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Structure, composition and diversity of the tropical wet evergreen forest of the Agasthyamalai Region of Kerala, Western Ghats

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Abstract

Detailed phytosociological analysis of Agasthyamalai region of Western Ghats has so far not been carried out. This study is a pioneer attempt in this direction. Structure, composition, dynamics and diversity of the wet evergreen forest of the Agasthyamalai region of the southern Western Ghats were assessed using stratified random sampling by the census quadrat method. 0.1 ha plots were laid out in four localities of Agasthyamalai. From the quadrat data gathered primary and secondary analysis of the vegetation were done. A total of 435 individuals belonging to 79 species and spreading over 37 families was recorded. High stand density (1087.5 trees/ha), species density (79 species in 0.4 ha), medium basal area (64.09 m^2/ha), low maturity (22.39%), low similarity between stands (<50.76%), the 'L' shaped curve of different dbh classes, medium diversity (3.143, Shannon's index value), high species richness (7.07, Margalef's index value) and low species evenness (0.89, Pielou's index value) were observed. On the basis of dominance and association, this forest type is identified as *Mesua-Cullenia- Dimocarpus* type and Clusiaceae, Myrtaceae and Lauraceae were the most important families.

KEY WORDS - Phytosociology, Agasthyamalai region of Kerala, India.

Introduction

The Western Ghats, which is one of the nine biogeographic regions of India, possesses various types of tropical forest. Many plants found in the Western Ghats have a narrow distribution. Extremely restricted areas have been reported as the type localities for a number of species of plants, many of which are endangered or rare (Ramesh and Pascal, 1991). In the Western Ghats there are about 150 taxa exclusively confined to the Agasthyamalai and its environs in Tirunelveli, (Tamil Nadu) and the Thiruvananthapuram (Kerala) hills (Henry, *et al.*, 1984).

The Agasthyamalai range, a compact block of hills situated at the southernmost end of the subcontinent, is one of the richest stands of diverse vegetation along the Western Ghats. Agasthyamalai and its environs are one of the important centres of plant speciation. Many plants new to science have been discovered and described from this region, most of them being narrow endemics (Shetty and Vivekananthan, 1991). Apart from the two foregoing 'mega hot spots', 26 endemic centres have been identified in India by Nayar (1996); the Agasthyamalai region is one amongst them. It also comes under the five sites in the Indian subcontinent, that have been recognised internationally as not only rich but also priority sites for data sheet treatment (WCMC, 1992) and it is well known for its species richness and endemicity. For

example, the Chemmunji peak area in the Agasthyamalai range is the type locality for half a dozen endemic species. Agasthyar peak itself is floristically an exceptionally rich area with a number of species of restricted distribution (Henry *et al.*, 1978).

The quality of a habitat is generally reflected in the status of vegetation cover and its seasonal variation. Wildlife is an integral part of the forest ecosystem. It is very closely linked with the most important element of the ecosystem, *viz.* the vegetational cover. Any quantitative change, such as from primary to secondary type, will have a definite bearing on the Wildlife. Vegetation forms the most important component, as it performs the interception and conversion of light energy to chemical energy which is required for the sustenance of animal and plant life. Vegetation is thus responsible for supplying energy to the ecosystem, a function which is essentially coupled with resource recycling. Structural characteristics and associated functional properties of the vegetation reflect the resultant of many environmental components such as climate, physiography, soil disturbances of different nature and magnitude (Mueller-Dombois and Ellenberg, 1974). For management of the forest ecosystem, it is essential to evaluate these components in time to get information about its structure and function (Rao and Mishra, 1994). The common approach to evaluate a habitat for a wildlife is to analyse the various components of the ecosystem and synthesise this information in relation to the habitat and preference of a given species for different components employing empirical or mathematical models.

Study area

Agasthyamalai range, a compact block of hills situated at the southernmost end of the Indian subcontinent has some of the richest and most diverse vegetation among the Western Ghats. The part of Agasthyamalai in Kerala comes under the Thiruvananthapuram Wildlife Division of the Kerala Forest Department (Fig.1). The elevation ranges from 100 to 1880 m. A variety of seral and edaphic stages of evergreen forest is seen along an elevation gradient from southern secondary moist mixed deciduous forest to the climax wet evergreen forest. The rainfall is very high, about 300 to 500 cm a year. Mean maximum temperature is 24°C. and minimum about 16°C. The wet evergreen forest is mainly situated between 600 and 1200 m. Below 600 m seral and edaphic stages of evergreen forest are seen and above 1200m vegetation changes to subtropical hill forest. A detailed compositional data for lowland evergreen

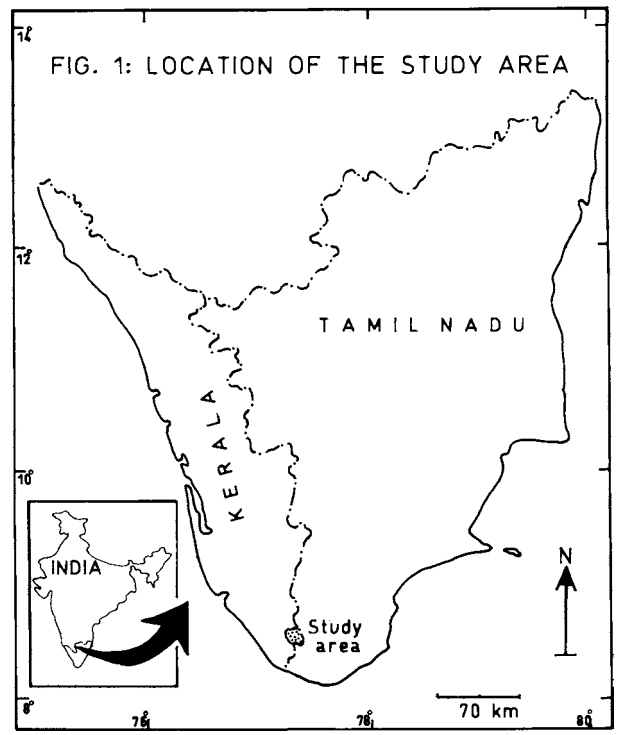

Figure 1. Study area: the Agasthyamalai region of Kerala, Western Ghats, south-western India.

(riverine) forest and subtropical hill forest of Kallar and Ponmudi (places adjacent to Agasthyamalai region) have been given by Greller *et al* (1997). The present study is based on the wet evergreen forests in the Kerala region of Agasthyamalai. According to Champion and Seth (1968), two types of wet evergreen forest are seen in this area, i.e. west coast tropical evergreen forest and southern hill top tropical evergreen forest. West coast tropical evergreen forest is characterised by a luxurious growth of trees of different sizes and shapes arranged in serial tiers and is seen mainly in slopes and valleys. Southern hill top tropical forest is of a stunted evergreentype and is found on the top of hills and along the ridges, mostly confined to 1000 to 1300 m. According to the classification of Pascal (1988) the plesioclimax of this region is the *Cullenia-Mesua-Palaquium* series.

Methodology

Plots of 0.1 ha size were established in four regions of the Agasthyamalai part of Kerala along an altitudinal gradient. The first plot, the Bonaccord locality, is taken from low altitude (around 600 m). It is a region where the west coast tropical semi-evergreen forest merges with the evergreen forest and the biotic pressure is at the maximum for this plot from the adjoining tea plantations. The slope is gentle with a small percentage of exposed rock. The second quadrat was taken from

the catchment area of Karamanayar (Karamana locality), around 800 m. The third one was from the Athirumalai at 1000 m. The second and third quadrats experience low biotic pressures and occupy inaccessible areas with almost steep slopes. This two areas are also remote from human habitation and have a thick undergrowth. The fourth quadrat from 1200 m is at Chemmunjimottai region. This quadrat occupies the hilltop region and exposed to very high winds. The undergrowth is very little and the plot occupies an almost flat region with a good percentage of exposed rock. Of these four plots the first three are from the west coast tropical evergreen forest and the fourth one is from the southern hill top tropical evergreen forest. All tree species above 10cm dbh (at 1.3 m) were enumerated. The quadrat data gathered from each zone were analysed for percentage frequency (Mueller-Dombois and Ellenberg, 1974), nature of vegetation (Raunkiaer, 1934), species association (Robert, 1974), family importance value (Keel *et al.*, 1993), maturity index (Pichi-Sermolli, 1948), species distribution (Whitford, 1949; Curtis and Mclntosh, 1951) and similarity index (Sorenson, 1948). For calculating species richness Margalef (R1) index was used which is represented as follows.

$$R_1 = \frac{S-1}{\log(n)} \qquad \text{(Margalef, 1958)}$$

S= Total number of species; and n = total number of individuals of all species.

Species diversity is of the one most important characteristics of a community. Species diversity of trees was determined as per Shannon's index (1963):

$$\text{Shannon's index (H')} = -\sum_{i=1}^{S} [(n_i/n) \log (n_i/n)]$$

Where n_i = total number of individuals of a species '*i*'; *n* = total number of individuals of all species in the area.

The concentration of dominance (CD) values were measured by Simpson's index (1949).

$$CD = \sum_{i=1}^{S} (n_i/n)^2$$

Where n_i and *n* were the same as for the Shannon's index equation.

The distribution of individuals among the species is called species evenness or equitability (E). The following index was used to calculate evenness:

$$\text{Pielou's index (1975)} \quad E1 = \frac{H'}{\log S}$$

H^1 = Shannon's index value; and S = number of species

Results

The data obtained from each quadrat were analysed separately and then the localities of west coast evergreen forests were pooled together (Table 1) to get the qualitative and quantitative data of this type. The Chemmunjimottai locality was analysed individually for hilltop evergreen forest (Table 2). All the four localities were pooled for the analysis of Wet evergreen forest (Table 3). Phytosociological studies reveal that *Mesua nagassarium* (1.51) shows the highest mean density in this area followed by *Diospyros candolleana, Carallia brachiata* (0.41) and *Xanthophyllum arnottianum* (Table 3). *Mesua nagassarium* shows wide ecological amplitude in this area especially at higher altitudes. The stand density shows a gradual increase from lower altitude to high altitude in west coast evergreen forest i.e. in the first three quadrats (Table 4). The low stand density of west coast evergreen forest in Bonaccord (860 trees/ha) is because of the prevailing biotic pressures from the adjoining tea estates. The highest stand density recorded in this type is at Podium, because of its location at a high altitude and far away from tribal settlements. The high density value for this locality could be attributed to the high density of *Cinnamomum verum* and *Syzygium cuminii*.

The mean abundance value shows high figures for *Vateria indica* (2.27), *Mesua nagassarium* (2.04) and *Diospyros candolleana* (1.66). Typically a community will generally consist of a small number of abundant species and a much large number of moderately common and rare species. A community in the early stages will have a small number of species with uneven distribution, being succeeded eventually by a mature community of a large number of species with a much more even abundance distribution (May, 1976). The mean percentage frequency shows the high frequencies of *Mesua nagassarium* (60.00), *Cullenia exarillata* (51.60) and *Xanthophyllum arnottianum* (33.33). Bonaccord and Karamana localities show a high percentage frequency of *Dimocarpus longan* (60 and 80 respectively), Podium exhibits a high percentage frequency of *Cullenia exarillata* (70) and Chemmunji shows a very high percentage frequency of *Mesua nagassarium* (90).

The percentage frequency of species indicates its distribution in the area. The absence or low percentage of species in higher classes [60 to 80 (D) and 80 to 100% (E)] suggests that characteristic species of an area are absent or very few in number. A constant species may have wide ecological tolerance and oc-

Table 1. Floristic composition: density (D), abundance (AB), percentage frequency (PF), relative basal area (RB) and IVI of west-coast evergreen forest.

	Species	D%	AB%	PF	RB	IVI
1.	*Cullenia exarillata* Robyns	0.63	1.32	43.33	5.65	49.41
2.	*Dimocarpus longan* Lour.	0.90	1.49	60.00	1.65	18.14
3.	*Mesua nagassarium* (Burm.f.)Kosterm	0.33	1.08	30.00	6.00	13.07
4.	*Ficus hispida* L.f.	0.06	0.66	6.66	11.3	12.84
5.	*Diospyros candolleana* Wight.	0.56	1.50	36.66	0.92	11.12
6.	*Bischofia javanica* Bl.	0.10	1.27	6.66	8.68	10.66
7.	*Hydnocarpus macrocarpa* (Bedd.)Warb	0.30	1.11	26.66	4.50	10.61
8.	*Vateria indica* L.	0.60	1.51	36.66	0.56	10.34
9.	*Cinnamomum verum* Pressi.	0.70	1.33	30.33	0.31	9.14
10.	*Xanthophyllum arnottianum* Wight.	0.33	1.66	26.66	0.19	8.99
11.	*Gluta travancorica* Bedd.	0.20	1.33	13.33	4.84	8.84
12.	*Wendlandia bicuspidata* Wight.&Arn.	0.40	1.00	33.33	0.64	8.80
13.	*Calophyllum apetalum* Willd.	0.20	0.77	16.66	4.91	8.58
14.	*Holigarna arnottiana* Hook.f.	0.23	1.33	16.66	3.57	8.18
15.	*Aporusa lindleyana*(Wight.)Bill.	0.40	0.81	30.00	0.47	7.45
16	*Syzygium caryophyllatum*(L.)Alston	0.13	0.33	13.33	3.74	7.34
17.	*Vitex altissima* L.	0.16	1.00	10.00	3.47	5.92
18.	*Syzygium cuminii* (L.)Skeels	0.10	1.33	16.66	0.64	5.83
19.	*Syzygium mundagam* (Bourd.)Chitra	0.16	0.50	20.00	0.73	5.71
20.	*Knema attenuata* (HK.f.&Thoms.)Warb	0.23	1.00	23.33	0.55	5.45
21.	*Ailanthus triphysa* (Dennst.)Alston	0.03	0.33	3.33	4.52	5.42
22.	*Syzygium hemisphericum* (Wt.)Alston	0.10	0.33	10.00	2.78	4.88
23.	*Palaquium ellipticum* (Daiz.)Baillon	0.13	0.83	10.00	2.34	4.55
24.	*Garcinia gummi-gutta* (L.)Robs	0.23	0.83	16.66	0.78	4.51
25.	*Ficus tsjahela* Burm.f.	0.10	0.66	10.00	2.28	4.45
26.	*Ixora nigricans* R Br.*ex* Wight &Arn.	0.26	0.44	20.00	0.06	4.36
27.	*Olea dioica* Meissn.	0.13	0.66	3.33	0.84	4.04
28.	*Terminalia bellirica* (Gaertn.)Roxb.	0.03	0.33	3.33	3.30	3.93
29.	*Polyalthia coffeoides* Hook.f.& Thoms.	0.26	1.66	10.00	0.40	3.93
30.	*Ormosia travancorica* Bedd.	0.03	0.33	3.33	2.70	3.40
31.	*Mallotus philippensis* (Lam.)Muell.-Arg.	0.13	0.44	10.00	0.83	3.23
32.	*Spondias indica.* (W.&A.)Airy Shaw&Forman	0.03	0.33	3.33	2.09	2.72
33.	*Polyalthia suberosa* Hook.f.&Thoms.	0.13	0.66	6.66	0.05	2.62
34.	*Dipterocarpus bourdilloni* Brand	0.13	1.33	6.66	0.23	2.61
35.	*Goniothalamus rhynchantherus* Dunn	0.06	0.33	6.66	0.78	2.58
36.	*Meiogyne pannosa* (Daiz.)Sindaii	0.06	0.66	6.66	0.96	2.55
37.	*Actinodaphne bourdillonii* Gamble	0.06	0.33	6.66	0.72	2.52
38.	*Macaranga peltata* (Roxb.)Muell.-Arg.	0.06	0.66	6.66	0.81	2.41
39.	*Artocarpus gomezianus* subsp. *zeylanicus* Jarret	0.06	0.33	6.66	0.50	2.30
40.	*Leea indica* (Burm.f.)Merr.	0.13	1.33	3.33	0.46	2.08
41.	*Lagerstroemia microcarpa* Wight	0.03	0.33	3.33	1.40	2.04
42.	*Mallotus tetracoccus* (Roxb.) Kurz	0.10	1.00	3.33	0.24	1.99
43.	*Mastixia arborea* subsp. *meziana* (Wang.) Mathew	0.10	1.00	6.66	0.26	1.90
44.	*Toona ciliata* M Roem	0.03	0.33	3.33	1.13	1.77
45.	*Canthium pergracile* Bourd.	0.06	0.66	6.66	0.12	1.72
46.	*Semecarpus travancorica* Bedd.	0.10	0.50	6.66	0.08	1.59
47.	*Ixora arborea* Roxb.*ex.* J.E.Sm.	0.10	0.50	6.66	0.07	1.58
48.	*Buchanania lanzan* Spreng	0.03	0.33	3.33	0.66	1.55
49.	*Strychnos nux-vomica* L	0.03	0.33	3.33	0.81	1.51
50.	*Schleichera oleosa* (Lour.) Oken	0.03	0.33	3.33	0.68	1.37
51.	*Humboldtia trijuga* Joseph & Chandras	0.03	0.33	3.33	0.33	1.23
52.	*Artocarpus heterophyllus* Lam.	0.03	0.33	3.33	0.55	1.20
53.	*Dichapetalum gelonioides* (Roxb.) Engler	0.03	0.33	3.33	0.43	1.13

continued—

Table 1 continued—

54.	*Stereospermum chelonoides* (L.f.)DC.	0.03	0.33	3.33	0.21	1.10
55.	*Canarium strictum* Roxb.	0.03	0.33	3.33	0.21	1.10
56.	*Litsea ligustrina* (Nees)Hook.f.	0.03	0.33	3.33	0.46	1.09
57.	*Artocarpus hirsutus* Lam.	0.03	0.33	3.33	0.43	1.00
58.	*Mangifera indica* L.	0.03	0.33	3.33	0.24	0.94
59.	*Casearia ovata* (Lam.)Willd.	0.03	0.33	3.33	0.03	0.93
60.	*Sterculia urens* Roxb.	0.03	0.33	3.33	0.02	0.92
61.	*Kingiodendron pinnatum* (Roxb.*ex*.DC)Harms	0.03	0.33	3.33	0.02	0.92
62.	*Agrostistachys borneensis* Becc.	0.03	0.33	3.33	0.20	0.90
63.	*Gordonia obtusa* Wall *ex* Wight.&Arn.	0.03	0.33	3.33	0.17	0.87
64.	*Hydnocarpus alpina* Wight.	0.03	0.33	3.33	0.14	0.83
65.	*Carallia brachiata* (Lour.)Merr.	0.03	0.33	3.33	0.14	0.83
66.	*Aglaia elaeagnoidea* (Juss.)Benth.	0.03	0.33	3.33	0.11	0.80
67.	*Poeciloneuron indicum* Bedd.	0.03	0.33	3.33	0.06	0.76
68.	*Syzygium occidentale* (Bourd.)Gandhi	0.03	0.33	3.33	0.04	0.74
69.	*Symplocos macrophylla* subsp.*zeylanicus* (Bedd.)Nooteb.	0.03	0.33	3.33	0.04	0.67
70.	*Symplocos macrocarpa* subsp.*rosea* Gamble	0.06	0.33	6.66	0.18	0.63
71.	*Baccaurea courtallensis* Wt. Muell.-Arg.	0.03	0.33	3.33	0.07	0.52

Table 2. Floristic composition, density (D), abundance (AB), percentage frequency (PF), relative basal area (RB) and IVI of Hilltop evergreen forest.

	Species	D%	AB%	PF	RB	IVI
1	*Mesua nagassarium* (Burm.f.)Kosterm	2.70	3.00	90.00	4.09	44.20
2	*Carallia brachiata* (Lour.)Merr.	0.80	1.60	50.00	2.23	17.65
3	*Xanthophyllum arnottianum* Wight	0.50	1.25	40.00	5.44	16.40
4	*Knema attenuata* (Hook.f.&Thoms.)Warb	0.10	1.00	10.00	13.02	15.52
5	*Actinodaphne bourdillonii* Gamble	0.40	1.33	30.00	6.51	14.98
6	*Gluta travancorica* Bedd.	0.30	1.00	30.00	6.83	14.32
7	*Agrostistachys borneensis* Becc.	0.50	1.00	50.00	1.71	14.19
8	*Diospyros candolleana* Wight	0.70	2.33	30.00	2.52	13.93
9	*Vernonia travancorica* Hook.f.	0.50	1.25	40.00	2.52	13.48
10	*Syzygium mundagam* (Bourd.)Chitra	0.40	1.33	30.00	4.34	12.81
11	*Litsea oleoides* Meissn.	0.10	1.00	10.00	10.07	12.57
12	*Mastixia arborea* subsp. *meziana* (Wang.)Mathew	0.10	1.00	10.00	9.48	11.98
13	*Dimocarpus longan* Lour.	0.40	1.33	30.00	3.37	11.84
14	*Hydnocarpus pentandra* (Buch Hom.)Oken	0.30	1.00	30.00	4.34	11.83
15	*Syzygium cuminii* (L.)Skeels	0.50	1.67	30.00	0.71	10.16
16	*Wendlandia bicuspidata* Wight&Arn	0.40	2.00	20.00	1.71	8.66
17	*Ficus tsjahela* Burm.f.	0.30	1.50	20.00	2.52	8.49
18	*Actinodaphne salicina* L.	0.20	1.00	20.00	1.55	6.54
19	*Artocarpus heterophyllus* Lam.	0.10	1.00	10.00	3.48	5.98
20	*Symplocos macrophylla* subsp.*zeylanicus* Gamble	0.10	1.00	10.00	3.26	5.76
21	*Tarenna alpestris* (Wt.)Balakar.	0.20	2.00	10.00	1.71	5.19
22	*Diospyros ferrea var.angustifolia* (Miq.)Mohanan	0.10	1.00	10.00	2.23	4.73
23	*Poeciloneuron indicum* Bedd.	0.10	1.00	10.00	1.71	4.21
24	*Elaeocarpus tuberculata* Roxb.	0.10	1.00	10.00	1.63	4.13
25	*Ardisia depressa* Clarke	0.10	1.00	10.00	1.55	4.05
26	*Calophyllum apetalum* Willd.	0.10	1.00	10.00	1.12	3.62
27	*Olea dioica* Roxb.	0.10	1.00	10.00	0.39	2.89

Table 3. Floristic composition, density (D%), abundance (AB%), percentage frequency (PF), relative basal area (RB) and IVI of wet evergreen forest.

	Species	D	AB	PF	RB	IVI
1.	*Mesua nagassarium* (Burm.f.) Kosterm	1.51	2.04	60.00	5.52	28.63
2.	*Cullenia exarillata* Robyns	0.31	0.66	51.66	4.24	24.70
3.	*Dimocarpus longan* Lour.	0.32	1.41	33.33	2.08	14.99
4.	*Xanthophyllum arnottianum* Wight.	0.41	1.45	33.33	1.51	12.69
5.	*Diospyros candolleana* Wight.	0.63	1.66	15.00	1.32	12.52
6.	*Gluta travancorica* Bedd.	0.25	1.16	21.66	5.34	11.58
7.	*Knema attenuata* (HK.f.&T.) Warb	0.16	1.00	16.66	3.67	10.48
8.	*Syzygium mundagam* (Bourd.) Chitra	0.28	0.91	25.00	1.63	9.51
9.	*Carallia brachiata* (Lour.) Merr.	0.41	0.96	26.66	0.66	9.24
10.	*Actinodaphne bourdillonii* Gamble	0.23	0.83	18.33	2.17	8.75
11.	*Wendlandia bicuspidata* Wight.&Arn.	0.40	1.50	16.66	0.91	8.73
12.	*Syzygium cuminii* (L) Skeels	0.30	1.50	23.33	0.66	7.99
13.	*Agrostistachys borneensis* Becc.	0.26	0.66	26.66	0.58	7.54
14.	*Mastixia arborea* subsp. *meziana* (Wang.) Mathew	0.10	1.00	8.33	2.57	6.94
15.	*Vernonia travancorica* HK.f.	0.25	0.62	20.00	0.63	6.74
16.	*Ficus tsjahela* Burm.f.	0.20	1.08	15.00	2.34	6.47
17.	*Ficus hispida* L.f.	0.03	0.38	3.33	8.48	6.42
18.	*Litsea oleoides* Meissn.	0.05	0.50	5.00	2.52	6.28
19.	*Calophyllum apetalum* Willd.	0.15	0.88	13.33	3.96	6.10
20.	*Hydnocarpus pentandra* (Buch-Hom.) Oken	0.15	0.50	15.00	1.08	5.91
21.	*Bischofia javanica* Bl.	0.05	0.63	3.33	6.52	5.33
22.	*Hydnocarpus macrocarpa* (Bedd.) Warb	0.15	0.55	13.33	3.38	5.30
23.	*Vateria indica* L.	0.30	2.27	18.33	0.42	5.17
24.	*Cinnamomum verum* Presl.	0.35	0.66	15.16	0.23	4.57
25.	*Holigarna arnottiana* HK.f.	0.11	0.66	8.33	0.68	4.09
26.	*Aporusa lindleyana* (Wight) Baill.	0.20	0.04	15.00	0.35	3.72
27.	*Syzygium caryophyllatum* (L.) Alston	0.06	0.16	6.66	2.81	3.67
28.	*Artocarpus heterophyllus* Lam.	0.06	0.66	6.66	1.28	3.63
29.	*Olea dioica* Roxb.	0.11	0.83	11.66	0.73	3.46
30.	*Actinodaphne salicina* L.	0.10	0.50	10.00	0.39	3.27
31.	*Symplocos macrophylla* subsp.*rosea* (Bedd.)Nooteb.	0.06	0.60	6.66	0.14	3.21
32.	*Vitex altissima* L.	0.08	0.50	5.00	2.60	2.96
33.	*Ailanthus triphysa* (Dennst.)Alston	0.01	0.16	1.66	3.39	2.71
34.	*Tarenna alpestris* (Wight)Balakr.	0.10	1.00	5.00	0.43	2.59
35.	*Poeciloneuron indicum* Bedd.	0.06	0.66	6.66	0.47	2.48
36.	*Syzygium hemisphericum* (Wight)Alston	0.05	0.16	5.00	2.09	2.44
37.	*Diospyros ferrea var.angustifolia* (Miq.)Mohanan	0.05	0.50	8.33	0.56	2.36
38.	*Palaquium ellipticum* (Daiz.)Baillon	0.06	0.41	5.00	1.76	2.27
39.	*Garcinia gummi-gutta* (L.)Robs	0.11	0.41	8.33	0.59	2.25
40.	*Ixora nigricans* R.Br. *ex* Wight.&Arn.	0.13	0.22	10.00	0.05	2.18
41.	*Elaeocarpus tuberculata* Roxb.	0.05	0.50	5.00	0.41	2.06
42.	*Ardisia depressa* Clarke	0.05	0.50	5.00	0.39	2.02
43.	*Terminalia bellirica* (Gaertn.) Roxb.	0.01	0.16	1.66	2.50	1.97
44.	*Polyalthia coffeoides* Hk.f.&Thoms.	0.13	0.83	5.00	0.30	1.96
45.	*Ormosia travancorica* Bedd.	0.01	0.16	1.66	2.03	1.70
46.	*Mallotus philippensis* (Lam.) Muell.-Arg.	0.06	0.22	5.00	0.63	1.61
47.	*Spondias indica.* (W.&A.)Airy Shaw&Forman	0.01	0.16	1.66	1.57	1.36
48.	*Polyalthia suberosa* Hook.f.&Thoms.	0.06	0.33	3.33	0.04	1.31
49.	*Dipterocarpus bourdilloni* Brand	0.06	0.66	3.33	0.18	1.30
50.	*Goniothalamus rhynchantherus* Dunn	0.03	0.16	3.33	0.58	1.29
51.	*Meiogyne pannosa* (Daiz.)Sindaii	0.03	0.33	3.33	2.87	1.27
52.	*Macaranga peltata* (Roxb.)Muell.-Arg.	0.03	0.33	3.33	0.61	1.20
53.	*Artocarpus gomezianus* subsp.*zeylanicus* Jarret	0.03	0.16	3.33	0.38	1.15

continued—

Table 3 continued—

54. *Leea indica* (Burm.f.)Merr.	0.06	0.66	1.66	0.02	1.04
55. *Lagerstroemia microcarpa* Wt.	0.01	0.16	1.66	1.05	1.02
56. *Mallotus tetracoccus* (Roxb.)Kurz	0.05	0.50	1.66	0.24	0.99
57. *Toona ciliata* M.Roem.	0.01	0.16	1.66	0.85	0.88
58. *Canthium pergracile* Bourd.	0.03	0.33	3.33	0.09	0.86
59. *Semecarpus travancorica* Bedd.	0.05	0.25	3.33	0.06	0.79
60. *Ixora arborea* Roxb.*ex*.J.E.Sm.	0.05	0.25	3.33	0.06	0.79
61. *Buchanania lanzan* Spreng	0.01	0.16	1.66	0.49	0.77
62. *Strychnos nux-vomica* L	0.01	0.16	1.66	0.66	0.75
63. *Schleichera oleosa* (Lour.)Oken	0.01	0.25	1.66	0.51	0.68
64. *Humboldtia trijuga* Joseph&Chandras	0.01	0.16	1.66	0.25	0.61
65. *Dichapetalum gelonioides* (Roxb.)Engler	0.01	0.16	1.66	0.33	0.56
66. *Canarium strictum* Roxb.	0.01	0.16	1.66	0.16	0.55
67. *Stereospermum chelonoides* (L.f.)DC.	0.01	0.16	1.66	0.16	0.55
68. *Litsea ligustrina* (Nees)HK.f.	0.01	0.16	1.66	0.34	0.54
69. *Artocarpus hirsutus* Lam.	0.01	0.16	1.66	0.33	0.50
70. *Mangifera indica* L.	0.01	0.16	1.66	0.18	0.47
71. *Casearia ovata* (Lam.)Willd.	0.01	0.16	1.66	0.03	0.46
72. *Kingiodendron pinnatum* (Roxb.*ex* DC.)Harms	0.01	0.16	1.66	0.02	0.46
73. *Sterculia urens* Roxb.	0.01	0.16	1.66	0.02	0.46
74. *Gordonia obtusa* Wall *ex* W.&A.	0.01	0.16	1.66	0.13	0.43
75. *Hydnocarpus alpina* Wt.	0.01	0.16	1.66	0.10	0.41
76. *Aglaia elaeagnoidea* (Juss.)Benth.	0.01	0.16	1.66	0.08	0.40
77. *Syzygium occidentale* (Bourd.)Gandhi	0.01	0.16	1.66	0.03	0.37
78. *Symplocos macrocarpa* subsp .*macrocarpa* Gamble	0.03	0.16	3.33	0.14	0.31
79. *Baccaurea courtallensis* (Wight)Muell.-Arg.	0.01	0.16	1.66	0.05	0.26

Table 4. Secondary analysis of the vegetation of different localities.

	Bonaccord	**Karamana**	**Podium**	**Chemmunji**
Altitude	600m.	800m.	1000m	1200m.
Stand density (trees\ha)	860	1100	1370	1020
Species density (species \0.1ha)	37	40	32	27
Basal area(m^2)	67.98	93.47	65.59	29.34
Frequency distribution	A 31(83.78%)	26 (65.00%)	20 (62.50%)	15 (55.55%)
	B 5(13.51%)	11 (27.50%)	8 (25.00%)	9 (33.33%)
	C 1(02.70%)	2 (5. 00%)	2 (6.25%)	2 (7.04%)
	D 0(00.00%)	1 (2. 50%)	2 (6.25%)	0 (0.00%)
	E 0(00.00%)	0 (0.00%)	0 (0.00%)	1 (3.70%)
Dominant tree species	*Dimocarpus longan, Gluta travancorica, Syzygium caryophyllatum*	*Cullenia exarillata, Bischofia javanica, Dimocarpus longan*	*Cullenia exarillata, Ficus hispida, Cinnamomum verum*	*Mesua nagassarium, Carallia brachiata, Xanthophyllum arnottianum*
Maturity index value	17.57	21.00	26.56	24.44
Species distribution	Regular 0	1	3	1
	Random 14	15	11	10
	Contiguous 23	24	18	16

cur in several associations (Kershaw, 1973). The absence of species in high frequency classes in low altitudes reflects the heterogeneity of stands. Homogeneity has been assessed according to Raunkiaer's (1934) "Law of Frequency". A plant species is considered homogeneously distributed if the number of individuals is the same in all parts of an area. A decreasing number of species in successive 20% frequency class intervals but an increase in the 80 to 100% class has been widely interpreted as being a fundamental community characteristic indicating homogeneity (McIntosh, 1975). Only Chemmunji exhibits a homogeneous vegetation (Table 3). The heterogeneity decreases from low altitude to high altitude. Bonaccord shows a highly heterogeneous nature of vegetation. In this locality the fourth and fifth classes were not represented and this may be due to the biotic pressures from the adjoining tea plantations and tribal settlements.

The basal area cover shows high basal area of *Bischofia javanica* (6.52) and *Mesua nagassarium* (5.52). The high basal area cover of the west coast evergreen forest of Karamana is due to the low human interference. The low basal area cover of Bonaccord and Podium are due to the anthropogenic activities from the nearby tea estates and tribal settlements. The very low basal area of Chemmunji is due to the prevailing edaphic conditions and high wind velocity. The high basal area of *Ailanthus triphysa* (introduced tree) in Bonaccord indicates human activities in the past.

Low percentage of trees in higher girth classes in Podium is due to high altitude and unfavourable conditions. Karamana follows the classic negative exponential pattern ('L' shaped curve) commonly found in undisturbed rainforests while Bonaccord shows a disturbed nature. The distribution of girth classes of this region follows the classic negative exponential pattern commonly found in undisturbed rainforests. The 'L' shaped curve of different gbh classes indicates good regeneration in this forest (Fig.2.).

The mean IVI of species shows that *Mesua nagassarium* (28.63) has the highest IVI followed by *Cullenia exarillata* (24.70) and *Dimocarpus longan* (14.99). Of these three species *Dimocarpus longan* dominates at the low altitudes i.e. in Bonaccord; *Cullenia exarillata* at the medium altitudes, i.e. in Karamana and Podium; and *Mesua nagassarium* at the high altitude, i.e. in Chemmunji locality.

Discussion

In the classification of Gadgil and Meher-Homji, (1986) the vegetation of Agasthyamalai hill ranges comes under the "*Cullenia-Mesua-Palaquium* series".

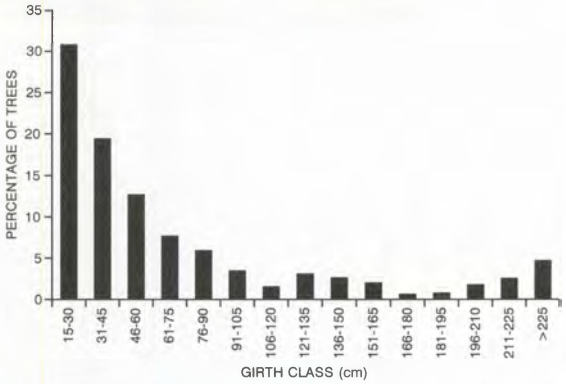

Figure 2. Girth class distribution of trees in the study area.

According to the present study the vegetation of Agasthyamalai comes under *Cullenia-Dimocarpus-Mesua* type. *Palaquium* has very low IVI in this area. *Mesua-Cullenia-Dimocarpus* can be regarded as a subtype of *Cullenia-Mesua-Palaquium* series. A similar subtype, *Cullenia-Aglaia Palaquium,* has been observed in Kalakad-Mundanthurai sanctuary (1250-1450m.) of Agasthyamalai (Tamil Nadu) by Ganesh *et al.* (1996).

The stand density of other evergreen forest of the Western Ghats are as follows; Idukki, 780 trees/ha; Nilambur, 908 tree/ha (Sanal, 1997); Ranni, 892 trees/ha; Parambikulam, 881trees/ha (Sankar and Sanal, 1998); Silent Valley, 1082 trees/ha (Basha, 1987); Attappady, 1520 trees/ha (Pascal, 1988); tropical wet evergreen forests of south-west India, 635 trees (30cm gbh/ha) (Pascal and Raphael Pelissier, 1996) and Agasthyavanam Biological Park, 460 trees/ha (Varghese, *et al.*, 1998). These show the basal area cover of the wet evergreen forest of Agasthyamalai region (900) is in the medium range.

For the evergreen forest of the Western Ghats the following basal area values were reported; 68.20 m^2/ha in Idukki region; 64.83 m^2/ha in Nilumbur region (Sanal, 1997); 88.39 m^2/ha in Ranni region; 83.55 m^2/ha in Parambikulam region (Sankar and Sanal, 1998); 88.76m^2/ha m in Silent Valley region (Basha, 1987); 59.6m^2/ha in Attapady region (Pascal, 1988). These show the basal area cover of the wet evergreen forest of Agasthyamalai region (64.09) is in the medium range.

Hooker (1906) observed that the most distinctive character of the 'Malabar' flora in contrast to those of Deccan is primarily the presence of Clusiaceae, Dipterocarpaceae, Myristicaceae, Palmae and Bambusaceae. Pascal (1988) reported that the best represented families in terms of the number of species in Uppangala forest of the Western Ghats, are Euphorbiaceae (20 species) and Anacardiaceae (7 species), etc. Ganesh *et al.* (1996) got high Family

Table 5. Relative importance of families of wet evergreen forest: RD, relative density; RDI, relative diversity; RDO, relative dominance; FIV, family importance value.

Family	Total IVI	RD	RDI	RDO	FIV
Clusiaceae	39.46	17.81	8.37	22.18	48.37
Myrtaceae	23.73	8.61	7.22	9.36	25.19
Lauraceae	23.42	7.03	7.66	6.31	21.01
Anacardiaceae	19.06	4.32	6.07	7.89	18.28
Euphorbiaceae	20.76	6.35	6.77	5.11	18.23
Moraceae	18.31	3.31	7.22	5.58	16.11
Rubiaceae	15.10	6.69	6.51	2.13	15.33
Ebenaceae	14.88	6.47	4.40	3.86	14.73
Sapindaceae	15.67	6.16	3.25	4.86	14.19
Flacourtiaceae	12.10	3.12	3.96	5.38	12.47
Xanthophyllaceae	12.69	5.45	2.55	4.25	12.25
Bombacaceae	8.03	2.85	0.70	6.14	9.67
Rhizophoraceae	9.24	4.07	2.55	2.53	9.15
Myristicaceae	10.48	1.54	2.55	2.08	6.17
Annonaceae	5.84	2.40	2.81	0.86	6.07
Asteraceae	6.74	2.45	1.85	1.76	6.06
Dipterocarpaceae	6.45	3.30	1.40	0.57	5.31
Cornaceae	6.93	0.94	2.55	1.44	4.93
Symplocaceae	4.00	0.94	3.25	0.55	4.75
Oleaceae	3.46	1.09	2.55	0.36	4.00
Verbenaceae	2.96	0.75	0.70	1.41	2.86
Elaeocarpaceae	2.06	0.49	1.85	0.22	2.56
Myrsinaceae	2.02	0.49	1.85	0.21	2.55
Sapotaceae	2.27	0.60	0.70	1.24	2.54
Meliaceae	1.28	0.30	1.40	0.29	1.99
Caesalpiniaceae	1.07	0.30	1.40	0.06	1.76
Combretaceae	1.96	0.15	0.70	0.77	1.62
Simaroubaceae	2.71	0.15	0.70	0.77	1.62
Fabaceae	1.70	0.15	0.70	0.70	1.55
Leeaceae	1.04	0.60	0.70	0.01	1.18
Lythraceae	1.02	0.15	0.70	0.32	1.17
Strychnaceae	0.75	0.15	0.70	0.20	1.05
Dichapetalaceae	0.56	0.15	0.70	0.11	0.96
Theaceae	0.43	0.15	0.70	0.04	0.89
Burseraceae	0.55	0.15	0.70	0.03	0.88
Bignoniaceae	0.55	0.15	0.70	0.03	0.88
Sterculiaceae	0.46	0.15	0.70	0.05	0.85

Table 6. Richness, diversity and evenness of tree species in different localities: I = Simpson's index value, H' = Shannon's index value.

Locality		Bonaccord	Karamana	Podium	Chemmunji
Species richness value	(R_1)	8.0819	8.2970	6.3008	5.6216
Heterogeneity indices value	(I)	0.0328	0.0420	0.0514	0.0922
	(H')	3.3691	3.3080	3.0962	2.7987
Species eveness value	(E1)	0.9330	0.8967	0.8933	0.8491

Table 7. Community coefficient of localities of wet evergreen forest.

	% dissimilarity			
Locality	Bonoccord	Karamana	Podium	Chemmunji
Bonoccord	—	55.85	59.38	68.75
Karamana	44.15	—	50.73	49.25
Podium	40.62	49.27	—	62.71
Chemmunji	31.25	50.75	37.29	—
	% similarity			

Importance Value (FIV) for Lauraceae, Rubiaceae and Euphorbiaceae in the Tamil Nadu part of Agasthyamalai. In the wet evergreen forest of Agasthyamalai, Clusiaceae records the highest FIV (48.37) followed by Myrtaceae (25.19) and Lauraceae (21.01) (Table 5). Euphorbiaceae was the most dominant family in terms of species richness (seven species). In the present study a total of 79 species spread over 37 families were recorded from a 0.4 ha area. Ganesh *et al.* (1996) reported 90 tree species under 35 families (3.82 ha) from Kalakad Mundanthurai Tiger Reserve, Agasthyamalai (Tamil Nadu).

The maturity index value increases with the altitude. When compared to Andaman islands (36.60; Roy *et al.*, 1993) the maturity index value of Agasthyamalai is low (mean value 22.39). The distribution of species shows normal pattern of highly contiguous, medium random and very low regular distribution. According to Whitford (1949), in pioneer communities plants tend to be aggregated but as the community progresses towards climax, their distribution become more random or even regular. The maturity value (22.39) and contiguous distribution of species denote the early successional status of the forest.

In terms of number of tree species per unit area, Agasthyamalai appears to have a high density. In the Agasthyamalai region of Kerala we got 435 individuals spread over 79 species in 0.4 ha. Number of species per plot appears to diminish from low altitude to high altitude except in Karamana which shows a higher density than all other localities. In this region, climatic shift is more rapid due to the Foehn effect and to the gradual transformation in the rainfall pattern from the south-west monsoon regime (with a peak in July) to the two peak regimes characterised by the dominance of rains during October - December i.e. N.E. Monsoon (Ramesh and Pascal 1991). For evergreen forest of Kalakad - Mundanthurai, Ganesh *et al.* (1996) reported 45 species per ha (>10 cm dbh). The species per ha reported from other parts are: 176 species per ha in Barro Colorado Island in Panama and 155 - 283 species per ha in upper Amazonia (Gentry, 1990). Cousens (1951) reported 183 species in 60 acres in the Malayan peninsula (A total of 379 trees of gbh of and above 10 cm); Ashton (1964) reported 760 species (among 3000 trees of above 10 cm gbh) from a 45 ha plot in Brunei; Murca Pires *et al.* (1953) reported 60 species (320 trees of gbh of and above 10 cm) in a one ha plot in Sumatra and 244 species representing 136 genera and 56 families among 2607 trees of and above 30cm gbh from a 5 ha forest in Amazonia; Basha, (1987) reported 383 individuals of 33 species in a quarter ha area in Silent Valley. Nicholson (1965) reported 198 species (of and above 30 cm) in 1.81 ha in Sabah, Malaysia; Okali and Adams (1987) reported 50 species in 4.05 ha in Nigeria, Africa. Pascal and Raphael Pelissier (1996) reported floristic richness of 91 species belonging to 31 families in 3.12 ha for the Uppangala forest of Western Ghats (of and above 30cm gbh). Pascal (1988) reported 34 species (gbh of and above 10cm at 800m) from Silent Valley and 27 species in 1000 m^2 from Attapadi.

Shannon index of diversity (>10cm gbh) for this area (3.143) appears to have a medium value when compared to other sites in the Western Ghats (Table 6). The following values are reported for the evergreen forests of other regions of Kerala: Silent Valley, 3-3.9 (Basha *et al.*, 1992); Nelliampathy, 3-3.7 (Chandrasekhara, 1991); Nilambur 3.59 and Idukki, 2.83 (Sanal, 1997); Achankovil, 1.5-2.2 (Sankar and Sanal, 1998); Agasthyavanam Biological Park, 2.8 (Varghese *et al.*, 1998); Kalakad-Mundanthurai Tiger Reserve, 3.37 (Ganesh *et al.*, 1996); Attapadi, 4.00 (Pascal, 1988). Shannon's index for the climax evergreen forest of the Western Ghats is distributed around 3.6 and 4.3. The present study reveals that in Agasthyamalai diversity decreases as altitude increases. Maximum diversity appears in Bonaccord which suffers disturbances from the adjoining habitations and from there diversity decreases along altitude and reaches a minimum in Chemmunji.

The concentration of dominance which is inversely proportional to the diversity shows an increase from low altitude to high altitude and reaches a comparatively high concentration of dominance in the hilltop evergreen forest. The ratio E (Equitability) gives an idea of the real distribution as compared to maximum dispersion taking into account the number of species present in the plot. From the evergreen forest of Nilambur, Sanal (1997) reported an evenness of 0.92-0.98 and from Idukki he reported 0.95-0.97. Good distribution of species among individuals is seen in Bonaccord.

All localities show below 50.75% similarity (Table 7). This may be accounted for by the variation of the

hills due to change of aspect and resultant microclimatic differences at different aspects. Because of the difference in microclimate, the species composition in the tree layer differed on different aspects although the dominant species remain the same. The variation in species composition between low altitude (600 m) and high altitude (1200 m) amounts to 68.75% (Table 6). Low similarity between adjacent stands was exhibited by Podium and Chemmunji (37.3%). This is because of the transition of the stand from west coast evergreen to hilltop evergreen.

Summary and conclusion

Density, abundance, percentage frequency and basal area show wide ecological amplitude of *Mesua nagassarium* in this area, especially in higher altitudes. The 'Law of Frequency" and similarity index values show the highly heterogeneous nature of the vegetation in low and medium altitudes i.e. in west coast evergreen forests. Hilltop evergreen shows homogeneous nature of vegetation characterised by *Mesua nagassarium*. The species association and mean IVI show the association of the *Mesua-Cullenia-Dimocarpus* series. Of these *Mesua nagassarium* dominates at high altitudes, *Cullenia exarillata* middle and *Dimocarpus longan* low altitudes. The Maturity index values and pattern of species distribution show the early successional status of the vegetation. The stand density, maturity index values, regular distribution of species and concentration of dominance show a gradual increase from low to high altitude in the west coast evergreen forest. Heterogeneous nature of vegetation, species evenness and diversity decrease from low to high altitudes. The low species richness, basal area, diversity and evenness of Hilltop evergreen are due to adverse edaphic and climatic conditions prevailing there. Agasthyamalai has comparatively high species per unit area and stand density. The distribution of girth classes follows the classic negative exponential pattern commonly found in undisturbed rainforests. The `L' shaped curve indicates good regeneration in this forest. High species richness, medium diversity and low equitability are the conspicuous features of the vegetation. The biodiversity of this region is threatened due to fragmentation of climax forest and various anthropogenic pressures from tribal settlements, tea plantations, etc.

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