125.363	0.621	0.208	0.025	0.854
54	*Casearia sp*	0.48	254.571	0.621	0.208	0.025	0.854
55	*Millettia extensa*	0.48	538.457	0.621	0.208	0.025	0.854
56	*Bassia butyracea*	0.48	38.727	0.621	0.208	0.018	0.847
57	*Holarrhena pubescens*	0.48	33.654	0.621	0.208	0.018	0.847
58	*Syzygium formosum*	0.48	316.493	0.621	0.208	0.018	0.847
59	*Litsea glutinosa*	0.48	263.816	0.621	0.208	0.013	0.842
60	*Wrightia tinctoria*	0.48	315.564	0.621	0.208	0.009	0.838
61	*Acacia sp*	0.48	48.461	0.621	0.208	0.005	0.834
62	*Antidesma acidum*	0.48	208.101	0.621	0.208	0.005	0.834
63	*Dalbergia sp*	0.48	15.114	0.621	0.208	0.005	0.834
64	*Dysoxylum thyrsoideum*	0.48	95.819	0.621	0.208	0.005	0.834
65	*Zizyphus xylocarpa*	0.48	16.49	0.621	0.208	0.005	0.834
66	*Glochidion gamblei*	0.48	9.573	0.621	0.208	0.003	0.832
	Total	229.05	17014.67				

D: Density $400m^{-2}$; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

Table 2. Phytosociological attributes in Bamboo Brake forest (Type II)

Sl No	Names of Plants	Density $400m^{-2}$	TBA $400m^{-2}$ (cm^2)	RF	RD	RDm	IVI
1	*Dendrocalamus hamiltonii*	814.21	18.226	14.286	89.994	32.881	137.161
2	*Schima wallichii*	6.84	125.771	4.511	0.756	19.644	24.911
3	*Bombax ceiba*	8.95	285.991	6.767	0.989	5.102	12.858
4	*Albizia odoratissima*	3.68	1092.283	3.008	0.407	7.909	11.324
5	*Stereospermum colais*	2.11	532.069	3.008	0.233	4.838	8.079
6	*Heteropanax fragrans*	8.42	129.608	5.263	0.931	1.498	7.692
7	*Terminalia alata*	6.84	78.616	4.511	0.756	2.188	7.455
8	*Sterculia villosa*	5.26	42.321	5.263	0.582	1.315	7.16
9	*Albizia chinensis*	4.21	546.782	3.008	0.465	2.367	5.84
10	*Castanopsis indica*	0.53	290.154	0.752	0.058	4.799	5.609
11	*Bauhinia purpurea*	2.63	42.321	3.759	0.291	0.407	4.457
12	*Terminalia bellirica*	1.05	45.007	1.504	0.116	1.95	3.57
13	*Lagerstroemia parviflora*	2.11	109.053	3.008	0.233	0.103	3.344
14	*Bischofia javanica*	2.11	114.633	0.752	0.233	2.262	3.247
15	*Alstonia scholaris*	1.05	10.58	1.504	0.116	1.101	2.721
16	*Gynocardia odorata*	1.05	284.715	1.504	0.116	1.085	2.705
17	*Mallotus philippensis*	2.11	4639.174	1.504	0.233	0.656	2.393
18	*Macaranga pustulata*	1.05	62.572	1.504	0.116	0.761	2.381
19	*Engelhardtia spicata*	0.53	123.76	0.752	0.058	1.447	2.257
20	*Castanopsis tribuloides*	1.05	73.07	1.504	0.116	0.589	2.209
21	*Trema orientale*	0.53	20.547	0.752	0.058	1.37	2.18
22	*Callicarpa vestita*	1.58	14.92	1.504	0.175	0.338	2.017
23	*Albizia procera*	3.16	455.652	0.752	0.349	0.781	1.882
24	*Firmiana colorata*	1.58	1399.233	1.504	0.175	0.198	1.877
25	*Crateva religiosa*	1.05	753.22	1.504	0.116	0.256	1.876
26	*Callicarpa arborea*	1.05	63.757	1.504	0.116	0.237	1.857
27	*Dalbergia stipulacea*	1.05	10.58	1.504	0.116	0.151	1.771
28	*Cordia obliqua*	1.05	10.58	1.504	0.116	0.129	1.749
29	*Grewia eriocarpa*	1.05	56.311	1.504	0.116	0.116	1.736
30	*Drymicarpus racemosus*	1.05	524.32	1.504	0.116	0.031	1.651

Table 2 (contd.). Phytosociological attributes in Bamboo Brake forest (Type II)

Sl No	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
31	*Erythrina stricta*	0.53	90.534	0.752	0.058	0.779	1.589
32	*Pandanus nepalensis*	2.11	158.868	0.752	0.233	0.349	1.334
33	*Duabanga grandiflora*	0.53	24.777	0.752	0.058	0.471	1.281
34	*Pentapanax fragrans*	0.53	139.031	0.752	0.058	0.346	1.156
35	*Tetrameles nudiflora*	0.53	367.828	0.752	0.058	0.222	1.032
36	*Pterospermum acerifolium*	0.53	158.631	0.752	0.058	0.216	1.026
37	*Rhus semialata*	1.05	83.691	0.752	0.116	0.135	1.003
38	*Kydia calycina*	0.53	53.562	0.752	0.058	0.164	0.974
39	*Wrightia arborea*	1.05	84.239	0.752	0.116	0.091	0.959
40	*Macaranga indica*	0.53	334.764	0.752	0.058	0.144	0.954
41	*Bassia butyracea*	0.53	69.474	0.752	0.058	0.134	0.944
42	*Nayariophyton zizyphifolium*	0.53	208.339	0.752	0.058	0.087	0.897
43	*Phyllanthus emblica*	0.53	65.134	0.752	0.058	0.072	0.882
44	*Ostodes paniculatus*	0.53	9.299	0.752	0.058	0.055	0.865
45	*Bridelia sikkimensis*	0.53	1460.748	0.752	0.058	0.047	0.857
46	*Bauhinia vahlii*	0.53	127.107	0.752	0.058	0.044	0.854
47	*Bridelia retusa*	0.53	1169.265	0.752	0.058	0.044	0.854
48	*Talauma hodgsonii*	0.53	20.003	0.752	0.058	0.021	0.831
49	*Acrocarpus fraxinifolius*	0.53	162.696	0.752	0.058	0.019	0.829
50	*Careya arborea*	0.53	942.734	0.752	0.058	0.011	0.821
51	*Ficus semicordata*	0.53	8.266	0.752	0.058	0.011	0.821
52	*Glochidion gamblei*	0.53	214.249	0.752	0.058	0.011	0.821
53	*Salacia brunoniana*	0.53	1324.221	0.752	0.058	0.01	0.82
54	*Terminalia chebula*	0.53	44.16	0.752	0.058	0.009	0.819
	Total	904.74	19277.444				

D: Density 400m^{-2}; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

Table 3. Phytosociological attributes in Riverine Forest (Type III)

Sl No	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
1	*Sterculia villosa*	14.44	628.06	5.825	7.182	23.486	36.493
2	*Terminalia bellirica*	16.67	155.31	6.796	8.287	10.47	25.553
3	*Terminalia alata*	8.89	1133.04	2.913	4.42	12.2	19.533
4	*Syzygium cumini*	12.22	68.78	4.854	6.077	6.421	17.352
5	*Holarrhena pubescens*	18.89	469.26	4.854	9.392	1.541	15.787
6	*Dillenia pentagyna*	8.89	738.48	3.883	4.42	6.565	14.868
7	*Aglaia spectabilis*	7.78	1392.7	3.883	3.867	3.83	11.58
8	*Careya arborea*	6.67	41.71	3.883	3.315	4.035	11.233
9	*Lagerstroemia parviflora*	5.56	2464.81	4.854	2.762	3.197	10.813
10	*Syzygium claviflorum*	11.11	31.5	1.942	5.525	1.931	9.398
11	*Aphanamixis polystachya*	7.78	176.68	2.913	3.867	1.586	8.366
12	*Acacia catechu*	7.78	1699.6	1.942	3.867	2.123	7.932
13	*Pterygota alata*	3.33	2452.82	2.913	1.657	2.726	7.296
14	*Lannea coromendalica*	2.22	68.4	1.942	1.105	2.922	5.969
15	*Strebulus asper*	4.44	86.99	1.942	2.21	1.516	5.668
16	*Choerospondias axillaris*	2.22	660.4	1.942	1.105	2.38	5.427
17	*Firmiana colorata*	2.22	100.86	1.942	1.105	2.369	5.416
18	*Nayariophyton zizyphifolium*	2.22	187.8	1.942	1.105	2.04	5.087
19	*Wrightia arborea*	4.44	1324.3	1.942	2.21	0.652	4.804
20	*Casearia vareca*	3.33	3025.57	2.913	1.657	0.06	4.63
21	*Wrightia tinctoria*	3.33	3116.66	1.942	1.657	0.518	4.117
22	*Stereospermum colais*	2.22	125.99	1.942	1.105	0.877	3.924
23	*Albizia lucidor*	3.33	28.27	1.942	1.657	0.1	3.699
24	*Acacia pennata*	2.22	28.27	1.942	1.105	0.15	3.197
25	*Grewia optiva*	2.22	2112.15	1.942	1.105	0.084	3.131

Table 3 (contd.). Phytosociological attributes in Riverine Forest (Type III)

Sl No	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
26	*Trema nodiflora*	2.22	179.08	0.971	1.105	1.018	3.094
27	*Litsea cubeba*	1.11	34.9	0.971	0.552	1.505	3.028
28	*Pterospermum acerifolium*	1.11	2521.53	0.971	0.552	1.217	2.74
29	*Persea sp*	2.22	1882.1	0.971	1.105	0.173	2.249
30	*Sapindus rarak*	2.22	143.31	0.971	1.105	0.138	2.214
31	*Ventilago denticulata*	2.22	42.23	0.971	1.105	0.042	2.118
32	*Bauhinia variegata*	1.11	3741.68	0.971	0.552	0.357	1.88
33	*Heynea trijuga*	1.11	907.97	0.971	0.552	0.319	1.842
34	*Crateva religiosa*	1.11	784.97	0.971	0.552	0.085	1.608
35	*Litsea glutinosa*	1.11	400	0.971	0.552	0.061	1.584
36	*Hiptage bengalensis*	1.11	1208.94	0.971	0.552	0.049	1.572
37	Unidentified Liana	1.11	3158.4	0.971	0.552	0.033	1.556
38	*Shorea robusta*	1.11	1445.56	0.971	0.552	0.02	1.543
39	*Premna mucronata*	1.11	1053.72	0.971	0.552	0.017	1.54
40	*Combretum decandrum*	1.11	43.01	0.971	0.552	0.015	1.538
41	*Mallotus philippensis*	1.11	337.57	0.971	0.552	0.014	1.537
42	*Millettia pachycarpa*	1.11	357.61	0.971	0.552	0.014	1.537
	Total	201.11	40560.94				

D: Density 400m^{-2}; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

Table 4. Phytosociological attributes in Semi – evergreen Mixed Forest (Type IV)

Sl No	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
1	*Aglaia chittagonga*	20.67	23.278	5.143	8.611	6.196	19.95
2	*Shorea robusta*	11.33	214.426	2.286	4.722	11.903	18.911
3	*Pterospermum acerifolium*	9.33	152.705	5.143	3.889	7.333	16.365
4	*Schima wallichii*	14.67	437.589	2.857	6.111	5.348	14.316
5	*Michelia champaca*	13.33	725.602	2.857	5.556	5.637	14.05
6	*Terminalia bellirica*	5.33	899.889	2.857	2.222	8.276	13.355
7	*Duabanga grandiflora*	6	536.195	2.857	2.5	4.938	10.295
8	*Tetrameles nudiflora*	0.67	952.796	0.571	0.278	6.22	7.069
9	*Aglaia spectabilis*	6	1177.875	1.143	2.5	2.983	6.626
10	*Albizia lebbek*	4.67	17.433	1.714	1.944	2.877	6.535
11	*Sapindus rarak*	2.67	121.976	1.143	1.111	4.15	6.404
12	*Mallotus philippensis*	6.67	88.011	3.429	2.778	0.132	6.339
13	*Pterygota alata*	3.33	229.424	1.714	1.389	2.883	5.986
14	*Terminalia myriocarpa*	3.33	378.229	1.143	1.389	2.659	5.191
15	*Chukrasia tabularis*	2.67	3457.665	1.143	1.111	2.705	4.959
16	*Dillenia pentagyna*	5.33	141.07	2.286	2.222	0.428	4.936
17	*Combretum decandrum*	5.33	52.018	2.286	2.222	0.316	4.824
18	*Persea odoratissima*	4	349.803	2.286	1.667	0.775	4.728
19	*Dalbergia stipulacea*	6	15.329	1.714	2.5	0.114	4.328
20	*Crateva unilocularis*	4.67	15.329	1.714	1.944	0.487	4.145
21	*Nayariophyton zizyphifolium*	4.67	1340.16	1.143	1.944	0.9	3.987
22	*Rhus insignis*	3.33	22.685	1.143	1.389	1.112	3.644
23	*Lagerstroemia parviflora*	4	1889.835	1.143	1.667	0.618	3.428
24	*Toona ciliata*	1.33	234.999	1.143	0.556	1.55	3.249
25	*Ficus elastica*	2	1480.54	0.571	0.833	1.814	3.218
26	*Syzygium cumini*	3.33	1297.547	1.714	1.389	0.05	3.153
27	*Cinnamomum bejolghota*	1.33	1340.16	1.143	0.556	1.185	2.884
28	*Knema erratica*	2.67	48.581	1.143	1.111	0.576	2.83
29	*Bauhinia purpurea*	3.33	86.476	1.143	1.389	0.204	2.733
30	*Grewia disperma*	4	152.376	0.571	1.667	0.368	2.606
31	*Bombax ceiba*	0.67	234.999	0.571	0.278	1.579	2.428
32	*Castanopsis hystrix*	1.33	41.042	0.571	0.556	1.224	2.351
33	*Bridelia sikkimensis*	2.67	27.722	1.143	1.111	0.096	2.349
34	*Ficus hookeriana*	2.67	137.257	1.143	1.111	0.086	2.339
35	*Litsea monopetala*	0.67	19.919	0.571	0.278	1.412	2.261
36	*Grewia sp*	1.33	1201.258	0.571	0.556	1.048	2.175
37	*Gynocardia odorata*	0.67	544.649	0.571	0.278	1.265	2.114
38	*Callicarpa vestita*	1.33	544.649	1.143	0.556	0.32	2.019
39	*Acacia pennata*	0	141.554	1.143	0.833	0.032	2.008
40	*Alseodaphne andersii*	1.33	1321.722	0.571	0.556	0.87	1.997
41	*Ficus hispida*	2.67	116.086	0.571	1.111	0.212	1.894
42	*Bridelia retusa*	1.33	46.434	1.143	0.556	0.129	1.828
43	*Holarrhena pubescens*	2.67	286.59	0.571	1.111	0.094	1.776

Table 4 (contd.). Phytosociological attributes in Semi – evergreen Mixed Forest (Type IV)

Sl No	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
44	*Machilus villosa*	1.33	21.084	1.143	0.556	0.071	1.77
45	*Cedrela toona*	0.67	278.973	0.571	0.278	0.863	1.712
46	*Albizia procera*	1.33	158.359	0.571	0.556	0.49	1.617
47	*Stereospermum colais*	2	182.099	0.571	0.833	0.104	1.508
48	*Pandanus nepalensis*	2	134.164	0.571	0.833	0.073	1.477
49	*Cinnamomum glaucescens*	0.67	1147.617	0.571	0.278	0.612	1.461
50	*Rhus semialata*	2	2769.315	0.571	0.833	0.041	1.445
51	*Castanopsis indica*	2	18.898	0.571	0.833	0.031	1.435
52	*Ficus semicordata*	2	48.999	0.571	0.833	0.029	1.433
53	*Ficus nervifolia*	1.33	51.211	0.571	0.556	0.262	1.389
54	*Alstonia scholaris*	0.67	130.875	0.571	0.278	0.538	1.387
55	*Bauhinia vahlii*	1.33	302.374	0.571	0.556	0.21	1.337
56	*Gordonia excelsa*	1.33	315.442	0.571	0.556	0.166	1.293
57	*Adina cordifolia*	1.33	188.46	0.571	0.556	0.14	1.267
58	*Bassia butyracea*	1.33	225.367	0.571	0.556	0.111	1.238
59	*Premna bracteata*	1.33	32.719	0.571	0.556	0.108	1.235
60	*Persea minutiflora*	1.33	123.572	0.571	0.556	0.082	1.209
61	*Magnolia pterocarpa*	0.67	3091.215	0.571	0.278	0.356	1.205
62	*Oroxylum indicum*	1.33	77.53	0.571	0.556	0.065	1.192
63	*Heynea trijuga*	1.33	15.129	0.571	0.556	0.045	1.172
64	*Colebrookea oppositifolia*	1.33	779.177	0.571	0.556	0.044	1.171
65	*Drypetes lancifolia*	1.33	28.845	0.571	0.556	0.018	1.145
66	*Engelhardtia spicata*	0.67	617.052	0.571	0.278	0.249	1.098
67	*Erythrina stricta*	0.67	20.94	0.571	0.278	0.249	1.098
68	*Salix tetrasperma*	0.67	15.129	0.571	0.278	0.185	1.034
69	*Beilschmiedia dalzellii*	0.67	249.238	0.571	0.278	0.173	1.022
70	*Juglans regia*	0.67	281.508	0.571	0.278	0.138	0.987
71	*Garcinia stipulata*	0.67	70.777	0.571	0.278	0.127	0.976
72	*Morus macroura*	0.67	53.1	0.571	0.278	0.114	0.963
73	*Celtis timorensis*	0.67	57.009	0.571	0.278	0.107	0.956
74	*Cryptocarya amygdalina*	0.67	89.885	0.571	0.278	0.107	0.956
75	*Actinodaphne angustifolia*	0.67	282.81	0.571	0.278	0.098	0.947
76	*Tectona grandis*	0.67	117.683	0.571	0.278	0.098	0.947
77	*Knema tenuinervia*	0.67	1146.674	0.571	0.278	0.086	0.935
78	*Gmelina arborea*	0.67	1262.326	0.571	0.278	0.072	0.921
79	*Ficus cunia*	0.67	486.719	0.571	0.278	0.065	0.914
80	*Horsfieldia kingii*	0.67	29.682	0.571	0.278	0.06	0.909
81	*Saurauja roxburghii*	0.67	405.398	0.571	0.278	0.057	0.906
82	*Litsea hookeri*	0.67	2271.257	0.571	0.278	0.056	0.905
83	*Terminalia alata*	0.67	125.692	0.571	0.278	0.043	0.892
84	*Persea glaucescens*	0.67	532.145	0.571	0.278	0.026	0.875
85	*Wrightia tomentosa*	0.67	1532.885	0.571	0.278	0.02	0.869
86	*Dalbergia sp*	0.67	8.847	0.571	0.278	0.019	0.868
87	*Talauma hodgsonii*	0.67	76.099	0.571	0.278	0.019	0.868
88	*Litsea citrata*	0.67	21.966	0.571	0.278	0.015	0.864
89	*Miliusa roxburghiana*	0.67	41.042	0.571	0.278	0.01	0.859
90	*Helicia nilagirica*	0.67	214.426	0.571	0.278	0.009	0.858
91	*Aporosa roxburghii*	0.67	95.096	0.571	0.278	0.008	0.857
92	*Caryota urens*	0.67	2264.87	0.571	0.278	0.007	0.856
93	*Castanopsis armata*	0.67	1251.944	0.571	0.278	0.007	0.856
94	*Maesa chisia*	0.67	13616.235	0.571	0.278	0.007	0.856
95	*Millettia pachycarpa*	0.67	1696.14	0.571	0.278	0.007	0.856
96	*Sorindeia madagascarensis*	0.67	44.026	0.571	0.278	0.004	0.853
	Total	238	62026.627				

D: Density 400m^{-2}; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

Table 5. Phytosociological attributes in Wet Mixed Deciduous Forest (Type V)

Sl No.	Names of Plants	Density $400m^{-2}$	TBA $400m^2$ (cm^2)	RF	RD	RDm	IVI
1	*Schima wallich.*	80	108.757	4.348	26.087	17.898	48.333
2	*Bombax ceiba*	6.67	126.687	2.174	2.174	37.924	42.272
3	*Bassia butyracea*	6.67	104.7	4.348	2.174	10.926	17.448
4	*Castanopsis lanceifolia*	6.67	13951.275	2.174	2.174	10.304	14.652
5	*Gynocardia odorata*	6.67	4842.375	2.174	2.174	4.784	9.132
6	*Acacia pennata*	13.33	530.044	4.348	4.348	0.17	8.866
7	*Duabanga grandiflora*	3.33	171.446	2.174	1.087	4.307	7.568
8	*Litsea cubeba*	3.33	157.181	2.174	1.087	3.897	7.158
9	*Litsea glutinosa*	13.33	104.7	2.174	4.348	0.489	7.011
10	*Callicarpa arborea*	6.67	13156.209	4.348	2.174	0.123	6.645
11	*Morus macroura*	10	251.542	2.174	3.261	0.85	6.285
12	*Ostodes paniculata*	3.33	67.008	2.174	1.087	2.624	5.885
13	*Dendrocnide sinuata*	10	218.43	2.174	3.261	0.383	5.818
14	*Morus laevigata*	10	1006.167	2.174	3.261	0.354	5.789
15	*Bridelia retusa*	10	325.704	2.174	3.261	0.201	5.636
16	*Pandanus nepalensis*	6.67	11000.044	2.174	2.174	0.346	4.694
17	*Stereospermum colais*	6.67	81.797	2.174	2.174	0.32	4.668
18	*Grewia disperma*	6.67	126.687	2.174	2.174	0.212	4.56
19	*Macaranga indica*	6.67	163.593	2.174	2.174	0.205	4.553
20	*Sterculia villosa*	3.33	176.943	2.174	1.087	1.286	4.547
21	*Crateva unilocularis*	6.67	270.78	2.174	2.174	0.171	4.519
22	*Ficus hookeri*	6.67	6108.46	2.174	2.174	0.128	4.476
23	*Talauma hodgsonii*	6.67	94.492	2.174	2.174	0.118	4.466
24	*Engelhardtia spicata*	6.67	973.972	2.174	2.174	0.064	4.412
25	*Dalbergia sericea*	3.33	9953.044	2.174	1.087	0.394	3.655
26	*Lagerstroemia parviflora*	3.33	312.137	2.174	1.087	0.381	3.642
27	*Brassaiopsis hainla*	3.33	261.357	2.174	1.087	0.208	3.469
28	*Trema orientalis*	3.33	138.466	2.174	1.087	0.181	3.442
29	*Pyrularia edulis*	3.33	115.432	2.174	1.087	0.126	3.387
30	*Cinnamomum bejolghota*	3.33	301.361	2.174	1.087	0.098	3.359
31	*Ficus semicordata*	3.33	723.216	2.174	1.087	0.069	3.33
32	*Mallotus philippensis*	3.33	104.7	2.174	1.087	0.054	3.315
33	*Ailanthus integrifolia*	3.33	58.894	2.174	1.087	0.05	3.311
34	*Ficus elastica*	3.33	670.08	2.174	1.087	0.05	3.311
35	*Phoebe pallida*	3.33	442.358	2.174	1.087	0.05	3.311
36	*Michelia champaca*	3.33	126.687	2.174	1.087	0.045	3.306
37	*Alnus nepalensis*	3.33	320.644	2.174	1.087	0.041	3.302
38	*Casuerina glomerata*	3.33	1904.449	2.174	1.087	0.041	3.302
39	*Myrsine semiserrata*	3.33	3283.392	2.174	1.087	0.041	3.302
40	*Helicia nilagrica*	3.33	408.983	2.174	1.087	0.037	3.298
41	*Cleidion javanicum*	3.33	151.292	2.174	1.087	0.026	3.287
42	*Oroxylum indicum*	3.33	461.727	2.174	1.087	0.023	3.284
	Total	306.67	123469.3				

D: Density $400m^{-2}$; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

Table 6. Phytosociological attributes in Lower Bhabar Sal Forest (Type VI)

Sl No.	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
1	*Shorea robusta*	45.71	82.984	6.742	17.112	34.16	58.014
2	*Lagerstroemia parviflora*	20	258.459	5.618	7.487	2.364	15.469
3	*Aglaia spectabilis*	15.71	137.419	3.371	5.882	5.99	15.243
4	*Tectona grandis*	10	926.595	2.247	3.743	8.803	14.793
5	*Syzygium cumini*	17.14	6733.519	5.618	6.417	0.988	13.023
6	*Dillenia pentagyna*	7.14	161.986	1.124	2.674	6.502	10.3
7	*Mallotus philippensis*	11.43	28.718	3.371	4.278	0.558	8.207
8	*Cedrela toona*	2.86	754.289	2.247	1.07	4.347	7.664
9	*Holarrhena pubescens*	7.14	2424.067	3.371	2.674	1.125	7.17
10	*Spondias axillaris*	1.43	44.871	1.124	0.535	4.985	6.644
11	*Casearia glomerata*	7.14	97.203	1.124	2.674	2.062	5.86
12	*Ailanthus interrigifolia*	1.43	1470.437	1.124	0.535	3.957	5.616
13	*Duabanga grandiflora*	1.43	35.168	1.124	0.535	3.797	5.456
14	*Firmiana colorata*	5.71	701.924	1.124	2.139	1.544	4.807
15	*Schima wallichii*	7.14	64.615	1.124	2.674	0.493	4.291
16	*Dalbergia stipulacea*	4.29	36.346	2.247	1.604	0.29	4.141
17	*Callicarpa vestita*	2.86	75.833	1.124	1.07	1.728	3.922
18	*Oroxylum indicum*	2.86	164.524	2.247	1.07	0.368	3.685
19	*Polyalthia simarum*	2.86	70.112	1.124	1.07	1.304	3.498
20	*Acacia gageana*	5.71	2212.924	1.124	2.139	0.195	3.458
21	*Eugenia bracteata*	5.71	6461.486	1.124	2.139	0.17	3.433
22	*Bridelia retusa*	2.86	137.419	2.247	1.07	0.114	3.431
23	*Careya arborea*	5.71	1308.451	1.124	2.139	0.083	3.346
24	*Terminalia alata*	1.43	72.411	1.124	0.535	1.625	3.284
25	*Bombax ceiba*	1.43	195.471	1.124	0.535	1.424	3.083
26	*Pterospermum acerifolium*	1.43	656.665	1.124	0.535	1.386	3.045
27	*Syzygium ramosissimum*	4.29	25.24	1.124	1.604	0.168	2.896
28	*Michelia champaca*	4.29	473.954	1.124	1.604	0.117	2.845
29	*Terminalia bellirica*	1.43	217.178	1.124	0.535	1.08	2.739
30	*Mangifera sylvaticum*	1.43	214.541	1.124	0.535	1.063	2.722
31	*Lannea coromendalica*	2.86	431.214	1.124	1.07	0.36	2.554
32	*Grewia optiva*	2.86	382.933	1.124	1.07	0.252	2.446
33	*Engelhardtia spicata*	1.43	287.385	1.124	0.535	0.769	2.428
34	*Ficus altissima*	2.86	306.529	1.124	1.07	0.23	2.424
35	*Maesa chisia*	1.43	25.24	1.124	0.535	0.672	2.331
36	*Litsea monopetala*	1.43	1077.363	1.124	0.535	0.633	2.292
37	*Sapium baccatum*	1.43	54.294	1.124	0.535	0.595	2.254
38	*Nayariophyton zizyphifolium*	1.43	1144.334	1.124	0.535	0.558	2.217
39	*Alstonia Scholaris*	1.43	118.755	1.124	0.535	0.443	2.102
40	*Phoebe attenuate*	1.43	1809.328	1.124	0.535	0.419	2.078
41	*Persea minutiflora*	1.43	66.186	1.124	0.535	0.411	2.07
42	*Gmelina arborea*	1.43	949.479	1.124	0.535	0.279	1.938
43	*Gynocardia odorata*	1.43	312.754	1.124	0.535	0.253	1.912
44	*Adina cordifolia*	1.43	100.961	1.124	0.535	0.152	1.811
45	*Grewia disperma*	1.43	700.106	1.124	0.535	0.128	1.787
46	*Wrightia arborea*	1.43	356.336	1.124	0.535	0.116	1.775
47	*Alangium chinensis*	1.43	1109.782	1.124	0.535	0.095	1.754
48	*Aegle marmelos*	1.43	2358.554	1.124	0.535	0.081	1.74
49	*Elaeocarpus aristatus*	1.43	1012.412	1.124	0.535	0.081	1.74
50	*Semecarpus anacardium*	1.43	167.752	1.124	0.535	0.072	1.731

Table 6 (contd.). Phytosociological attributes in Lower Bhabar Sal Forest (Type VI)

Sl No	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
51	*Pavetta polyantha*	1.43	122.162	1.124	0.535	0.059	1.718
52	*Dalbergia sissoo*	1.43	1816.539	1.124	0.535	0.045	1.704
53	*Dalbergia volubilis*	1.43	32.42	1.124	0.535	0.041	1.7
54	*Celtis timorensis*	1.43	8483.504	1.124	0.535	0.038	1.697
55	*Litsea glutinosa*	1.43	140.12	1.124	0.535	0.032	1.691
56	*Brassaiopsis hispida*	1.43	95.314	1.124	0.535	0.026	1.685
57	*Zanthoxylum nitidum*	1.43	2139.902	1.124	0.535	0.026	1.685
58	*Trema orientalis*	1.43	1837.934	1.124	0.535	0.024	1.683
59	*Cyathea spinulosa*	1.43	2765.09	1.124	0.535	0.021	1.68
60	*Sorindeia madagascarensis*	1.43	3698.303	1.124	0.535	0.019	1.678
61	*Alstonia nerufolia*	1.43	40.496	1.124	0.535	0.017	1.676
62	*Garuga pinnata*	1.43	197.883	1.124	0.535	0.015	1.674
63	*Lasiococca symphylifolia*	1.43	44.871	1.124	0.535	0.015	1.674
	Total	26571	60431045				

D: Density 400m^{-2}; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

Table 7. Phytosociological attributes in Upper Bhabar Sal Forest (Type VII)

Sl No.	Names of Plants	Density 400m^{-2}	TBA 400m^{-2} (cm^2)	RF	RD	RDm	IVI
1	*Shorea robusta*	94	114.489	10.638	34.815	31.186	76.639
2	*Schima wallichii*	16	391.4	6.383	5.926	30.266	42.575
3	*Terminalia alata*	24	8673.086	6.383	8.889	7.513	22.785
4	*Lagerstroemia parviflora*	26	70.673	6.383	9.63	2.746	18.759
5	*Engelhardtia spicata*	2	883.406	2.128	0.741	10.783	13.652
6	*Mallotus philippensis*	10	1477.683	8.511	3.704	0.803	13.018
7	*Wrightia arborea*	12	704.997	4.255	4.444	1.249	9.948
8	*Terminalia bellirica*	6	221.702	6.383	2.222	0.359	8.964
9	*Anthocephalus cadamba*	2	377.077	2.128	0.741	5.403	8.272
10	*Glochidion gamblei*	14	17310.68	2.128	5.185	0.682	7.995
11	*Dillenia pentagyna*	6	48.267	4.255	2.222	0.414	6.891
12	*Bombax ceiba*	4	160.819	4.255	1.481	1.034	6.77
13	*Grewia disperma*	8	122.185	2.128	2.963	1.477	6.568
14	*Tectona grandis*	8	35.336	2.128	2.963	1.472	6.563
15	*Pandanus nepalensis*	4	156.399	4.255	1.481	0.254	5.99
16	*Entada rheedii*	6	592.942	2.128	2.222	0.09	4.44
17	*Terminalia myriocarpa*	2	339.047	2.128	0.741	1.57	4.439
18	*Albizia procera*	4	257.745	2.128	1.481	0.488	4.097
19	*Ficus altissima*	4	277.036	2.128	1.481	0.152	3.761
20	*Bauhinia vahlii*	2	203.537	2.128	0.741	0.55	3.419
21	*Bridelia sp.*	2	6073.3	2.128	0.741	0.439	3.308
22	*Sterculia villosa*	2	1088.322	2.128	0.741	0.426	3.295
23	*Emblica officinale*	2	684.11	2.128	0.741	0.235	3.104
24	*Mangifera indica*	2	590.587	2.128	0.741	0.173	3.042
25	*Erythrina stricta*	2	191.915	2.128	0.741	0.1	2.969
26	*Albizia julibrissin*	2	2520.652	2.128	0.741	0.071	2.94
27	*Aralia foliolosa*	2	1005.12	2.128	0.741	0.044	2.913
28	*Ficus hookeriana*	2	334.124	2.128	0.741	0.022	2.891
	Total	270	44906.64				

D: Density 400m^{-2}; RF: Relative Frequency; RD: Relative Density; RDm: Relative Dominance; IVI: Importance Value Index

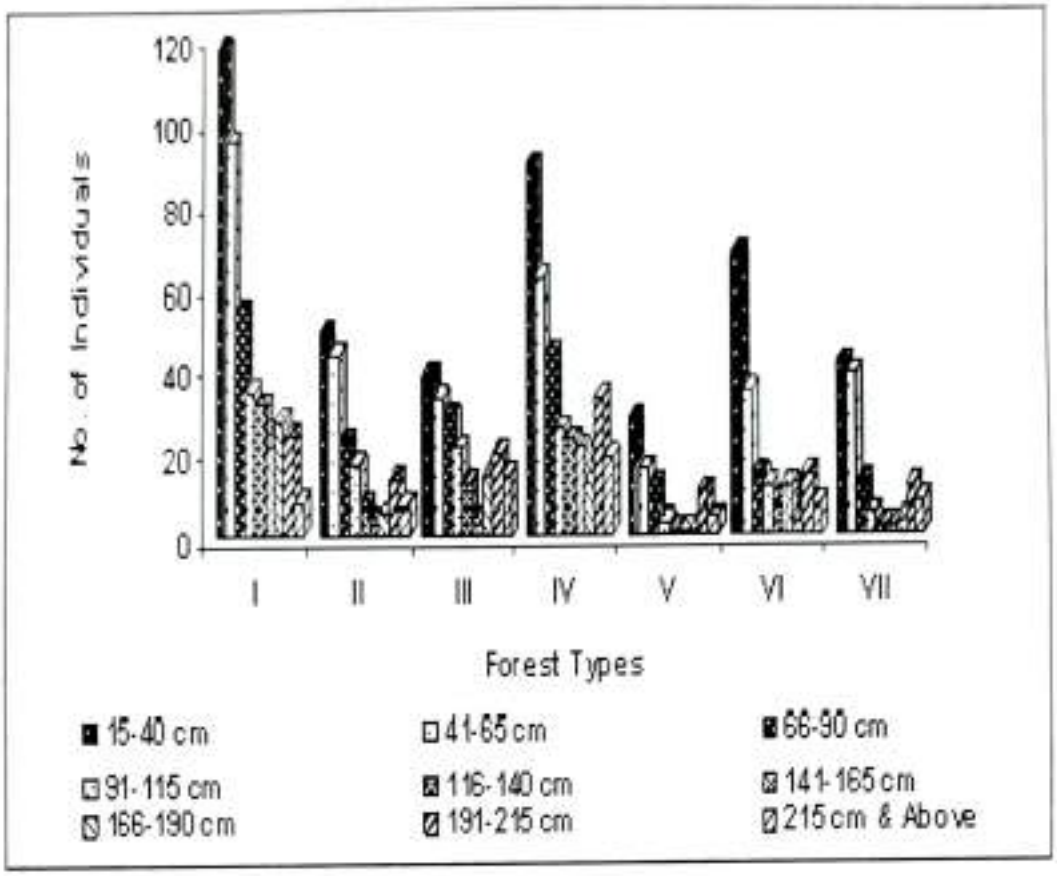

Fig 1. Graph showing girth class distribution in different forest types

Phytosociological Structure

Quantitative analysis of vegetation in 7 different forest types are shown in Tables 1 – 7, with their Density 400m^{-2}, total Basal Area (TBA) 400 m^{-2}, RD, RF, RDm and IVI. *Shorea robusta* is the most predominant species in Types I, VI & VII, whereas Type-II is dominated by *Dendrocalamus hamiltonii*. However, Type-III is quite heterogeneous with *Sterculia villosa*, *Terminalia bellirica*, *Terminalia alata* and *Syzygium cumini*, among the important species, co-habiting the same niche and in Type IV *Shorea robusta* is nearly equally predominant with *Aglaia chittagonga*. This Type is quite heterogeneous as the species like *Pterospermum acerifolium*, *Schima wallichii*, *Michelia champaca* and *Terminalia bellirica* are also highly predominating. On the other hand, Type-V is more pronounced with the presence of *Schima wallichii*, *Bombax ceiba*, *Bassia butyracea* and *Castanopsis lanceifolia*. Considering the total density 400 m^{-2} of forests, Type-II is with most dense (904.74) vegetation, which is followed by Types-V with 306.67 and the Type-III showed the least density of 201.11 only. Remaining Types (VII, VI, IV & I) had a moderate density with 270, 265.71, 238 & 229.05 respectively.

If the RF of different species are considered, except for the Types I, II & VII where only one species is most commonly found, in other Types there are no such plants, instead, the predominant species are nearly equally dispersed in the vegetation. This has also been reflected in the RD values of high IVI plants in these Types. RDm is calculated over the basal area of different species. It is expected that the trees with very high RD values will also score high RDm values. However, this can be interfered by the species with excessively high GBH values.

In Types I, II, VI & VII the species with highest RD and RDm values are same. But, this has been shifted in other Types. In Type III *Holarrhena pubescens* is with highest RD value. But, the highest RDm value has been recorded by *Sterculia villosa* with its much thick trunk in comparison to the dominating species. So, the thick trunk and comparatively better RD and RF values all together made this species most important in this Type.

Sal is not a frequent species in Type IV and is fourth in its RD value. But, this has scored highest RDm value. Also, the species is not at all well distributed in the vegetation. So, the high GBH of its individuals made it to score highest RDm.

The most interesting situation developed in Type- V, where *Schima wallichii* is recorded with highest RD, RF & IVI scores but for RDm *Bombax ceiba* emerged highest with a much better score. This is certainly due to the very large girth of this very fast growing tree species.

But, the situations in these forests are no doubt more congenial for the very aggressive and tolerant species *Shorea robusta*. However, in newly formed habitat plants like *Bombax ceiba*, *Litsea glutinosa* etc. try to dominate. *Tectona grandis* is not a naturally growing plant in the region but perform nicely if planted. In forest enrichment program, sometimes teak is planted in comparatively open areas inside natural forests.

So, all the seven types of vegetation showed a profound degree of heterogeneity in their species composition but some are with one clearly dominating species. It is expected that, in matured vegetation one species will be dominating as in the cases of I, VI & VII. However, in the complete dominance of *Dendrocalamus hamiltonii* in Type II is not a similar situation. Bamboos generally spread in open areas in the forest. Creation of such areas is generally the result of anthropogenic or other biotic activities or due to some sudden natural disaster. *D. hamiltonii* is now spreading nicely in this Type and reintroduced the vegetation of the Type into the developmental phases. However, the co-dominance of a few species in vegetation indicates that the forest is still in its seral stages (Odum 1971). The low number of individuals for the high girth class and much more for small girth and the thin distribution of mature trees in the vegetations of this region are indicative of excessive anthropogenic, biotic and natural interferences to the natural forest ecosystem.

Similarity Index (SI)

Similarity indices among different forest types are given in Table 8. It is interesting to note that no two forest types are same with over 50% as their SI value. The highest value has been recorded between the Types-IV & VI (SI = 40.51%) and the lowest for Types III & V (16.67%). Forest types IV & VI are situated almost in the similar altitude but the nature of dominants created the difference. The clear dominance of *Shorea robusta* in Type VI caused the difference in the selection of co-habiting species of trees in the forest. On the other hand, Type III is a riverine vegetation, which should be extremely different from that of a mixed deciduous vegetation (Type V) situated in higher altitude hill-slope locality. However, this low level of SI values between different forest types of the region is probably mainly due to (i) extremely high biodiversity in area and (ii) numerous locality factors including edaphic, precipitation, aspect etc. In addition, anthropogenic factors might have some role.

Table 8. Similarity Index within different Forest Types in Darjiling foothill region

Forest types	No. of spp A+B	Total species	Common	Similarity Index
Type IV / Type VI	158	126	32	40.51
Type I / Type III	108	87	21	38.89
Type II / Type IV	149	121	28	37.58
Type II / Type V	96	78	18	37.5
Type II / Type VII	82	67	15	36.59
Type I / Type VI	128	105	23	35.94
Type IV / Type V	137	113	24	35.04
Type I / Type VII	94	78	16	34.04
Type I / Type IV	161	134	27	33.54
Type I / Type II	120	100	20	33.33
Type II / Type VI	117	98	19	32.48
Type III / Type VI	105	88	17	32.38
Type V / Type VI	105	90	15	28.57
Type VI / Type VII	91	78	13	28.57
Type IV / Type VII	123	106	17	27.64
Type III / Type IV	138	119	19	27.54
Type V / Type VII	70	61	9	25.71
Type II / Type III	96	84	12	25
Type I / Type V	108	95	13	24.07
Type III / Type VII	70	62	8	22.86
Type III / Type V	84	77	7	16.67

Type I: Eastern Himalayan Sal Forest; Type II : Bamboo Brake; Type III : Riverine Forest; Type IV : Semi-evergreen Mixed Forest; Type V : Wet Mixed Deciduous Forest; Type VI : Lower Bhabar Sal Mixed Forest; Type VII : Upper Bhabar Sal Mixed Forest

This appears to be very interesting or, in other words, this is the expression of the extremely high phytodiversity in the region. With little change in habitat conditions almost a new set of species is selected for a particular Type of vegetation. But, there are at least two species [*Lagerstroemia parviflora* and *Mallotus philippensis*] which are present in all the seven Types. Similarly three species [*Schima wallichii, Terminalia alata* and *Terminalia bellirica*] are present in six Types. Similarly, ten species are present in five Types, 15 species in four Types, 19 species in three Types, 37 species in two Types and 118 species in one Type of vegetation only. This is one very interesting situation and is possible only due to the reasons expressed in the earlier paragraph.

Diversity Indices

Diversity can be expressed in different ways. Following types of tests have been made to understand the species diversity in the selected types of forests (Table 9):

Table 9. Diversity Indices of trees in different types of forests in Darjiling foothill region

Indices / Forest Types	Simpson's Index (CD)	Shanon-Weaver Index (SD)	Menhinick's Index (SR)
Type I	0.23	7.23	3.15
Type II	0.81	0.98	1.37
Type III	0.04	5.02	3.64
Type IV	0.03	5.86	5.17
Type V	0.08	4.66	4.38
Type VI	0.05	5.13	4.75
Type VII	0.15	3.66	2.41

I. *Species Richness* (SR): Menhinick Index of SR value for different forest types ranges from 1.37 (Type- II) to 5.17 (Type- IV). Forests in Types VI, V, III & I are also with high SR values of 4.75, 4.38, 3.64 & 3.15 respectively. And, for Type VII, where only 28 species of trees occur is also with a very low SR value (2.41). However, this forest type has moderate species richness, and concentration of dominance. Out of these, Types III, IV & VI showed high species diversity (SD) and SR with correspondingly low concentration of dominance (CD). Type II showed poor species diversity and species richness with correspondingly high CD value. May be the anthropogenic interference and aggressive invasion by bamboo population together caused this substantial change in different diversity indices.

II. *Species Diversity* (SD): Shanon – Weaver Index of SD for these forest types ranged between 0.98 (Type-II) to 7.23 (Type-I). However, it is over 5.00 in Types III, IV & VI (5.02, 5.86 & 5.13) and very close to this middle value i.e. 4.66 in Type-V.

III. *Concentration of Dominance* (CD): This is the measurement of the diverseness among the dominants in the vegetation. Lower the value, more diverse is the vegetation and *vice versa* with highest value being 1.00. The clear dominance of one particular species can not be good for the associated species. But, a situation where a number of species are co-dominating that must be congenial for the occurrence of a larger number of species. The determined value ranges between 0.03 and 0.81. In Type-II, where *Dendrocalamus hamiltonii* is with extremely high IVI and highest CD values is not favouring other species of trees to flourish. This is followed by Type-I with 0.23 and Type-VII with 0.15. The CD values for Types-III, IV, V & VI are quite low thereby indicating a good assemblage of different species in these forest types.

Frequency Class Distribution

To understand the nature of the forest community Raunkiaer's *frequency class* distribution was preformed with frequencies categorized into five classes with an interval of 20 and compared with the Raunkiaer's formulation A>B>C=D<E. Frequency class distribution in different forests (Fig. 2) show varying degree of deviation from the normal model in all the forest types, which again is indicative of biotically disturbed community without uniform distribution pattern. Although forest Types I & II appear to be uniform, but the absence of tree species in the frequency percentage class C and D clearly indicate some form of interference in the forest. Similarly, absence of higher frequency percentage class E in forest Types III, IV & V also points to severe biotic stress in these forests.

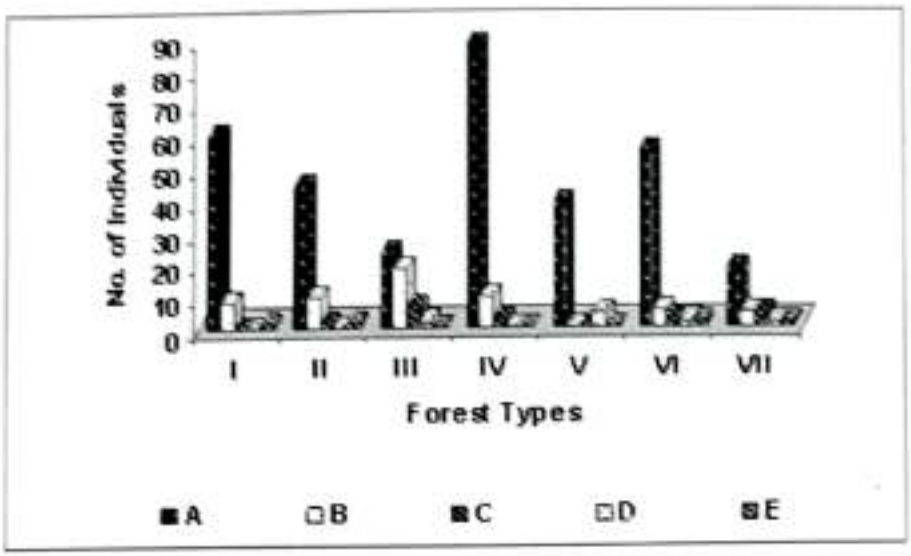

Fig 2. Showing the frequency class distribution in different forest types

Regeneration Potential of Seedlings and Saplings (RPS)

This is the measurement of the capacity of regeneration of different species in a particular forest. The level of RPS in a forest determines its future composition. RPS values in these forests are presented in Table 10. Type-I is found to be vibrant with highest number of 135.428 seedlings and saplings $400m^{-2}$ followed by Types-VII & VI with 99.4 & 87.572 $400m^{-2}$ respectively. Type-V had the lowest number of only 54 seedlings and saplings $400m^{-2}$. Types-II, III & IV also showed low level of regeneration. But with respect to number of regenerating species Type-II is richer with 75 species followed by Type-I with 63 species. The intermediate disturbance hypothesis (Connell 1978; Gurevitch *et al* 2002) states that the species diversity will be highest at intermediate level of disturbance and this appear to be true for Type-II. Type V is poor with only 18 regenerating species. Other Types had also a fairly good level of recruitment.

Table 10. Regeneration potential of seedlings and saplings in different forest types

Forest Type	No. of Species	Seedlings $400m^{-2}$	Saplings $400m^{-2}$
Type I	63	117.332	18.096
Type II	75	40.844	14.896
Type III	45	44.112	9.92
Type IV	47	51.132	15.332
Type V	18	44.332	9.668
Type VI	39	73	14.572
Type VII	31	86.8	12.6

Possible Compositional Changes

To predict the possible compositional change in these forests RPS of five dominant species were computed on the basis of the number of seedlings and saplings (Table 11).

Table 11. Distribution pattern of five different highly regenerating species (seedling & saplings) 400m^{-2} in different forests

Name	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII
Actinodaphne ovata	-	4.16	-	-	-	-	-
Aglaia spectabilis	-	-	3.112	-	-	-	-
Bauhinia purpurea	-	-	-	-	-	-	4.4
Bauhinia vahlii	-	-	-	-	-	6.144	-
Crataeva religiosa	-	-	2.776	-	-	-	-
Cryptocarya amagydina	-	-	-	-	-	-	6
Dalbergia sericea	4.904	-	-	-	-	-	-
Dalbergia tamarindifolia	-	-	-	-	2.668	-	-
Heynea trijuga	7.144	-	-	-	-	-	-
Lagerstroemia parviflora	-	-	-	-	-	-	6.4
Litsea monopetala	4.192	5.684	-	-	-	-	-
Litsea salicifolia	-	-	4	-	-	-	-
Macaranga peltata	-	-	-	4.332	-	-	-
Mallotus philippensis	11.144	6	-	9.136	11.668	14.716	7.6
Morus macroura	-	-	-	-	2.668	-	-
Ostodes paniculata	-	-	-	-	4.332	-	-
Premna mucronata	-	-	-	-	-	3.428	-
Pterospermum acerifolium	-	-	6.888	4	-	-	-
Pterygota alata	-	-	8.112	-	-	-	-
Schima wallichii	-	4.08	-	6.336	15.332	-	-
Shorea robusta	65.24	-	-	5.332	-	18	32.6
Syzygium cumini	-	-	-	-	-	4.716	-
Terminalia bellirica	-	1.792	-	-	-	-	-

1. *Shorea robusta* has an excellent regeneration status of seedlings and sapling in Types I, IV, VI & VII and is expected to maintain the major skeleton of vegetation there. This species showed an excellent power of generation in Types-I & VII and contributing highest number of recruitments. *Schima wallichii, Heynea trijuga Litsea monopetala, Pterospermum acerifolium, Cryptocarya amagydina & Bauhinia purpurea* may be its close associates in these forests.

2. *Shorea robusta* is making rapid ingress also into the semi-evergreen mixed forest and may form a major constituent if not dominating in years to come.

3. In the middle canopy *Mallotus philippensis* will dominate in all the forest Types except for Type III with *Dalbergia sericea*,

4. Liana like *Bauhinia vahlii* will be an important component of Type VI forest.

5. But, the most important factor is the anthropogenic interference which is difficult to predict. Human population in these areas is increasing at an alarming rate which will certainly interfere at least with the population of timber yielding species like *Shorea robusta, Lagerstroemia parviflora, Schima wallichii, Syzygium cumini* etc.

6. Under such disturbed situation, it is expected that plants like *Mallotus philippensis, Litsea monopetala, Actinodaphne ovata, Ostodes paniculata, Crataeva religiosa, Premna mucronata* and liana like *Bauhinia vahlii, Dalbergia sericea, D. tamarindifolia* etc. will flourish.

So, under natural process of regeneration or self recruitment it is expected that *Shorea robusta* will continue to remain as the most dominating tree in sal dominating forest types and in future it will also dominate in some other forest types which are now in different seral stages. However, in Type II forest *Dendrocalamus hamiltonii* will increase its dominance and will certainly interfere with the survival of not only the tree species but with the inhabitants in all other strata in the forest.

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