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Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India

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Abstract. Vegetation structure and species composition of tropical ecosystems were studied through nine transects at Veerapuli and Kalamalai reserve forests in the Western Ghats of Tamil Nadu, India. Species diversity, dominance, species richness and evenness indices of plant communities and also population structure of woody plants were enumerated. A total of 244 species (183 genera and 76 families) were recorded. Species richness (number of species) were 82,142 and 96 species per 0.3 ha respectively for the study areas of low-elevation forest (LEF), mid-elevation forest (MEF) and high elevation forest (HEF). Species diversity indices were greater in MEF compared to the other two forests except juveniles. In contrast, greater dominance value indices were recorded in LEF than other forests. Density and basal area of the MEF were twice greater than the LEF, while HEF showed greater tree density and low basal area when compared to LEF. The stem density and species richness (number of species) decreased with increased size classes of trees observed in the present study indicated good regeneration status. Population structure of juveniles and seedlings also reflects good regeneration status. *Terminalia paniculata* (IVI of 99.9) and *Hopea parviflora* (IVI of 103.8) were dominant tree species respectively in LEF and MEF whereas in HEF *Agrostistachys meeboldii* (63.65), *Cullenia excelsa* (63.67) and *Drypetes oblongifolia* (39.67) share the dominance. Past damage (anthropogenic perturbation) may be one of the reasons for single species dominance in LEF and MEF. Occurrence of alien species such as *Eupatorium odoratum* and *Ageratum conyzoides* also indicated the past disturbance in LEF. The variations in plant diversity and population structure are largely due to anthropogenic perturbation and other abiotic factors.

Key words: conservation, plant diversity, population structure, regeneration, tropical forest, Western Ghats

Introduction

The Western Ghats of India, consisting of a chain of mountains constitute one of the 18 tropical biodiversity hotspots in the world (WCMC 1992). Particularly Agasthyamalai hills of southern Western Ghats is one of the important centres of plant diversity and edemism in India and also a proposed biosphere reserve (Henry et al. 1984). During the last few decades these forests were subjected to various anthropogenic pressures such as agriculture, construction of hydro-electric project, raising of monoculture plantations, unscientific extraction of minor

forest produce and other developmental activities. The deciduous and semi-evergreen forest fragments here at Veerapuli and Kalamalai reserve forests are possibly the transformation of the evergreen forests, which were subjected to various anthropogenic perturbations in the past. The ever increasing demand of forest products and forest land, together with the increased population growth have put the remaining patches of forests on the verge of extinction.

Regeneration in many Indian forests, including those forests of Western Ghats, is inadequate to maintain balanced populations (Sukumar et al. 1992). Successful conservation of forest ecosystems will ultimately depend upon an understanding of forest ecosystem dynamics. Sustainable management of natural tropical forests is not possible without a better holistic understanding of how such forests actually work ecologically and interact with humans (Hubbell and Foster 1983). As part of an integrated research project, a general hypothesis was framed to test the influence of human interference on species composition, ecosystem structure and certain functional processes in the tropical forest of Western Ghats in Tamil Nadu (Sundarapandian 1997). Detailed vegetation analyses and regeneration status of the remaining forests are necessary as they form the basis for future plans to manage and restore these vanishing resources. However, studies on the influence of biotic and abiotic stresses on the plant species, regeneration potential and the patterns of secondary succession in the Western Ghats of Tamil Nadu are limited. Therefore, the present study is significant in generating useful baseline data in order to conserve and manage the native flora and fauna of these tropical forest ecosystems in the region and elsewhere in the tropical forests in India. In order to achieve this objective the following studies were carried out: (1) inventory and description of the plant species and richness of the tropical forest ecosystems, (2) understanding the regeneration status of tree species and (3) to study the patterns of secondary succession in the Veerapuli and Kalamalai forest reserve.

Study area

The study area at Veerapuli and Kalamalai forest reserve, located 400 km south of Madurai (77°15′ E, 8°29′ N) is part of Agasthyamalai hills in South India (Figure 1). The mean annual rainfall recorded in the study sites were 2300 mm, and 3000 mm at low- and mid-elevation (250–700 m) and at high-elevation (1000–1150 m), respectively, of which 81% occurred from June to November. December to March represents dry period. Average monthly maximum and minimum temperatures were 30 and 26 °C in summer and 28 and 24 °C in winter, respectively, in mid- and low-elevation. Temperature does not vary much over the seasons at high-elevation. Mean maximum temperature was 24 °C and the minimum was 16 °C.

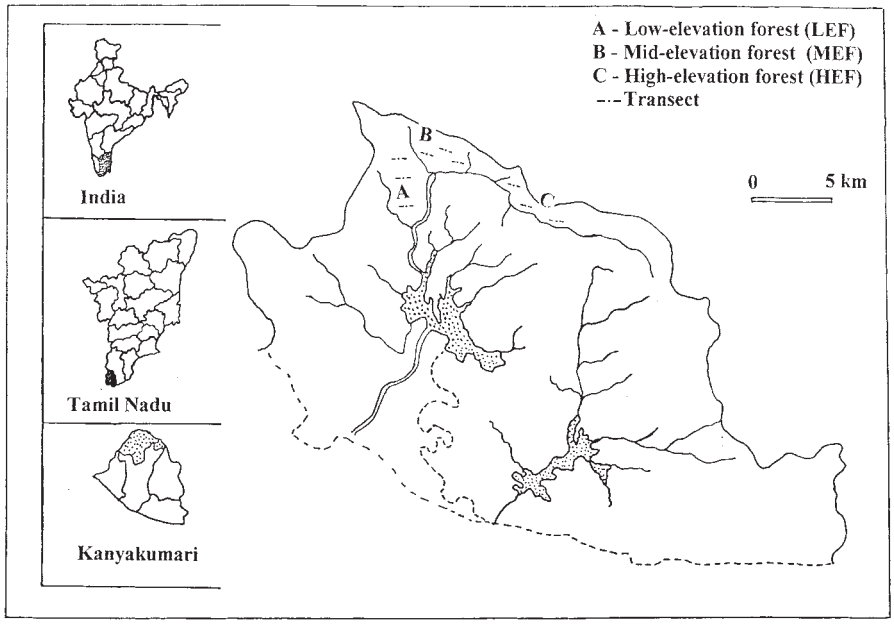

Figure 1. Map of the study area showing location of the study.

Methods

Phytosociological studies were carried out in three selected regions, i.e., low-elevation forests (LEF), evergreen forest (MEF) and high-elevation forest (HEF) (Table 1). LEF and MEF have about the same rainfall distribution because they lie within 10 km radius and these sites are a continuous stretch of tropical forests ranging from 250 to 700 m above mean sea level. LEF is dominated by deciduous species. However, LEF lies close to the human inhabitation, the forest floor often has been subjected to annual wild fires during summer. It indicates that over a period of time these evergreen forests might have transformed into deciduous forests due to anthropogenic perturbation. All along the Western Ghats, in general deciduous forests occur in low elevation of about 500 m; mid-elevation forests occur at an altitude of 500–1000 m while high elevation forests occur above 1000 m. The density, frequency, basal area and importance value index (IVI) were estimated at each site through three transects (1 km; ten 10×10 m^2 quadrates at an interval of 100 m) for trees (individuals with diameter at breast height (DBH) more than 10 cm), saplings (>3–<10 cm DBH), and shrubs. A Similar number of quadrats (1×1 m^2) in the same transects were studied for herbs at each study site (Kershaw 1973; Misra 1968). Similarly lianas (all climbers of all sizes) whose base fell inside the quadrats (10×10 m^2) were enumerated. Epiphytes were not sampled in this study due to technical problems. The plant samples were identified in the field with the help of Gamble's (1925) flora and a field key prepared by Pascal and Ramesh (1987) and later verified with the reference material (herbarium specimens)

Table 1. Consolidated details of phytosociological analyses of tropical forest ecosystems at Veerapuli and Kalamalai Forest Reserve of Agastyamalai hills in the Western Ghats of Tamil Nadu, India.

Criteria	LEF	MEF	HEF
Altitude (m)	250–400	500–700	1000–1150
Number of species* (No./0.3 ha)			
Tree	48 (27)	74 (43)	53 (30)
Shrubs	10	24	12
Herbs	16	24	17
Climbers and lianas	8	20	14
Density (No. ha^{-1})			
Adult tree (>10 cm DBH)	436	873	971
Juveniles (>3–<10 cm DBH)	310	861	1556
Seedlings (<10 cm DBH)	4342	8638	12844
Shrubs	2882	3772	3136
Herbs	702657	7619	8335
Climbers and lianas	273	1015	438
Basal area (m^2 ha^{-1})			
Adult tree	28.350	67.400	64.260
Juveniles	0.863	1.900	3.230
Seedlings	0.601	2.220	2.935
Shrubs	0.161	1.323	0.439
Herbs	4.050	0.099	0.118
Climbers and lianas	0.014	0.197	0.056
Species diversity index (Shannon index)			
Adult tree	2.459	2.758	2.449
Juveniles	2.378	3.208	3.233
Seedlings	2.934	3.403	3.267
Shrubs	1.474	2.169	1.708
Herbs	1.188	2.485	2.284
Climbers and lianas	1.309	2.739	2.048
Dominance index			
Adult tree	0.147	0.143	0.130
Juveniles	0.142	0.069	0.071
Seedlings	0.093	0.054	0.047
Shrubs	0.314	0.227	0.223
Herbs	0.535	0.133	0.148
Climbers and lianas	0.204	0.082	0.195
Species richness			
Adult tree	1.293	1.455	0.968
Juveniles	1.136	1.611	0.913
Seedlings	0.668	0.592	0.379
Shrubs	0.186	0.391	0.214
Herbs	0.019	0.275	0.186
Climbers and lianas	0.484	0.628	0.669
Evenness index			
Adult tree	1.718	1.688	1.658
Juveniles	1.827	1.919	2.077
Seedlings	1.785	1.955	2.000
Shrubs	1.474	1.571	1.583
Herbs	0.987	1.801	1.857
Climbers and lianas	1.449	2.106	1.787

* Values in the parentheses represent number of adult tree (>30 cm DBH) species.

at Botanical Survey of India, Coimbatore. A reference collection of specimens were preserved in the University herbarium. Species diversity was calculated using the equation (Margalef 1968)

$$H' = -\sum(n_i/N)\ln(n_i/N)$$

where H'= Shannon index of general diversity, n_i = importance value index of species i, N = importance value index of the community. The index of dominance of the community was calculated by Simpson's index (Simpson 1949) as

$$c = \sum(n_i/N)^2$$

where c = index of dominance; n_i and N being the same as in the Shannon index of general diversity. The index of the species richness (d) was calculated following Menhinick (1964) as:

$$d = S/\sqrt{n}$$

where S = number of species, n = number of individuals. The evenness index of the community (e) was calculated by following Pielou (1966) as:

$$e = H'/\log S$$

where S = number of species, H' = Shannon index.

Results

A total of 244 plant species belonging to 183 genera and 76 families were recorded from nine transects along an altitudinal gradient (Tables 1 and 2). The number of species were greater in the mid-elevation forests (MEF; 142) compared to low-elevation forests (LEF; 82) and high-elevation forests (HEF; 96). Tree density and basal area of the MEF were twice greater than the LEF. However, HEF showed greater tree density and low basal area when compared to MEF. Diversity indices (Shannon Weiner Index) were greater in MEF compared to the other two forests except for juvenile populations. In contrast, greater dominance value indices were recorded in LEF than in other forests. Species richness values were greater in MEF compared to other forests except for seedlings and climbers and lianas. A similar trend was observed in the evenness indices except for trees.

Taxonomically, the number of plant families were more in the MEF (53) followed by HEF (46) and LEF (35). Twenty one families were common among the three elevation forest types (Table 2). About five families were common between LEF and MEF. Similarly, 21 families were common between MEF and HEF. The number of

Table 2. Family-wise contribution of genera (G), species (S) and density (D; No./ha) in the Tropical forest ecosystems at Veerapuli and Kalamalai Forest Reserve of Agastyamalai Hills in the Western Ghats of Tamil Nadu, India.

	LEF			MEF			HEF		
Families	G	S	D	G	S	D	G	S	D
Acanthaceae				2	2	357	3	3	4375
Anacardiaceae	2	2	637	3	3	463	2	3	386
Ancistrocladaceae				1	1	360			
Anonaceae	2	3	77	4	4	492	2	2	489
Apocynaceae	3	3	96	2	2	6	1	1	10
Araceae				1	1	77			
Araliaceae							1	1	70
Arecaceae	2	2	6	4	4	1927	1	2	1048
Aristolochiaceae				1	1	80			
Asclepiadaceae	1	1	3						
Asteraceae	2	2	563						
Balanophoraceae							1	1	16
Bignoniaceae				1	1	9			
Bombacaceae				1	1	110	1	1	623
Burseraceae				1	1	6			
Celastraceae	1	1	3	1	1	73	2	2	13
Chloranthaceae				1	1	70			
Clusiaceae				3	3	562	1	1	176
Combretaceae	2	7	1195						
Connaraceae				1	1	47	1	1	243
Cornaceae							1	1	63
Cycadaceae	1	1	20						
Dilleniaceae	1	1	57						
Dioscoreaceae	1	1	10	1	1	83			
Dipterocarpaceae				3	4	1536			
Ebenaceae	1	1	13	1	3	173	1	1	129
Elaegnaceae							1	1	7
Erythroxylaceae				1	1	3			
Euphorbiaceae	5	5	712	6	7	526	6	9	3639
Fabaceae	6	6	395	5	5	215	1	1	3
Flacourtiaceae				2	2	385	2	2	96
Gramineae	5	6	696530	4	4	5000	1	1	532
Grassulaceae							1	1	336
Hypoxidaceae	1	1	1257	1	2	263	1	2	1045
Icacinaceae	1	1	3	2	2	99	1	1	105
Lauraceae	1	1	56	6	6	269	7	8	2837
Lecythidaceae	1	1	400						
Liliaceae	1	1	50	1	1	130	1	1	7
Loganiaceae				1	1	13	1	1	3
Malpighiaceae				1	1	13	1	1	3
Malvaceae	1	1	53						
Melastomaceae				1	4	310	1	1	187
Meliaceae				3	3	53	2	2	5.16
Menispermaceae				1	1	7			
Moraceae	3	3	80	2	2	62	1	1	24
Myrsinaceae							1	1	10
Myristicaceae				1	1	106	1	1	289

Table 2. Continued.

Families	LEF			MEF			HEF		
	G	S	D	G	S	D	G	S	D
Myrtaceae				1	4	582	2	4	1293
Oleaceae	1	1	134	3	3	217	2	2	6
Orchidaceae				1	1	20	1	1	10
Piperaceae	1	1	10	1	1	160	1	1	87
Podocarpaceae							1	1	10
Pteridophytes	1	1	87	4	6	562	5	5	2326
Rhamnaceae	2	2	100	1	1	13			
Rosaceae				1	1	53	1	1	3
Rubiaceae	3	3	860	9	16	3142	9	11	4951
Rutaceae	2	2	47	4	4	44	5	5	63
Sapindaceae	3	3	106						
Sapotaceae	1	1	59	4	4	1236	2	2	1034
Staphyleaceae							1	1	3
Sterculiaceae	2	3	1410	1	2	40			
Symplocaceae				2	2	56	1	1	13
Ternstroemiaceae				1	1	3	1	1	3
Tiliaceae	2	2	33						
Urticaceae				1	1	3	2	2	42
Verbenaceae	2	2	9	2	2	23			
Vitaceae				2	2	37			
Xanthophyllaceae	1	1	197	1	1	486			
Zingiberaceae	2	2	4490	2	2	307	1	1	103
Others				14	14	1931	3	3	38

genera was 67, 125 and 86 respectively, in LEF, MEF and HEF. Seventeen families in LEF, 28 families in MEF and 30 families in HEF were represented by only one individual species. Combretaceae, Fabaceae, Euphorbiaceae and Gramineae (Poaceae) were some of the dominant families in terms of the number of species in LEF, whereas Rubiaceae was the dominant family in MEF and HEF followed by Euphorbiaceae and Lauraceae. When analysed density-wise for families, Gramineae, Asteraceae, Sterculiaceae and Combretaceae in LEF, Gramineae, Sapindaceae, Dipterocarpaceae and Arecaeae in MEF and Rubiaceae, Acanthaceae, Euphorbiaceae and Lauraceae were some of the important families in HEF.

With increasing tree size (>10 cm DBH) classes, species richness (number of species per 0.3 ha) and density (No. ha^{-1}) decreased in all the forests (Tables 3 and 4). A similar trend was observed in the tree juvenile size (>3–<10 cm DBH) class distribution except LEF. The lowest size class of tree, 10–20 cm DBH, considered in the present study, contributed more than 47% to total tree density in LEF while other two forests (MEF and HEF), this size class contributed more than 50%. However, in juvenile population of trees, lowest size class (3–4 cm DBH) contributed about 50% in HEF and 25% in LEF and MEF. About two thirds of the species (19 out of 27 tree species in LEF; 33 out of 36 tree species in HEF) figured in the lowest diameter class

Table 3. Diameter class-wise (DBH) species richness (number of species) and density (No. ha^{-1}) of trees (>10 cm DBH) in the tropical forests at the Veerapuli and Kalamalai Forest Reserves of Agastymalai Hills in the Western Ghats of Tamil Nadu, India.

Diameter class (DBH) (cm)	Number of species			Density		
	LEF	MEF	HEF	LEF	MEF	HEF
10–20	19	24	23	64	144	159
20.1–30	11	20	13	35	61	82
30.1–40	11	12	9	19	26	28
40.1–50	3	11	7	10	26	13
50.1–60	1	5	2	2	6	6
60.1–70	1	2	5	3	3	8
70.1–80	0	5	2	0	9	8
80.1–90	2	1	2	2	1	3
90.1–100	0	0	1	0	0	1
>100.1	0	1	0	0	1	0

Table 4. Diameter class-wise (DBH) species richness (number of species) and density (No./ha) of tree juvenile population (>3–<10 cm DBH) in the tropical forests at the Veerapuli and Kalamalai Forest Reserves of Agastymalai Hills in the Western Ghats of Tamil Nadu, India.

Diameter class (DBH) (cm)	Number of species			Density		
	LEF	MEF	HEF	LEF	MEF	HEF
3–4	9	29	33	23	87	259
4.1–5	8	20	21	14	53	80
5.1–6	8	14	19	11	34	52
6.1–7	6	14	13	17	27	31
7.1–8	7	13	14	22	30	27
8.1–9	3	10	14	5	20	25
9.1–10	1	6	9	1	7	9

(10–20 cm DBH) itself. While in MEF, about 50% of species (23 out of 43 tree species) accounted in the lowest size class. However, more than 60% of the species in juvenile populations were accounted for lowest size class (3–4 cm DBH) except in LEF. Only few very large (>70 cm DBH) size trees were recorded in these forests. Size class distributions of some dominant plant species are presented in Figure 2a–c. Most of the species showed L shaped curve, *Myristica dactyloides* was an exception. Only few species (*Hopea parviflora*, *Vateria indica* in MEF; *Cullenia excelsa* and *Calophyllum polyanthum* in HEF, *Pterocarpus marsupium* in LEF) showed J shaped curve.

The LEF was dominated by deciduous tree species such as *Terminalia paniculata* followed by *Careya arborea*, *Pterocarpus marsupium*, and *Buchnania lanzan*, whereas in MEF it was *Hopea parviflora* followed by *Xanthphyllum flavescens*, *Mesua ferrea*, *Diospyros bourdillonii*, *Ixora brachiata* and *Syzygium laetum* (Table 5).

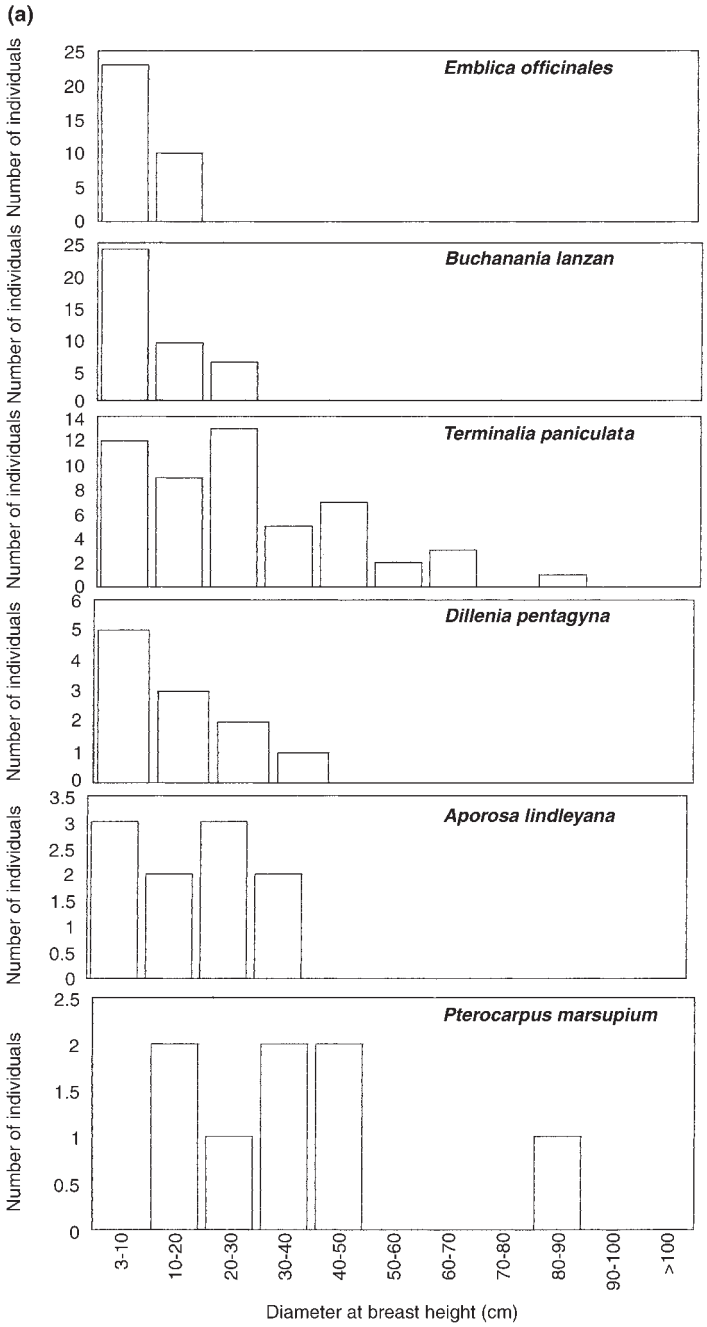

Figure 2. (a) Diameter class-wise (DBH) distribution of some dominant species in the Low-elevation (LEF) tropical forests at Veerapuli and Kalamalai Forest Reserve of Agastyamalai hills in the Western Ghats of Tamil Nadu, India. (b) Diameter class-wise (DBH) distribution of some dominant species in the Mid-elevation (MEF) tropical forests at Veerapuli and Kalamalai Forest Reserve of Agastyamalai hills in the Western Ghats of Tamil Nadu, India. (c) Diameter class-wise (DBH) distribution of some dominant species in the High-elevation (HEF) tropical forests at Veerapuli and Kalamalai Forest Reserve of Agastyamalai hills in the Western Ghats of Tamil Nadu, India.

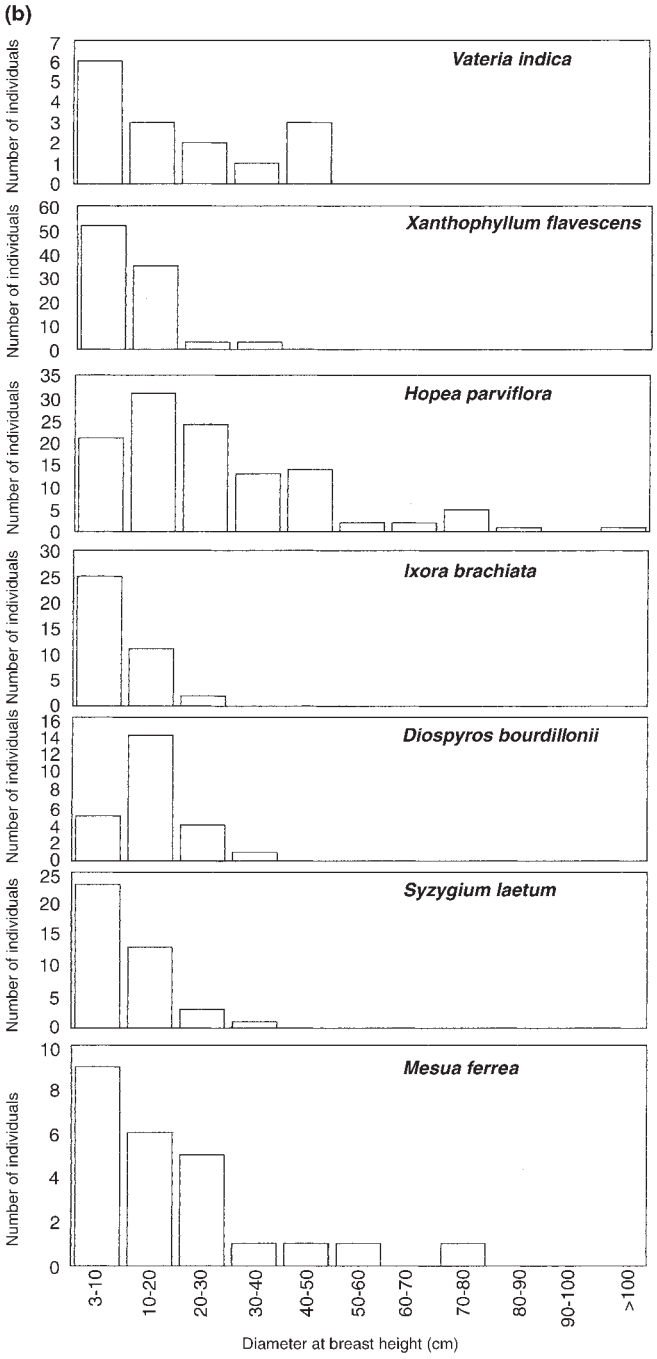

Figure 2. Continued.

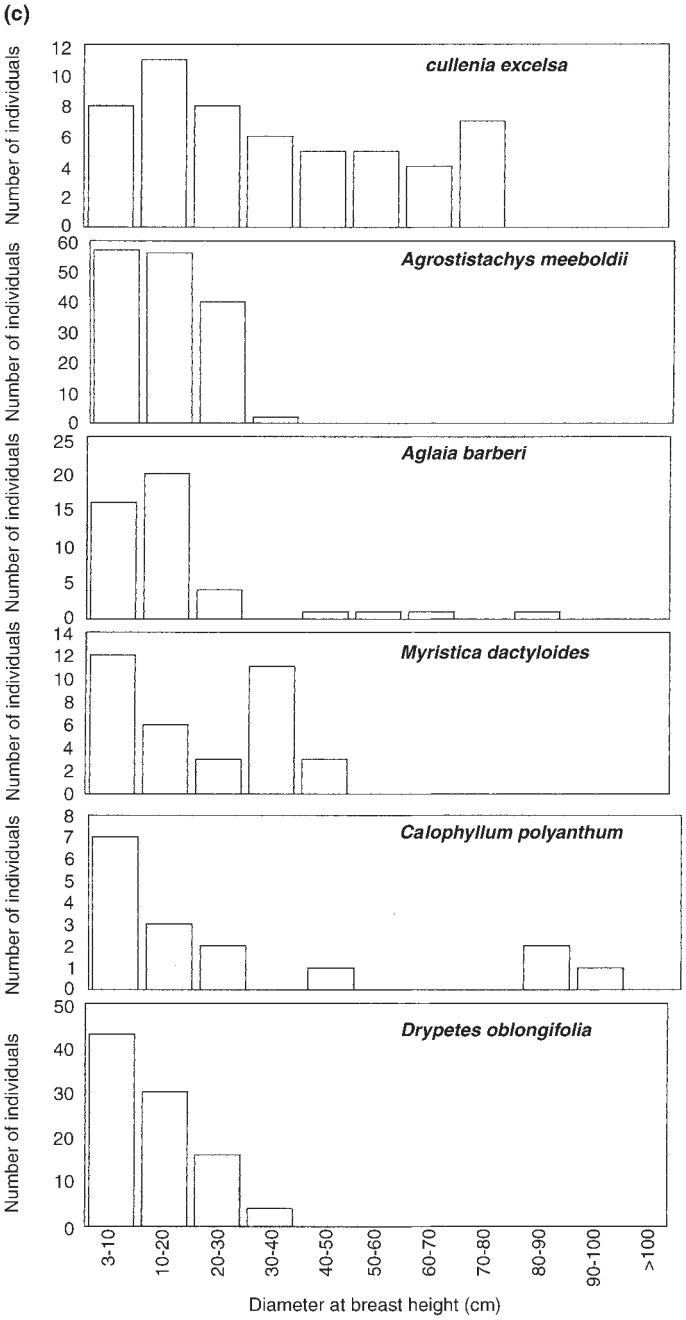

Figure 2. Continued.

Agrostistachys meeboldii and *Cullenia excelsa* contributed more IVI values in HEF followed by *Drypetes oblongifolia, Myristica dactyloides, Aglaia barberi* and *calophyllum polyanthum*. Only six species were common in LEF and MEF. Similarly, eight species were common in MEF and HEF. Species represented by one or two individuals were considered rare. About 60% (60–62.5%) of total number of species were considered rare in these forests.

The species richness of shrub and herbaceous community in MEF (in terms of number of species) were two times greater when compared to the other two forests. In LEF, shrub community was dominated by *Helicteres isora* and *Eupatorium odoratum* followed by *Zizyphus oenoplia. Calamus brandisii* and *Ochlandra travancorica* were the dominant species in MEF. *Nilgirianthus foliosus, Calamus* sp. and *Saprosma corymbosum* were the dominant species in HEF. Herbaceous community in LEF was dominated by *Themeda cymbaria*, while grasses and *Curculigo trichocarpa* were dominant in MEF. *Rungia wightiana, Ophiorrhiza* and *Curculigo orchiodes* in HEF. Climbers and lianas were greater in MEF followed by HEF and LEF. *Calycopteris floribunda* was the dominant species in LEF, while *Ancistrocladus heyneanus, Piper* and *Jasminum azoricum* in MEF and *Connarus wightii, Vipris bilocularis, Piper* and *Toddalia asiatica* in HEF.

Juvenile (>3–<10 cm DBH) population of tree species was greater in MEF (47) compared to others (LEF 20 and HEF 36). Most of the dominant tree species had good representation of individuals at juvenile stage (Table 6). However, no juveniles were recorded for 13, 18 and 8 adult tree species respectively in LEF, MEF and HEF. Similarly, juveniles of six species in LEF, 26 species in MEF and 14 species in HEF were not represented by any adults. Juvenile population (density) was dominated by the species such as *B. lanzan* followed by *Emblica officinalis, T. paniculata, C. arborea* and *Dillenia pentagyna* in LEF while *X. flavescens* followed by *I. Brachiata* and *S. laetum* in *MEF* and *Octotropis travancorica* followed by *A. meeboldii* and *D. oblongifolia* in HEF. Greater basal area of the juvenile population was recorded for *E. officinalis* followed by *B. lanzan* in LEF while *X. flavescens* followed by *S. laeatum* and *I. Brachiata* in MEF and *Octotropis travancorica* followed by *A. meeboldii* and *D. oblongifolia* in HEF.

Larger number of the dominant tree species had good representation in seedling population (Table 6). Seedlings of 20 species in LEF, 26 species in MEF and 21 species in HEF were not represented by any adults. No seedlings were recorded for 5, 15 and 8 adult tree species respectively in LEF, MEF and HEF. Seedling populations (density) in LEF was dominated by *I. brachiata* followed by *T. paniculata, B. lanzan, C. arborea* and *P. marsupium*, whereas greater basal area was recorded for *T. paniculata* followed by *I. brachiata* and *B. lanzan. Psychotria nigra* was dominant in the seedling population at MEF followed by *Dimocarpus longan* and *H. parviflora*. Greater basal area was recorded for the same species. *Psychotria annamalayana* was the dominant species in the seedling population at HEF followed by *P. nigra, D. oblongifolia* and *Cinnamomum virum*. However, greater basal area was

Table 5. Importance value index (IVI) of different plant categories in the tropical forest ecosystems at the Veerapuli and Kalamalai Forest Reserves of Agastyamalai in the Western Ghats of Tamil Nadu, India.

Name of the species	LEF	MEF	HEF
Trees			
Actinodaphne companulate J. Hk.	–	–	0.95
Aglaia barberi Gamble	–	1.04	25.05
Agrostistachys meeboldii Pax. & K. Hoffm.	–	–	64.65
Alstonia scholaris R. Br.	3.12	–	–
Antidesma zeylanicum Lam.	–	2.13	–
Aporosa lindleyana Baill	12.24	–	–
Artocarpus heterophyllus Lam.	–	5.06	3.16
Baccaurea courtallensis M. Arg.	–	1.04	–
Beilschmiedia gemmiflora Kosterm	–	–	1.17
Berrya cordifolia (W.) Burret	1.82	–	–
Bridelia crenulata Roxb.	1.90	–	–
Buchanania Lanzan Spr.	24.99	–	–
Calophyllum polyanthum Wall. Ex Choisy	–	1.12	16.87
Canarium strictum Roxb.	–	1.26	–
Careya arborea Roxb.	29.09	–	–
Casearia bourdillonii Mukh.	–	–	0.95
Cinnamomum malabathrum (Burm. f.) Bl.	–	–	1.01
Cinnamomum verum J. S. Presl.	–	–	3.2
Cullenia excelsa Wt.	–	–	63.67
Cycas sp.	1.85	–	–
Dalbergia latifolia Roxb.	3.17	–	–
Dillenia pentagyna Roxb.	13.59	–	–
Dimocarpus longan Lour.	1.82	3.46	–
Diospyros bourdilloni Brandis	–	15.77	–
Diospyros sp.	–	4.53	2.91
Dipterocarpus indicus Bedd.	–	2.08	–
Drypetes oblongifolia (Bedd.) A. Shaw	–	–	39.66
Dysoxylum beddomei Hiern	–	–	2.40
Emblica officinalis Gaertn.	16.36	–	–
Epiprinus mallotiformis (Mueller) Croizat	–	–	0.95
Ficus sp.	3.98	–	–
Gluta travancorica Bedd.	–	7.05	–
Gomphandra tetrandra (Wall.) Sleumer	–	4.13	9.77
Gordonia obtusa Wall.	–	1.68	2.40
Grewia tiliaefolia Vahl.	3.88	–	–
Holigarna arnottiana J. Hk.	–	–	6.87
Hopea parviflora Bedd.	–	103.79	–
Hunteria corymbosa Roxb.	–	1.33	–
Hydnocarpus alpina Wt.	–	1.05	–
Hymenodictyon orixense (Roxb.) Mabb.	1.82	–	–
Ixora brachiata Roxb.	7.90	14.28	–
Ixora sp.	–	1.10	–
Kingiodendron pinnatum (Roxb.) Harms	–	7.57	–
Litsea laevigata (Nees) Gamble	–	1.14	–
Litsea mysorensis Gamble	–	–	0.97
Macaranga peltata (Roxb.) Mueller	1.96	–	–
Mallotus beddomei J. Hk.	–	–	1.92
Mallotus philippensis M. Arg.	–	1.10	–

Table 5. Continued.

Name of the species	LEF	MEF	HEF
Mangifera indica L.	–	1.18	–
Mastixia arborea (Wt.) Bedd.	–	–	7.91
Mesua ferrea L.	–	16.18	–
Myristica dactyloides Gaertner	–	1.10	26.16
Nageia wallichiana (Presl.) Kuntze	–	–	1.03
Neolitsea zeylanica (Nees) Merr.	–	1.11	–
Nothopegia racemosa (Dalz.) Ramam.	–	–	1.01
Octotropis travancorica Bedd.	–	–	2.02
Olea dioica Roxb.	–	1.23	–
Palaquium ellipticum (Dalz.) Baillon	–	1.04	–
Persea macrantha (Nees) Kosterm.	–	–	1.46
Polyalthia wightii L.	4.65	–	0.96
Prunus ceylanica (Wt.) Miq.	–	1.41	–
Pterocarpus marsupium Roxb.	27.27	–	–
Pterospermum rubiginosum Heyne	–	2.15	–
Sapindus emarginatus Vahl.	2.86	–	–
Scolopia crenata (Wt. & Arn.) Clos.	–	4.33	–
Stereospermum personatum (Hassk) Chatterjee	–	3.41	–
Symplocos racemosa Roxb.	–	1.20	–
Syzygium gardneri Thw.	–	–	4.15
Syzygium laetum Gandhi	–	13.19	–
Syzygium mundagam (Bourd.) Chithra	–	7.63	1.17
Syzygium thwaitesii Duthie	–	1.15	–
Tabernaemontana heyneana Wall.	9.47	1.10	–
Terminalia arjuna W. & A.	11.18	–	–
T. chebula Retz.	1.95	–	–
T. crenulata Roth.	2.28	–	–
T. paniculata Roth.	99.90	–	–
Tricalysia apiocarpa Gamble	–	–	4.19
Turpinia malabarica Gamble	–	–	1.37
Vateria indica L. f.	–	9.41	–
Vitex altissima L.	–	8.44	–
Xanthophyllum flavescens Roxb.	5.99	26.11	–
Others	4.97 (2)	16.93 (4)	–
Shrubs			
Ardisia pauciflora Heyne Ex Roxb.[a]	–	–	1.20
Blachia umbellata Baill.	–	1.91	–
Boehmeria clomerulifera Miq.	–	0.84	–
Calamus brandisii Becc.[b]	2.33	132.55	38.68
Calamus travancoricus Bedd.[c]	–	–	82.72
Cipadessa baccifera Miq.	–	0.84	–
Clausena heptaphylla W. & A.	5.86	–	–
Clausena indica Oliv.	–	–	1.68
Desmodium velutinum (Willd.) DC.	10.95	–	–
Diotacanthus albiflorus Benth.	–	9.02	–
D. grandis (Bedd.) Benth Ex Clarke	–	–	6.06
Eupatorium odoratum L.	101.83	–	–
Glycosmis mauritiana (Lam.) Tanaka	–	0.79	–
Helicteres isora L.	130.36	–	–

Table 5. Continued.

Name of the species	LEF	MEF	HEF
Ixora elongata Heyne	–	3.23	–
Ixora lanceolaria Colebr.	–	12.64	–
Ixora nigricans Br.	–	7.36	–
Lasianthus cinereus Gamble	–	–	1.68
Leea indica (Burm. F.) Merr.	–	3.49	–
Meiogyne ramarowii (Dunn) Gandhi	–	2.34	–
Memecylon heyneanum Benth.	–	6.69	–
Memecylon sp.	–	4.55	–
Microtropis stocksii Gamb.	2.10	8.90	–
Mitrephora heyneanam Thw.	–	2.95	–
Nilgirianthus foliosus (Wight) Bremek	–	–	93.43
Ochlandra travancorica Gamb.	–	41.75	–
Pavetta indica L.	–	–	1.82
Pavetta thomsonii Brem.	–	1.35	–
Psychotria nudiflora W. & A.	–	13.93	–
Psychotria sp.	–	15.48	16.43
Rauwolfia beddomei Hk. F.	–	4.06	1.80
Saprosma corymbosum Bedd.	–	0.82	51.82
Symplocos microphylla Wall. Ex DC.	–	5.86	2.72
Thespesia lampas D. & G.	1 2.21	–	–
Trema orientalis (L.) Blume	1 1.00	–	–
Zizypus oenoplia (L.) Miller	2 1.18	–	–
Others	2.18 (1)	18.65 (2)	–
Herbs			
Ageratum conyzoides L.	3.09	–	–
Apama siliquosa Lam.	–	13.43	–
Blanophora indica Wall.	–	–	1.70
Bolbitis x prolifera (Bory) C. Chr. & Tardieu	–	2.35	16.59
Chasalia ophioxloides (Wall.) Gralb.	–	11.11	–
Chloranthus brachystachys L.	–	12.00	–
Clerodendron viscosum Vent.	1.02	0.88	–
Crypsimus montanus Sledge	2.06	–	3.49
Curculigo orchioides Gaertn.	1 7.61	9.42	29.77
C. trichocarpa (Wight) Bennet & Raizada	–	15.64	7.65
Digitaria ciliaris Koel	7.32	15.49	–
Elatostemma lineolatum Wight	–	–	3.06
Geodorum densiflorum Schlechter	–	2.63	2.31
Globba orixensis L.	2 0.68	15.70	–
Grass (unidentified)	1 3.53	54.71	13.92
Hemidesmus indicus R. Br.	1.02	–	–
Imperata cylindrica Beauv.	2.06	–	–
Kalanchoe sp.	–	–	27.90
Leptochilus lanceolatus Fee	–	13.71	2.63
Memecylon sp.	–	9.14	6.89
Neurocalyx calycinus (Benn.) Robins	–	2.76	–
Oldenlandia sp.	1.02	–	–
Ophiorrhiza mungos L.	–	5.41	29.95
Panicum sp.	7.30	17.58	–
Pouzolzia bennettiana Wt. Ic. t.	–	–	2.45

Table 5. Continued.

Name of the species	LEF	MEF	HEF
Pteridium aquilinum (L.) Kuhn	–	0.81	–
Pteris argyraea T. Moore	–	2.27	24.92
Pteris confusa T.G. Walker	–	0.99	–
Pteris sp.	–	2.856	–
Rungia wightiana Nees	–	–	94.04
Selaginella sp.	–	–	24.35
Strobilanthes sp.	–	2.02	–
Themeda cymbaria Hackel	217.02	–	–
Themeda sp.	2.05	–	–
Trichopus zylanicus Gaertn.	2.04	2.12	–
Zingiber roseum (Roxb.) Roscoe	1.11	3.20	8.39
Others	1.05	83.78	–
	(1)	(1)	
Climbers & Lianas			
Ancistrocladus heyneanus Grah.	–	56.47	–
Asparagus sp.	42.12	–	–
Butea parviflora Roxb.	24.25	–	–
Calycopteris floribunda Lam.	125.30	–	–
Canthium angustifolium Colebr.	–	21.01	3.76
Canthium sp.	–	11.90	–
Connarus wightii J. Hk.	–	15.60	113.5
Coscinium fenestratum Colebr.	–	8.01	–
Derris benthamii Thw.	4.89	13.25	9.83
Elaeagnus kologa Schlecht	–	–	11.20
Entada scandens Benth.	–	12.22	–
Hiptage benghalensis (L.) Kurz.	–	7.51	3.72
Jasminum azoricum L.	–	24.28	3.73
Luvunga sarmentosa (Bl.) Kurz.	–	20.16	14.69
Piper sp.	8.81	31.43	35.88
Pothos scandens L.	–	18.70	–
Randia rugulosa Thw.	–	5.95	–
Smilax zeylanica L.	–	15.32	6.78
Strychnos wallichiana Stevd. Ex DC.	–	11.45	3.73
Toddalia asiatica Lam.	–	2.89	21.38
Vepris bilocularis Engler	–	9.64	43.39
Zizyphus rugosa Lam.	78.14	4.62	–
Others	16.48	9.59	28.41
	(2)	(2)	(2)

Values in parentheses represent number of unidentified species. [a] Shrub or small tree; [b] Slender scandent shrub; [c] A graceful, sleder climber (Gamble 1925).

recorded for *D. oblongifolia* followed by *C. virum*, *Agrostistachys indica*, *P. nigra* and *O. travancorica*.

Discussion

Agastyamalai hills (2000 km^2) of southern Western Ghats, one of the 26 centres of plant diversity and endemism in India, harbour more than 2000 species

Table 6. Density (No. ha^{-1}) and basal area (m^2 ha^{-1}) of tree juvenile (>3–<10 cm DBH) and seedling (<3 cm DBH) population recorded in the tropical forests at the Veerapuli and Kalamalai Forest Reserve of Agastyamalai Hills in the Western Ghats of Tamil Nadu, India.

	Saplings			Seedlings		
Name of the species	LEF	MEF	HEF	LEF	MEF	HEF
Acrocarpus fraxinifolius Wt.		3 (0.003)			6 (0.001)	
Actinodaphne campanulata J. Hk.			3 (0.003)			63 (0.007)
Aglaia barberi Gamble			53 (0.12)		30 (0.011)	417 (0.116)
Agrostistachys indica Dalz.			5 (0.053)		147 (0.056)	73 (0.245)
A. meeboldii Pax. & K. Hoffm.			190 (0.46)			533 (0.089)
Allophylus sp.				3 (0.0001)		
Alstonia scholaris R. Br.				3 (0.002)		
Antidesma menasu Miq. Ex Tul.		10 (0.01)	37 (0.083)		17 (0.003)	13 (0.005)
A. zeylanicum Lam.		17 (0.037)			180 (0.036)	
Aporosa lindleyana Baill.	10 (0.027)			233 (0.017)		
Arenga wightii Griff.					33 (0.009)	
Artocarpus heterophyllus Lam.			1 (0.04)		43 (0.014)	13 (0.003)
A. hirsutus Lam.				3 (0.001)		
Baccaurea courtallensis M. Arg.		10 (0.013)			20 (0.008)	
Beilschmiedia gemmiflora Kosterm.		3 (0.006)	7 (0.017)		20 (0.003)	63 (0.004)
Bridelia crenulata Roxb.	7 (0.020)			33 (0.001)		
Buchanania lanzan Spr.	80 (0.250)			497 (0.056)		
Calophyllum polyanthum Wall. Ex Choisy			23 (0.057)		3 (0.001)	127 (0.022)
Canarium strictum Roxb.					3 (0.001)	
Careya arborea Roxb.	17 (0.037)			340 (0.036)		
Caryota urens L.					130 (0.020)	
Casearia bourdillonii Mukh.						13 (0.001)
Cassia fistula L.				3 (0.0003)		
Chionanthus leprocarpa Thw.		10 (0.013)			73 (0.016)	
Cinnamomum malabathrum (Burm. f.) Bl.			40 (0.090)		47 (0.006)	230 (0.049)
C. verum J. S. Presl.			60 (0.110)			937 (0.333)
Clerodendrum infortunatum L.				3 (0.0002)		
Cryptocarya bourdillonii Gamble			7 (0.006)		3 (0.001)	70 (0.012)

Table 6. Continued.

Name of the species	Saplings			Seedlings		
	LEF	MEF	HEF	LEF	MEF	HEF
Cullenia excelsa Wt.			27 (0.043)		110 (0.042)	443 (0.168)
Cycas sp.				17 (0.001)		
Dalbergia latifolia Roxb.	3 (0.006)			23 (0.002)		
Dillenia pentagyna Roxb.	17 (0.067)			20 (0.002)		
Dimocarpus longan Lour.	3 (0.003)	17 (0.040)		53 (0.002)	867 (0.089)	
Diospyros bourdilloni Brandis		17 (0.060)		13 (0.001)	77 (0.012)	
D. pruriens Dalz.		17 (0.027)				
Diospyros sp.			13 (0.030)			113 (0.017)
Diotacanthus sp.					253 (0.098)	
Dipterocarpus indicus Bedd.					3 (0.001)	
Drypetes oblongifolia (Bedd.) A. Shaw			143 (0.310)			1097 (0.395)
Emblica officinalis Gaertn.	77 (0.260)			117 (0.017)		
Epiprinus mallotiformis (Mueller) Corizat			27 (0.009)			
Erythroxylum obtusifolium J. Hk.			3 (0.003)			
Eugenia thwaitesii Duthie						950 (0.138)
Euonymus sp.		3 (0.017)				
Excoecaria crenulata Wt. Ic.						20 (0.004)
Ficus sp.	3 (0.006)	3 (0.009)		10 (0.001)	10 (0.003)	
Garcinia travancorica Bedd.		3 (0.009)			150 (0.019)	
Gluta travancorica Bedd.		27 (0.047)			317 (0.046)	
Gomphandra tetrandra (Wall.) Sleumer		3 (0.020)	47 (0.110)	3 (0.0003)	83 (0.032)	53 (0.017)
Grewia tiliaefolia Vahl.				23 (0.002)		
Holarrhena pubescens Wallich Ex Don				33 (0.005)		
Holigarna arnottiana J. Hk.			7 (0.006)			
Hopea parviflora Bedd.		70 (0.027)			817 (0.283)	

Hopea sp.		10 (0.023)				
Hydnocarpus alpina Wt.		3 (0.003)			123 (0.026)	
Hymenodictyon orixense (Roxb.) Mabb.				7 (0.0004)		
Isonandra lanceolata Wt.		6 (0.013)	107 (0.140)		333 (0.158)	750 (0.151)
Ixora brachiata Roxb.	3 (0.003)	83 (0.210)		817 (0.069)	413 (0.010)	
I. notoniana Wall.			3 (0.003)			80 (0.017)
Ixora sp.		3 (0.023)			237 (0.042)	
Kingiodendron pinnatum (Roxb.) Harms		3 (0.023)			113 (0.017)	
Lepisanthes decipiens (W. & A.) Thw.					10 (0.002)	177 (0.030)
Litsea laevigata (Nees) Gamble	3 (0.003)			53 (0.003)		
L. mysorensis Gamble			63 (0.100)			333 (0.035)
Macaranga peltata (Roxb.) Mueller				47 (0.005)	3 (0.001)	
Mallotus beddomei J. Hk.			37 (0.060)			23 (0.010)
M. muricatus Wt. Bedd.			7 (0.006)			
M. philippensis M. Arg.		3 (0.003)		107 (0.005)	67 (0.035)	
M. stenanthus M. Arg.			3 (0.003)			273 (0.086)
Mangifera indica L.		3 (0.003)				
Mastixia arborea (Wt.) Bedd.						43 (0.011)
Memecylon malabaricum (Cl.) Cogn.		17 (0.030)			43 (0.012)	
Mesua ferrea L.		30 (0.096)			323 (0.068)	
Microtropis wallichiana Wt.						10 (0.004)
Murraya paniculata (L.) Jacq.			3 (0.006)	7 (0.001)		10 (0.003)
Myristica dactyloides Gaertn.		3 (0.003)	4 (0.100)		100 (0.018)	173 (0.031)
Nageia wallichiana (Presl.) Kuntze						7 (0.001)
Neolitsea zeylanica (Nees) Merr.			3 (0.003)		187 (0.019)	790 (0.080)
Nothapedytes foetida (Wt.) Sleumer		3 (0.006)				
Nothopegia travancorica Bedd. Ex J. Hk.		10 (0.027)			83 (0.024)	293 (0.039)
N. racemosa (Dalz.) Raman.			70 (0.116)			
Octotropis travancorica Bedd.			343 (0.640)			630 (0.239)
Odina wodier Roxb.				7 (0.0004)		
Olea dioica Roxb.	7 (0.006)			127 (0.008)	24 (0.007)	3 (0.001)
Orophea erythrocarpa Bedd.		33 (0.057)	73 (0.210)		287 (0.032)	413 (0.064)
Persea macrantha (Nees) Kosterm.		3 (0.003)	6 (0.006)			137 (0.020)
Phaeanthus malabaricus Bedd.		26 (0.060)		10 (0.001)	43 (0.009)	

Table 6. Continued.

Name of the species	Saplings			Seedlings		
	LEF	MEF	HEF	LEF	MEF	HEF
Phoenix loureirii Kunth				3 (0.001)		
Pinanga dicksonii Bl.		10 (0.009)			47 (0.019)	
Polyalthia coffeoides J. Hk. & Thw.	7 (0.009)			53 (0.008)		
Prunus ceylanica (Wt.) Miq.		13 (0.020)			37 (0.013)	3 (0.001)
Psychotria anamallayana Bedd.		43 (0.043)	53 (0.050)			1230 (0.164)
P. nigra (Gaertn.) Alston			20 (0.026)		1517 (0.590)	1177 (0.241)
Pterocarpus marsupium Roxb.				290 (0.004)		
Pterospermum diversifolium Bl.		3 (0.009)		120 (0.005)	17 (0.005)	
P. rubiginosum W. & Arn.				7 (0.001)	17 (0.002)	
Sapindus emarginatus Vahl.				80 (0.012)		
Schefflera racemosa Harms.						70 (0.001)
Schleichera oleosa (Lour.) Oken.				20 (0.001)		
Scolopia crenata (W. & A.) Clos.		13 (0.030)			233 (0.049)	80 (0.018)
Stereospermum personatum (Hassk.) Chatterjee					3 (0.0003)	
Syzygium laetum Gandhi		77 (0.226)			337 (0.093)	137 (0.038)
S. gardneri Thw.		3 (0.006)	10 (0.030)		33 (0.003)	
S. mundagam (Bourd.) Chithira		20 (0.069)	20 (0.046)		37 (0.017)	163 (0.024)
Tabernaemontana heyneana Wall.	10 (0.013)			0.03 (0.0002)		
Terminalia bellirica (Gaertn) Roxb.	3 (0.020)			3 (0.001)		
T. chebula Retz.	7 (0.003)			147 (0.023)		
T. paniculata Roth.	40 (0.079)			660 (0.284)		
T. tomentosa W. & A.				47 (0.007)		
Tricalysia apiocarpa Gamble						17 (0.004)
Vateria indica L.		20 (0.043)			273 (0.071)	
Vitex altissima L.				3 (0.0002)		
Walsura trifolia Harm.					17 (0.007)	
Xanthophyllum flavescens Roxb.	7 (0.009)	173 (0.470)		187 (0.016)	213 (0.062)	
Others	6 (0.030)	34 (0.047)	2 (0.033)	53 (0.005)	23 (0.046)	
	2[a]	6[a]	1[a]	1[a]	1[a]	

Values in the parentheses represent basal area (m^2 ha^{-1}), [a] refers to the number of unidentified species in the study sites.

Table 7. Percentage contribution of distribution patterns of species in the tropical forests at Veerapuli and Kalamalai Forest Reserve of Agastymalai hills in the Western Ghats of Tamil Nadu, India.

Categories	LEF	MEF	HEF
Tree			
Regular	0	0	10 (3)
Random	14.8 (4)	11.6 (5)	13.3 (4)
Contiguous	85.2 (23)	88.4 (38)	76.7 (23)
Juveniles			
Regular	0	0	2.8 (1)
Random	0	4.3 (2)	36.1 (13)
Contiguous	100 (20)	95.7 (45)	61.1 (22)
Seedlings			
Regular	0	0	0
Random	0	14.5 (8)	20.9 (9)
Contiguous	100 (44)	85.5 (47)	79.1 (34)
Trees with buttresses	8.9% (12)	16.97% (47)	9.74% (30)
Trees with Epiphytic load	12.59% (17)	25.65% (71)	1.30% (4)
Trees with woody climbers	2.96% (4)	14.08% (39)	0.97% (3)

Values in parentheses represent number of species.

(Henry et al. 1984). Of these, 244 plant species occurred in the transects at Veerapuli and Kalamalai reserve forests. The floristic richness recorded in the present study (82–142 species in 0.3 ha; Table 1) closer to the values obtained in the various regions of Western Ghats (173 in 3.82 ha in Kalakad Mundanthurai Tiger Reserve, Ganesh et al. 1996; 92 species in 3.12 ha in Kadamakal Reserve, Elouard et al. 1997; 398 species in 75 ha in 108 belt transects in the entire length of hill chain of Western Ghats, Ghate et al. 1998). The level of endemism is low when (19.3%) compared to the endemism (48%) reported in Western Ghats (Ramesh et al. 1997). However, the endemicity (19.3%) recorded in the present study lies well within the range (2–55%) reported by Ghate et al. (1998) in the entire length of the hill chain of Western Ghats. Among these endemic species, trees accounted for 36 (76.6%), shrubs 10 (21.3%) and climbers and lianas 1 (2.1%). Herbs did not have any endemics. This indicates that trees make substantial contribution to the levels of endemism in these forests. Similarly, the greater contribution of trees to endemism was reported by Ramesh and Pascal (1991), Ganesh et al. (1996) and Sundarapandian (1997).

Tree density ($>$10 cm DBH size class) in tropical forests varied from 245–859 stems per hectare (Richards 1952; Ashton 1964; Campbell et al. 1992). The density of 436–971 stems ha^{-1} for the diameter threshold $>$10 cm DBH obtained in the present study is well within the limits reported for tropical forests (Gentry 1988; Chandrasekara and Ramakrishnan 1994; Strasberg 1996; Pascal and Pelissier 1996; Sundarapandian and Swamy 1997; Parthasarathy and Karthikeyan 1997a,b; Ghate et al. 1998). However, the values were lower than those reported by Pascal (1988) and Jose et al. (1994) in Western Ghats. The stem basal area in Veerapuli

and Kalamalai forest reserve ranged between 28.4–67.4 m^2 ha^{-1} for >10 cm diameter threshold were well within the range recorded by others. However, these values were lower than those reported by Singh et al. (102.7 m^2 ha^{-1}; 1981), Parthasarathy et al. (94.6 m^2 ha^{-1}; 1992), Burgess (73.6 m^2 ha^{-1}; 1961) and Sundrapandian and Swamy (81.38 m^2 ha^{-1}; 2000) differences in density and basal area may be attributed to altitudinal variation (Rai and Proctor 1986), species composition, age structure, successional stage of the forest and degree of disturbance (Sundarapandian 1997).

Legris and Meher-Homji (1968) considered the vegetation series of the Malabar coast (south-west India) as one of the two concentration zones comprising of species of the Indian and Malaysian Peninsulas. Dipterocarpaceae family was less represented in the Veerapuli and Kalamalai forest reserve (four species), while five species were recorded in Uppangala, Western Ghats (Elouard et al. 1997). However, dipterocarps were well represented in the lowland regions of evergreen forests.

The enumerated species belonged to 35–53 families in the present study is well within the range of 16–58 families found in the tropical forests (Gentry 1998; Campbell et al. 1992). The values obtained in the present study are at a higher side compared to those recorded by others (Johnston and Gillman 1995; Pascal and Pelissier 1996; Parthasarathy and Karthikeyan 1997a). Graminae, Asteraceae, Sterculiaceae and Combretaceae were the predominant families in terms of density in LEF, while Graminae, Rubiaceae, Dipterocarpaceae and Arecaceae were dominant in MEF. Rubiaceae, Acanthaceae, Euphorbiaceae and Lauraceae were some of the important families in HEF. The differences in the family wise distribution may be attributed to heterogeneity in the habitat.

Single species such as *Terminalia paniculata* (IVI of 99.9) and *Hopea parviflora* (IVI of 103.8) were the dominant tree species in LEF and MEF respectively whereas in HEF, *Agrostistachs meeboldii*, *Cullenia excelsa* and *Drypetes oblongifolia* shared the dominance. According to Keel and Prance (1979), dominance increases as a function of stress, while Jacobs (1987) holds that in tropical forests dominance by single species often indicates past damage. This may be the major reason for single species dominance in LEF and MEF. LEF was subjected to annual wild fires. This could be one of the reasons for grass (*Themeda cymbaria*) domination. Present study suggests that repeated burning and other associated disturbances alter the course of succession by giving an advantage to certain species over others such as *T. paniculata* and *T. cymbaria*. Recurrence of annual fires may also lead to loss of local biodiversity. MEF was not disturbed in the recent past but it might have occurred in the distant past. However, disturbance may not be a sole reason for single species dominance. Richards (1952) is of the opinion that adverse climatic conditions also some times result in single species dominance.

Rare species (those represented ≤2 individuals) accounted for 60–62.5% which is greater than those found by others elsewhere (38%, Poore 1968; 40.2%, Manokaran and Kochumen 1987; 26–31%, Parthasarathy and Karthikeyan 1997b). However, the

value obtained in the present study is comparable with those values reported by Paijmans (1970), Ho et al. (1987) and Gentry (1988). Many widespread tropical species tend to be locally abundant in certain areas and relatively rare in others (Hubbell and Foster 1983). It is exemplified by *Myristica dactyloides*, *Aglaia barberi* and *Calophyllum polyanthum* in the present study area where they are abundant with an IVI of 26.18, 25.05 and 16.87 respectively in HEF and IVI of only 1.1, 1.04 and 1.12 in MEF.

The stem density decreased with increased size classes of trees observed in the present study is in agreement with others (Chandrasekara and Ramakrishnan 1994; Brokaw et al. 1997; Sundrapandian 1997; Parthasaraty and Karthikeyan 1997a,b). This indicated that these forests have no girth class-based selective felling in the recent past and typical mature stand with good regeneration potential. Similar results were also reported elsewhere (Ho et al. 1987; Lieberman et al. 1985; Swaine et al. 1987; Campbell et al. 1992; Nadkarni et al. 1995). Species richness interms of the number of species also decreased with increased diameter classes. A similar observation was also made by Parthasarathy and Karthikeyan (1997b) in India. The species-level variation in population structure may be attributed to species preference in site quality, topography, altitude and forest stature.

Abundant population of juveniles in these forests provides an idea of the regeneration status of different species. On the basis of occurrence of seedlings, juveniles and adult tree species, we recognize three categories of species (a) those found only as mature trees, and/or juveniles without seedlings, (b) those as seedlings without juveniles and mature trees and (c) those as seedlings, juveniles and mature trees. However, the juvenile population of dominant tree species were lower (40 No. ha^{-1} in *T. panicualta*; 17 in *Careya arborea*; No individuals in *Pterocarpus marsupium*; 80 in *Buchnania lanzan*; 10 in *Aporosa lindleyana*) in LEF. This may be due to repeated human interference in LEF. Such anthropogenic perturbations may alter the structure and composition of forest ecosystem (Sundarapandian and Swamy 1997). Similarly several studies are available on the impact of perturbation on the relative fragility of tropical forests (Toky and Ramakrishnan 1983; Proctor 1989; Turner et al. 1994). In the present study, recurrence of fire in LEF affects the regeneration both directly through burning of seeds, seedlings and juveniles and indirectly through its action on the edaphic factors as observed by Sundarapandian (1997) at Kodayar in Western Ghats. Dominant species of MEF also showed poor representation (70 No. ha^{-1} in *H. parviflora*; 17 in *Diospyros bourdillonii*; 30 in *Mesua ferrea*) of juveniles. Similarly, lower representation of juveniles for certain primary tree species was reported by Swaine and Hall (1988) in Kade, Ghana. These results are in agreement with the findings of Hubbell (1979) where less abundant species were disproportionately represented by large trees. The first five dominant tree species regenerate through juveniles ranged from 0–80 and seedling from 290–660 in the LEF whereas in MEF, juveniles ranged from 17–178 and seedlings from 77–817. However, in HEF, regeneration through juveniles ranged 0–190 and seedlings from 30–1097. Similarly, regeneration of dominant species ranged from 70–1350 and 8–808 in evergreen

forests respectively at Kakachi (Ganesh et al. 1996) and Kodayar (Sundarapandian and Swamy 1997) in the Western Ghats. The greater regeneration of five dominant species in the form of seedlings and juveniles in MEF and HEF may be due to low disturbance and the support of good micro-environment (Sundarapandian 1997).

Perturbation of any kind to the ecosystem results in alteration of the structure of the biological community and proliferation of noxious weeds (Ramakrishnan 1992). In the present study, the presence of exotic weeds *Eupatorium odoratum* and *Ageratum conyzoides* in LEF reflect the past disturbance events. Specifically *A. conyzoides* indicates that this region still has been under the influence of some kind of disturbance.

The changes in species composition among the forests may be due to altitude and edaphic factors. The altitudinal variation might be due to variation in temperature, relative humidity, radiation values, wind movements and edaphic factors (Nakashizukg et al. 1992), but the variation in species composition along an altitude is very difficult to explain (Proctor et al. 1988). In Veerapuli and Kalamalai forest reserve, dipterocarps were recorded only in MEF. Similar results were found in Kodayar, Western Ghats (Sundarapandian and Swamy 2000) and Gunung Silam (Proctor et al. 1988). Similarly, *Xanthophyllum flavescens*, *Ixora brachiata* and *Dimocarpus longan* (evergreen species) were common in LEF and MEF, but completely abscent in HEF. The above evergreen species were recorded only near the perennial streams in the LEF. This indicates that moisture may be responsible for the evergreen species in LEF.

Conclusion

The quantitative inventory of vegetation at Veerapuli and Kalamalai reserve forests of Agastyamalai hills showed a high level of plant species diversity. It also shows good regeneration status in the form of juveniles and seedlings. Its biodiversity is threatened due to recurrence of annual fire and anthropogenic perturbation. Such type of disturbances also paved the way to alien plant invasion. Veerapuli and Kalamalai reserve forests of Agastyamalai hills serve as a watershed area for some perennial rivers, which are a main water source in the Kanyakumari district of Tamil Nadu. Kani tribes in this region also depend on minor forest produce for their livelihood. Therefore, the preservation of these forests are crucial not only for conservation of its rich biodiversity, but also for meeting the basic needs of the local population.

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