Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad–Mundanthurai Tiger Reserve, Western Ghats, India

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Plant biodiversity of an undisturbed mid-elevation evergreen forest in the southern Western Ghats was assessed by establishing 5 transects totalling 3.82 ha. All plants above 10 cm DBH were enumerated and 10% of the transect area was sampled to quantify the diversity of understorey community and to assess the regeneration status of tree species.

A total of 173 woody plant species from 58 families were recorded; of these 50% were tree species. Species diversity (H′) was 4.87, ranking highest among other similar sites in the Western Ghats. On the basis of dominance, this forest is identified as *Cullenia Aglaia Palaquium* type which is considered as a subtype of *Cullenia Mesua Palaquium* series. Stem density and basal area was 363.67 (0.5 ha) and 42.03 m^2/ha respectively. The 'L' shaped curve of different DBH classes indicates good regeneration in the climax forest. Small scale altitudinal changes on species composition are largely due to transition in vegetation types influenced by bioclimatic and edaphic factors.

A major impediment in documenting forest vegetation in the country has been the lack of any quantitative information. Forest vegetation has been largely described on the basis of qualitative criteria such as the physiognomy and the dominant species[1,2]. Quantitative descriptions of vegetation, documenting the relative abundance and distribution of plant species are uncommon. Within the Western Ghats, as elsewhere in the world, species richness is high in the wet evergeen forests. Yet except for Pascal's studies, based on 0.16 to 0.20 ha plots, there is no quantitative assessment of plant biodiversity for an area that covers 28,000 km^2.

Apart from deforestation, forest degradation is a major problem in Indian forests. Forest Survey of India's latest report shows that 40% of the country's forest has less than 10%–40% of canopy cover[3]. Regeneration in many of India's forests, including the forest of Western Ghats, is inadequate to replace the adults[4,5]. Thus in addition to quantitative assessment of plant biodiversity, we also need to assess the regeneration status of the forest communities.

The present study is based on the mid-elevation evergreen forests in the Agasthyamalai range of the southern Western Ghats. This range has been recognized as one of the five centres of high plant diversity in India by the International Union for Conservation of Nature and Natural Resources[6] and is well known for its species richness and endemicity. The area harbours not less than 2000 plant species out of 3500 species found in Western Ghats[7].

Previous floristic studies in Kalakad hills have been restricted to botanical explorations[8–13] until Parthasarathy *et al.*[14] undertook a quantitative study in the Sengaltheri forests in Kalakad–Mundanthurai Tiger Reserve (KMTR). However, this study was done at a lower elevation and in a transition zone between evergreen and semi-evergreen forests, and the wet evergreen forest at a higher elevation was not sampled intensively. Moreover, only large trees were sampled in 1 ha square plots. The present study makes a quantitative assessment of the evergreen forest at a higher elevation in the reserve, and it also includes all plants < 10 cm DBH.

This study is part of an overall project that seeks to assess and monitor biodiversity in the KMTR with the following objectives:

(i) to assess and describe plant species richness of the wet evergreen forest of Kalakad.
(ii) to describe the level of spatial heterogeneity in the composition of the forest and
(iii) to determine if there is adequate regeneration of major tree species.

Study area

KMTR is situated in the Agasthyamalai range of the southern Western Ghats, India, approximately at

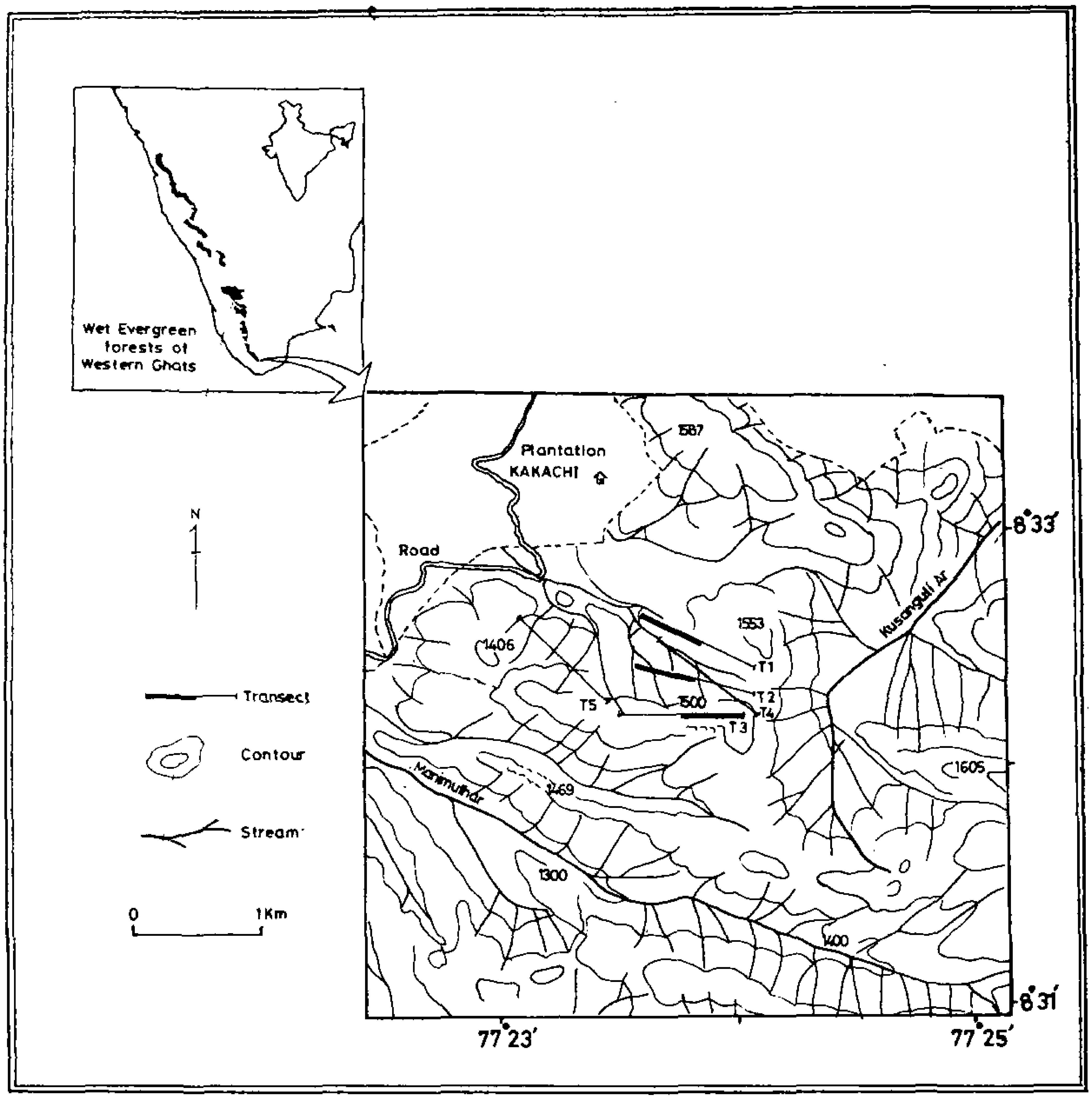

Figure 1. Map of the study area showing location of transects.

77°30'E and 8°40'N (Figure 1). The elevation of the reserve ranges from 100 to 1880 m (Agasthiar peak). The elevation gradient generates a range of vegetation from dry scrub at 150 m to dense evergreen forest above 1000 m. The study site is located near Kakachi (1250 m) in the core area of KMTR on a stretch of gently-undulating terrain, which abruptly increases in gradient forming a ridge facing northeast. The elevation of the ridge ranges from 1200 m at its base to 1550 m at its crest and is covered by dense primary forest interspersed with rock faces and *Ochlandra* facies. These forests are generally classified as belonging to the *Cullenia Mesua Palaquium* series[15]. The ridge occupies an area of more than 100 ha and is part of a continuous forest extending over 887 sq km of the KMTR.

The site receives over 3000 mm of rainfall from the SW and NE monsoons and six months of the year receives over 200 mm of rainfall per month (Figure 2). Temperature does not vary much over the seasons. Mean maximum temperature is 24°C and minimum about 16°C. The soil is poor in nutrients (R. Ganesan and N. Parthasarathy, unpublished) and much of the ground is rocky. Rocky areas occupy a substantial portion of the evergreen forest.

Methods

Vegetation sampling was done along the ridge from May 1992 to September 1993. Transect method was used to sample the vegetation. Five separate transects were laid in the study area (see Figure 1). Ten plots of 10 m × 10 m were established along three 1 km transects at intervals of 100 m resulting in a 0.1 ha sample for each transect. These were laid at 1220 m (T_1), 1300 (T_2) and 1450 m (T_3) altitude respectively, parallel to the ridge. The transects could not be run strictly along the same altitudinal belt because of topographic constraints. Transect 1 (T_1) ranged from 1220 m to 1300 m, T_2 from 1300 to 1400 and T_3 from 1450 to 1550 m. A preliminary analysis of species–area relationship showed that ten 10 m × 10 m plots were not sufficient as species continued to increase linearly with area. Hence it was decided to treat the first 500 m in the above three transects as a belt of 500 m × 10 m.

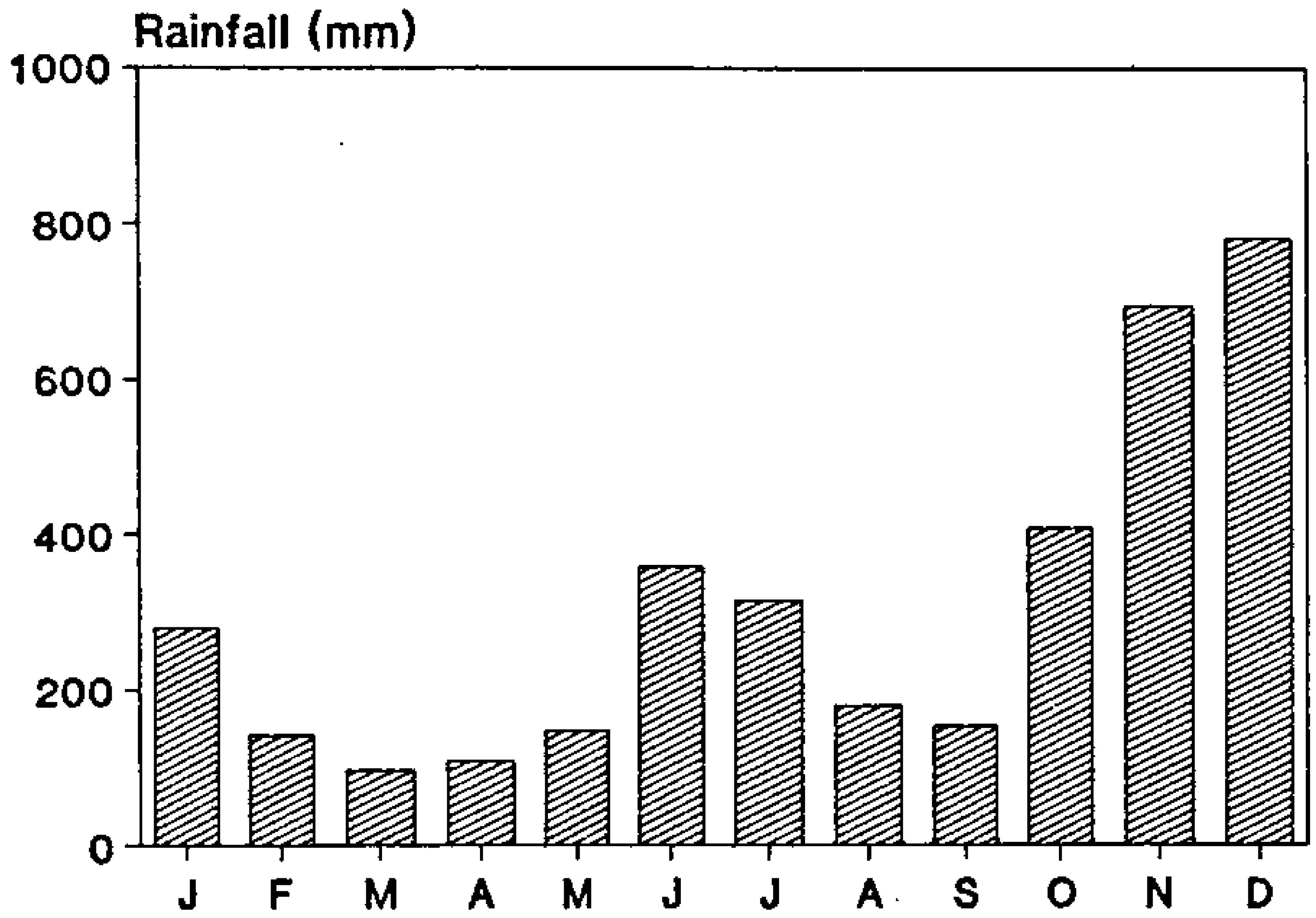

Figure 2. Mean monthly rainfall recorded at the site.

Two vertical transects of 990 m (T_4) and 940 m (T_5) long were laid descending from 1550 m to 1220 m and roughly bisecting the ridge. They are approximately parallel and 700 m away from each other. These transects could not be of 1 km length as they reached the crest at 990 m and 940 m respectively.

To sample small scale vegetation changes along altitudinal gradients, six plots were laid at intervals of 50 m elevation along the transects T_4 and T_5. Each of these six plots had 10 subplots of 10 m × 10 m forming a belt of 10 m × 100 m plot. These plots were established at approximately 1200 m, 1250 m, 1300 m, 1350 m, 1400 m and 1450 m, resulting in a 0.6 ha sample for each transect. The total area sampled in this study was 3.82 ha.

All woody vegetation above 10 cm DBH at 1.3 m height was enumerated and tagged in 500 × 10 m^2 belts in T_1, T_2 and T_3. Similarly the entire length of 990 m in T_4 and 940 m in T_5 were enumerated. All woody plants above 1 cm DBH and below 10 cm DBH were enumerated only in the 10 m × 10 m plots at intervals of 100 m in the T_1, T_2 and T_3. Six such plots at intervals of 50 m altitude along T_4 and T_5 were similarly enumerated. Herbs were sampled by randomly laying 1 m^2 plots in the 10 m × 10 m plots. Epiphytes were not sampled in this study. Trees and shrubs were included if their centre fell within the plot. Similarly lianas whose base fell inside the plot were enumerated. On uneven terrain, DBH was measured on the side facing the slope. Height was measured using a 2 m scale for shrubs and a pocket clinometer for trees wherever possible and visually estimated elsewhere. Altitude was recorded by a pocket altimeter with a sensitivity of 20 m.

To analyse the vegetation characteristics, two important value indices were calculated, one for species and another for family.

Species Importance Value (SIV) was calculated as follows. SIV = relative frequency + relative density + relative dominance.

Relative frequency = (number of plots containing a species × 100)/sum of frequencies of all species.

Relative density = (number of individuals of a species × 100) total number of individuals of all species.

Relative dominance = (basal area of a species × 100)/total basal area of all species.

The Family Importance Value (FIV) was calculated as mentioned by Keel *et al.*[16]. The FIV is given by

FIV = relative density + relative diversity + relative dominance.

Relative density = (number of individual of the species × 100)/total number of individuals in the sample.

Relative diversity = (number of species in the family × 100)/total number of species in the sample.

Relative dominance = (basal area of the family × 100)/total basal area in the sample.

For lianas, shrubs and herbs, SIV was calculated by adding the relative density and relative frequency only. Specimens were collected for all species. These samples were identified in the field with the help of Gamble[17] and later counter-checked with the reference material available at MH, Botanical Survey of India, Coimbatore. A reference collection of specimens with flowers/fruits was made and preserved as herbarium material.

Results

Floristics and forest structure

A total of one hundred and seventy three species of plants were recorded from the five transects representing 136 genera and 58 families. Canopy and understorey trees accounted for 90 species in 35 families, shrubs (height < 5m, DBH >1 cm) 50 species in 17 families, herbs (excluding grasses) 18 species in 14 families and lianas 15 species in 11 families. When the species abundance was represented in octaves and the number of species on an arithmetic scale, the resulting pattern was seen to follow the standard log normal distribution (Figure 3). The best fit curve $S_r = 17e^{-(0.246r)2}$ followed the observed distribution closely towards the higher end of the scale (chi square = 2.41 $p < 0.01$). At the lower end there were still 7 species which are rare and do not occur in the present sample. Maximum diversity was seen among canopy and understorey trees (Shannon diversity index 4.87).

Trees

Lauraceae, Rubiaceae and Euphorbiaceae were the three most dominant families in terms of species richness in the forest (Figure 4). However FIV index for pooled

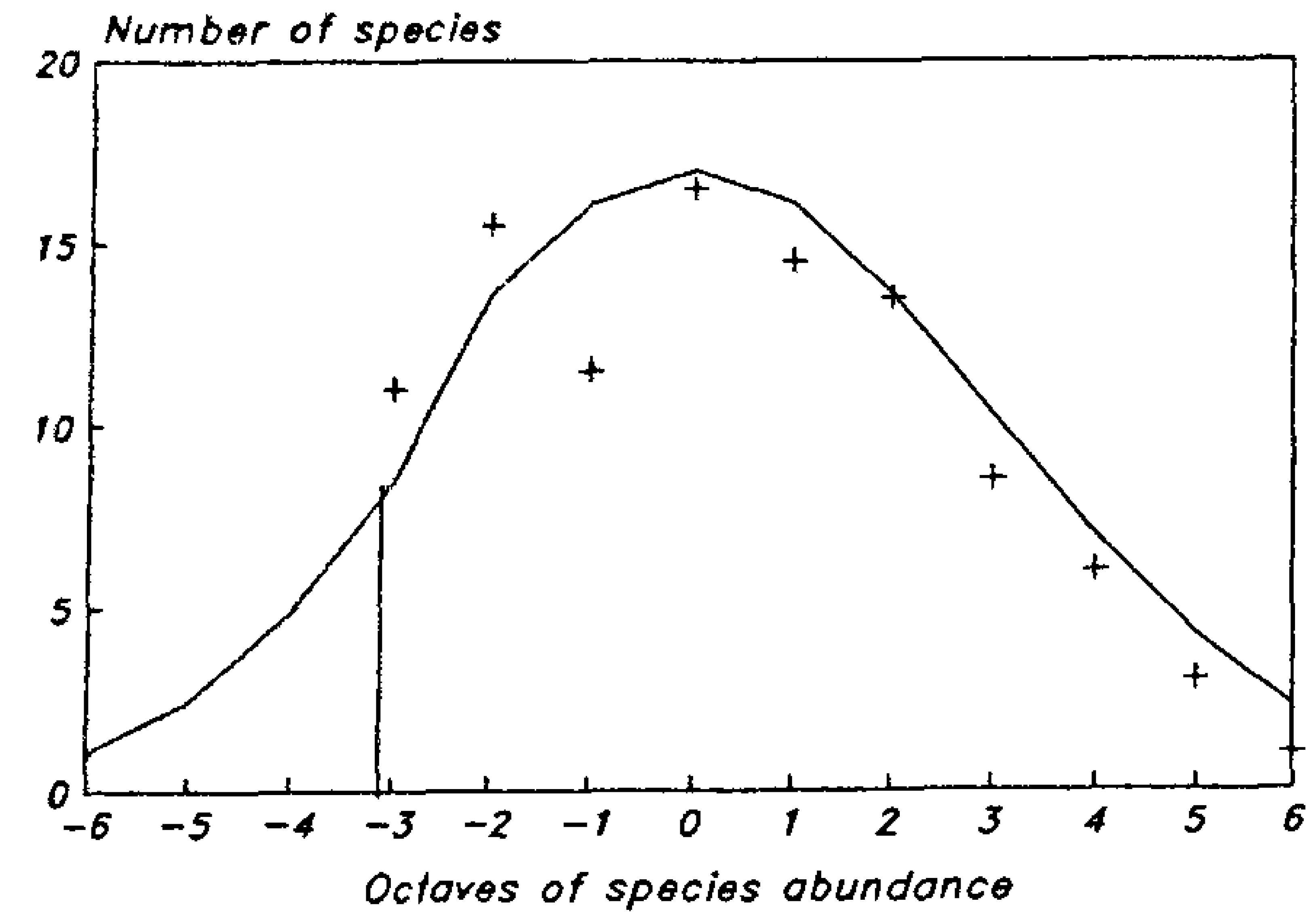

Figure 3. Log normal distribution of species abundance (> 10 cm DBH).

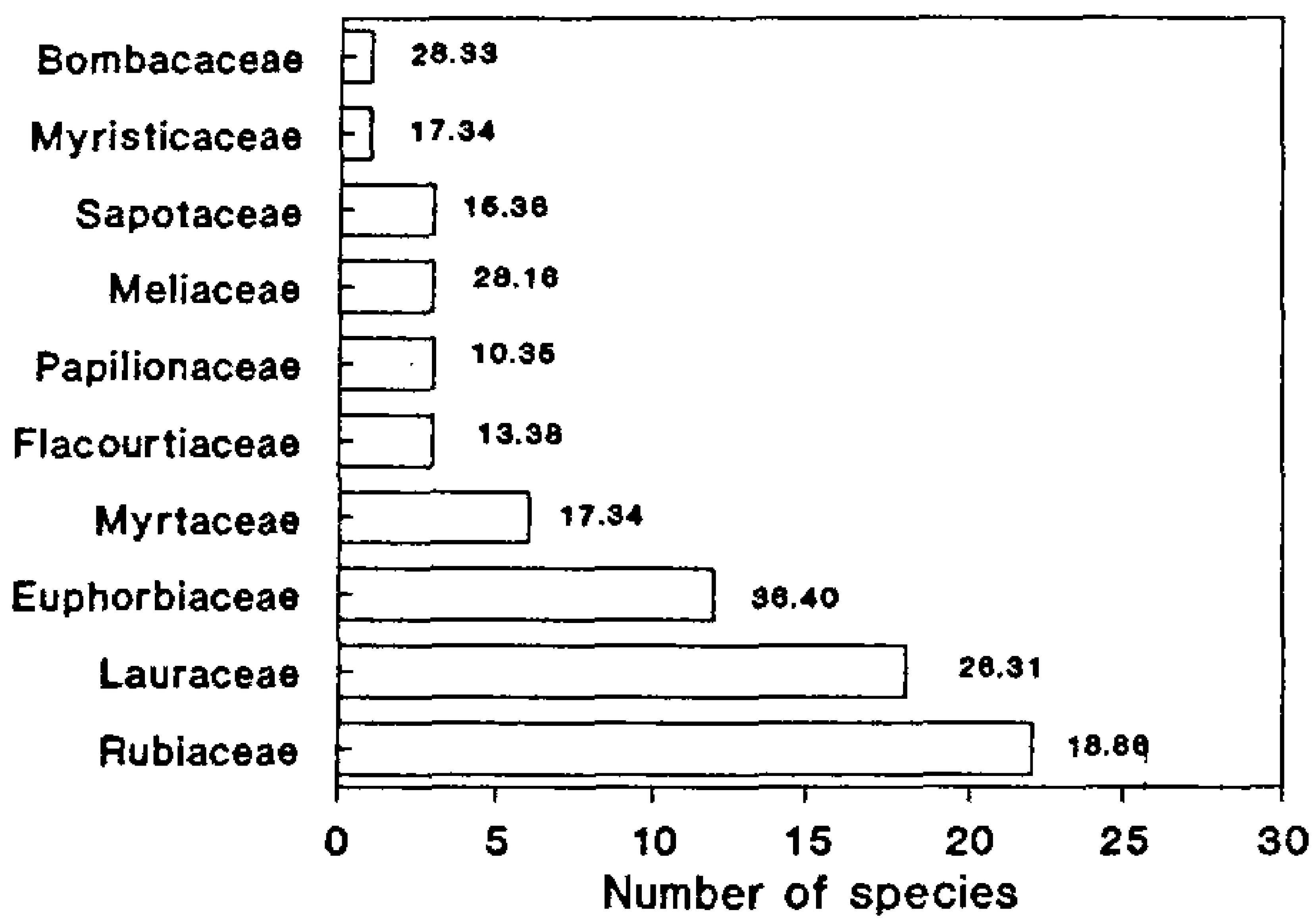

Figure 4. Family dominance based on species richness. FIV values are given at the end of each bar.

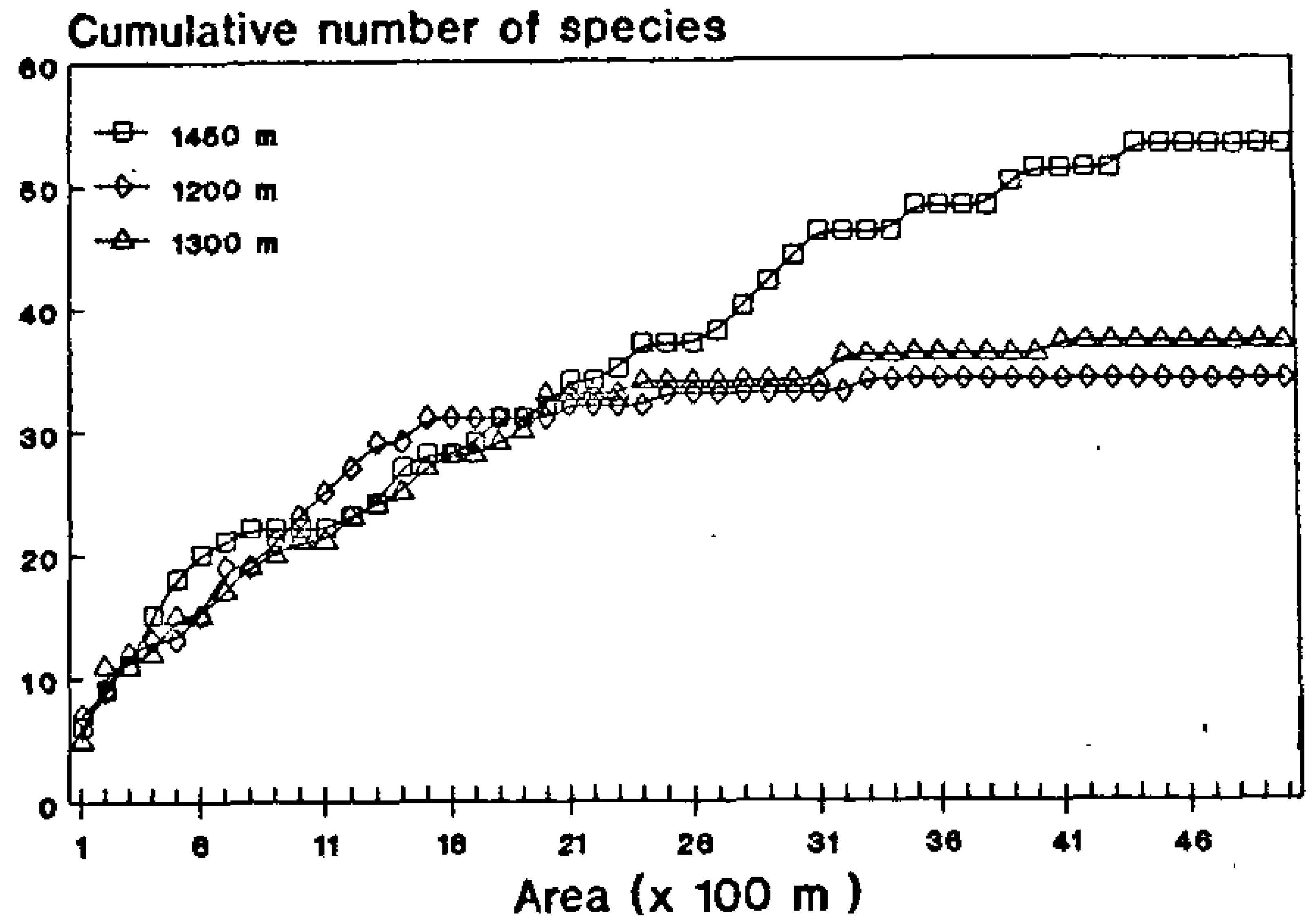

Figure 5. Species–area relationship of trees > 10 cm DBH.

data from all five transects showed that Euphorbiaceae was the most important family with an FIV value of 36.4 followed by Bombacaceae (28.33) and Lauraceae (26.31) (Figure 4). Euphorbiaceae dominated the understorey and only *Macaranga peltata* and *Mallotus tetracoccus* reached the canopy and subcanopy.

Bombacaceae was represented by only one species – *Cullenia exarillata* but because of its larger DBH and high density, it was the second dominant family. In contrast, Lauraceae and Rubiaceae in spite of their high species richness, do not have high FIV value because of their lower density and lower basal areas. Thirty one families were represented by just one species and only sixteen families had more than 3 species. Lauraceae was dominated by trees (16 out of 18 species) and all of them occur at very low abundance. Among Rubiaceae, except for *Tricalysia apiocarpa* and *Canthium ficiforme*, all other members were shrubs with less than 10 cm DBH.

The species area curve constructed to determine the adequacy of sampling in the three transects showed that very few species are added after 45 plots (Figure 5). For transect T_1 and T_2 such saturation occurred in less than 40 plots. In T_3 more number of plots were needed for the same. As each transect sampled 5000 m^2 (0.5 ha) of forest (of fifty 100 m^2, contiguous plots), it appears that by 4500 m^2, most of the species found in the patch are encountered.

The 0.5 ha sample from T_1, T_2 and T_3 was used for comparison between transects. Species diversity was higher in T_3 than T_1 (Table 1). Morisita Horn index (measure of beta diversity) showed 19% similarity between the T_3 and T_1 (Morisita Horn index = 0.1893) but 50% similarity between T_1 and T_2 (Morisita Horn index = 0.5004).

From the SIV values calculated with pooled data, *Cullenia exarillata*, *Aglaia elaeagnoidea* var. *bourdillonii* and *Palaquium ellipticum* emerged as the most important species in the forest (Table 2). *A. elaeagnoidea* had the highest density among them. SIV values are influenced by relative dominance and relative density to various degrees for each species. For large trees like *C. exarillata* and *P. ellipticum*, relative dominance accounted for 70% of the SIV value whereas for *A. elaeagnoidea*, although being abundant, accounted for only 32%, because of its smaller girth.

Palm diversity was very low inside the forest. Only one species, *Bentinckia codapanna* with two saplings was encountered. *Nageia wallichiana* (Podocarpaceae), the only gymnosperm in the forest, had only seven individuals (> 10 cm DBH) from the 2708 stems sampled.

Stem density and basal area are shown in Table 1. The first 10 dominant species in the forest accounted for 65% (1496) of the stems sampled, 31% (744) of these

Table 1. Dominant tree species, stem density, basal area and species diversity of different life-forms in the three horizontal transects of 0.5 ha. Number of species is given in parenthesis

Transect	Dominant tree species	Stem density	Basal area (m^2)	Species diversity* Tree	Shrub	Herb	Liana
1250 m	*Cullenia exarillata* *Palaquium ellipticum* *Agrostistachys borneensis*	358	30.01	3.89 (31)	3.72 (27)	1.76 (4)	–
1300 m	*Cullenia exarillata* *Aglaia elaeagnoidea* *Agrostistachys borneensis*	315	27.43	3.96 (36)	3.07 (19)	2.06 (5)	1.79 (5)
1450 m	*Aglaia elaeagnoidea* *Alseodaphane semicarpifolia* *Hydnocarpus alpina*	418	42.35	4.47 (48)	2.47 (29)	2.96 (9)	2.23 (6)

*Shannon–Wiener diversity index calculated to base 2.

are accounted by the top three species, viz *C. exarillata, A. elaeagnoidea* var. *bourdillonii* and *P. ellipticum.*

The DBH distribution from pooled data shows a typical 'L' shaped curve (Figure 6). Though T_1 and T_2 did not differ in their distribution (Kolmogorov–Smirnov test $D = 0.0305$ $p < 0.05$), T_3 differed significantly from T_1 ($D = 0.096$ $p < 0.05$) and T_2 ($D = 0.92$ $p < 0.05$). However the general similarity of the 'L' shaped curve in all the transects indicates the undisturbed nature of the forest stand.

The change in abundance of the dominant species along the elevational gradient at intervals of 50 m is shown in Figures 7 *a* and *b*. Based on their abundance at different elevations, they were classified into two categories; low elevation and high elevation species.

The low elevation species: *Palaquium ellipticum, Cullenia exarillata, Myristica dactyloides, Epiprinus mallotiformis, Artocarpus heterophyllus, Holigarna nigra* and *Elaeocarpus tuberculatus* were found in both the transects but restricted to elevation < 1300 m with the exception of *E. mallotiformis* in transect 5.

The high elevation species: Trees like *Pygeum sisparense, Alseodaphne semicarpifolia, Memecylon malabaricum* and *Syzygium densiflorum* were restricted to above 1400 m whereas *Hydnocarpus alpina, Drypetes longifolia, Mastixia arborea* also found elsewhere, occurred at a higher density at this altitude.

Shrubs (1 m–5 m)

Over 50 species of shrubs were encountered in the area, dominated by Rubiaceae 14 spp. (30%) and Acanthaceae 9 spp. (18%). Shrub diversity ($H' = 3.91$) was significantly less than tree diversity ($H' = 4.17$; $t = 20.29$, $df = 2725$ $p < 0.001$). Dominant species were *Nilgirianthus foliosus, N. perrottetianus, Diotacanthus grandis* and *Agrostistachys indica.* The latter two species were common in all the three transects (Table 2).

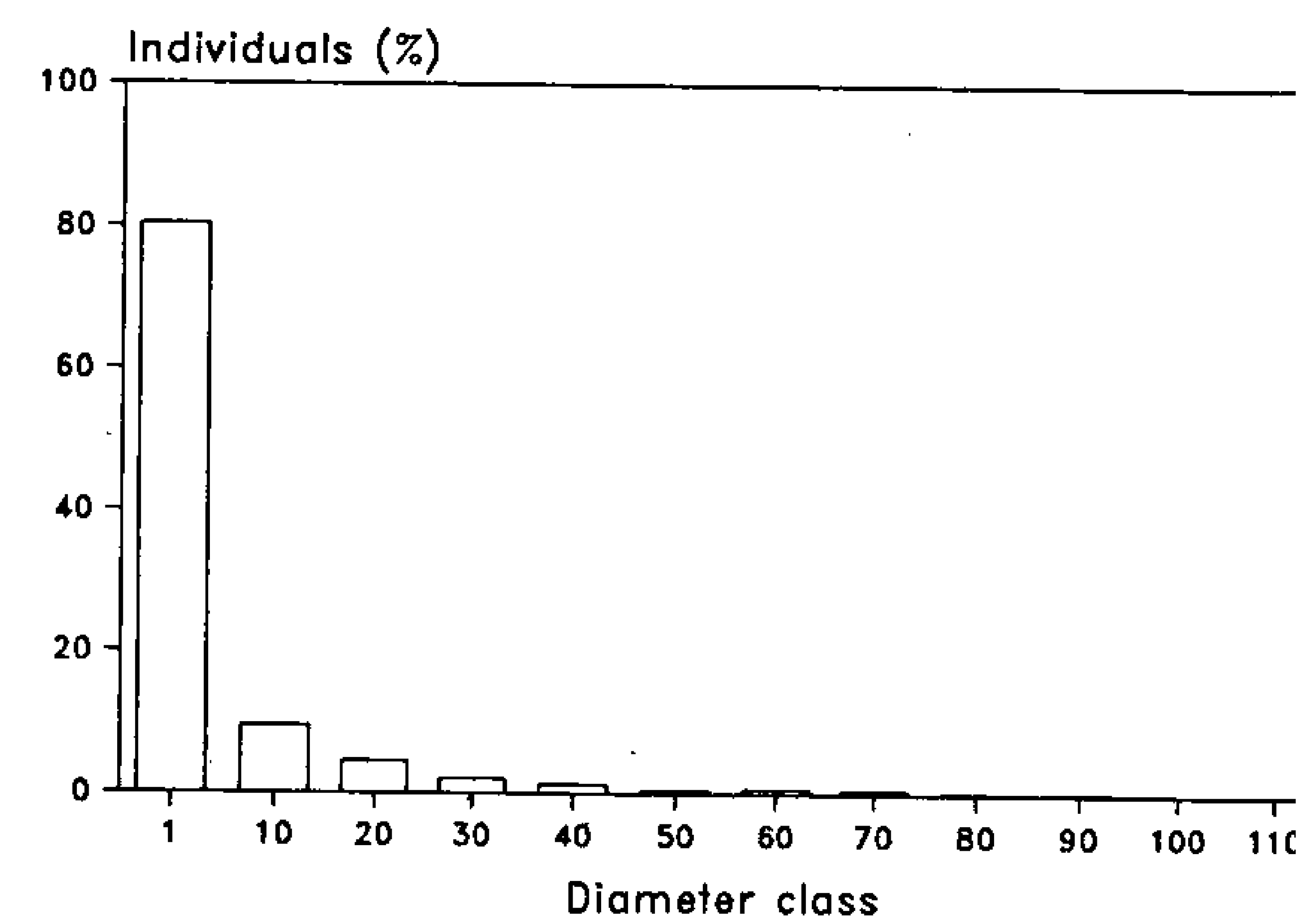

Figure 6. Size class distribution of all individuals in the transects.

Elevational changes in diversity showed a decreas from 1250 m (T_1) to 1450 m (T_3) (Table 1). Shrub density at every 50 m altitudinal interval also showed maximum density at 1250 m.

Herbs (<1 m)

The herb community was not dominated by any single family. Families like Rubiaceae, Euphorbiaceae and Zingiberaceae had 2 to 3 species while others were monospecific. Eighteen species of herbs were recorded Only *Curculigo orchioides* was common to all transects (Table 2).

Elevational changes in diversity increased from lower to higher elevations (Table 2), while abundance shows a high at 1250 m altitude and a low at 1300 m followed by a steady rise further up. Pteridophytes like ferns were found in greater density in the lower altitudes (T_1 and T_2).

Table 2. Floristic composition, frequency, density and SIV of different life-forms sampled from all five transects. The variety names of the species are given as footnote.

Species	Pooled data			
	Frequency	Density	Basal area (cm^2)	SIV
Trees				
Cullenia exarillata Robyns. (Bombacaceae)	138	243	514977.37	39.60
Aglaia elaeagnoidea (Juss.) Benth.[a] (Meliaceae)	181	419	171726.27	33.30
Palaquium ellipticum (Dalz.) Baillon (Sapotaceae)	68	104	178361.29	15.59
Hydnocarpus alpina Wight (Flacourtiaceae)	82	114	77912.93	12.29
Myristica dactyloides Gaertn. (Myristicaceae)	75	99	93727.58	12.04
Tricalysia apiocarpa (Dalz.) Gamble (Rubiaceae)	56	69	128838.17	11.42
Alseodaphne semicarpifolia Nees[b] (Lauraceae)	30	41	151195.95	9.91
Syzygium gardneri Thw. (Myrtaceae)	47	62	61803.26	7.68
Calophyllum austroindicum Kosterm. ex Stevens (Guttiferae)	32	32	86410.73	6.82
Artocarpus heterophyllus Lam. (Moraceae)	51	51	42216.82	6.63
Diospyros malabarica (Desr.) Kostel. (Ebenaceae)	29	35	45593.96	4.95
Holigarna nigra Bourd. (Anacardiaceae)	36	44	28028.56	4.90
Ormosia travancorica Bedd. (Papilionaceae)	19	22	54047.17	4.28
Mastixia arborea (Wight) Bedd. (Cornaceae)	24	30	24369.06	3.54
Neolitsea fischeri Gamble (Lauraceae)	13	14	45937.94	3.29
Cinnamomum travancoricum Gamble (Lauraceae)	16	19	30006.26	2.93
Cryptocarya lawsonii Gamble (Lauraceae)	23	25	13968.43	2.84
Casearia ovata (Lam.) Willd. (Flacourtiaceae)	23	23	12493.28	2.70
Scolopia crenata (Wight & Arn.) Clos (Flacourtiaceae)	17	18	23549.88	2.67
Elaeocarpus munronii (Wight) Mast. (Elaeocarpaceae)	12	18	25154.00	2.46
Memecylon malabaricum (Clarke) Cogn. (Melastomataceae)	17	22	13896.50	2.39
Beilschmiedia wightii (Nees) (Lauraceae)	14	14	9174.14	1.71
Elaeocarpus tuberculatus Roxb. (Elaeocarpaceae)	9	9	13435.78	1.44
Canthium ficiforme Hook. f. (Rubiaceae)	9	9	13168.98	1.42
Macaranga peltata (Roxb.) Muell.-Arg. (Euphorbiaceae)	10	10	5827.31	1.19
Vepris bilocularis (Wight & Arn.) Engler (Rutacea)	6	7	11196.63	1.09
Celtis timorensis Spamoghe (Ulmaceae)	7	7	4800.16	0.87
Rapanea wightiana (Wall. ex DC) Mez. (Myrsinaceae)	8	8	2598.53	0.86
Nageia wallichiana (Presl.) Kuntze. (Podocarpaceae)	7	7	2613.12	0.77
Persea macrantha (Nees) Kosterm. (Lauraceae)	5	6	3225.74	0.65
Gordonia obtusa Wall. ex Wight & Arn. (Theaceae)	3	3	3934.58	0.45
Trichilia connaroides (Wight & Arn.) Bentvelzen (Meliaceae)	4	4	1406.56	0.44
Litsea wightiana (Nees) Hook. f. (Lauraceae)	2	4	2410.94	0.37
Glochidion fagifolium Bedd. (Euphorbiaceae)	2	3	2687.61	0.34
Litsea insignis Gamble (Lauraceae)	1	1	2340.00	0.20
Eugenia floccosa Bedd. (Myrtaceae)	1	3	633.08	0.20
Dysoxylum malabaricum Bedd. ex Hiern (Meliaceae)	1	1	1655.35	0.17
Michelia nilagirica Zenk. (Magnoliaceae)	1	1	1098.03	0.14
Ternstroemia japonica (Thunb.) Thunb. (Theaceae)	1	1	1017.86	0.14
Litsea glabrata (Wall.ex Nees) Hook. f. (Lauraceae)	1	1	835.03	0.13
Mallotus tetracoccus (Roxb.) Kurz (Euphorbiaceae)	1	1	459.96	0.11
Prunus ceylanica (Wight) Miq. (Rosaceae)	1	1	174.28	0.10
Understorey trees				
Agrostistachys borneensis Becc. (Euphorbiaceae)	129	236	67852.86	19.00
Gomphandra coriacea Wight (Icacinaceae)	108	147	39164.89	13.26
Drypetes longifolia (Blume) Pax & Hoffm. (Euphorbiaceae)	69	118	42864.61	10.15
Xanthophyllum flavescens Roxb. (Xanthophyllaceae)	22	79	49524.49	6.35
Epiprinus mallotiformis (Muell.-Arg.) Croizat (Euphorbiaceae)	48	66	13638.24	5.75
Antidesma menasu (Tul.) Miq.ex Muell.-Arg. (Stilaginaceae)	33	42	8050.51	3.77
Acronychia pedunculata (L.) Miq. (Rutaceae)	29	40	8551.20	3.49
Syzygium mundagam (Bourd.) Chithra (Myrtaceae)	28	32	9461.44	3.18
Ixora nigricans R. Br. ex Wight & Arn. (Rubiaceae)	9	65	1837.83	2.99
Litsea ligustrina (Nees) Hook. f. (Lauraceae)	16	20	4656.67	1.85
Clerodendrum viscosum Vent. (Verbenaceae)	11	24	6819.07	1.81
Glycosmis pentaphylla (Retz.) DC. (Rutacea)	16	17	3731.35	1.70

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Table 2. contd....

Species	Frequency	Density	Basal area (cm²)	SIV
		Pooled data		
Syzygium benthamianum (Wight ex Duthie) Gamble (Myrtaceae)	13	16	6167.77	1.60
Syzygium densiflorum Wall. ex Wight & Arn. (Myrtaceae)	6	13	16063.38	1.53
Nothopegia travancorica Bedd. ex Hook. f. (Anacardiaceae)	12	17	2223.02	1.40
Cinnamomum sulphuratum Nees (Lauraceae)	11	16	2072.12	1.30
Mallotus resinosus (Blanco) Merr. (Euphorbiaceae)	12	13	2655.36	1.27
Euphorbia antiquorum L. (Euphorbiaceae)	10	10	6052.31	1.20
Pygeum sisparense Gamble (Rosaceae)	10	14	1122.02	1.13
Gomphia serrata (Gaertn.) Kanis (Ochnaceae)	9	11	1892.49	1.00
Viburnum punctatum Buch.-Ham. ex D.Don (Caprifoliaceae)	8	8	4457.03	0.94
Miliusa wightiana Hook. f. & Thomas. (Annonaceae)	5	5	10627.87	0.94
Atalantia wightii Tanaka (Rutaceae)	4	4	11745.09	0.89
Eugenia rottleriana Wight & Arn. (Myrtaceae)	6	8	4244.71	0.82
Vernonia travancorica Hook. f. (Compositae)	7	7	1164.41	0.70
Murraya paniculata (L.) Jack (Rutaceae)	4	12	334.78	0.68
Actinodaphne bourdillonii Gamble (Lauraceae)	5	6	2074.49	0.60
Memecylon flavescens Gamble (Melastomataceae)	4	4	4592.89	0.58
Tarenna asiatica (L.) Kuntze ex K. Schum. (Rubiaceae)	4	5	1145.19	0.46
Eugenia thwaitesii Duthie (Myrtaceae)	4	6	91.23	0.45
Neolitsea cassia (L.) Kosterm. (Lauraceae)	4	6	145.68	0.45
Isonandra perrottetiana A.DC. (Sapotaceae)	4	4	592.12	0.40
Octotropis travancorica Bedd. (Rubiaceae)	4	4	377.76	0.39
Schefflera wallichiana (Wight & Arn.) Harms. (Araliaceae)	3	4	1697.43	0.39
Apollonias arnottii Nees (Lauraceae)	3	4	438.26	0.34
Eugenia maboides Wight (Myrtaceae)	3	3	913.40	0.32
Nothopodytes nimmoniana (Graham) Mabberley (Icacinaceae)	3	3	651.94	0.31
Litsea nigrescens Gamble (Lauraceae)	2	2	1705.81	0.26
Maesa indica (Roxb.) DC. (Myrsinaceae)	2	2	461.84	0.21
Ligustrum perrottetii DC. (Oleaceae)	1	1	2376.79	0.20
Isonandra lanceolata Wight (Sapotaceae)	2	2	191.91	0.20
Olea dioica Roxb. (Oleaceae)	1	1	735.71	0.13
Ficus virens Ait. (Moraceae)	1	1	115.04	0.10
Garcinia travancorica Bedd. (Guttiferae)	1	1	220.98	0.10
Vaccinium leschenaultii Wight[c] (Vacciniaceae)	1	1	156.21	0.10
Pavetta thomsonii Bremek[4] (Rubiaceae)	1	1	109.40	0.10
Canthium travancoricum (Bedd.) Hook. f. (Rubiaceae)	1	1	95.07	0.10
Goniothalamus wightii Hook.f. & Thoms. (Annonaceae)	1	1	120.81	0.10
Total	**1773**	**2708**	**2254894.56**	**300.00**
Shrubs				
Nilgirianthus foliosus (Wight) Bremek. (Acanthaceae)	16	815		27.33
Agrostistachys indica Dalz. (Euphorbiaceae)	23	321		14.07
Diotacanthus grandis (Bedd.) Benth. ex Clarke (Acanthaceae)	20	316		13.33
Psychotria connata Wall. (Rubiaceae)	36	197		12.97
Nilgirianthus perrottetianus (Nees) Bremek. (Acanthaceae)	12	313		11.66
Lasianthus cinereus Gamble (Rubiaceae)	28	201		11.50
Saprosma corymbosum (Bedd.) Bedd. (Rubiaceae)	22	222		10.94
Cinnamomum filipedicellatum Kosterm. (Lauraceae)	15	142		7.18
Calamus brandisii Beccari ex Beccari & Hook. f. (Arecaceae)	12	83		4.84
Psychotria anamalayana Bedd. (Rubiaceae)	16	48		4.59
Phyllanthus fimbriatus (Wight) Muell.-Arg. (Euphorbiaceae)	18	25		4.31
Micrococca beddomei (Hook. f.) Prain (Euphorbiaceae)	16	22		3.82
Psychotria nigra (Gaertn.) Alston. (Rubiaceae)	10	51		3.49
Nilgirianthus punctatus (Nees) Bremek. (Acanthaceae)	6	65		3.12
Ochlandra scriptoria (Dennst.) Fischer (Poaceae)	3	82		3.03
Hedyotis purpurascens Hook. f. (Rubiaceae)	9	23		2.46
Xenacanthus pulneyensis (Clarke) Bremek. (Acanthaceae)	5	49		2.44
Ardisia pauciflora Heyne ex Roxb. (Myrsinaceae)	9	19		2.35

contd....

Table 2. contd....

Species	Pooled data Frequency	Density	Basal area (cm^2)	SIV
Lasianthus strigillosus Hook. f. (Rubiaceae)	8	23		2.27
Symplocos wyanadense (Kuntze) Nooteb. (Symplocaceae)	9	16		2.26
Unidentified	5	38		2.12
Calamus pseudo-tenuis Beccari ex Beccari & Hook.f. (Arecaceae)	7	18		1.92
Euonymus crenulatus Wall. ex Wight & Arn. (Celastraceae)	7	10		1.68
Goldfussia tristis Wight (Acanthaceae)	3	36		1.66
Microtropis stocksii Gamble (Celastraceae)	7	8		1.62
Leptacanthus rubicundus Nees (Acanthaceae)	3	32		1.54
Meiogyne pannosa (Dalz.) Sinclair (Annonaceae)	6	6		1.37
Chasalia curviflora (Wall. ex Kurz) Thw. (Rubiaceae)	6	6		1.37
Unidentified	5	9		1.26
Mussaenda hirsutissima (Hook.f.) Hutchinson ex Gamble (Rubiaceae)	5	5		1.14
Osbeckia aspera (L.) Blume (Melastomataceae)	5	5		1.14
Litsea sp. (Lauraceae)	5	5		1.14
Barleria involucrata Nees[c] (Acanthaceae)	4	8		1.03
Rauvolfia densiflora (Wall.) Benth. ex Hook. f. (Apocyanaceae)	4	5		0.94
Solanum sp. (Solanaceae)	3	3		0.68
Excoecaria crenulata Wight (Euphorbiaceae)	2	9		0.66
Erythroxylum obtusifolium (Wight) Hook. f. (Erythroxylaceae)	2	6		0.57
Lasianthus sp. (Rubiaceae)	2	4		0.51
Croton laccifer L. (Euphorbiaceae)	2	3		0.48
Didyplosandra lurida (Wight) Bremek, (Acanthaceae)	2	2		0.46
Symplocos nairii Henry, Gopalan & Swamin. (Symplocaceae)	1	1		0.23
Pittosporum tetraspermum Wight & Arn. (Pittosporaceae)	1	1		0.23
Medinilla malabarica Bedd. (Melastomataceae)	1	1		0.23
Byrsophyllum tetrandrum (Bedd.) Hook.f. ex Bedd. (Rubiaceae)	1	1		0.23
Actinodaphne campanulata Hook. f. (Lauraceae)	1	1		0.23
Neurocalyx calycinus (R. Br. ex Benn.) Robins (Rubiaceae)	1	1		0.23
Lobelia nicotianifolia Roth ex Schultes (Lobeliaceae)	1	1		0.23
Clausena indica (Dalz.) Oliver (Rutaceae)	1	1		0.23
Memecylon subcordatum Cogn. (Melastomataceae)	1	1		0.23
Polyscias acuminata (Wight) Seem. (Araliaceae)	1	1		0.23
Herbs				
Curculigo orchioides Gaertn. (Hypoxidaceae)	11	12		2.67
Grasses	8	8		1.92
Rungia wightiana Nees (Acanthaceae)	7	10		1.77
Elastostema lineolatum Wight[f] (Urticaceae)	4	6		1.02
Lycianthus laevis (Dunal) Bitter (Solanaceae)	3	4		0.75
Dorstenia indica Wall. ex Wight (Moraceae)	2	2		0.48
Oldenlandia sp. (Rubiaceae)	2	2		0.48
Phyllanthus sp. (Euphorbiaceae)	2	2		0.48
Plectranthus malabaraicus (Benth.) Willemse (Labiatae)	2	2		0.48
Elettaria cardamomum L. (Zingiberaceae)	1	3		0.30
Pouzolzia sp. (Urticaceae)	1	2		0.27
Sonerila sp. (Melastomataceae)	1	2		0.27
Selaginella sp. (Pteridophyte)	1	2		0.27
Curculigo trichocarpa (Wight) Bennet & Raizada (Hypoxidaceae)	1	1		0.24
Ophiorrhiza grandiflora Wight (Rubiaceae)	1	1		0.24
Zingiber roseum (Roxb.) Roscoe (Zingiberaceae)	1	1		0.24
Anaphyllum wightii Schott. (Araceae)	1	1		0.24
Begonia malabarica Lam. (Begoniaceae)	1	1		0.24
Cyanotis arachnoidea Clarke (Commelinaceae)	1	1		0.24
Lianas				
Toddalia asiatica (L.) Lam. (Rutaceae)	8	16		2.15
Zanthoxylum tetraspermum Wight & Arn. (Rutaceae)	5	9		1.32

contd....

Table 2. contd....

Species	Pooled data Frequency	Density	Basal area (cm^2)	SIV
Embelia basaal (Roem. & Schultes) A.DC. (Myrsinaceae)	4	7		1.05
Connarus wightii Hook. f. (Connaraceae)	3	7		0.84
Jasminum azoricum L. (Oleaceae)	3	3		0.72
Tylophora subramanii Henry (Asclepiadeacea)	2	4		0.54
Tetrastigma leucostaphylum (Dennst.) Alston (Vitaceae)	2	2		0.48
Elaeagnus kologa Schlecht. (Elaeagnaceae)	2	2		0.48
Oxyceros rugulosus (Thw.) Tirvengadum (Rubiaceae)	1	1		0.24
Ficus amplocarpa Govindarajalu & Masilamoney (Moraceae)	1	1		0.24
Piper sp. (Piperaceae)	1	1		0.24
Derris benthamii (Thw.) Thw. (Papilionaceae)	1	1		0.24
Segeretia hamosa Brongn. (Rhamnaceae)	1	1		0.24
Jasminum malabaricum Wight (Oleaceae)	1	1		0.24
Canthium angustifolium Roxb. (Rubiaceae)	1	1		0.24
Total	**506**	**3374**		**200.00**

a = var. *bourdillonii* (Gamble) K. K. N. Nair
b = var. *parvifolia* Hook. f.
c = var. *zeylanica* Clarke
d = var. *puberula* Bremek.
e = var. *elata* (Dalz.) Clarke
f = var. *linearis* Wedd.

Lianas

The forest was poorly represented by large lianas. Only 15 species of lianas were recorded, of which ten species occurred in the > 10 cm DBH class. These constituted only 1% (25 out of 2733 stems) of the forest stand and all occurred at low densities. The Shannon value was 3.05. *Embelia basaal* was the only common liana with a density of 1.83 per ha. Elevation-wise liana diversity increased from T_2 to T_3, T_1 at 1200 m did not have any large class liana (Table 1).

Comparison of lifeforms in 1 m^2 subplots among the three transects showed that herbs and shrubs had greater representation in T_3. Species richness among trees, lianas, shrubs and herbs, however, did not show any significant differences between them (chi square = 5.475, $df = 6$, $p < 0.05$).

Tree saplings

Most of the dominant species had good representation in the saplings except *P. ellipticum* which did not have many adults and saplings (Table 3). While 7 species did not have any saplings, 8 species did not have any adults but some of them, *Nothopegia travancorica* and *Neolitsea fischeri* had large number of saplings in the 3000 m^2 area.

Aglaia elaeagnoidea, Hydnocarpus alpina and *Gomphandra coriacea* are the common sapling species found in all the three elevations. Frequency of tree sapling

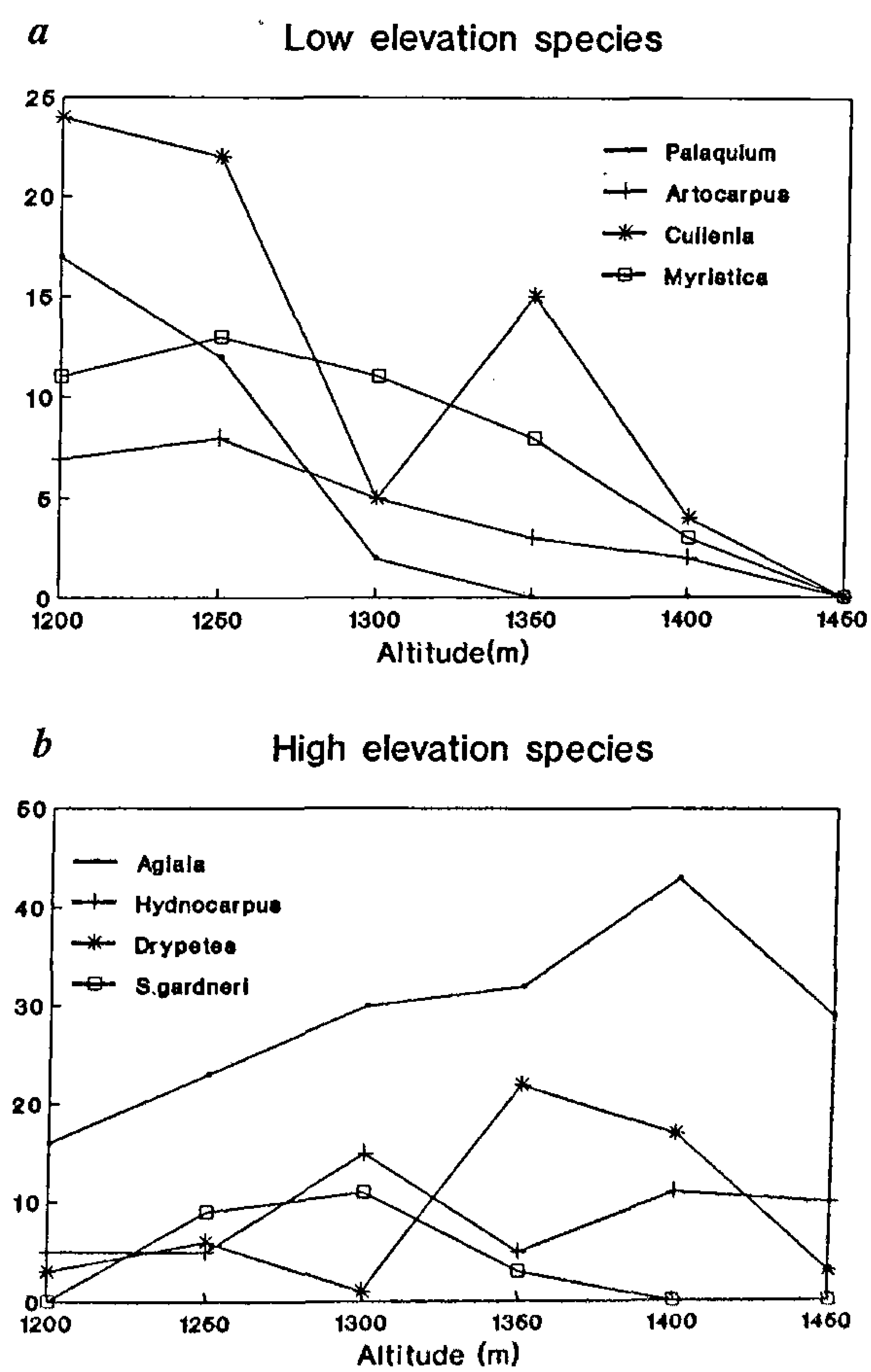

Figure 7 *a*, *b*. Distribution of dominant tree species along elevational gradients. ***a***, Low elevation species; ***b***, High elevation species.

Table 3. Comparison of tree and sapling density in three horizontal transects (0.1 ha)

Species	Transect 1			Transect 2			Transect 3			Pooled		
	Adult	Sapling	SIV	Adult	Sapling	SIV	Adult	Sapling	SIV	Adults	Sapling	SIV*
Cullenia exarillata	12	25	38.87	7	17	61.79				19	42	40.18
Aglaia elaeagnoidea var. *bourdillonii*	14	44	35.98	11	55	81.2	12	3	27.59	37	102	31.83
Palaquium ellipticum	2	7	11.11	1		6.32				3	7	19.25
Agrostistachys borneensis	11	90	31.55	3	45	8.6				14	135	18.94
Gomphandra coriacea	2	9	5.45	2	6	8.84	3	1	10.03	7	16	14.53
Myristica dactyloides	7	16	19.56	1	6	3.97				8	22	14.27
Hydnocarpus alpina	1	1	2.86	2	10	13.31	18	10	38.79	21	21	12.40
Syzygium gardneri	2	11	2.86	1	8	15.84				3	19	8.48
Calophyllum austroindicum					8		2		10.83	2	8	7.24
Artocarpus heterophyllus	1	4	7.76							1	4	7.22
Epiprinus mallotiformis	3		9.94	2	8	21.13				5	8	6.48
Holigarna nigra	3	4	13.70	1		6.63				4	4	5.59
Alseodaphne semecarpifolia							7	3	51.79	7	3	4.72
Acronychia pedunculata				1	1	3.97	2	10	5.90	3	11	4.35
Drypetes longifolia	6	9	13.70	4	11	4.02				10	20	4.35
Antidesma menasu	6	11	17.13	3	8	21.93				9	19	3.88
Syzygium mundagam	1		3.22	1	1	5.42				2	1	3.51
Tricalysia apiocarpa				2	6	17.69	4	1	12.15	6	7	2.52
Scolopia crenata	2	1	6.45							2	1	2.49
Cinnamomum travancoricum	1	38	3.96					9		1	47	2.43
Clerodendrum viscosum	1	14	2.79							1	14	2.09
Litsea ligustrina							1	1	2.98	1	1	2.07
Elaeocarpus tuberculatus	1	6	3.39							1	6	1.72
Cinnamomum filipedicellatum	2	10	6.56							2	10	1.45
Rapanea wightiana							6	2	17.54	6	2	1.28
Macaranga peltata	1	3	6.73							1	3	1.24
Viburnum punctatum	1		3.03		1					1	1	1.02
Gomphia serrata	1		2.81					4		1	4	0.91
Eugenia floccosa							1	2	3.71	1	2	0.61
Beilschmiedia wightii	2	1	2.79							2	1	0.58
Litsea wightiana	3	9	8.74	1		4.86				4	9	0.47
Glochidion fagifolium				2		6.27		1		2	1	0.46
Octotropis travancorica				1	45	3.96				1	45	0.42
Syzygium densiflorum							13	4	39.49	13	4	0.23
Tetrastigma lecuostaphylum				1	10	4.02				1	10	0.22
Fagraea ceilanica							1	2	2.94	1	2	0.21
Memecylon flavescens							1	1	3.83	1	1	0.16
Eugenia maboides							1	14	3.17	1	14	0.12

* SIV values from 5 transects.

distribution showed more resemblance between lower and middle elevation (T_1 and T_2) when compared to higher elevations (T_3) (Table 3). In T_3, saplings were dominated by *Eugenia maboides*, *Hydnocarpus alpina*, while some dominant species like *Aglaia elaeagnoidea* and *Alseodaphne semicarpifolia* had poor recruitment. In general, understorey growth was dominated by shrubs (2483 per 0.3 ha) and not by tree saplings (562).

Discussion

Species richness

The Western Ghats harbour over 3500 species of flowering plants out of the 17,000 species described from India[18]. The Agasthyamalai range in the southern Western Ghats alone includes more than 2000 or 57% of the 3500 species[7]. Of these, 173 or 8.65% occurred in the transects at Kakachi.

The species–area relationship for the horizontal transects shows that by 4500 m^2 the species accumulation curve saturates for transects at 1200 m and 1300 m. For the transect at 1450 m, it did not saturate and is likely to increase even beyond the 50th plot (0.50 ha). This may be due to the transition in vegetation type at this altitude. The shape of the species area curves obtained at Kakachi was similar to those of Silent valley[15] and Anamalais[19] as most of the species there were also encountered by 0.45–0.5 ha. These cannot be strictly compared because they involve non-contiguous plots separated by long distances. Similar saturation of species area curves between 0.4 and 0.5 ha are also recorded from montane rainforests in South America[20]. Further, the log normal distribution of species abun-

Table 4. Summary of vegetation studies in the evergreen forests of Western Ghats

	Locality	Vegetation type	Altitude (m)	Plot (m^2)	No. of trees	Basal area (m^2)	No of species	Shannon index (H′)	Source
1	Silent Valley Kerala	*Palaquium ellipticum* *Cullenia exarillata* *Ficus* sp.	1120	800		102.7	34	4.08	22
2	Silent Valley Kerala	*Elaeocarpus tuberculatus* *Eugenia* sp. *Poeciloneuron indicum*	1050	500		47.7	36	4.15	22
3	Attapadi Kerala	*Cullenia exarillata* *Mesua ferrea* *Palaquium ellipticum*	1100	1000			37	3.52	22
4	Kadamakal N. Coorg Karnataka	*Dipterocarpus indicus* *Kingiodendron pinnatum* *Humboltia brunonis*	650–700	1600	2926	64.9	70	4.3	15
5	Naravi Karnataka	*Dipterocarpus indicus* *Humboltia brunonis* *Poeciloneuron indicum*	750	1600	1925	70	35	3.6	15
6	New Someshwara Karnataka	*Dipterocarpus indicus* *Diospyros candolleana* *Diospyros oocarpa*	420	1400	1314	67.7	25	3.2	15
7	Magod Karnataka	*Persea macarantha* *Diospryos* sp. *Holigarna arnottiana*	370	1600	1875	67.7	35	4	15
8	Attapadi Kerala	*Cullenia exarillata* *Mesua ferrea* *Palaquium ellipticum*	900	2000	1520	59.6	32	4	15
9	Suthanbi	sub type 1 (of Attapadi)	750	1600	1200	60.7	32	3.7	15
10	Bhagawati	sub type 2 (of Attapadi)	900	1000	2250	64	12	2.1	15
11	Kankumbi Karnataka	*Memecylon umbellatum* *Syzygium cumini* *Actinodaphne angustifolium*	780	1600	1787	40.3	44	4.1	15
12	Sengaltheri Kalakad Tamil Nadu	*Cullenia exarillata* *Mesua ferrea* *Palaquium ellipticum*	900–1170	1000	852	59.73	77	3.5	14
				1000	856.	77.38	64	3.3	14
				1000	915	55.3	85	3.6	14
				1000	725	94.64	84	3.6	14
				1000	885	64.87	82	3.7	14
				1000	574	61.7	80	3.6	14
13	Puthuthottam cardamom plantation Anamalais Tamil Nadu	*Cullenia exarillata* *Mesua ferrea* *Palaquium ellipticum*	1085	1600	812		31	4	19
14	Varagaliar RF Anamalais Tamil Nadu	Transition between *Cullenia exarillata* *Mesua ferrea* *Palaquium ellipticum* and *Dipterocarpus bourdilonii* *D. indicus* *Anaclosa densiflora*	650	1600	1063		41	4.8	19
15	Nelliampathy Kerala	*Palaquium ellipticum* *Cullenia exarillata* *Mesua ferrea*	950	10,000	496	61.9	30	1.28	24
16	Kakachi Kalakad Tamil Nadu	*Cullenia exarillata* *Aglaia elaeagnoidea* *Palaquium ellipticum*	1250–1450	38,200	582.7	42.03	90	4.87	Present study

Singh *et al.*[22] and Pascal[15] considered plants > 10 cm GBH, Parthasarathy *et al.*[14], > 30 cm GBH and others > 10 cm DBH.

dance at Kakachi shows that only 7 species could be encountered with additional sampling. Extensive random search in the area revealed 6 uncommon species which were not encountered in the plots. Therefore it appears that a linear plot of 500 m × 10 m (0.5 ha) is sufficient to estimate the diversity of tree species at Kakachi, provided the elevation and the vegetation type remains the same. This may also be true for other mid-elevation forests of the Western Ghats.

In terms of number of tree species per unit area, Kakachi forests appear to have the highest density. Although we did not sample a sufficiently large contiguous area for the work reported here, our ongoing studies for three 1 ha plots reveal on an average 45 species of >10 cm DBH per hectare. Comparable data from similar undisturbed sites are not available. Studies by Pascal[15,21] and Singh *et al.*[22] in the Western Ghats calculated species richness and diversity at 10 cm GBH (3.3 DBH) or 40 cm GBH (12.7 DBH) which are not on par with the present study (see Table 4). Removal of girth limits also does not allow for comparison because of smaller sampling area of Pascal[15] (0.2 ha) and Singh *et al.*[22] (<0.1 ha). When similar comparisons are made with neotropical forests, Kakachi with 45 species per hectare is less species rich than BCI in Panama (176 spp. per ha); Upper Amazonia (155–283 spp. per ha) and La Selva in Costa Rica with 100 spp. from 2 to 4 ha (ref. 23). However it should be noted that all these are lowland rainforest sites having greater richness than montane sites.

Shannon index of diversity (>10 cm DBH) for Kakachi appears to have a higher value than other sites in the Western Ghats such as Anamalais[19], Nelliampathy[24] and Sengaltheri, Kalakad[14]. Differences in the computations of Shannon index could make comparisons difficult. For instance, the Shannon value at Kakachi calculated to base 'e' is only 3.37 while that to base 2 is 4.87. Magurran[25] suggests the use of the latter for all purposes. Further, because of differences in area sampled, lack of uniform plot dimensions and standard girth or diameter classes, it is difficult to compare sites. Overall, Kakachi appears to be the most diverse site of all the wet evergreen forests sampled in the Western Ghats. The possible reasons for high diversity at Kakachi could be the larger area sampled and the linear nature of the transects which better estimates species diversity. Moreover the transition in vegetation type at 1450 m from the tropical wet evergreen to subtropical evergreen forest contributed to higher species richness. Further, bioclimatic and topographic factors like bimodal rainfall regime and relatively steeper slopes at Kakachi compared to other sites could also be a cause for some of the differences in species richness observed.

The vegetation of Kakachi does not fit the classical *Cullenia Mesua Palaquium* series described by Pascal[15]. Attapadi forest of Kerala, which also has a similar dominance of *Cullenia Aglaia* and *Palaquium*, and where *Mesua* also occurs as one amongst the 6 dominant species, is identified as the *Cullenia Mesua Palaquium* series by Pascal[15]. In the Kakachi forest *Mesua* does not occur at all and hence can be described as *Cullenia Aglaia Palaquium* type which can be considered as a new subtype of *Cullenia Mesua Palaquium* series. However the *Cullenia Mesua Palaquium* type occurs only at a lower altitude (1000 m), contiguous with the Kakachi forest.

The flora at Kakachi consists of 50.6% tree species (>10 cm DBH), 29.8% shrubs, 10.7% herbs and only 8.9% were lianas. Based on floras, Daniel *et al.*[26] have shown that for the Western Ghats in general, herbs (52%) form the dominant component followed by trees (20%) and shrubs (16%). Similar comparison with other sites in Neotropics like BCI, La Selva and Ecuador also reveals domination by herb and shrub community, with less than 25% belonging to trees of >10 cm DBH[23,27]. The overwhelming dominance of tree flora in Kakachi appears similar to the Manus reserve in Amazonia[23,28]. This may be because in Kakachi like Manus the epiphytes and herbs were not completely surveyed, which could increase the floristic diversity, thereby reducing the dominance of tree and shrub species.

Stem density and basal area comparisons are again possible only for a few sites as mentioned before where values pertain to 10 cm DBH. Among them, Kakachi with 582.7 stems per ha, has a lower value than sites in Sengaltheri of Kalakad (Table 3) and evergreen forests of Karnataka[29]. Some sites at Sengaltheri were located in 30-year-old abandoned cardamom plantations which had larger number of small-sized stems leading to higher stem density per unit area[14]. Basal area comparison reveals that the values in Kakachi are the lowest among other evergreen forests in the Western Ghats. For sites like Nelliampathy[24] and Sengaltheri[14], higher basal area might be due to the differences in the altitude sampled. Both these sites were between 1000 and 1200 m altitude representing very tall and large diameter trees. Species composition also contributes to this difference as some species like *Mangifera indica* and *Bischofia javanica* which are restricted to this altitude have very large girths (>3 m) (personal observation). Exceptionally high basal area recorded in Silent Valley sampled by Singh *et al.*[22] (Table 4) may be due to smaller plot size which allows the presence of only one or two large trees[15].

Endemism

The Agastyamalai range is known for high levels of endemism in plant species[10]. Of the 2000 species found in Agasthyamalai (2000 sq km), roughly 7.5% are localized endemics. At Kakachi, of the total 173 plant species found in the transects, 8 (4.62%) were localized endemic and account for 5.33% of the total endemic species in the region. Of these, trees account for 5 (62.5%), shrubs 2 (25%) and lianas 1 (12.5%).

Herbs did not have any endemics. This indicates that trees in the evergreen forest make a substantial contribution to the levels of endemism in this area. Moreover, Pascal[21] also refers to high levels (43.4%) of endemism among trees and shrubs in the *Cullenia Mesua Palaquium* forest. Much of this can be attributed to the overall prevalence of endemism among tree species in the hill top floras of the Western Ghats[30].

Elevational aspects

The effect of small scale altitudinal changes on species richness in the Western Ghats is not well documented. In Kakachi, transects and the subplots demonstrate that species richness increased with elevation. This increase is due to the changes in vegetation type toward the ridge from the wet evergreen forest to a more tropical sub montane forest[31]. Some species such as *Alseodaphne semicarpifolia, Xanthophyllum flavescens* and *Syzygium densiflorum* are common only above 1400 m. Many species like *Tricalysia apiocarpa, Drypetes longifolia* and *Elaeocarpus munronii* have a more disjunct distribution within the 250 m altitude range. Some species like *Palaquium ellipticum* were restricted to lower elevations and only one half of the tail was sampled in this study. The other half of the distribution occurs below 1200 m which was not sampled. Some of the elevational distribution patterns are probably due to edaphic factors and influence of strong winds especially around the exposed areas and presence of *Ochlandra* spp in the study plot. Some species like *Dimocarpus longon, Canarium strictum* and *Heritiera papilio* were rare in the site because their optimal habitats occur at lower elevations where they are common. More sampling from lower elevations is required to determine the complete elevational ranges of these species.

Regeneration

Though many forests in the Western Ghats are reported to have poor regeneration[4,5], the first five dominant species at Kakachi show adequate regeneration ranging from 7 to 135 individuals per 0.1 ha at the 1 to 10 cm DBH levels. Similarly in BCI it ranged from 4 to 47 individuals per 0.1 ha of the most abundant tree species[32]. However low density species like *Syzygium mundagam* and species with large diameter classes like *Calophyllum austroindicum* did not have many saplings in the plots. These species also suffer very high mortality at the seed stage from vertebrate seed predators[33]. Such high predation could have depressed their recruitment. Regeneration in such species could also be episodic.

Conclusion

The wet evergreen forests of Kakachi show a high level of plant species diversity compared with the other evergreen formations in the Western Ghats. It also shows good regeneration relative to many dry forests in India.

Comparative analysis with other sites in the Western Ghats was severely hindered due to lack of any standard protocol in sampling vegetation. Future studies should follow certain norms of standardized sampling which could be readily used across sites for easy comparison. This is very important for sites which will be used for monitoring vegetation dynamics.

Even though this medium elevation forest is one of the least disturbed sites in the Western Ghats, its biodiversity is threatened due to fragmentation of climax forest. Fragmentation has resulted from anthropogenic pressures like tea and cardamom plantations and other developmental projects like dams and reservoirs. Though the KMTR is spread over 887 sq km, the evergreen forests are restricted to a much smaller area at the medium elevations which are also the preferred sites for tea, coffee and cardamom plantations. Further, these forests in the Agasthyamalai hills serve as watershed areas for many major perennial rivers like Tambaraparani, Manimuthar, Kodayar and Pachaiyar which are the main water source for the southern districts of Tamil Nadu. Thus preservation of these forests is crucial not only for maintaining the biodiversity, but also for meeting the basic needs of the human populations in the plains.

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Managing the impact of seasonal rainfall variability through response farming at a semi-arid tropical location

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A method of Response Farming Programme for managing risks associated with variable seasonal rainfall was developed for a semi-arid location using daily rainfall records for the period 1971–94. The risks are intense rains threatening soil erosion, prolonged heavy rains threatening water logging, prolonged low rainfall periods, early cessation of rains long before the maturity of crops and too little rainfall in relation to crop water requirements. Onset relations, i.e. relations between season rainfall parameters (amount, duration and average rainfall per day) and date of onset of the rainy season are determined. It has been demonstrated how these relationships can be used in the selection of crops/cropping systems, fertilizer application rates, plant population, etc.

In rainfed agriculture, farmers must cope with rainfall variability both within and between seasons. If rainfall were uniform every year, farmers would choose a single management plan. Crops, planting date, seeding rate, fertilizer and insecticide would be planned for that anticipated single rainfall pattern. Obviously, this is not the case and variability of rainfall creates major problems. Response Farming is a means of coping with this seasonal rainfall variability which provides a method of identifying and quantifying seasonal rainfall variability and its related risks and of addressing the latter at the farm level. This is accomplished through improved prediction of expected rainfall behaviour in the approaching cropping season enabling improved decisions at the field level. The date of onset acts as a rainfall (amount, duration, average rainfall per day) predictor for the remainder of the season. Current rainfall is used to determine the management strategies which are responsive to the weather patterns. Stewart[1] developed Response Farming Strategies by studying the relationship between