Article

Tree inventory along the altitudinal gradients in Singara Range, Western Ghats, India

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Abstract
Environmental gradients are the driving forces that shape species density, community composition, stand structure and diversity. Distribution of plants in Nilgiri hill is the result of topographic variations and climatic differences. This study was conducted in Singara range of The Nilgiri Biosphere Reserve, which lies between the altitudes of 900 to 2150 Meter above mean sea level (MSL). A total of 60 quadrates of 10×50 m size were laid in the forest across five elevational ranges with 250-meter interval covering 1250 meter altitude. A total of 181 species in 115 Genera & 56 Families were recorded in the present study. *Anogeissus latifolia* was the most dominant species across the study area and was present in four zones except the highest elevation zone E (1900-2150), which is shola forest while the former zones were tropical dry deciduous and semi-evergreen forest. A total of 56, 62, 46, 40 and 82 tree species were found in Zone A, Zone B, Zone C, Zone D and Zone E respectively.

Keywords Western Ghats; Nilgiri Biosphere Reserve; elevation gradient; tree diversity; tropical forest.

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1 Introduction

Biodiversity is one of the most prominent features of conservation strategy of protected area (Myers et al., 2000; Bruner et al., 2001; Zhang et al., 2014). Western Ghats is the treasure of endemic species and an abode of the diverse type of flora and fauna of the globe (Ninan and Sathyapalan, 2005). It is one of the mega biodiversity hot spots known for its environmental and topographical variations of the terrain with various undulating mountainous part of southwestern India. Endemism and diversity of vascular plants particularly floristic diversity is still unexplored in some parts of the Western Ghats. Among 35 biodiversity hotspots of the world (Myers, 1988), Western Ghats represent a rich source of several promising medicinal and economically important plants (Gautam et al., 2007). This large stretch of the mountainous forest of Western Ghats is spread over a total area of about 160,000 km2 (Prasad et al., 2008). It spreads into 6 states of India namely Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala.

Nilgiri Biosphere Reserve (NBR), situated in the Western Ghats, is the first Biosphere Reserve established in India (1986) with a rich repository of biological diversity at a vast area (5500 sq. km) (Daniels, 1992). Biodiversity of NBR is severely threatened from deforestation, degradation, patchiness, unsustainability and forest produce extraction such as timber, firewood, medicinal plant parts collection by forest dwellers and other people (Narendran et al., 2001).

The study site i.e. NBR has a representative selection of major vegetation types of peninsular India such as evergreen and semi-evergreen forest, moist deciduous forest, tropical dry deciduous forest and tropical dry thorn forest (Champion and Seth, 1968). Tree species composition and diversity have been widely documented in order to perform conservation, effective management and logical exploitation of forests (Parthasarathy, 2001). Monitoring of plant species and documentation of baseline data should be on a local level not at country level; to infer threatened, vulnerable, or endemic species of the region (Venu, 1999).

Tropical dry forests are fairly less known forest types even within the country and are species-poor when compared to tropical wet forests. The dearth of baseline information has halted the conservation prioritization of the region from various threats (Sudhakar and Reddy, 2005). So, there is an immediate need for the floristic inventory that could be a beneficial tool for the species which are prone to vulnerability.

To obtain conservation value floristic species richness, zones of endemism, threat and vulnerability could be tackled by baseline data. The present study illustrates the vegetation documentation for effective conservation and will also provide the baseline data of the region along with elevational gradient and comparatively micro-level, i.e., regional level. The detailed information on diversity along with altitudinal gradient of Reserve Forest will be helpful for conservation at the regional level in an effective manner (Ramesh et al., 1997). Though the Western Ghats is dominated by deciduous trees, there is a paradigm shift of floristic diversity at higher elevation in stand structure and composition. There is shrubby vegetation at lower altitude, deciduous type at mid elevation and evergreen and temperate trees at upper riches of the area. One of the difficulties in studying patterns of species richness along an elevational gradient is that many factors change with elevation creating confounding conditions with each other (Korner et al., 2007; Zhang et al., 2016). Small-scale tree inventories provide an effective data to explore forest structure and species composition within tropical forest communities (Castillo-Campos et al., 2008; Mohandass et al., 2014). Therefore the present study was aimed to quantify the tree species diversity, density and stand structure along with altitudinal gradients in Singara Range of NBR.

2 Study Area and Methodology

2.1 Study site

The study was conducted at Singara Range, Nilgiris North Division in Nilgiri District of Tamil Nadu state of southern part of peninsular India, which is situated in the Nilgiri Biosphere Reserve of the Western Ghats, a global biodiversity hotspot. It is located between 11^{o} 28´ N to 11^{o} 34´ N and, 76^{o} 32´E to 76^{o} 44´ E (Fig. 1).

The elevation of Singara Range varies from 881 to 2210 meter above MSL (Fig. 2). The soil is basically andisol or black soil rich in humus and organic content. The bedrock of the area is composed of gneiss, charnocknites, and schists (Von-lengerke, 1977).

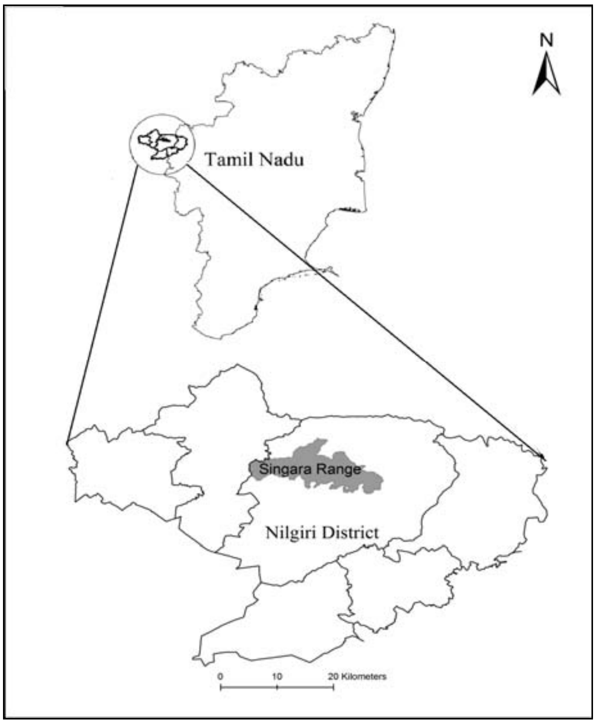


Fig. 1 Location map of Singara range in Nilgiri District, Tamil Nadu, India.

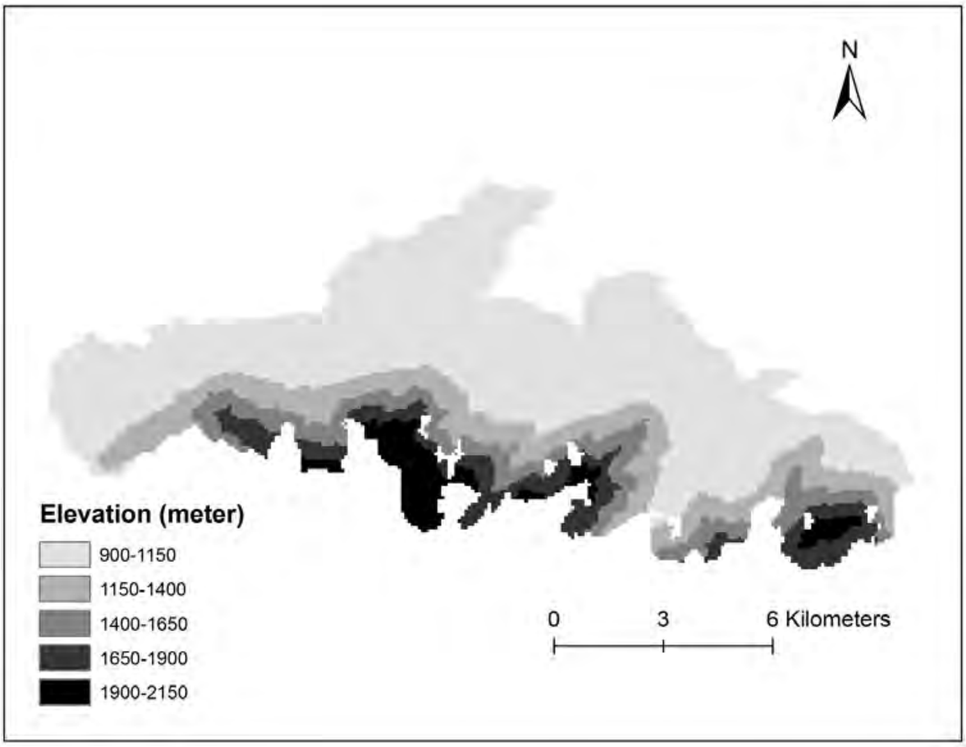


Fig. 2 Elevation map of Singara Range A, B, C, D, E zones in ascending order of altitudinal gradient.

Singara range, due to elevation gradient, receives precipitation strongly influenced by regional topography & temperature resulting variation in vegetation and endemism (Gadgil and Meher-Homji, 1990).

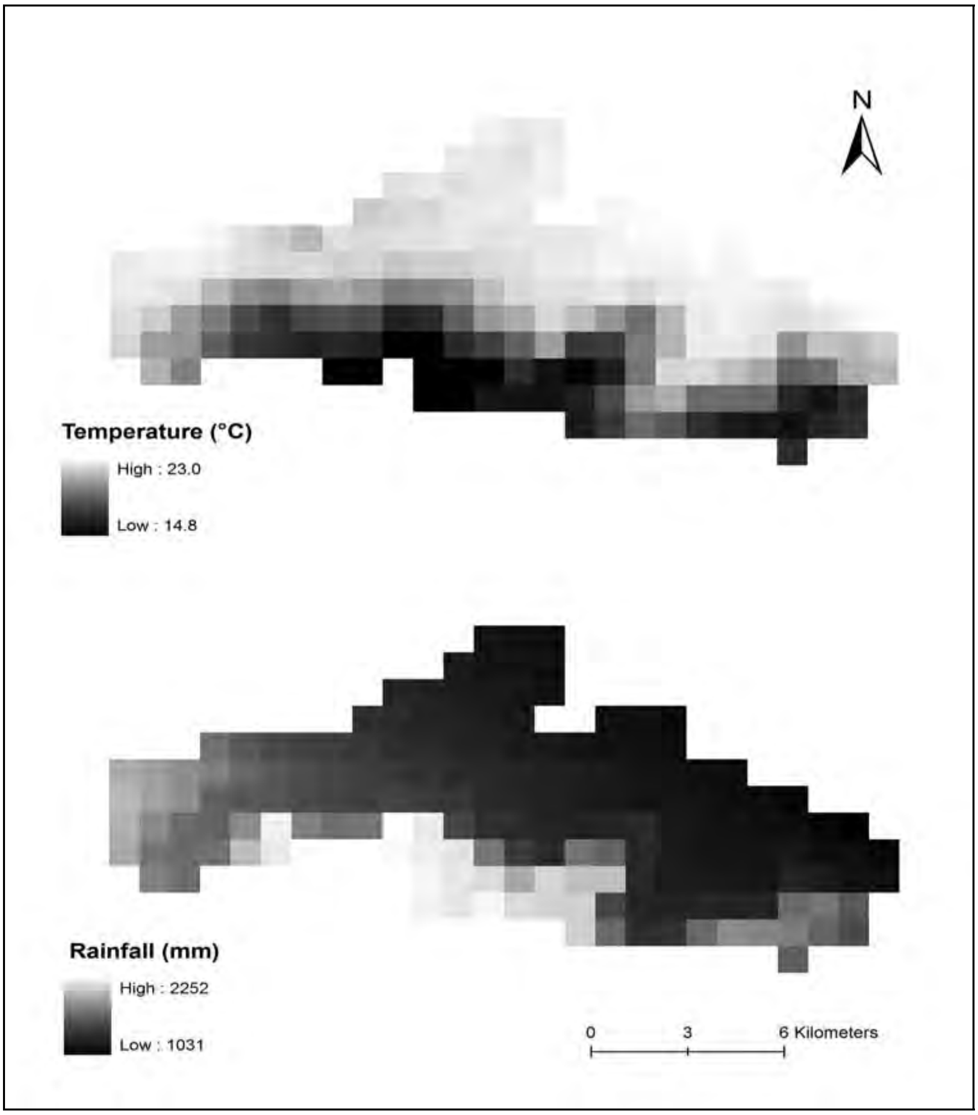


Fig. 3 Temperature and rainfall pattern of Singara Range.

2.2 Data collection and analysis

The study area was divided into five different elevation classes (viz. Zone A, Zone B, Zone C, Zone D and Zone E) with 250-meter elevational interval (Fig. 2). For each class, 12 plots of 0.05 ha (n=60) were studied. The dimension of the plot was 10x50m. The spatial characteristics i.e. latitude, longitude, and altitude of each quadrat were collected by using a Global Positioning System. To cover different elevation, slope, aspect, steepness, density, rainfall and temperature gradients plots were laid down in almost all variables of topography and climate. All trees ⩾10 cm GBH inside the plots were enumerated.

Vegetation data was collected between the month of March and June 2014. All the trees were identified using checklists and flora of Mudumalai (Sharma et al. 1978) as well as photographs and plant samples were collected. Measurements such as girth at breast height (GBH) and height (H) were recorded for all trees.

The total number of species, stem density and basal area were calculated. The diversity of all living stems was estimated by using the Shannon–Wiener index (H’) and Simpson’s dominance index (1-D). Stem size distribution was also analyzed to see stand structure. All statistical analyses were performed using IBM SPSS Statistics 20 and Microsoft Excel.

3 Results and Discussion

In all, we recorded a total of 1572 individuals belonging to 181 species, 115 genera, and 56 families. Shannon-Weiner diversity index was 4.089, whereas Simpson dominance (1-D) index was 0.9426. Stand density and stand basal area were 524 stems ha^{-1} and 25.32 m^2 ha^{-1} respectively (Table 1).

Table 1 Description of diversity, stand density and basal area of trees species in Singara Range, Western Ghats.

Variable	Trees
Species richness	181
Number of genera	115
Number of families	56
Shannon index	4.089
Simpson index (1-D)	0.9426
Stand density (stems ha-^{1})	524
Stand basal area (m^2 ha^{-1})	25.32

The most dominant species across the study area was *Anogeissus latifolia* from Combertacae family followed by *Grewia tiliifolia* and *Tectona grandis* from Tiliaceae and Verbenaceae family respectively. Stand Density of *Anogeissus latifolia* was 113 stems ha^{-1} and basal area was 3.98 m^2 ha^{-1} while the importance value index (IVI) was 44.53. *Grewia tiliifolia* and *Tectona grandis* had stand density of 34 and 12 stems ha^{-1} and basal area of 0.93 and 1.74 m^2 ha^{-1} with 15.41 and 10.49 IVI value respectively (Table 2).

Table 2 List of top ten dominant species and their stand density, basal area and IVI.

S.N.	Species Name	Family	Number of Individuals	Basal Area (m^2 ha^{-1})	IVI
1	*Anogeissus Latifolia*	Combretaceae	338	3.9766	44.53
2	*Grewia Tilfolia*	Tiliaceae	101	0.9302	15.41
3	*Tectona Grandis*	Verbenaceae	37	1.7370	10.50
4	*Terminalia Chebula*	Combretaceae	43	0.7636	8.68
5	*Litsea Wightiana*	Lauraceae	30	1.2802	8.61
6	*Kydia Calycina*	Malvaceae	49	0.4397	8.15
7	*Phyllanthus Emblica*	Euphorbiaceae	43	0.2889	6.62
8	*Pterocarpus Marsupium*	Fabaceae	30	0.4811	5.64
9	*Syzygium Calophyllifolium*	Myrtaceae	16	0.8983	4.93
10	*Syzygium Tamilnadensis*	Myrtaceae	14	0.7333	4.70
11	*Lagerstroemia Lanceolata*	Lythraceae	18	0.7555	4.50
12	*Terminalia Bellerica*	Combretaceae	17	0.5824	4.48
13	*Erythroxylum Monogynum*	Erythroxylaceae	40	0.1310	4.16
14	*Syzygium Montanum*	Myrtaceae	16	0.4262	3.98
15	*Psychotria Nilgherense*	Rubiaceae	13	0.5486	3.91
16	*Lasianthus Venulosus*	Rubiaceae	17	0.4494	3.77
17	*Eleocarpus Variablis*	Elaeocarpaceae	14	0.3952	3.37

18	*Syzygium Cumini*	Myrtaceae	7	0.4462	3.31
19	*Semecarpus Anacardium*	Anacardiaceae	14	0.1489	3.13
20	*Lagerstroemia Parviflora*	Lythraceae	14	0.3102	3.03
21	*Syzygium Arnottianum*	Myrtaceae	10	0.4458	2.95
22	*Olea Dioica*	Oleaceae	15	0.1824	2.77
23	*Celtis Tetrandra*	Ulmaceae	13	0.2504	2.73
24	*Bischofia Javanica*	Bischofiaceae	4	0.5224	2.68
25	*Michelia Nilagirica*	Magnoliaceae	17	0.1664	2.65
26	*Syzygium Grande*	Myrtaceae	4	0.4882	2.55
27	*Bridelia Crenulata*	Euphorbiaceae	13	0.1184	2.39
28	*Symplocos Foliosa*	Symplocaceae	14	0.2398	2.39
29	*Mangifera Indica*	Anacardiaceae	3	0.4482	2.33
30	*Randia Dumetorum*	Rubiaceae	12	0.0232	2.32
31	*Chloroxylon Swietenia*	Flindersiaceae	14	0.1280	2.31
32	*Canarium Strictum*	Burseraceae	6	0.3356	2.26
33	*Symplocos Cochinchinensis*	Symplocaceae	13	0.2141	2.22
34	*Maytenus Emarginata*	Celastraceae	20	0.0493	2.20
35	*Canthium Dicoccum*	Rubiaceae	14	0.0947	2.18
36	*Litsea Insignis*	Lauraceae	9	0.1732	2.17
37	*Mahonia Leschenaultii*	Berberidaceae	14	0.0441	2.16
38	*Turpina Nepalensis*	Staphyleaceae	10	0.1857	2.10
39	*Radermachera Xylocarpa*	Bignoniaceae	12	0.1933	2.08
40	*Terminalia Crenulata*	Combretaceae	11	0.2072	2.07
41	*Daphniphyllum Neilgherrense*	Daphniphyllaceae	11	0.1121	2.06
42	*Cassia Fistula*	Caesalpiniaceae	11	0.0378	1.95
43	*Pterolobium Hexapetalum*	Fabaceae	14	0.0635	1.87
44	*Elaeocarpus Oblongus*	Elaeocarpaceae	10	0.1605	1.82
45	*Shorea Roxburghii*	Dipterocarpaceae	6	0.1965	1.71
46	*Phyllanthus Indofischeri*	Euphorbiaceae	13	0.0737	1.67
47	*Excoecaria Crenulata*	Euphorbiaceae	11	0.0786	1.56
48	*Cinnamomum Wightii*	Lauraceae	10	0.0921	1.55
49	*Cassine Paniculata*	Celastraceae	3	0.1949	1.51
50	*Meliosma Simplicifolia*	Sabiaceae	6	0.0806	1.43
51	*Ficus Mollis*	Moraceae	8	0.0897	1.41
52	*Terminalia Arjuna*	Combretaceae	4	0.1531	1.41
53	*Acacia Sinuata*	Fabaceae	12	0.0233	1.40
54	*Symplocos Pendula*	Symplocaceae	8	0.0382	1.39
55	*Meliosma Wightii*	Sabiaceae	8	0.0291	1.36
56	*Saprosma Fragrans*	Rubiaceae	4	0.1376	1.35
57	*Ficus Virens*	Moraceae	4	0.1822	1.34
58	*Persea Macrantha*	Lauraceae	4	0.1299	1.32
59	*Dalbergia Latifolia*	Fabaceae	7	0.0740	1.29
60	*Naringi Crenulata*	Rutaceae	8	0.0094	1.28
61	*Butea Monosperma*	Fabaceae	6	0.0282	1.23
62	*Atlanta Monophyla*	Rutaceae	6	0.0267	1.22
63	*Dodonaea Angustifolia*	Sapindaceae	7	0.0086	1.21
64	*Eurya Nitida*	Theaceae	4	0.1000	1.20
65	*Viburnum Punctatum*	Caprifoliaceae	6	0.0623	1.18
66	*Acacia Dealbata*	Fabaceae	8	0.0750	1.17

67	*Acacia Chundra*	Fabaceae	7	0.0404	1.15
68	*Sterculia Guttata*	Sterculiaceae	2	0.2014	1.11
69	*Euodia Lunuankenda*	Rutaceae	4	0.0253	1.09
70	*Diospyros Montana*	Ebenaceae	6	0.0844	1.08
71	*Ficus Religiosa*	Moraceae	4	0.1106	1.06
72	*Myrsine Wightiana*	Myrsinaceae	5	0.0440	1.04
73	*Cinnamomum Macrocarpum*	Lauraceae	4	0.1044	1.03
74	*Acacia Leucophloea*	Fabaceae	6	0.0199	1.01
75	*Elaeocarpus Tuberculatus*	Elaeocarpaceae	5	0.0342	1.00
76	*Strychnos Nux-Vomica*	Loganiaceae	3	0.0588	0.97
77	*Syzygium Densiflorum*	Myrtaceae	4	0.0824	0.95
78	*Premna Tomentosa*	Lamiaceae	5	0.0579	0.91
79	*Bridelia Montana*	Euphorbiaceae	3	0.0891	0.91
80	*Randia Candolleana*	Rubiaceae	5	0.0072	0.90
81	*Ziziphus Rugosa*	Rhamnaceae	4	0.0190	0.88
82	*Syzygium Malabaricum*	Myrtaceae	4	0.0613	0.86
83	*Ilex Denticulata*	Aquifoliaceae	3	0.0707	0.84
84	*Bauhinia Racemosa*	Fabaceae	3	0.0218	0.83
85	*Randia Tomentosa*	Rubiaceae	4	0.0017	0.81
86	*Mallotus Philippensis*	Euphorbiaceae	4	0.0423	0.79
87	*Leucus Lanceifolia*	Lamiaceae	3	0.0469	0.74
88	*Mitragyna Parvifolia*	Rubiaceae	4	0.0260	0.72
89	*Lagerstroemia Reginae*	Lythraceae	2	0.1040	0.72
90	*Casearia Esculenta*	Flaucourtiaceae	4	0.0209	0.70
91	*Ligustrum roxburghii*	Oleaceae	5	0.0497	0.70
92	*Ixora Pavetta*	Rubiaceae	4	0.0183	0.69
93	*Cinnamomum Malabathrum*	Lauraceae	5	0.0468	0.69
94	*Strychnos Potatorum*	Loganiaceae	2	0.0476	0.68
95	*Pittosporum Neilgherrense*	Pittosporaceae	4	0.0617	0.68
96	*Olea Paniculata*	Oleaceae	3	0.0288	0.67
97	*Eriolaena Hookeriana*	Sterculiaceae	4	0.0111	0.66
98	*Litsea Zeylanica*	Lauraceae	3	0.0240	0.65
99	*Celtis Wightii*	Ulmaceae	3	0.0699	0.65
100	*Aegle Marmelos*	Rutaceae	4	0.0056	0.64
101	*Pinus Patula*	Pinaceae	2	0.0353	0.63
102	*Ligustrum Neilgherrense*	Oleaceae	4	0.0483	0.63
103	*Mimusops Elengi*	Sapotaceae	2	0.0794	0.62
104	*Ilex Wightiana*	Aquifoliaceae	2	0.0321	0.62
105	*Pongamia Pinnata*	Fabaceae	3	0.0144	0.61
106	*Albizia Lebbeck*	Fabaceae	3	0.0593	0.61
107	*Vaccinium Neilgherrense*	Ericaceae	5	0.0270	0.61
108	*Viburnum Erubescens*	Adoxaceae	3	0.0101	0.60
109	*Gardneria Ovata*	Loganiacae	2	0.0260	0.60
110	*Neolitsea Scrobiculata*	Lauraceae	2	0.0713	0.59
111	*Acacia Nilotica*	Fabaceae	3	0.0080	0.59
112	*Limonia Acidissima*	Rutaceae	3	0.0050	0.58
113	*Symplocos Obtusa*	Symplocaceae	2	0.0206	0.58
114	*Meliosma Arnottiana*	Sabiaceae	3	0.0496	0.57
115	*Cordia Gharaf*	Cordiaceae	2	0.0113	0.54

116	*Rhodomyrtus Tomentosa*	Ericaceae	2	0.0073	0.52
117	*Sterculia Urens*	Sterculiaceae	2	0.0035	0.51
118	*Hedyotis Stylosa*	Rubiaceae	2	0.0022	0.50
119	*Ixora Notaniana*	Rubiaceae	2	0.0019	0.50
120	*Schleichera Oleosa*	Sapindaceae	2	0.0452	0.49
121	*Cassine Glauca*	Celastraceae	3	0.0249	0.47
122	*Sterculia Villosa*	Sterculiaceae	3	0.0245	0.47
123	*Ficus Dalhousiae*	Moraceae	1	0.0565	0.47
124	*Garuga Pinnata*	Burseraceae	3	0.0153	0.43
125	*Murraya Paniculata*	Rutaceae	2	0.0288	0.42
126	*Stereospermum Personatum*	Bignoniaceae	2	0.0269	0.42
127	*Neolitsea Zeylanica*	Lauraceae	3	0.0102	0.41
128	*Madhuca Indica*	Sapotaceae	1	0.0401	0.41
129	*Bambusa Arundinacea*	Poaceae	3	0.0078	0.40
130	*Schefflera Stellata*	Araliaceae	3	0.0052	0.39
131	*Cinnamomum Walaiwarense*	Lauraceae	1	0.0363	0.39
132	*Carissa Spinarum*	Apocynaceae	3	0.0029	0.39
133	*Macaranga Peltata*	Euphorbiaceae	2	0.0183	0.38
134	*Ziziphus Glabrata*	Rhamnaceae	2	0.0122	0.36
135	*Gardenia Gummifera*	Rubiaceae	2	0.0096	0.35
136	*Buchanania Lanzan*	Anacardiaceae	2	0.0066	0.34
137	*Schrebera Swietenioides*	Oleaceae	2	0.0056	0.33
138	*Albizia Amara*	Fabaceae	2	0.0053	0.33
139	*Lasiosiphon Eriocephalus*	Thymelaeaceae	2	0.0027	0.32
140	*Casearia Thwaitesii*	Flaucourtiaceae	1	0.0187	0.32
141	*Ilex Malabarica*	Aquifoliaceae	2	0.0025	0.32
142	*Rubus Ellipticus*	Rosaceae	2	0.0014	0.32
143	*Gmelina Arborea*	Verbenaceae	1	0.0174	0.32
144	*Carmona Retusa*	Cordiaceae	2	0.0006	0.31
145	*Toddalia Asiatica*	Rutaceae	2	0.0006	0.31
146	*Litsea Oleoides*	Lauraceae	1	0.0165	0.31
147	*Gmelina Arborea*	Lamiaceae	1	0.0165	0.31
148	*Haldina Cordifolia*	Rubiaceae	1	0.0130	0.30
149	*Gmelina Asiatica*	Lamiaceae	1	0.0112	0.29
150	*Meliosma Simplicosa*	Sabiaceae	1	0.0105	0.29
151	*Scolopia Crenata*	Flacourtiaceae	1	0.0095	0.28
152	*Ziziphus Mauritiana*	Rhamnaceae	1	0.0089	0.28
153	*Macaranga Indica*	Euphorbiaceae	1	0.0083	0.28
154	*Excoecaria Oppositifolia*	Euphorbiaceae	1	0.0061	0.27
155	*Nothopegia Beddomei*	Anacardiaceae	1	0.0049	0.27
156	*Rhododendron Nilagirica*	Ericaceae	1	0.0049	0.27
157	*Givotia Rottleriformis*	Euphorbiaceae	1	0.0047	0.27
158	*Ficus Racemosa*	Moraceae	1	0.0042	0.26
159	*Viburnum Hebanthum*	Caprifoliaceae	1	0.0036	0.26
160	*Careya Arborea*	Lecythidaceae	1	0.0034	0.26
161	*Rhus Mysorensis*	Anacardiaceae	1	0.0034	0.26
162	*Tarenna Asiatica*	Rubiaceae	1	0.0034	0.26
163	*Sapindus Emarginatus*	Sapindaceae	1	0.0032	0.26
164	*Neolitsea Cassia*	Lauraceae	1	0.0031	0.26

165	*Hardwickia Binata*	Caesalpiniaceae	1	0.0027	0.26
166	*Psychotria Congesta*	Rubiaceae	1	0.0014	0.25
167	*Litsea Floribunda*	Lauraceae	1	0.0012	0.25
168	*Randia Tamilnadensis*	Rubiaceae	1	0.0011	0.25
169	*Rosa Leschenaultiana*	Rosaceae	1	0.0011	0.25
170	*Carissa Carandas*	Apocynaceae	1	0.0010	0.25
171	*Dodonaea Viscosa*	Sapindaceae	1	0.0009	0.25
172	*Psychotria Bisulcata*	Rubiaceae	1	0.0008	0.25
173	*Sarcococca Saligna*	Buxaceae	1	0.0007	0.25
174	*Hymenodictyon Orixense*	Rubiaceae	1	0.0005	0.25
175	*Tetrastigma Leucostaphylum*	Vitaceae	1	0.0005	0.25
176	*Prunus Ceylanica*	Rosaceae	1	0.0004	0.25
177	*Berberis Tinctoria*	Berberidaceae	1	0.0004	0.25
178	*Cassia Auriculata*	Caesalpiniaceae	1	0.0003	0.25
179	*Photinia Integrifolia*	Rosaceae	1	0.0003	0.25
180	*Ziziphus Xylopyrus*	Rhamnaceae	1	0.0003	0.25
181	*Buchanania Axillaris*	Anacardiaceae	1	0.0003	0.25

We studied the area into 5 elevation zones namely A, B, C, D, and E. Zone A begins from 900 meters to 1150 meters had 56 species 44 genus and 28 families. Zone B had 62 species, 53 genera, and 32 families. Zone C and Zone D had the same number of families i.e. 22 each with 46 and 40 species belonging to 36 and 32 genera respectively. Zone E, the highest altitude of the study area had 82 species, 50 genus, and 29 families. It had a highest basal area of 48.06 m^2 ha^{-1} with a standard deviation of 19.71 and 705 individuals ha^{-1} with a standard deviation of 114 (Table 3).

Table 3 Zone-wise elevation differences and floristic inventory species, genus, family basal area, stem density.

Class Code	**Elevation in meter**	**Basal area (m^2 ha^{-1}) Mean (SD)**	**Stem density per hectare Mean (SD)**	**Trees**		
				Species	**Genus**	**Family**
Zone A	900-1150	27.43 (28.25)	453 (149)	56	44	28
Zone B	1150-1400	16.94 (5.41)	482 (111)	62	53	32
Zone C	1400-1650	16.24 (8.14)	505 (127)	46	36	22
Zone D	1650-1900	17.20 (5.90)	480 (101)	40	32	22
Zone E	1900-2150	48.06 (19.71)	705 (154)	82	50	29

Shannon-Weiner index of diversity indicates that Zone A is much diverse and B, C and D Zones are following decreasing trend of diversity at a higher elevation. Shannon-Weiner index also showed the highest diversity in the Zone E which was shola forest. On the other hand, Simpson Index did not show any definite pattern of dominance, although lowest and highest elevation zone had less dominance except B, C, and D zone (Fig. 4).

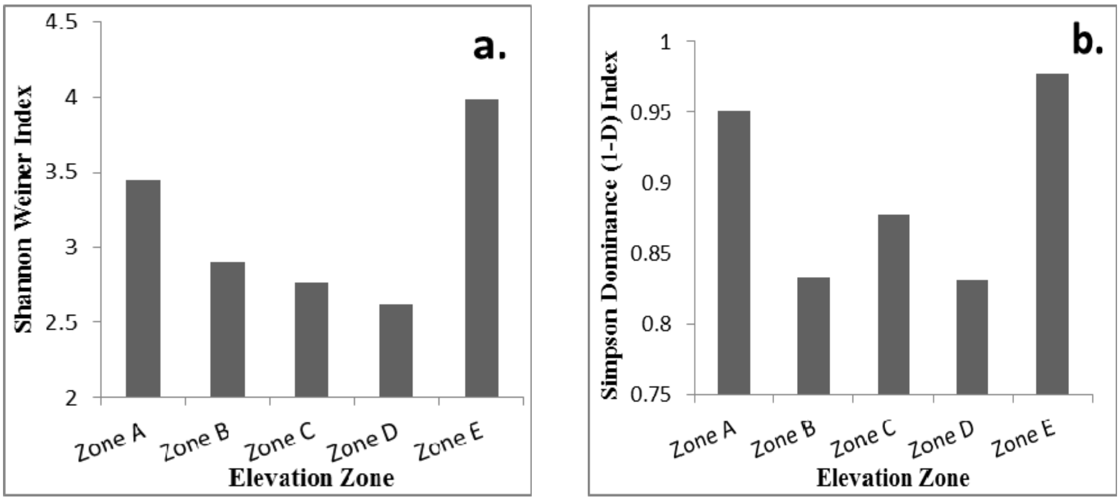
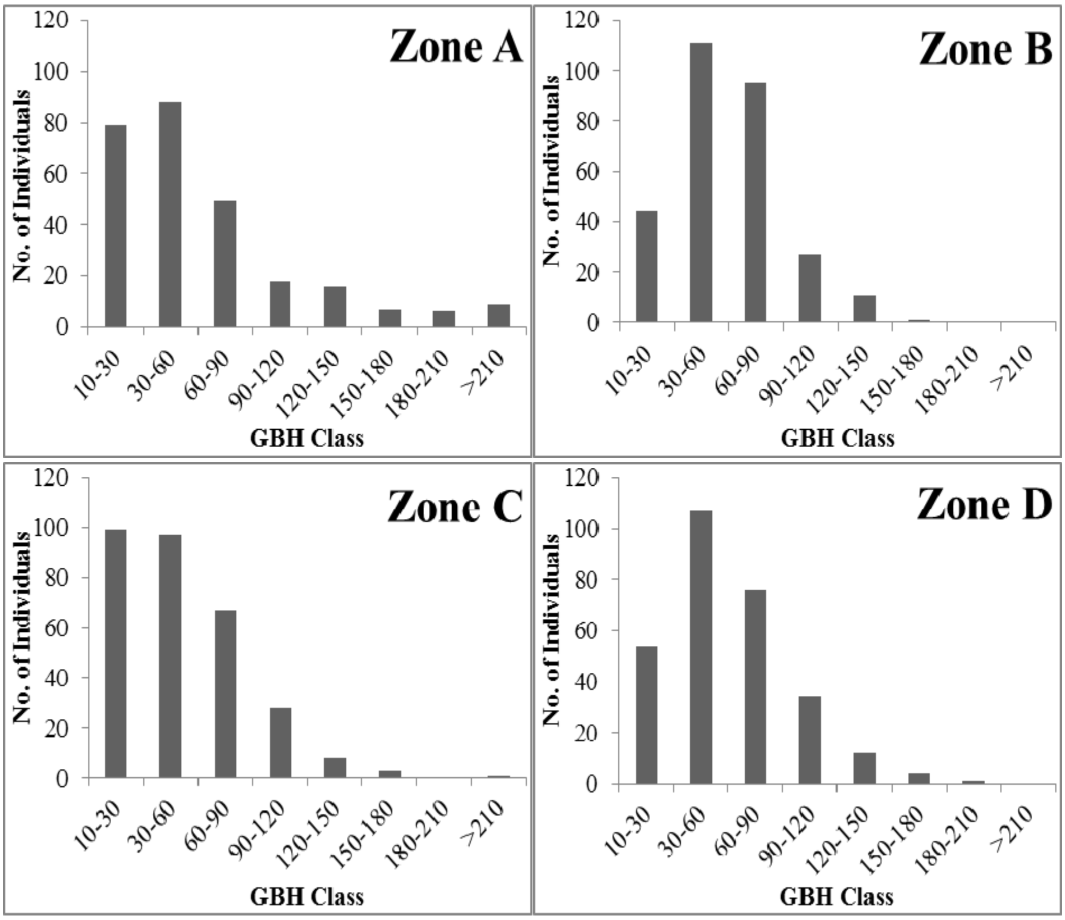


Fig. 4 a. Shannon-Weiner and **b.** Simpson Dominance (1-D) Index along with elevation gradient in Singara Range.

Tree stand structure of Singara forest showed that all zones had a different pattern of distribution but for 30-60 cm gbh class we found the highest number of individuals in all five zones except zone C where 10-30 size class was slightly more than 30-60 size class of GBH (Fig. 5).



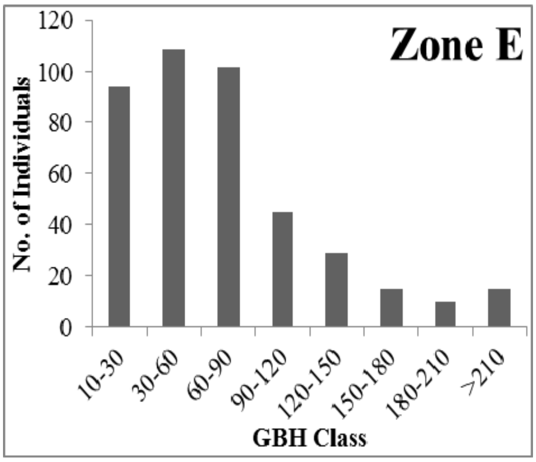


Fig. 5 Stand structure of tree species along with elevation gradients in Singara Range.

4 Discussion

Elevational variations play a pivotal role in shaping forest community and is well documented for various geographical region and species (Stevens, 1992; Bhattarai et al., 2004; Carpenter, 2005). Present study area had vegetation changes at various elevational zones. Lower elevation (900-1150) had shrub as well as evergreen trees due to topographic and climatic variation. Middle zone B, C, D had mostly deciduous trees while zone E (1900-2150) had Shola vegetation. It occurred at the higher elevations of the Western Ghats including Singara range in NBR. Due to lack of tolerance and resistance to environmental changes these vegetation are found only at upper elevational undisturbed zone (Meher-Homji, 1987). Because of this reason Zone E had shown differences in almost all patterns *viz.* richness, diversity, density and stand structure of Singara Range.

The present study revealed that maximum species richness was encountered at lower elevations as well as in the montane forest. There are generally two patterns in species distribution; first gradual decrease in species richness (MacArthur, 1972) and a second peak in species richness at intermediate elevations (Grytnes and Vetaas, 2002). If we are excluding zone E then only we can find the general trend of vegetation change (Sharma, 2009). This is all due to topography and precipitation in the penultimate highest hill of the Nilgiri support characteristic shola vegetation. Variation in tree species composition and the proportion of dominant species may directly be attributed to altitudinal pattern, temperature and rainfall distribution (Reddy et al., 2011).

5 Conclusion

The study revealed and quantified the diversity of Singara Range, Nilgiri North Division forest at various zones of elevation, which will be helpful to forest manager to make a strategy to conserve native plants and threatened species at the micro level that is regional level. The inference of the study is that micro scale inventory of tree diversity of community with topographic and climatic variables have direct implication for conservation and management practices which in consequence will sustain an ecosystem of each zone. Our study suggests that stand structure composition and species richness are controlled by topographic and climatic factors.

Besides harboring 181 tree species and their growing population, these forests support rich insects, birds, reptiles, and mammals, many of which help in the functioning and sustainability of the ecosystem. It is imperative that this vegetation must be preserved by involving all the stakeholders, because this area not only harbors a sizeable proportion of regional flora, but also the rich cultural tradition associated with it.

Therefore, diversity, composition, and stand structure of the community of trees only on the basis of elevation or altitude could not be generalized if there is complexity in a topographic and climatic variation of the region. In this case, micro-level monitoring of tree population will be helpful for management practices of the region.

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