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B.R. Ramesh

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Evergreen Forests of the Biligirirangan Hills, South India
Ecology, Structure and Floristic Composition

By

B.R. Ramesh

Membres du jury

Prof. V M Meher-Homji, French Institute of Pondicherry, India (guide)

Prof. H Lieth, Department of Biology, University of Osnabruck, Germany (thesis examiner)

Dr. K A Shankarnarayan, ICAR-Central Arid Zone Research Institute, India (thesis examiner)

Prof. K S Paliwal, School of Biological Sciences, Madurai Kamaraj University (Viva examiner)

EVERGREEN FORESTS OF THE BILIGIRIRANGAN HILLS, SOUTH INDIA

ECOLOGY, STRUCTURE AND FLORISTIC COMPOSITION

Thesis submitted to the University of Madras in partial fulfilment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

BOTANY

by

B. R. RAMESH, M.Sc.

FRENCH INSTITUTE,
PONDICHERRY - 605001



DECEMBER 1989

Dr. V.M. Meher-Homji,
Research Ecologist,
French Institute,
Pondicherry-605001.

Pondicherry
11-12-1989

CERTIFICATE

This is to certify that the thesis "**EVERGREEN FORESTS OF THE BILIGIRIRANGAN HILLS, SOUTH INDIA: ECOLOGY, STRUCTURE AND FLORISTIC COMPOSITION**" submitted by **Mr. B.R. Ramesh**, is a bonafide record of research work done by the candidate during the period of study under me (from 15th December, 1984 to December, 1989) and that the thesis has not formed the basis of any Degree, Diploma, Associateship, Fellowship or other similar titles. The thesis represents an independent work on the part of the candidate, prepared under my supervision.

SUPERVISOR

To my beloved mother

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CONTENTS

INTRODUCTION		1
CHAPTER 1		
	GEOGRAPHY, GEOLOGY AND SOILS OF THE BILIGIRIRANGAN HILLS: AN OUTLINE	4
	I GEOGRAPHY	4
	II GEOLOGY	6
	III SOILS	7
	1 GENERAL PHYSICO-CHEMICAL ASPECTS	7
	2 ORGANIC MATTER CYCLE	13
	3 SOIL MOISTURE	16
CHAPTER 2		
	THE CLIMATE	20
	1 RAINFALL	20
	1.1 Location of raingauge stations	20
	1.2 Annual rainfall	23
	1.3 Seasonal rainfall	24
	1.4 Rainy days	28
	1.5 Rainfall variability and trends	30
	1.6 Conclusion	36
	2 MICROCLIMATE	37
	2.1 Location	37
	2.2 Temperature	37
	2.3 Relative humidity	40
	2.4 Saturation deficit	42
	2.5 Conclusion	44
CHAPTER 3		
	MAIN VEGETATION TYPES	45
	1. CRITERIA USED FOR CLASSIFICATION OF VEGETATION	45
	1.1 Climax	45
	1.2 Physiognomic classification	47
	1.3 Phenology	47
	1.4 Successional stages	48
	2 DECIDUOUS TYPES	51
	2.1 <i>Anogeissus-Pterocarpus-Terminalia</i> type	51
	2.2 <i>Anogeissus-Chloroxylon-Albizia</i> type	52
	3 EVERGREEN/SEMI-DECIDUOUS TYPES	53
	3.1 Physiognomic classification	53
	3.2 Floristic groups using correspondence analysis	54
	3.3 Overall classification of the evergreen types	59
	3.4 Semi-deciduous forests	60
	4 SHRUB SAVANNA (GRASSLAND) OF HIGH ELEVATIONS	60
	5 VEGETATION MAPPING	62
CHAPTER 4		
	METHODOLOGY	64
	1 STRUCTURAL ANALYSIS	64
	2 FLORISTIC COMPOSITION	70
CHAPTER 5		
	ELAEOCARPUS TUBERCULATUS-MICHELIA CHAMPACA-CANARIUM STRICTUM TYPE	71
	1 LOCATION	71
	2 FLORISTIC COMPOSITION	72
	3 ALTITUDINAL VARIATIONS	74
	4 LATITUDINAL VARIATIONS	75

CHAPTER 6		
	MESUA FERREA-PALAUQUIUM ELLIPTICUM-OLEA GLANDULIFERA TYPE	76
	1 LOCATION	76
	2 STRUCTURAL STUDY	76
	2.1 Spatial structure	76
	2.2 Floristic structure	88
	3 FLORISTIC STUDY	93
	4 REGENERATION	96
	5 COMPARISON WITH THE MEDIUM ELEVATION TYPES OF THE WESTERN GHATS	100
	6 CONCLUSION	102
CHAPTER 7		
	DIOSPYROS OVALIFOLIA-MEMECYLON LUSHINGTONII TYPE	103
	1 LOCATION	103
	2 FLORISTIC STUDY	103
	3 CONCLUSION	105
CHAPTER 8		
	LAURACEOUS TYPE	106
	1 LOCATION	106
	2 STRUCTURAL ANALYSIS OF THE AVERAGE TYPE	106
	2.1 Spatial structure	107
	2.2 Floristic structure	118
	3 STRUCTURAL AND FLORISTIC VARIATIONS	123
	4 FLORISTIC STUDY	139
	5 CONCLUSION	145
CHAPTER 9		
	PHYTOGEOGRAPHY	147
	1 FLORISTIC ELEMENTS	148
	2 FLORISTIC ELEMENTS WITHIN THE EVERGREEN TYPES OF THE BRH	153
	3 FLORISTIC COMPARISON BETWEEN GUTTIRAYANS, THE BRH AND THE NILGIRIS	154
	4 CONCLUSION	159
	GENERAL CONCLUSIONS AND SUMMARY	161
	PLATES	165
	ANNEXE	172

INTRODUCTION

The tropical evergreen forests with their biological richness and diversity throw a great challenge to any ecologist. Although many of them are actively working on tropical forests in several countries, the work is still inadequate to understand the tropical ecosystem (Golley, 1983).

In India, stretches of tall dense evergreen rain forests are found in the Western Ghats, North East India and in the Andaman and Nicobar Islands.

The evergreen forests of the Eastern Ghats unlike their counterparts in the Western Ghats, are found in patches confined to moist pockets, particularly above 800m elevation. Thus the isolation of these forests confers on them the status of an 'ecological island' of great interest, especially from the phytogeographical point of view.

The Eastern Ghats are characterised by a series of isolated hills; the Khondmal hills in the Baudh-Khondmal (Phulbani) district of Orissa form the northern extremity, the middle part extends along the Coromandel coast while the last part is oriented westwards meeting the Western Ghats through the highrising Nilgiris. The Biligirirangan hills (BRH) at the tail end of the Eastern Ghats form an important link between the Western Ghats and the Eastern Ghats.

The geographical location of the BRH between the two Ghat systems is interesting from the ecological point of view because of the environmental complexities and variety of vegetation types found here.

Detailed surveys of the evergreen forests of the BRH which are mostly confined to the borders of streams, moist valleys and hilltops have revealed the presence of some characteristic species of the Western Ghats, the Eastern Ghats and of high altitudes, besides those having wide distribution making this region quite diversified floristically. The very presence of Western Ghats species away from their main belt indicates the relict nature of these forests. Further, the topography and diversity of bioclimates prevailing in this area add yet another dimension to the scientific importance of the region.

There are no reports of any ecological work carried out in the BRH prior to the present study. However, this area has been botanically explored by some authors: Blatter (1908) surveyed the BRH under the flora of North Coimbatore region, when a part of the BRH was under the Madras presidency; Barnes (1944) has dealt with a limited number of groups, with emphasis on orchids and other herbaceous flora; Kammathy *et al.* (1967) have given a comprehensive account of the BRH flora, listing 825 species. More recently Rao & Razi (1981) and Saldanha (1984) have covered BRH in the Flora of Mysore District and Flora of Karnataka, respectively.

As in other tropical regions, here also the forest area is continuously shrinking mostly due to anthropic pressure and to some extent due to fire. Beginning from 1885, a series of coffee plantations were established by the Britishers in the central ranges of the BRH. At present there are 4 coffee estates (Honnametti, Attikan, Bedguli and Billigirangan estates) covering over 570 ha. The remnants of forests in some valleys and a few surviving trees amidst these coffee estates indicate the existence of rich evergreen forests in this region in the past. Further, human settlements (mostly coffee estate workers) and cattle have already made a strong impact on the surrounding forests.

The Sholagars, a relatively primitive tribe, are the earliest inhabitants of the BRH. They are primarily forest dwellers subsisting on honey, tubers, fruits etc. In recent years they have been brought together under resettlement schemes by the Forest Department providing them with degraded forest land for cultivation. Encroachment in the foothills is also increasing every year. This can be easily seen by comparing the satellite pictures of different years. Regular occurrence of fire is another menace requiring immediate attention. Thus with pressure from all sides, these forests need immediate conservation measures. As a first step it is necessary to understand the ecology of these forests, particularly the evergreen forests, which are mostly dependent on the local climatic and topographic conditions.

To fulfil the above objective some fundamental studies have been made along the following lines:

-Soil, one of the most important ecological parameters, has been investigated in different sites of the BRH for their texture, fertility status, toxicity, carbon mineralisation and moisture content.

-For macroclimate, rainfall which is the only parameter available in this region has been analysed for its distribution pattern, spatial and temporal variations. Microclimate with reference to temperature, relative humidity and saturation deficit were studied under forest cover and compared with the open shrub-savanna.

-A suitable classification of different vegetation types has been worked out and their distribution shown on a map using the recent remote sensing techniques.

-The structure and/or floristic composition of each evergreen type has been studied. For structure, the height of the stand, height and girth distribution, number and position of the structural ensembles, basal area and biomass, floristic richness and diversity have been considered. Floristic composition is given according to habitat preference.

-Phytogeographic analysis of all the evergreen species has been made in order to understand their distribution pattern and "vicariant" aspect of a few species worked out.

GEOGRAPHY, GEOLOGY AND SOILS OF THE BILIGIRIRANGAN HILLS: AN OUTLINE

The Biligirirangan hills are located in the south-eastern corner of the Mysore plateau. Their abrupt rise in this corner of the Mysore plateau is reflected in the heterogeneity of the environmental conditions.

I GEOGRAPHY

The Biligirirangan hill range (BRH) is oriented in a north-south direction running through Chamrajnagar, Yellandur and Kollegal taluks of Mysore district in Karnataka and Satyamangalam taluk of Periyar district in Tamil Nadu. The Biligirirangan hill range derives its name from a Hindu temple located in the northern part of the range in Karnataka State.

The study site is situated between 11°40'-12°09' N latitude and 77°05'-77°15' E longitude (Fig.1) covering an area of nearly 450 km² spread over four Reserved Forests (Table 1). Recently the Karnataka Forest Department has declared the area covering the Biligirirangaswamy Temple R.F., Chamrajnagar S.F. and Doddasampige R.F. as "Biligirirangaswamy Temple" (BRT) wild life sanctuary.

Table 1 - Forest administrative divisions

Reserved Forest	Range	Division	State
1. Biligirirangan temple R.F.	Yellandur	Chamrajnagar	Karnataka
2. Chamrajnagar State Forest	Punjur	Chamrajnagar	Karnataka
3. Doddasampige R.F.	Kollegal	Kollegal	Karnataka
4. Guttiyalattur R.F.	Satyamangalam	Satyamangalam	Tamil Nadu

The BRH (mean elevation: 750 m) comprises 2 main ranges:

- the western range which includes many hills with an average elevation of about 1350 m. The terrain is undulating with a network of valleys and slow west flowing streams.

- the eastern range is a chain of hills with an average elevation of about 1650 m

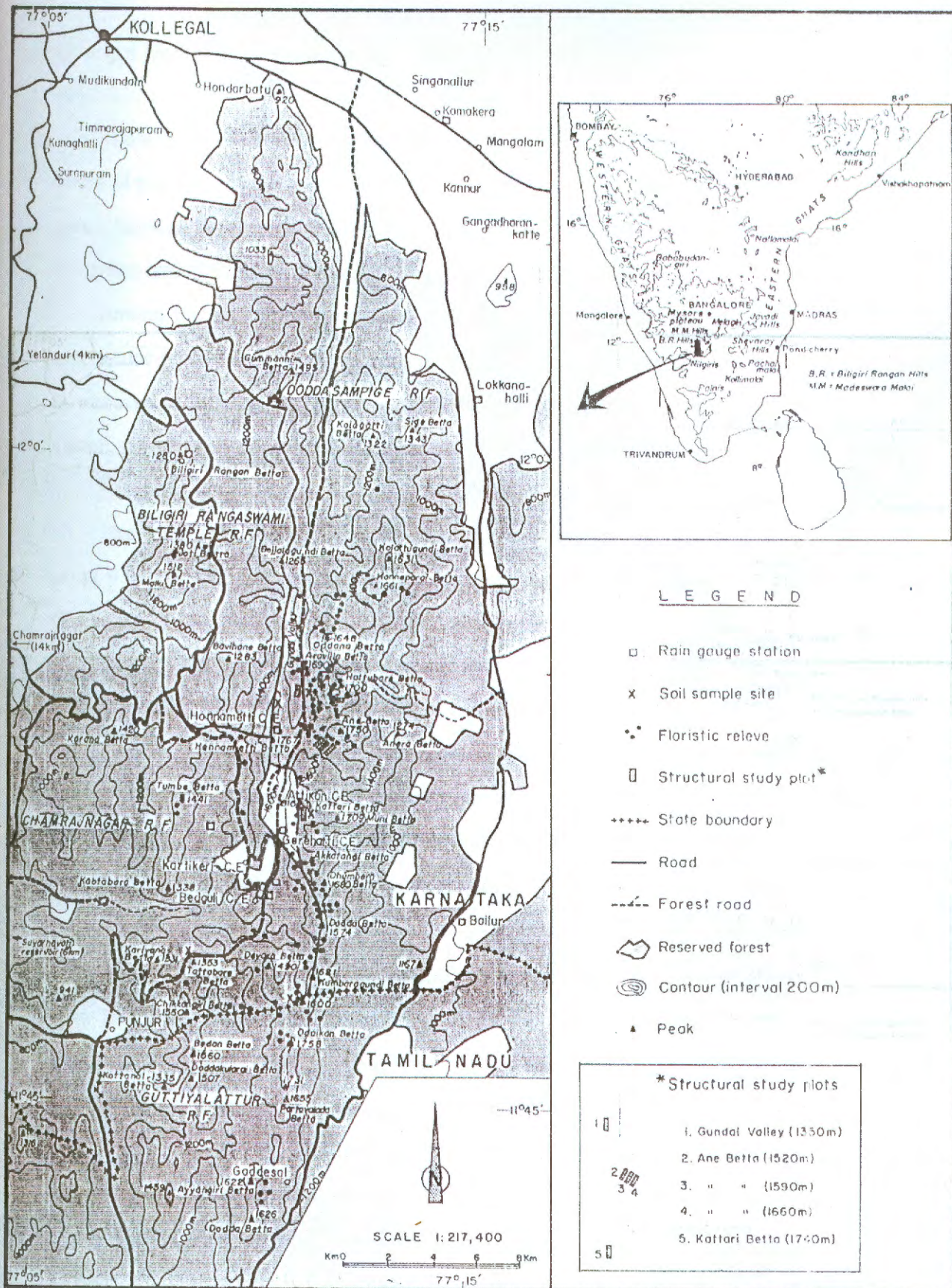


Fig. 1 - Map of the study area

forming a high ridge. The Kattaribetta is the highest peak here attaining a height of 1816 m.

There is yet another peak, Honnamettibetta (1767 m), branching out from the centre of the eastern range and running northwards, forming a central ridge. Gundal valley flanked by the central and eastern ridges provides an ideal habitat for evergreen forests, a sizeable area of which is now under coffee plantations.

Among the important streams to the west of the BRH is the Pangadi stream which later joins the Nirdurgi stream providing a very good water source for the Suvarnavathi reservoir. The Attikan stream flows northwards between the central and eastern ridges and later joins the Gundal stream.

II GEOLOGY

The main rock formation is the Precambrian charnockite, about 2600 million years B.P. It is also the major constituent of the Palnis, the Nilgiris and the Eastern Ghats.

Charnockite is a coarse granular rock mainly composed of quartz, feldspar and hypersthene besides other minerals. It is a metamorphic rock derived from gneiss, formed under great pressure at high temperatures in the presence of CO₂ and water. Like gneiss, charnockite also varies from region to region. The chemical analysis of a charnockite sample from Biligirangan hills conducted by Janardhan *et al.* (1983) indicates: SiO₂ 69.9%; Al₂O₃ 15.1%; TiO₂ 0.41%; FeO(total) 2.36; FeO 1.3%; MgO 1.09%; MnO 0.02%; CaO 3.2%; Na₂O 4.79%; K₂O 1.49%; P₂O₅ 0.08%; CO₂ 0.1%; F 140 ppm; Cl 110 ppm; Sr 440 ppm; Ba 550 ppm; Zr 190 ppm; Cr₂O₃ 290 ppm; Cl 0.1 ppm; Th 1 ppm. Further they showed that these chemical constituents exhibit certain differences compared to the samples in the Nilgiris and other regions.

There are certain outcrops of quartzite and amphibolites between Kumbaragundibetta and Akkatangibetta and traces of amphibolites alone near Kariyanbetta (Bourgeon, *pers.comm.*). These formations are classified under "Sargur group" (formerly under old "Dharwar System") which belongs to Early to Middle Archean 3000 million years B.P. (Swaminathan and Ramakrishnan, 1981).

III SOILS

The parent rock material and climatic factors are important in determining the soil characteristics. Besides climate, the physical and chemical properties of soils also have a role in determining the floristic and structural features of the vegetation.

1 GENERAL PHYSICO-CHEMICAL ASPECTS

Soil samples were collected from six* pedons (Fig.1) at different elevations representing different vegetation types.

The results of the analyses are given in Tables 2, 3, 4 and 5.

1.1 Classification of soils

The classification followed here is the recent U.S. Soil Classification by Soil Survey Staff (1988).

The soil types of the six pedons have been given in Table 2. Soils at pedons 1, 3, 4, 5 and 6 belong to the order Inceptisols and suborder Tropepts (suborder for tropical Inceptisols).

When the upper 10-30 cm layer of soil is dry for more than 3 months, the soil moisture regime is considered as 'Ustic'. The region of the pedons 3, 4, 5 and 6 fall under locally high rainfall zone (1500-1900 mm). However, this region receives very low rainfall during the dry period (January, February and March), but still the soil moisture is more than 15% in the upper 40 cm layer (Table 6) of soil both under shrub savanna and under forest. Under such conditions the soils can be called 'Typic'.

Pedons 4 (under forest cover), 5 and 6 (shrub savanna) at a higher elevation (>1480 m) with base saturation less than 50% and carbon more than 12 kg/m² may be considered as 'Typic Humitropept'.

Pedon 3 at medium elevation (1350 m) and under forest cover shows a base saturation of more than 50% and can therefore be considered as 'Typic Eutropept'.

In pedon 1 (1200 m-tree savanna) which is in a comparatively drier region, soils are less weathered and can be called 'Lithic Ustropept'.

* A pedon is a three-dimensional body of soil that has lateral dimensions large enough to include representative variations in the shape and relation of horizons and in composition of soil (Soil Survey Staff, 1975).

Pedon 2 (1200 m - savanna-woodland) which has a clayey horizon with a base saturation of more than 50% can be classified under the order Alfisol and suborder Udalf. It can be called Haplustalf based on the colour combination.

Table 2 - Types of soils at six pedons

ORDER	SUBORDER	GREAT GROUPS <i>(according to soil moisture regime)</i>
Inceptisol	Tropept	Typic Humitropept (pedons 4, 5 & 6) Typic Eutropept (pedon 3) Lithic Ustropept (pedon 1)
Alfisols	Udalf	Haplustalf (pedon 2)

Except in pedon 1, soils in all the other pedons show strong weathering of parent material into kaolinite and sometimes even a little gibbsite. This is indicated by the $\text{SiO}_2:\text{Al}_2\text{O}_3$ ratio which is less than 2 or a little more. Pedon 1 represents less weathered soils; however, its $\text{SiO}_2:\text{Al}_2\text{O}_3$ ratio is very low (1.11 molecular) except in the top soils. This low value may be due to the presence of chlorites and not gibbsite in the clay.

1.2 Soil texture

The textural triangle (Soil Survey Staff, 1951) has been used to determine the soil texture based on the percentages of sand, silt and clay.

In pedons 1 and 2, the soil texture varies from clay to clay loam or sandy clay loam. Pedon 3 is rich in clay 10 cm below the surface. Pedon 4 has clay loam throughout the profile. Pedons 5 and 6 are dominated by sandy loam and sandy clay loam respectively.

1.3 Fertility

Fertility depends mainly on the pH and degree of base saturation (S/T). Among the exchangeable bases calcium and magnesium are important. Low calcium content is associated with acid characteristics and vice-versa. Thus excessive leaching of these elements lowers the pH of the soil (Dutil, 1982).

Table 3 - Soil analysis of pedons 1 and 2

	PEDON 1 (1140 m) <i>Tree savanna</i>		PEDON 2 (1200 m) <i>Savanna-woodland</i>		
Profile (cm)	0-25	-60-	0-30	-80-	-130-
Gravel (%)	17	-	28	46	72
pH					
H ₂ O	6.48	6.35	6.18	5.96	6.18
KCl	5.75	5.60	5.40	5.33	5.36
Granulometry					
Coarse sand (%)	21.4	34.4	31.0	26.1	32.3
Fine sand (%)	12.1	14.3	12.2	10.8	12.2
Coarse silt (%)	7.4	7.8	5.6	5.5	5.6
Fine silt (%)	14.9	14.6	15.8	14.5	10.0
Clay (%)	44.2	28.8	35.3	43.1	39.8
Texture type	Clay	Sandy Clay loam	Clay loam	Clay	Sandy clay
Organic material					
Carbon (%)	3.44	0.49	2.68	0.57	0.60
Nitrogen (%)	2.65	0.98	2.38	0.81	0.67
Carbon/Nitrogen	13.0	5.0	11.3	7.0	8.9
Organic matter (%)	5.92	0.84	4.61	0.98	1.03
Exchangeable bases					
Ca (me/100 g)	21.4	5.8	10.7	5.3	6.6
Mg (me/100 g)	6.3	3.5	3.0	1.3	1.5
Na (me/100 g)	0.4	0.6	0.2	0.5	0.5
K (me/100g)	0.2	0.0	0.2	0.0	0.0
S=Σ (me/100 g)	28.3	9.9	14.1	7.1	8.6
Exch. capacity (me/100 g at pH 7)	30.3	12.8	19.2	10.3	12.6
Base saturation	0.93	0.77	0.73	0.69	0.68
Exchangeable acid					
Exch. Al in KCl N (me/100 g)	0.0	0.0	0.0	0.0	0.0
Triacid analysis of Soil					
Fire loss (%)	13.54	12.38	12.49	11.09	12.36
Quartz + insoluble (%)	33.57	27.22	34.89	24.39	23.40
SiO ₂ combined (%)	19.50	17.60	19.95	21.33	17.39
Al ₂ O ₃ (%)	17.39	26.84	18.90	24.95	26.46
Fe ₂ O ₃ (%)	13.87	14.30	12.44	14.30	19.59
TiO ₂ (%)	0.86	0.71	0.86	0.57	1.14
MnO (%)	0.19	0.12	0.17	0.14	0.08
MgO (%)	0.53	0.36	0.31	0.27	0.27
CaO (%)	0.69	0.18	0.38	0.17	0.19
P ₂ O ₅ (%)	0.09	0.09	0.14	0.09	0.12
Total (%)	100.23	99.80	100.53	97.30	101.00
SiO ₂ /Al ₂ O ₃ (molecular)	2.13	1.11	1.79	1.45	1.12

Table 4 - Soil analysis of pedons 3 and 4

Profile (cm)	PEDON 3 (1350 m) <i>Mesua- Palaquium- Olea</i> type				PEDON 4 (1740 m) <i>Lauraceous</i> type		
	0-10	10-40	40-80	80-130	0-8	12-17	45-55
Gravel (%)	45	20	18	22	65	39	63
pH							
H ₂ O	6.45	6.44	6.17	5.82	5.58	4.13	4.02
KCl	5.94	5.71	5.58	5.57	4.88	3.78	3.83
Granulometry							
Coarse sand (%)	34.1	24.0	17.8	22.0	35.6	18.3	18.2
Fine sand (%)	9.3	10.9	11.2	10.0	4.3	7.1	13.7
Coarse silt (%)	4.6	5.0	5.4	4.5	4.0	7.1	10.5
Fine silt (%)	17.7	14.6	12.4	11.6	19.0	38.8	23.0
Clay (%)	34.2	45.4	53.1	51.8	37.1	28.8	34.6
Texture type	Clay loam to Sandy- clay loam	Clay	Clay	Clay	Clay loam	Clay loam	Clay loam
Organic material							
Carbon (%)	5.78	1.71	0.92	0.71	12.1	3.95	3.50
Nitrogen (%)	4.05	1.82	0.76	0.53	8.89	4.35	2.80
Carbon/Nitrogen	14.3	9.4	12.1	13.4	14.5	9.1	12.5
Organic matter (%)	9.94	2.94	1.58	1.22	22.20	6.79	6.02
Exchangeable bases							
Ca (me/100g)	24.1	7.8	6.2	4.8	18.6	0.8	1.3
Mg (me/100g)	3.9	1.8	2.4	2.4	2.5	0.2	0.1
Na (me/100g)	0.1	0.0	0.0	0.0	0.0	0.5	0.0
K (me/100g)	0.1	0.0	0.0	0.0	0.8	0.3	0.2
S=Σ (me/100g)	28.2	9.6	8.6	7.2	21.9	1.8	1.6
Exchange capacity (me/100g at pH 7)	30.2	14.9	13.9	12.1	37.2	20.0	20.5
Base saturation	0.93	0.64	0.62	0.59	0.59	0.09	0.08
Exchangeable acid							
Exch. Al in KCl N (me/100 g)	0.0	0.0	0.0	0.0	0.1	2.8	3.8
Triacid analysis of Soil							
Fire loss (%)	18.79	11.71	11.23	11.30	28.18	15.20	12.70
Quartz + insoluble(%)	35.50	31.59	20.21	17.03	22.67	27.60	24.70
SiO ₂ combined (%)	15.80	19.58	24.46	25.47	14.73	21.61	24.14
Al ₂ O ₃ (%)	14.55	20.41	24.95	26.84	15.12	17.58	20.03
Fe ₂ O ₃ (%)	13.87	14.87	15.30	17.59	13.34	14.30	13.34
TiO ₂ (%)	1.14	1.14	1.07	0.93	1.67	1.85	2.00
MnO (%)	0.15	0.14	0.04	0.03	0.23	0.20	0.12
MgO (%)	0.33	0.29	0.33	0.28	0.71	0.24	0.96
CaO (%)	0.77	0.27	0.19	0.15	0.75	0.24	0.09
P ₂ O ₅ (%)	0.23	0.20	0.17	0.18	0.33	0.27	0.33
Total (%)	101.13	100.20	97.95	99.80	97.73	99.09	98.41
SiO ₂ /Al ₂ O ₃ (molecular)	1.84	1.63	1.67	1.61	1.66	2.09	2.05

Table 5 - Soil analysis of pedons 5 and 6

	PEDON 5 (1480 m) <i>shrub savanna</i>		PEDON 6 (1600 m) <i>shrub savanna</i>				
Profile (cm)	0-25	100	0-25	25-45	45-70	70-110	110-175
Gravel (%)	8	36	17	36	53	24	29
pH							
H ₂ O	4.56	4.89	4.82	4.96	5.15	4.76	5.00
KCl	4.15	4.37	4.29	4.45	4.47	4.21	4.42
Granulometry							
Coarse sand (%)	26.9	39.1	33.8	29.9	31.5	36.0	32.9
Fine sand (%)	16.6	20.7	12.9	14.3	19.4	18.2	20.6
Coarse silt (%)°	6.6	9.6	4.8	7.8	9.2	6.5	7.4
Fine silt (%)	19.0	17.8	16.8	27.7	19.1	14.5	14.5
Clay (%)	30.8	12.8	31.6	20.2	20.8	24.7	24.6
Texture type	Clay loam	Sandy loam	Sandy clay loam	Loam	Sandy clay loam	Sandy clay loam	Sandy clay loam
Organic material							
Carbon (%)	5.90	1.15	7.74	2.83	1.15	0.60	0.49
Nitrogen (%)	3.91	0.81	4.82	2.23	1.16	0.39	0.32
Carbon/Nitrogen	15.1	14.2	16.0	12.7	9.9	15.4	15.3
Organic matter (%)	10.15	1.98	13.31	4.87	1.98	1.03	0.84
Exchangeable bases							
Ca (me/100g)	1.3	0.2	0.9	0.2	0.2	0.1	0.2
Mg (me/100g)	0.5	0.1	0.4	0.1	0.0	0.0	0.1
Na (me/100g)	0.0	0.0	0.0	0.3	0.2	0.0	0.0
K (me/100g)	0.0	0.0	0.2	0.0	0.0	0.0	0.0
S=Σ (me/100g)	1.8	0.3	1.5	0.6	0.4	0.1	0.3
Exchange capacity(me/100g at pH 7)	28.4	14.3	4.6	15.8	13.3	8.2	5.1
Ratio of saturation	0.06	0.02	0.33	0.04	0.03	0.01	0.06
Exchangeable acid							
Exch. Al in KCl N (me/100g)	4.0	2.1	3.0	1.7	2.0	1.7	0.4
Triacid analysis of soil							
Fire loss %	16.38	8.20	21.24	14.26	11.73	12.50	13.87
Quartz + insoluble %	49.25	47.32	40.32	40.57	40.19	38.80	33.07
SiO ₂ combined %	13.72	17.74	13.13	15.13	15.44	12.83	13.16
Al ₂ O ₃ %	12.28	15.12	15.69	20.03	21.54	26.84	29.86
Fe ₂ O ₃ %	6.48	9.72	6.72	8.58	8.15	6.15	7.58
TiO ₂ %	0.93	0.64	1.14	0.86	0.86	1.00	0.86
MnO %	0.02	0.02	0.06	0.07	0.06	0.02	0.03
MgO %	0.49	0.52	0.49	0.58	0.66	0.49	0.22
CaO %	0.14	0.27	0.10	0.06	0.05	0.03	0.01
P ₂ O ₅ %	0.16	0.12	0.15	0.15	0.21	0.21	0.17
Total %	99.85	99.67	99.04	100.29	98.89	98.87	98.83
SiO ₂ /Al ₂ O ₃ (molecular)	1.90	1.99	1.42	1.28	1.22	0.81	0.75

- In pedons 1, 2 and 3 which are at medium elevations (1140-1350 m), the pH (H₂O) is nearly 6 or more and base saturation is rather high: >60%. Among exchangeable bases, calcium and magnesium are significant and even higher compared to the other 3 pedons. Small amounts of potassium present only in the top soils is linked to the considerable amount of organic matter. In pedon 3 sodium is present only in the top soils.

- In pedons 4, 5 and 6 which are at high elevations (1480-1740 m), the pH is less, or slightly higher, than 5. The exchangeable bases and base saturation are also very low except in the top soils of pedon 4.

It is interesting to note that the high percentage of organic matter throughout the profile of pedon 4 is mainly responsible for the high exchange capacity of the soils (20-37 me/100g). The presence of potassium throughout the profile, unlike in the other pedons, is also due to the accumulation of organic matter.

1.4 Toxicity

The presence of exchangeable aluminium in pedons 4, 5 and 6, mostly as a result of desaturation¹, further reduces soil fertility. In pedons 5 and 6 which bear *shrub savanna*, the exchangeable aluminium is high in the top soils (3-4 me/100g) but decreases in the lower layers of the profile. It is the reverse in pedon 4 (Lauraceous forest), where the value of exchangeable aluminium in the top soil is low, mostly due to the abundant organic matter provided by the forest.

Although phytotoxicity of aluminium is not proved in the majority of plants, excess aluminium causes a reduction in the growth of many plant species, principally by its effect on root growth. Coppenet and Juste (1982) have indicated that the threshold of aluminium toxicity varies depending upon the amount of organic matter present in the soil. This threshold is higher in soils rich in organic matter.

Studies carried out in the African savannas by Sanford and Wangeri (1985) revealed that many sedges and grasses can resist the toxicity of aluminium by

¹ Soils are called desaturated, when acidic elements like H⁺, Al⁺⁺⁺, Mn⁺⁺ occupy the exchangeable sites of the exchange complex. In other words the more acidic a soil lower is the percentage of basic cation saturation.

associating themselves with mycorrhizae which can absorb the excess aluminium. Medeiros and Haridasan (1985) have shown that certain species can accumulate aluminium without affecting other nutrient budget.

1.5 Conclusion

The uplands have a cooler climate, sometimes with higher rainfall and have steep slopes which favour leaching. In this type of environment, leaching of micronutrients render the soils infertile which generally have low pH and high exchangeable aluminium. Further, the low rate of litter decomposition limits the input of micronutrients eventually leading to an accumulation of organic matter. Such conditions are also common in the high elevations of the Nilgiris and Palnis (Blasco, 1971).

Bourgeon (*pers. comm.*) is of the view that soils of high elevations function differently from those of low elevations and the difference is reflected in the architecture of forests at low and high elevations. This view is supported by the present study. Pedon 4 which is at a high elevation (1740 m) with infertile soils has low forests with short boled trees less than 15 m in height and multiple twisted branches; on the other hand, pedon 3, at medium elevation (1350 m) has fertile soil and the forest is more than 30 m high with straight boled trees.

2 ORGANIC MATTER CYCLE

In a forest which is undisturbed for several years, one would expect the stock of organic matter in the soils to be maintained at a steady state with the annual input of carbon through litterfall equalling the amount of carbon mineralised annually.

$$L+R= m \times C$$

where L=annual carbon input through litter fall; R=annual carbon input through roots;

m=annual rate of carbon mineralisation; C=total carbon content of the soil

These parameters gives a fair idea of the organic matter turnover.

In the present study, L and R have not been measured. However, litterfall has been measured in many tropical forests. The amount of litter fall varies from one author to another, sometimes at the same elevation with similar ecosystems (12.3 -

15.3t - Laudelout & Meyer, 1964; 6.3 - 7.2t - Mitchell, 1964; 7.2t - Hopkins, 1966; 23.3t - Kira & Shidei, 1967; 12.6t - Bullock, 1973; 5.5t - Blasco & Tassy, 1975; 6.4 - 7.9t - Franken, 1979; 8.7t - Puig, 1979; 3 - 4.2t - Rai, 1981; 8.5t - Pascal, 1984 among others). According to Golley (1983), on an average, tropical forests produce about 5 tons of dry organic matter per hectare per year as the input to the decomposer system, which is much higher than typical temperate forests which is about 1 t/ha/year.

However, the fact remains that litterfall is higher in low elevation forests than in the high elevation forests with obvious differences in the biomass which is higher in the low altitude tall forests. For example, in the sholas of Palni hills at 2100 m, the annual input of dry organic matter from litterfall (L) is 0.55 kg/m^2 (Blasco & Tassy, 1975) whereas in the evergreen forests of Attapadi in the Western Ghats at 900 m, it is 0.85 kg/m^2 (Pascal, 1984).

By extrapolating the above values for the BRH: in medium elevation types, the litterfall may be less than or equal to that of the Western Ghats types; in high altitude types, the litterfall may be less than that of the medium elevation types.

It has also been estimated that the conversion of fresh organic matter to humus occurs at a rate ranging from 30 to 50% per year (Golley, 1983). According to Schlesinger (1977), the organic carbon in tropical forest soils average 10.4 kg C/m^2 , the range of variation being 3.7 to 20.5 kg C/m^2 , while the temperate forests average 11.8 kg C/m^2 ($5.6 - 24 \text{ kg C/m}^2$).

2.1 Estimation of Carbon (C)

The carbon content in the soil upto a depth of 1.2 to 1.3 m has been measured in two different evergreen forest types in the BRH: one in the *Mesua-Palaquium-Olea* type at 1350 m and the other in the Lauraceous type at 1740 m. The results are given in Table 6 along with a comparison of the carbon content in the soils of three evergreen forests of low elevations (from 100-800 m) of the Western Ghats (data from Ferry, *pers. comm.*).

Table 6 - Carbon content in 5 soil profiles of the BRH and the Western Ghats

		Depth (cm)	Thickness (cm)	Carbon (%)	Density g/cm ³	Carbon kg/cm ²	Average Temp at 1m depth (°C)
Billigirangan Hills	Lauraceous type (1740 m)	0-20	20	8.24	0.65	8.4	18
		20-40	20	3.75	0.90	5.7	
		40-60	20	3.01	1.00	4.0	
		60-80	20	1.32	1.00	2.5	
		80-100	20	0.80	1.00	1.6	
		100-120	20	0.71	1.20	1.7	
		Σ:0-120	120				
Mesua-Palaquium-Olea type (1350 m)	0-10	10	5.78	0.90	3.8	19.5	
	10-40	30	1.71	1.15	5.2		
	40-80	40	0.92	1.30	4.2		
	80-130	50	0.71	1.30	3.9		
	Σ:0-130	130					17.1
Western Ghats	Uppangala 1 (850 m)	0-7	7	5.20	1.12	3.9	21.5
		7-23	16	1.73	1.14	3.0	
		23-97	74	0.81	1.14	5.6	
		97-127	30	0.47	1.14	1.6	
		Σ:0-127	127				
Uppangala 2 (450 m)	0-19	19	3.75	1.11	5.2	22.5	
	19-39	20	1.87	1.13	1.8		
	39-92	53	0.95	1.14	3.6		
	92-125	33	0.31	1.27	1.2		
	Σ:0-125	125					11.8
Makut (240 m)	0-13	13	3.08	1.09	3.2	24	
	13-90	77	1.45	1.09	5.9		
	90-120	30	0.57	1.09	1.7		
	Σ:0-120	120					10.8

The parent rock in all these forests is charnockite, sometimes with gneiss as in Uppangala forest. Soil temperature at 1 m depth was measured in April in all these forests. The values obtained indicate a decrease in temperature with increase in altitude. Ferry (*pers. comm.*) further observed that biological decomposers such as earthworms, termites and fungi are active in the Western Ghats forests and in the *Mesua-Palaquium-Olea* type in BRH, particularly during the wet season, whereas in the Lauraceous forest (1740 m) of BRH, termites are absent but the other two are abundant.

There is a marked difference in the carbon content of the *Lauraceous* type (23.9 kg C/m²) and the *Mesua - Palaquium - Olea* type (17.1 kg C/m²) in the BRH. The difference between the latter type and the low elevation forests of the Western Ghats (10.8-14.1 kg C/m²) is also significant.

2.2 Conclusion

Despite the lack of precise data for all the terms of the carbon budget, the above analysis clearly indicates a gradient in the annual rate of carbon mineralisation. Carbon mineralisation is slightly higher in the low elevation (200-850 m) evergreen forests of the Western Ghats than in the *Mesua - Palaquium - Olea* type of medium elevation (1350 m) and more than 50% higher when compared to the high elevation Lauraceous forest (1740 m).

Temperature is one of the prime controllers of decomposition processes (Golley, 1983), playing an important role in the activity of biological decomposers. The difference in the carbon content of the low elevation Western Ghats forests and *Mesua-Palaquium-Olea* type of BRH can be attributed to the difference in soil temperatures, which varies from 4 to 5°C. Although the difference in soil temperature between the *Mesua-Palaquium-Olea* type and Lauraceous type is 2°C, the absence of termites and other factors such as soil acidity and chemical composition of the litter, especially of Lauraceae members, is probably responsible for the low decomposition in the latter type.

3 SOIL MOISTURE

The effectiveness of rainfall in promoting plant growth depends on how much of it reaches the soil mass occupied by roots and the amount that can be stored there. This in turn depends on many factors including the seasonal rainfall distribution, topography, soil texture, amount of evaporation and the type of plant cover (Kramer, 1949).

The study area receives considerable rainfall between April and part of December, while January, February and March are relatively drier months. In order to assess the moisture status of the soil at the end of the dry period (end of March), 3 additional pedons labelled A, B, C in Table 7 were studied in the same sites as those of pedons 3, 4 and 6 (Tables 4 and 5).

Soil samples were collected on 26th March 1987. Honnametti raingauge station, which is in the vicinity of the sites of these 3 pedons, recorded only 4 mm on 12th January and 10 mm on 15th March, 1987.

3.1 Methodology

The soil moisture was determined on weight basis. Soil samples were collected at intervals of 10 cm depth (up to 120 cm inside forests and up to 100 cm in open shrub savanna), tightly closed in plastic bags and then weighed. The soil samples were then taken out of the bags and dried in an oven at 105°C and reweighed. The difference in weights represents the moisture content.

Table 7 - Soil moisture at the end of the dry period (March) in pedons A, B and C.

	Depth (cm)	Gravel (%)	Moisture (%)
Pedon A (<i>Mesua - Palaquium - Olea</i> type)	0-20	59.6	15.1
	20-40	37.5	14.8
	40-60	18.6	17.5
	60-80	32.0	16.6
	80-100	4.02	20.5
	100-120	4.1	23.0
Pedon B (Lauraceous type)	0-20	46.3	19.9
	20-40	28.1	24.0
	40-60	50.5	15.4
	60-80	12.8	19.7
	80-100	3.9	15.8
	100-120	0	12.9
Pedon C (<i>shrub savanna</i>)	0-20	3.6	23.9
	20-40	20.5	16.9
	40-60	24.8	14.1
	60-80	21.8	16.1
	80-100	4.75	21.4

3.2 Results

Three soil profiles were studied at each site. Their median values are used for comparison of the three sites (Table 7 and Fig. 2).

Since gravels are inert particles with regard to water, their percentage in each sample was determined. In other soils the water holding capacity is mostly dependent on the soil texture, organic matter and other physical properties.

The soil texture of the site of pedon A (*i.e.*, pedon 3 of Table 4) is clayey whereas that of pedon B (pedon 4, Table 4) is clay loam with a significant amount of organic matter. The texture of the site of pedon C (pedon 6, Table 5), which represents shrub savanna, is sandy clay loam.

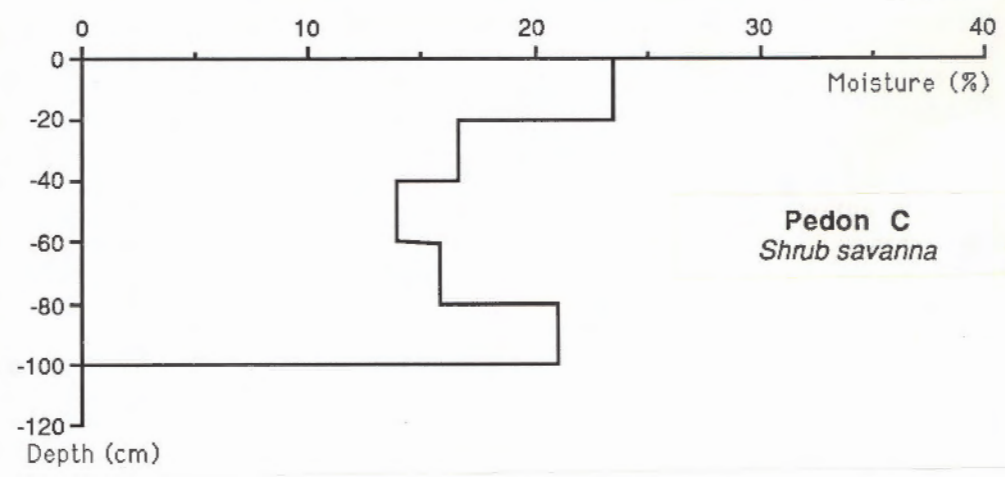
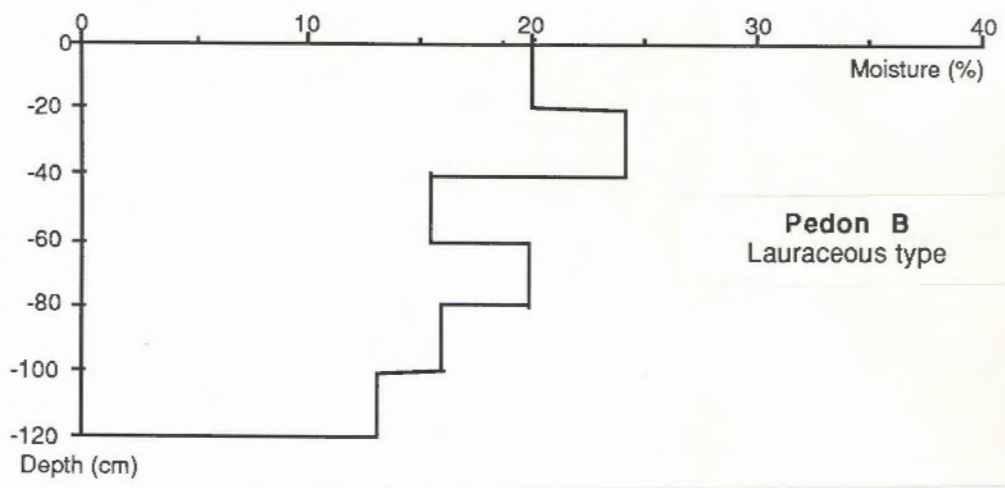
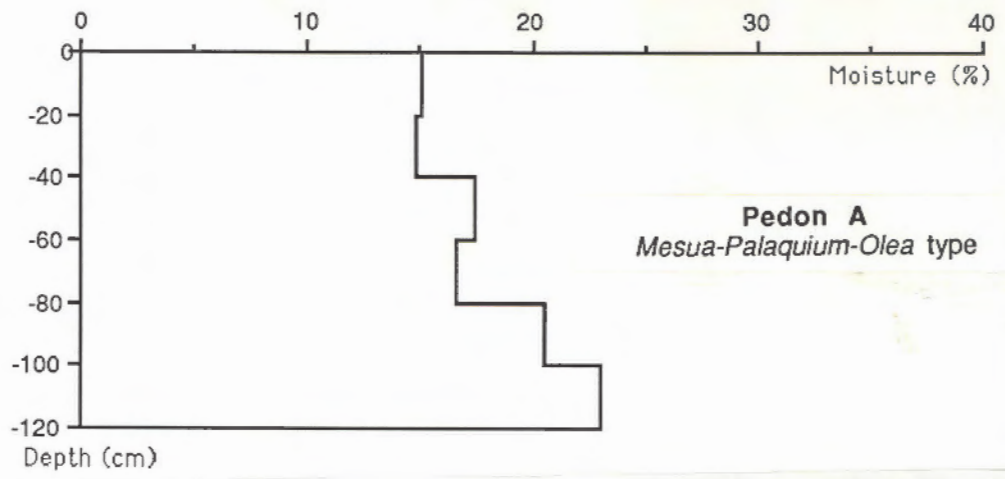


Fig. 2 - Soil moisture content at the end of the dry period (March) in pedons A, B and C

Pedons A and B (Table 7) which are under forest cover show significant amounts of gravel in the upper 80 cm of the horizon. The soil moisture content in pedon A (in the *Mesua-Palaquium-Olea* forest type) is about 15% in the upper 40 cm and gradually increases towards the base of the profile, attaining 23% at 100-120 cm. In pedon B (in the Lauraceous forest type), this pattern is generally the reverse of pedon A. The upper 40 cm comprises 20 to 24% moisture, gradually decreasing to 13% at 100-120 cm depth. The abrupt decline in the moisture level at 40-60 cm depth is mainly due to the presence of over 50% gravel in the sample. Although gravel is absent in the lowermost 20 cm layer, the moisture content is lowest with 13%. Here the soil is slightly hard, probably representing the last stage in the weathering of the parent rock material.

In pedon C (open shrub savanna) the percentage of gravel is very low (less than 5%) in the uppermost and lowermost layers, while the moisture content is very high : 21.4 and 24%, respectively. The middle layers with a higher percentage of gravel (20.5 to 24.8%), have a lower percentage of moisture (14.1 to 16.9%).

3.3. Conclusion

Sandy soils are inert, loose and not cohesive with very low water holding capacity. On the other hand clayey soils are colloidal with a much higher water holding capacity. Loamy soils contain more or less equal amounts of sand and clay or clay and silt and can hold more available water than sand and are better aerated than clay (Kramer, 1949).

The tendency of soil moisture to increase with depth in pedon A (Table 7 and Fig. 2) may be correlated with a concomitant increase in the proportion of clay (pedon 3, Table 4). On the other hand the decrease in soil moisture with depth observed in pedon B (Table 7 and Fig. 2) corresponds to the declining values of organic matter (pedon 5, Table 3).

THE CLIMATE

Climate plays a major role in determining the types of vegetation. In the study area only rainfall data is available at the regional level. Although some data on temperature is available in coffee estates, they are mostly of room temperatures and hence have not been taken into consideration in the present study. However, temperature and relative humidity can be easily studied in the field; they have been measured both under forest cover as well as in open area.

1 RAINFALL

Rainfall in the study area owes its origin to three important meteorological phenomena:

-the south-west monsoon linked to the arrival of moisture laden south-westerly winds from the Arabian Sea. These rains affect a major part of the Indian subcontinent.

-Rainfall resulting from thermic ascending convection accompanied by high atmospheric humidity. They are linked to the zenithal passage of the sun.

-Rainfall from cyclones or depressions formed in the Bay of Bengal after the withdrawal of the south-west monsoon.

1.1 Location of raingauge stations

Rainfall data have been obtained from private Coffee Estates, Forest Department, Public Works Department and Sericulture Department. Fig. 3 shows the location of raingauge stations in the BRH and the surrounding plateau. In the BRH there are 6 raingauge stations, situated between 1220 and 1750 m elevation. They are not uniformly distributed. Gaddesa! and B.R. Hills meteorological stations represent the southern and the northern extremes, respectively. Kartikere, Gorehatti, Attikan and Honnametti are in the central region, located within 7 km from each other.

Seven other stations near the study area were selected to compare the rainfall pattern with the surrounding plateau. They are located between 694 and 1100 m altitude.

The data period studied is not uniform. For the stations on the plateau the period

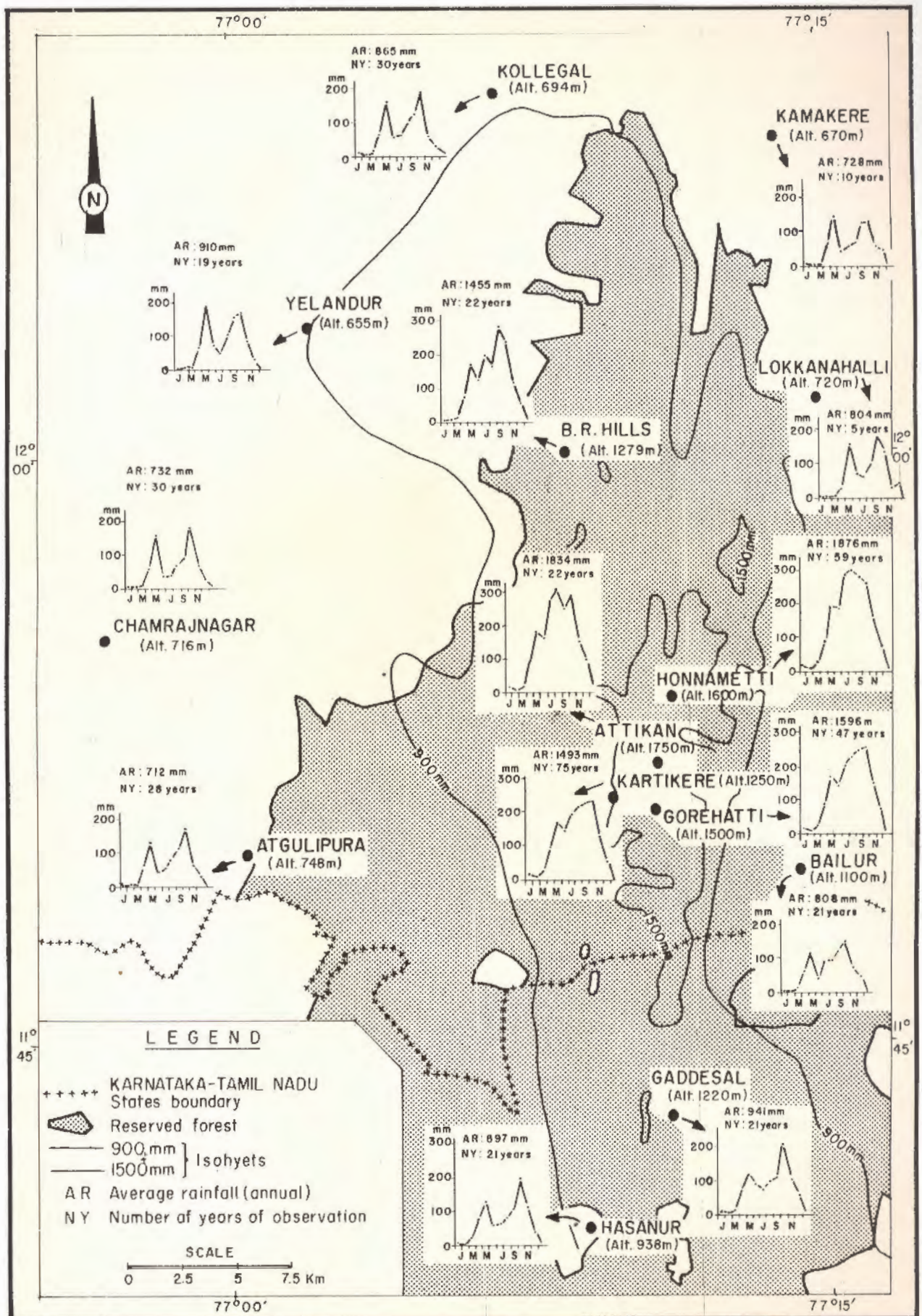


Fig. 3 - Average annual rainfall

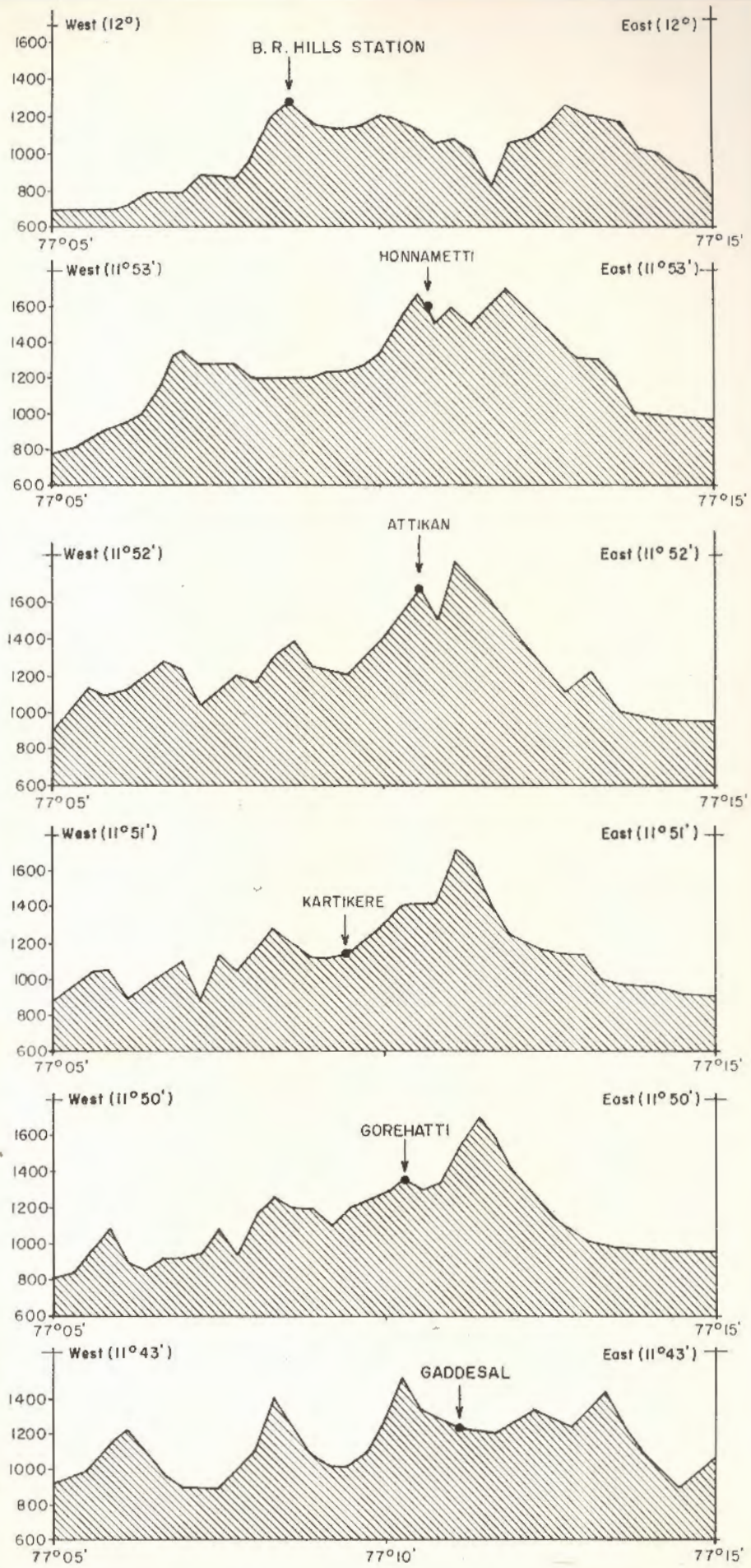


Fig. 4 - Location of rain gauge stations across the east-west oriented hills

of observation varies from 19 to 34 years, exceptions being Kamakere (10 years) and Lokkanahalli (5 years). Despite this inconsistency, the main rainfall pattern does not show much variation.

Since rainfall is more variable in the hilly terrain, it would be worth considering long term data. For Kartikere, Gorehatti and Honnametti, data is available for 47 to 75 years but only 21 to 22 years for Gaddesal, Attikan and B.R. Hills meteorological stations.

1.2 Annual rainfall

The average annual rainfall over the BRH and the surrounding plateau is shown in Fig. 3. The most conspicuous feature is the general increase in annual rainfall in the BRH as compared to the surrounding plateau.

The stations on the plateau lying between 650 and 1100 m receive an annual rainfall of 700-950 mm. In all other stations the rainfall curve shows 2 peaks, one in May and another in September or October.

In the BRH the rainfall distribution pattern varies according to the local topography and exposure. Fig. 4 shows the location of the stations across the east-west oriented hills.

Gaddesal (1220 m) which lies on the eastern slope of the BRH receives only 941 mm and the rainfall pattern is more or less the same as that of the other stations of the plateau, except that it is a little more pronounced in October. However, the other stations of the BRH have the advantage of westerly exposure and higher elevation and consequently show a sharp increase in the amount of rainfall.

The middle part of the BRH comprising many closely placed high peaks (1600-1800 m) exerts orographic influence as may be seen in the centrally located stations. Gorehatti at an elevation of 1360 m receives rainfall of 1596 mm, almost 100 mm more than Kartikere (1493 mm) located at 1200 m. However, the rainfall pattern for both the stations remains the same, with peaks in May and October. Honnametti and Attikan which are situated above 1600 m receive conspicuously higher rainfall: >1800 mm. The rainfall curves of both these stations show more or less the same pattern except that the peak in October at Attikan may be due to the lesser rainfall in

September. October rainfall is more or less same at Honnametti and Attikan. It is interesting to note that whereas the rainfall curve from July to September-October shows a gradual rise in Kartikere and Gorehatti, in Honnametti and Attikan the curve rises abruptly from June to July, followed by maximum rainfall in August, which pattern is typical of the south-west monsoon regime.

A comparison between the B.R.Hillsw meteorological station (1270 m) in the northern part of the studied area and Kartikere located southwards at almost the same altitude (1250 m) is revealing. While the amount of rainfall is more or less the same in both (1455 mm and 1493 mm, respectively), the rainfall curves are different. In Kartikere the curve shows two peaks, one in May and the other in October, the B.R. Hills station shows a peculiar curve with three peaks in an ascending order of rainfall amount: the first peak in May (173 mm), the second in July (196 mm) and the third in September (281 mm).

Isohyets for 900 mm and 1500 mm rainfall have been drawn based on the rainfall data of the available stations and also taking into consideration the altitude and the exposure. Stations with similar rainfall distribution (Fig. 3) Kollegal, Yellandur, Hasanur and Gaddesal stations between 650 and 1220 m have served as connecting points for the 900 mm isohyet. The 1500 mm isohyet based on the data of B.R. Hills meteorological station and Kartikere station would run more or less between 1200 and 1400 m contour lines along the western side of the BRH. However, this interpretation for 1500 mm isohyet may not hold good for the eastern slope of the BRH, where the rainfall is comparatively low (940 mm) even at 1200 m (Gaddesal). The 1500 mm isohyet for this eastern slope would follow a higher altitudinal contour of around 1500 m. This assumption is based on the fact that the eastern flank of the BRH would be more or less similar to the eastern and north-eastern slopes of the Nilgiris for which data have been given by Von Lengerke (1977).

1.3 Seasonal rainfall

Rainfall is the result of three important meteorological phenomena. The south-west monsoon brings rains from late May to mid-October. The depressions and cyclones originating in the Bay of Bengal during the prevalence of the north-east wind

system are responsible for the rains from mid-October to mid-January. Finally, convection processes are also capable of producing rains in the hot pre-monsoon season. The seasonal variations in rainfall depend on the geographic and topographic locations of the stations vis a vis the above mentioned phenomena.

Fig. 5 shows the season-wise rainfall distribution pattern. May, October and December which are transitional months between the different seasons are highlighted by different bands.

April-May

Rainfall during these two months is generally related to local convection. The amount of rainfall during May is higher than during April. The second half of May marks the transition towards the south-west monsoon season; local convection, operating with high atmospheric moisture brings rain.

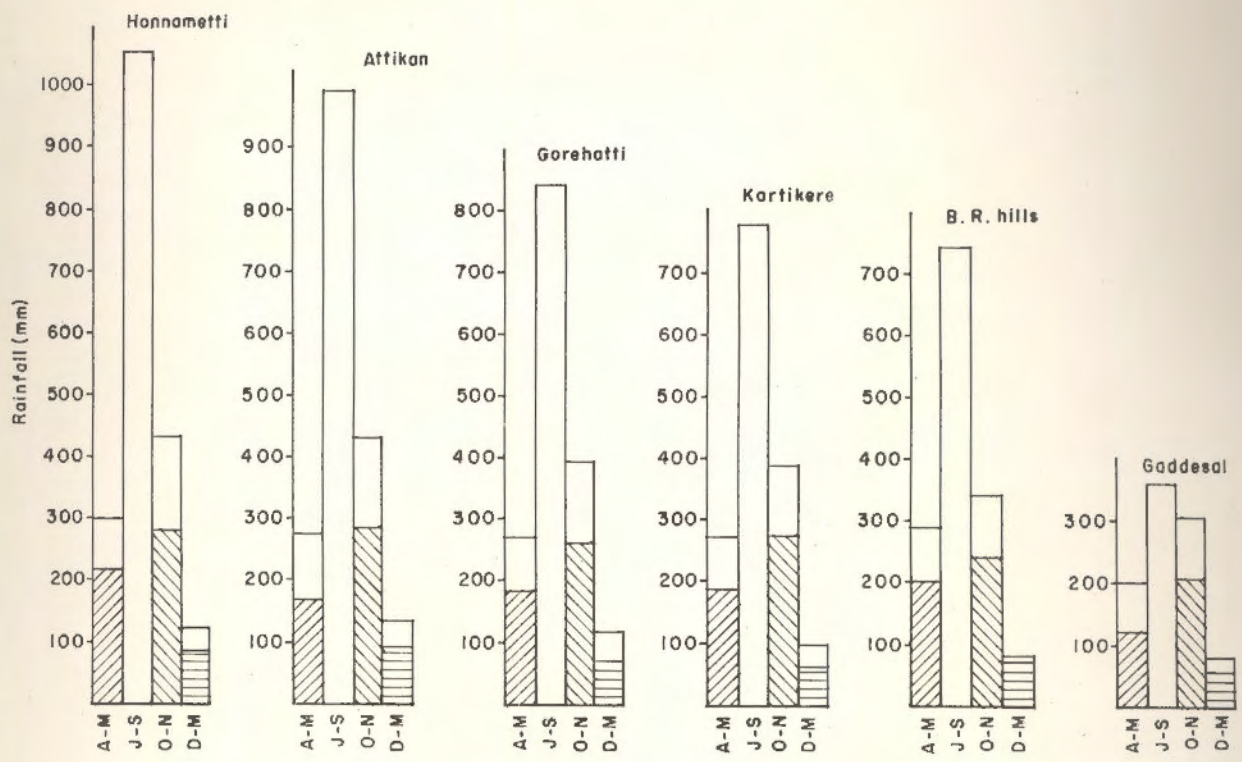
In the BRH rainfall during April-May ranges between 200-300 mm, accounting for 15-21% of the total rainfall, whereas in the surrounding plateau, it is between 180-220 mm during these two months *i.e.*, 22-30% of the total rainfall.

June-September

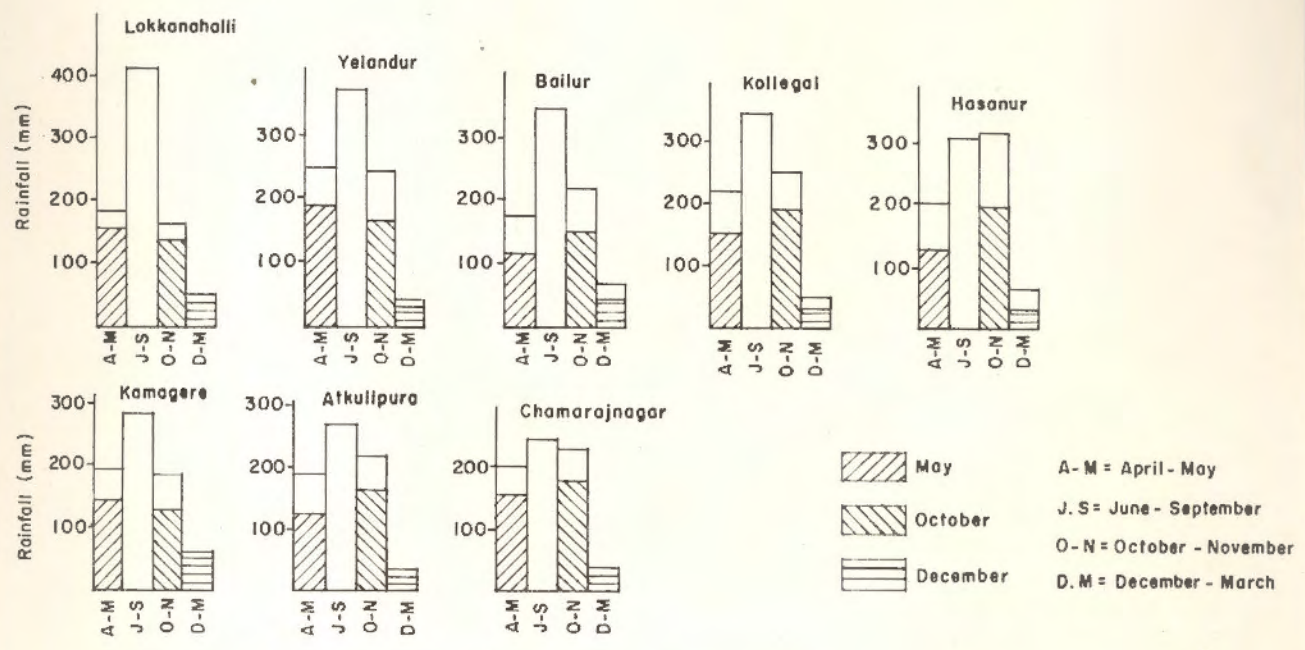
The South-West monsoon which begins towards the end of May or first week of June in Southern Kerala brings heavy rains on the windward side of the Western Ghats. As a rule there is a sharp decrease in rainfall towards the East and North-East crest of the Western Ghats, except for some highrising hills inducing orographic rainfall. This is depicted in Fig. 6 which represents a SSW-NNE oriented transect across the West coast, Western Ghats, Nilgiris, Mysore plateau and the BRH extending from 10°35'N to 12°13'N and from 76°00'E to 77°28'E

As already indicated in the annual rainfall pattern (Fig. 3), it is the South-West monsoon period which brings about the greatest contrast between the rainfall quantum on the plateau and the BRH.

Among the stations in the BRH, Gorehatti, Attikan and Honnametti receive as much as 840-1500 mm (52-54% of the total) during the S.W. monsoon. Kartikere and B.R. Hills meteorological station receive around 51% of the total rainfall. However, Gaddesal on the leeward side receives only 360 mm (38%).



A: Stations in the B.R.H



B: Stations in the surrounding plateau

Fig. 5 - Average seasonal rainfall

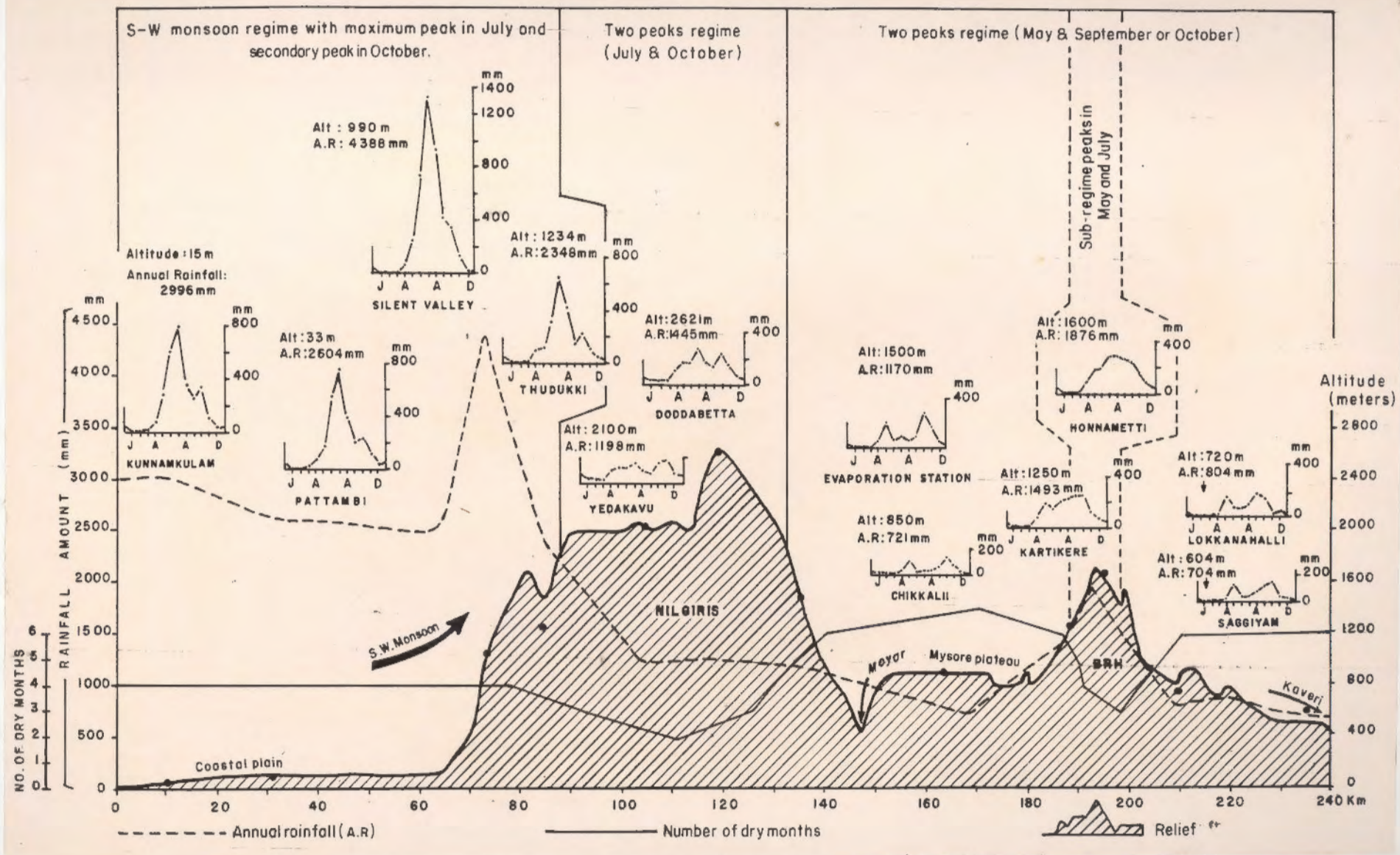


Fig. 6 - A SSW-NNE Climate transect of the coastal plain, the Western Ghats, the Nilgiris and Biligirirangan Hi (data based on Pacal, 1982)

The surrounding plateau receives 230-400 mm (32 to 43%) during June - September, the sole exception being Lokkanhalli (51%) for which data is available for five years only.

October-November

Rainfall during this period, particularly in October, is associated with different climatic phenomena such as the withdrawal of the S.W. monsoon, onset of the N.E. monsoon and local convection. In November, the depressions and cyclones originating in the Bay of Bengal bring considerable rain to southern India. Spatial differentiation of rainfall during this period among the stations on the plateau and the BRH is relatively small: BRH receives 300-430 mm accounting for 23% (except Gaddesal 33%) of the total rainfall. October-November rainfall in the stations on the plateau ranges from 160 to 315 mm (30% of the total). Thus the contribution of the October-November rains to the total is on the whole greater in the stations on the plateau than in those of the BRH.

October receives higher rainfall compared to November.

December-March

This period is characterised by extremely low rainfall both in the BRH (80-120 mm) and in the surrounding plateau (40-60 mm). December, still being under the influence of depressions and cyclonic disturbances, receives a higher amount of rainfall compared to January-March.

1.4 Rainy days

The frequency and intensity of rains are probably more important than the rainfall amount in accounting for moisture availability. The most common parameter for this is the number of rainy days. A rainy day is defined as one with rainfall of 2.5 mm or more.

The average number of rainy days per year in the BRH and in the surrounding plateau is shown in Fig. 7. It is reminiscent of the spatial difference of rainfall between the plateau and the BRH.

On the plateau the number of rainy days varies from 33 to 61 days.

The BRH stations show a relatively higher number of rainy days except for

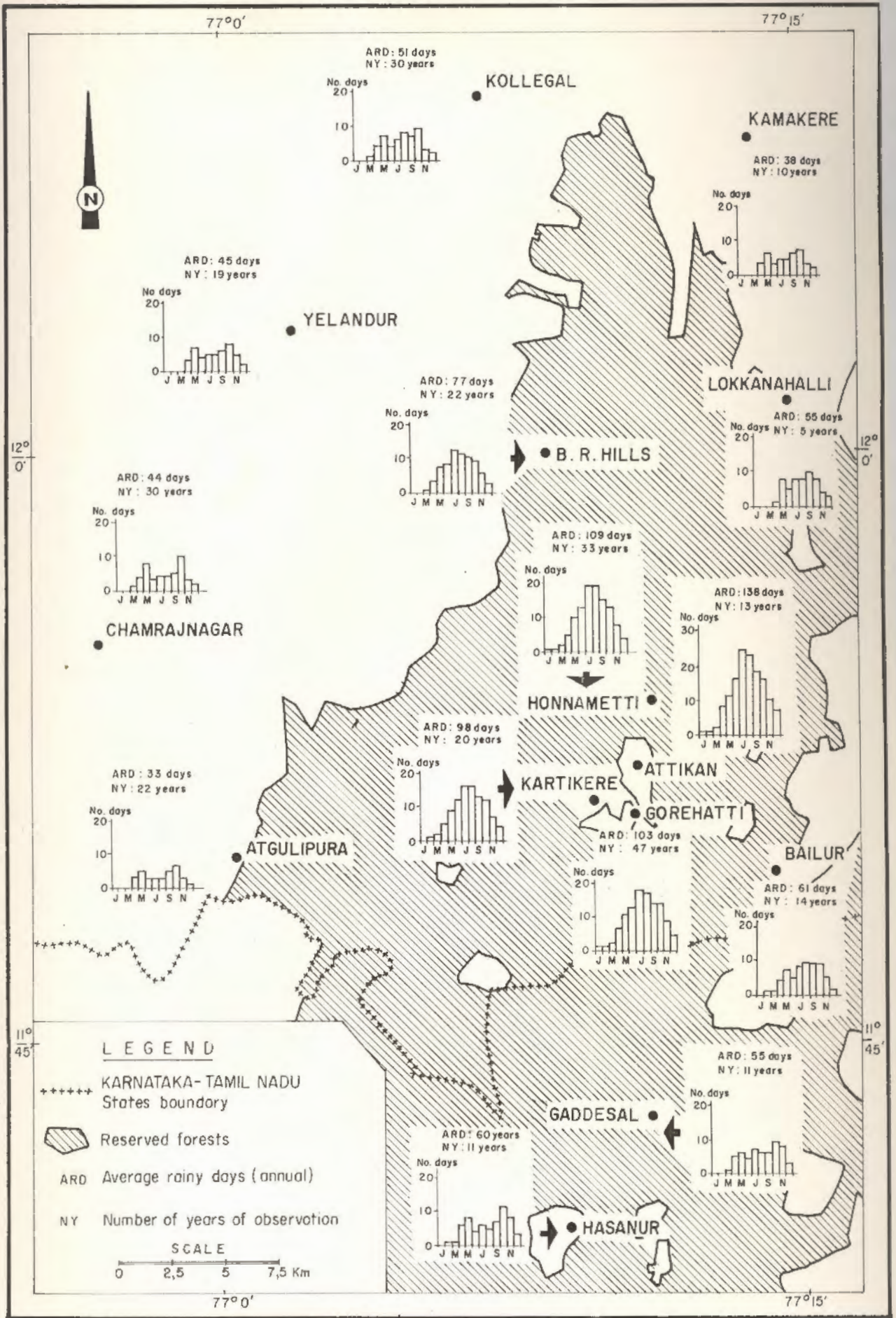


Fig. 7 - Average number of rainy days

Gaddesal (55 days). In the central region, stations with rainfall data of more than 20 years include Kartikere, Gorehatti and Honnametti. They have an average of 98-109 rainy days. In Attikan (data of 13 years), the number of rainy days is 138.

As shown in Fig. 8, the general tendency is towards an increase in the number of rainy days with increase in average rainfall*. The magnitude of the difference in rainy days in the hilly region depends on the topography and exposure. For example, Kartikere and B.R. Hills meteorological stations have more or less the same amount of average rainfall, but the number of rainy days is 98 in the former and 77 in the latter.

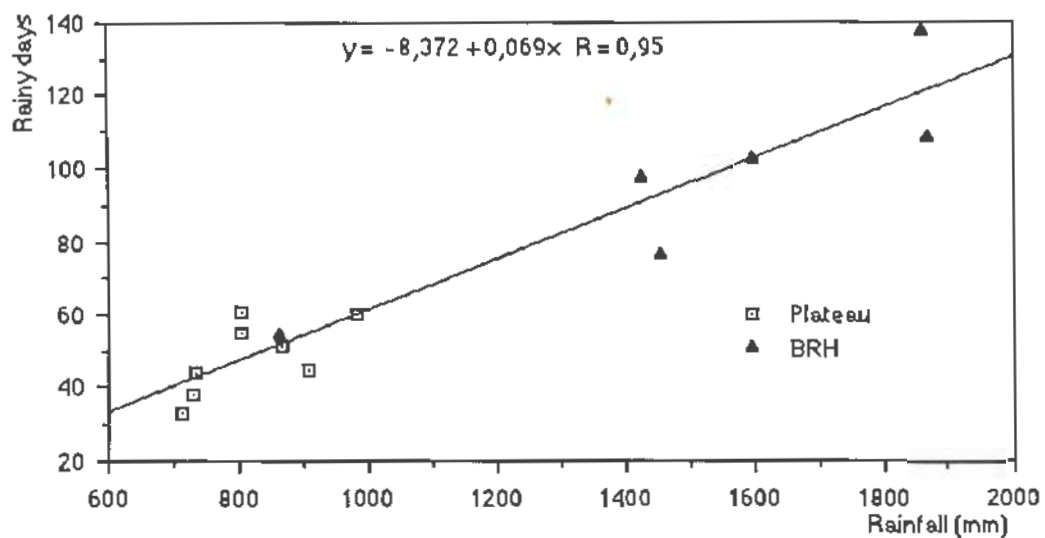


Fig. 8 - Scattergram of average annual rainfall and rainy days

The pattern of rainy days shows a remarkable difference between the BRH and the plateau. The south-west monsoon is responsible for the higher number of rainy days accounting for more than 50% of the total.

In contrast, the number of rainy days in most of the stations in the surrounding plateau is maximum in October, followed by May when convectional rains are generally predominant (Fig. 7).

1.5 Rainfall variability and trends

To assess the rainfall variability and its trend, two statistical parameters are used:

- variability expressed in terms of coefficient of variation

* Average annual rainfall has been calculated for the same years as those taken for average rainy days.

- moving average, which gives an idea of the rainfall trend in time.

1.5.1 Coefficient of variation (C.V.)

Annual

Fig. 9 suggests that high variability is generally associated with low rainfall and vice-versa.

For the five stations located on the BRH, the annual average rainfall varies between 1455 mm and 1867 mm. The coefficient of variation (CV) varies from 16% to 21%.

Gaddesal on the eastern slope has a rainfall of 941 mm with a high C.V. of 34.7%. The stations on the plateau receiving 719 - 910 mm have C.V. values ranging from 21% to 48%.

Seasonal

For C.V., 3 representative stations, 2 from BRH (Honnametti and Kartikere) and one from the plateau (Chamrajnagar) have been considered according to seasons. Fig. 10. shows the season-wise C.V. for all these stations.

In all 3 stations, rainfall variability is the highest during December-March. The C.V. value in Honnametti and Kartikere is 79% and 82%, respectively and in Chamrajnagar it is still higher (116%).

Honnametti and Kartikere, subjected to a more or less regular south-west monsoon during June-September, have C.V. values of 22% each. During the same period, the C.V. in Chamrajnagar is 40% which is similar to the C.V. during October-November.

For the periods April-May and October-November, during which weather conditions favour convectional processes or depressions and cyclonic disturbances, the C.V. ranges from 40 to 46%.

Thus the above analysis clearly indicates the lower variability linked to a more or less regular south-west monsoon, particularly in the BRH stations, while high variability is the result of erratic convectional rainfall or cyclonic disturbances.

1.5.2 Rainfall trend

In order to show the rainfall trend, graphs (Fig. 11) depicting inter-yearly

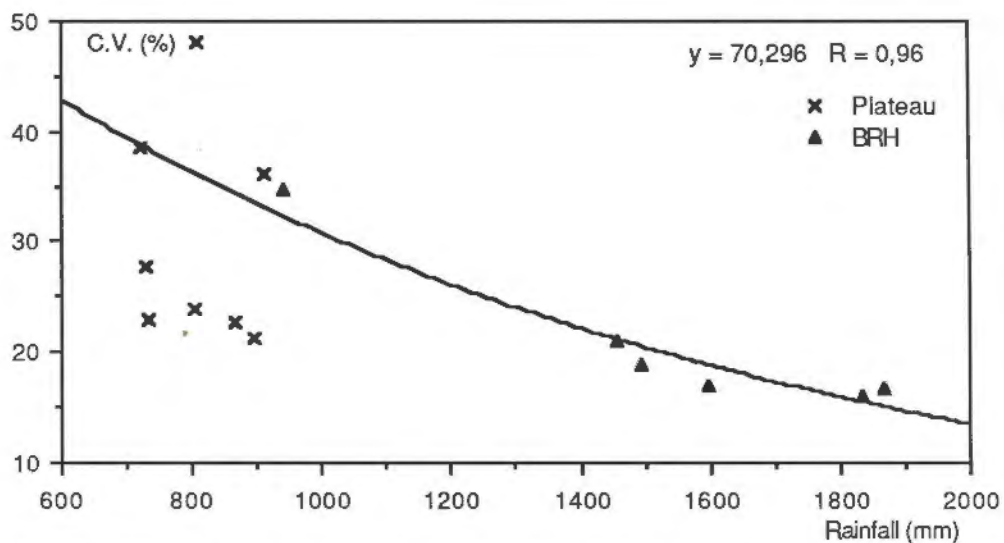


Fig. 9 - Scattergram of averages and coefficients of variation (C.V.) of annual rainfall

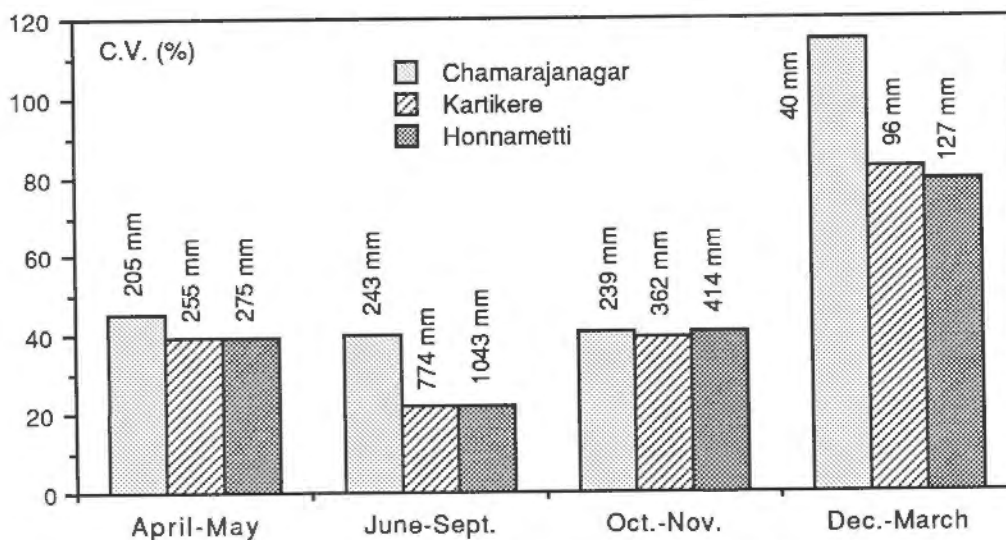


Fig. 10 - Coefficients of variation of seasonal rainfall in three stations

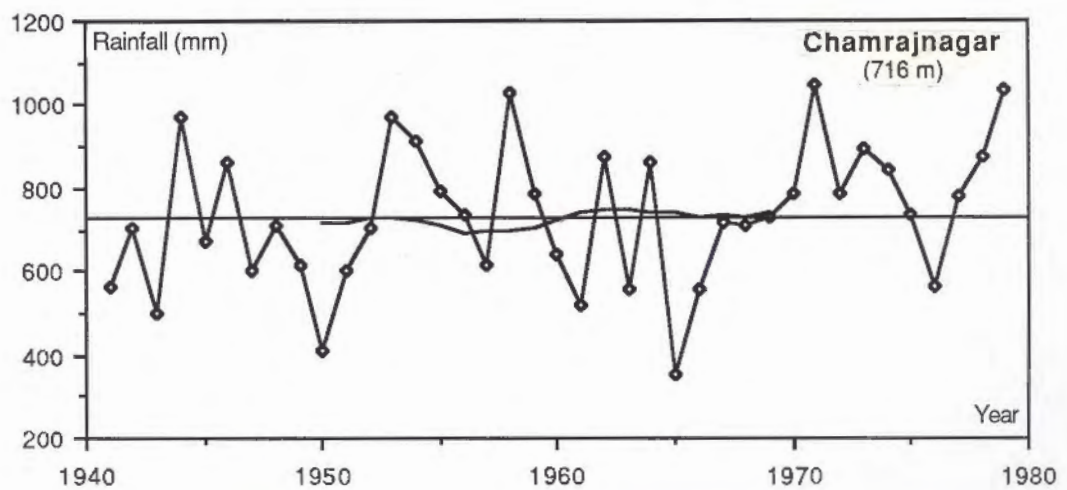
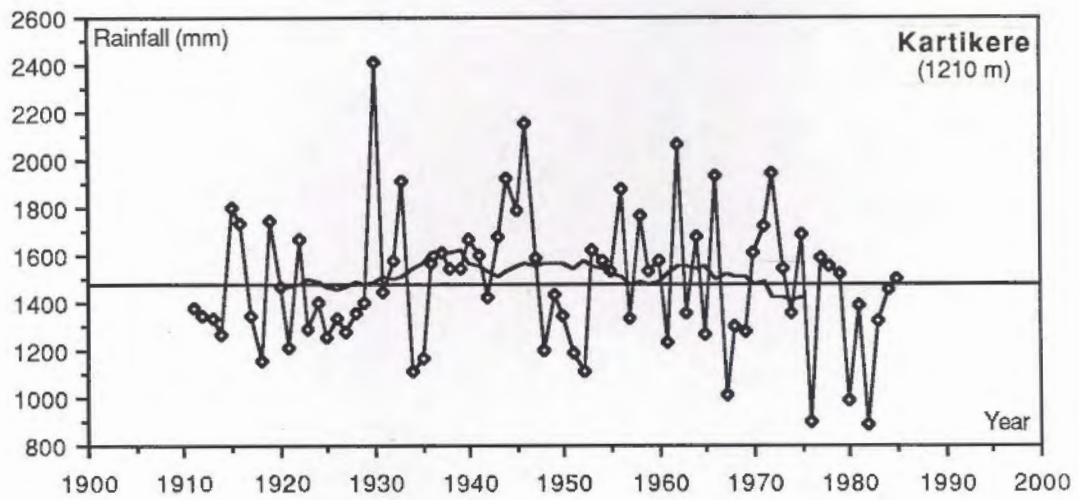
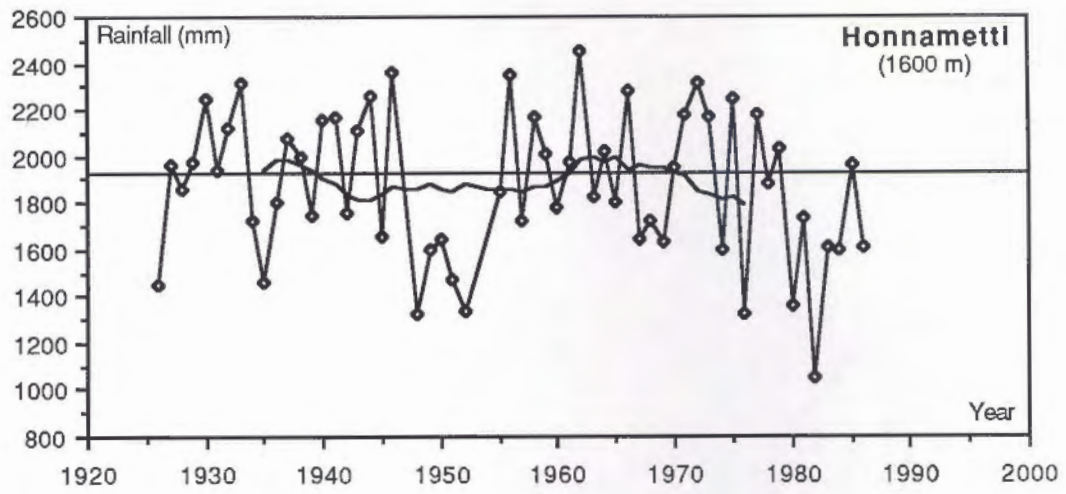


Fig. 11 - Twenty-year moving averages of annual rainfall in three stations

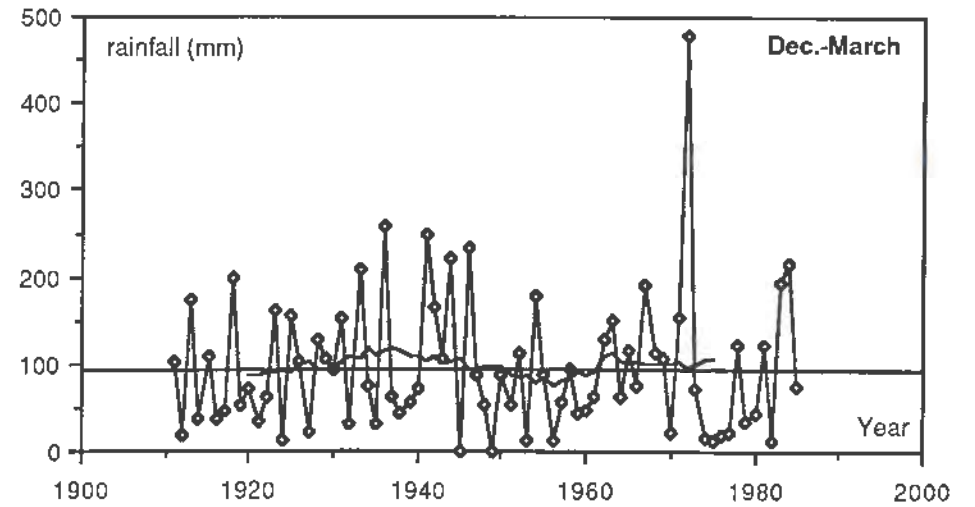
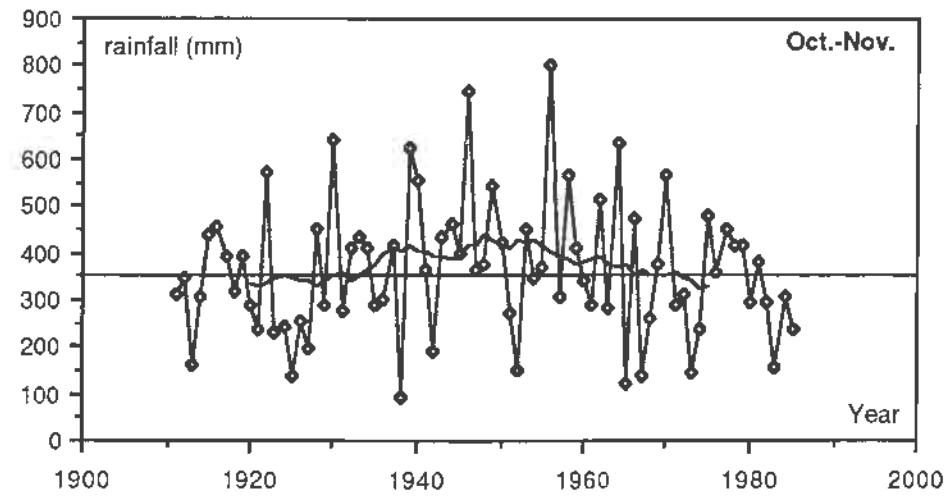
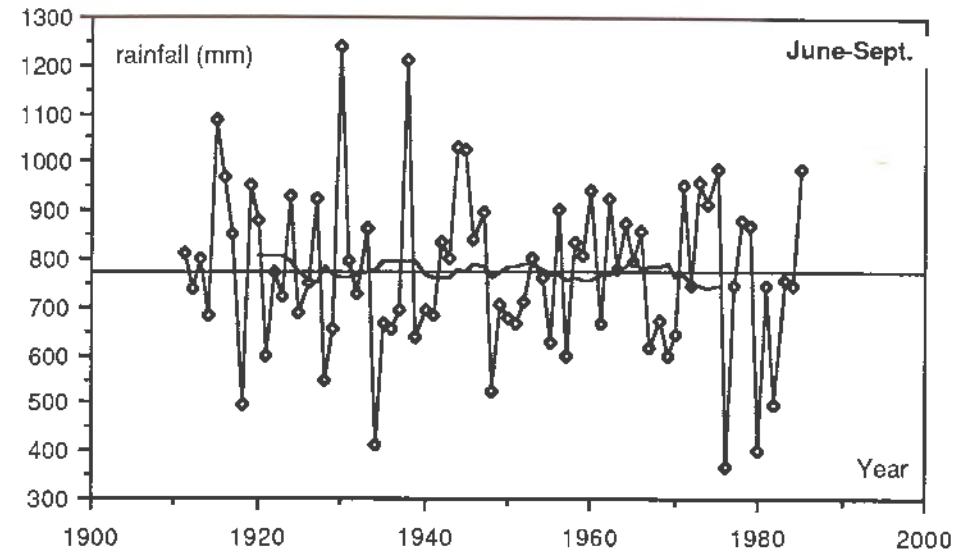
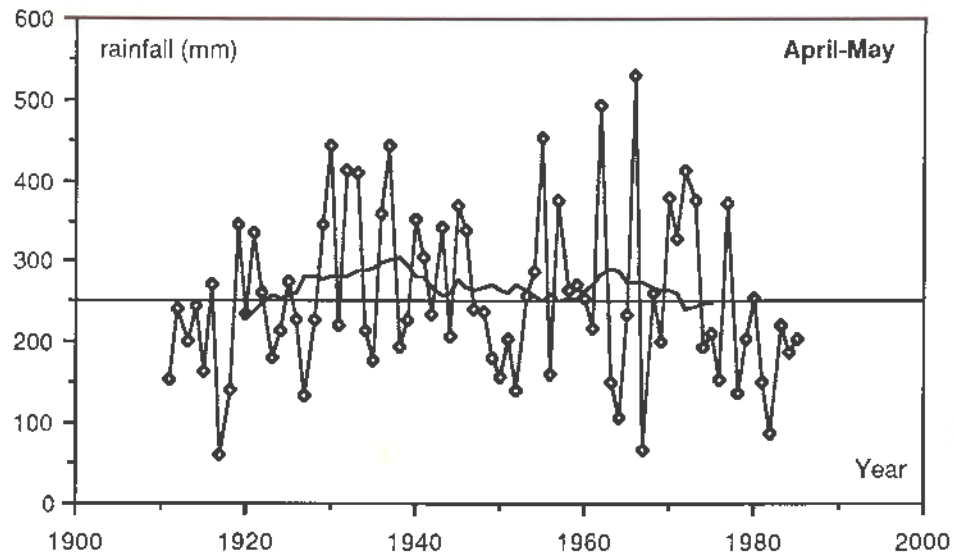


Fig. 12 - Twenty-year moving averages of seasonal rainfall in Kartikere

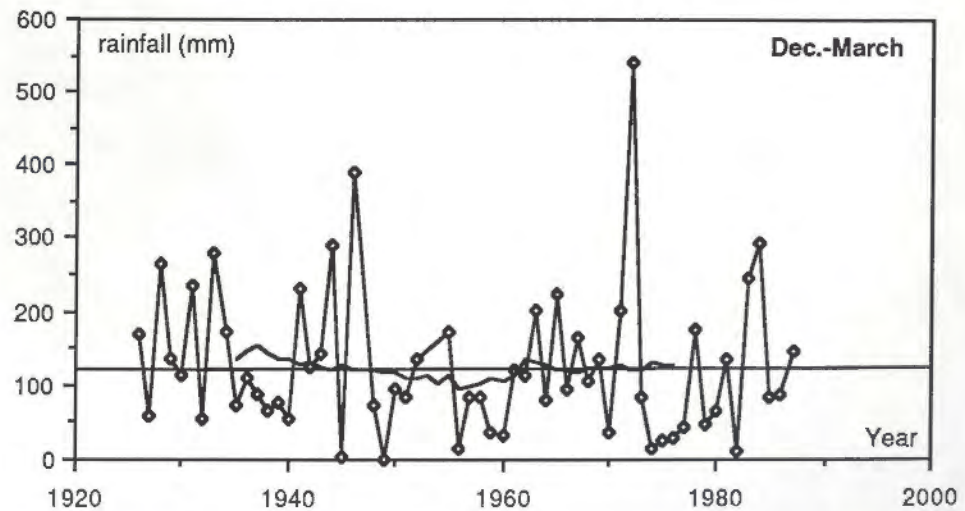
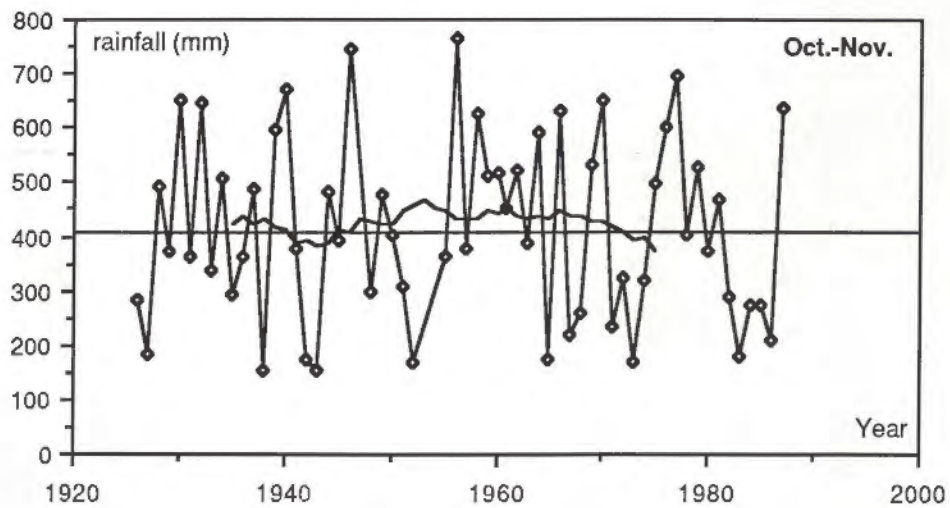
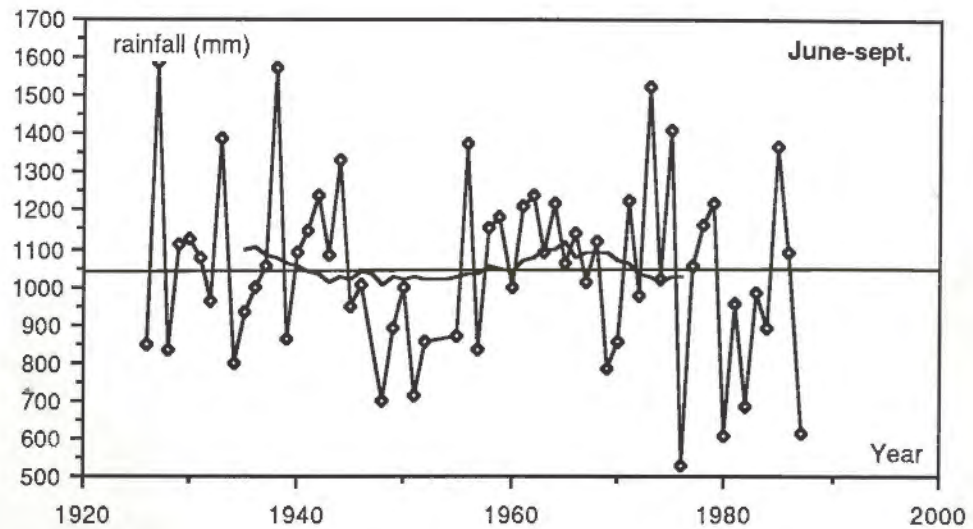
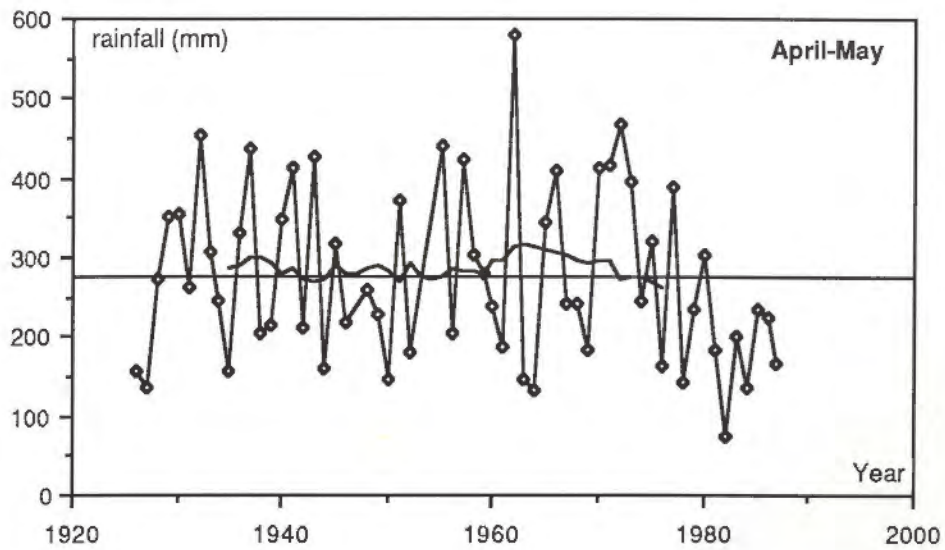


Fig. 13 - Twenty-year moving averages of seasonal rainfall in Honnametti

fluctuations of annual rainfall and 20-year moving averages* around the long term average have been prepared for the same 3 stations, viz., Honnametti, Kartikere and Chamrajnagar.

The inter-annual fluctuation of annual rainfall is erratic at all the 3 stations.

In Chamrajnagar, the moving average is more or less near the long term average, and hence no definite rainfall trend is discernible.

In Kartikere, during most years the moving averages lie above the long term average, except for a declining tendency in recent years. Honnametti station, which comes under the high rainfall zone in the BRH, shows consistently low averages (between 1947-1951) and a pronounced declining trend during 1980s (with the lowest rainfall record of 1053 mm in 1982).

Thus, as the patterns of moving averages are different in Honnametti and Kartikere stations of the BRH, there is no regional trend except for a common declining tendency in recent years.

If the moving averages are considered season wise (Figs. 12 and 13), a waning trend can be observed in Kartikere and Honnametti stations, mostly due to consistently low rainfall (less than the long term average) during April-May (rains due to convection) during the past 7 to 10 years. In addition, the lowest rainfall was recorded during June-September, 1976 (366 to 530 mm) followed by 402 to 609 mm in 1980.

1.6 Conclusion

The southern Mysore plateau on the leeward side of the Nilgiris and the Western Ghats is characterised by a rainfall regime with two peaks, one in May and the other in September or October. The BRH, in the south-east corner of this plateau, shows a unique rainfall regime having the combined influence of the south-west monsoon and autumn rains. However, the evolution of this regime is gradual with increase in altitude, thus manifesting the orographic effect.

Part of December and the period from January to March with significantly lower rainfall (80 - 120 mm) can be considered as dry periods. The rainfall during April -

* -average calculated for every 20 years and obtained value projected for every tenth year

May as premonsoon showers is important for vegetation as well as for coffee plants. However, the recent declining trend in the April - May rainfall (Fig. 12 and 13) may lengthen the dry period, eventually affecting the threshold of the evergreen forests.

2 MICROCLIMATE

2.1 Location

Hygrothermographs with weekly rotations were set up at three sites for monitoring the temperature and relative humidity. One was installed inside the forest at Jodugere at an altitude of 1480 m. This instrument provided temperature data between May 1987 and February 1988 covering winter and almost the entire rainy period. Humidity values were obtained for May, June, July, November and December, 1987.

The second instrument was placed inside the forest in Honnametti, at an elevation of 1700 m. It recorded the temperature data between December 1986 and June 1987 as well as humidity for the same months except February.

The third was also set up at Honnametti but in a shrub-savanna (grassland) on the crest of a hill (1710 m), exposed to both the east and the west. The data recorded is for the same period as the previous one.

The results are given in Table 8 and Fig. 14, 15 and 16.

2.2 Temperature

In spite of the difference in altitude, the variation in temperature between the Jodugere and Honnametti forests is not very great. Inside the forests, the mean temperature of the coldest month (t) varies between 14.3 and 16.4°C (December/January) while the mean temperature of the hottest month (T) varies from 23.2 to 23.9°C (May). However, in the shrub-savanna, the same parameters are slightly higher with t=17.9°C and T=24.5°C.

The mean of the minimum of the coldest month (January or February) is 12.3 to 13.5°C in the forests and still lower (10.7°C) in the shrub-savanna.

The absolute minimum recorded during December/January in both the forests is similar: 11°C, but in the grassland the minimum is 9°C registered in February.

The absolute maximum in forests attains 28.5 to 29°C during April/May, whereas

a sharp increase is recorded in the shrub-savanna with values as high as 48.5°C (in April).

Temperatures for the rainy seasons are available only for Jodugere. Thermic amplitude which is 5.1°C in May, varies from 2.3°C to 5.3°C during the south-west monsoon (June-September). The lowest thermic amplitude of 2.2°C prevails during October-November when the number of rainy days is more and winter is approaching. The period from December to February which represents winter, is a fairly dry period. The temperature is low at night and high during the day and hence the thermic amplitude shows a gradual increase (Fig. 14).

Table 8 - Microclimatic data

		Biligirirangan hills (BRH)			Western Ghats (from Pascal 1984)	
		Jodugere forest (1420 m)	Honnametti forest (1700 m)	Honnametti shrub-savanna (1710 m)	Sheltered forests (Attapadi- Bhagavati- 800-900 m)	Forest on the crest (Poochipara- 900 m)
Temperature (°C)	Mean temperature of the coldest month (t)	14.3 (Jan.)	16.4 (Dec.-Jan.)	17.9 (Dec.)	19.7 (August/Dec.)	17.9 (Jan.)
	Mean of the minimum of the coldest month (m)	12.3 (Jan.)	13.1 (Feb.)	10.7 (Feb.)	16.3-17.5 (Dec./Feb.)	13.8 (Jan.)
	Absolute minimum	11 (Dec.-Jan.)	11 (Jan.)	9 (Feb.)	9-14 (Dec./Feb.)	10 (Jan.)
	Mean temperature of the hottest month (T)	23.9 (May)	23.2 (May)	24.5 (May)	23.9-24.6 (May)	>26.3 (April)
	Absolute maximum	28.5 (May)	29 (April)	42 (April)	27.5-29.5 (March/April)	31.5 (April)
Relative humidity (%)	Lowest monthly mean	56.6 (May)	57.3 (May)	61.9 (May)	70.1-76.3 (Jan./Feb./March)	60.1 (March)
	Absolute minimum	26 (May)	23 (April)	18 (April)	36-40 (March)	~0.5 (Jan.-March)
	Highest monthly mean	84.3 (Dec.)	88.3 (Jan.)	75.3 (June)	97.7 (July)	?90 (July)
Daily maximum of saturation deficit: DsM ((mm of Hg)	Lowest DsM	3-4 (Dec.-Jan.)	4 (Dec.-Jan.)	8.8 (Jan.)	0.8 (July)	?<5.4
	Absolute maximum	20.4 (May)	23.1 (April)	50.4 (April)	17.6-19.4 (March/Feb.)	?
	Highest DsM	14.8 (May)	13 (April)	28.8 (April)	8.8-9.7 (March)	19.6 (March)

The thermic amplitude is quite high in the Honnametti shrub-savanna when compared to the Honnametti forest. During the dry season (December-March) the thermic amplitude in the shrub savanna varies from 12.7° to 16.9°C, while it is 4.2° to 7.5°C in the forest. During April-May also the thermic amplitude is higher in the shrub savanna, attaining a maximum of 20.5°C in April.

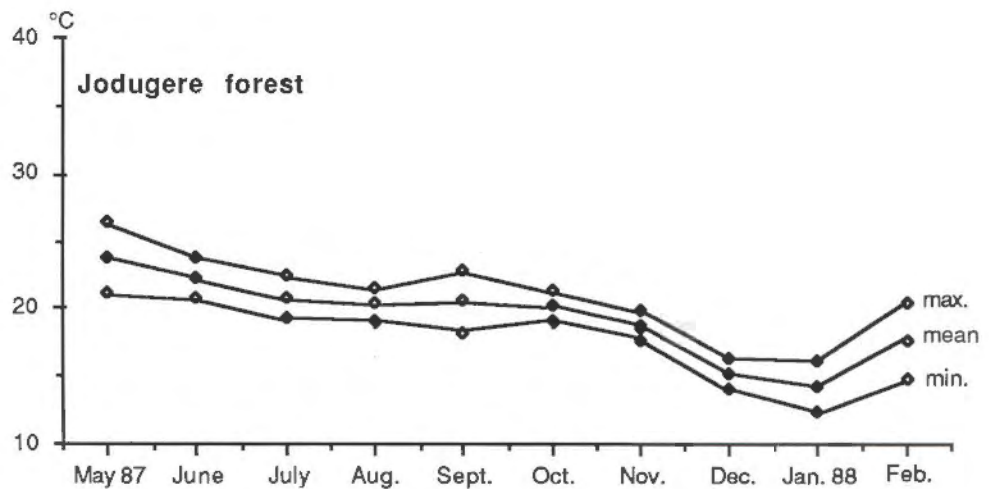
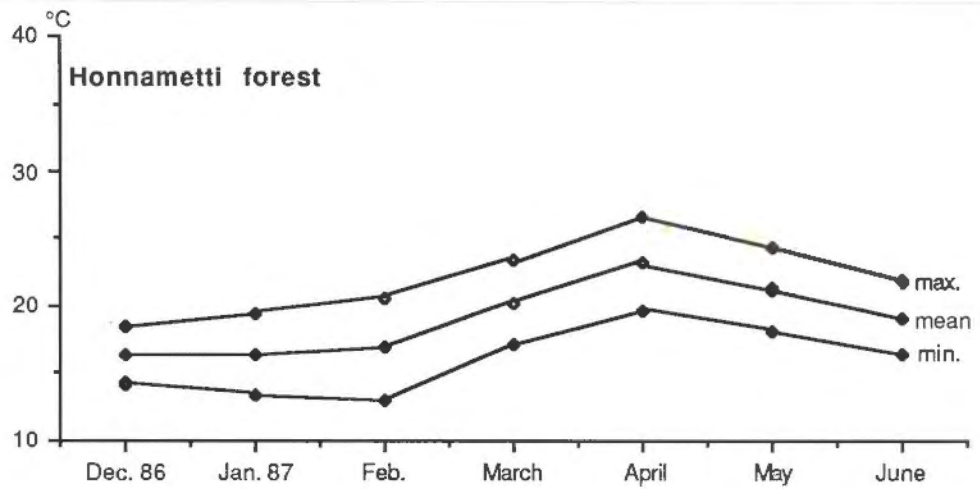
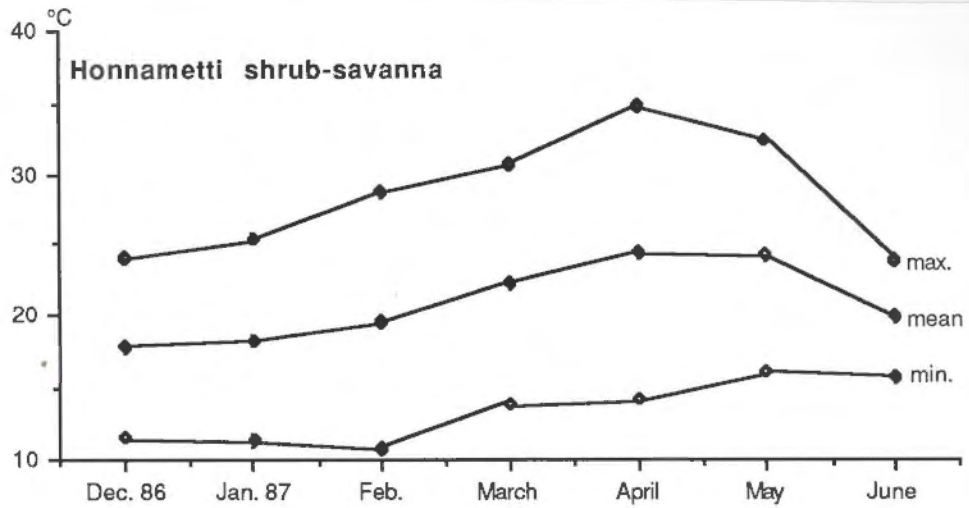


Fig. 14 - Monthly mean temperatures

A comparison of temperatures recorded by Pascal (1984) in some forests of the Western Ghats at 800-900 m such as the sheltered sites in Attapadi and Bhagavati and on the crest in Poochipara with those of Jodugere and Honnametti forests in the BRH (Table 8) shows that the values of t (14.3-16.4°C) and m (12.3-13.1°C) in the BRH forests (>1400 m) are slightly lower than those of the Western Ghats forests. This may be due to the higher elevation. However, the other parameters are more or less similar to the Western Ghat forests. The maximum thermic amplitude in these 3 Western Ghats forests ranges between 6° and 10°C.

Studies made by Legris and Blasco (1969) in the montane shola (hill forest) and shrub-savanna show that in Gundar forest (2140 m), the daily amplitude during the dry season is around 12°C with the mean minimum of 0°C and mean maximum of 12°C while during the rainy season it is around 5°C. In the savannas (Manavanur and Pulavachi, both at 2050 m), the thermic amplitude is the highest during the dry season, generally between 40-45°C, and the absolute minimum often falls below 0°C, specially during December-February.

2.3 Relative humidity

The extreme values of relative humidity are given in Table 8. Although complete data could not be obtained for the rainy season, the available data indicate that the highest monthly mean is 84.3% in Jodugere forest in December and slightly higher in Honnametti forest : 88.3% in January. These high values during the dry season are mostly due to the early morning fog. In both the forests, the lowest monthly mean is around 57% in May.

In the shrub-savanna these parameters are slightly reversed. Although the highest monthly mean is in June (75.3%), it is not very high when compared to December and January (72.4-74.5%). In the forests the mean relative humidity is slightly lower than that of the shrub savanna: 71-72% in June and the lowest monthly mean is almost 62%, which is a little higher than in the forests

Like temperature, the relative humidity in the shrub-savanna shows a greater amplitude (Fig.15) when compared to that in the forests: the monthly mean of the maximum relative humidity in the recorded months is above 88%, whereas the

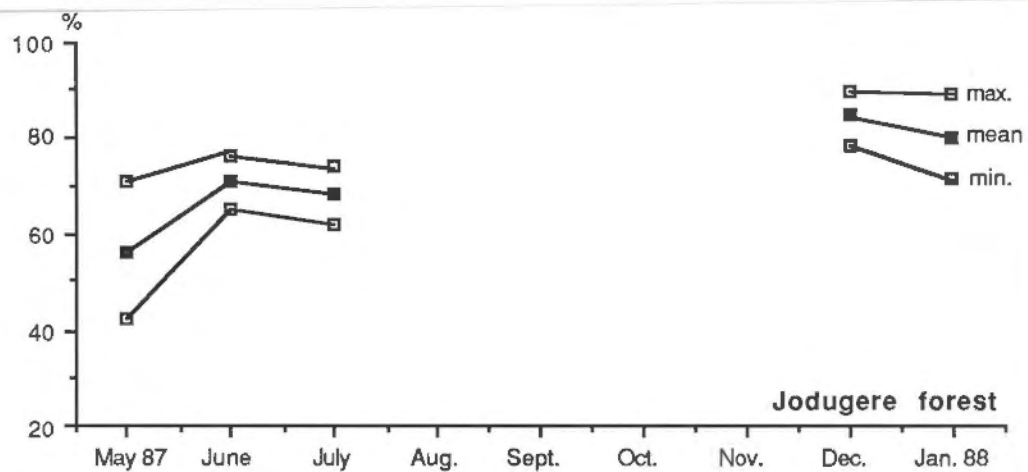
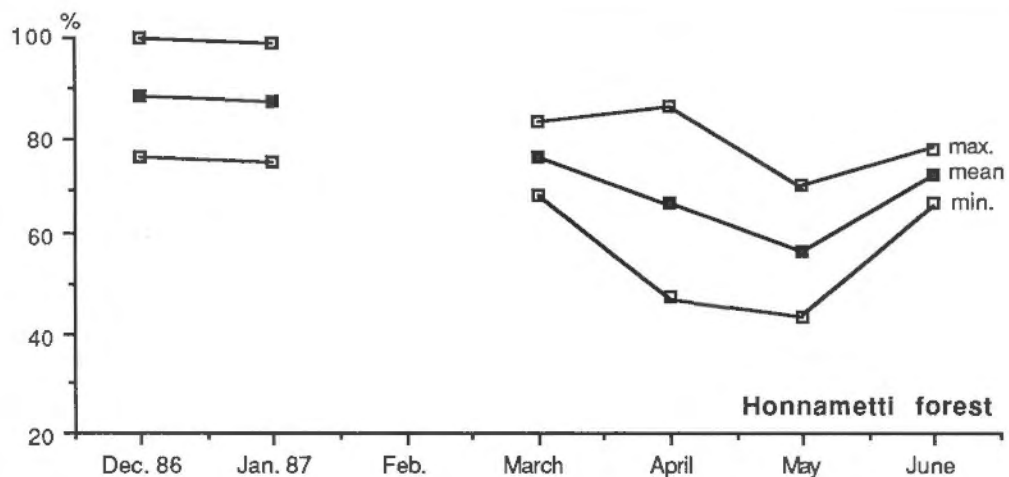
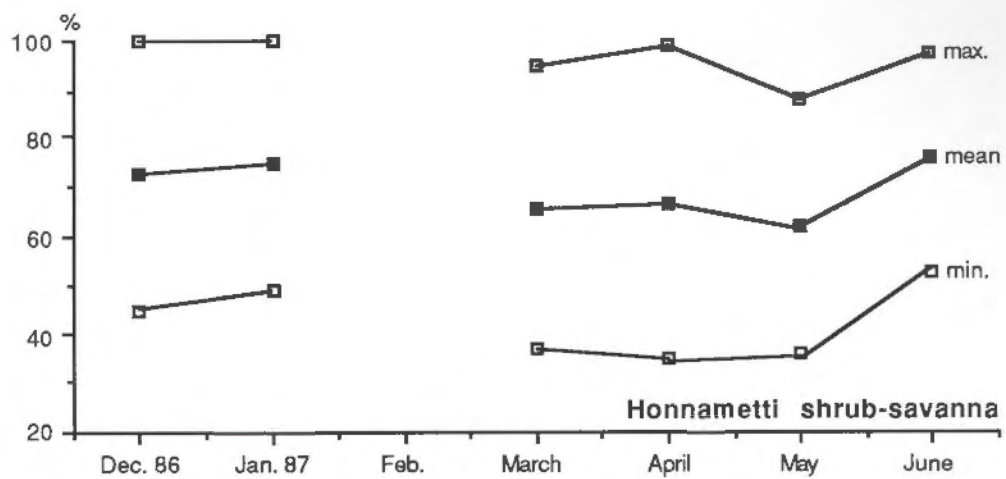


Fig. 15 - Monthly mean humidity

minimum varies between 34% and 53%. These extremes are obviously related to direct exposure to fog or rains which result in saturation or near saturation on one hand and quick evaporation due to the influence of winds and direct solar radiation on the other.

The absolute minimum is 23-26% (May/April) in the forests. It is still lower in the shrub-savanna with 18% recorded in April.

The forests of the Western Ghats (Table 8) which are strongly influenced by the south-west monsoon, show the highest monthly mean of more than 90% in July. In the BRH, complete data could not be obtained for the S.W. monsoon period. However, in Jodugere forest where data could be obtained from June and July, the highest monthly mean was 74% in July.

The lowest monthly mean in the sheltered forests of the Western Ghats is also higher when compared to the BRH. However, in Poochipara forest, which is on the crest of the Western Ghats, it is 60.1% which is more or less the same as in Honnametti shrub-savanna.

2.4 Saturation deficit

Humidity may be expressed as saturation deficit ($D_s = F - f$), which reflects the evaporating potentiality of the atmosphere in a better way. The maximum (saturated) vapour pressure (F) depends exclusively on temperature. The atmospheric vapour pressure (f) varies with humidity and can be obtained from the degree of relative humidity ($H\%$) recorded: $f = HF$ (f and F are expressed in mm of Hg).

The D_s has been calculated for the two extreme periods of the day: minimum (D_{sm} 4-7 hrs) and maximum (D_{sm} 12-14 hrs). The results are given in Fig.16.

The D_{sm} is low in all three stations, less than 5.4 mm (Fig.16) throughout the recorded period when dew at dawn is a regular occurrence even during the dry period. In Jodugere forest, the lowest D_{sm} is during December and January: 1.2 mm; in Honnametti forest it is almost nil in December, followed by 1 mm in January, while in the shrub-savanna of Honnametti it is nil in both December and January.

The highest D_{sm} recorded is between March and May in all 3 stations. The peak is in May (April data not available) in Jodugere forest: 14.8 mm, while in Honnametti

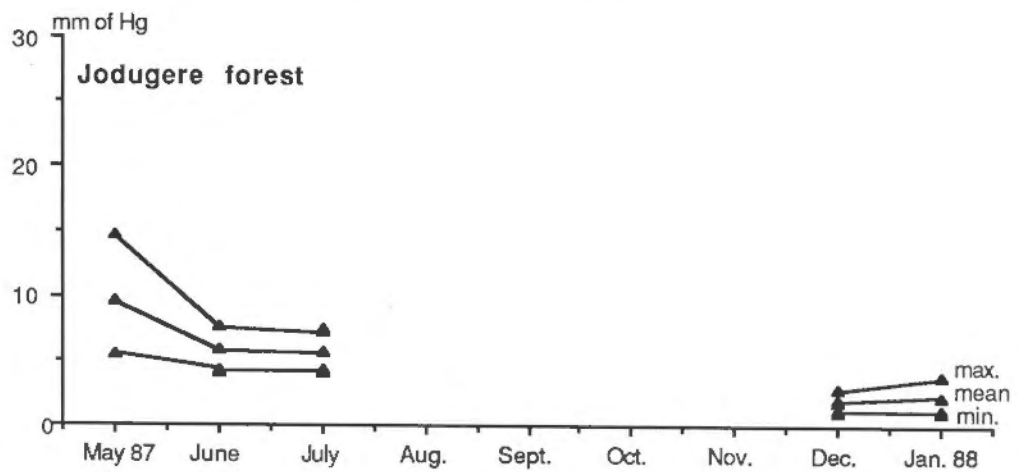
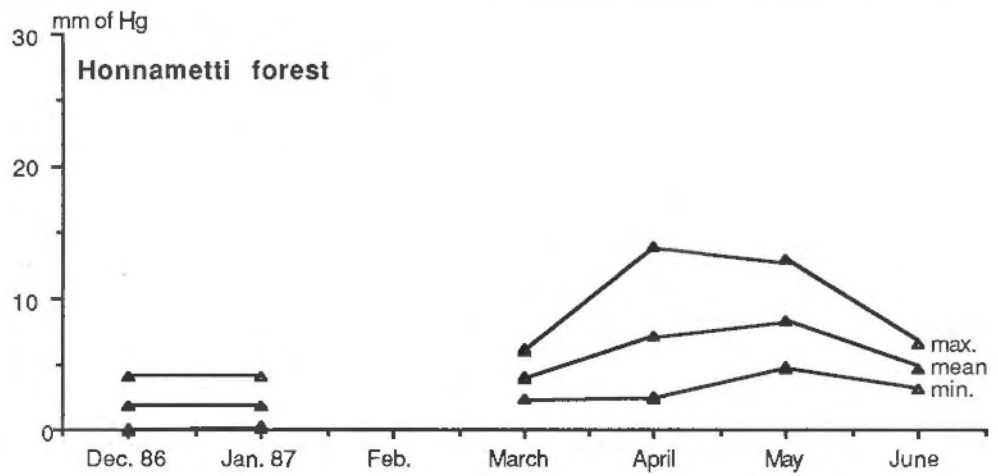
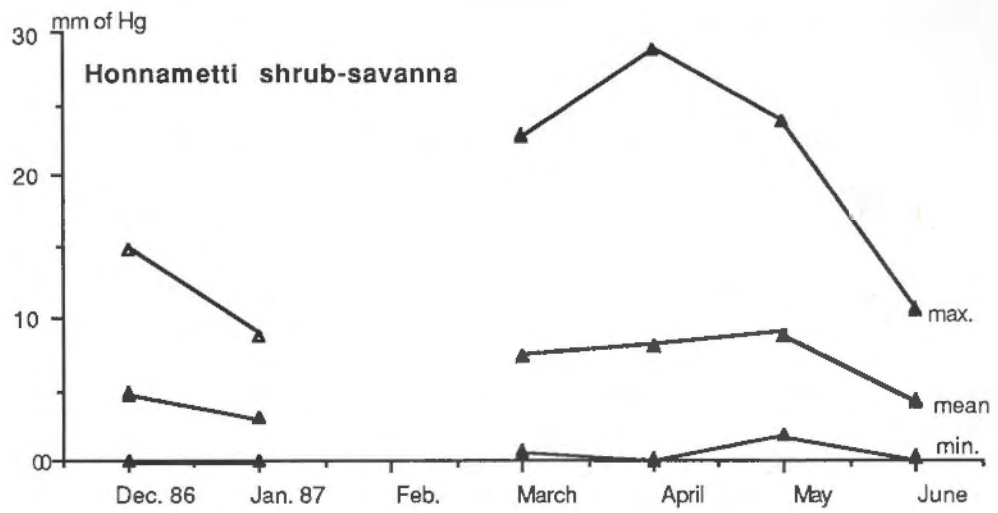


Fig. 16 - Monthly mean saturation deficit

forest it is in April: 13 mm. In the shrub-savanna of Honnametti the highest DsM is almost double (28.8 mm in April) that of the forest.. As data is not available or is inadequate during the south-west monsoon period, the lowest DsM (Table 8) in the recorded months is between 3 and 4 mm during December-January in Jodugere and Honnametti forests, while it is almost double in the shrub-savanna (8.8 mm in January).

However, in the forests of the Western Ghats the lowest DsM (0.8-5.4 mm) is during the peak of the rainy season (July). The highest DsM, ranging between 8.8 and 9.7 mm, is in March in the sheltered forests of Attapadi-Bhagavati; this value is twice (19.6 mm) that obtained in the forest on the crest of the Western Ghats. The Dsm is low (≥ 4 mm) throughout the year.

Legris and Blasco (1969) observed that in the Gundar shola (2140 m) the Ds never exceeds 15 mm whereas in the Mannavanur savanna (2050 m) it often exceeds 50 mm. The absolute maximum in BRH is higher (20.4-23 mm) than in the Gundar shola and the sheltered forest of the Western Ghats, while in Honnametti shrub-savanna the absolute maximum is more or less similar to that of Mannavanur savanna.

2.5 Conclusion

- Although there is an inverse relationship between the temperature and elevation at the regional level, the temperature, and to some extent, the humidity inside the forest are dependent on the topography and the status of the forest. These parameters also differ at different levels under the canopy (Haddow *et al.*, 1961; Cachan and Duval, 1963).

- The thermic amplitude is always higher in the open shrub-savanna and to some extent in the forest exposed to direct winds.

- In the BRH, unlike in the Niligris and the Palnis (Legris and Blasco, 1969), there is no evidence of temperature reaching 0°C or lower and the area may be considered as sub-montane stage.

- The humidity is always higher inside the forest than in the open shrub-savanna.

MAIN VEGETATION TYPES

The diversity of the vegetation types in the BRH is the result of the variety of topographic features, soil types and bioclimates encountered in these hills. Further, in some parts of the range, biotic pressure, specially human and to some extent fire has modified the vegetation to varying degrees.

An international vegetation map at the scale of 1/1,000,000 (Gausson *et al.*, 1961) has been published by the French Institute, Pondicherry, in collaboration with the Indian Council of Agricultural Research. The BRH which has been covered in the Cape Comorin sheet shows two types of vegetation:

- dry vegetation type under *Anogeissus* - *Pterocarpus* - *Tectona* "series", physiognomy being savanna woodland, and
- high altitude montane forest.

A map of the main vegetation types prepared from Landsat imagery of the Nilgiri hills (India) at the scale of 1/250,000 includes a part of the BRH (Bellan, 1985). In this map, the BRH shows 3 vegetation types *viz.*, (1) medium elevation eco-floristic zone (900 to 1800m): semi-deciduous or deciduous low density forest, (2) wet evergreen forest and (3) mosaic of degraded vegetation and coffee plantations.

Sukumar (1985) classified the BRH vegetation under 5 categories: (1) Tropical evergreen shola grassland, (2) mixed deciduous forest, (3) *Anogeissus* dry deciduous type, (4) dry deciduous woodland and scrub and (5) riparian fringing and associated dry deciduous forest.

As the above mentioned classifications are too general, particularly those concerning the evergreen formations, an attempt is made to re-classify the vegetation.

1. CRITERIA USED FOR CLASSIFICATION OF VEGETATION

The primary criteria for describing a vegetation are the floristic associations and their physiognomy, which are either developmental or climax in status.

1.1 Climax

According to Clements (1916, 1936), a climax is the mature stable and optimal state of a phytocoenose representing the final outcome of a progressive series of

successive stages of vegetation. Under a given climate all the successions converge towards a unique climax which is the 'climatic climax'.

As far as the forest is concerned the notion of climax has been further modified by recent authors (Hallé *et al.*, 1978; Whitmore 1978; Pascal 1984, 1986) by considering the whole mosaic of a forest which includes sylvegenetic dynamics, structure and floristic composition, when it is in equilibrium with the environmental conditions.

The degradation of climax formations may lead to 2 types of formations (Pascal, 1986):

- formations with moderate destruction which could return to a climax if protected. They are called potentially climax-linked.

- highly degraded formations which can no longer return to a climax under natural conditions.

Grasslands, especially of high elevations, evoke controversies as to whether they are degraded or climax formations. Ranganathan (1938) considered grassland as a climatic climax maintained by frost, while Champion (1936) and Bor (1938) asserted that these grasslands are "sub climax" formations rendered stable by the regular occurrence of fires.

According to Meher-Homji (1967), during winter the seedlings of forest species in open areas undergo a sort of physiological desiccation. During winter nights, the upper layers of soils are exposed to freezing temperatures. However, as the sun comes up, the temperature rises imposing loss of water through transpiration. The seedlings with superficial root system are unable to meet this demand from the frozen soil.

Since frost is not evident in the BRH, it seems that edaphic and biotic factors play an important role in maintaining the grasslands. Heavy rainfall on higher landscapes causes leaching of micro-nutrients in the soil, thus lowering the pH of the soil and accumulation of exchangeable aluminium which is more toxic to deeprooted plants. However, most of the grasses associated with mycorrhizae can resist the toxicity of aluminium (Sanford and Wangeri, 1985). The role of biotic factors, such as grazing

and fire, in maintaining grasslands is well known. Thus in the present context shrub savannas may be regarded as bio-edaphic climax formations.

1.2 Physiognomic classification

Physiognomy is the external appearance of the vegetation which includes biological forms, structure and density.

The nomenclature proposed by the Yangambi Conference (CSA, 1956) based on different physiognomic types has been adopted by Legris (1963) for the vegetation types of India.

- *Woodland/dense forest* : trees are dense with distinct overlapping of crowns.
- *Savanna-woodland to tree savanna* is characterized by tall grasses forming a more or less continuous ground cover. In the former, the trees are not dense and the crowns overlap only a little. In the latter, the trees are widely spaced.
- *Shrub savanna* (grassland)* is a mixture of grasses, shrubs and herbs; trees are very scattered or absent. Grass cover is continuous.
- *Scrub woodland* is a thicket in which a few short-statured trees emerge here and there.
- *Thickets* represent clumps of thorny shrubs and coppice shoots of unarmed trees. They are either closed or discontinuous, depending on the degree of disturbance.

1.3 Phenology

Forests can be separated into 3 categories based on the relative percentage of evergreen and deciduous species,

- Evergreen forests comprise pure patches of evergreen species, although a few deciduous ones may be found in the openings.
- In deciduous forests, the majority of species shed their leaves in a particular season.
- Semi-deciduous forests are a mixture of deciduous and evergreen species in varying proportions. Champion (1936) has referred to such forests as semi-evergreen

* The term "shrub savanna" is more appropriate than "grassland", wherein a number of herbaceous, under-shrubby and shrubby species are mixed with grasses (Trochain, 1954, 1957; Fosberg, 1961; Meher-Homji, 1967).

but in order to avoid a confusion between a semi-evergreen species (shedding its leaves for a very brief period of two weeks or so) and a semi-evergreen forest, it is preferable to term the latter type as semi-deciduous.

1.4 Successional stages

Succession is either progressive towards the climax or retrogressive. The former deals with events taking place over several decades or an even longer period. The latter is due to exploitation without suitable conservation measures.

In the BRH, 3 groups of climax formations have been recognised. Their possible successional trends are given in Fig. 17.

- Evergreen or semi-deciduous climax forests and their degradation stages :

In this category most of the trees are evergreen with a few deciduous ones in natural openings and at the fringes. They are climax forests in equilibrium with the environmental or edaphic conditions. Their structural physiognomy, and to some extent the floristic composition, varies according to the elevation or local ecological conditions within the same elevation range.

Moderate degradation of the evergreen climax forest does not greatly alter its structure and floristic composition. With protection it can revert to its original status, and hence may be regarded as potentially climax-linked forest type. However, continued exploitation or fire may lead to a disturbed structure and impoverishment of the characteristic species. Protection of highly disturbed forests at this stage leads to another progressive succession and then towards secondary climax which is more or less similar to the structure of the primary type but with a different floristic composition.

In high elevation forests, disturbance (mostly fire) leads to the invasion of evergreen heliophilous species or cold tolerant species in open areas. Repeated fires, felling of trees and degradation of soil gradually leads to shrub savanna through savanna-woodland and tree savanna phases. Protection at this stage by checking soil erosion and tree planting may lead to a progressive secondary succession.

Overexploitation of an already disturbed forest, particularly of low and medium elevation types, may lead to secondary semi-deciduous or secondary deciduous forests.

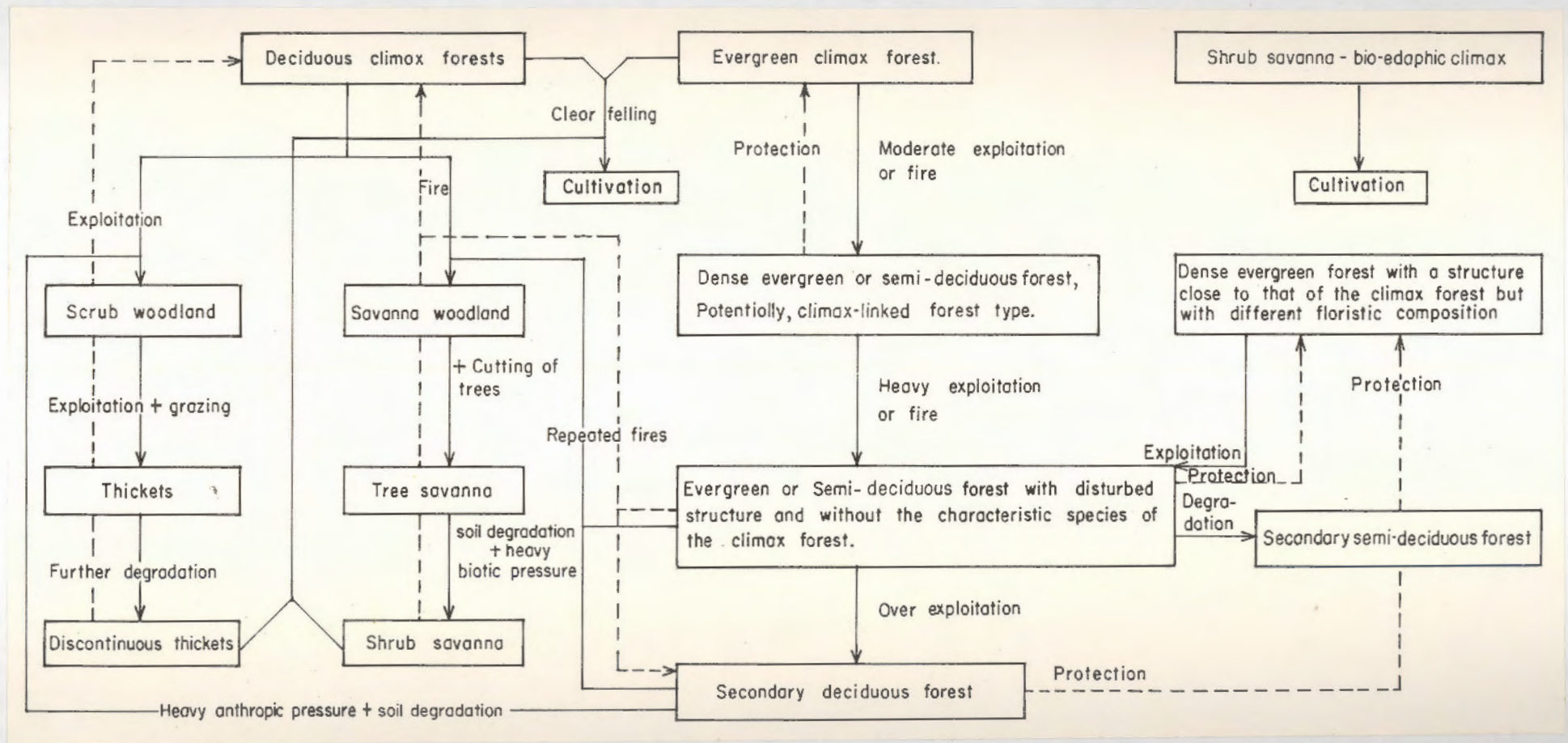


Fig. 17 - Stages of successions derived from climax forests. (adapted from Meher-Homji, 1981; Pascal, 1986)

In secondary semi-deciduous forests there are 2 types of seral stages depending on the mode of further degradation:

- Savanna woodland to shrub savanna with repeated occurrence of fires
- Scrub woodland to thickets due to overgrazing along with soil degradation.

The protection provided in less altered soils may reverse the trends of degradation towards a progressive secondary succession.

- The deciduous climax forest and their degradation stages:

The climax formation may be a dense forest if rainfall exceeds 1200 mm with favourable edaphic conditions, or it may be an open forest or savanna woodland if rainfall is less (Pascal, 1986). In addition, topography may also intervene in determining the type of climax. For example, a tree savanna on a steep slope at 400-800 m elevation may take a much longer time to reach the climax forest stage than a tree savanna on a more or less flat terrain. There may be differences in their floristic composition also.

- In general, degradation of a deciduous climax forest leads to different types depending on the degrading agent.

- When fire is the degrading factor the sequence is savanna woodland - tree savanna - shrub savanna

- When grazing and constant lopping of trees are the dominant factors, the ensuing physiognomies are scrub woodland - thicket - discontinuous thicket.

- Shrub savanna: a bio-edaphic climax formation

As mentioned above, in some places shrub savanna may be regarded as a bio-edaphic formation. These savannas are mostly maintained by repeated fires, enabling the luxuriant growth of grasses in the next season. In some places, the Forest Departments are trying to raise plantations in these shrub savannas by adding lime to the soil to neutralise the low pH but have met with very little success.

* * *

The application of the above criteria to the data collected by extensive field surveys helped in distinguishing the different types of vegetation in the BRH. All these types are in the altitudinal range of 700-1800 m.

2 DECIDUOUS TYPES

2.1 Anogeissus - Pterocarpus - Terminalia type

As mentioned earlier, savanna-woodland and tree savanna are classified under *Anogeissus-Pterocarpus-Tectona* series in the BRH (Gausson *et al*, 1961). However, the present study indicates that *Tectona grandis* is rare under natural conditions. On the other hand, *Terminalia alata* and *T. paniculata* appear to be more common, as also *Anogeissus* and *Pterocarpus*. Based on this observation the deciduous formations of the BRH can be grouped under the *Anogeissus-Pterocarpus-Terminalia* series.

2.1.1 Woodland to savanna-woodland

The savanna-woodland covers a large part of the western flank and southern part of the BRH between 900 and 1350 m. However, the woodlands are localised in small patches in the very humid valleys. Floristically, both the types are more or less similar. However, structural differences exist due to variations in the rainfall of the region. For example, in the central part of the western flank of the BRH where rainfall is considerably higher, 3 ensembles are present with the top canopy reaching a height of 20 m or more. On the other hand, in the relatively drier zones (<1200 mm)), particularly towards the north, the canopy trees are short and without a clear stratification underneath. Often this stage gradually leads to a tree savanna type, especially on steep slopes and also near the dry ridges of valleys.

Some common species and their probable position in the *structural ensembles:

Ensemble I comprises *Anogeissus latifolia*, *Celtis tetrandra*, *Dalbergia paniculata*, *Grewia tiliifolia*, *Pterocarpus marsupium*, *Tectona grandis* (very rare under natural conditions), *Terminalia alata*, *T. bellirica*, *T. paniculata*, *Stereospermum personatum*, *Syzygium cumini*., among others.

Noteworthy species of ensemble II include *Buchanania lanzan*, *Careya arborea*, *Hymenodictyon excelsum*, *Kydia calycina*, *Lagerstroemia parviflora* (rare), *Schleichera oleosa*, *Sterculia villosa*.

Among those recorded in Ensemble III, mention may be made of *Bridelia retusa*, *Cassia fistula*, *Catunaregam torulosa*, *Embllica officinalis*, *Eriolaena hookeriana*,

* explained in Chapter 4.

Glochidion velutinum, *Meyna laxiflora*, *Radermachera xylocarpa*.

The undergrowth consists of shrubs and herbs dominated by grasses. Shrubs and herbs are represented by *Clerodendrum serratum*, *Grewia hirsutus*, *Helicteres isora*, *Leea chinensis*, *Pavetta tomentosa*, *Polygala arillata* etc. The grasses are often tall, *Cymbopogon nardus*, and *Themeda cymbaria* being conspicuous among the others.

On the western slopes of the BRH, between 900 and 1100 m, there are some narrow belts of very low dense deciduous forests dominated by *Anogeissus latifolia*.

2.1.2 Tree savanna

Tree savanna covers a large part of the south-western, western and northern part of the BRH. Along the eastern part they are found on steep slopes. They sometimes form mosaics with savanna woodland in the moist valleys.

Tree savannas mostly occur by way of ecotones or transitional zones. They represent two distinct transitional zones with different floristic composition.

(i) As a transition zone between savanna woodland and scrub woodland (750-1100 m) specially on steep slopes mainly comprising *Boswellia serrata*, *Commiphora caudata*, *Givotia rottleriformis*, *Gyrocarpus jaquinii*, *Sterculia urens*, along with *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Pterocarpus marsupium*, *Terminalia alata*.

(ii) At the upper limits of the medium elevation (1000-1400 m), tree savannas are found in the transitional zone between savanna woodland and shrub savanna, particularly on the dry ridges of valleys. The main species are *Bridelia retusa*, *Embllica officinalis*, *Glochidion velutinum*, *Terminalia alata*, *T. chebula*, *Wendlandia thyrsoides*, *Ziziphus rugosa*.

2.2 Anogeissus - Chloroxylon - Albizia type

2.2.1 Scrub woodland to thickets

These types occur along the periphery of the BRH between 700-900 m, sometimes even going upto 1200 m, especially along the eastern slope and in the northern parts of the BRH.

Common species in these types are :

Acacia chundra

Albizia amara

Anogeissus latifolia

Azadirachta indica

Buchanania axillaris

Canthium dicoccum

Catunaregam dumetorum

Chloroxylon swietenia

Diospyros melanoxylon

D. montana

Dodonaea viscosa

Euphorbia antiquorum

Gyrocarpus jaquinii

Hardwickia binata

Ixora arborea

Limonia elephantum

Madhuca longifolia var. latifolia

Phoenix humilis

Premna tomentosa

Pterolobium hexapetalum

Rhus mysorensis

Ziziphus oenopia

3 EVERGREEN/SEMI-DECIDUOUS TYPES

The evergreen forests of the BRH can be classified into different types based on their physiognomy and floristic composition. As mentioned earlier, the BRH with their varied topography and altitudinal range have different climatic conditions and soil types which are the main factors differentiating the evergreen forests.

3.1 Physiognomic classification

- Medium elevation* (1000-1400 m):

In this altitudinal range, the evergreen forests are confined along streams and to moist valleys. Their physiognomy varies according to the topography and exposure.

Tall ripicole or gallery forests: Here the top canopy often exceeds 20 m in height. The stratification underneath is distinctly 3 to 4 layered. Big buttressed trees can also be seen very close to the streams. Such forests are confined to the western flank and the valleys between the central and eastern ridges.

Low ripicole or gallery forests: In these forests the canopy is seldom higher than 15 m and lack distinct stratification underneath. They are generally seen on the steep eastern slopes and in the northern part of the BRH where the climate is comparatively dry.

- High elevation (1400-1800 m):

* Riparian evergreen formations below 1000 or 1100 m are not considered in the present study because they are either very discontinuous or are represented by only one or two rows of trees. The most common trees found in such formations are *Mangifera indica*, *Pongamia pinnata*, *Syzygium cumini*, *Terminalia arjuna*.

Low (sub) montane forests:- These forests are confined to valleys, glens, hollows and depressions where the soil moisture is good. They are locally called "sholas". Physiognomically they are stunted forests with short boled trees, rarely higher than 15m. The crowns are dense and the leaves generally coriaceous. The branches are covered with mosses, lichens and epiphytes. Stratification is not clear.

-These physiognomic types may be further classified into different floristic groups using correspondence analysis and by overall field observations.

3.2 Floristic groups using correspondence analysis

To facilitate the search for the main floristic groups, the presence-absence data have been subjected to correspondence analysis (Lebart and Fénelon, 1975).

3.2.1 Methodology

Computer was used to analyze 100 representative stations (excluding stations with unique floristic composition) and 96 species excluding lianes, deciduous species and also those species appearing only once.

The table of 96 species (lines) and 100 stations (columns) can be considered as the co-ordinates of 96 individuals (species) in a 100 dimension (station) space.

The aim of correspondence analysis is to project the cloud of 96 points on independent axes or planes in this space and search for axes or planes bearing maximum inertia (*i.e.*, information). In other words, the axes or planes on which the projected points have maximum dispersion are significant.

Correspondence analysis considers individuals (species) and variables (stations) as totally symmetrical and the same analysis can also be regarded as that of 100 stations in a 96 dimensional (species) space. The axes/planes having maximum inertia in this case are the same as the preceding ones. Thus both individuals and variables can be shown on the same plane (Figs.19 and 20).

Since the presence-absence data are used, stations having species with restricted distribution are considered significant. Thus in this analysis the weightage for an axis depends on the stations and species having higher absolute contribution.

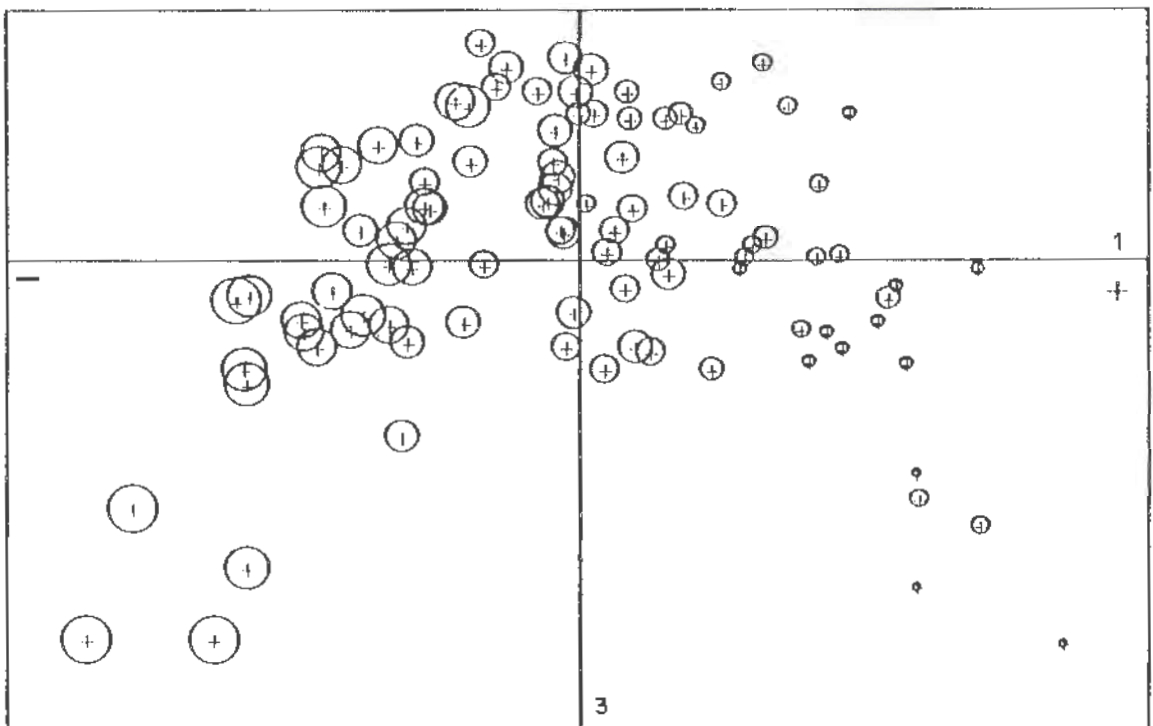
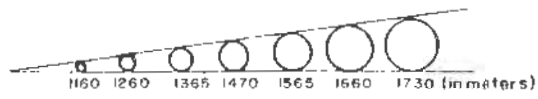
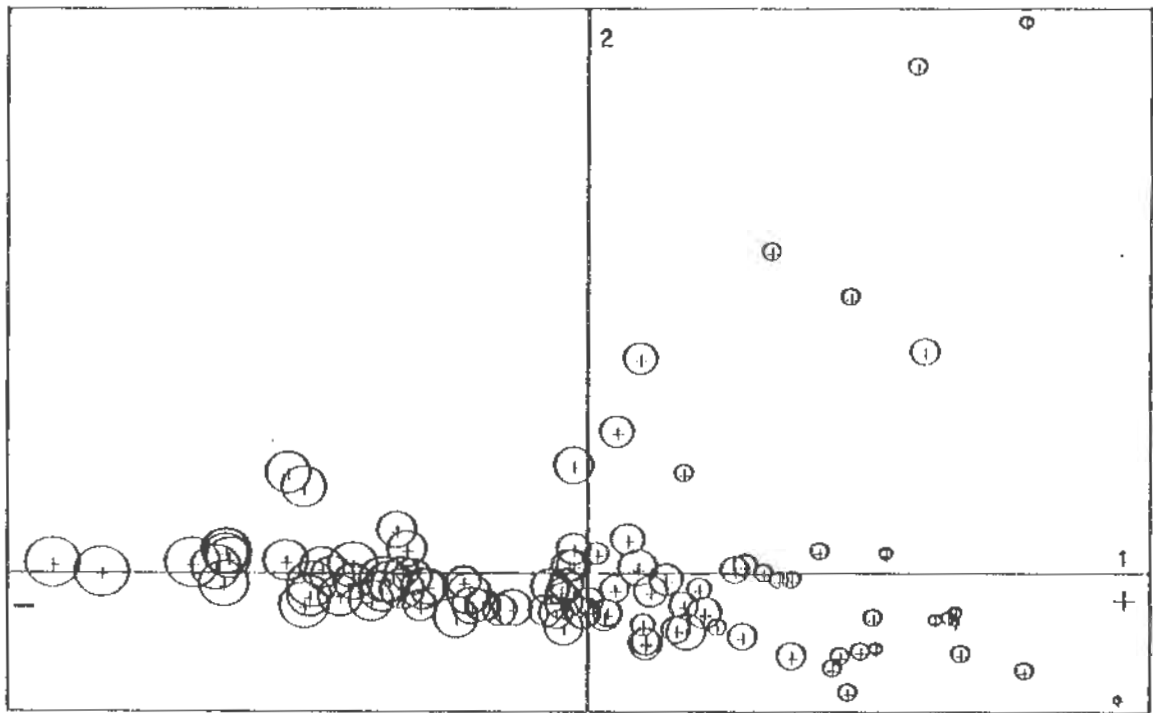


Fig. 18 - Altitudinal gradient of stations determined by the axis 1

fihl

main

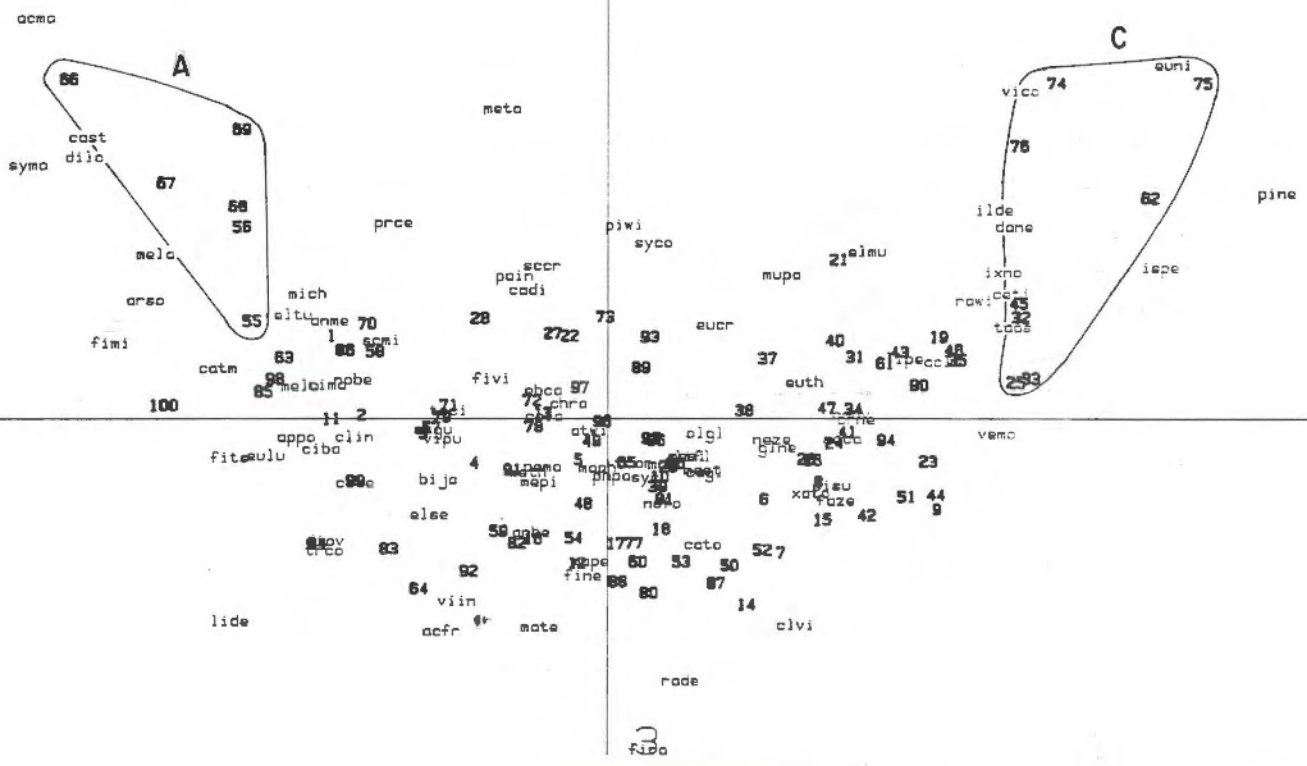


Fig. 20 - Ordination 1 and 3 (total inertia 15.53%)

3.2.2 Results and interpretations

-The first 3 axes account for 22.77% of the total inertia. Of them axis 1 by itself accounts for 10.53% and mainly distributes stations and species along an altitudinal gradient. It arranges the taxa occurring at low altitudes on the negative side and high altitudes on the positive side (Fig.18). Axes 2 and 3 account for 7.24% and 5%, respectively, to the total inertia.

On these axes, stations and species are considered important when their absolute contribution to these axes is relatively high.

- The ordination involving axes 1 and 2 shows 3 main groups of stations (Fig.19). Each group is characterised by stations with relatively high absolute contribution. Group C stations are separated from groups A and B on axis 1. Further, group B stations are segregated from group A by axis 2.

Group A: represented by stations 55,56,66,67,68,69 and 85. Their absolute contribution to axis 1 ranges between 2 and 5%. Interestingly, they are tall ripicole forests along streams in the western flank and in the Gundal valley between 1070 and 1330 m.

The clustering of these stations is due to some species with 2-3% absolute contribution to axis 1. These species include typical ripicole elements such as *Elaeocarpus tuberculatus*, *Syzygium malabaricum* etc, and others like *Aphanamixis polystachya*, *Ardisia solanacea*, *Callicarpa tomentosa*, *Canarium strictum*, *Dimocarpus longan*, *Mangifera indica*.

Group B: Stations 63,79,95,96,97,98,100 with 3-24% absolute contribution to axis 2 form a distinct group B. Species with significant absolute contribution to axis 2 are *Clausena indica*, *Diospyros ovalifolia*, *Euonymus crenulatus*, *Ficus microcarpa*, *F. tsjahela*, *Memecylon lushingtonii*, *Milium eriocarpa*, *Nothopegia beddomei*.

Group B stations represent low forests with common characteristic species such as *Diospyros ovalifolia* and *Memecylon lushingtonii*. They are confined to the eastern slopes and to the northern part of the BRH at elevations of 1160-1550 m. Stations 95, 96 and 97 (1440-1550 m) are transitional ones with high altitude types. This can be judged by the presence of typically high altitude species like *Celtis timorensis*, *Ixora*

notoniana, *Meliosma pinnata* ssp. *arnottiana*, *Rapanea wightiana*, *Schefflera capitata*, *Vernonia monosis*.

Group C includes stations 55,56,66,67,68,69 and 85, all located above 1600 m. Their absolute contribution to axis 1 varies between 2 and 4% The projection to the positive side of this group C is mainly due to the considerable absolute contribution (2-5%) of certain species which are generally found along the margins of high altitude forests such as *Daphniphyllum neilgherrense*, *Isonandra perrottetiana*, *Ixora notoniana*, *Rapanea wightiana*, *Syzygium densiflorum*, *Tarenna asiatica* .

-The ordination axes 1 and 3 (Fig.20) show a parabolic shaped cloud (Gutman's effect), indicating that axis 3 is a polynomial function of axis 1 and does not give significant additional information when compared to axis 1.

3.2.3 Conclusion

The correspondence analysis clearly demonstrates the distribution of species and stations along an altitudinal gradient and the association of certain species characteristic of a particular altitude or habitat.

Further this analysis clearly brings out the two evergreen types: tall ripicole forests (group A) and low forests (group B) at medium elevations (1000-1400 m) with their characteristic species. At high altitudes, group C stations emerge in the analysis by the weightage of some heliophilous and cold tolerant species which are generally confined to the margins of the forest where the microclimate is different compared to that inside the forest. However, the members of the family Lauraceae that are the most predominant at higher altitudes (>1400 m) have been considered to typify the high altitude low forests.

3.3 Overall classification of the evergreen types

Four types of associations have been recognised on the basis of overall floristic composition (in all the stations), personal observations and clues from 'correspondence analysis'. They are classified according to altitude and named after some species based on their value as characteristic species or for their abundance or both:

* Medium elevation ripicole or gallery forests (1000-1400 m)

. Tall forests

- *Elaeocarpus tuberculatus* - *Michelia champaca* - *Canarium strictum* type

- *Mesua ferrea* - *Palaquium ellipticum* - *Olea glandulifera* type

. Low forests

- *Diospyros ovalifolia* - *Memecylon lushingtonii* type

* High elevation forests (1400-1800 m)

. Low Lauraceous forest type

The distribution, structure and floristic composition of these types are discussed in the later chapters.

3.4 Semi-deciduous forests

Semi-deciduous forests in the BRH are confined between 1100-1400 m, and are mostly transitional to the evergreen types. In Gundal valley they form big patches mostly comprising deciduous trees such as *Celtis tetrandra*, *Dalbergia paniculata*, *Grewia tiliifolia*, *Pterocarpus marsupium*, *Terminalia alata*, *T. paniculata* which are intermixed with evergreen ones, viz., *Aphanamixis polystachya*, *Canthium dicoccum*, *Dimocarpus longan*, *Elaeocarpus serratus*, *Litsea floribunda*, *Mallotus philippensis*, *Neolitsea zeylanica*, *Syzygium cumini*.

Some patches of such semi-deciduous forests along the south-eastern slope form a transition to the Lauraceous type. The deciduous species are more or less the same as above. In addition, species of Lauraceae, *Mallotus philippensis*, *Meliosma simplicifolia* ssp. *pungens*, *Syzygium cumini*, *Vernonia monosis*, *Viburnum punctatum*, *Xantolis tomentosa*, are also found here.

4 SHRUB SAVANNA (GRASSLAND) OF HIGH ELEVATIONS

Shrub savannas interspersed amidst low montane forests (locally called sholas) dominate the landscape at higher altitudes, particularly on the eastern ridge of the BRH. The common species encountered in the shrub savannas are :

*Artemesia parviflora**Coleus sp.**Conyza stricta**Curcuma neilgherrense**Cyanotis fasciculata**Exacum bicolor**Hebenaria sp.**Lagera alata**Oldenlandia sp.**Phlebophyllum kunthianum**Phoenix humilis**Hypericum mysorense*

Among grasses, *Cymbopogon flexuosus*, *C. nardus*, *Themeda cymbaria*, *T. triandra* are common. Seedlings of some tree species such as *Chionanthus ramiflora*, *Embllica officinalis*, *Glochidion neilgherrense*, *G. velutinum*, *Wendlandia thyrsoides* etc., are also observed. Particularly striking is the occurrence of the dome-shaped shrub *Phlebophyllum kunthianum* very common above 1600 m. Below this elevation it is *Phoenix humilis* which dominates the shrub-savanna.

* * *

Table 9 gives the vegetation types of the BRH and their correspondence to the classification of Forests types of India, (Champion and Seth, 1968).

Table 9 - Vegetation types of the BRH and their correspondence to the types of Champion and Seth's (1968) classification

Forest types in the BRH			Champion and Seth's classification (1968)	
Deciduous forest types	Forests	Anogeissus-Pterocarpus-Terminalia type	5A/C1b: Dry teak forest 3B/C1c: Slightly moist teak forest 5/2S1: Secondary dry deciduous forest	
		Anogeissus-Chloroxylon-Albizia type	5A/C3: Southern dry mixed deciduous forest 5A/E4: Hardwickia forest	
	Physiognomy	Savanna Woodland to Tree savanna	5/DS2: Dry savanna forest	
		Scrub Woodland to Thickets	5/DS1: Dry deciduous scrub	
Evergreen / Semi-deciduous forest types	Medium elevation, ripicole or gallery forests	High forests	Tropical wet evergreen forests	1A/C3: Southern hill top tropical evergreen forest (alt. > 1000 m)
		Low forests		
	High elevation low forests	Diospyros-Memecylon type	Tropical broad leaved hills forests	8A/C1: Southern sub-tropical hill forest
Lauraceous type				

5 VEGETATION MAPPING

As a corollary to the vegetation studies, a cartographic synthesis has been attempted to show the precise distribution of the vegetation types described earlier. The information presented in the vegetation map at the scale of 1: 100, 000 (enclosed in the folder on the back cover) has been obtained from my own intensive field studies carried out from 1984 to 1988, supplemented by the data obtained from the Forest Department and from Remote Sensing.

The Working Plans (for the period 1973-1994) of Chamrajnagar Division and Kollegal Division was consulted and the location of plantations and legal status of the forests obtained from the Forest Departments.

Landsat imagery of 1973 and Air photographs of 1980 were consulted. However, the limits of the different vegetation types have been taken from the False Colour Composite (FCC) of the SPOT satellite (May, 1986) at the scale of 1:100,000.

The limits of the evergreen formations could be easily distinguished in the FCC by their bright red colour. The forests of high elevations appear in homogeneous red hue. As the imagery was taken in May, just after the brief leaf fall period, in the tract of deciduous forests, the savanna woodlands appear greyish red and tree savannas reddish grey. Scrub woodlands to thickets come out in dark grey to shallow pink. Shrub savannas of high elevation appear in uniform dark grey colour.

The different vegetation types whose limits have been drawn from the satellite imagery are depicted by different symbols on the map. The location of some species with restricted distribution, particularly in the Lauraceous type, are indicated by numbers.

It is rather difficult to make out the plantations on the Satellite imagery. For example, coffee plantations appear red in like the evergreen forests while the teak and silver oak plantations appear in reddish grey like the savanna woodlands. Because of this problem the limits of the plantations have been taken from the forest maps, toposheets of Survey of India and Air photographs.

The mapped region covers 4 reserved forests viz., Biligiriranga Swamy R.F., Chamrajnagar S.F., Doddasampige R.F., Guttiyalattur R.F. and Talamalai R.F. Their boundaries have been adopted from the toposheets of the Survey of India at the scale of 1: 50, 000 published in 1970.

METHODOLOGY

The methodology used for the structure and floristic composition is both qualitative and quantitative. The structural aspects worked out on small plots are more precise, uniform and easier to compare with other plots; the floristic composition studied on larger areas covers the variability from place to place.

1 STRUCTURAL ANALYSIS

The methodology adopted by Pascal (1984) for the forests of the Western Ghats has been followed here.

Plots of various sizes (300 to 3000 m²) were selected at different sites to show the structure of the forest type and its variations as a result of exposure, topography or altitude.

1.1 Field work

Each plot was divided into subplots measuring 5 x 5 m or 10 x 10 m. All trees, shrubs, and lianas whose girth at 1.30 m from the ground (or above the buttresses) is ≥ 10 cm were identified and measured. Height was measured by means of graduated poles for smaller trees and by Relascope for the taller ones. Heights of the first forking and the base of the foliage were also measured. The slope angles of each subplot were measured by a dendrometer.

Further, a map locating each individual ($G \geq 10$ cm) inside the plot and crown projections, measured by 4 perpendicular radii, were drawn for smaller representative plots (20 x 30 m) in the *Mesua-Palaquium-Olea* and Lauraceous types.

Vertical profiles of the forest were also drawn.

1.2 Spatial structure

1.2.1 Vertical structure

The vertical structure of individuals is shown in profiles measuring 5 x 30, 40 or 60 m. The structural sets of the present, past and future are indicated in the representative plots of *Mesua-Palaquium-Olea* and Lauraceous types. These profiles clearly show the layering of the forest.

1.2.2 Horizontal structure

The horizontal plan includes:

- a diagram of the plot showing the contours and direction of the slopes (by arrows), boulders, dead and trailing lianas on the ground. Every individual has been located by giving numbers and identified upto the species level.

- crown projection: a general plan indicates the coverage of ground by tree crowns. It is further split at a smaller scale to show the relative importance of the different structural ensembles.

1.2.3 Structural ensembles

The growth programme which determines the successive architectural phases of a tree is called architectural model by Oldeman (1974). Following his method, trees may be divided into 3 sets according to their architecture.

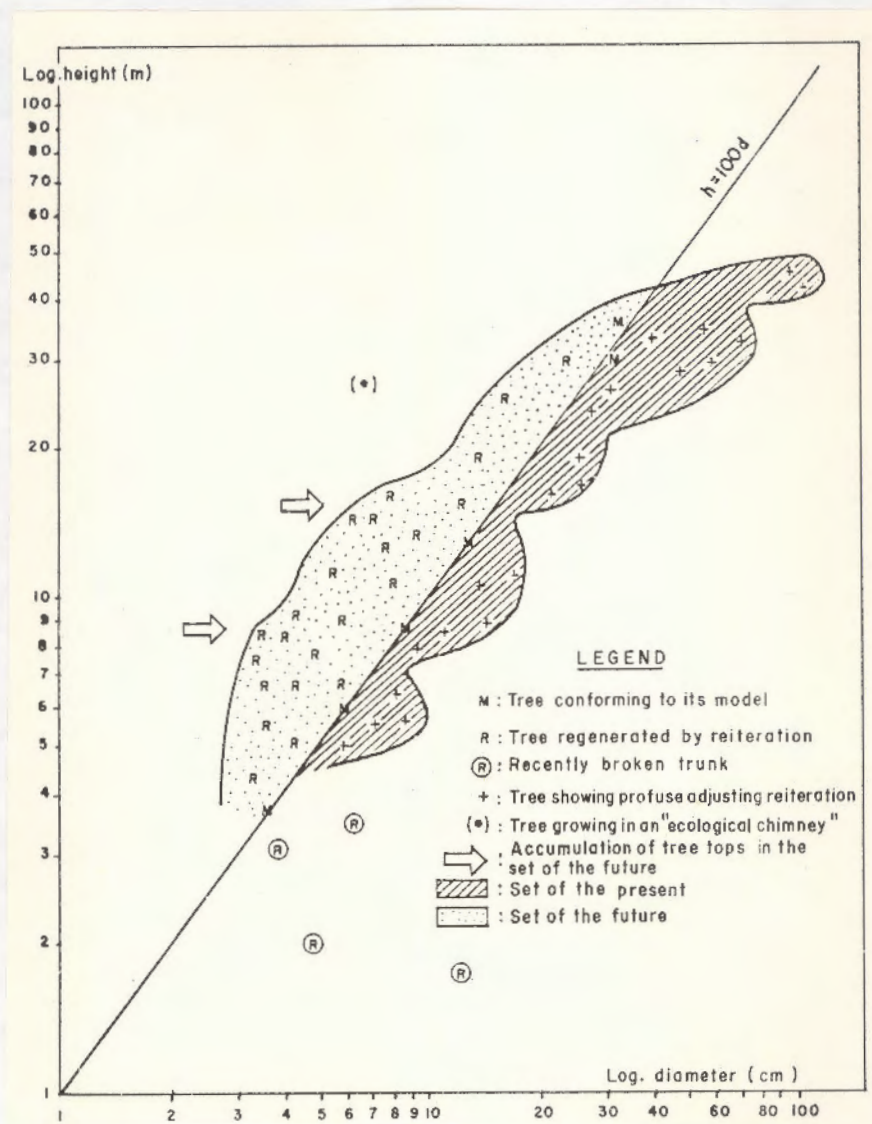
- Trees growing in conformity with their initial model, trees reiterating after injury and trees either with vigorous growth or those having uncertain architectural status *i.e.*, with long periods of suppression followed by brief spurts of vigorous growth during favourable conditions are classed under the set of the future.

- Trees with spontaneous reiteration and those which lack any potential for further growth are grouped under the set of the present.

- Senescent and badly damaged trees constitute the set of the past.

The formula $H=100d$ is a model of expression of harmonious relationships between the height (H) and trunk diameter (d). The change in this expression can be used as a measure of deviation from the model (Hallé *et al.*, 1978).

The distribution pattern of the structural sets as a function of height/diameter relationships (Fig. 21) is interesting: trees growing in conformity with their initial model are distributed more or less along the line $H=100d$. Trees regenerating after damage and those with vigorous growth are to the left of this line. Trees reiterating spontaneously are found to the right and constitute the set of the present. They may be subdivided into structural ensembles corresponding to the layering of the forest for adult trees. This layering is almost entirely masked in the natural forest by the trees of the future which fill all the gaps.



The logarithmic expression of height/diameter coordinates concentrate higher values and spread out the lower ones.

These facts established in tall evergreen forests of French Guiana (Oldeman, 1974), are found to be valid for Indonesia (Laumonier, 1980), Africa (Devineau, 1975) and India (Pascal, 1984).

1.2.4 Girth and height distribution

The girth and height distribution of trees of the different classes as well as of the structural ensembles are shown by means of histograms.

1.2.5 Density

Density is defined as the number of individuals per unit area. Counts were made in each quadrat and the total number of individuals was divided by the total area of the plot and multiplied by 10,000 m² to express the result in terms of the total number of individuals per hectare.

1.2.6 Canopy cover

Canopy cover is calculated from the crown projection of each structural ensemble as well as of all the individuals collectively and is expressed in percentage.

1.2.7 Basal area

Basal area corresponds to the sum of the cross sectional area of trees measured at a height of 1.3 m from the ground or above the buttresses.

The basal area has been calculated by using the following equation for different girth limits and structural ensembles

$$\frac{C^2}{4\pi} \quad \text{where } C = \text{circumference (girth)}$$

1.2.8 Biomass

In order to estimate the biomass in a forest, complete harvesting of the sample area is not possible. Under such circumstances, the trunk diameter (D) and the tree height (H) may be considered to assess the biomass. Therefore, the biovolume (D²H) has been used as an index of biomass. However, the formula D²H, which is generally applicable for cylindrical objects, introduces a systematic error when used for tree trunks, as the latter are progressively narrower towards the apex. In such cases we may assume that the space around the progressively narrow portion of the trunk within the imaginary cylinder which is based on the diameter at a height of 1.3m represents the biomass of branches and foliage.

1.3 Floristic structure: richness and diversity

1.3.1 Floristic richness

The number of species present is plotted against the sample area to produce a species-area curve. Two curves are drawn, one for all the species (trees, shrubs, herbs and lianas excluding epiphytes) and another for trees and lianas with girth ≥ 10 cm.

Floristic richness at the level of the sampling plot gives only a partial picture of the forest type. Hence a large area has been surveyed to obtain a better picture of the flora of each forest type.

1.3.2 Floristic diversity

Several indices of diversity have been proposed; of these, 4 indices have been calculated here for individuals with girth ≥ 10 cm.

- Simpson's index (1949) is the sum of the squares of the proportion of each species.

$$D = 1 - \sum_{i=1}^S \left(\frac{n_i}{N}\right)^2$$

where, n_i = number of individuals of the species 'i'

N = total number of individuals in the plot

S = number of species in the plot

Simpson's index expressed in this form may be easily interpreted in terms of probability : e.g. $D=0.90$ indicates that for 100 pairs of trees taken at random, 10 will be of the same species and 90 will be of different species.

- Shannon-Wiener's index (H'): The value of this index depends on the number of individuals in the sample plot and their distribution among the species. The index is maximum when the species have the same number of individuals and minimum when the individuals are maximally concentrated in one species. The formulae used are:

$$(1) H' = 3.3219 \left(\log_{10} N - \frac{1}{N} \sum_{i=1}^S n_i \log_{10} n_i \right)$$

$$\text{which is derived from } H' = 1 - \sum_{i=1}^S \left(\frac{n_i}{N}\right) \log_2 \left(\frac{n_i}{N}\right)$$

$$(2) H \text{ max} = \log_2 S$$

$$(3) E = \frac{H'}{H \text{ max}}$$

where n_i , N and S denote the same as in Simpson's index and 3.3219 corresponds to the conversion factor from \log_2 to \log_{10} .

The equitability ratio (E) gives an idea of the real distribution (H') as compared to the maximum dispersion (H max) taking into account the number of species present in the plot.

The number of individuals per species is shown in the form of histograms. The relative density of each species is given in percentages.

- Importance value index (IVI): Each of the three quantitative parameters, *viz.* density, basal area and frequency, has its own individual importance. However, a complete picture of the ecological status of a species with respect to a particular community structure can be obtained by synthesising the percentage values of relative density, relative dominance and relative frequency (Curtis and McIntosh, 1950). To calculate the IVI, the method described by Cain *et al.* (1956) has been followed. The total area of the plot is subdivided into quadrats of 10 x 10 m.

- Density: n_i = number of individuals of the species 'i';

- Relative density: $rD = \frac{n_i}{N} \times 100$

where N = total number of individuals in the plot;

- Dominance: d_i = sum of the basal area (at 1.30 m or above the buttresses) of individuals of the same species;

- Relative dominance: $rd = \frac{d_i}{d} \times 100$

where d = total basal area of the plot;

- Frequency: $f_i = \frac{c_i}{c} \times 100$

where c_i = number of quadrats where the species is present and c = total number of quadrats studied.

- Relative frequency: $rF = \frac{f_i}{F} \times 100$

where F = $\sum f_i$

Thus the IVI of each species is: $rD + rd + rF$. This value may vary from 0 to 300.

IVI of botanical families are also given by adding the IVI of the different species of a family found in the plot.

2 FLORISTIC COMPOSITION

For a better picture of the floristic composition, each type of evergreen forest in the BRH was surveyed thoroughly by relevé analysis method. The total number of relevés covered is 130. In the field a check list of plants is prepared for each relevé. The nature of the habitat and its influence on the distribution of species were noted. This is primarily a qualitative method.

A floristic list was prepared for each type (see Annexe) indicating for each species its frequency, its position in the structural ensemble and habitat characteristics such as streams, openings, margins etc. These lists are quite exhaustive for trees and shrubs.

**ELAEOCARPUS TUBERCULATUS - MICHELIA CHAMPACA -
CANARIUM STRICTUM TYPE**

In the midst of deciduous forests, narrow strips of tall evergreen forests are encountered along streams in the valleys. As they are dependent on the high moisture content of the soil, these riparian (or gallery) forests have been termed as an edaphic type. At their fringes, evergreen trees mingle with deciduous trees.

The type is characterised by hygrophilous species such as *Elaeocarpus tuberculatus*, *Salix tetrasperma*, *Syzygium malabaricum*. These forests are narrow with uneven canopy and hence light can penetrate through the margins and openings, promoting the growth of heliophilous species like *Canarium strictum* and *Aphanamixis polystachya*. The presence of *Michelia champaca*, is a noteworthy feature of these forests; one individual of remarkable size in the Gundal valley has become an object of veneration and pilgrims trek long distances to worship this tree. Even the reserved forest has been named after the local Kannada vernacular name of the species "Dodda Sampige".

1. LOCATION

The ripicole forests are found between 1000-1400 m. In the western half they are confined to the streams in the valleys of the Biligiriranga Swamy temple R.F., Chamrajnagar R.F. and Guttiyallatur R.F, while in the eastern half they are found in the Gundal valley, the valley between Oddanabetta and Honnaparabetta and in some valleys along the eastern slopes.

As the slope becomes less steep with decrease in altitude, the network of valleys in the west have slower flowing streams providing ample moisture for the luxuriant growth of ripicole forests. The Gundal valley located between the central and eastern ridges also provides good humid conditions. On the other hand, steeper slopes in the east provide a terrain for fast flowing streams. Hence the water is quickly drained off resulting in low soil saturation and also increasing soil erosion. As a result a rapid change in the physiognomy and floristic composition can be observed. Even

the ripicole type may change to low *Diospyros-Memecylon* forests as observed in some valleys of the eastern slopes.

In the western half these riparian forests are flanked by deciduous forests while in the Gundal valley they are generally bordered by semi-deciduous forests.

2. FLORISTIC COMPOSITION

This type of forest comprises 139 species including 21 deciduous ones which are intermixed or found along the margins (Pteridophytes are excluded). The list of species according to families is given in Annexe 1.

The structure of this type varies, depending on the degree of soil saturation, size of water course, presence of big boulders, etc. and hence no detailed structural studies were carried out. However, they are generally tall forests with 3-4 structural ensembles. The top canopy often exceeds 25 m particularly in the more humid regions.

2.1 Trees of structural ensemble I (SE I)

There are no true emergents. However there are a few species which exceed 25m under favourable conditions. Among them *Elaeocarpus tuberculatus* (often with very big buttresses) and *Salix tetrasperma* grow very near the streams. Some other species adapted to comparatively less humid conditions include *Acrocarpus fraxinifolius*, *Cassine glauca*, *Mangifera indica* and *Michelia champaca*. Among trees ranging from 20 to 25 m, mention may be made of *Dimocarpus longan*, *Elaeocarpus serratus*, *Ficus nervosa*, *Meliosma pinnata* ssp. *arnottiana*, *Persea macrantha* and *Syzygium cumini*. There also a few heliophilous species such as *Aphanamixis polystachya*, *Canarium strictum*, *Celtis tetrandra*, *Chukrasia tabularis*, *Ficus microcarpa*, *F. tsjahela*, *F. virens* and *Toona ciliata*.

Deciduous species which may reach the main canopy are *Albizia odoratissima*, *Dalbergia latifolia*, *D. paniculata*, *Grewia tiliifolia*, *Pterocarpus marsupium*, *Stereospermum personatum*, *Terminalia alata*, *T. bellirica*.

2.2 Trees of structural ensemble II

This ensemble also includes some species of the preceding ensemble growing under less favourable conditions. *Bischofia javanica*, *Ficus hispida*, *F. mollis*, *F.*

racemosa, and *Viburnum punctatum* are quite conspicuous bordering water courses. The common species in this ensemble are *Actinodaphne lawsonii*, *Canthium dicoccum*, *Cinnamomum travancoricum*, *Litsea floribunda*, *Mallotus philippensis*, *Meliosma simplicifolia* ssp. *pungens*, *Neolitsea zeylanica*, *Phoebe paniculata* and *Prunus ceylanica* etc. *Casearia ovata*, *Cinnamomum sulphuratum*, *Olea glandulifera*, and *Xantolis tomentosa* are also common to the Lauraceous type.

Species growing in the openings of the main canopy include *Mallotus tetracoccus* and *Sterculia guttata*. *Trichilia connaroides* is rarely seen along the margins.

Careya arborea, *Erythrina stricta*, *Kydia calycina* and *Sapindus laurifolius* represent the deciduous species of ensemble II.

2.3 Trees of structural ensemble III

This ensemble comprises many heliophilous species. *Callicarpa tomentosa*, *Catunaregam torulosa*, *Chionanthus ramiflora*, *Glochidion neilgherrense*, *G. velutinum*, *Murraya paniculata* are common along the margins. Species growing in openings of the canopy include *Clerodendrum viscosum*, *Litsea deccanensis*, *Macaranga peltata*, *Memecylon lushingtonii* and *Meyna laxiflora*. *Antidesma menasu* and *Euodia lunu-ankenda* are commonly seen under dense canopy. *Diospyros ovalifolia* a characteristic species of the low forest type of medium elevations, is found in the degraded forests of this type along the valley north of Oddanabetta.

Deciduous species are represented by *Cassia fistula*, *Cordia macleodii*, *Emblica officinalis*, *Oroxylum indicum*, *Radermachera xylocarpa*.

2.4 Trees of structural ensemble IV

This ensemble also includes large shrubs. Among them *Syzygium malabaricum* is characteristic of swampy habitats, other common and widely spread species being *Ardisia solanacea*, *Atalantia wightii*, *Clausena indica*, *Cocculus laurifolius*, *Maesa indica*, *Nothapodytes foetida*, *Psychotria elongata* and *P. nigra*. *Symplocos cochinchinensis* and *Ziziphus rugosa* are common along the margins.

Among deciduous species, *Eriolaena hookeriana* and *Helicteres isora* are common in the western half of the BRH.

2.5 Shrubs and herbaceous layer

Paucity of species in this stratum may be attributed to rocky outcrops and eroded soils. Common shrubs are *Chasalia ophioxylodes*, *Cipadessa baccifera*, *Pavetta indica* etc. *Mussaenda sp.* often occur along the margins. *Arisaema sp.*, *Elatostema lineolatum*, *Globba bulbifer*, *Munronia pinnata*, *Polygonum chinense* are some of the common herbs.

2.6 Climbers

Woody lianas are common and are represented by *Calamus gamblei*, *Diploclisia glaucescens*, *Entada pursaetha*, *Gnetum ula*, *Mezoneuron cuculatum*, *Scutia myrtina*, *Toddalia asiatica var. floribunda*. The non-woody climbers include *Allophylus cobbe*, *Asparagus racemosus*, *Carissa inermis*, *Jasminum azoricum* and *Piper hymenophyllum*. *Caesalpinia sepiaria*, *Rubus fairholmianus*, *R. niveus* are common along margins.

3. ALTITUDINAL VARIATIONS

At higher elevations this type undergoes a gradual change in the floristic composition as well as in the abundance of certain species:

- At the upper limits *i.e.*, between 1350 and 1400 m, one can notice that the gradual decrease in the height of trees and the disappearance of some deciduous species like *Anogeissus latifolia*, *Grewia tiliifolia* etc. of lower elevations.

- The 1400-1500 m elevation range is a transition zone for medium and high altitude species. The trees are stunted and some species such as *Ficus hispida*, *F. microcarpa*, *F. mollis*, *Litsea deccanensis*, *Munronia pinnata* disappear. There is also a decrease in the number of some typical species like *Aphanamixis polystachya*, *Dimocarpus longan*, *Elaeocarpus tuberculatus* and *Michelia champaca*. On the other hand, there is an increase in Lauraceae members, *Casearia ovata* and *Xantolis tomentosa*. Some other species such as *Celtis timorensis*, *Elaeagnus kologa*, *Euonymus crenulatus*, *Eurya nitida*, *Fagraea ceilanica*, *Ixora notoniana*, *Rauwolfia densiflora*, *Vernonia monosis* (along margin) also make their appearance.

- Below 1000 m, the structure of this type becomes more irregular often due to the widening of streams or due to increasing dryness of the valleys. Many evergreen

species disappear although some like *Chukrasia tabularis*, *Mangifera indica* and *Syzygium cumini* continue to thrive below 1000 m; other species such as *Derris indica* and *Terminalia arjuna* which are absent at higher elevations make their appearance here. In some places, the water courses are without any evergreen trees.

4. LATITUDINAL VARIATIONS IN INTERMEDIATE ZONES: 1360-1500 m

Besides altitudinal variations, this type of forest also shows latitudinal variations in some valleys.

- The valleys (1360-1500 m) towards the west of Dumberabetta and Akkatangibetta are interesting because of the occurrence of *Memecylon talbotianum* and *Memecylon lushingtonii* which are characteristic species of the Western Ghats and Eastern Ghats respectively.

- The valleys between Anebetta and Hattubarebetta are characterised by the presence of certain species of high altitude such as *Daphniphyllum neilgherrense*, *Isonandra perrottetiana*, *Rapanea wightiana* and *Viburnum coriaceum*.

Acrocarpus fraxinifolius, *Actinodaphne lawsonii*, *Artocarpus heterophyllus*, *Casearia ovata*, *Cassine glauca*, *Cinnamomum sulphuratum*, *Clausena indica*, *Ficus nervosa*, *Macaranga peltata*, *Schefflera capitata*, *Villebrunea integrifolia* are recorded only in the Gundal valley.

MESUA FERREA - PALAQUIUM ELLIPTICUM - OLEA GLANDULIFERA TYPE

This forest type is represented by just a small patch which is structurally and floristically quite different from other formations in the BRH.

Structurally, this formation is distinctly stratified. Trees are tall with straight boles, some of them provided with buttresses. Floristically certain species found here make them comparable to the medium elevation types of the Western Ghats (Pascal, 1984). Moreover, the presence of a few characteristic species of the Eastern Ghats makes this pocket extremely interesting.

1 LOCATION

This small patch lies at an elevation of 1300-1400 m in the Gundal valley, between Aravillabetta and Honnamettibetta, covering an area of approximately 0.5 km²

The once vast extent of this forest type is now encroached upon by coffee estates on all three sides.

Below 1300 m this forest gradually merges with the *Elaeocarpus-Aphanamixis-Michelia* type along the Gundal stream and above 1400 m the nature of the forest progressively changes both structurally and floristically to the Lauraceous type.

2. STRUCTURAL STUDY

The structural studies were carried out in two plots. One in a 'L' shaped plot of 1600 m² on a gentle slope and the other in a 3000 m² (10 x 300 m) plot with both good as well as moderately disturbed patches of forest.

2.1 Spatial structure

2.1.1 Vertical profile

Fig. 22-a and b show two adjacent strips, each measuring 5 x 30 m. Only individuals with girth ≥ 10 cm have been considered.

The crowns of the first ensemble (canopy trees) are between 15 and 32 m. In Fig. 22-a there are openings in the main canopy in the left and middle part of the profile true emergents are absent, while in Fig. 22-b the canopy is more or less

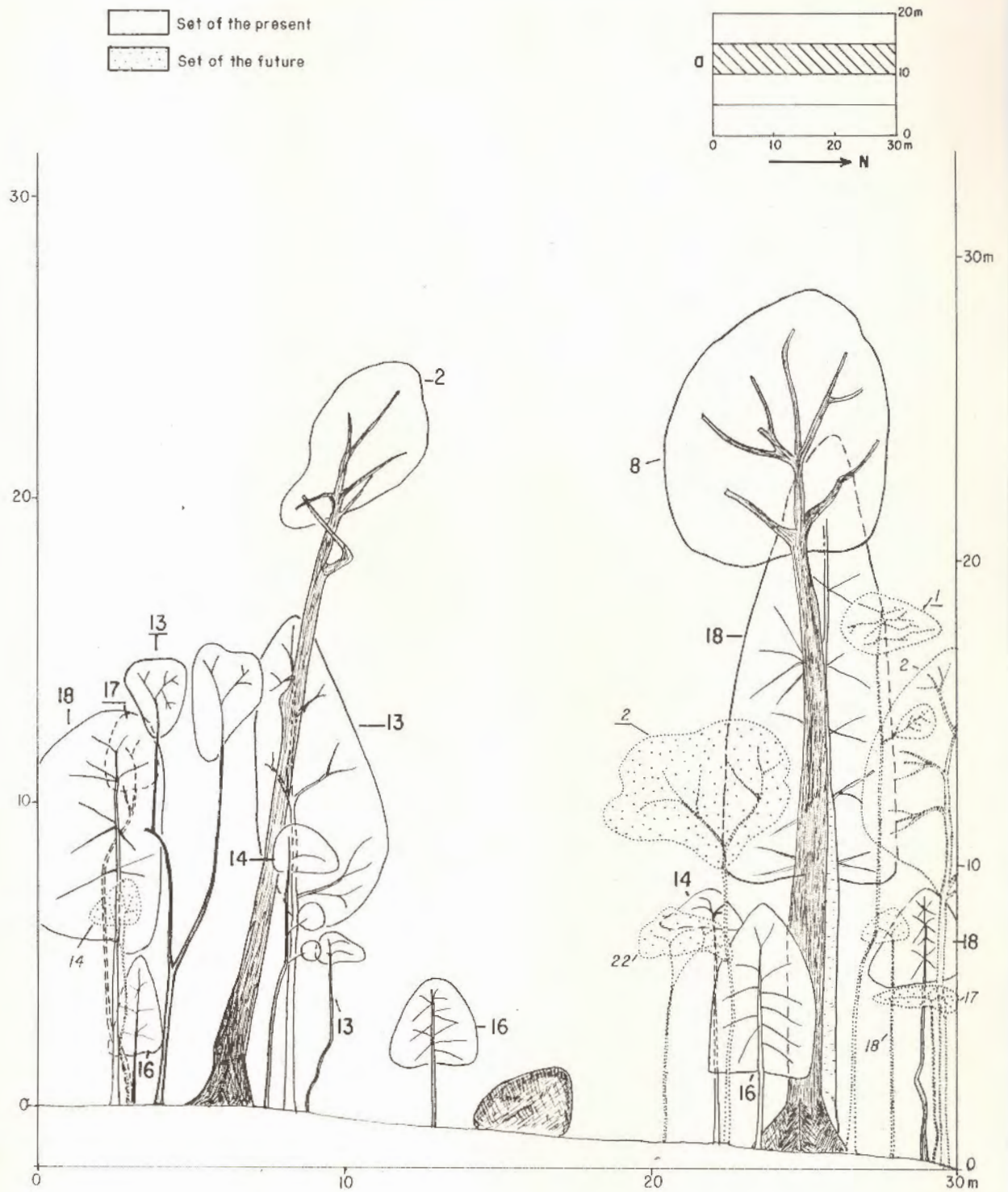
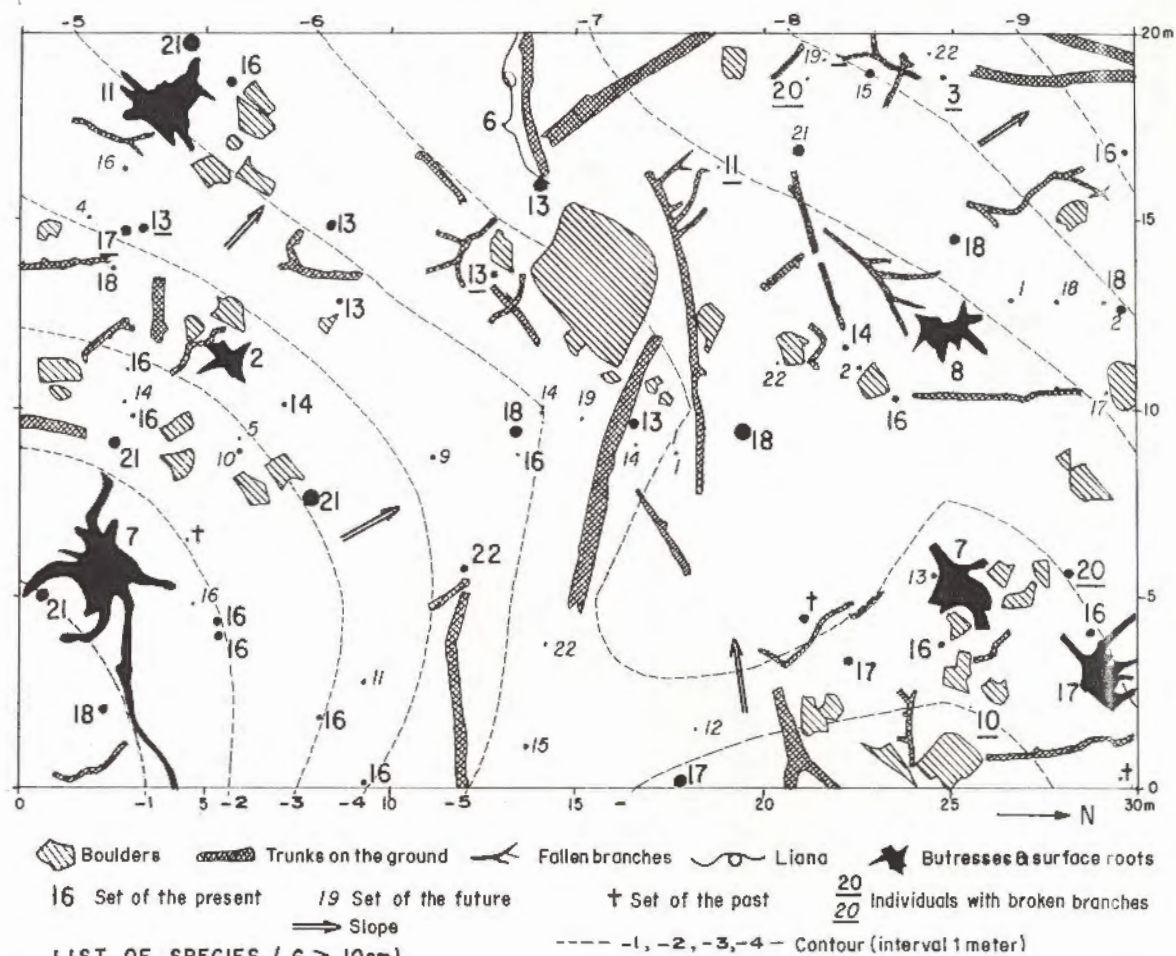


Fig. 22a - Vertical profile (5 x 30 m)



Fig. 22b - Vertical profile (5 x 30 m)



1. *Actinodaphne bourdillonii* Gamble
2. *Aglaiia joinii* Viswa & Rama.
3. *Antidesma menasu* Tul.
4. *Atalantia wightii* Tan.
5. *Beilschmiedia wightii* (Benth) J. Hk.
6. *Cayratia* sp.
7. *Chionanthus ramiflora* Roxb.
8. *Cinnamomum kerakaense* Kosterm.
9. *Clerodendrum viscosum* Vent.
10. *Cryptocarya neilgherrensis* Meisner.
11. *Dimocarpus longan* Lour.

12. *Diospyros ovalifolia* Wt.
13. *Epiprinus mollotiformis* (Meull) Croiz.
14. *Isonandra perrattetiana* DC.
15. *Litsea oleoides* J. Hk.
16. *Meiogyne pannosa* (Dolz) Sinclair.
17. *Mesua ferrea* L.
18. *Myristica doctyloides* Gaertn.
19. *Neolitsea zeylanica* (Nees) Merrill.
20. *Phaebe paniculata* Nees.
21. *Palaquium ellipticum* (Dolz) Baillon
22. *Villebrunea integrifolia* Gaud.

Fig. 23 - Plan of the sampling plot (20 x 30 m)

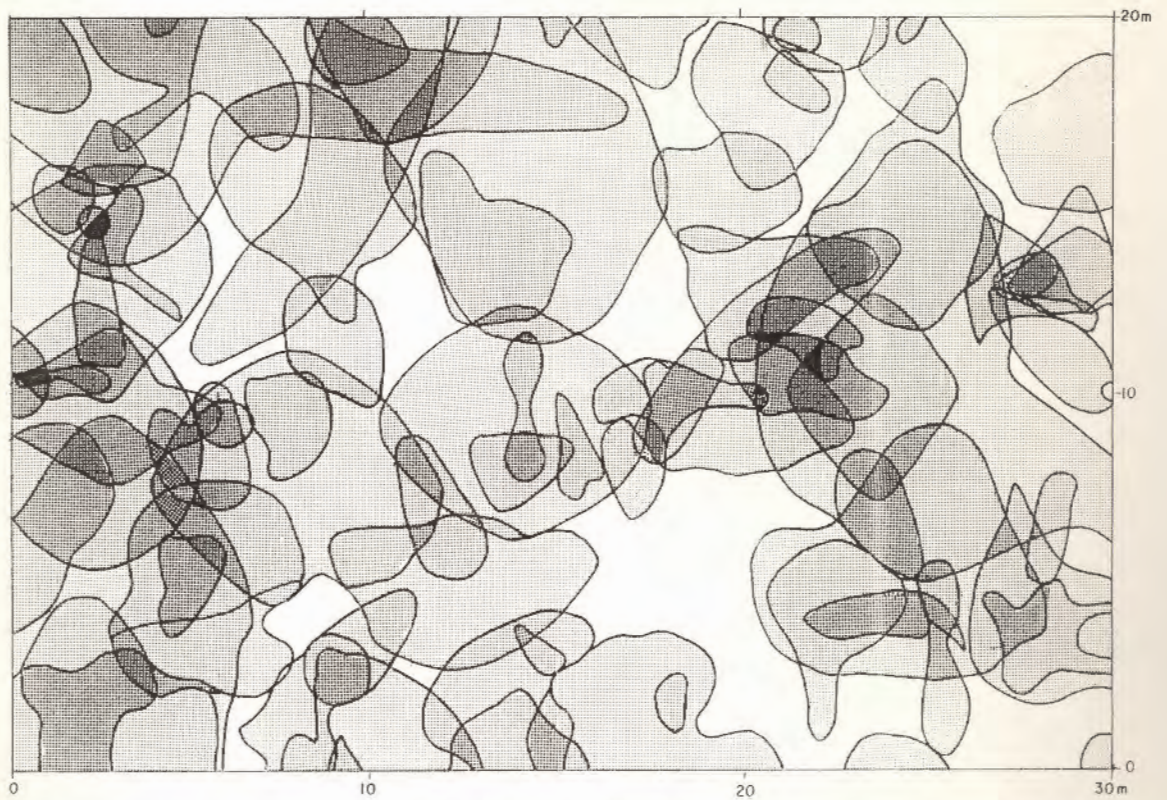
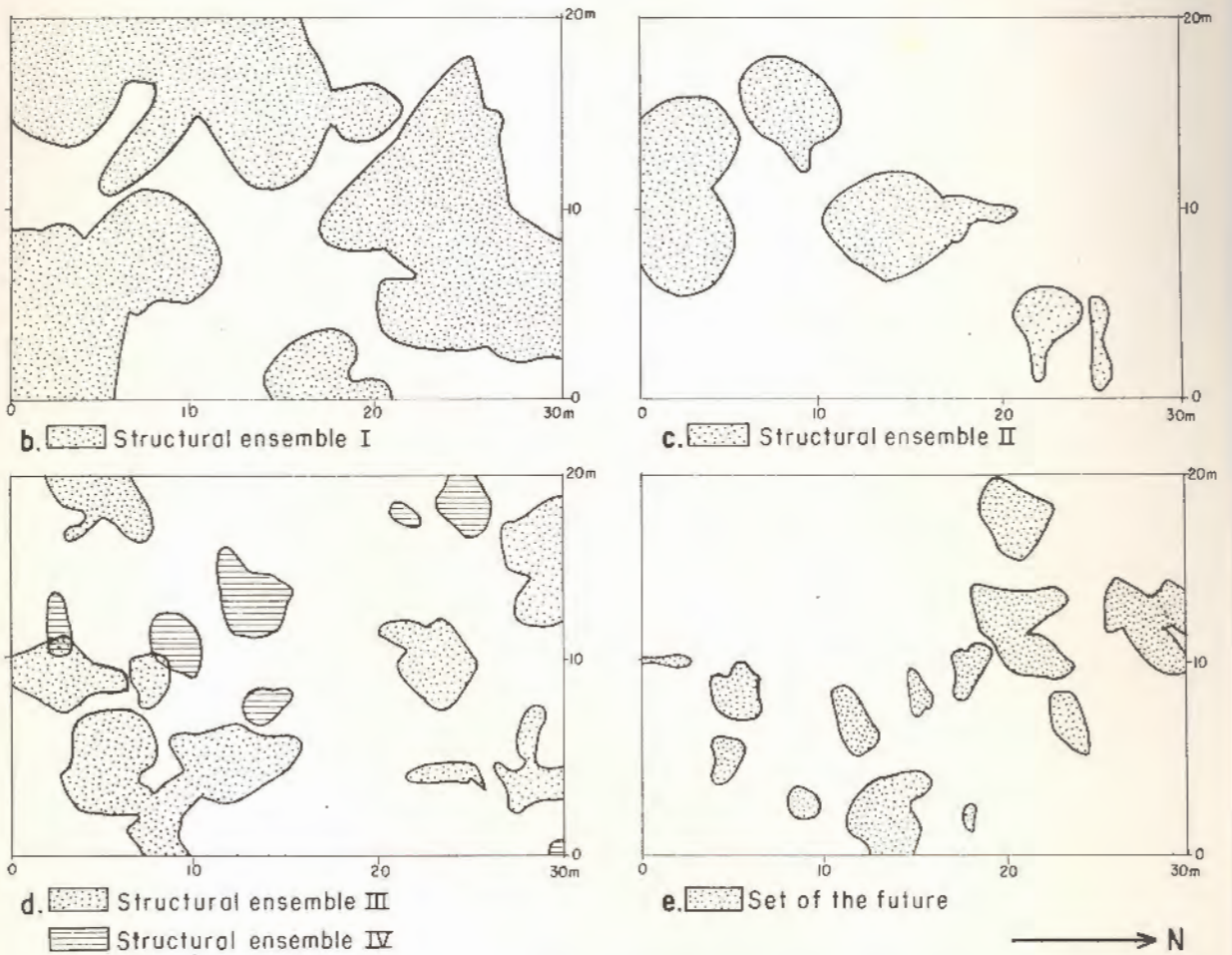


Fig. 24 - Crown projection

continuous. The presence of two big trees of *Chionanthus ramiflora*, a heliophilic species, in the upper part of the canopy indicates past disturbance.

The trees of the second structural ensemble range between 13 and 21 m. They are comparatively less dense. Below these are the structural ensembles III and IV, which are fairly dense specially in the left half of the profiles.

The trees of the set of the future are more concentrated in the openings of the main canopy.

Myristica dactyloides and *Meiogyne pannosa* are characteristic by their branching pattern. The former shows horizontal and verticillate branches while the latter has horizontal, alternate-spiral branches and is more common in structural ensembles III and IV.

2.1.2 Horizontal Plans

The ground plan of the 600 m² (20 x 30 m) plot is illustrated in Fig. 23. It shows the position of the individuals of the different sets. The north-west oriented gradient of the slope is shown by contours at intervals of 1 m.

The fallen trees and branches are evidences of strong winds in this valley. The big boulder (which is not an outcrop) may have rolled down from the top of the hill. The area occupied by the buttresses of some big trees are also shown.

The crown projections in Fig. 24-a indicate that the total cover is considerable: 85%. The big gap near the centre of the plot is due to a fallen tree. Crown projections of the different ensembles are shown in Fig. 24-b, c, d, e. and the percentage of ground cover of each of these is given in Table 10. The maximum contribution is by structural ensemble I (59.5%) but this shows a big discontinuity in the centre and north-western corner of the plot. There is a sudden drop in the percentage of ground cover of the lower ensembles as well as of the set of the future. The structural ensemble II accounts for only 20.3%. while the structural ensembles III and IV represent 24.8% and 7.1% respectively.

The set of the future constitutes 17.3%.

2.1.3 Height/diameter relationships and structural ensembles

The height/diameter relationships are given in Figs: 25-a and b taken in two separate plots of 3000 m² and 1600 m². Trees of the set of the future to the left of and near the H=100d line constitute 50.2% of the total number of individuals when both the plots are taken together. If the 3000 m² (10 x 300) plot alone is considered, the future trees represent 54.3%. This may be due to the fact that the first half (10 x 150 m) of the plot is comparatively open and consequently allows more light into the undercanopy, enabling several individuals to grow vigorously.

Four structural ensembles can be distinguished in the set of the present (*i.e.* below the H=100 d line).

Structural ensemble I including emergents (21-37 m) accounts for 12.7% of the total number of individuals. The most common species is *Palaquium ellipticum* (24.6%) followed by *Myristica dactyloides* (17.8%) and *Dimocarpus longan* (13.7%); *Casearia ovata*, *Litsea oleoides* and *Neolitsea zeylanica* (5.5%); *Mesua ferrea* and *Persea macrantha* (4.1%); *Chionanthus ramiflora*, *Cinnamomum keralaense* and *Epiprinus mallotiformis* (2.7%); *Actinodaphne lawsonii*, *Aglaia jainii*, *Bellschmiedia wightii*, *Bischofia javanica*, *Canarium strictum*, *Diospyros sylvatica*, *Phoebe paniculata* and *Toona ciliata* (1.4%).

Structural ensemble II (13-20 m) comprises 7.2% of the total number of individuals. It includes *Agrostistachys meeboldii*, *Artocarpus heterophyllus*, *Cryptocarya neilgherrensis*, *Ficus nervosa*, *Isonandra perrottetiana*, *Mallotus tetracoccus*, in addition to some species of structural ensemble I.

Structural ensembles III (7-14 m) and IV (<7 m) contribute 16.1% and 12% respectively. Species common to both these ensembles are *Antidesma menasu*, *Meiogyne pannosa*, *Villebrunea integrifolia*, whereas *Atalantia wightii*, *Ardisia pauciflora*, *Coffea arabica*, *Mallotus stenanthus*, *Neopeltandra longipes* are more common in structural ensemble IV.

The set of the past comprises only 10 trees and constitutes 1.8% of the total number of individuals

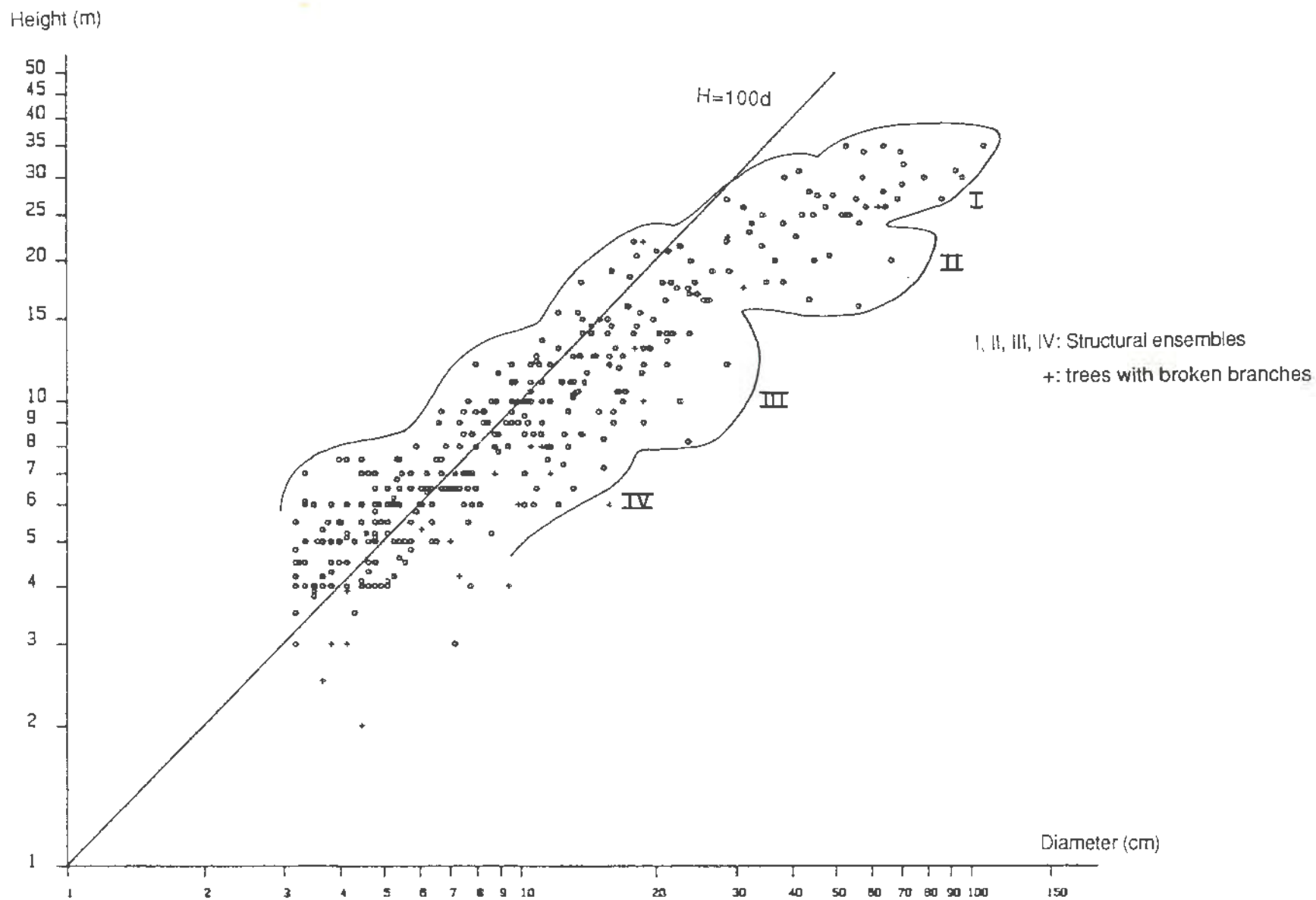


Fig. 25a - Height/diameter relationships in logarithmic coordinates (3000 m²)

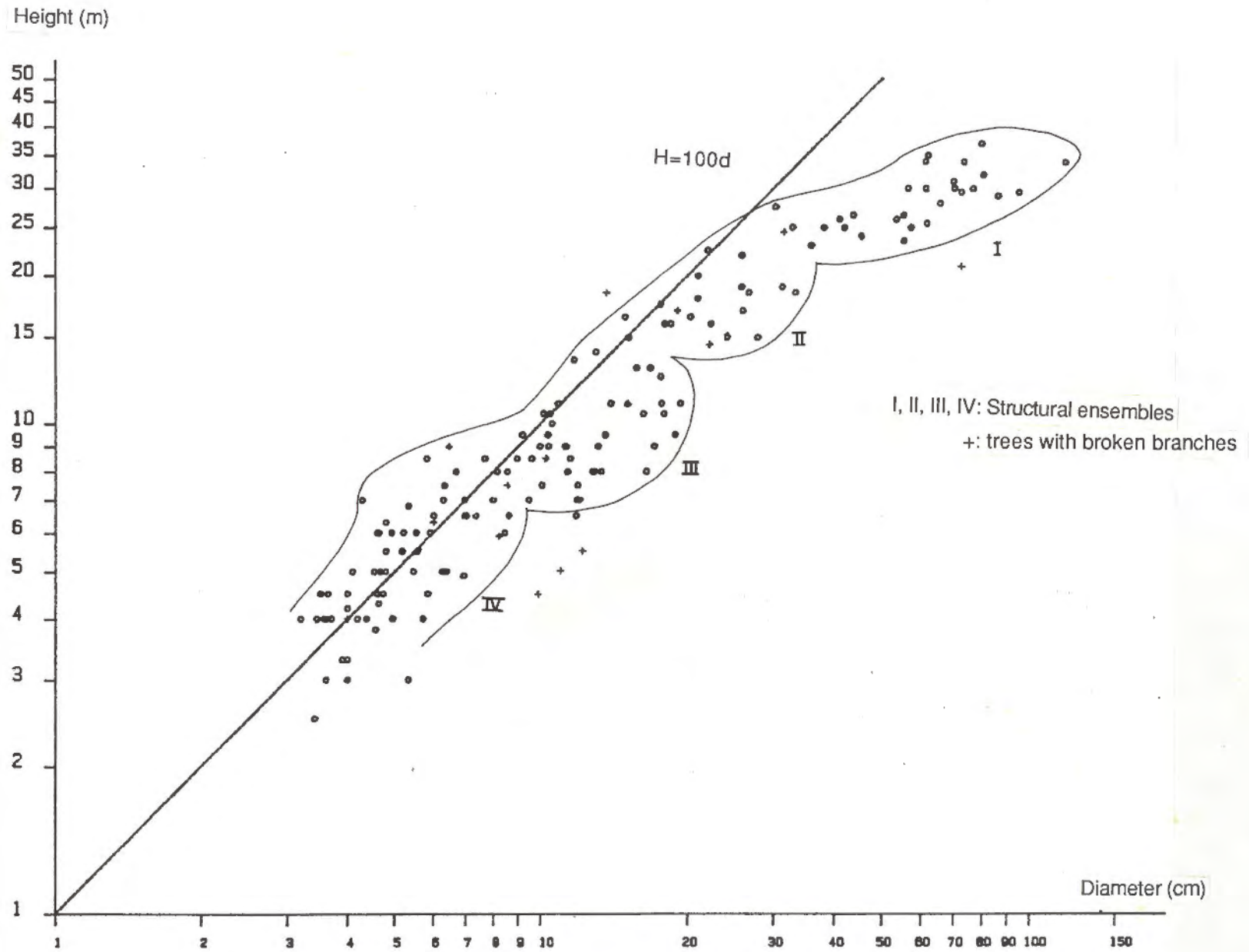


Fig. 25b - Height/diameter relationships in logarithmic coordinates (1600 m²)

2.1.4 Girth distribution (Fig. 26)

The girth distribution pattern is basically 'L' shaped for the total number of individuals ($G \geq 10$ cm) as well as for the set of the future.

Trees of the set of the future are very common in the 10-20 cm class and show a sudden fall in the 20-30 cm girth class.

The girth distribution pattern is assymmetrically bell-shaped for structural ensembles II and III of the set of present. Structural ensemble I is more or less uniformly distributed between 90 and 380 cm.

2.1.5 Height distribution (Fig. 27)

The height distribution is roughly bell-shaped. The distribution pattern for the total number of individuals ($G \geq 10$ cm) shows two peaks: one in the 4-6 m class mostly due to the high frequency of trees of the future and another peak in the 24-26 m class, contributed by the structural ensemble I. The deficiency in the 2-4 m class is due to the girth limit of ≥ 10 cm taken for the sampling plot.

2.1.6 Density

The density of the different sets and structural ensembles according to girth classes are given in Table 10. The total number of trees/ha with girth ≥ 10 cm is 1216. The large trees with girth ≥ 120 cm are moderate in number (145/ha) and represent 12% of the individuals.

Table 10- Density and percentage of ground cover

	Set of the present				Set of the future	Set of the past	Total
	Structural Ensemble I + Emergents	Structural Ensemble I	Structural Ensemble III	Structural Ensemble IV			
Number of trees/ha							
G ≥ 10 cm	154	87	196	146	611	22	1216
% without lianas	12.7	7.2	16.1	12.0	50.2	1.8	100
G ≥ 40 cm	154	87	133	7	70	7	458
G ≥ 80 cm	154	48	2	-	5	2	211
G ≥ 120 cm	130	13	-	-	-	2	145
Percentage of ground cover	59.5	20.3	24.8	7.1	17.3	-	85.2

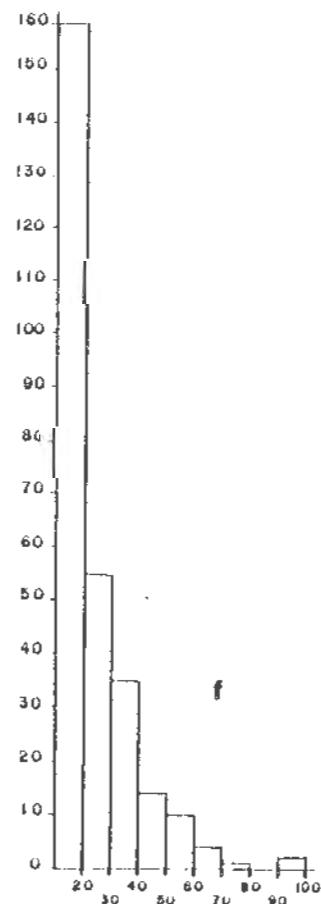
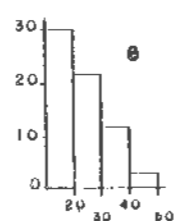
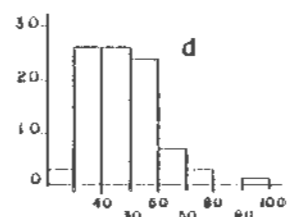
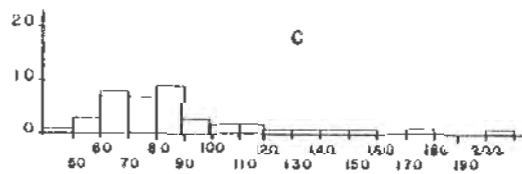
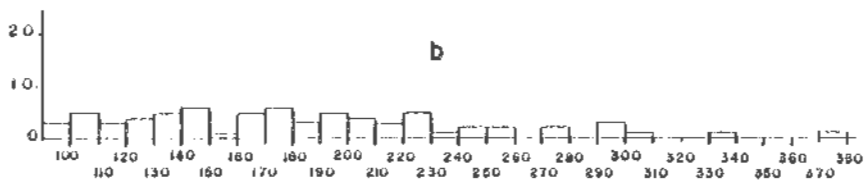
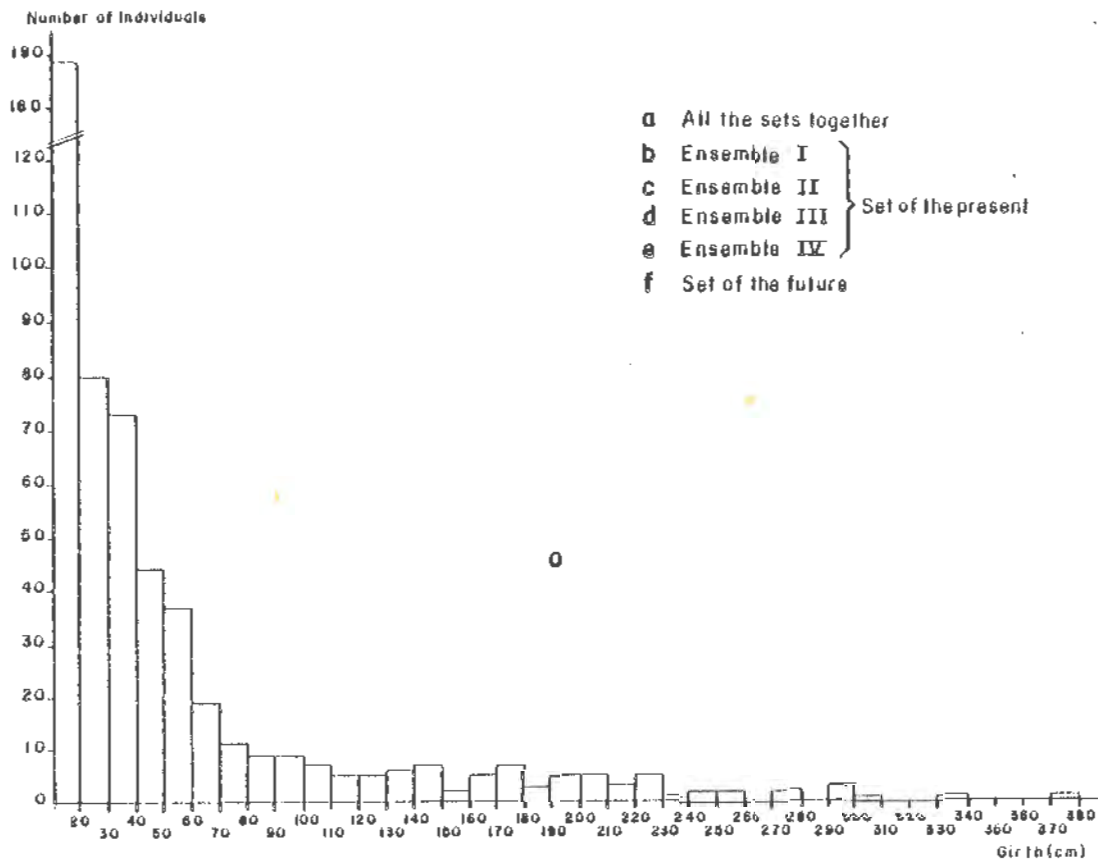


Fig. 26 - Girth distribution

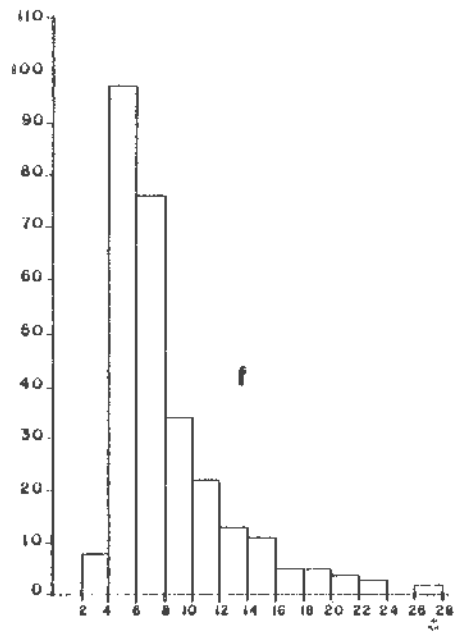
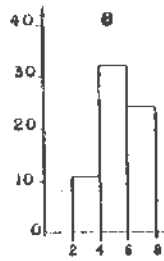
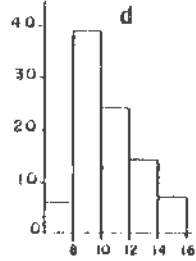
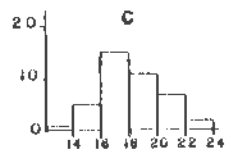
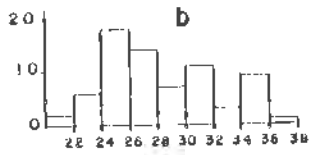
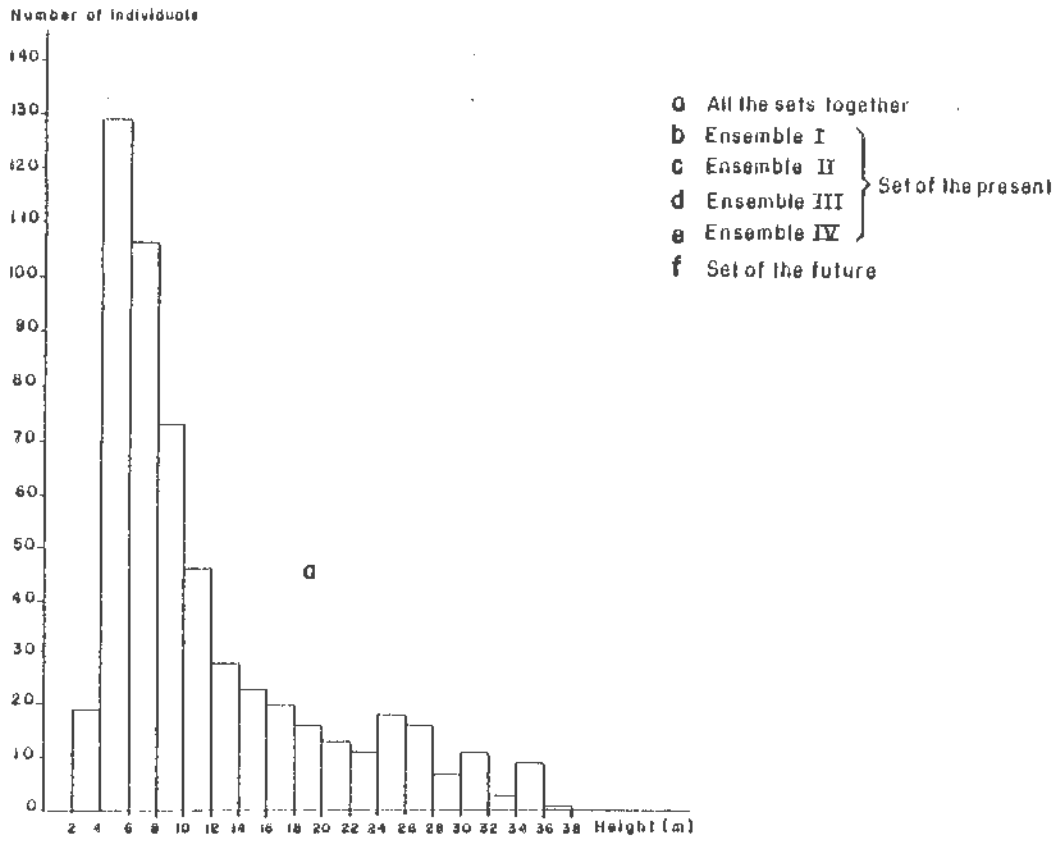


Fig. 27 - Height distribution

2.1.7 Basal area and biomass index (D^2H)

As shown in Table 11, the total basal area/ha is 60.1 m^2 of which more than one third is contributed by big trees ($G \geq 120$ cm).

The total D^2H is 1962.5 m^3/ha .

In the set of the present, the structural ensemble I together with emergents accounts for 12.7% of the individuals constituting 75.5% of the total basal area and 86.3% of the biovolume (Tables 10 and 11). The structural ensemble II comprises only 7.2% of the individuals, but represents 10.7% of the basal area and 7.6% of the biovolume. The remaining 2 sets constitute 28.1% of the individuals and comprise 7.2% of the basal area and 2.8% of the biovolume.

The trees of the set of the future which constitutes 50.2% of the individuals represent only 5.8% of the basal area and 3.2% of the biovolume.

Table 11 - Basal area and D^2H

	Set of the present				Set of the future	Set of the past	Total	
	Structural Ensemble I + Emergents	Structural Ensemble II	Structural Ensemble III	Structural Ensemble IV				
Basal area (m^2/ha)	$G \geq 10$ cm	45.4	6.4	3.6	0.7	3.5	0.5	60.1
	% without lianas	75.5	10.7	6.0	1.2	5.8	0.8	100
	$G \geq 40$ cm	45.4	6.4	3.0	0.1	1.7	0.4	57.0
	$G \geq 80$ cm	45.4	5.0	0.1	-	0.3	0.2	51.0
	$G \geq 120$ cm	43.3	2.6	-	-	-	0.2	46.1
$D^2H(m^3/ha)$		1694.3	149.9	49.6	5.2	61.8	1.7	1962.5
	%	86.3	7.6	2.5	0.3	3.2	0.1	100

2.2 Floristic structure

2.2.1 Floristic richness

The species-area curve which is an index of the floristic richness has been worked out in the total 4600 m^2 area (1600 and 3000 m^2 plots). Species with $G \geq 10$ cm (54 species) as well as species without a girth-limit (78 species) have been recorded (although ferns are included, epiphytes have not been taken into consideration).

The results obtained are shown in Fig. 28. The lower curve represents species with girth ≥ 10 cm. It can be seen that 36% of the species are already recorded in the first 200 m^2 . In the upper curve which represents all the species without a girth limit,

55% of the species are in the first 300 m². Both the curves then slope gradually upwards but a plateau is not attained. The slight fall (shown by arrows in Fig. 28) is due to the crossing from the 1600 m² plot to the adjacent 3000 m² plot.

The list given in Annexe 2 has been compiled after a thorough survey of this forest type. It comprises 107 species including 79 species with girth ≥ 10 cm.

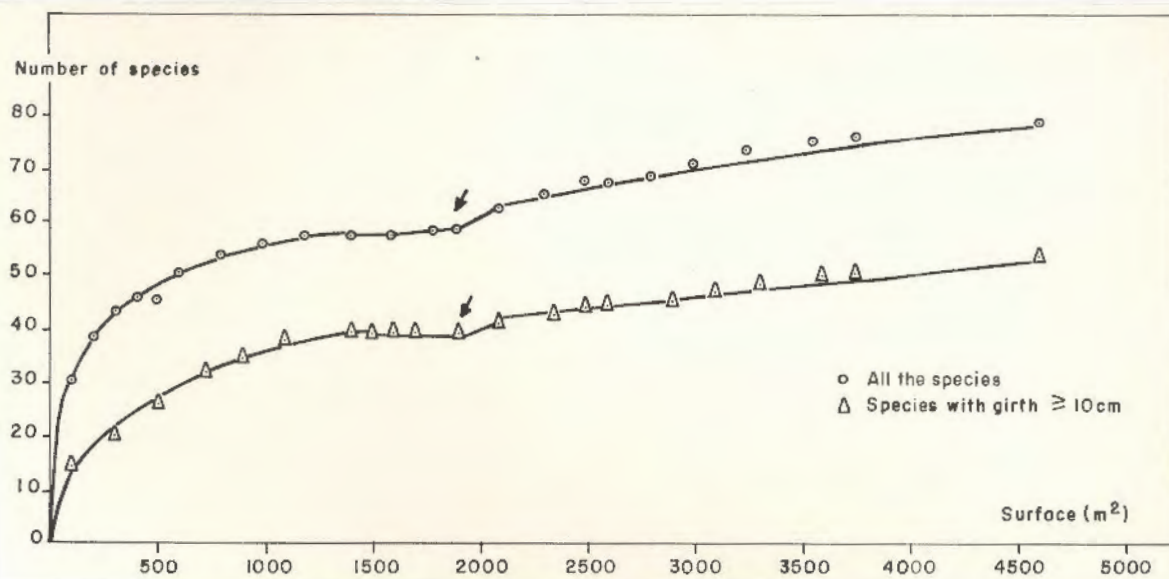


Fig. 28 - Species-area curves

2.2.2 Floristic diversity

The relative density of each species ($G \geq 10$ cm) in the 4600 m² plot is shown in Fig. 29. The distribution pattern is typically 'L' shaped. Of the total number of 54 species, 17 are represented by just 1 or 2 individuals. The first 5 species in Fig. 29 together constitute 52.6%. *Meiogyne pannosa* by itself accounts for 19.5%, while the joint contribution of *Palaquium ellipticum*, *Villebrunea integrifolia*, *Neolitsea zeylanica* and *Myristica dactyloides* is 32.6%. The next 5 species *Isonandra perrottetiana*, *Dimocarpus longan*, *Mesua ferrea*, *Litsea oleoides* and *Epiprinus mallotiformis* account for 19.8%. The above 10 species together make up 72.4% of the relative density. They are well distributed, except for *Villebrunea integrifolia* which colonises the openings.

The importance value index (IVI) calculated in an area of 3600 m²* is given in Table 12. The first 16 species have an IVI of more than 5, eight of them exceeding 10.

* In the 4600 m² area only 3600 m² has been divided into smaller sub plot of 10 x 10 m which is essential for calculating the IVI.

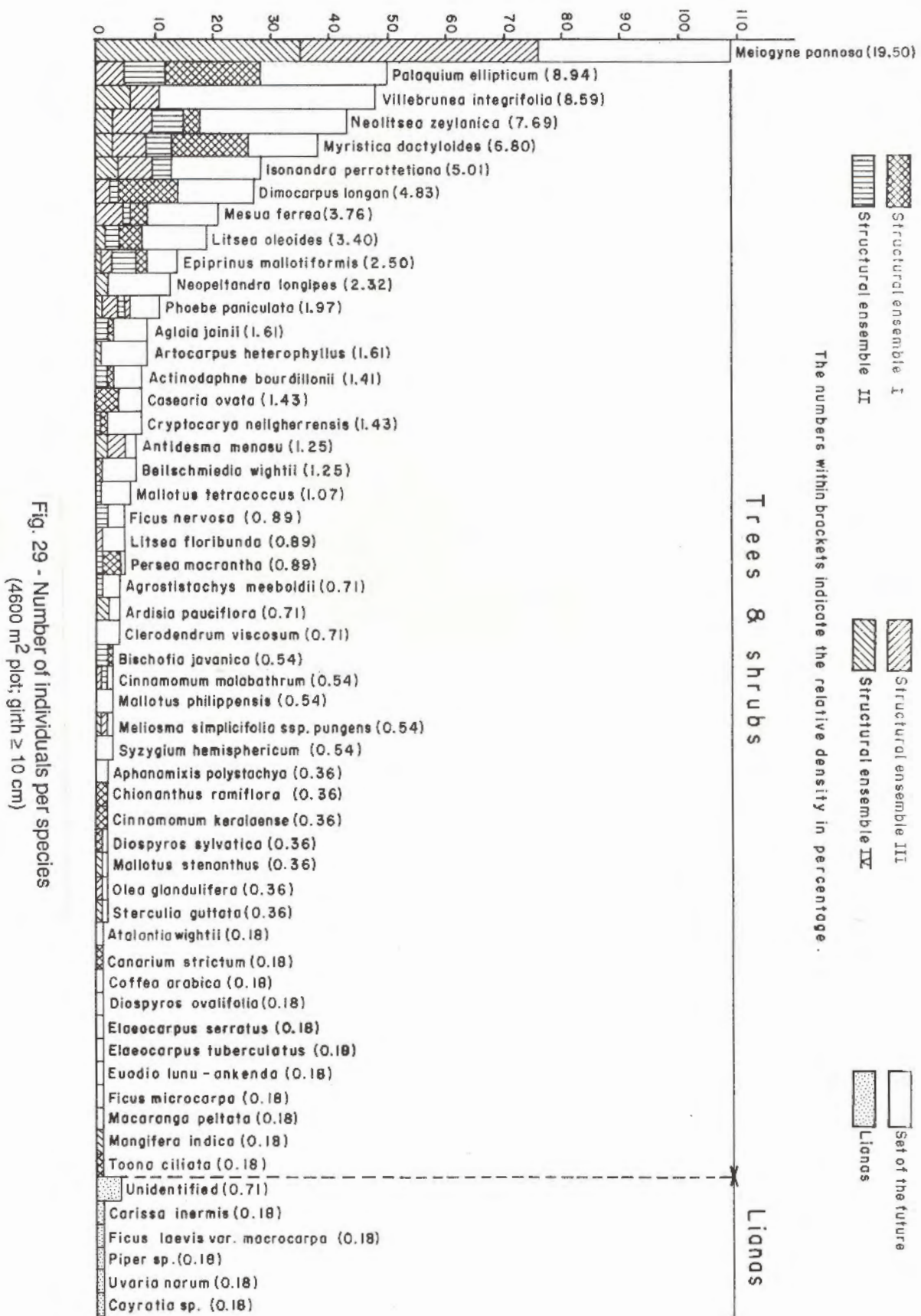


Table 12 - Relative Importance of species

Species	Families	Importance Value Index
<i>Palaquium ellipticum</i>	Sapotaceae	34.96
<i>Meiogyne pannosa</i>	Annonaceae	34.15
<i>Dimocarpus longan</i>	Sapindaceae	26.39
<i>Myristica dactyloides</i>	Myristicaceae	24.94
<i>Neolitsea zeylanica</i>	Lauraceae	17.62
<i>Villebrunea integrifolia</i>	Urticaceae	16.52
<i>Litsea oleoides</i>	Lauraceae	14.97
<i>Isonandra perrottetiana</i>	Sapotaceae	10.62
<i>Chionanthus ramiflora</i>	Oleaceae	9.65
<i>Mesua ferrea</i>	Clusiaceae	9.54
<i>Epiprinus mallotiformis</i>	Euphorbiaceae	7.60
<i>Actinodaphne bourdillonii</i>	Lauraceae	6.46
<i>Phoebe paniculata</i>	Lauraceae	5.89
<i>Aglaiia jainii</i>	Meliaceae	5.70
<i>Casearia ovata</i>	Flacourtiaceae	5.63
<i>Persea macrantha</i>	Lauraceae	5.07
<i>Bischofia javanica</i>	Euphorbiaceae	4.98
<i>Cinnamomum keralaense</i>	Lauraceae	4.86
<i>Cryptocarya neilgherrensis</i>	Lauraceae	3.96
<i>Artocarpus heterophyllus</i>	Moraceae	3.84
<i>Neopeltandra longipes</i>	Euphorbiaceae	3.81
<i>Antidesma menasu</i>	Euphorbiaceae	3.76
<i>Beilschmiedia wightii</i>	Lauraceae	3.63
<i>Toona ciliata</i>	Meliaceae	2.88
<i>Ficus nervosa</i>	Moraceae	2.62
<i>Litsea floribunda</i>	Lauraceae	2.49
<i>Clerodendrum viscosum</i>	Verbenaceae	2.35
<i>Mallotus tetracoccus</i>	Euphorbiaceae	2.25
<i>Agrostistachys meeboldii</i>	Euphorbiaceae	1.87
<i>Meliosma simplicifolia</i> ssp. <i>pungens</i>	Sabiaceae	1.82
<i>Cinnamomum malabathrum</i>	Lauraceae	1.81
Climbers (unidentified)		1.76
<i>Ardisia pauciflora</i>	Myrsinaceae	1.75
<i>Syzygium hemisphericum</i>	Myrtaceae	1.23
<i>Sterculia guttata</i>	Sterculiaceae	1.17
<i>Aphanamixis polystachya</i>	Meliaceae	1.16
<i>Mallotus philippensis</i>	Euphorbiaceae	1.16
<i>Canarium strictum</i>	Burseraceae	0.97
<i>Mallotus stenanthus</i>	Euphorbiaceae	0.82
<i>Olea glandulifera</i>	Oleaceae	0.75
<i>Diospyros sylvatica</i>	Ebenaceae	0.67
<i>Macaranga peltata</i>	Euphorbiaceae	0.60
<i>Ficus microcarpa</i>	Moraceae	0.60
<i>Atalantia wightii</i>	Rutaceae	0.59
<i>Carissa inermis</i>	Apocynaceae	0.59
<i>Coffea arabica</i>	Rubiaceae	0.59
<i>Diospyros ovalifolia</i>	Ebenaceae	0.59
<i>Elaeocarpus serratus</i>	Elaeocarpaceae	0.59
<i>Euodia lunu-ankenda</i>	Rutaceae	0.59
<i>Uvaria narum</i>	Annonaceae	0.59
<i>Cayratia</i> sp.	Vitaceae	0.59

Table 13 - Relative importance of families

Families	Number of species	Importance Value index
Lauraceae	10	66.76
Sapotaceae	2	45.58
Annonaceae	2	34.74
Euphorbiaceae	9	26.85
Sapindaceae	1	26.39
Myristicaceae	1	24.94
Urticaceae	1	16.52
Oleaceae	2	10.40
Meliaceae	3	9.74
Clusiaceae	1	9.54
Moraceae	3	7.06
Flacourtiaceae	1	5.63
Verbenaceae	1	2.35
Sabiaceae	1	1.82
Climbers	1	1.76
Myrsinaceae	1	1.75
Ebenaceae	2	1.26
Myrtaceae	1	1.23
Rutaceae	2	1.18
Sterculiaceae	1	1.17
Burseraceae	1	0.97
Apocynaceae	1	0.59
Elaeocarpaceae	1	0.59
Rubiaceae	1	0.59
Vitaceae	1	0.59

Table 14 - Floristic diversity

Area (m ²)	Number of species=S (G≥10 cm)	Number of individuals=N (G≥10 cm)	Area/species (m ²)	N/S	Simpson's index	Shannon-Wiener's index		
						H'	Hmax	E=H'/Hmax
4600	54	559	83	10.2	0.92	4.5	5.8	0.78

Palaquium ellipticum (35) and *Meiogyne pannosa* (34.2) together present an IVI of 69.2, suggesting a degree of co-dominance. However, *Palaquium ellipticum* with some big individuals shows a high relative dominance ($rD= 18.24$) but low relative density ($rd= 9.25$) and relative frequency ($rf= 7.47$), when compared to *Meiogyne pannosa* whose rD (3.73) is low. However, the rD (19.39) and rf (11.03) are high.

Mesua ferrea and *Olea glandulifera* which have been used to typify this forest have IVI of 9.54 and 0.75 respectively. The IVI of families (Table 13) indicate that Lauraceae (66.76), represented by 10 species, is predominant. These species become more numerous with further increase in altitude. Thus the high IVI of Lauraceae may suggest that this type is at the upper limit of the medium elevation range. Other families with IVI more than 25 are represented by only one or two species (except Euphorbiaceae).

The floristic diversity index is given in Table 14. The ratio of the number of individuals per species is 10.2 and the area occupied by each species is 83 m². Simpson's index shows that out of 100 pairs taken at random only 8 are composed of the same species. Shannon-Wiener's index $H'= 4.5$ is high and comparable to certain types of evergreen formations of the Western Ghats (Table 16). The value of 'E' (0.78) indicates that the species are well distributed.

3 FLORISTIC STUDY

This type of forest comprises 107 species belonging to 50 families. Each species has been classified according to its habit, its position in the structural ensembles and ecological preference such as streams, openings etc. (Annexe 2).

3.1 Emergents and trees of structural ensemble I

Emergents are very few, unlike in other rain forests of the Western Ghats and just overlap the main canopy. *Elaeocarpus tuberculatus* and *Michelia champaca* are giant trees growing near water courses. *Acrocarpus fraxinifolius* and *Cassine glauca* are very tall heliophytes; the latter has several big individuals with large girths. *Mesua ferrea* and *Ficus nervosa* are also seen as emergents in some places.

SE I is floristically rich and can be divided into two classes following Raunkiaer's (1934) classification of life forms: megaphanerophytes (≥ 30 m) and mesophanerophytes (≤ 30 m).

Trees with potentiality to grow more than 30 m high (megaphanerophytes) are *Chrysophyllum lanceolatum*, *Dimocarpus longan*, *Litsea oleoides*, *Myristica dactyloides*, *Palaquium ellipticum* and *Syzygium gardneri*. *Ficus nervosa* and *Mesua ferrea* are widely distributed while *Mangifera indica* and *Persea macrantha* are frequent in moist regions. The presence of big heliophilous species like *Chionanthus ramiflora* and *Toona ciliata* indicate past openings.

Trees with lesser height potential (mesophanerophytes) ranging from 20 to 30 m in height are *Actinodaphne lawsonii*, *Aglaiia jainii*, *Aphanamixis polystachya*, *Beilschmiedia wightii*, *Casearia ovata*, *Cinnamomum keralaense*, *Diospyros ovalifolia*, *D. sylvatica*, *Elaeocarpus serratus*, *Epiprinus mallotiformis*, *Ficus microcarpa*, *Meliosma pinnata* spp. *arnottiana*, *Olea glandulifera* and *Syzygium cumini* among others. In open places *Canarium strictum* and *Celtis tetrandra* are often encountered. *Neolitsea zeylanica* and *Phoebe paniculata* sometimes exceed 20 m; however they are more common in structural ensembles II and III.

3.2 Trees of structural ensemble II

This ensemble also includes trees of species like *Aphanamixis polystachya*, *Casearia ovata*, *Epiprinus mallotiformis*, mesophanerophytes of the preceding ensemble growing under less favourable conditions. Other important species in this ensemble are *Actinodaphne malabarica*, *Artocarpus heterophyllus*, *Cryptocarya neilgherrensis*, *Euodia lunu-ankenda*, *Litsea floribunda*, *Meliosma simplicifolia* spp. *pungens*, *Prunus ceylanica*, etc. The heliophilous species in the openings are *Macaranga peltata* and *Sterculia guttata*. *Bischofia javanica* and *Viburnum punctatum* are common in wet regions, particularly *Bischofia javanica* which attains good heights near streams.

Species common to the structural ensemble II and the upper limits of the structural ensemble III are *Agrostistachys meeboldii*, *Cinnamomum malabathrum*, *Isonandra perrottetiana*. The first species is generally rare under a dense canopy.

However, it is often seen colonising open areas especially in the middle of the forest. In the *Cullenia-Mesua-Palaquium* type in the Western Ghats (Pascal, 1984), individuals of *Agrostistachys meeboldii* are taller and quite common in the second storey.

3.3 Trees of the structural ensembles III and IV

Among the species common to these two ensembles, *Meiogyne pannosa* is abundant in both. It is characterised by its cone-shaped crowns. Other common species in these two ensembles are *Ardisia pauciflora*, *Chionanthus malabaricus*, *Cocculus laurifolius*, *Glochidion sp.*, *Syzygium hemisphericum* etc.

The openings are generally colonized by *Clerodendrum viscosum*, *Mallotus tetracoccus*, *Neopeltandra longipes*, *Villebrunea integrifolia* (also found along margins). *Debregeasia longifolia* and *Trema orientalis* are common in the fire affected openings. *Callicarpa tomentosa*, *Symplocos cochinchinensis ssp. laurina*, *Vernonia monosis* grow along the margins.

Cyathea sp., a tree fern, is occasionally present along the streams.

3.4 Shrubs and herbaceous layer

The distribution and abundance of species belonging to this group depend upon exposure, soil moisture and rocky out crops.

Among the shrubs, *Nilgirianthus barbatus* with winged stems are often seen in exposed moist places. *Coffea arabica* is common as an undergrowth shrub. Evidently it is an escape from the surrounding coffee estates. *Atalantia wightii*, *Clausena dentata*, *Psychotria elongata* are also frequently encountered. *Solanum gigantea* is very common in areas affected by fire.

The herbaceous layer is mostly constituted by *Elatostema lineolatum* and a number of ferns which are uniformly distributed, often forming a mosaic with *Geodorum densiflorum* in open moist places. *Anoectochilus elatior*, *Arisaema sp.*, *Munronia pinnata* and *Ophiopogon intermedius* are also common.

Among other plants, the epiphytic *Lycopodium sp.* hanging from the branches of tall trees and *Peperomia sp.* and *Procris wightiana* anchored to the cracks in the barks or in crevices of moist rocks are noteworthy.

3.5 Climbers

Among climbers, *Calamus gamblei* and *Piper sp.* are very common. *Calamus gamblei* usually forms a dense cover difficult to penetrate. It is an economically important species for the local tribes, providing them the cane for basket weaving and other purposes.

Another interesting species is *Ficus laevis var. macrocarpa*, a cauliflorious species which is very rare and was observed only once. Other species found occasionally are: *Allophylus cobbe*, *Cayratia sp.*, *Gnetum ula* and *Hiptage benghalensis*. The climbers armed with prickles or spines are represented by *Carissa inermis*, *Toddalia asiatica var. floribunda* and *Zanthoxylum tetraspermum*. The last two species are woody with broad based prickles.

Woody lianas are generally very few in number when compared to the evergreen forests of the Western Ghats .

4 REGENERATION

To understand the successional status of this forest, the regeneration of some of the important canopy trees, the predominant ones of the understory as well as those growing in the gaps have been studied.

To plot seedlings and saplings, the middle line of the rectangular plots used to study big individuals ($G \geq 10$ cm) is considered. The total length of this middle line is 336 m. The seedlings and saplings touching this line are counted and their heights measured.

507 seedlings and saplings belonging to 38 species of trees and shrubs were encountered along the central line.

Only a few individuals succeed in the competition for survival. If only individuals exceeding a height of 75 cm (fairly well established ones) are considered, then there are just 200 individuals spread over 30 species.

The relative density (rd) of all the individuals and those having height ≥ 75 cm are given in Table 15.

Table 15 - Relative density of seedlings and saplings

Species	Total no. of individuals	rd(%)	No. of individuals ≥ 75 cm	rd(%) ≥ 75 cm
<i>Dimocarpus longan</i>	123	24.26	48	24.00
<i>Palaquium ellipticum</i>	121	23.87	14	7.00
<i>Litsea oleoides</i>	61	12.03	17	8.50
<i>Coffea arabica</i>	29	5.72	11	5.50
<i>Myristica dactyloides</i>	22	4.34	11	5.50
<i>Neolitsea zeylanica</i>	22	4.34	12	6.00
<i>Neopeltandra longipes</i>	16	3.16	14	7.00
<i>Meiogyne pannosa</i>	15	2.96	8	4.00
<i>Aphanamixis polystachya</i>	14	2.76	9	4.50
<i>Villebrunea integrifolia</i>	13	2.56	7	3.50
<i>Beilschmiedia wightii</i>	9	1.78	3	1.50
<i>Phoebe paniculata</i>	8	1.58	6	3.00
<i>Clerodendrum viscosum</i>	7	1.38	7	3.50
<i>Cryptocarya neilgherrensis</i>	7	1.38	7	3.50
<i>Isonandra perrottetiana</i>	6	1.18	6	3.00
<i>Cinnamomum malabathrum</i>	5	0.99	3	1.50
<i>Psychotria elongata</i>	4	0.79	0	0.00
<i>Litsea floribunda</i>	3	0.59	2	1.00
<i>Aglaia jainii</i>	2	0.39	2	1.00
<i>Agrostistachys meeboldii</i>	2	0.39	2	1.00
<i>Chionanthus ramiflora</i>	2	0.39	0	0.00
<i>Mesua ferrea</i>	2	0.39	1	0.50
<i>Actinodaphne lawsonii</i>	1	0.20	1	0.50
<i>Antidesma menasu</i>	1	0.20	1	0.50
<i>Artocarpus heterophyllus</i>	1	0.20	0	0.00
<i>Atalantia wightii</i>	1	0.20	1	0.50
<i>Canarium strictum</i>	1	0.20	0	0.00
<i>Casearia ovata</i>	1	0.20	1	0.50
<i>Cassine glauca</i>	1	0.20	0	0.00
<i>Epiprinus mallotiformis</i>	1	0.20	1	0.50
<i>Mallotus philippensis</i>	1	0.20	1	0.50
<i>Memecylon lushingtonii</i>	1	0.20	0	0.00
<i>Meliosma simplicifolia</i> ssp. <i>pungens</i>	1	0.20	1	0.50
<i>Olea glandulifera</i>	1	0.20	1	0.50
<i>Persea macrantha</i>	1	0.20	1	0.50
<i>Syzygium hemisphericum</i>	1	0.20	1	0.50

4.1 Regeneration of canopy tree species

When all the height classes of seedlings and saplings are considered, the relative density of *Dimocarpus longan* and *Palaquium ellipticum* is the highest, about 24% each, followed by *Litsea oleoides* with 12%. All the 3 species are common canopy trees. The height distribution patterns of these 3 species are shown in Fig. 30.

If only saplings ≥ 75 cm are considered, then *Dimocarpus longan* and *Litsea oleoides* which are relatively less dominant among adult trees have high relative densities (24% and 8.5%, respectively) when compared to *Palaquium ellipticum* whose density is only 7%.

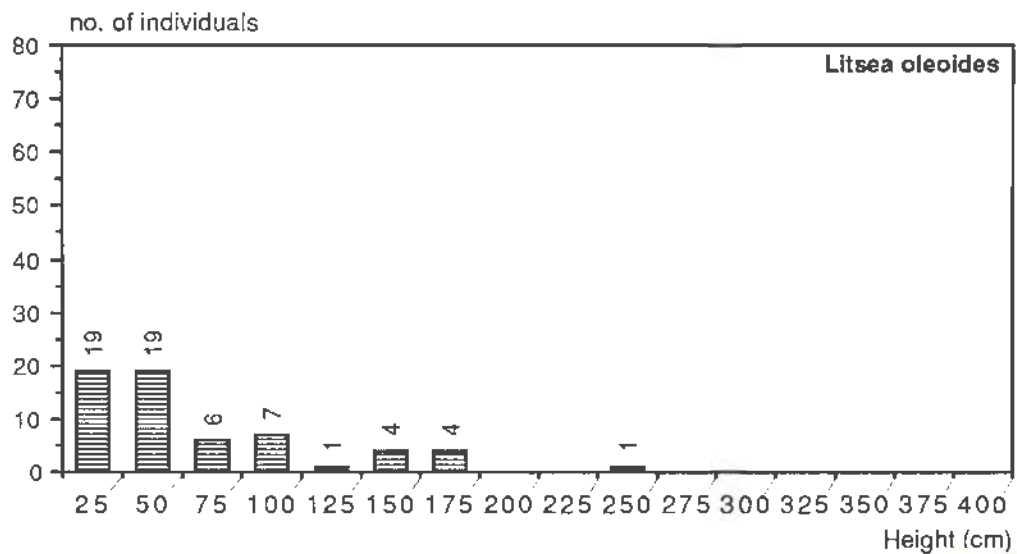
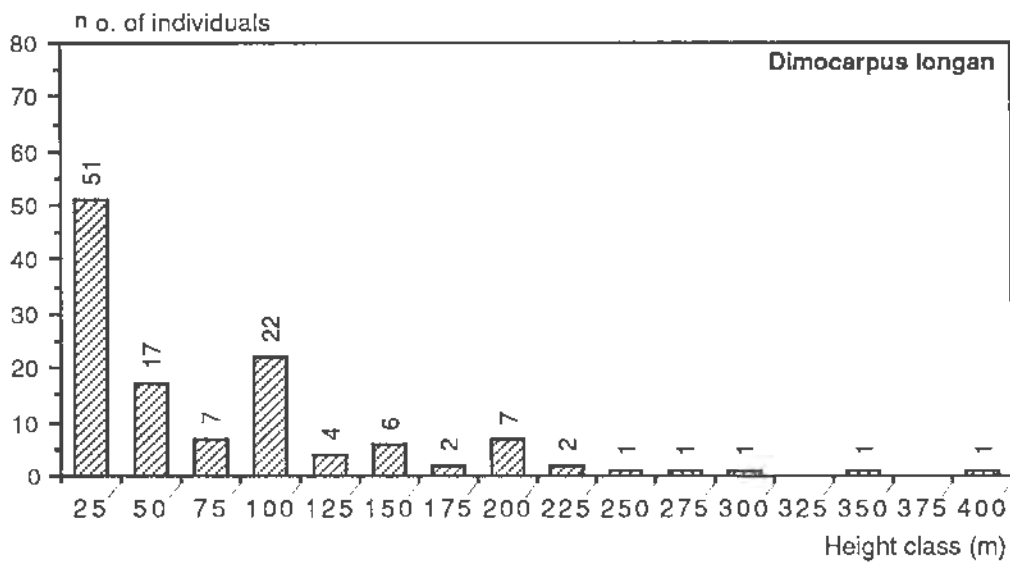
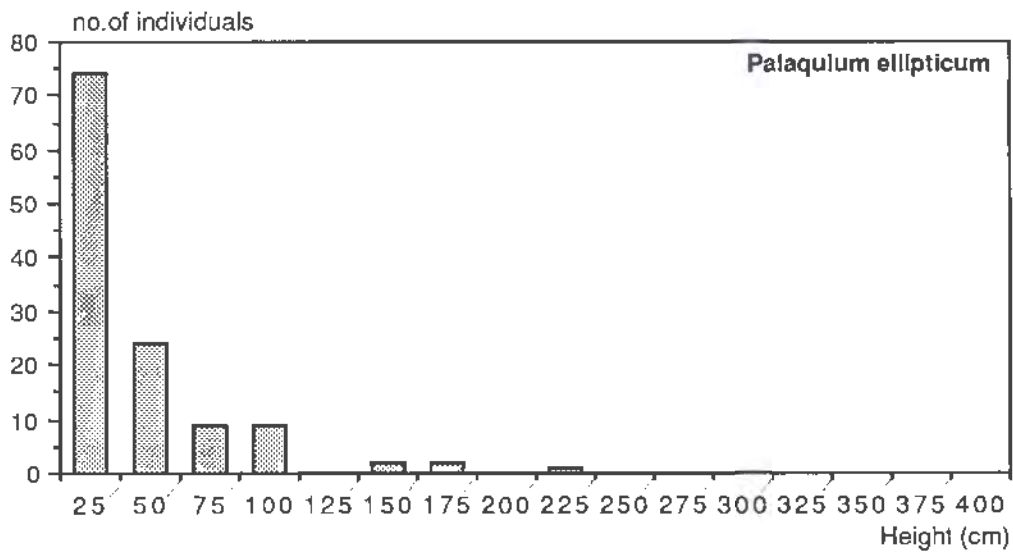


Fig. 30 - Regeneration pattern of common canopy species

Regeneration (sapling ≥ 75 cm height) is very low in the other common canopy trees: *Myristica dactyloides* (about 5%), *Neolitsea zeylanica* (6%) and *Mesua ferrea* (0.5%).

On the other hand, *Aphanamixis polystachya* although not well represented (0.4%) in the adult stage, shows an increase in its recruitment (4.5%). *Olea glandulifera*, one of the characteristic species of this forest type, does not show considerable regeneration.

4.2 Regeneration of understorey species

Meiogyne pannosa which belongs to structural ensembles III and IV has the highest relative density (20%) among the big individuals ($G \geq 10$ cm). However, its regeneration (sapling ≥ 75 cm height) is extremely low: 4%.

As this forest is surrounded by coffee estates, there is a considerable invasion of *Coffea arabica* which accounts for 5.5% of the seedlings and saplings.

Memecylon lushingtonii is a characteristic species of the Eastern Ghats. Although it is not found among adult species, a few seedlings are found in the openings.

The mosaic structure of the forest depends mostly on the gap dynamics (Christensen and Franklin, 1987; Spies and Franklin 1989). Variations in the size of the gaps may produce variations in the composition as well as in the relative density of species (Brokaw and Scheiner, 1989).

In this forest, *Clerodendrum viscosum* and *Villebrunea integrifolia* are common pioneer species in the openings. *Clerodendrum viscosum* although not well represented (0.7%) among adults (in the studied plots) shows a good regeneration of 3.5%, particularly in saplings ≥ 75 cm high. *Villebrunea integrifolia* which is not strictly shade-intolerant is common in smaller gaps intermixing with other climax species. However, regeneration of *Villebrunea integrifolia* is poor (3.5%) compared to their proportion in the adult group (9.1%). *Neopeltandra longipes* although not strictly shade-intolerant, has a good regeneration (7%) especially in disturbed patches.

Macaranga peltata and *Mallotus tetraococcus*, two other shade-intolerants, do not show any significant regeneration and are not encountered along the central line.

Macaranga peltata is a common species in openings in the evergreen forests of the Western Ghats.

5 COMPARISON WITH THE MEDIUM ELEVATION TYPES OF THE WESTERN GHATS

Several spatial and floristic features of this forest type are similar to those of the rain-forests of the Western Ghats.

In the Western Ghats, the structural and floristic aspects of forests have been studied by Kadambi (1950), Arora (1965), Singh *et al.* (1984), Rai (1981) and Pascal (1984). The data given by Pascal (1984) of the Attapadi (*Cullenia-Mesua-Palaquium* type) and Suthanabi* (*Mesua-Palaquium-Hopea* type) at medium elevations are compared with the *Mesua-Palaquium-Olea* type in the BRH (Table 16).

- The *Mesua-Palaquium-Olea* type of the BRH at an altitude of 1300-1400 m range corresponds to the forests at the upper limit of the medium elevation range (800-1400 m) of the Western Ghats. This is indicated by the predominance of Lauraceae members, which generally prefer cool climates.

- The two Western Ghats types come under the high rainfall zone (2000-5000 mm) while the BRH type thrives under lower rainfall of 1800 mm which is quite marginal for evergreen forests. The lower rainfall is compensated by its geographic location in a valley and clayey soil which can hold a significant amount of soil moisture. This is also the case in the *Cullenia-Mesua-Palaquium* type in Karyan Shola in the eastern fringe of the Western Ghats (Pascal *pers. comm.*).

- The distribution pattern of the sets of the future and of the present are not very different from those of Suthanabi and Attapadi except for the lower value of SE III (4.7%) in Suthanabi and of SE IV (2.6%) in Attapadi. Interestingly, mortality is lowest (1.8%) in the BRH type when compared to those of the Western Ghats types (4.3-6%).

- The total basal area is more or less the same but the biovolume in BRH is comparatively low due to the absence of true emergents and lower canopy (37 m).

- The floristic diversity of the BRH (studied in 4600 m² area) is slightly higher

* Suthanabi represents an edaphic facies in the *Hopea-Poeciloneuron* type (Pascal, 1984).

Table 16 - Comparison with medium elevation types of the Western Ghats

Types	Altitudinal Range	Average Rainfall	Spatial structure								Floristic diversity					
			Set of the future tree/ha	Set of the present trees/ha				Set of the past	Basal area m ² /ha	Bio-volume m ³ /ha	Surface m ²	N/S	Simpson's index	Shannon-Wiener's index		
				I + E	I	III	IV							H'	Hmax	E=H'/Hmax
Cullenia-Mesua-Palaquium type Attapadi-900 m (Pascal,1984)	700-1400	2000-5000	64.8%	9.9%	5.6%	12.8%	2.6%	4.3%	59.6	2209.5	2000	9.5	0.90	4	5	0.79
Mesua-Palaquium-Hopea type Suthanabi-750 m (Pascal,1984)	850-1250	2000-5000	53.4%	16.3%	7.2%	4.7%	10%	6%	60.7%	2236	1600	5.8	0.87	3.7	5	0.75
Mesua-Palaquium-Olea type BRH 1350 m	1300-1400	1800	50.2%	12.7%	7.2%	16.1%	12%	1.8%	60.1	1962.5	4600	10.2	0.92	4.5	5.8	0.78

than in the two plots of the Western Ghats types.

The absence of the common species of evergreen forests of the Western Ghats like *Cullenia* (up to Kerala), *Drypetes*, *Garcinia*, *Holigarna*, *Hopea*, *Knema* etc. and the presence of *Olea glandulifera* (more common in the Eastern Ghats) and *Litsea oleoides* (common in Nilgiris and Palnis at above 1200 m) make this type unique and transitional between the Western and Eastern Ghats types.

6 CONCLUSION

The resemblance in structure, and to some extent in floristics, to the Western Ghats forests makes this forest type unique in the BRH. Its small area in a state of delicate equilibrium with the climatic conditions makes it vulnerable to any disturbance. As already mentioned, coffee estates on all sides severely restrict not only the expansion of this forest, but also the size of its population. Fire has caused considerable damage to this forest. The openings thus created have been filled by heliophilous species. Regeneration studies although not conducted in detail, nevertheless give sufficient idea about the successional status of this forest. The decrease in the regeneration of some climax species such as *Aglaia jainii*, *Beilschmiedia wightii*, *Meiogyne pannosa*, *Mesua ferrea*, *Myristica dactyloides*, *Palaquium ellipticum* etc., on one hand and increase in the regeneration of species which are common to semi-evergreen forests like *Aphanamixis polystachya*, *Dimocarpus longan* etc. indicate the impact of disturbance. Unless strict measures are taken to prevent fire and anthropic pressure is controlled, the whole of this forest type may gradually disappear.

DIOSPYROS OVALIFOLIA - MEMECYLON LUSHINGTONII TYPE

Floristically this type is typified by certain species that are very common in the Eastern Ghats, such as *Diospyros ovalifolia*, *Memecylon lushingtonii* and *Olea glandulifera*. Another distinguishing feature of this type is the absence of some of the characteristic species of the other types of BRH like *Elaeocarpus tuberculatus*, *Mesua ferrea*, *Michelia champaca* and *Palaquium ellipticum*. Physiognomically, this type occurs as low forests with trees seldom higher than 15 m. The spatial structure is not well defined, either because of their degraded condition or because they are found along steep valleys.

1. LOCATION

The low forests are mostly found along the steep valleys of the eastern slopes and near Gummannibetta in the northern part of the BRH. These regions receive less rainfall (900-1200 mm) than the western flank of the BRH. Moreover, the steep terrain on the eastern side forms a kind of barrier for the extension of some of the characteristic species of the ripicole (*Elaeocarpus* - *Michelia* - *Canarium* type) forests described earlier.

Under favourable conditions the lower limit of this type is generally 1200 m. As the valleys widen, the moisture retaining capacity decreases resulting in unfavourable conditions for this type of forest. The upper limit is about 1400 m. Above 1500 m it is replaced by the Lauraceous type. The transitional zone lies between 1400 and 1500m.

2. FLORISTIC STUDY

This forest type is represented by 77 species (Annexe 3). Generally the height of the trees decreases towards the margin. Distinct stratification is not observed below the canopy.

All the species present in this type have been classified below according to habit or habitat preference.

2.1 Trees and large shrubs

2.1.1 Trees near streams

True ripicole species are absent. However, *Bischofia javanica*, *Ficus microcarpa* and *Persea macrantha* are found growing near the streams.

2.1.2 Between streams and edge of the forest

- Among the canopy trees are two characteristic species viz., *Diospyros ovalifolia* and *Memecylon lushingtonii*, the latter being very common towards the margin. Other common species are *Canthium dicoccum*, *Cassine glauca*, *Celtis timorensis*, *Euodia lunu-ankenda*, *Ficus tsjahela*, *Litsea floribunda*, *Mallotus philippensis*, *Neolitsea zeylanica*, *Olea glandulifera*, *Phoebe paniculata* and *Syzygium cumini*; *Aphanamixis polystachya*, *Dimocarpus longan*, *Ficus nervosa*, *Prunus ceylanica*, *Nothopegia beddomei* are rare.

- Trees or shrubs under the canopy: in this group *Miliusa eriocarpa*, a species of the Eastern Ghats, is very common between 1250-1300 m. *Ehretia canarensis* is rare, being recorded only in this type of forest. Other common species include *Antidesma menasu*, *Atalantia wightii*, *Cipadessa baccifera*, *Clausena indica*, *Cocculus laurifolius*, *Euonymus crenulatus*, *Maesa indica*, *Nothapodytes foetida*, *Pavetta indica*, *Psychotria nigra*, *Scolopia crenata*.

2.1.3 Heliophilous trees along margins and in openings

Callicarpa tomentosa, *Chionanthus ramiflora*, *Murraya paniculata*, *Trichilia connaroides* (rare) are found growing along the margins, while *Celtis tetrandra*, *Macaranga peltata*, *Meyna laxiflora*, *Sapindus laurifolius* and *Sterculia guttata* are generally present in the openings.

2.1.4 Species of high altitudes

The extension of some of the characteristic species of this forest type above 1400 m (upto 1530 m) marks the intermediate zone where some species of high elevation type such as *Casearia ovata*, *Cinnamomum travancoricum*, *Fagraea ceilanica*, *Ixora notoniana*, *Meliosma pinnata* ssp. *arnottiana*, *Schefflera capitata* and *Xantolis tomentosa* are also found. Heliophilous species occurring along the margins

in this intermediate zone are *Glochidion neilgherrense*, *Ligustrum perrottetii*, *Mallotus tetracoccus*, *Rapanea wightiana*, *Vernonia monosis*.

2.2 Under shrubs of the herbaceous layer

This stratum is more or less open except in degraded forests where *Nilgirianthus heyneanus* covers the entire forest floor. Of the other herbs, *Elatostema lineolatum* and *Ophiopogon intermedius* are commonly found in moist soils. *Aeschynanthus perrottetii* and *Lycopodium phlegmaria* are occasionally found as epiphytes.

2.3 Climbers

Common climbers are *Allophylus cobbe*, *Asparagus racemosus*, *Hiptage benghalensis*, *Jasminum azoricum*, *Piper hymenophyllum*, *Smilax perfoliata*, *Toddalia asiatica*, *Uvaria narum* etc.

3. CONCLUSION

This forest type is structurally and floristically quite different when compared to the *Elaeocarpus* - *Michelia* - *Canarium* and *Mesua* - *Palaquium* - *Olea* types of medium elevations. The canopy here is lower and a distinct layering is lacking. Floristically it is less rich compared to the other two types: certain species are absent while some others become less frequent.

All these results point to unfavourable conditions, viz., lesser rainfall, steep terrain which enhance leaching and soil erosion, rendering them infertile. The presence of *Diospyros ovalifolia* and *Memeeylon lushingtonii* along with *Olea glandulifera* suggests that the edapho-climatic conditions of this type are similar to those of the evergreen forests of the Eastern Ghats which resemble this type both structurally and floristically.

LAURACEOUS TYPE

Most of the evergreen formations in the BRH are represented by this type. They are mostly confined to sheltered regions such as valleys, hollows, depressions, where soil moisture conditions are favourable. Generally the trees are stunted with short boles, rarely higher than 15 m. The branches are covered with mosses, lichens and other epiphytes. Stratification is not evident. Floristically, it is characterized by the absence of some species of medium elevation types and the appearance of certain characteristic species of high altitudes which eventually form a type at higher limits. The high elevations are dominated by the family Lauraceae represented here by 8 species, and most of them in abundance.

1 LOCATION

The majority of the forests occupy the high eastern ridge from Doddabetta (southern extremity) up to Kolattugundibetta. They also occur as patches along the central ridge (Honnamettibetta) and in the northern part around Gummanibetta. They are poorly represented on the western side. The lower limit of this type is generally 1350-1400 m, while the upper limit is 1600-1760 m.

Fire is the main destructive agent of these low montane forests. Most of the forests, especially those towards the eastern slope, are badly damaged. However, some good patches of forests can still be seen around Honneparaibetta, Kattaribetta, Dhumberabetta and Kumbaragundibetta.

2 STRUCTURAL ANALYSIS OF THE AVERAGE TYPE

Structural studies of this type of forest were carried out in Kattaribetta. The sampling area measuring 1200 m² (20 x 60 m) is on a gentle slope in a shallow valley at an elevation of 1740 m. This 20 x 60 m plot extending from the interior of the forest to the margin was divided into two equal halves of 600 m² each to show the differences in the structure of the forest in the interior and the forest near the border.

Plot 1 represents a forest in the interior of the forest while plot 1A is towards the margin. Analysis of the spatial and floristic structure was made according to the

structural sets and structural ensembles (SE) for plot 1 while for plot 1A analyses were made only for the total stand.

2.1 Spatial structure

2.1.1 Vertical profile

The vertical profile (Fig. 31-a, b and c) comprises only individuals of girth ≥ 10 cm.

Fig. 31-a and b represent two adjacent strips measuring 5 x 50 m each. Both show a diminution in the height of the trees with increase in slope towards the margin of the forest. The first 30 m in each strip represents a part of plot 1. Here the trees are more or less well spaced out. Crowns of the first ensemble are between 6-15 m. The trees of the second ensemble and of the set of the future are poorly represented.

In the next 25 m of each strip, *i.e.* in plot 1A, the trees are short boled, closely placed and with dense canopy. The structural ensembles are not easily distinguishable.

Fig. 31-c depicts the profile on a 3 x 15 m strip perpendicular to the margin of the forest. Two individuals towards the interior are about 10 m; however, the other trees towards the margin are less than 6 m high. Here the individuals are more densely arranged and there is no distinct stratification.

Regarding individuals of girth ≤ 10 cm, the understorey towards the interior is completely covered by *Nilgirianthus sp.* (with angular stems). They are often more than 3 m high. In some places it is so dense that clumps of *Nilgirianthus* had to be completely removed to enable measurement of girths of trees.

2.1.2 Horizontal plan

Fig. 32 shows the horizontal plan of both the plots together (20 x 60 m). Only individuals with $G \geq 10$ cm are represented. The distribution of the sets of the present and of the future are shown only in plot 1. The slope is gradual and south-east oriented, which is depicted in the form of contours. There are a few fallen trees and branches in the interior. Cross sections of the strongly fluted boles of some big trees are also indicated. The density of trees is higher towards the border of the forest.

Crown projections of trees were measured in an area of 20 x 50 m towards the interior and includes plot 1 and a part of 1A (Fig. 33). The total area covered is nearly



Fig. 31a - Vertical Profile (5 x 50 m) of plots 1 and 1A
 (Legend of tree numbers same as in Fig. 2)

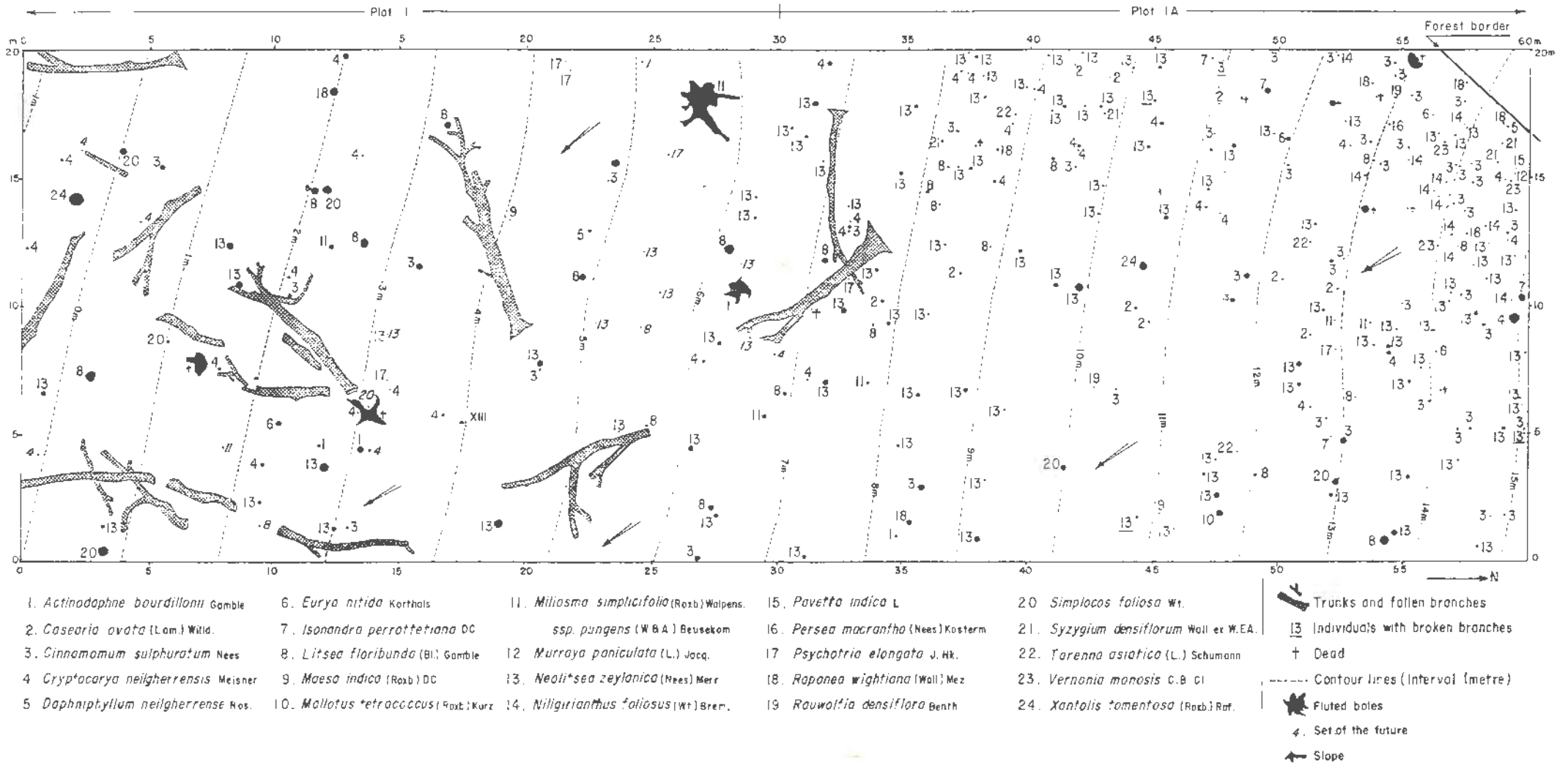
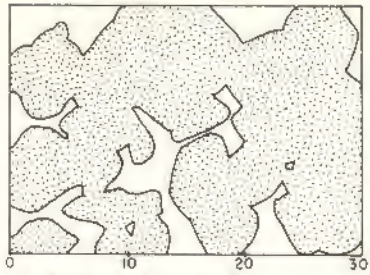


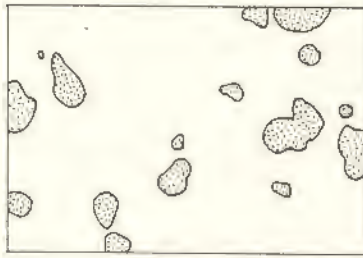
Fig. 32 - Plan of the sampling plots 1 and 1A (20 x 60 m)



b. Structural ensemble I



c. Structural ensemble II

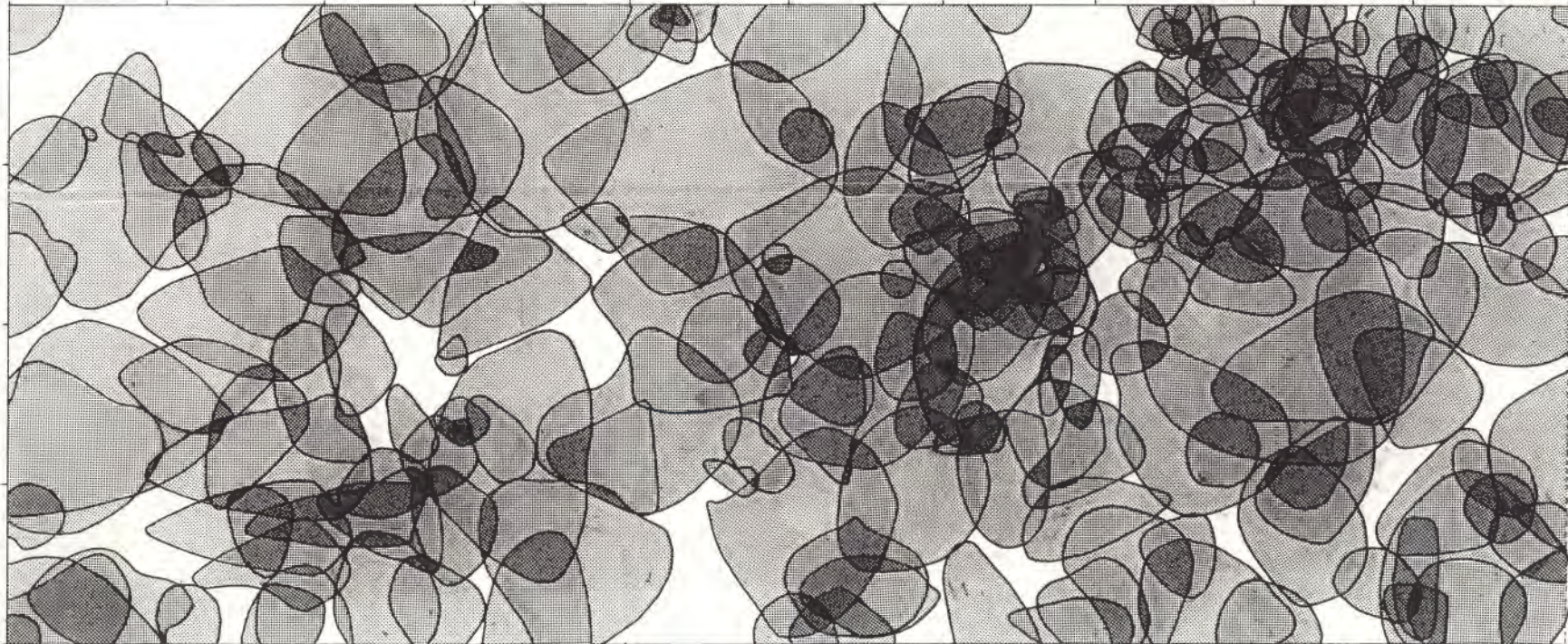


d. Set of the future

→ N

Plot I

Plot 1A



e. All the sets together

Fig. 33 - Crown Projection

90%. There are many areas with dense foliage and more than 4 super-imposed crowns, particularly in the north-east corner of the plot.

If plot 1 is taken alone, the total cover constitutes 88% (Table 17). Crown projection of structural ensemble I accounts for 74.8% while structural ensemble II and set of the future constitute only about 12% each (Fig. 33-b, c and Table 17).

2.1.3 Height/diameter relationships and structural ensembles

Hallé and Oldeman (1978) expressed the relation $H=100d$ for trees conforming to the initial model. This empirical rule was based on ecological inventories made in the tall forests of French Guiana and has been tested in the tall forests of the Western Ghats by Pascal (1984) and also in the *Mesua-Palaquium-Olea* type in the BRH during the course of the present study.

In the low montane forests, lack of studies on growth models makes the application of the $H=100 d$ rule debatable.

Height/diameter relationships have been studied only in plot 1 measuring 600 m² of 20 x 30 m (Fig. 34). Individuals which are to the left and very close to the right side of the line marking $H=100d$ represent the set of the future. They account for 29.5% of the total number of individuals, including 18 young trees with the potential to reach the canopy. It is interesting to note that the value of the set of the future is very low compared to that of the tall forests where it is more than 50%. Hence, the low value of the set of the future may eventually affect the equilibrium of the forest as mortality is not adequately compensated by regeneration.

Although 5 more individuals are to the left of the $H=100d$ line they are not considered as belonging to the set of the future. They are potentially shrubby species viz., *Psychotria elongata* and *Maesa indica* (denoted as P and M in Fig. 34). In the strict sense, they should be included in the structural ensemble III of the set of the present.

According to Fig. 34, the set of the present to the right of the line $H=100d$ can be subdivided into 2 structural ensembles (SE), or 3 if we consider those 5 shrubby individuals which are in the set of future.

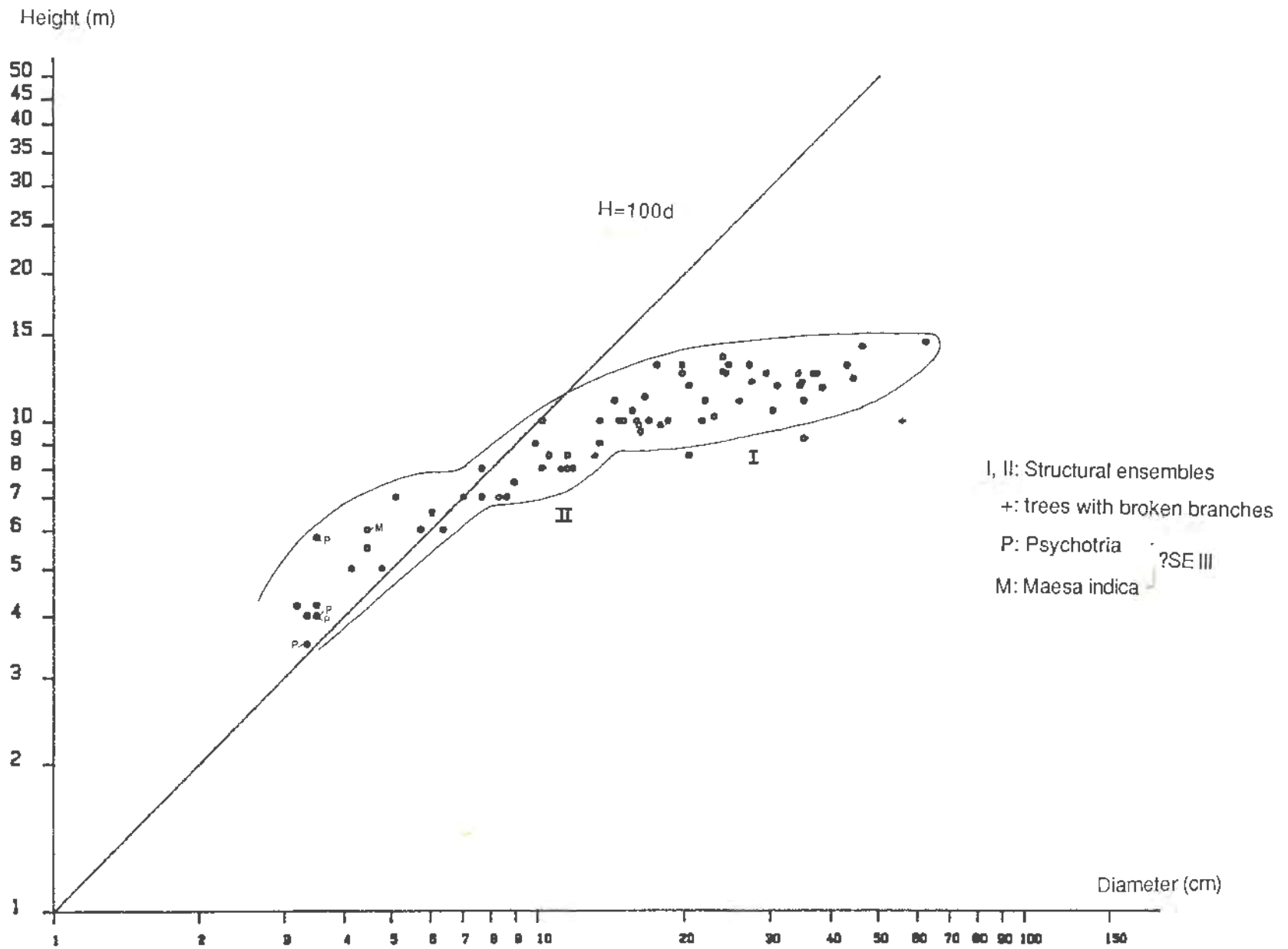


Fig. 34 - Height/diameter relationships in logarithmic coordinates (plot 1: 600 m²)

SE I with trees 9.5 to 14.5 m high comprise 56.4% of the total number of individuals. This value is very high compared to SE I of tall forests. Among the individuals of SE I, the contribution of *Neolitsea zeylanica* is maximum (31.7%) followed by *Litsea floribunda* (19.5%); *Cinnamomum sulphuratum*, *Cryptocarya neilgherrensis* and *Symplocos foliosa* (9.8%); *Actinodaphne lawsonii* and *Meliosma simplicifolia ssp. pungens* (4.9%); *Daphniphyllum neilgherrense*, *Eurya nitida*, *Rapanea wightiana* and *Xantolis tomentosa* (2.4%).

SE II (7-9 m) constitutes only 14.1% of the total number of individuals. Here the most dominant species is *Cryptocarya neilgherrensis* (54.5%) followed by *Neolitsea zeylanica* (18.2%), *Cinnamomum sulphuratum*, *Meliosma simplicifolia ssp. pungens*, *Xantolis tomentosa* (9.1%).

2.1.4 Girth distribution

The girth distribution pattern for individuals with $G \geq 10$ cm in plot 1 is shown in Fig 35. The pattern for the total number of individuals is not 'L' shaped mainly because of the paucity of trees of the set of the future.

In structural ensembles I and II of the set of the present the girth distribution pattern is assymmetrically bell-shaped in the former and symmetrical in the latter. In SE I the mode is in the 50-60 cm class while in SE II it is in the 30-40 cm girth class.

In plot 1A (Fig. 37-a) the girth distribution pattern for the total number of individuals is a perfect L-shape. The high frequency in the 10-20 cm girth class is mostly because of the presence of small sized individuals along the dense border.

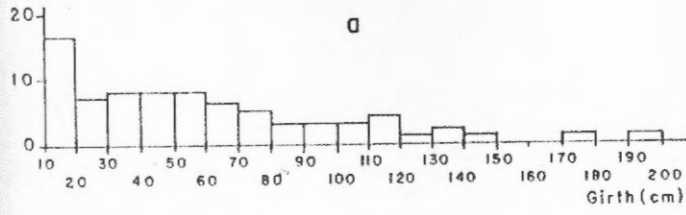
2.1.5 Height distribution

The height distribution patterns for trees of $G \geq 10$ cm in plot 1 are shown in Fig. 36. They are roughly bell-shaped except in SE II. The low frequency below the 6 m height class is due to the ≥ 10 cm girth limit taken for the sampling.

In SE I the mode is in the 10-12 m class while in SE II the mode is attained in the 8-10 m class.

In plot 1A (Fig 37-b), the mode is in the 4-6 m height class and comprises more than 50% of the individuals which are near the margin. The majority of individuals above the 10 m class are located away from the margin.

Number of individuals



- a All the sets together
- b Ensemble I } Set of the
- c Ensemble II } present
- d Set of the future

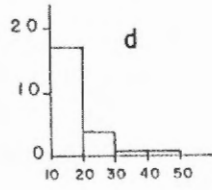
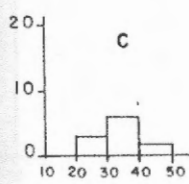
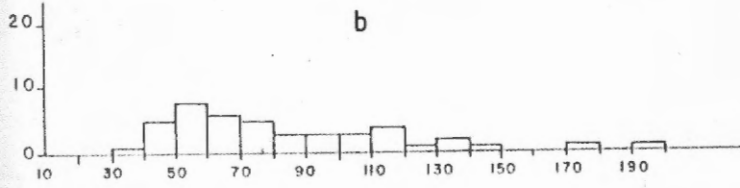
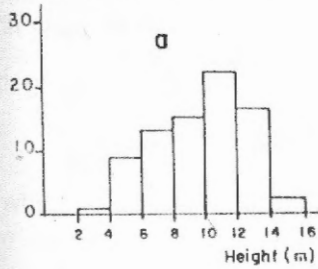


Fig. 35 - Girth distribution in plot 1

Number of individuals



- a All the sets together
- b Ensemble I } Set of the
- c Ensemble II } present
- d Set of the future

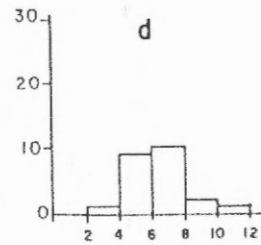
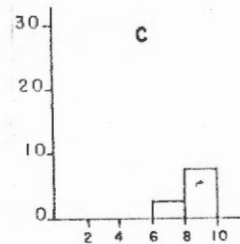
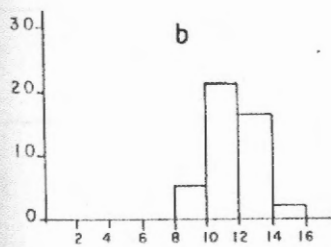


Fig. 36 - Height distribution in plot 1

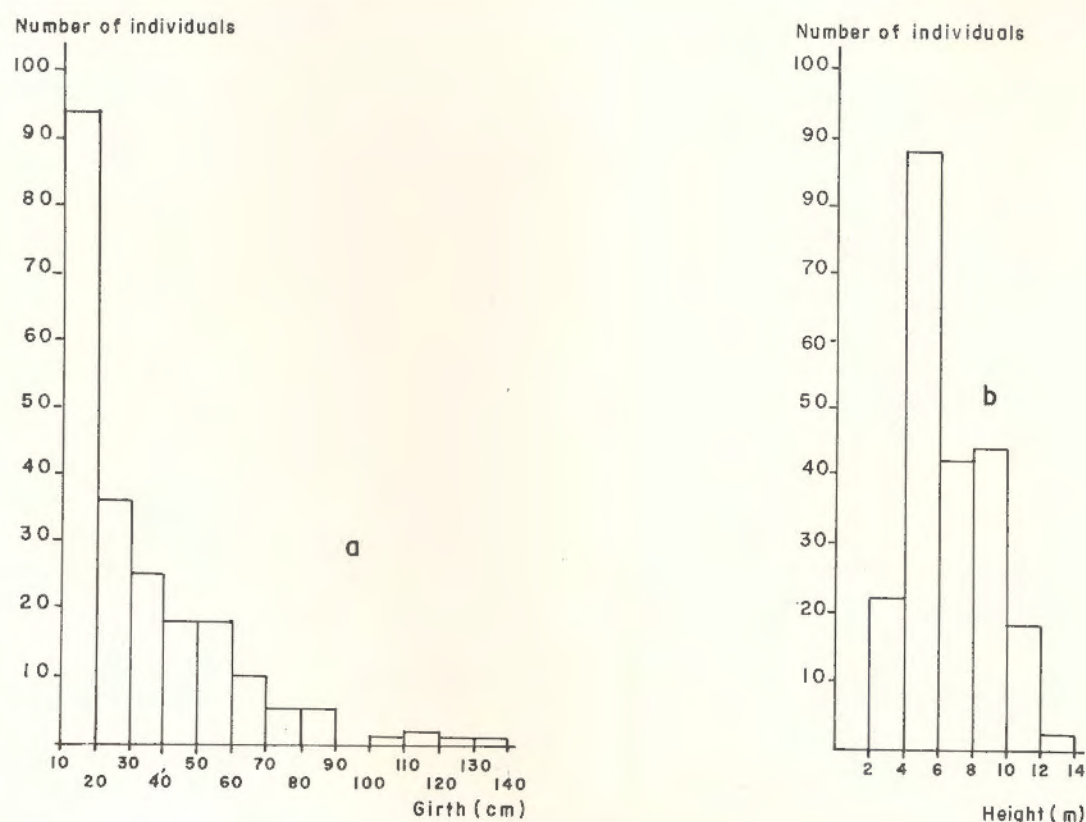


Fig. 37 - Girth and height distribution in plot 1A

2.1.6 Density

Table 17 shows the density of the different structural ensembles with different girth classes in plot 1. The total number of trees with girth ≥ 10 cm is 1300/ha. Trees with girth ≥ 120 cm are very few, representing only 7.7% of the total.

In plot 1A (Table 18) the total number of individuals with girth ≥ 10 cm is 3800/ha, of which big trees with $G \geq 120$ cm are only 33 in number representing just 0.9%.

Table 17 - Density and percentage of ground cover in plot 1

	Set of the present		Set of the future	Total	
	Structural Ensemble I	Structural Ensemble II			
Number of trees/ha	G ≥ 10 cm	733	183	1300	
	% without lianas	56.4	14.1	100	
	G ≥ 40 cm	717	33	767	
	G ≥ 80 cm	317	-	317	
	G ≥ 120 cm	100	-	100	
Percentage of ground cover					
		74.8	11.7	12.3	88

Table 18 - Basal area, Biovolume (D^2H) and Density in plot 1A

	Basal area (m^2/ha)	Biovolume(D^2H) (m^3/ha)	Density (No. of trees/ha)
G \geq 10 cm	48.1	493.2	3800
G \geq 40 cm	38.6	420.9	1083
G \geq 80 cm	16.3	169.3	200
G \geq 120 cm	4.2	50.1	33

2.1.7 Basal area and biomass index (D^2H)

The total basal area of the trees in plot 1 is $51.1 m^2/ha$ (Table 19). However, if only trees with $G \geq 120$ cm are considered, it is only $18.8 m^2/ha$.

The total biovolume (D^2H) is $763.6 m^3/ha$.

In the set of the present, SE I which represents 56.4% of the total number of individuals accounts for 94.4% of the basal area and 96.4% of the bio-volume. SE II is poorly represented (14.1% of the total) comprising 3.4% and 2.3%, respectively.

The set of the future constitutes 29.5% of the total number of individuals but only 2.2% of the basal area and 1.3% biovolume.

The total basal area of plot 1A (Table 18) is $48.1 m^2/ha$ which is quite similar to that of plot 1 ($51.1 m^2/ha$). However, the small number of big trees in plot 1A contributes to a low biovolume ($493.3 m^3/ha$) when compared to that of the plot 1 ($763.6 m^3/ha$).

Table 19 - Basal area and Biovolume (D^2H) in plot 1

	Set of the present		Set of the future	Total
	Structural Ensemble I	Structural Ensemble II		
Basal area (m^2/ha)	G \geq 10 cm	48.3	1.7	51.1
	% without lianas	94.4	3.4	100
	G \geq 40 cm	48.2	0.5	48.9
	G \geq 80 cm	36.6	-	36.6
	G \geq 120 cm	18.8	-	18.8
Biovolume D^2H (m^3/ha)	735.7	17.8	10.1	763.6
%	96.4	2.3	1.3	100

2.2 Floristic structure

2.2.1 Floristic richness

The species-area curves in the 1200 m² area (plots 1 and 1A together) are shown in Fig. 38. The upper curve represents all the species in the plot without a girth limit (40 species including ferns and epiphytes), while the lower one is of species with $G \geq 10$ cm (25 species).

The first 100 m², close to the border shows a sharp rise in both the curves representing 64% of the species without girth limit and 60% of the species with girth ≥ 10 cm. Both the curves then become gentle and very close to attaining a plateau. However, an overall survey conducted in this Lauraceous type revealed 99 species.

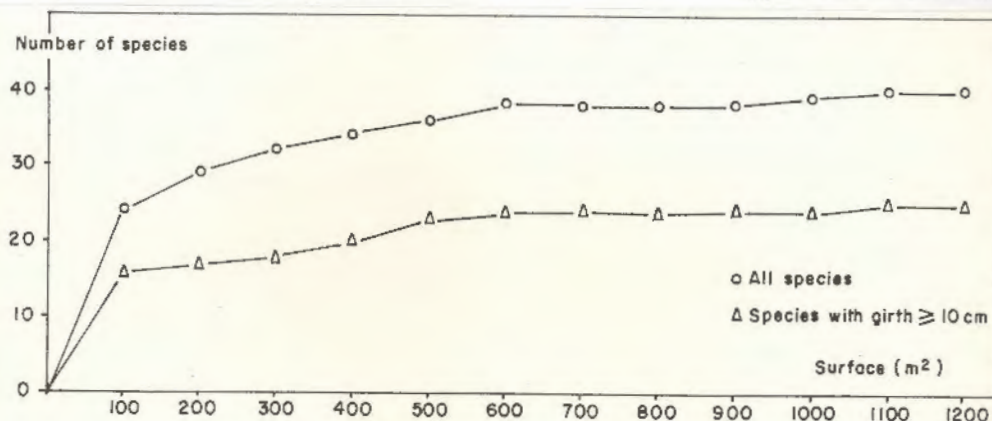


Fig. 38 - Species-area curves

2.2.2 Floristic diversity

Figs. 39 and 40 show the distribution of the number of individuals per species, as well as their relative density, in plots 1 and 1A, respectively. For each species the number of individuals belonging to the different structural ensembles is also indicated. Of the 13 species in plot 1, the first four are Lauraceae members accounting for 70.5%, *Neolitsea zeylanica* by itself comprising 29.5%. The heliophilous species in openings are of *Daphniphyllum neilgherrense* and *Rapanea wightiana* constituting 1.28% each.

24 species are represented in plot 1A (Fig. 40). Here also the first four are Lauraceae species representing 71.31%, of which *Neolitsea zeylanica* is dominant accounting for 38.43%, followed by *Cinnamomum sulphuratum* (17.6%). Species characteristic of the edge of the forest are *Daphniphyllum neilgherrense*, *Isonandra*

Fig. 40 - Number of individuals per species in plot 1A

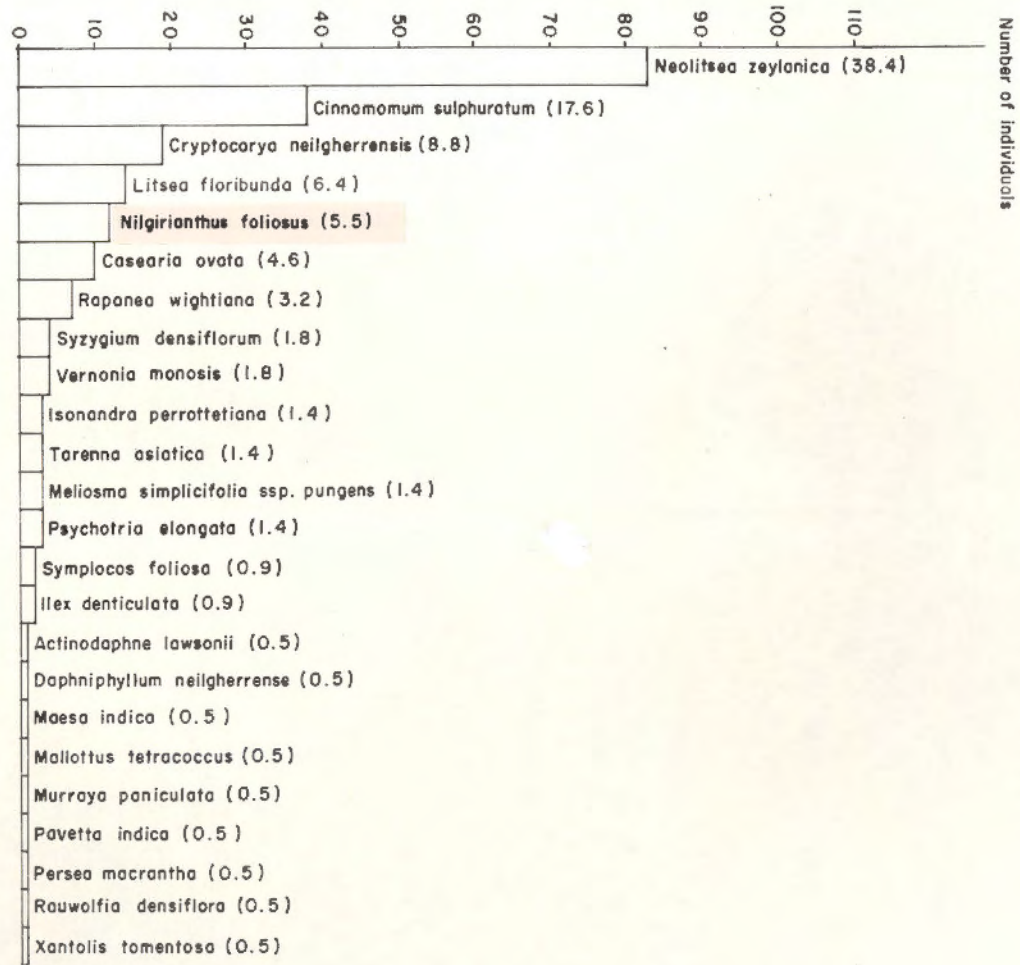
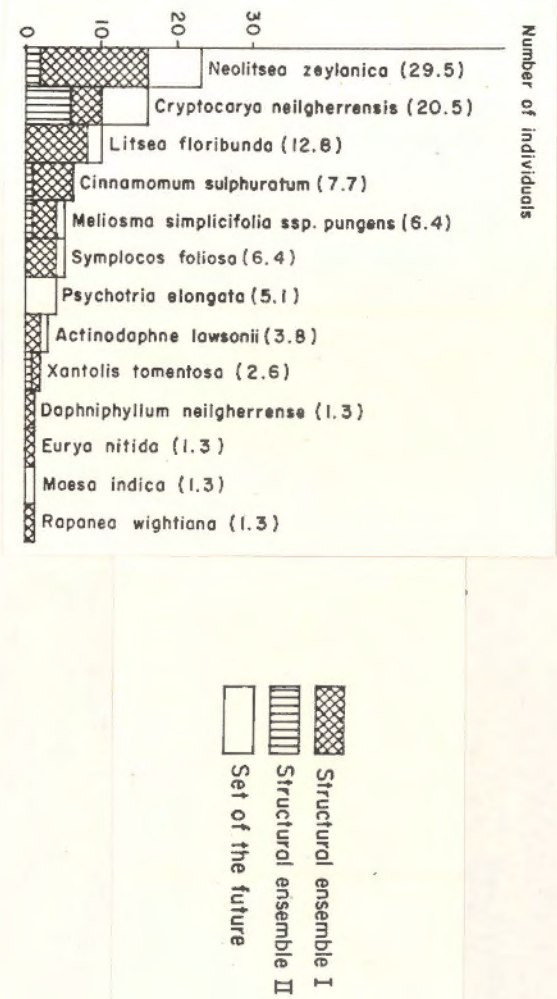





Fig. 39 - Number of individuals per species in plot 1



 Structural ensemble I
 Structural ensemble II
 Set of the future

perrottetiana, *Mallotus tetracoccus*, *Murraya paniculata*, *Nilgirianthus foliosus*, *Rapanea wightiana*, *Syzygium densiflorum*, *Tarenna asiatica* and *Vernonia monosis* together constituting 16.2%.

The important value index (IVI) in the two plots is analysed separately.

In plot 1 (Table 20) the first 6 species have an IVI of more than 24, of which the IVI of 3 Lauraceae species alone exceeds 40.

In plot 1A (Table 21) only the first 4 species (all belonging to Lauraceae) have an IVI of more than 26.

The IVI of *Neolitsea zeylanica* is very high in both the plots: 70.7 in plot 1 and 93.3 in plot 1A.

The IVI of families in plots 1 and 1A are given in Tables 22 and 23, respectively. True to the nature of this high elevation forest, Lauraceae is the dominant family, with IVI of 193.8 (in plot 1) and 192.1 (in plot 1A). However, in plot 1A, the importance of heliophilous species, which are more common along the border of the forest, can be seen in the relatively high IVI of Sapotaceae (particularly *Isonandra perrottetiana*) and Myrsinaceae (*Rapanea wightiana*) which follow the Lauraceae in importance.

The diversity index for the two plots are classified in Table 24. The number of individuals per species is 6 in plot 1 and 9 in plot 1A. Simpson's index shows that out of 100 pairs taken at random 17 pairs are composed of the same species in plot 1 and 20 pairs in plot 1A. Shannon-Wiener's index, H' is low in both the plots: 3.02 in plot 1 and 3.14 in plot 1A. These values are much lower than those found in tall evergreen forests.

The values of 'E' indicate that the species are better distributed in plot 1 (0.82) when compared to plot 1A (0.68).

2.3 Influence of the forest margin

A comparison of plots 1 and 1A shows that microclimatic complexities at the margin of the forest (Table 8) are mainly responsible for the high density and higher species richness in plot 1A. In fact the forest along the margin is so dense that very often it is difficult to penetrate it.

Table 20 - Relative importance of species in plot 1

Species	Families	Importance Value Index
<i>Neolitsea zeylanica</i>	Lauraceae	70.7
<i>Litsea floribunda</i>	Lauraceae	45.5
<i>Cryptocarya neilgherrensis</i>	Lauraceae	40.5
<i>Symplocos foliosa</i>	Symplocaceae	28.3
<i>Meliosma simplicifolia</i>	Sabiaceae	27.6
<i>Cinnamomum sulphuratum</i>	Lauraceae	24.5
<i>Xantolis tomentosa</i>	Sapotaceae	18.3
<i>Actinodaphne lawsonii</i>	Lauraceae	12.7
<i>Psychotria elongata</i>	Rubiaceae	10.8
<i>Rapanea wightiana</i>	Myrsinaceae	7.0
<i>Eurya japonica</i>	Theaceae	5.3
<i>Daphniphyllum neilgherrense</i>	Euphorbiaceae	4.7
<i>Maesa indica</i>	Myrsinaceae	4.1

Table 21 - Relative importance of species in plot 1A

Species	Families	Importance Value Index
<i>Neolitsea zeylanica</i>	Lauraceae	93.3
<i>Cinnamomum sulphuratum</i>	Lauraceae	40.1
<i>Cryptocarya neilgherrensis</i>	Lauraceae	27.7
<i>Litsea floribunda</i>	Lauraceae	26.1
<i>Casearia ovata</i>	Flacourtiaceae	13.3
<i>Rapanea wightiana</i>	Myrsinaceae	13.3
<i>Isonandra perrottetiana</i>	Sapotaceae	10.5
<i>Nilgiranthus foliosus</i>	Acanthaceae	8.2
<i>Syzygium densiflorum</i>	Myrtaceae	7.8
<i>Symplocos foliosa</i>	Symplocaceae	7.2
<i>Tarenna asiatica</i>	Rubiaceae	6.9
<i>Xantolis tomentosa</i>	Sapotaceae	6.5
<i>Meliosma simplicifolia</i>	Sabiaceae	5.3
<i>Psychotria elongata</i>	Rubiaceae	5.0
<i>Vernonia monosis</i>	Asteraceae	4.8
<i>Ilex denticulata</i>	Aquifoliaceae	3.9
<i>Mallotus tetracoccus</i>	Euphorbiaceae	3.7
<i>Actinodaphne lawsonii</i>	Lauraceae	2.5
<i>Daphniphyllum neilgherrense</i>	Euphorbiaceae	2.4
<i>Persea macrantha</i>	Lauraceae	2.3
<i>Maesa indica</i>	Myrsinaceae	2.3
<i>Pavetta indica</i>	Rubiaceae	2.3
<i>Rauwolfia densiflora</i>	Apocynaceae	2.3
<i>Murraya paniculata</i>	Rutaceae	2.3

Table 22 - Relative importance of families in plot 1

Families	Number of species	Importance Value Index
Lauraceae	5	193.8
Symplocaceae	1	28.3
Sabiaceae	1	27.6
Sapotaceae	1	18.3
Myrsinaceae	2	11.2
Rubiaceae	1	10.8
Theaceae	1	5.3
Euphorbiaceae	1	4.7

Table 23 - Relative importance of families in plot 1A

Families	Number of species	Importance Value Index
Lauraceae	6	192.1
Sapotaceae	2	17.0
Myrsinaceae	2	15.6
Rubiaceae	3	14.2
Flacourtiaceae	1	13.3
Acanthaceae	1	8.2
Myrtaceae	1	7.8
Symplocaceae	1	7.2
Euphorbiaceae	2	6.1
Sabiaceae	1	5.3
Asteraceae	1	4.7
Aquifoliaceae	1	3.9
Apocynaceae	1	2.3
Rutaceae	1	2.3

Table 24 - Floristic Diversity in plot 1 and 1A

	Area (m ²)	Number of species=S (G ≥ 10 cm)	Number of individuals=N (G ≥ 10 cm)	N/S	Simpson's Index	Shannon-Wiener's Index		
						H'	Hmax	E=H'/Hmax
plot 1	600	13	78	6.0	0.83	3.02	3.70	0.82
plot 1A	600	24	216	9.0	0.80	3.14	4.59	0.68

The changes in spatial structure are related to:

- the height of the tree stand. In the interior of the forest the tree stand is always higher with an apparent stratification when compared to the plot near the margin.
- Density of plot 1A is almost 3 times more than that of plot 1.
- The basal area is not very different in both, but the biomass is lower in plot 1A due to the diminution in the height of the stand.

Regarding floristic diversity, the low equitability index in plot 1A is due to the abundance of some species and the rarity of many others.

3 STRUCTURAL AND FLORISTIC VARIATIONS

The variations in structure and floristic composition are linked to the altitude and location of the plots.

To study these variations, 4 sampling plots were selected at different altitudes. The first 3 plots are located in the Anebetta valley (facing north).

They are:

- Plot 2: measuring 600 m² (10 x 60 m) situated at the bottom of the valley at 1520 m which is more humid than the other 2 plots.
- Plot 3: measuring 400 m² (10 x 40 m) located more or less in the middle of the valley at 1590 m. The presence of many heliophilous species, particularly *Vernonia monosis*, in this plot suggests a disturbance in the past.
- Plot 4: measuring 300 m² (10 x 30 m) at the top of the valley on exposed terrain at 1660 m.

The fourth plot, plot 1 in Kattaribetta is taken for the upper limit (1740 m).

It is interesting to note that these plots not only reveal the variations due to altitude but also the effect of exposure or disturbance on the spatial and floristic structure of the forest.

3.1 Variations in spatial structure

3.1.1 Horizontal plan

The ground plans of plots 2, 3 and 4 are shown in Fig. 41-a, 42-a and 43-a, respectively.

The plan of plot 2 at the broad lower end of the valley shows a gentle slope towards the stream. In this plot the big trees have buttresses and are well distributed.

Plot 3 in the middle of a valley has a steep slope towards the stream. There is a big tree fallen near the stream probably as a result of soil erosion

Plot 4 on an exposed crest slopes gently in the NNE direction. The trees are closely spaced.

3.1.2 Vertical profiles

The vertical profiles for plots 2, 3 and 4 are shown in Fig. 41-b, 42-b and 43-b respectively. Only individuals with girth ≥ 10 cm are included. These profiles clearly show the diminution in the height of the canopy trees with increase in elevation. This feature is more pronounced on exposed terrain (Plot 4).

The profile of plot 2 in the 5 x 60 m strip shows 3 structural ensembles. The crowns of the first ensemble *i.e.*, the canopy trees, is between 15 and 26 m; the second ensemble is between 8 and 16 m while the third ensemble is between 3 and 8 m. Some trees of *Persea macrantha* show multiple boles, each one equivalent to a big tree.

In plot 3, the profile of the 5 x 40 m strip does not show a distinct stratification. The canopy is uneven. Some top canopy trees close to the stream exceed 16 m. A gradual decrease in the height of the canopy trees can be observed with increase in slope, except for one tree to the extreme left of the profile.

Plot 4 on exposed terrain is more or less flat. Canopy trees, as well as the undergrowth, are dense. The stand is less than 8 m high. There is no discernible stratification.

3.1.3 Girth distribution

The girth distribution pattern for plots 2, 3 and 4 are given in Fig. 44. Only individuals with $G \geq 10$ cm have been taken into consideration.

In all 3 plots the patterns are distinctly 'L' shaped.

Plots 3 and 4 have a large number of individuals in the small girth classes (10-40 cm) as compared to plots 2 and 1 (Fig. 35). Plot 4 shows the highest frequency of individuals in the 10-20 cm girth class but lacks trees of big girth classes.

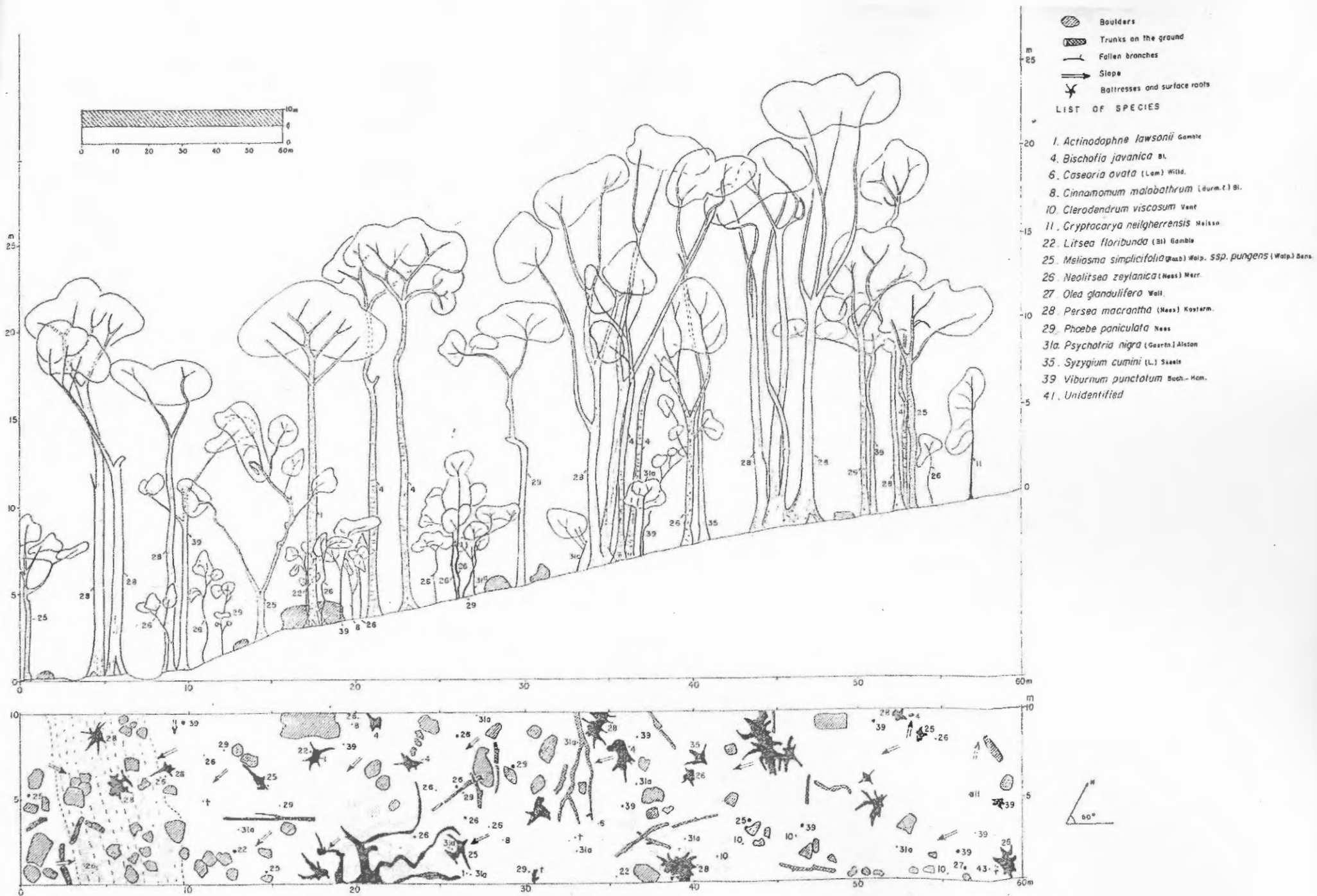


Fig. 41 - Plot 2: a-Plan of the sampling plot (10 x 60 m); b-Vertical profile (5 x 60 m)



LIST OF SPECIES

- 2. *Antidesma menasu* Miq. ex Tul.
- 3. *Artocarpus heterophyllus* Lam.
- 4. *Bischofia javanica* Bl.
- 5. *Callicarpa tamentosa* (L.) Murray
- 6. *Caseario ovata* (Lam.) Willd.
- 7. *Celtis tetrandra* Roxb.
- 11. *Cryptocarya neilgherrensis* Metson.
- 15. *Ficus nervosa* Roth.
- 19. *Isonandra perrattetiana* ac.
- 21. *Ligustrum gamblei* Ramam.
- 22. *Litsea floribunda* (Bl.) Gamble
- 23. *Maesa indica* (Roxb.) DC.
- 25. *Meliosma simplicifolia* (Roxb) Walp ssp. *pungens* (Walp) Bens.
- 26. *Neolitsea zeylanica* (Hass) Merr.
- 27. *Olea glandulifera* Wall.
- 28. *Persea macrantha* (Hass) Kosterm.
- 29. *Phaebe paniculata* Hass
- 31. *Psychotria elongata* J.Hk.
- 34. *Symplocos cochinchinensis* (Lour.) Maera ssp. *laurina* (Retz.) Noot.
- 37. *Toona ciliata* Roem.
- 38. *Vernonia monosis* C.B. Cl.
- 39. *Viburnum punctatum* Buch.-Ham.
- 41. Unidentified

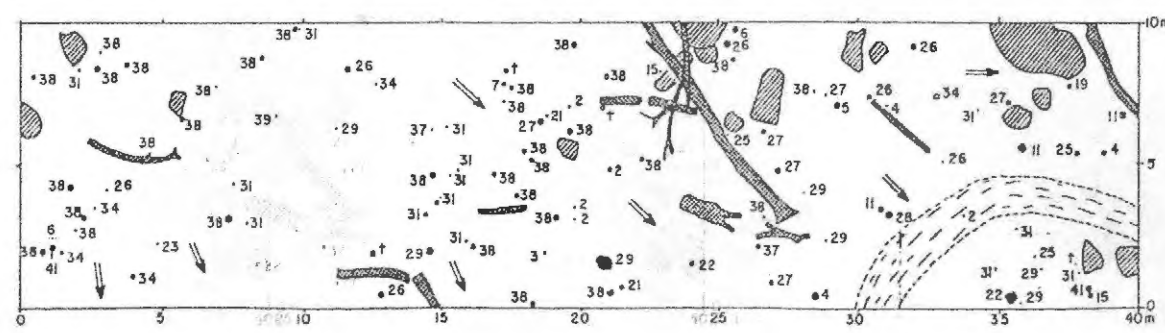
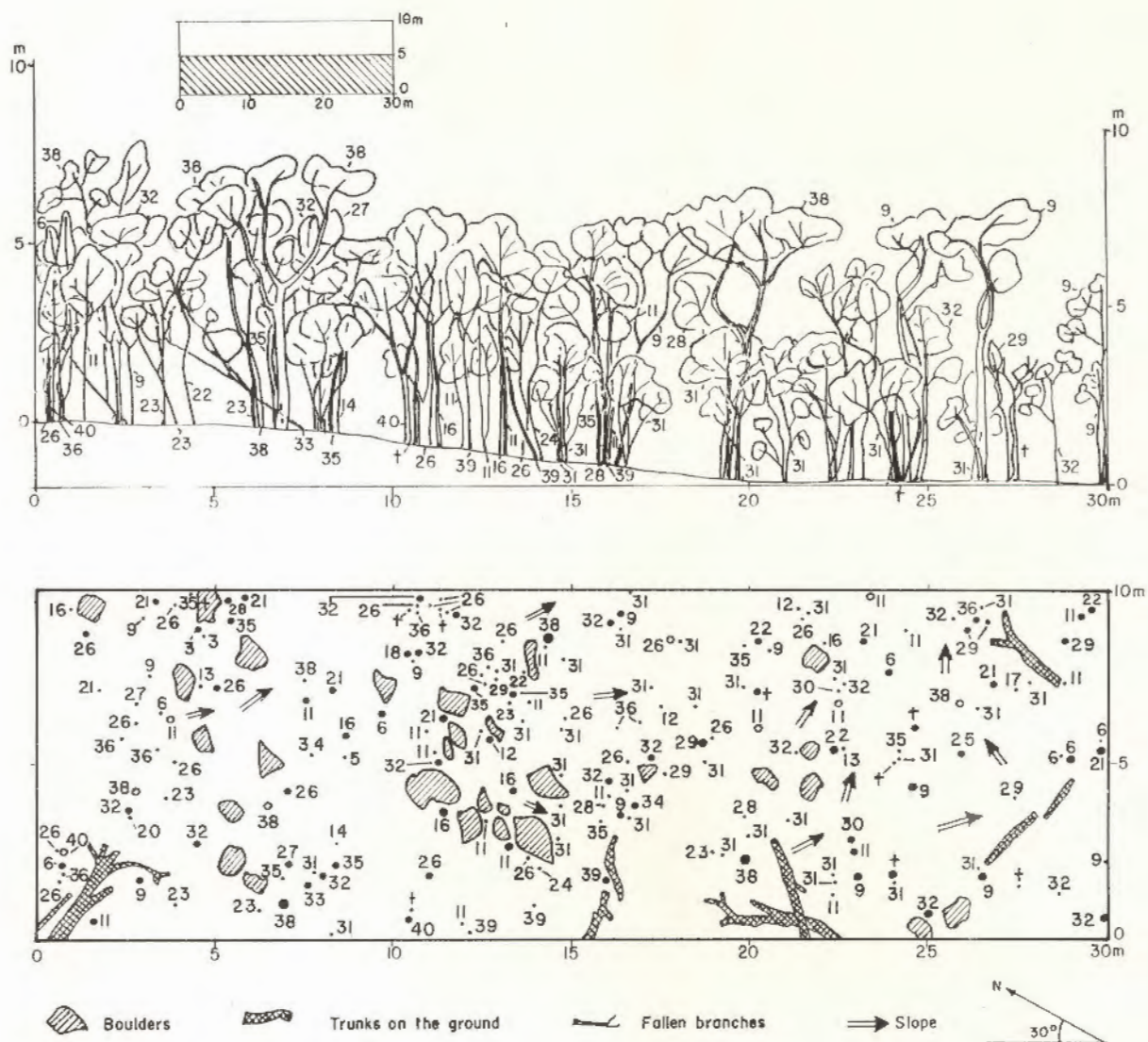


Fig. 42. Plot 3: a-Plan of the sampling plot (10 x 40 m); b-Vertical profile (5 x 40 m)



LIST OF SPECIES

- | | |
|--|--|
| 3. <i>Artocarpus heterophyllus</i> Lam. | 25. <i>Meliosma simplicifolia</i> (Roxb.) Walp. ssp. <i>pungens</i> (Walp.) Bens. |
| 5. <i>Callicarpa tamentosa</i> (L.) Murray | 26. <i>Neolitsea zeylanica</i> (Nees) Merr. |
| 6. <i>Casearia avata</i> (Lam.) Willd. | 27. <i>Olea glandulifera</i> Wall. |
| 9. <i>Cinnamomum sulphuratum</i> Nees | 28. <i>Persea macrantha</i> (Nees) Kosterm. |
| 11. <i>Cryptocarya neilgherrensis</i> Melissn. | 29. <i>Phoebe paniculata</i> Nees. |
| 12. <i>Daphniphyllum neilgherrense</i> Ros. | 30. <i>Pittasparum neilgherrense</i> W.B.A. |
| 13. <i>Elaeagnus kologa</i> Schlecht. (Climber) | 31. <i>Psychotria elongata</i> J. Hk. |
| 14. <i>Eurya japonica</i> Thunb. | 32. <i>Rapanea wightiana</i> Mez. |
| 16. <i>Glochidian neilgherrense</i> Wt. | 33. <i>Schefflera capitata</i> Harms. |
| 17. <i>Glacidion velutinum</i> Wt. | 34. <i>Symplocos cochinchinensis</i> (Lour.) Moore
ssp. <i>laurina</i> (Retz) Noot. |
| 18. <i>Ilex denticulata</i> Wall. | 35. <i>Syzygium cumini</i> (L.) Skeels. |
| 20. <i>Ixora notoniana</i> Wall. | 36. <i>Tarenna asiatica</i> (L.) Schum. |
| 21. <i>Ligustrum gamblei</i> Romm. | 38. <i>Vernonia monosis</i> C.B. Cl. |
| 22. <i>Litsea floribunda</i> (Bl.) Gamble | 39. <i>Viburnum punctatum</i> Buch.-Ham. |
| 23. <i>Maesa indica</i> (Roxb.) DC. | 40. <i>Xantolis tamentosa</i> (Roxb.) Raf. |
| 24. <i>Meliosma pinnata</i> (Roxb.) Walp. ssp. <i>arnattiana</i> (Walp.) Bens. | |

Fig. 43 - Plot 4: a-Plan of the sampling plot (10 x 30 m)
b-Vertical profile (5 x 30 m)

The presence of a larger number of big trees in plot 2 is mainly due to the humid conditions of the habitat.

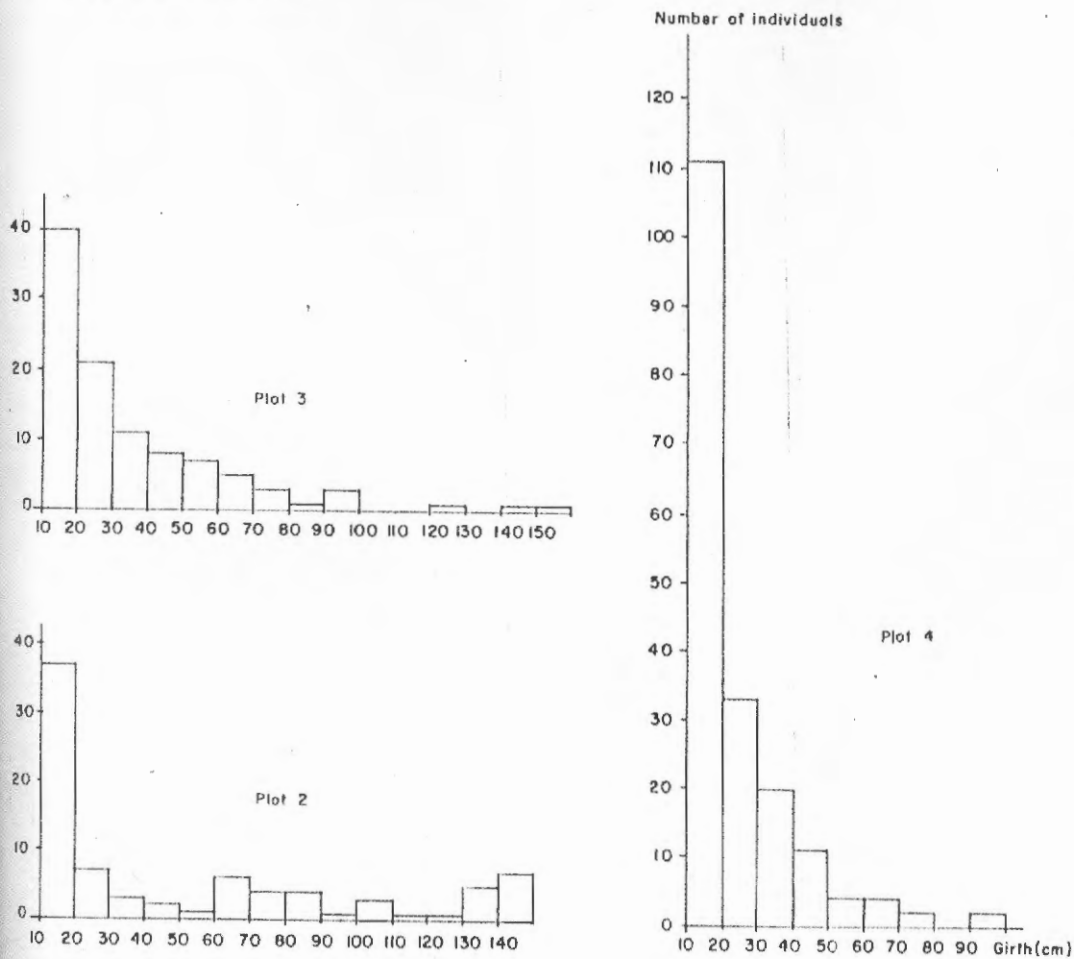


Fig. 44 - Girth distribution in plots 2, 3 and 4

3.1.4 Height distribution

Although the decrease in the height of trees appears to be linked to a certain extent with increase in elevation (Fig. 45), other factors are also involved. Thus the average height of plots 3 (8 m) and 4 (5 m) is lower than that of plot 1 even though they are at a lower elevation. This is because of the steep slope in plot 3 and the exposed nature of plot 4, whereas plot 1 is in a slightly sheltered location.

The height distribution of trees with $G \geq 10$ cm is given in Fig. 46. The distribution patterns of all the Anebeta plots are more or less bell-shaped except in plot 2.

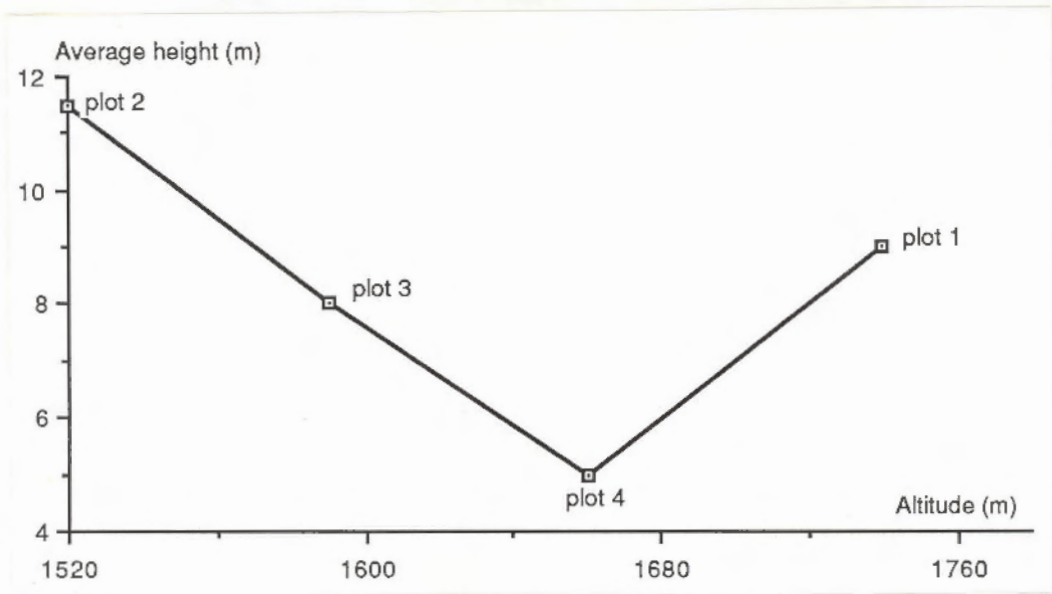


Fig. 45 - Average height of trees according to altitudinal gradient

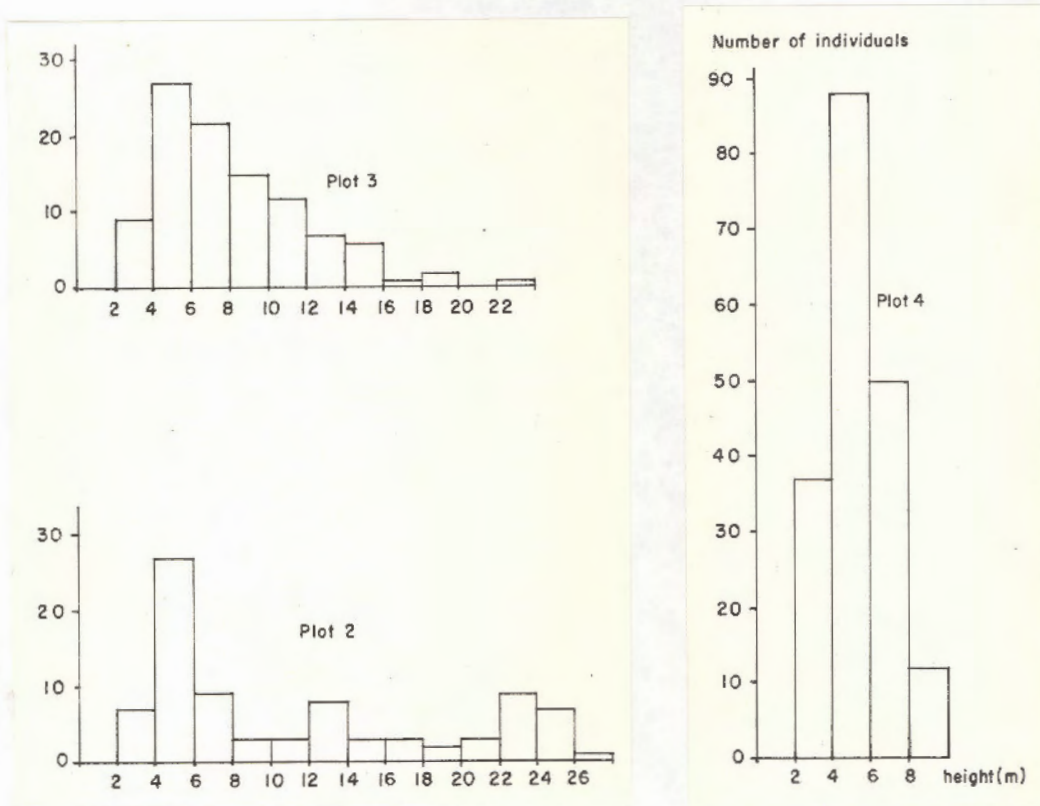


Fig. 46 - Height distribution in plots 2, 3 and 4

In plots 2, 3 and 4 (Fig. 46) a large number of individuals are represented in the 4-6 m height class. However, in plot 1 of Kattaribetta (Fig. 36) the mode is in the 10-12m height class, largely due to the paucity of young individuals.

Trees exceeding 14 m in height represent 33% of all individuals in plot 2, 10% in plot 3 and 2.5% in plot 1, whereas they are totally lacking in plot 4.

3.1.5 Density

The density of trees in plots 2, 3 and 4 of Anebetta and plot 1 of Kattaribetta are given in Table 25. The degree of disturbance and exposure seem to be the determinant factors for high or low density. Plot 4 which is on exposed terrain shows very high density (6233 individuals/ha) which is more than four times that of plots 1 and 2 and more than double the density of plot 3. However, this trend is almost reversed for trees $G \geq 80$ cm in plot 4.

The density of big trees/ha ($G \geq 120$ cm) in plot 2 is very high (267/ha) which is more than double the density of *Mesua-Palaquium-Olea* type (145/ha). This may be due to the proximity of the plot to the stream.

Table 25 - Density, basal area and D^2H

Density (no. of individuals/ha)		Kattari Betta	Anebetta		
		Plot 1 (1740m)	Plot 2 (1520 m)	Plot 3 (1590 m)	Plot 4 (1660 m)
Density (no. of individuals/ha)	$G \geq 10$ cm	1300	1417	2550	6233
	$G \geq 40$ cm	767	633	750	767
	$G \geq 80$ cm	317	417	175	67
	$G \geq 120$ cm	100	267	75	-
Basal area (M^2/ha)	$G \geq 10$ cm	48.3	64.3	39.9	38.3
	$G \geq 40$ cm	48.2	62.5	33.3	21.2
	$G \geq 80$ cm	36.6	55.1	18.7	4.5
	$G \geq 120$ cm	18.8	44.1	12.0	-
D^2H (M^3/ha)	$G \geq 10$ cm	763.6	1698.5	682.6	319.4
	$G \geq 40$ cm	742.1	1682.4	621.8	197.6
	$G \geq 80$ cm	568.7	1560.4	401.8	40.0
	$G \geq 120$ cm	303.5	1282.4	266.5	0

3.1.6 Basal area and Biomass Index (D^2H)

These results are given in Table 25. In plot 2 the basal area (64.3 m²/ha) and biovolume (1698.5 m³/ha) are more or less similar to the *Mesua-Palaquium-Olea* type 60.1 m²/ha and 1962.5 m³/ha respectively. More than 68% of these high values are contributed by large trees ($G \geq 120$ cm).

The low values of basal area in plots 3 (39.9 m²/ha) and 4 (38.3 m²/ha) when compared plots 1 and 2 are mainly due to the paucity of big trees ($G \geq 120$ cm) in the former, while they are completely absent in the latter. This trend is also reflected in the biovolume. However, in plot 4 the biovolume (319.4 m³/ha) is less than half that of plots 1 and 3 and just one fifth the biovolume of plot 2.

Although plot 4 lacks big trees, its basal area is almost the same as that of plot 3, because of the high density of trees in it.

3.2 Variations in floristic structure

3.2.1 Species-altitude curve

The floristic richness in function of altitudinal gradient for plots 1, 2, 3 and 4 is shown in Fig. 47*.

Plot 1 (1740 m) and 2 (1520 m) which are sheltered have a smaller number of species (15 and 13 respectively) when compared to plot 3 at 1590 m (22 species) and plot 4 at 1660 m (30 species), where the increase in the number of species is due to the addition of heliophilous species.

3.2.2 Species-individual curve

The total number of species as well as the number of individuals belonging to each species encountered in the plots 1, 2, 3 and 4 are given in Fig. 48.

Two levels of floristic richness can be recognised:

- a higher level with the first 40 individuals belonging to 14-16 species and the first 80 individuals to 24 species (Plots 3 and 4).

- a lower level (Plots 1 and 2) where the first 40 individuals belong to 10-11 species and the first 80 individuals over 13-15 species.

* Only trees with $G \geq 10$ cm have been considered

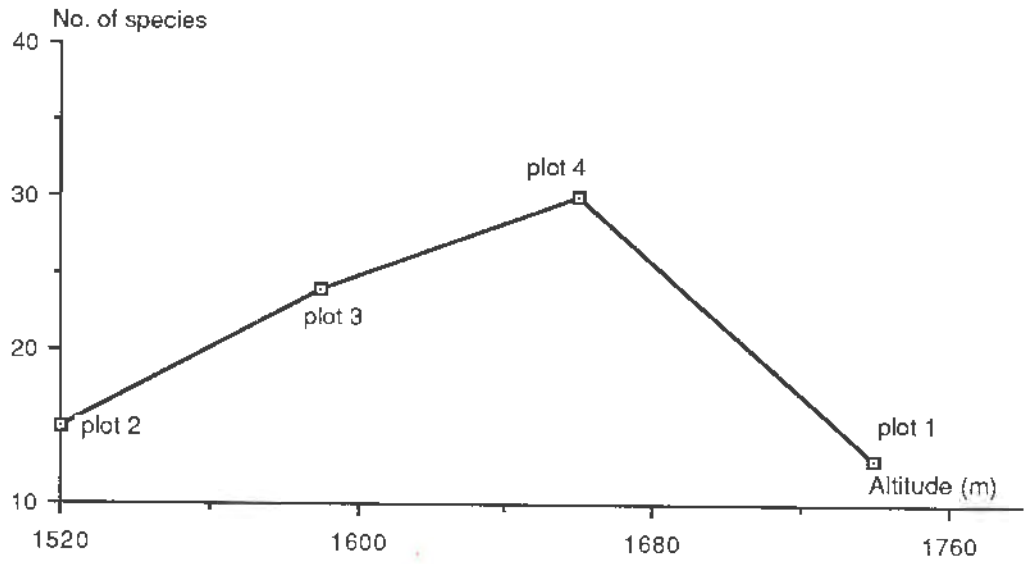


Fig. 47 - Species-altitude curve

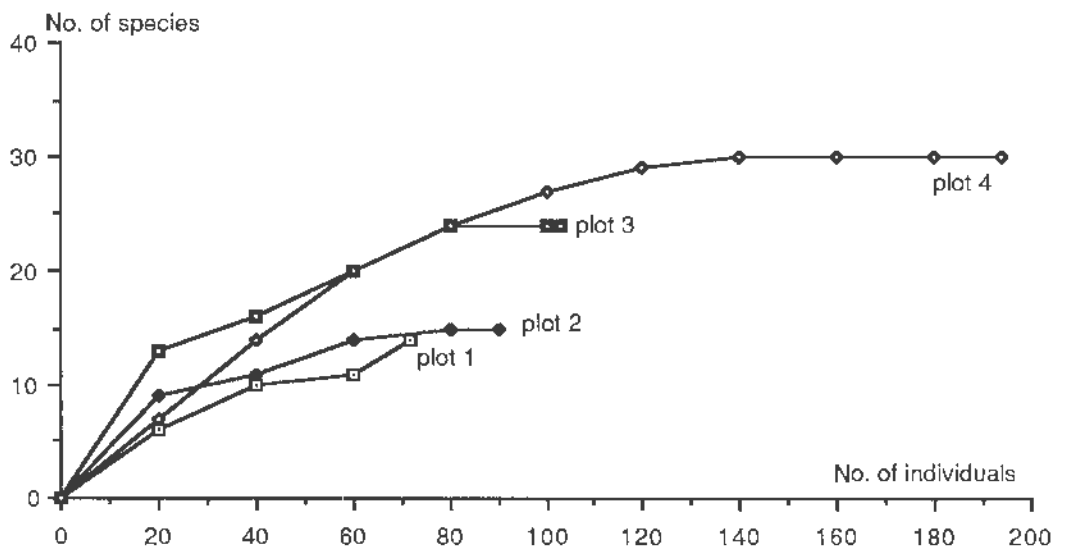


Fig. 48 - Species-individuals curves

3.2.3 Floristic diversity

The relative densities of species in plots 2, 3 and 4 are given in Fig. 49.

The first 4 species represent more than 50% in plots 2 and 3 and 47% in plot 4.

In plot 2, *Bischofia javanica*, *Persea macrantha* and *Viburnum punctatum* which are species characteristic of humid conditions account for 34.2%. There is only one heliophilous species represented by *Clerodendrum viscosum* (7.1%).

In plot 3, *Vernonia monosis*, heliophilous species dominates others with 33.3% representation. This indicates the secondary nature of the forest in this zone. There are 5 other heliophilous species (indicated in the Fig. by *) together representing 7%. The three characteristic species of humid zones, viz., *Bischofia javanica*, *Persea macrantha* and *Viburnum punctatum* are also present in this plot and account for 4%.

Plot 4, which is on exposed terrain, has 10 heliophilous species (7 of them not recorded in the other plots). The relative density of these species is 28%, *Rapanea wightiana* accounting for 8% and *Vernonia monosis*, 3.7%.

As already mentioned, in plot 1 (Fig. 39) the first 4 species account for 70.5%. Two heliophilous species in the openings constitute 2.6% of the total number of individuals.

The important value index (IVI) of the species of plots 2, 3 and 4 is given in Tables 26, 28 and 30.

In plot 2, the IVI of the first 6 species is more than 26 including 2 Lauraceae species (*Persea macrantha* and *Neolitsea zeylanica*) whose IVI exceed 40. The highest IVI is that of *Persea macrantha*: 72.43.

In plot 3, IVI is more than 23 for the first 4 species and exceeds 17 for the first 6 species. *Vernonia monosis* has the highest value of 75.64.

In plot 4, the first 6 species have an IVI of more than 21 each. The first 4 species show a certain degree of co-dominance.

The IVI of families of plots 2, 3 and 4 is given in Tables 27, 29 and 31. Lauraceae is dominant in all the plots (including Plot I, Table 22) with IVI ranging from 88 to 193. The IVI of Lauraceae vis à vis altitude for all the plots studied in the BRH is shown in Fig. 50. In general, the IVI increases with increase in elevation. However,

Fig. 49 - Number of individuals per species in plots 2, 3 and 4

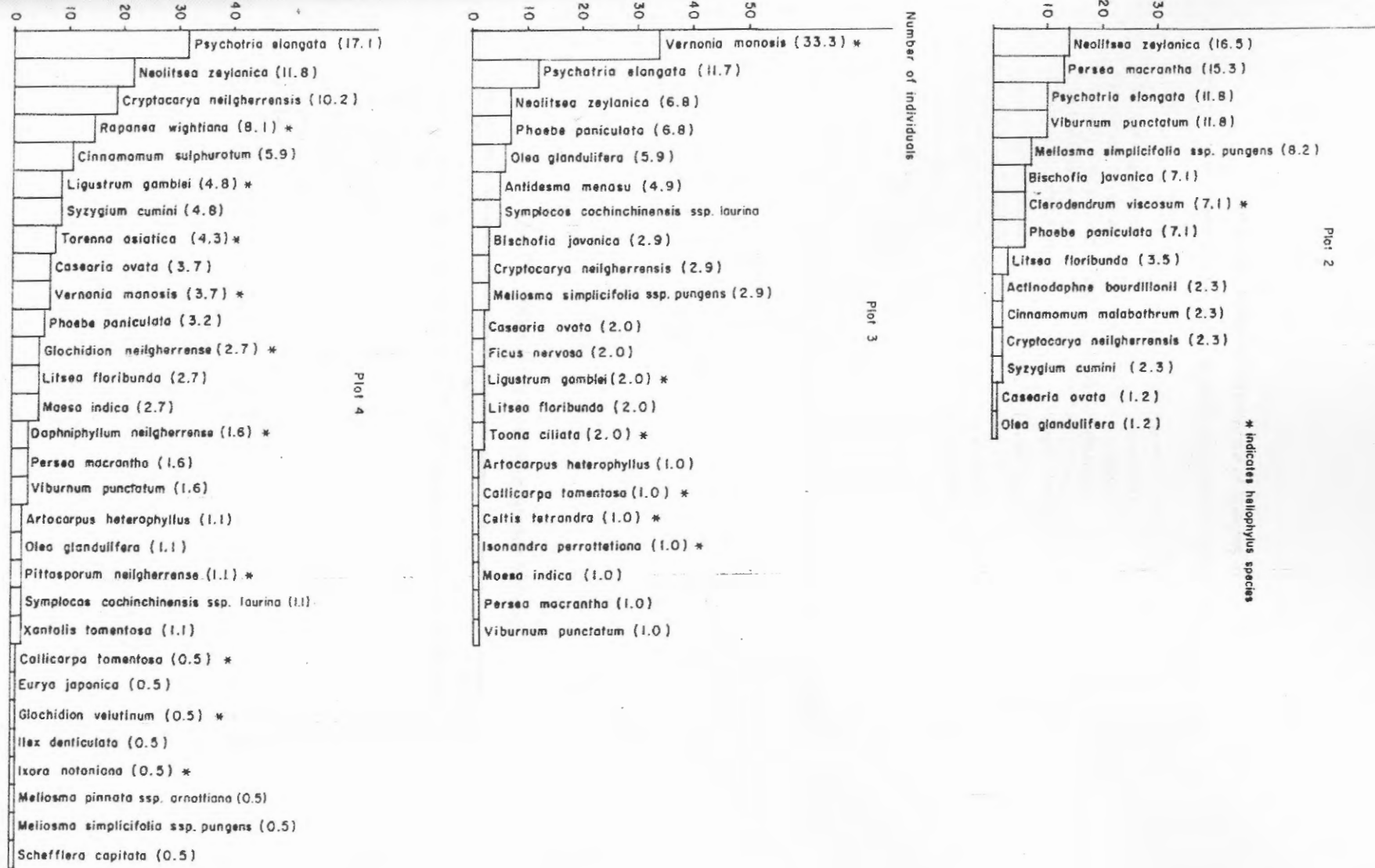


Table 26 - Relative importance of species in plot 2

Species	Families	Importance Value Index
<i>Persea macrantha</i>	Lauraceae	72.43
<i>Neolitsea zeylanica</i>	Lauraceae	41.08
<i>Meliosma simplicifolia</i> ssp. <i>pungens</i>	Sabiaceae	28.97
<i>Bischofia javanica</i>	Euphorbiaceae	28.65
<i>Viburnum punctatum</i>	Caprifoliaceae	28.27
<i>Psychotria elongata</i>	Rubiaceae	26.02
<i>Phoebe paniculata</i>	Lauraceae	15.71
<i>Clerodendrum viscosum</i>	Verbenaceae	11.85
<i>Syzygium cumini</i>	Myrtaceae	11.26
<i>Litsea floribunda</i>	Lauraceae	9.00
<i>Actinodaphne bourdillonii</i>	Lauraceae	8.77
<i>Cryptocarya neilgherrensis</i>	Lauraceae	6.75
<i>Cinnamomum malabathrum</i>	Lauraceae	5.51
<i>Olea glandulifera</i>	Oleaceae	2.98
<i>Casearia ovata</i>	Flacourtiaceae	2.75

Table 27 - Relative importance of families in plot 2

Families	Number of species	Importance Value Index
Lauraceae	7	159.25
Sabiaceae	1	28.97
Euphorbiaceae	1	28.65
Caprifoliaceae	1	28.27
Rubiaceae	1	26.02
Verbenaceae	1	11.85
Myrtaceae	1	11.26
Oleaceae	1	2.98
Flacourtiaceae	1	2.75

Table 28 - Relative importance of species in plot 3

Species	Families	Importance Value Index
<i>Vernonia monosis</i>	Asteraceae	75.64
<i>Phoebe paniculata</i>	Lauraceae	28.61
<i>Psychotria elongata</i>	Rubiaceae	24.96
<i>Neolitsea zeylanica</i>	Lauraceae	23.65
<i>Cryptocarya neilgherrensis</i>	Lauraceae	18.81
<i>Casearia ovata</i>	Flacourtiaceae	17.83
<i>Olea glandulifera</i>	Oleaceae	16.04
<i>Antidesma menasu</i>	Euphorbiaceae	11.93
<i>Bischofia javanica</i>	Euphorbiaceae	11.12
<i>Symplocos cochinchinensis</i> ssp. <i>laurina</i>	Symplocaceae	11.01
<i>Litsea floribunda</i>	Lauraceae	9.81
<i>Meliosma simplicifolia</i> ssp. <i>pungens</i>	Sabiaceae	7.99
<i>Persea macrantha</i>	Lauraceae	7.29
<i>Ficus nervosa</i>	Moraceae	5.73
<i>Toona ciliata</i>	Meliaceae	5.67
<i>Ligustrum gamblei</i>	Oleaceae	5.54
<i>Callicarpa tomentosa</i>	Verbenaceae	4.59
<i>Isonandra perrottetiana</i>	Sapotaceae	3.08
<i>Celtis tetrandra</i>	Ulmaceae	2.83
<i>Artocarpus heterophyllus</i>	Moraceae	2.71
<i>Maesa indica</i>	Myrsinaceae	2.58
<i>Viburnum punctatum</i>	Caprifoliaceae	2.58

Table 29 - Relative importance of families in plot 3

Families	Number of species	Importance Value Index
Lauraceae	5	88.17
Asteraceae	1	75.64
Rubiaceae	1	24.96
Euphorbiaceae	2	23.05
Oleaceae	2	21.58
Flacourtiaceae	1	17.83
Symplocaceae	1	11.01
Moraceae	2	8.44
Sabiaceae	1	7.99
Meliaceae	1	5.67
Verbenaceae	1	4.59
Sapotaceae	1	3.08
Ulmaceae	1	2.83
Caprifoliaceae	1	2.58
Myrsinaceae	1	2.58

Table 30 - Relative importance of species in plot 4

Species	Families	Importance Value Index
<i>Cryptocarya neilgherrensis</i>	Lauraceae	31.25
<i>Vernonia monosis</i>	Asteraceae	30.83
<i>Neolitsea zeylanica</i>	Lauraceae	29.74
<i>Psychotria elongata</i>	Rubiaceae	28.18
<i>Cinnamomum sulphuratum</i>	Lauraceae	22.93
<i>Rapanea wightiana</i>	Myrsinaceae	21.70
<i>Ligustrum gamblei</i>	Oleaceae	15.42
<i>Syzygium cumini</i>	Myrtaceae	14.08
<i>Casearia ovata</i>	Flacourtiaceae	12.35
<i>Tarenna asiatica</i>	Rubiaceae	9.92
<i>Litsea floribunda</i>	Lauraceae	9.67
<i>Phoebe paniculata</i>	Lauraceae	9.55
<i>Glochidion neilgherrense</i>	Euphorbiaceae	9.06
<i>Maesa indica</i>	Myrsinaceae	6.70
<i>Xantolis tomentosa</i>	Sapotaceae	5.83
<i>Daphniphyllum neilgherrense</i>	Euphorbiaceae	5.26
<i>Persea macrantha</i>	Lauraceae	4.62
<i>Viburnum punctatum</i>	Caprifoliaceae	4.45
<i>Olea glandulifera</i>	Oleaceae	4.18
<i>Pittosporum neilgherrense</i>	Pittosporaceae	3.83
<i>Symplocos cochinchinensis</i> ssp. <i>laurina</i>	Symplocaceae	3.83
<i>Artocarpus heterophyllus</i>	Moraceae	2.49
<i>Ilex denticulata</i>	Aquifoliaceae	2.48
<i>Schefflera capitata</i>	Apocynaceae	1.96
<i>Meliosma simplicifolia</i> ssp. <i>pungens</i>	Sabiaceae	1.87
<i>Callicarpa tomentosa</i>	Verbenaceae	1.70
<i>Eurya japonica</i>	Theaceae	1.53
<i>Glochidion velutinum</i>	Euphorbiaceae	1.53
<i>Ixora notoniana</i>	Rubiaceae	1.53
<i>Meliosma pinnata</i> ssp. <i>arnottiana</i>	Sabiaceae	1.53

Table 31 - Relative importance of families in plot 4

Families	Number of species	Importance Value Index
Lauraceae	6	107.76
Rubiaceae	3	39.63
Asteraceae	1	30.83
Myrsinaceae	2	28.40
Oleaceae	2	19.60
Euphorbiaceae	3	15.85
Myrtaceae	1	14.08
Flacourtiaceae	1	12.35
Sapotaceae	1	5.83
Caprifoliaceae	1	4.45
Pittosporaceae	1	3.83
Symplocaceae	1	3.83
Sabiaceae	2	3.40
Moraceae	1	2.49
Aquifoliaceae	1	2.48
Apocynaceae	1	1.96
Verbenaceae	1	1.70
Theaceae	1	1.53

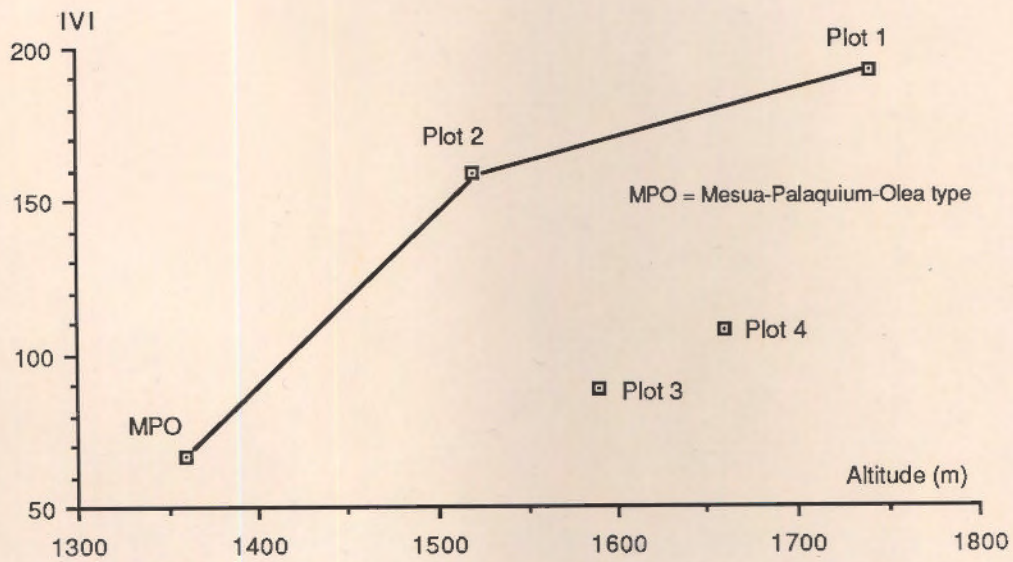


Fig. 50 - Importance value index (IVI) of Lauraceae according to altitude

Table 32 - Floristic diversity

Station	Area (m ²)	Number of species=S (G≥10 cm)	Number of individuals=N (G≥10 cm)	N/S	Simpson's index	Shannon-Wiener's index		
						H'	H _{max}	E=H'/H _{max}
plot 2 (1520 m)	600	15	85	5.7	0.90	3.51	3.91	0.90
plot 3 (1590 m)	400	22	102	4.6	0.85	3.55	4.46	0.80
plot 4 (1660 m)	300	30	187	6.2	0.92	4.18	4.91	0.85

plot 3 (disturbed canopy) and plot 4 (exposed nature of the terrain) are exceptions to the rule.

Comparison of the floristic diversity of plots 2, 3 and 4 is made in Table 32.

Plot 4, on exposed terrain, shows a high degree of diversity ($H' = 4.18$) when compared to the other plots because of the larger number of heliophilous species. The number of individuals per species is also high (6.2). Simpson's index indicates that out of 100 pairs taken at random, 8 are composed of the same species.

Plot 3, which is probably a secondary forest, shows less floristic diversity when compared to plot 4. The low equitability ratio E (0.80) is due to the abundance of *Vernonia monosis*.

On the other hand, the H' value of plots 1 and 2, which are less disturbed particularly with regard to canopy, ranges from 3.02 to 3.51.

4 FLORISTIC STUDY

The variations in topography and local climatic conditions in this high elevation type which includes the majority of the evergreen forests in the BRH confer a certain degree of heterogeneity to its floristic composition.

4.1 Main factors for floristic variations

- *Exposure:*

As mentioned in Chapter 2, the microclimatic conditions, *i.e.*, temperature and relative humidity, outside the forest show greater amplitude when compared to the interior. Further, direct light and high wind velocity are responsible for the floristic and structural changes as seen in plot 1 and 1-a of Kattaribetta. Morphological changes such as shortening of internodes of the branches, reduction in size and thickening of leaves are also observed.

- *Altitude:*

Since altitude reflects the temperature, it is often responsible for some major changes in the floristic composition.

In the BRH, such variations in the floristic composition can be observed in the middle part of its eastern half. The region between Dumberabetta ($11^{\circ}51'$) and Hattubarebetta ($11^{\circ}55'$) is a complex of many high altitude peaks ranging between

1600 and 1800 m. This abrupt rise in the elevation favours the appearance of some species tolerant of cooler climates and at the same time creates conditions unfavourable to some others which either disappear or are reduced in number.

4.2 General floristic composition and distribution of species

As evident from the greater importance value, the high elevation forests are mainly of the Lauraceous type.

A list of 99 species encountered in this high elevation type is given in Annexe 5. As the studies are basically on trees and shrubs, the representation of herbaceous species in the list is not complete. The floristic composition is given according to the habit, ecological preference and their altitudinal and latitudinal distribution.

4.2.1 Species with wide distribution

This group includes a large number of species with a wide ecological amplitude. Some of them show a marked preference for the margins/openings of the forest or for the vicinity of streams.

4.2.1.1 Species inside the forest

- Trees

Species with a preference for humid conditions are represented by *Bischofia javanica*, *Viburnum punctatum* and *Persea macrantha*. The first two species are recorded only upto 1650 m. *Bischofia javanica* seems to be more common around Bidigadigudda. *Ficus racemosa* is confined to a few valleys.

Canopy trees such as *Cinnamomum sulphuratum* (specially above 1500 m), *Litsea floribunda*, *Neolitsea zeylanica* are very common throughout the high elevation range. *Mallotus philippensis* and *Syzygium cumini* are abundant between Odaikanbetta and Doddabetta and in the northern part. Other species commonly encountered are *Canthium dicoccum*, *Cinnamomum travancoricum*, *Cryptocarya neilgherrensis*, *Elaeocarpus serratus*, *Olea glandulifera*, *Phoebe paniculata*, *Scolopia crenata*, *Xantolis tomentosa* etc... *Meliosma simplicifolia* ssp. *pungens* is common at the lower limits of the high elevation range. *Casearia ovata* and *Meliosma pinnata* ssp. *arnottiana* are common upto 11°58' latitude. They become rare further north and almost disappear near Gummannibetta.

Actinodaphne lawsonii is mostly encountered between Odaikanbetta and Oddanabetta, and seems to be more frequent above 1600 m.

Fagraea ceilanica and *Schefflera capitata* are stranglers (later becoming trees) found mostly on trees of *Litsea floribunda*. They are common throughout the medium elevation range.

Atalantia wightii and *Nothapodytes foetida* are small trees under the canopy. The former is rare above 1600 m as well as in the northern part of the BRH.

Certain characteristic species of medium elevations like *Aphanamixis polystachya*, *Ardisia solanacea*, *Artocarpus heterophyllus*, *Cassine glauca*, *Euodia lunu-ankenda*, *Ficus nervosa*, *Prunus ceylanica*, are occasionally found in some valleys at higher elevations upto 1600 m.

- **Shrubs**

Below 1600 m *Nilgirianthus heyneanus*, an undershrub, is the most important species of the undergrowth. Other common species include *Cipadessa baccifera*, *Maesa indica*, *Psychotria elongata*, *P. nigra*.

- **Climbers**

Common climbers inside the forest are *Asparagus racemosus*, *Cayratia* sp., *Piper* sp., *Toddalia asiatica* var. *floribunda*; *Hiptage benghalensis* and *Celastrus paniculatus* are observed occasionally; however, *Hiptage* is found only upto 1550 m.

Toddalia asiatica var. *floribunda* is a vicariant of *T. asiatica* var. *gracilis* which is confined to dry deciduous forests below 800 m.

4.2.1.2 Species along the margins and openings

Species growing along the margins of the forest and in the openings are mostly heliophilous species.

Species found along the forest margins throughout the BRH include *Chionanthus ramiflora*, *Glochidion neilgherrense*, *Vernonia monosis*, *Wendlandia thyrsoides*. *Callicarpa tomentosa* is frequent in humid forests; *Symplocos cochinchinensis* var. *laurina* is common between Odaikanbetta and Oddanabetta, particularly on the western slopes of Dhumberabetta at 1350-1400 m, where it is

found growing in clumps along with *Wendlandia thyrsoides*. *Murraya paniculata* is common to the north of Dhumberabetta.

Species frequently encountered along the margins of the medium elevation type often extend their area to the high elevation type; examples are *Catunaregam torulosa*, *Glochidion velutinum*, (both upto 1650 m) and *Ziziphus rugosa* (upto 1550 m). However, *Catunaregam* and *Ziziphus* are quite rare.

Catunaregam torulosa (confined to medium and high elevations) is a vicariant of *Catunaregam dumetorum* which is very common in dry deciduous forests of low elevations.

Openings inside the forest are either due to fire or to fallen trees. The pioneers in the openings are *Clerodendrum viscosum*, *Trema orientalis* etc. *Macaranga peltata* is generally found in open humid forests. The presence of many big trees like *Sterculia guttata* and *Celtis tetrandra* indicate past disturbance. Some openings are dominated by *Vernonia monosis*.

Among shrubs, *Chromolaena odoratum* is dominant along the margin of the forest. *Solanum sp.*, *Albizia marginata*, *Securinega virosa*, *Phyllanthus polyphyllus* are rarely encountered in these disturbed forests.

The most common straggler along the forest margin upto 1600 m is *Allophylus cobbe*. *Rubus fairholmianus* and *R. niveus* are common between Kumbaragundibetta and Honneparaibetta and extend upto 1750 m.

4.2.2 Species with restricted distribution

The restricted distribution of some species is due more to altitude than to latitude.

Fig. 51 and 52 show the latitudinal and altitudinal range of some of the species of the margin and interior of the forests.

4.2.2.1 Species inside the forest

All the species (Fig. 51 and 52) belonging to this category are more frequent above 1600 m.

Celtis timorensis is commonly found in the 1300-1700m range between Bidigadigudda (11°49'lat.) and Honneparaibetta (11°57' lat.).

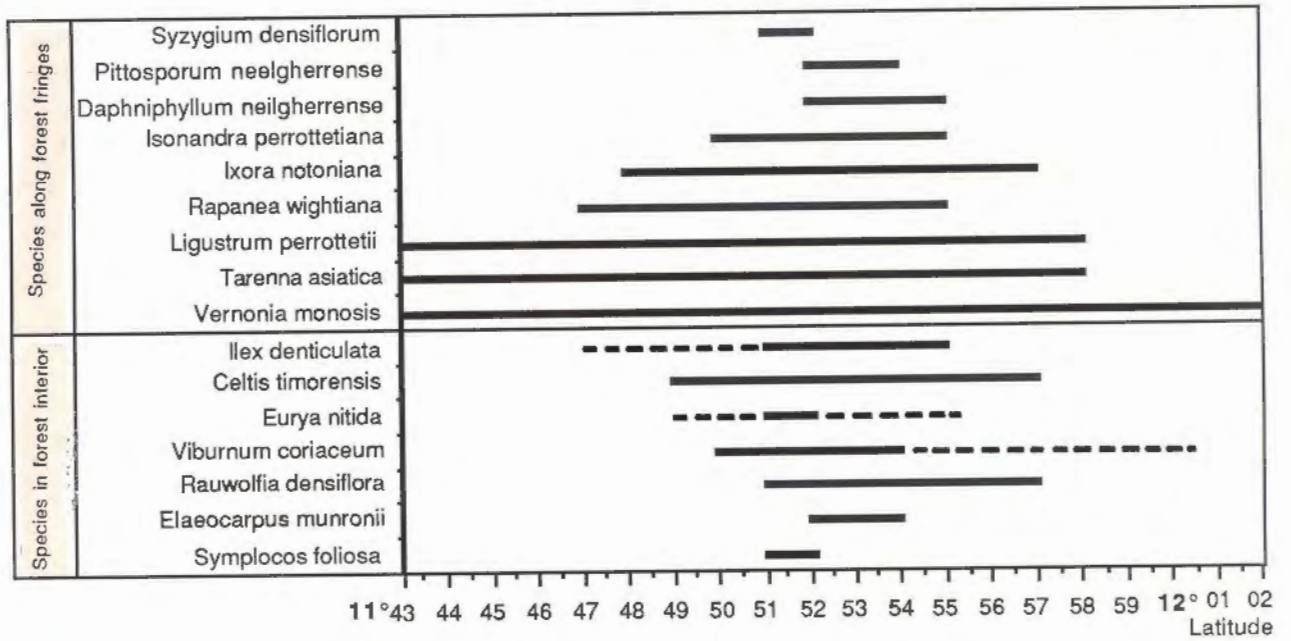


Fig. 51 - Distribution of species according to latitudinal range

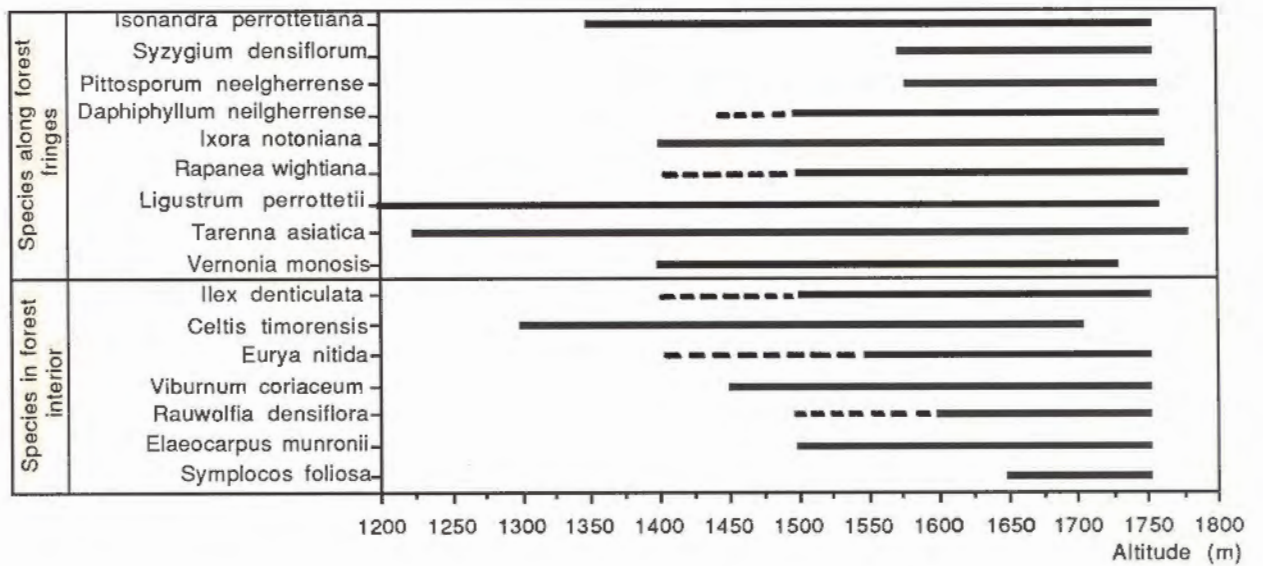


Fig. 52 - Distribution of species according to altitudinal range

Eurya nitida and *Ilex denticulata* are characteristic of low montane forests. In the BRH they show more or less the same altitudinal distribution (1400-1750m) but are more frequent above 1600 m. *Eurya* is a small tree common near Kattaribetta, while *Ilex* extends further south where they are often found below 1500 m.

Rauwolfia densiflora, a shrub or small tree with milky latex, is common above 1600 m between Akkatangibetta and Oddanabetta.

Elaeocarpus munronii and *Symplocos foliosa* have a very narrow range of distribution. The former species is very rare in the BRH while the latter is confined to Kattaribetta at elevations above 1650 m where it is very common.

Some species are recorded only in a few stations: *Eugenia thwaitesii* (1450 m) in Hattubarebetta; *Euonymus crenulatus* (1450-1700 m) in Anebetta and Dhumberabetta; *Schefflera micrantha*, a strangler (1350-1500 m) in Odaikanbetta and Akkatangibetta.

Salix tetrasperma is a big tree growing along streams at medium elevations. In Kattaribetta (1700 m) it is found as a shrub along a dry stream bed.

Among shrubs, *Lasianthus venulosus* is recorded only in Kattaribetta above 1650 m. *Nilgirianthus sp.* (with angular stem) is very abundant in the undergrowth between Akkatangibetta and Kattaribetta (above 1600 m). It often surpasses 3 m in height. *Solanum laeve*, an undershrub, is very common in openings.

Of the climbers, *Gardneria ovata* with slender stems is common between Akkatangibetta and Kattaribetta above 1600 m. *Zanthoxylum tetraspermum* with woody armed stem, is another characteristic species of high altitudes. However, they are restricted to humid forests in the 1400-1550 m range between Annebetta and Aravillabetta.

4.2.2.2 Species along the margin of the forest

As already mentioned, *Vernonia monosis* shows a wide range of distribution, as also *Ligustrum perrottetii* and *Tarenna asiatica*. However, *Ligustrum* and *Tarenna* stop more or less at Honneparabetta (11°58' lat.) *Tarenna asiatica* is very common in scrub-woodland to thickets below 800 m, where it is shrubby with chartaceous leaves.

At higher elevations, it has adapted itself to withstand the strong winds and cooler climate as a small tree with stout and short branches and coriaceous leaves.

Isonandra perrottetiana and *Rapanea wightiana* are very common, especially above 1600 m, along the margin between Akkatangibetta and Dhumberabetta. The former species is also found in the *Mesua-Palaquium-Olea* type where the leaves are much broader compared to those at higher elevations.

Viburnum coriaceum is frequently encountered between Dhumberabetta and Hattubarebetta above 1600 m. It is also observed in the north (Gummani betta) at elevations of 1350-1400 m.

Ixora notoniana is found between Odaikanbetta and Honneparaibetta at 1400-1740 m.

Daphniphyllum neilgherrense is confined to the region between Kattaribetta and Hattubarebetta; it is often found in openings inside the forest.

Pittosporum neilgherrense and *Syzygium densiflorum* have a narrow distribution both latitudinally and altitudinally (>1560 m). *Syzygium* is more common in Akkatangibetta, Kattaribetta and Honnamettibetta.

Among shrubs, *Barleria involucrata* and *Nilgirianthus foliosus* are found growing densely along the margins of the forest, especially in Kattaribetta and Honnamettibetta.

All the above mentioned species are common in the sholas of the Nilgiris and Palnis at high altitudes. For most of the species, the BRH forms the eastern limit of their distribution.

5 CONCLUSION

There is an overall reduction in the values of the spatial structure with increase in altitude. However, the magnitude of these variations depend on the exposure of the terrain and disturbances, if any, in the stand.

Gradual decrease in temperature, increase in wind velocity and infertility of the soil may affect the height of the stand, causing a compression of the top canopies, where more biomass gets concentrated as compared to the lower ones.

The floristic richness and diversity vary from one habitat to another and studies on a small plot may not give a correct picture of the same. However, it may be deduced that floristic richness and diversity is low in high elevation types when compared to tall forests of low and medium elevations.

PHYTOGEOGRAPHY

The large varieties of climatic types in India and its geographical position in the past has enabled the penetration of floristic elements from Malaysia, Africa, China, the Mediterranean region and temperate countries.

India has been divided into different floristic provinces by Clarke (1897), Hooker (1907), Gaussen (1933), Chatterjee (1939), Razi (1955) and others. According to Meher-Homji's (1984) biogeographic classification based mainly on the distribution of the vegetation types, BRH belongs to the Teak zone and to the zone of evergreen forests.

One of the most enigmatic problems for the phytogeographers is the disjunct distribution of certain taxa. To explain this, various hypotheses have been put forward by different authors.

Migratory routes have been proposed to explain (i) the Himalayan element on the South Indian hill tops and (ii) the Indo-malaysian element in North-East India on one hand and in the Western Ghats on the other. The commonly held theory is that lowering of temperature during the Pleistocene glaciation is responsible for providing a passage along the hilly tracts for the Himalayan flora to migrate southwards (Medlicot and Blanford, 1879; Burkill, 1924; Hora, 1949; Auden, 1949; Dey, 1949; Meher-Homji, 1972).

Legris (1963) suggested East coast-Eastern Ghats route linking Assam to the Western Ghats through Bengal, the hills of Orissa, the Eastern Ghats, the Mysore plateau and the Nilgiris. This is supported by the presence of fossils belonging to the humid Indo-malaysian element in the Miocene Cuddalore sandstone series which extends from Madurai to Pondicherry and further north upto Rajahmundry (Meher-Homji, 1983).

Another school of thought considers the species showing disjunct distribution as 'relict' ones (Meher-Homji, 1983). The record of plant fossils in the Cuddalore Sandstone series, the Warkalli deposits and Quilon beds of Kerala, the Deccan Intertrappean Series of Central India, North-East India, Bengal Basin, Kutch,

Rajasthan and Siwaliks reveals the existence of tropical wet evergreen forest species throughout the peninsula during the Miocene-Pliocene. The northward movement of the Indian plate, the uplift of the Himalayas and the Western Ghats contributed towards the onset of a drier climate and replacement of evergreen forests by deciduous ones over the greater part of the peninsula during the late Tertiary. The evergreen species could survive only in suitable humid regions like the north-eastern and south-western parts of India or in moist pockets of the Eastern Ghats as relict species.

1. FLORISTIC ELEMENTS

The species composition of the evergreen forests of the BRH has been analysed for the different floristic elements according to their distribution pattern. However, only species of evergreen trees, large shrubs and climbers have been considered and deciduous species, under shrubs, herbs and epiphytes have been excluded.

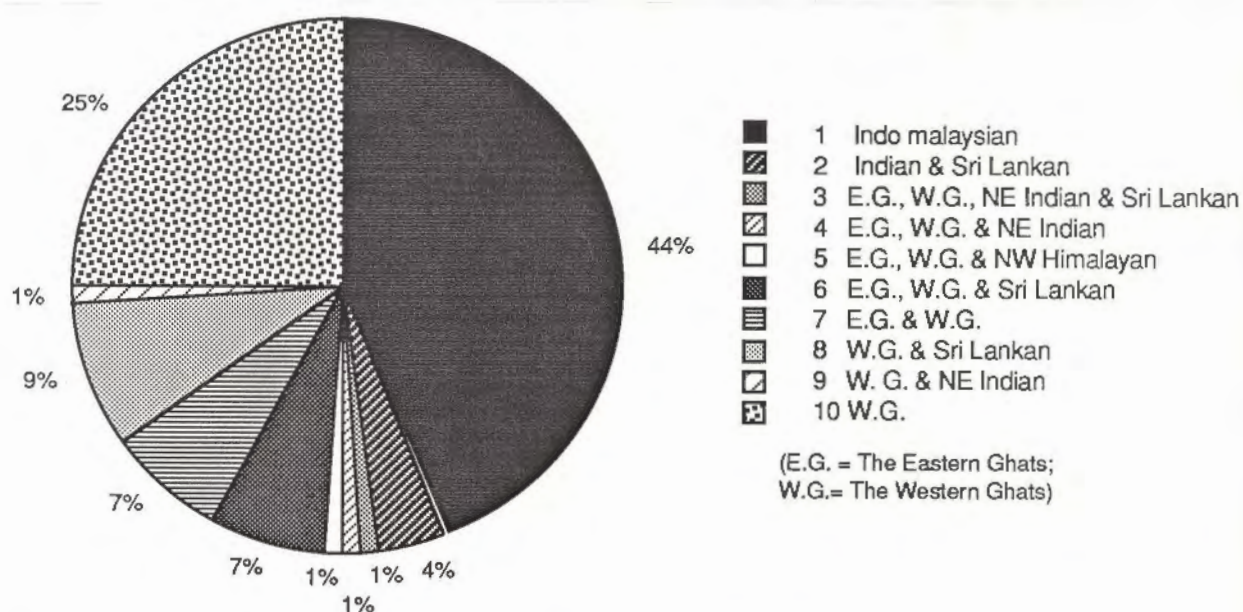


Fig. 53 - Distribution of floristic elements

Ten floristic elements have been recognised according to their geographic range of distribution. The list of species is given in Annexe 5 and the percentages of various elements are shown in Fig. 53. The present study reveals 78 species as new records for the BRH region. Of the 78, 72 species are marked with an asterisk in Annexe 5 and in the remaining 4 are deciduous species in the semi-deciduous forest represented by *Dalbergia latifolia*, *D. paniculata*, *Phyllanthus polyphyllus* and *Sapindus laurifolius*. and 2 are herbs: *Boehmeria sp.* and *Elatostema lineolatum*.

1.1 Indo-malaysian elements

This element constitutes the largest group with 44%. The following species of this element are common in the humid zones of the Western Ghats and N.E. India but not reported from the intermediate Eastern Ghats except the BRH: *Acrocarpus fraxinifolius*, *Casearia ovata*, *Elaeocarpus tuberculatus*, *Fagraea ceilanica*, *Mesua ferrea*, *Aphanamixis polystachya*, *Chrysophyllum lanceolatum*, *Debregeasia longifolia*. *Dimocarpus longan* and *Ficus nervosa* are also common in the humid zones of the above mentioned regions but show limited extension in the Shevarayans and Kollaimalai hills of the Eastern Ghats (Matthew, 1983) above 1400 m elevation.

Chionanthus ramiflora is common throughout the Eastern Ghats above 900 m and is also found along the comparatively dry eastern slopes of the Western Ghats. Its distribution range extends to South China and Australia, which pattern is also included under the Indo-malaysian element in a broad sense.

High altitude species commonly found along the margins of the sholas include *Daphniphyllum neilgherrense*, *Eurya nitida*, *Rapanea wightiana* and *Viburnum coriaceum*. They extend up to the Himalayas and in countries of higher latitudes such as China, Japan and Korea. Of these, the first two species are rarely encountered in Shevarayans and Kollaimalais of the Eastern Ghats, while the last two species are absent in the Eastern Ghats except in the BRH. However, Matthew (1983) has reported *Rapanea capitellata* var. *sessilis* from Kollaimalais.

Cocculus laurifolius, one of the few arborescent species of Menispermaceae, is common in the Western Himalayas, Malayan peninsula and S. Japan. Its occurrence is reported in the BRH, the Nilgiris and the Anamalais in South India, but not from the intermediate areas.

Salix is primarily a temperate genus, but one species, viz., *Salix tetrasperma*, is found in India, Afghanistan, Indochina, Malaysia and S. China. It generally grows along water courses. In the BRH and in Yercaud (Matthew, 1983) lofty trees exceeding 30 m in height can be seen.

A few species of the Indo-malaysian elements exhibit vicariance. For example, *Securinega virosa* commonly found at elevation above 800 m is replaced by another

closely allied species *S. leucopyrus* at lower altitude. *Tarennia asiatica* shows wide ecological amplitude. At lower elevations it is common in thickets with shrubby habit and chartaceous leaves. However, at higher elevation (>1400 m) it assumes a tree habit with very thick leaves. Some authors consider this as *T. asiatica* forma *rigida*.

1.2 Indian and Sri Lankan element

The distribution of this element is the second largest in terms of area but the percentage is very low (4%). *Macaranga peltata* and *Mallotus tetracoccus* are broad-leaved heliophytic species which are more common in the humid zones of the Western Ghats, N.E. India and Sri Lanka.

1.3 Eastern Ghats, Western Ghats, N.E. India and Sri Lanka

This element consists of only 2 species (1%). *Clausena dentata* is fairly common throughout the region. *Rauwolfia densiflora* is confined to montane forests in the 1300-2300 m elevation range. In the Eastern Ghats it has been reported from Rampa hills near Godavari (Gamble, 1957).

1.4 Element of the Eastern Ghats, Western Ghats and N.E. India

It is represented by a single species, *Phoebe paniculata*, which is closely allied to *P. wightii* found in the higher elevation of the peninsula: in the Nilgiris, Palnis, Bababudangiri hills and Kollaimalais (Gamble, 1957).

1.5 Eastern Ghats, Western Ghats and N.W.Himalayan element

This group contains only one species, *Olea glandulifera*. Interestingly, this species is absent in N.E. India and is very rare or absent in the main belt of the Western Ghats except in the eastern fringes like the Bababudangiri, Nilgiris etc. It is dominant throughout the Eastern Ghats at elevation above 800 m (particularly in the BRH, Madeshwaramalai, Melagiri, etc.). In the BRH its presence together with some of the typical Western Ghats species prompted us to name the vegetation type as *Mesua-Plaquium-Olea* type. In the NW Himalaya it is found between Kashmir and Nepal.

1.6 Eastern Ghats, Western Ghats and Sri Lankan element

This element comprises 7% of the species. *Diospyros ovalifolia* belonging to this element is one of the dominant species in the evergreen formations of the Eastern Ghats and in the drier zones of Sri Lanka. In the Western Ghats it is restricted to the

drier slopes along the eastern fringes. *Diospyros sylvatica*, one of the very common species in the humid zones of both low and medium elevations of the Western Ghats, has also been recorded in some very moist pockets of the Eastern Ghats, particularly in the BRH, Melagiris (Matthew, 1983) and Rampa hills in North Circars (Gamble, 1957; Rao, 1958). *Miliusa eriocarpa*, *Nothopegia beddomei* and *Persea macrantha* are common in both the Western Ghats and the Eastern Ghats.

Ilex denticulata, one of the characteristic montane species, is frequently found above 1800 m in the Nilgiris and Palnis. Its occurrence in the BRH and the Shevarayans between 1400 and 1800 m is its eastern most extension. *Canthium dicoccum* var. *umbellatum* (above 1000 m) with thick leaves and umbellate inflorescence is the vicariant of *Canthium dicoccum* with sub-coriaceous leaves and cymose inflorescence of lower elevation.

1.7 The Eastern Ghats and the Western Ghats element

Representatives of this group account for 7%. Some species such as *Antidesma menasu*, *Chionanthus malabaricus*, *Epiprinus mallotiformis* are well represented in both the Western Ghats and the Eastern Ghats. However, *Litsea deccanensis* and *Memecylon lushingtonii* which are basically Eastern Ghats or Deccanian elements often extend into the Western Ghats. *M. lushingtonii* is one of the dominant trees in Ponnachi and Gutturayans (Eastern Ghats) above 1200 m.

Mahonia is a temperate Himalayan element. The presence of *Mahonia leschenaultii* with other Himalayan elements like *Rhododendron*, *Gaultheria* etc., in South Indian hill tops has led to some controversial opinions. However, as mentioned earlier, many authors support the Pleistocene glaciation theory to explain the occurrence of the Himalayan element in the remote South Indian hills. *M. leschenaultii* is common along the margins of sholas in the Nilgiris and further south above 1600 m. Its occurrence in the southern part of the BRH (Gaddesal) at 1200 m is semi-deciduous forests and in dry open scrubland in the Kotriboli hills (adjacent to the BRH) between 1150-1400 m indicates its ecological plasticity. It has also been reported from the Shevarayans (Matthew, 1983).

1.8 The Western Ghats and Sri Lankan element

Nine percent of the species belongs to this group. Most of these are denizens of the humid zone. The BRH marks the eastern limit for some of the common forest species of the Western Ghats (Pascal, 1984), such as *Ardisia pauciflora*, *Atalantia wightii*, *Eugenia thwaitesii*, *Psychotria nigra*, *Syzygium gardneri*, *S. hemisphericum*.

Agrostistachys meeboldii, one of the very common species in structural ensembles II or III of the *Cullenia-Mesua-Palaquium* type (Pascal, 1984) and *Myristica dactyloides* have been recorded in the Kollaimalais (part of the Eastern Ghats) by Matthew (1983). The distribution of the high altitude (>1400 m) species, *Psychotria elongata* and *Zanthoxylum tetraspermum* extends eastwards, beyond the BRH into the Melagiris, the Shevarayans and the Kollaimalais (Matthew, 1983).

1.9 Western Ghats and NE Indian element

This group is represented by a single species, *Canarium strictum*, which is very common throughout the Western Ghats. It has also been recorded from Sikkim, Assam and Upper Burma (Leenhouts, 1959) and Kollaimalai (Matthew, 1983).

1.10 Western Ghats element

This element comprises the second largest group (25%) in the BRH. The most noteworthy feature is the occurrence of certain taxa in the BRH which were previously denoted as endemic to the Western Ghats.

Some species belonging to this element and occurring at higher elevations such as *Ixora notoniana*, *Ligustrum perrottetii*, *Litsea oleoides*, *Mallotus stenanthus*, *Nilgirianthus barbatus*, *N. foliosus*, *Vernonia monosis* extend eastwards into the moist pockets of the Shevarayans and the Kollaimalais (Matthew, 1983).

On the other hand, for certain common species of low and medium elevations of the Western Ghats such as *Actinodaphne malabarica*, *Aglaija jainii*, *Beilschmiedia wightii*, *Ficus laevis* var. *macrocarpa*, *Meiogyne pannosa*, *Neopeltandra longipes*, *Palaquium ellipticum* and certain high altitude species like *Cinnamomum sulphuratum*, *Cryptocarya neilgherrensis*, *Pittosporum neilgherrense*, *Schefflera capitata*, *Symplocos foliosa*, *Syzygium densiflora*, etc., the BRH forms the easternmost limit.

Diospyros neilgherrensis is encountered only in the southern part of the BRH. This species is common along the drier eastern slopes of the Western Ghats and extends further along the Eastern Ghats up to Tirupati hills in Andhra Pradesh.

Among the climbers, *Toddalia asiatica* var. *floribunda* is the high altitude vicariant of *T. asiatica* var. *gracilis* of the open scrub forests of lower elevations.

2. FLORISTIC ELEMENTS WITHIN THE EVERGREEN TYPES OF THE BRH

The relative percentages of the floristic elements in each vegetation type are shown in Fig. 54. The Indo-malaysian element dominates in all the 4 types, with 41% in the *Mesua-Palaquium-Olea* type and 51% to 56% in the other 3 types. The significant difference lies in the Western Ghats element which constitutes 24 and 25% in the Lauraceous and *Mesua-Palaquium-Olea* types respectively, while they account for only 15-16% in the *Diospyros-Memecylon* and *Elaeocarpus-Canarium-Michelia* types. In the Western Ghats element, most of the species characteristic of low and medium elevations are confined to the *Mesua-Palaquium-Olea* type.

There are no significant differences among the other elements.

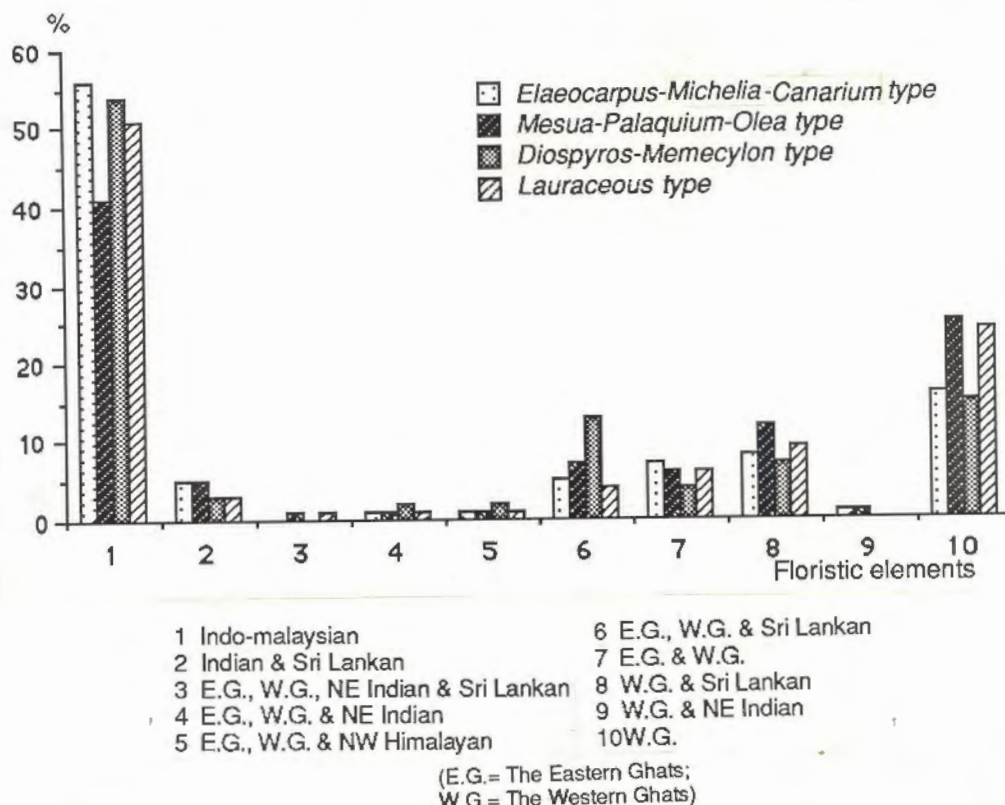


Fig. 54 - Distribution of elements within the four types of forests of the BRH

3. FLORISTIC COMPARISON BETWEEN THE GUTTIRAYANS, THE BRH AND THE NILGIRIS

A comparison of the evergreen forest flora of the BRH with the Nilgiris in the south-west and Guttirayans (Melagiris) in the north-east reveals the influence of elevation and geographical position of these hills on the distribution of species.

3.1 Location

The Guttirayans range which is one of the important hill ranges in the Eastern Ghats series, lies between $12^{\circ}11'-12^{\circ}19'$ N latitude and $77^{\circ}49'-77^{\circ}55'$ E longitude (Fig. 55). The altitudinal range is between 400 and 1400 m.

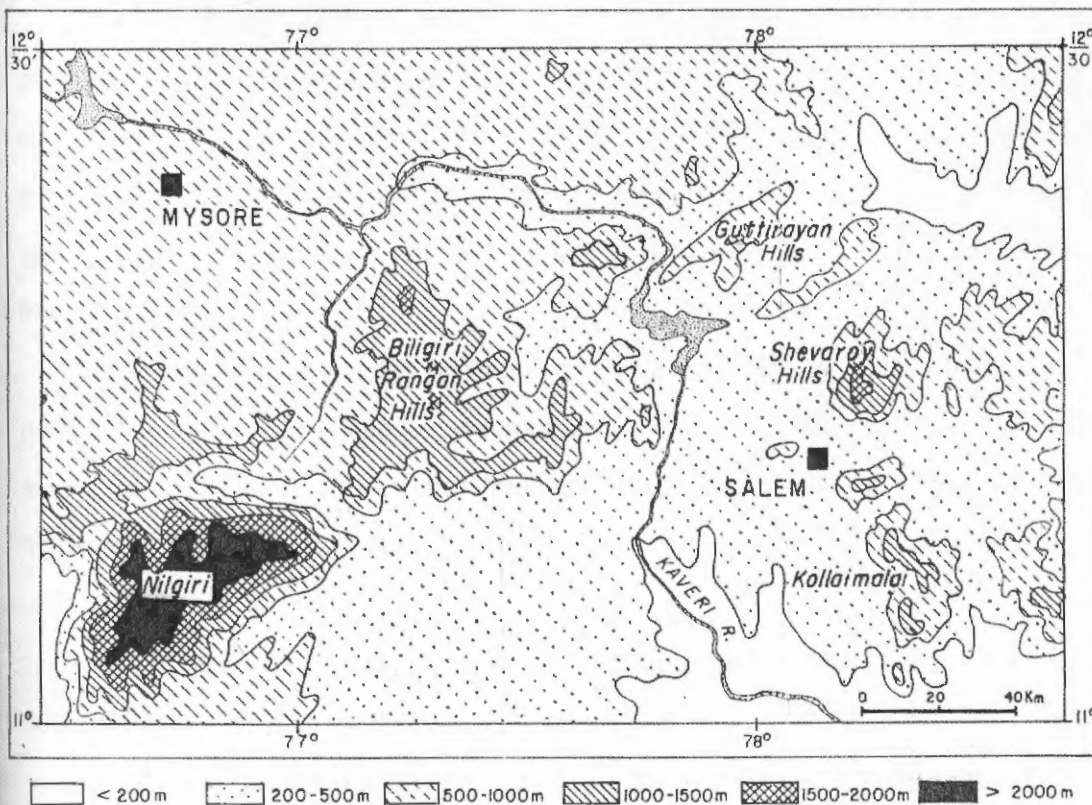


Fig. 55 - Location map

The Nilgiris range is the eastern offshoot of the Western Ghats, located between $11^{\circ}11'-11^{\circ}42'$ N latitude and $76^{\circ}14'-77^{\circ}01'$ E longitude. Its altitudinal range varies from 300 to 2634 m at Doddabetta, the second highest peak in peninsular India.

The BRH is located between the Guttirayans and the Nilgiris. Its altitudinal range varies from 700 to 1800 m.

3.2 Climate

Guttirayans

Unfortunately no climatic data is available for the Guttirayans. However, it would be appropriate to consider records from the adjacent hill range, the Shevarayans 100 km to the south-east of the Guttirayans which would exhibit more or less similar climatic conditions. Two raingauge stations in the Shevarayans, *viz.*, Yercaud at 1460 m and Hawthorne Estate at 1400 m experience an annual average of 1589 and 1392 mm, respectively.

Nilgiris

The climate of Nilgiris is one of the best described for tropical mountains (Legris and Blasco, 1969; Von Lengerke 1977). Pascal (1982) has distinguished 7 rainfall classes based on annual averages ranging from less than 600 mm per annum to more than 5000 mm. On the basis of the mean temperature of the coldest month (t), four classes are recognised (from $t < 13.5^{\circ}\text{C}$ to $t > 23^{\circ}\text{C}$). The length of the dry season varies from 2 to 7 months.

The microclimatic studies by Legris and Blasco (1969) indicate a low relative humidity during dry spells and low temperature (-9°C) during winter nights in the shrub savannas. In contrast, in the sholas (montane forests) the relative humidity is always higher with the temperature almost always more than 0°C even during winter nights.

BRH

Two rainfall classes can be distinguished in the BRH based on annual averages: 900-1500 mm, and above 1500 mm (Fig. 3).

As already indicated (Chapter 2), the minimum values of the temperature under forest cover as well as in open shrub savanna of the BRH (between 1480 and 1710 m elevation) are always higher when compared to the Nilgiris (Legris and Blasco, 1969) especially above 2000 m elevation

3.3 Floristics

Only the principal evergreen trees, shrubs and climbers have been considered (Annexe 6).

Guttirayans

In the Guttirayans, the evergreen formations are confined to elevations of 1000-1300 m. Structurally, trees are short with the top canopy reaching a height of about 15 m. However, in some small humid pockets, a few trees like *Diospyros sylvatica*, *Dimocarpus longan*, *Mangifera indica*, *Ficus talbotii*, *Persea macrantha* often attain heights of 20 m or more.

Species diversity in the Guttirayans is low when compared to the BRH and Nilgiris. Moreover all the 54 species recorded in the Guttirayans (Annexe 6) are also found in the other two regions, except for *Miliusa eriocarpa* which has not been reported from the Nilgiris and *Mallotus intermedius* which is absent in the BRH. All the evergreen formations in the Guttirayans are characterised by the dominance of 3 families: Ebenaceae (*Diospyros ovalifolia*), Melastomataceae (*Memecylon lushingtonii*) and Oleaceae (*Chionanthus ramiflora*, *Olea glandulifera*). Of these, *Diospyros ovalifolia* and *Memecylon lushingtonii* are found in small patches in the drier zones of the BRH and Nilgiris.

Lauraceae, which is an important family in the BRH and Nilgiris, is represented by only 3 species in the Guttirayans, viz., *Neolitsea zeylanica*, *Persea macrantha* and *Phoebe paniculata*.

The forest margin is ecologically a sensitive zone and displays a greater diversity in the composition of species with increase in elevation. Thus species typically found along the forest margins in the Guttirayans include *Chionanthus ramiflora*, *Glochidion neilgherrense*, *G. velutinum*, *Ligustrum perrottetiana*, *Tarenna asiatica*, *Wendlandia thyrsoides* and *Ziziphus rugosa* among others.

BRH

The BRH, with a greater elevation range and varied topographic features, display higher floristic richness than the Guttirayans. In the present study 229 species have been recorded from the evergreen and semi-deciduous forests of the BRH.

Of the four evergreen types in the BRH, the *Diospyros-Memecylon* type at 1200-1500 m more or less resembles the evergreen formations of the Guttirayans floristically. However, the *Diospyros-Memecylon* type appears to be more of a

transitional stage leading to a higher elevation type as indicated by the presence of *Meliosma*, *Rapanea*, *Schefflera*, etc. Interestingly, *Meliosma simplicifolia* ssp. *pungens* and *Rapanea wightiana* have also been recorded at 1400 m in the sholas of Ponnachi hills (12°03'-12°11' E lat. and 77°37'-77°41' N long.) between the BRH and Guttirayans.

Structurally, it is the Lauraceous type of the BRH which resembles the Guttirayans forest the most. However, *Diospyros ovalifolia* and *Memecylon lushingtonii* which are common in the Guttirayans are absent in the Lauraceous type of the BRH (except in the transition zones), while some families such as Araliaceae, Aquifoliaceae, Berberidaceae, Caprifoliaceae, Elaeocarpaceae, Icacinaceae, Loganiaceae, Magnoliaceae, Theaceae, Urticaceae etc. and also a few species of Euphorbiaceae, Rubiaceae, Rutaceae are conspicuous by their absence in the Guttirayans.

Lauraceae is one of the important and dominant families in the BRH. It is represented by 13 species belonging to 9 genera. *Beilschmiedia wightii*, which is present in the *Mesua-Palaquium-Olea* type, is also common in the other Western Ghat types and in the high altitudes of the Palnis but is absent in the Nilgiris. *Litsea oleoides*, a gigantic tree in the *Mesua-Palaquium-Olea* type of the BRH, is common in the montane forests of the Nilgiris but curiously has not been recorded in the Lauraceous type (1400-1800 m) in the BRH.

Species found at the fringes of the Lauraceous type, in addition to the species mentioned in the Guttirayans are *Barleria involucreta*, *Croton lacciferus* (rare), *Daphniphyllum neilgherrense*, *Elaeocarpus munronii*, *Isonandra perrottetiana*, *Ixora notoniana*, *Meliosma pinnata* ssp. *arnottiana*, *Nilgirianthus foliosus*, *Pittosporum neilgherrense*, *Syzygium densiflorum*, *Vernonia monosis*, *Viburnum coriaceum*.

Nilgiris:

Sharma *et al.* (1977) have recorded 2760 species of vascular plants in the Nilgiris. Blasco (1970,1971) has cited 82 endemic species exclusive to the higher elevations of the Nilgiris.

Bellan (1985) recently published a vegetation map of the Nilgiri hills, depicting the wet evergreen forests along the western slopes upto 1800 m and low evergreen forests (montane forests) above 1800 m.

The *Mesua-Palaquium-Olea* type of the BRH resembles structurally, and to some extent floristically, the forests (*Cullenia-Mesua-Palaquium* type) along the western slopes of the Nilgiris at medium elevations. However, floristically the former does not seem to be as rich as the latter because of the absence of several species such as *Cullenia exarillata*, *Calophyllum* spp., *Knema attenuata*, *Garcinia* spp., *Hydnocarpus* spp. which are typical of the latter type.

The 1400-1800 m elevation range (sub-montane stage) is a kind of transition for montane forests. Most of the species listed under the Guttirayans and the BRH are found here. However, some of them disappear or lose their predominance at higher altitudes, for example *Bischofia javanica*, *Cinnamomum travancoricum*, *Meliosma simplicifolia* ssp. *pungens* etc.

Above elevations of 1800 m in the Nilgiris, some additional species and some more genera of the following families are recorded: Araliaceae, Aquifoliaceae, Berberidaceae, Caprifoliaceae, Celastraceae, Elaeocarpaceae, Myrsinaceae, Myrtaceae, Rubiaceae, Rutaceae, Sabiaceae, Symplocaceae, Theaceae, etc. In addition, 3 new families of true montane type viz., Ericaceae, Thymeliaceae and Vacciniaceae make their appearance. The species belonging to these three families are generally confined to the margins of the forests.

Blasco (1971) studied the structural and floristic aspects of Lakkadi Shola (2300m) in the Nilgiris. A comparison of this shola with Kattari Shola (1740 m) in the BRH is shown in Table 33.

There is a clear indication of a diminution in the height of the canopy trees with increase in elevation. The density of woody individuals in Lakkadi Shola is more than double that of Kattari Shola. However, plot 1A (see Chapter 7) of Kattari Shola which includes a part of the forest border shows a very high density with 3800 individuals per hectare. In Lakkadi Shola, the relative density of the first 5 species shows the dominance of Myrtaceae (*Syzygium* spp.:32.5%), followed by Lauraceae

(*Cinnamomum* spp.:15%) whereas in Kattari Shola the first 4 species belonging to Lauraceae account for 70.5% of the total.

Table 33 - Structural and floristic comparison of the sholas of the Nilgiris and BRH

	Nilgiris (Lakkadi Shola) (2300 m)	BRH (Kattari Shola) (1740 m)
Height of the canopy (m)	8	9.5-14.5
Density of woody individuals/ hectare	3000	1300 (>10 cm girth)
Relative density of first 5 species	Syzygium calophyllifolium(26%) Cinnamomum spp.(15%) Syzygium densiflorum(6.5%) Turpinia cochinchinensis(5%) Isonandra candolleana(4%) ssp. pungens(6.4%)	Neolitsea zeylanica(29.5%) Cryptocarya neilgherrensis(20.5%) Litsea floribunda(12.8%) Cinnamomum sulphuratum(7.7%) Meliosma simplicifolia

The montane forests (>1800 m) of the Nilgiris may be called Lauro-Myrtaceous type, based on the richness of Lauraceae (17 or more species belonging to 7 genera) and dominance of Myrtaceae.

Meher-Homji (1967) is of the opinion that the species in the interior of the montane forests are of tropical stock while many along the margin are of subtropical to temperate stock where they can survive the cold and frost. Some species characteristic of the margin of montane forests are *Berberis tinctoria*, *Gaultheria fragrantissima*, *Ilex wightiana*, *Gnidia glauca*, *Mahonia leschenaultiana* (also found in the BRH), *Michelia nilagirica*, *Photinia serratifolia*, *P. notoniana*, *Rhamnus* spp., *Rhododendron nilagiricum*, *Rhodomyrtus parviflora*, *Ternstroemia japonica*, *Vaccinium* spp., *Viburnum* spp.

4. CONCLUSION

Eighty species recorded from the present study may be added to the 825 species already reported by Kammathy *et al.* (1967) in the Flora of Biligirirangan hills. There are no endemic species confined to the BRH. Curiously, of the 76 species endemic to the Eastern Ghats (Ahmedullah and Nayar, 1980) only one herbaceous species, *viz.*, *Barleria morrisiana* Bor ex Fisch. (Acanthaceae), is found in the BRH. The African element is also not represented.

The presence of a large number of Western Ghats species away from their main belt in the moist pockets of the BRH and a few in the Kollaimalais and Shevarayans of the Eastern Ghats indicate the relict nature of these forests.

Legris and Meher-Homji (1968) reported 20 to 25% of Indo-malaysian element in the wet evergreen "series" (forests) of the Western Ghats, Sri Lanka and NE India where rainfall exceeds 2000 mm and 5% in the tropical montane forests (shola) of the Western Ghats. As against this, in the evergreen forests of the BRH, the contribution of the Indo-malaysian element is 44%. The probable reasons for this indiscrepancy may be that the study of Legris and Meher-Homji (1968) involved very broad types ("series" in their terms). Secondly, the rainfall in the BRH is of the order of 1400-1800 mm per annum and therefore not so high as in the types of Legris and Meher-Homji (l.c.). Thirdly, our present study deals with submontane stage, not quite equivalent to the types of the previous authors.

Thus the BRH with its unique geographic position and favourable climatic conditions serves as a stepping stone for many Indo-malaysian species to migrate to the Western Ghats through the Nilgiris. At the same time it marks a terminal point for several species of the Western Ghats.

GENERAL CONCLUSIONS AND SUMMARY

The BRH with their varied topography and altitudinal range exhibit considerable variations in the rainfall distribution patterns. The stations on the Western side of the BRH which are directly exposed to the south-west monsoon, particularly at higher elevation (>1200m), receive more rainfall compared to those on the Eastern side at similar altitude. The combined influence of the S-W monsoon and the autumn rains at the high elevation support the bulk of the evergreen formations in the BRH.

Recordings of temperature and humidity in a forest of high elevation and in the nearby open shrub savanna reveal that these factors are more stable in the former than in the latter. Unlike in other tropical mountains like the Nilgiris and the Palnis, the temperature never comes down to 0°C in the BRH. Secondly the Himalayan elements like *Gaultheria*, *Rhododendron*, *Vaccinium* which are very common in the adjacent Nilgiris are absent in the BRH and hence even the higher elevation belt in the BRH is considered as submontane.

The edaphic conditions are mainly governed by the rainfall and the topography and they exert considerable influence on the vegetation and their structure.

At medium elevation, soils are fertile: pH is nearly 6 or more, with significant amounts of exchangeable bases such as calcium and magnesium; base saturation is more than 60%; rate of carbon mineralization is higher compared to high elevations indicating a good organic matter turnover. The clayey texture enables the soil to retain moisture to the extent of 14.8% to 23% even during the dry season. Such edaphic conditions favour the growth of tall evergreen forests like the *Mesua-palaquium-Olea* type.

At high elevation the forest is low with stunted trees and the edaphic conditions are quite different. The soil is less fertile with pH less than 5; exchangeable bases and ratio of base saturation are low. The presence of toxic exchangeable aluminium is further indicative of low fertility. The lower rate of carbon mineralization is due to low soil temperature and lesser biological activity resulting in poor turnover of organic matter.

All these climatic and edaphic variations are clearly reflected in the distribution as well as in the structure of the vegetation types. There are two main types of vegetation : deciduous and evergreen types. The Eastern slopes, northern part and foot hills of the BRH come under dry zones where rainfall is around 900mm or less. Here one encounters tree savanna particularly on the steeper slopes and scrub woodland and thickets along the foot hills which are under anthropic pressure. Savanna woodland is the dominant physiognomic type in the 900 to 1500mm rainfall zone especially along the Western flank of the BRH. The evergreen formations confined to streams and moist valleys exhibit considerable structural and floristic variations. They are either tall or stunted forests depending on the topography, elevation and exposure.

Undulating terrain and higher rainfall on the Western flank of the BRH with its net work of valleys and streams provides a perfect habitat for the riparian evergreen forests, with their characteristic hygrophilous species. These forests are generally tall, particularly along the perennial streams. Their structure varies according to the ruggedness of the terrain and also the water holding capacity of the soil.

In contrast, the steep terrain and low rainfall on the eastern side of the BRH are not conducive to the type of forests found on the western flank. Patches of evergreen forests belonging to *Diospyros-Memeceylon* type are confined to the moist valleys. Physiognomically these are low forests and show certain floristic differences when compared to their counterparts on the western side. Although these forests are along the streams, true hygrophilous species like *Elaeocarpus tuberculatus* and *Syzygium malabaricum* are conspicuously absent. Their floristic composition is more or less similar to the evergreen formations of the Eastern Ghats, suggesting similar ecological conditions.

The Gundal valley in the central part of the BRH has a small patch of tall evergreen forest belonging to the *Mesua-Palaquium-Olea* type. This forest is very interesting because it is structurally and floristically unique in this region. It very much resembles the medium elevation forests of the Western Ghats in its basal area and biomass. The presence of several typical species of the Western Ghats and some

common species of the Eastern Ghats makes it floristically different from the other forest types of the BRH.

At higher elevation, particularly above 1400m, the climate is cooler and wind velocity higher. Soils are rendered infertile due to leaching. The overall structure of the evergreen forests is altered in order to adopt itself to the climatic and edaphic conditions. The trees are stunted with multiple boles and twisted branches. The biomass is concentrated in the structural Ensemble I while the lower ensembles are impoverished.

The trees along the forest border show several morphological changes such as shorter internodes and thickening of leaves to control excessive transpiration. Further, the increased availability of light leads to competition among species resulting in high density of individuals at the border of the forests and also an increase in the floristic richness with the appearance of many heliophytes.

Besides these structural adjustments, there are also considerable floristic variations. These changes are more marked along the borders where there is considerable number of cold-tolerant and heliophilous species belonging to the Asteraceae, Caprifoliaceae, Euphorbiaceae, Myrsinaceae, Myrtaceae, Oleaceae, Rubiaceae and Sapotaceae.

The family Lauraceae is predominant throughout the type. *Symplocos foliosa*, *Ilex denticulata* and *Euria nitida* often form facies above 1650m, revealing their preference to the cooler climate.

The phytogeographical analysis indicates a large number of Indo-malaysian elements. However, more important is the presence of the Western Ghat elements contributing as much as 25% to the flora of the BRH, an outlier located some 120 kms away from the main humid strip of the Western Ghats. This indicates relict nature of these forests. However, presence of several common species of the Eastern Ghats and the Nilgiris add yet another dimension to the floristic diversity of the BRH. Thus the BRH with their unique geographical position and diverse climatic conditions serve as a meeting point for the species of 3 distinct floristic zones, viz. the Western Ghats, the Eastern Ghats and the Tropical montane (Nilgiris).

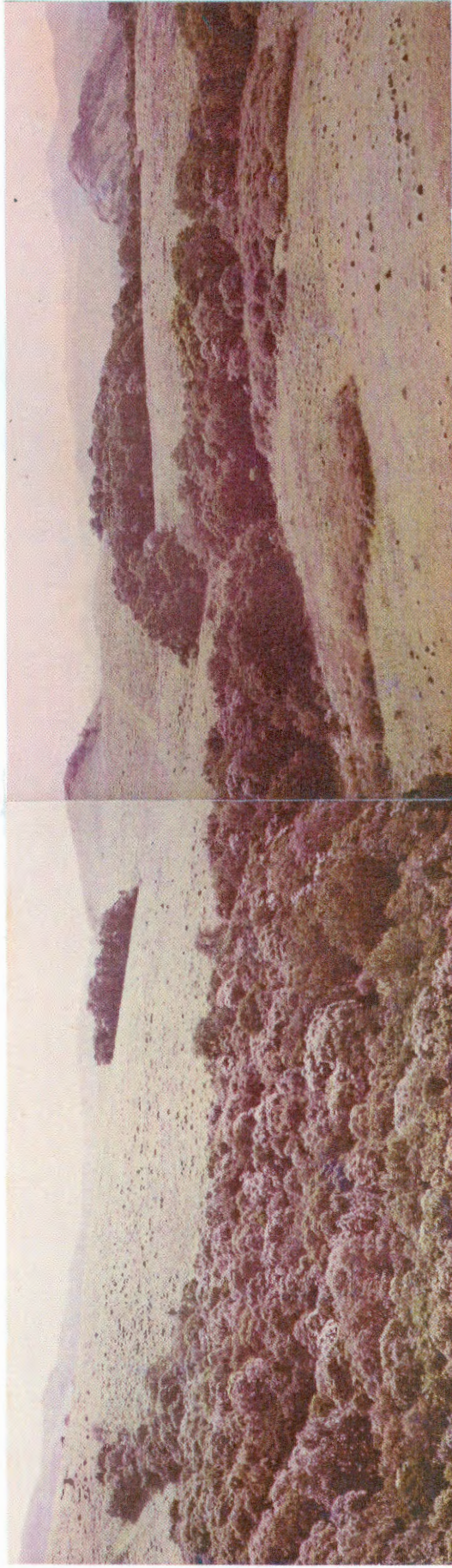
However, some of these forests are in a state of narrow equilibrium with their environment. Their fragility is already discernible in some types like the *Mesua-Palaquium-Olea*, where the Western Ghat elements show low rate of regeneration and the species with wider ecological amplitude have better regeneration, which may eventually lead to an imbalance.

Considerable area of BRH comes under reserved forests but these are threatened by various factors of degradation. The central part of the BRH once covered by vast extents of good forests is today covered by about 800 hectares of coffee plantations. As fire is of regular occurrence in these forests, construction of firelines would greatly control this major hazard. Increase in population has led to further encroachments in the foot hills of this range. Hence effective measures should be undertaken for the conservation of these relict forests.

A vegetation map at the Scale of 1: 100,000 has been prepared based on field work and using recent remote sensing technique (SPOT). This map derived from the FCC of SPOT imagery gives information about the general distribution of forest and their accessibility, the fragmentation and isolation of forest, the continuity of migratory routes. It is hoped that a proper interpretation of the data shown on the map would help in future forest and land-use management practices.



SPOT Satellite imagery (May, 1986) of the Biligirirangan hills region and its vicinity
(Scale \neq 1: 300,000; between Lat. $11^{\circ}50'$ - $12^{\circ}10'$ and Long. $77^{\circ}00'$ - $77^{\circ}20'$)



Patches of high elevation evergreen forest belonging to Lauraceous type alternating with shrub savanna (Jodugere, 1480 m)

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Legend for Annexe 1 to 4

- Structural level

I, II, III, IV	: structural ensembles I, II, III, IV
E	: emergents
T	: trees potential to reach canopy (=SE I)
t	: tree under the canopy
S	: shrub
H	: herb
Cl	: climber
St	: strangler
Ep	: epiphyte

- Frequency

Vc	: very common
C	: common
O	: occasional
R	: rare

- Ecology

M	: along forest margin
Op	: opening
*	: in the transition zone with the high elevation forest
D	: deciduous species
Ri	: ripicole

Annexe 1

ELAEOCARPUS TUBERCULATUS - MICHELIA CHAMPACA -
CANARIUM STRICTUM type

DICOTYLEDONS

ACANTHACEAE				<i>Emblica officinalis Gaertn.</i>	III	O	M,D
<i>Nilgirianthus heyneanus (Nees)</i> <i>Brem.</i>	H	C		<i>Glochidion neilgherrense Wt.</i>	III	R	M
ANACARDIACEAE				<i>G. velutinum Wt.</i>	III	O	M
<i>Mangifera indica L.</i>		I,E	C	<i>Macaranga peltata (Roxb.) M. Arg.</i>	I,III	O	Op
<i>Spondias pinnata (L.f.) Kurz</i>		O	M	<i>Mallotus philippensis (Lam.) M. Arg.</i>	II,III	C	
ANNONACEAE				<i>M. tetracoccus (Roxb.) Kurz</i>	II,III	O	Op
<i>Uvaria narum (Dunal) Wall.</i> <i>ex Wt. & Arn.</i>	Cl	C		FABACEAE (Caesalpinioideae)			
APIACEAE				<i>Acrocarpus fraxinifolius Wt.</i>	I,E	O	D
<i>Centella asiatica (L.) Urb.</i>	H			<i>Caesalpinia decapetala (Roth) Alston</i>	Cl	C	M
APOCYNACEAE				<i>Cassia fistula L.</i>	III	O	M,D
<i>Carissa inermis Vahl</i>	Cl	O		<i>Mezoneuron cucullatum (Roxb.)</i> <i>Wt. & Arn.</i>	Cl	R	
ARALIACEAE				FABACEAE (Faboideae)			
<i>Schefflera capitata (Wt. & Arn.)</i> <i>Hams</i>	St	O		<i>Dalbergia latifolia Roxb.</i>	I	O	M,D
BIGNONIACEAE				<i>D. paniculata Roxb.</i>	I	O	M,D
<i>Oroxylum indicum (L.) Benth. ex Kurz</i>	III	R	M,D	<i>Erythrina stricta Roxb.</i>	III	O	M,D
<i>Radermachera xylocarpa (Roxb.)</i> <i>K Schum.</i>	III	O	M,D	<i>Pterocarpus marsupium Roxb.</i>	I,II	O	M,D
<i>Stereospermum colais</i> <i>(Buch.-Ham. ex Dillw.) Mabbertley</i>	I	O	M,D	FABACEAE (Mimosoideae)			
BORAGINACEAE				<i>Acacia pennata (L.) Willd.</i>	Cl	O	M
<i>Cordia macleodii (Griff.) J. Hk. & Th.</i>	III	R	M,D	<i>Albizia odoratissima (L.f.) Benth.</i>	I,II	O	M,D
BURSERACEAE				<i>Entada pursaetha DC.</i>	Cl	C	
<i>Canarium strictum Roxb.</i>	I,II	C	Op	FLACOURTIACEAE			
CAPRIFOLIACEAE				<i>Casearia ovata (Lam.) Willd.</i>	II,III	O	
<i>Viburnum punctatum Buch.-Ham. ex</i> <i>D. Don</i>	II,III			<i>Scolopia crenata (Wt. & Arn.) Clos.</i>	III,IV	C	
CELASTRACEAE				ICACINACEAE			
<i>Cassine glauca (Rottb.) Kuntze</i>	I,E	O		<i>Nothapodytes nimmoniana (Grah.)</i> <i>Mabbertley</i>	IV	O	
COMBRETACEAE				LAURACEAE			
<i>Terminalia alata Heyne ex Roth</i>	I	O	M,D	<i>Actinodaphne lawsonii Gamble</i>	II,III	O	
<i>T. bellirica (Gaertn.) Roxb.</i>	I	O	M,D	<i>A. malabarica Balak.</i>	II,III	R	
ELAEOCARPACEAE				<i>Cinnamomum sulphuratum Nees</i>	II,III	C	
<i>Elaeocarpus serratus L.</i>	I,II	C		<i>C. travancoricum Gamble</i>	II,III	C	
<i>E. tuberculatus Roxb.</i>	I,E	C		<i>Cryptocarya neilgherrensis Meissn.</i>	I	C	
EUPHORBIACEAE				<i>Litsea deccanensis Gamble</i>	III	O	
<i>Antidesma menasu Miq. ex Tul.</i>	III,IV	O		<i>L. floribunda (Bl.) Gamble</i>	I	C	
<i>Bischofia javanica Bl.</i>	I,II	C		<i>Neolitsea zeylanica (Nees) Merr.</i>	II,III	C	
				<i>Persea macrantha (Nees) Kosterm.</i>	I	C	
				<i>Phoebe paniculata Nees</i>	II,III	C	IV
				LECYTHIDACEAE			
				<i>Careya arborea Roxb.</i>	II,III	O	M,D
				MAGNOLIACEAE			
				<i>Michelia champaca L.</i>	I,E	C	
				MALPIGHIACEAE			
				<i>Hiptage benghalensis (L.) Kurz</i>	Cl	C	

MALVACEAE

Kydia calycina Roxb.

MELASTOMATACEAE

Memecylon lushingtonii Gamble
M. talbotianum Brandis

MELIACEAE

Aphanamixis polystachya (Wall.)
Parker
Chukrasia tabularis A. Juss.
Cipadessa baccifera (Roth) Miq.
Munronia pinnata (Wall.) Harms
Toona ciliata M. Roem.
Trichilia connaroides (Wt. & Arn.)
Bert

MENISPERMACEAE

Cocculus laurifolius DC.
Diploclisia glaucescens (Bl.) Diels

MORACEAE

Artocarpus heterophyllus Lam.
Ficus hispida L.f.
F. microcarpa L.f.
F. mollis Vahl
F. nervosa Heyne ex Roth
F. racemosa L.
F. talbotii King
F. tsjahela N. Burman
F. virens Aiton

MYRISTICACEAE

Myristica dactyloides Gaertn.

MYRSINACEAE

Ardisia solanacea Roxb.
Maesa indica (Roxb.) DC.

MYRTACEAE

Eugenia thwaitesii Duthie
Syzygium cumini (L.) Skeels
S. malabaricum (Bedd.) Gamble

OLEACEAE

Chionanthus ramiflora Roxb.
Jasminum azoricum L.
Ligustrum perrottetii A. DC.
Olea glandulifera Wall. ex G. Don

PIPERACEAE

Peperomia sp.
Piper hymenophyllum Miq.

RHAMNACEAE

Scutia myrtina (Burm.f.) Kurz
Ziziphus rugosa Lam.

ROSACEAE

Prunus ceylanica (Wt.) Miq.
Rubus fairholmianus Gard.
R. niveus Thunb.

RUBIACEAE

Canthium dicoccum (Gaertn.) Merr.
Catunaregam torulosa (Dennst.)
Tiven
Chasalia ophioxyloides (Wall.) Craib.
Meyna laxiflora Robyns
Mussaenda glabrata (J. Hk.) Hutch.
ex Gamble
Pavetta indica L.
P. tomentosa Roxb. ex J.E. Sm.
Psychotria bisulcata Wt. & Arn.
P. elongata (Wt.) J. Hk.
P. nigra (Gaertn.) Alston
Wendlandia thyrsoides
(Roem. & Schult.) Steud.

RUTACEAE

Atalantia wightii Tanaka
Clausena indica (Dalz.) Oliver
Euodia lunu-ankenda (Gaertn.) Merr.
Murraya paniculata (L.) Jack.
Toddalia asiatica (L.) Lam.
var. *floribunda* (Wall.) Gamble

SABIACEAE

Meliosma pinnata (Roxb.) Walp.
ssp. *amottiana* (Walp.) Beus.
M. simplicifolia (Roxb.) Walp.
ssp. *pungens* (Walp.) Beus.

SALICACEAE

Salix tetrasperma Roxb.

SAPINDACEAE

Allophylus cobbe (L.) Raeusch.
Dimocarpus longan Lour.
Sapindus laurifolia Vahl

SAPOTACEAE

Xantolis tomentosa (Roxb.) Raf.

STERCULIACEAE

Eriolaena hookeriana Wt. & Arn.
Helicteres isora L.
Sterculia guttata Roxb. ex DC.

SYMPLOCACEAE

Symplocos cochinchinensis (Lour.)
Moore
ssp. *laurina* (Retz.) Noot.

TILIACEAE

Grewia tiliifolia Vahl

ULMACEAE

Celtis tetrandra Roxb.
Trema orientalis (L.) Bl.

URTICACEAE

Elatostema lineolatum Wt.
Procris crenata C. Robinson
Villebrunea integrifolia Gaud.

	I	O	M,D		II,III	C	
					III	C	Op
	III	R	Op		S	O	
	III,IV	R			III	C	Op
					S	O	M
	I	C			S	O	
	I	O			S	O	Op
	S	C			S	R	
	H	O			IV	C	
	I,II	C	Op		IV	C	
	I	R	Op		III,IV	O	M
	IV	C			IV	C	
	CI	C			IV	O	
					III	C	
					IV	O	
	I	O			CI	C	
	I	R					
	I,II	O			I,II	C	
	I,II	R			I	C	
	I	O					
	I	R					
	I	C					
	I	C					
					I,E	O	
	I	R					
					CI	C	
	IV				I	C	
	IV				I	O	Op
	IV	R			II,III	O	
	I,II	C					
	IV	C			IV	O	M,D
					IV	O	M,D
					I	C	Op,D
	III	O	M				
	CI	C					
	III	O	M				
	I	O					
	Ep	C					
	C	C			I	C	M
	CI	O			I	C	Op,D
	IV	O	M		III,IV	C	Op
	I				H	C	
	CI		M		H	C	
	CI		M		III	O	Op

VERBENACEAE

Callicarpa tomentosa (L.) Murray	III	C	Op
Clerodendrum viscosum Vent.	III	C	Op
Gmelina arborea Roxb.	III	O	M,D
Lantana camara L. var. aculeata (L.) Mold.	IV,S	O	M

VITACEAE

Cayratia sp.	Cl	C	
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MONOCOTYLEDONS**ARACEAE**

Arisaema sp.	H	C	
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ARECACEAE

Calamus gamblei Becc.	Cl	O	
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LILIACEAE

Asparagus racemosus Willd.	Cl	C	
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POACEAE

Dendrocalamus sp.	IV	O	M
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SMILACACEAE

Smilax perfoliata Lour.	Cl	O	
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ZINGIBERACEAE

Globba bulbifera Roxb.	H	C	
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GYMNOSPERMS**GNETACEAE**

Gnetum ula Brogn.	Cl	C	
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Annexe 2

MESUA FERREA - PALAQUIUM ELLIPTICUM - OLEA GLANDULIFERA
type

DICOTYLEDONS

ACANTHACEAE				<i>M. stenanthus</i> (Lam.) M. Arg.	III,IV	O	
<i>Nilgirianthus barbatus</i> (Nees) Brem.	S	O		<i>M. tetracoccus</i> (Roxb.) Kurz	III	O	Op
<i>N. heyneanus</i> (Nees) Brem.	H	C		<i>Neopeltandra longipes</i> Gamble	III	O	Op
ANACARDIACEAE				FABACEAE (Caesalpinioideae)			
<i>Mangifera indica</i> L.	I	R		<i>Acrocarpus fraxinifolius</i> Wt.	I+E	O	
ANNONACEAE				FABACEAE (Faboldeae)			
<i>Meiogyne pannosa</i> (Dalz.) Sinclair	III,IV	C	WG	Indet.	C	O	
<i>Uvaria narum</i> (Dunal) Wall. ex Wt. & Arn.	L	O		FLACOURTIACEAE			
APOCYNACEAE				<i>Casearia ovata</i> (Lam.) Willd.	I,II	C	
<i>Carissa inermis</i> Vahl	L	R		<i>Scolopia crenata</i> (Wt. & Arn.) Clos.	II,III	O	
Indet.	L	D		LAURACEAE			
ARALIACEAE				<i>Actinodaphne lawsonii</i> Gamble	I,II	C	
<i>Schefflera capitata</i> (Wt. & Arn.) Harms	St	O		<i>A. malabarica</i> Balak.	I	R	
ASTERACEAE				<i>Beilschmiedia wightii</i> Benth. ex J. Hk.	I,II	O	
<i>Vernonia monosis</i> C.B. Clarke	III	O	Op,M	<i>Cinnamomum malabathrum</i> (Burm.f.) Kosterm.	II,III	C	
BURSERACEAE				<i>C. keralaense</i> Kosterm.	I	O	
<i>Canarium strictum</i> Roxb.	I	O		<i>Cryptocarya neilgherrensis</i> Meissn.	I	C	
CAPRIFOLIACEAE				<i>Litsea floribunda</i> (Bl.) Gamble	I	C	
<i>Viburnum punctatum</i> Buch.-Ham. ex D. Don	I	O		<i>L. oleoides</i> (Meissn.) J. Hk.	I+E	C	
CELASTRACEAE				<i>Neolitsea zeylanica</i> (Nees) Merr.	I,II	C	
<i>Cassine glauca</i> (Rottb.) Kuntze	I+E	O		<i>Persea macrantha</i> (Nees) Kosterm.	I	O	
CLUSIACEAE				<i>Phoebe paniculata</i> Nees	I,II	C	
<i>Mesua ferrea</i> L.	I	C		LOGANIACEAE			
EBENACEAE				<i>Fagraea ceilanica</i> Thunb.	St.	O	
<i>Diospyros ovalifolia</i> Wt.	I	R		MAGNOLIACEAE			
<i>D. sylvatica</i> Roxb.	I	R		<i>Michelia champaca</i> L.	I+E	O	
ELAEOCARPACEAE				MALPIGHIACEAE			
<i>Elaeocarpus serratus</i> L.	I,II	O		<i>Hiptage benghalensis</i> (L.) Kurz	L		
<i>E. tuberculatus</i> Roxb.	I+E	C	R	MELASTOMATACEAE			
EUPHORBIACEAE				<i>Memecylon lushingtonii</i> Gamble	III,IV		Op
<i>Agrostistachys meeboldii</i> Pax & Hoffm.	II,III	C		MELIACEAE			
<i>Antidesma menasu</i> Miq. ex Tul.	III,IV	C		<i>Aglaia jainii</i> Viswa. & Rama.	I,II	O	
<i>Bischofia javanica</i> Bl.	I,II	C		<i>Aphanamixis polystachya</i> (Wall.) Paker	I,II		
<i>Epiprinus mallotiformis</i> (M. Arg.) Croizat	I,II	C		<i>Munronia pinnata</i> (Wall.) Harms	H		
<i>Glochidion</i> sp.	III	R		<i>Toona ciliata</i> M. Roem.	I		Op,M
<i>Macaranga peltata</i> (Roxb.) M. Arg.	II,III	O	Op	MENISPERMACEAE			
<i>Mallotus philippensis</i> (Lam.) M. Arg.	II,III	O		<i>Cocculus laurifolius</i> DC.	IV	O	
				MORACEAE			
				<i>Artocarpus heterophyllus</i> Lam.	I	O	
				<i>Ficus microcarpa</i> L.f.	I,II	O	
				<i>F. nervosa</i> Heyne ex Roth	I,II	O	

<i>F. laevis</i> Bl. var. <i>macrocarpa</i> (Miq.) Comer	L	R				
MYRISTICACEAE						
<i>Myristica dactyloides</i> Gaertn.	I,II	O				
MYRSINACEAE						
<i>Ardisia pauciflora</i> Heyne ex Roxb.	IV	O				
MYRTACEAE						
<i>Syzygium cumini</i> (L.) Skeels	I,II	O				
<i>S. gardneri</i> Thw.	I+E	R				
<i>S. hemisphericum</i> (Wt.) Alston	III,IV	O				
OLEACEAE						
<i>Chionanthus mala-elengi</i> (Dennst.) P.S. Green	IV	R				
<i>C. ramiflora</i> Roxb.	I,II,III	C	Op,M			
<i>Olea glandulifera</i> Wall. ex G. Don	I,II	O				
PIPERACEAE						
<i>Peperomia</i> sp.	Ep	C				
<i>Piper hymenophyllum</i> Miq.	L	C				
ROSACEAE						
<i>Prunus ceylanica</i> (Wt.) Miq.	I	R				
RUBIACEAE						
<i>Chasalia ophioxylodes</i> (Wall.) Craib.	H	C				
<i>Coffea arabica</i> L.	S	C				
<i>Psychotria elongata</i> (Wt.) J. Hk.	S	C				
RUTACEAE						
<i>Atalantia wightii</i> Tanaka	S	O				
<i>Clausena dentata</i> (Willd.) Roem. & Schult.	S	O				
<i>Euodia lunu-ankenda</i> (Gaertn.) Merr.	I	O				
<i>Murraya paniculata</i> (L.) Jack.	IV	O	Op			
<i>Toddalia asiatica</i> (L.) Lam. var. <i>floribunda</i> (Wall.) Gamble	L	O				
<i>Zanthoxylum tetraspermum</i> Wt. & Arn.	L	O				
SABIACEAE						
<i>Meliosma pinnata</i> (Roxb.) Walp. ssp. <i>arnottiana</i> (Walp.) Beus.	I,II	O				
<i>M. simplicifolia</i> (Roxb.) Walp. ssp. <i>pungens</i> (Walp.) Beus.	I	C				
SAPINDACEAE						
<i>Allophylus cobbe</i> (L.) Raeusch.	L		Op			
<i>Dimocarpus longan</i> Lour.	I+E	C				
SAPOTACEAE						
<i>Chrysophyllum lanceolatum</i> (Bl.) DC.	I	R				
<i>Isonandra perrottetiana</i> DC.	II,III	C				
<i>Palaquium ellipticum</i> (Dalz.) Baillon	I+E	C				
SOLANACEAE						
<i>Solanum giganteum</i> Jacq.	S	C	Op			
STERCULIACEAE						
<i>Sterculia guttata</i> Roxb. ex DC.	II,III	O	Op			
SYMPLOCACEAE						
<i>Symplocos cochinchinensis</i> (Lour.) Moore						
ssp. <i>laurina</i> (Retz.) Noot.	III,IV	O			M	
ULMACEAE						
<i>Celtis tetrandra</i> Roxb.	I,II	O			Op	
<i>Trema orientalis</i> (L.) Bl.	III	C			Op	
URTICACEAE						
<i>Debregesia longifolia</i> (N. Burman) Wedd.	IV	C			Op	
<i>Elatostema lineolatum</i> Wt.	H	C				
<i>Procris crenata</i> C. Robinson	Ep	C				
<i>Villebrunea integrifolia</i> Gaud.	III,IV	C			Op	
VERBENACEAE						
<i>Callicarpa tomentosa</i> (L.) Murray	III,IV	C			Op	
<i>Clerodendrum serratum</i> (L.) Moon	IV	O				
<i>C. viscosum</i> Vent.	III,IV	C			Op	
VITACEAE						
<i>Cayratia</i> sp.	L	C				
MONOCOTYLEDONS						
ARACEAE						
<i>Arisaema</i> sp.	H	C				
ARECACEAE						
<i>Calamus gamblei</i> Becc.	L	C				
LILIACEAE						
<i>Ophiopogon intermedius</i> D. Don	H	C				
ORCHIDACEAE						
<i>Anoectochilus elatior</i> Lindl.	H	O				
<i>Geodorum densiflorum</i> (Lam.) Schlechter.	H	C				
GYMNOSPERMS						
GNETACEAE						
<i>Gnetum ula</i> Brong.	L	O				
PTERIDOPHYTES						
CYATHEACEAE						
<i>Cyathea gigantea</i> (J. Hk.) Holttum	IV	R			R	

Annexe 3

DIOSPYROS OVALIFOLIA - MEMECYLON LUSHINGTONII - type

DICOTYLEDONS

ACANTHACEAE				Persea macrantha (Nees) Kosterm.	T	O	
Nilgirianthus heyneanus (Nees)				Phoebe paniculata Nees	t	C	
<i>Bern</i>	H	C		LOGANIACEAE			
ANACARDIACEAE				Fagraea ceilanica Thunb.	St	R	*
Nothopegia beddomei Gamble	T	R		MALPIGHIACEAE			
ANNONACEAE				Hiptage benghalensis (L.) Kurz	C	C	
Miliusa eriocarpa Dunn	t,S	C		MALVACEAE			
Uvaria narum (Dunal) Wall. ex Wt. & Arn.	C	C		Abutilon sp.	S	O	
ARALIACEAE				MELIACEAE			
Schefflera capitata (Wt. & Arn.) Harms	St	O	*	Aphanamixis polystachya (Wall.)			
ASTERACEAE				<i>Paker</i>	T	R	
Vernonia monosis C.B. Clarke	T	O	M,*	Cipadessa baccifera (Roth) Miq.	S	C	
BORAGINACEAE				Toona ciliata M. Roem.	T	R	
Ehretia canarensis (Clarke) Gamble	S	R		Trichilia connaroides (Wt. & Arn.)			
CELASTRACEAE				<i>Bent</i>	T	O	M
Cassine glauca (Rottb.) Kuntze	T	R		MENISPERMACEAE			
Euonymus crenulatus Wall. ex Wt. & Arn.	S	C		Cocculus laurifolius DC.	t	O	
EBENACEAE				MORACEAE			
Diospyros ovalifolia Wt.	T	Vc		Ficus microcarpa L.f.	T	O	
ELAEAGNACEAE				F. nervosa Heyne ex Roth	T	R	
Elaeagnus kologa Schlecht.	C	O		F. tsjahela N. Burman	T	C	
EUPHORBIACEAE				MYRSINACEAE			
Antidesma menasu Miq. ex Tul.	t	C		Maesa indica (Roxb.) DC.	S	C	
Bischofia javanica Bl.	T	C		Rapanea wightiana (Wall. ex DC.) Mez.	t	O	*
Croton laccifer L.	t	R	M,*	MYRTACEAE			
Glochidion neilgherrense Wt.	T	C	M	Syzygium cumini (L.) Skeels	T	C	
Macaranga peltata (Roxb.) M. Arg.	T	O	Op	OLEACEAE			
Mallotus philippensis (Lam.) M. Arg.	T	Vc		Chionanthus ramiflora Roxb.	T	C	M
M. tetracoccus (Roxb.) Kurz	T	O	Op	Jasminum azoricum L.	C	C	
FLACOURTIACEAE				Ligustrum perrottetii A. DC.	t		M
Casearia ovata (Lam.) Willd.	T	R		Olea glandulifera Wall. ex G. Don	T	C	
Scolopia crenata (Wt. & Arn.) Clos.	t	C		PIPERACEAE			
GESNERIACEAE				Piper hymenophyllum Miq.	C	C	
Aeschynanthus perrottetii DC.	Ep	C		ROSACEAE			
ICACINACEE				Prunus ceylanica (Wt.) Miq.	T	R	
Nothapodytes foetida (Wt.) Sleumer	t	C		RUBIACEAE			
LAURACEAE				Canthium dicoccum (Gaertn.) Merr.	T	Vc	
Cinnamomum travancoricum Gamble	T	C		Ixora notoniana Wall. ex G. Don	t	O	*
Litsea floribunda (Bl.) Gamble	T	C		Meyna laxiflora Robyns	t	O	Op
Neolitsea zeylanica (Nees) Merr.	T	C		Pavetta indica L.	S	O	
				Psychotria nigra (Gaertn.) Alston	S	O	
				Tarenna asiatica (L.) Schumann	t,S	O	*
				forma. rigida (Wt.) Raju			

RUTACEAE

<i>Atalantia wightii</i> Tanaka	t,S	C	
<i>Clausena indica</i> (Dalz.) Oliver	S	C	
<i>Euodia lunu-ankenda</i> (Gaertn.) Merr.	T	C	
<i>Murraya koenigii</i> (L.) Spreng.	S	O	
<i>M. paniculata</i> (L.) Jack.	S	C	M
<i>Toddalia asiatica</i> (L.) Lam.			
var. <i>floribunda</i> (Wall.) Gamble	C	C	

SABIACEAE

<i>Meliosma pinnata</i> (Roxb.) Walp.			
ssp. <i>arottiana</i> (Walp.) Beus.	T	O	*
<i>M. simplicifolia</i> (Roxb.) Walp.			
ssp. <i>pungens</i> (Walp.) Beus.	T	O	

SAPINDACEAE

<i>Allophylus cobbe</i> (L.) Raeusch.	Cl	C	
<i>Dimocarpus longan</i> Lour.	T	R	
<i>Sapindus laurifolia</i> Vahl	T	O	Op

SAPOTACEAE

<i>Xantolis tomentosa</i> (Roxb.) Raf.	T	O	*
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SOLANACEAE

<i>Solanum</i> sp.	H	C	
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STERCULIACEAE

<i>Sterculia guttata</i> Roxb. ex DC.	T	C	Op,D
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ULMACEAE

<i>Celtis tetrandra</i> Roxb.	T	O	Op,D
<i>C. timorensis</i> Span.	T	C	

URTICACEAE

<i>Elatosterna lineolatum</i> Wt.	H	Vc	
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VERBENACEAE

<i>Callicarpa tomentosa</i> (L.) Murray	t	C	M
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VITACEAE

<i>Cayratia</i> sp.	C	C	
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MONOCOTYLEDONS**LILIACEAE**

<i>Asparagus racemosus</i> Willd.	C	C	
<i>Ophiopogon intermedius</i> D. Don	H	C	

SMILACACEAE

<i>Smilax perfoliata</i> Lour.	C	O	
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PTERIDOPHYTES**LYCOPODIACEAE**

<i>Lycopodium phlegmaria</i> L.	H	C	
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Annexe 4

LAURACEOUS type

DICOTYLEDONS

ACANTHACEAE				FABACEAE (Mimosoideae)			
<i>Barleria involucrata</i> Nees	S	Lc	M	<i>Albizia chinensis</i> (Osbeck) Merr.	T	R	Op
<i>Nilgirianthus foliosus</i> (Wt.) Brem.	S	Lc	M	FLACOURTIACEAE			
<i>N. heyneanus</i> (Nees) Brem.	H	C		<i>Casearia ovata</i> (Lam.) Willd.	T	C	
<i>N. sp.</i>	S	LA		<i>Scolopia crenata</i> (Wt. & Arn.) Clos.	T	C	
APOCYNACEAE				ICACINACEAE			
<i>Carissa inermis</i> Vahl	Cl			<i>Nothapodytes foetida</i> (Wt.) Sleumer	t	C	
<i>Rauwolfia densiflora</i> (Wall.) Benth. ex J.H.K.	t	Lc		LAURACEAE			
AQUIFOLIACEAE				<i>Actinodaphne lawsonii</i> Gamble	T	C	
<i>Ilex denticulata</i> Wall.	t	C		<i>Cinnamomum sulphuratum</i> Nees	T	C	
ARALIACEAE				<i>C. travancoricum</i> Gamble	T	C	
<i>Schefflera capitata</i> (Wt. & Arn.) Harms	St	C		<i>Cryptocarya neilgherrensis</i> Meissn.	T	C	
<i>S. rostrata</i> (Wt.) Harms				<i>Litsea floribunda</i> (Bl.) Gamble	T	C	
var. <i>micrantha</i> (Clarke) Mahesh.	St	O		<i>Neolitsea zeylanica</i> (Nees) Merr.	T	C	
ASTERACEAE				<i>Persea macrantha</i> (Nees) Kosterm.	T	O	
<i>Vernonia monosis</i> C.B. Clarke	T	C	M	<i>Phoebe paniculata</i> Nees	T	C	
CAPRIFOLIACEAE				LOGANIACEAE			
<i>Viburnum coriaceum</i> Bl.	t	C	M	<i>Fagraea ceilanica</i> Thunb.	St	C	
<i>V. punctatum</i> Buch.-Ham. ex D. Don	T	O	Ri	<i>Gardneria ovata</i> Wall.	Cl	O	
CELASTRACEAE				MALPIGHIACEAE			
<i>Cassine glauca</i> (Rottb.) Kuntze	T	O		<i>Hiptage benghalensis</i> (L.) Kurz	Cl	C	
<i>Celastrus paniculatus</i> Willd.	Cl	C		MELIACEAE			
<i>Euonymus crenulatus</i> Wall. ex Wt. & Arn.	S, t	Lc		<i>Aphanamixis polystachya</i> (Wall.) Parker	T	O	
ELAEAGNACEAE				<i>Cipadessa baccifera</i> (Roth) Miq.	S	C	
<i>Elaeagnus kologa</i> Schlecht.	Cl	O	M	<i>Toona ciliata</i> M. Roem.	T	O	
ELAEOCARPACEAE				MENISPERMACEAE			
<i>Elaeocarpus munronii</i> (Wt.) Masters	T	R		<i>Cocculus laurifolius</i> DC.	t	O	
<i>E. serratus</i> L.	T	O		MORACEAE			
EUPHORBIACEAE				<i>Artocarpus heterophyllus</i> Lam.	T	R	
<i>Bischofia javanica</i> Bl.	T		Ri	<i>Ficus nervosa</i> Heyne ex Roth	T	O	
<i>Daphniphyllum neilgherrense</i> (Wt.) Fosenth.	T	Lc	M	MYRSINACEAE			
<i>Glochidion neilgherrense</i> Wt.	T	C	M	<i>Ardisia solanacea</i> Roxb.	S	C	
<i>G. velutinum</i> Wt.	T	O	M	<i>Maesa indica</i> (Roxb.) DC.	S	C	
<i>Macaranga peltata</i> (Roxb.) M. Arg.	T	O	Op	<i>Rapanea wightiana</i> (Wall. ex DC.) Mez.	T	C	M
<i>Mallotus philippensis</i> (Lam.) M. Arg.	T	C		MYRTACEAE			
<i>M. tetracoccus</i> (Roxb.) Kurz	T	O	Op	<i>Eugenia thwaitesii</i> Duthie	t	R	
<i>Phyllanthus polyphyllus</i> Willd.	T	O	Op	<i>Syzygium cumini</i> (L.) Skeels	T	C	
<i>Securinega virosa</i> (Roxb. ex Willd.) Pax & Hoffm.	S	R	M, Op	<i>S. densiflorum</i> Wall. ex Wt. & Arn.	T	Lc	M
FABACEAE (Caesalpinioideae)				OLEACEAE			
<i>Cassia fistula</i> L.	T	R	Op	<i>Chionanthus ramiflora</i> Roxb.	T	C	M
				<i>Jasminum azoricum</i> L.	Cl	C	
				<i>J. rottlerianum</i> DC.	Cl	C	

Ligustrum perrottetii A. DC.	T	C	M				
Olea glandulifera Wall. ex G. Don	T	C					
PIPERACEAE							
Piper hymenophyllum Miq.	Cl	C					
PITTIOSPORACEAE							
Pittosporum neelgherrense Wt & Arn.	T	O	M				
RHAMNACEAE							
Ziziphus rugosa Lam.	S,t	C					
ROSACEAE							
Prunus ceylanica (Wt.) Miq.	O	T					
Rubus fairholmianus Gard.	Cl	C	M				
R. niveus Thunb.	Cl	O	M				
RUBIACEAE							
Canthium dicoccum (Gaertn.) Merr.	T	C					
Catunaregam torulosa (Dennst.) Tiven.	t	O	Op				
Ixora notoniana Wall. ex G. Don	t	C	M				
Lasianthus venulosus Wt.	S	R					
Pavetta indica L.	S	O					
Psychotria elongata (Wt.) J. Hk.	S	C					
P. nigra (Gaertn.) Alston	S	C					
Tarenna asiatica (L.) Schumann forma. rigida (Wt.) Raju	S,t	C	M				
Wendlandia thyrsoides (Roem. & Schult.) Steud.	S,t	C	M				
RUTACEAE							
Atalantia wightii Tanaka	S	O					
Euodia lunu-ankenda (Gaertn.) Merr.	T	R					
Murraya paniculata (L.) Jack.	S	C	M				
Toddalia asiatica (L.) Lam. var. floribunda (Wall.) Gamble	Cl	C					
Zanthoxylum tetraspermum Wt. & Arn.	Cl	O					
SABIACEAE							
Meliosma pinnata (Roxb.) Walp. ssp. arnottiana (Walp.) Beus.	T	C					
M. simplicifolia (Roxb.) Walp. ssp. pungens (Walp.) Beus.	T	C					
SALICACEAE							
Salix tetrasperma Roxb.	t	R	Ri				
SAPINDACEAE							
Allophylus cobbe (L.) Raeusch.	Cl	C					
SAPOTACEAE							
Isonandra perrottetiana DC.	T	C	M,Op				
Xantolis tomentosa (Roxb.) Raf.	T	C					
SOLANACEAE							
Solanum laeve Dunal	H	C	Op				
STERCULIACEAE							
Sterculia guttata Roxb. ex DC.	T	O	Op				
SYMPLOCACEAE							
Symplocos cochinchinensis (Lour.) Moore							
ssp. laurina (Retz.) Noot.	t	C	M,Op				
S. foliosa Wt.	T	Lc					
THEACEAE							
Eurya nitida Korthals	S,t	O					
ULMACEAE							
Celtis tetrandra Roxb.	T	O	Op				
C. timorensis Span.	T	C					
Trema orientalis (L.) Bl.	S,t	C	Op				
VERBENACEAE							
Callicarpa tomentosa (L.) Murray	t	C	Op,M				
Clerodendrum viscosum Vent.	t	C	Op				
VITACEAE							
Cayratia sp.	Cl	C					
MONOCOTYLEDONS							
LILIACEAE							
Asparagus racemosus Willd.	Cl	C					
SMILACACEAE							
Smilax perfoliata Lour.	Cl	C					
GYMNOSPERMS							
GNETACEAE							
Gnetum ula Brogn.	Cl	O					

*Eurya nitida Korthals	+									
Fagraea ceilanica Thunb.	+									
Ficus hispida L. f.	+									
F. microcarpa L. f.	+									
*F. mollis Vahl		+								
*F. nervosa Roth	+									
F. racemosa L.	+									
*F. talbotii King	+									
F. tsjahela N. Burman						+				
F. virens Aiton	+									
Garuga pinnata Roxb.	+									
*Glochidion neilgherrense Wt.								+		
G. velutinum Wt.	+									
*Ilex denticulata Wall.						+				
*Isonandra perrottetiana DC.								+		
Ixora notoniana Wall.										+
*Lasianthus venulosus Wt.										+
Leea asiatica (L.) Ridsdale	+									+
Ligustrum perrottetii A. DC.										+
Litsea deccanensis Gamble								+		+
L. floribunda (Bl.) Gamble										+
*L. oleoides (Meissn.) J. Hk.										+
*Macaranga peltata (Roxb.) M. Arg.		+								
Maesa indica (Roxb.) DC.	+									
*Mahonia leschenaultii Takeda								+		
Mallotus philippensis (Lam.) M. Arg.	+									
*M. stenanthus (Lam.) M. Arg.										+
M. tetracoccus (Roxb.) Kurz		+								
*Mangifera indica L.	+									
*Meiogyne pannosa (Dalz.) Sinclair										+
Meliosma pinnata (Roxb.) Walp.										
ssp. arnottiana (Walp.) Beus.	+									
M. simplicifolia (Roxb.) Walp.										
ssp. pungens (Walp.) Beus.								+		
*Memecylon lushingtonii Gamble								+		
*M. talbotianum Brandis										+
*Mesua ferrea L.	+									
Meyna laxiflora Robyns	+									
Michelia champaca L.	+									
*Miliusa eriocarpa Dunn						+				
*Murraya koenigii (L.) Spreng.	+									
M. paniculata (L.) Jack.	+									
Myristica dactyloides Gaertn.										
Neolitsea zeylanica (Nees) Merr.	+								+	
*Neopeltandra longipes Gamble										+
Nilgirianthus barbatus (Nees) Brem.										+
N. foliosus (Wt.) Brem.										+
N. heyneanus (Nees) Brem.										+
Nothapodytes foetida (Wt.) Sleumer	+									
*Nothopegia beddomei Gamble								+		
Olea glandulifera Wall. ex G. Don						+				
*Palaquium ellipticum (Dalz.) Baillon										+
*Pavetta indica L.	+									
Persea macrantha (Nees) Kosterm.								+		
*Phoebe paniculata Nees										
*Pittosporum neelgherrense Wt. & Arn.						+				
P. wightii Mukerjee								+		+
*Prunus ceylanica (Wt.) Miq.	+									
Psychotria bisulcata Wt. & Arn.									+	
P. elongata (Wt.) J. Hk.									+	
P. nigra (Gaertn.) Alston									+	
Rapanea wightiana (Wall. ex DC.) Mez.	+									
Rauwolfia densiflora (Wall.) Benth. ex J. Hk.										
*Salix tetrasperma Roxb.	+		+							

Annexe 6

Comparison of the forest flora of the Guttirayans (G), the Biligirirangan hills (B) and the Nilgiris (N)

Species	Families	G	B	N
Trees and Shrubs				
<i>Acrocarpus fraxinifolius</i> Wt.	Fabaceae (Caesalpinioideae)		+	+
<i>Acronychia pedunculata</i> (L.) Miq.	Rutaceae			+
<i>Actephila excelsa</i> M. Arg.	Euphorbiaceae			+
<i>Actinodaphne lanata</i> Meissn.	Lauraceae			+
<i>A. lawsonii</i> Gamble	Lauraceae		+	+
<i>A. malabarica</i> Balak.	Lauraceae		+	+
<i>A. salacina</i> Meissn.	Lauraceae			+
<i>Aglaia jainii</i> Viswa. & Rama.	Meliaceae		+	?
<i>Agrostistachys meeboldii</i> Pax & Hoffm.	Euphorbiaceae		+	+
<i>Allophylus cobbe</i> (L.) Raeusch.	Sapindaceae	+	+	+
<i>Antidesma menasu</i> Miq. ex Tul.	Euphorbiaceae		+	+
<i>Aphanamixis polystachya</i> (Wall.) Parker	Meliaceae		+	+
<i>Apodytes benthamiana</i> Wt.	Icacinaceae			+
<i>Ardisia pauciflora</i> Heyne ex Roxb.	Myrsinaceae		+	+
<i>A. rhomboidea</i> Wt.	Myrsinaceae			+
<i>A. solanacea</i> Roxb.	Myrsinaceae	+	+	+
<i>Artocarpus heterophyllus</i> Lam.	Moraceae		+	+
<i>Atalantia wightii</i> Tanaka	Rutaceae		+	+
<i>Barleria involucreta</i> Nees	Acanthaceae		+	+
<i>Beilschmiedia wightii</i> Benth. ex J.Hk.	Lauraceae		+	
<i>Berberis tinctoria</i> Lesch.	Berberidaceae			+
<i>Bhesa indica</i> (Bedd.) Ding Hou	Celastraceae			+
<i>Bischofia javanica</i> Bl.	Euphorbiaceae	+	+	+
<i>Calophyllum</i> spp.	Clusiaceae			+
<i>Callicarpa tomentosa</i> (L.) Murray	Verbenaceae		+	+
<i>Canarium strictum</i> Roxb.	Burseraceae		+	+
<i>Canthium dicoccum</i> (Gaertn.) Merr.	Rubiaceae	+	+	+
<i>Caryota urens</i> L.	Arecaceae		+	+
<i>Casearia ovata</i> (Lam.) Willd.	Flacourtiaceae		+	+
<i>Cassine glauca</i> (Rottb.) Kuntze	Celastraceae		+	+
<i>Catunaregam torulosa</i> (Dennst.) Tirven.	Rubiaceae	+	+	+
<i>Celtis tetrandra</i> Roxb.	Ulmaceae	+	+	+
<i>C. timorensis</i> Span.	Ulmaceae	+	+	+
<i>Chionanthus malabaricus</i> (Wall. ex G. Don) Bedd.	Oleaceae	+	+	+
<i>C. ramiflora</i> Roxb.	Oleaceae	+	+	+
<i>Chrysophyllum lanceolatum</i> (Bl.) DC.	Sapotaceae		+	+
<i>Chukrasia tabularis</i> A. Juss.	Meliaceae	+	+	+
<i>Cinnamomum keralaense</i> Kosterm.	Lauraceae		+	?
<i>C. macrocarpum</i> J. Hk.	Lauraceae			+
<i>C. malabathrum</i> (Burm.f.) Kosterm.	Lauraceae		+	+
<i>C. sulphuratum</i> Nees	Lauraceae		+	+
<i>C. travancoricum</i> Gamble	Lauraceae		+	?
<i>C. wightii</i> Meissn.	Lauraceae			+
<i>Cipadessa baccifera</i> (Roth) Miq.	Meliaceae	+	+	+
<i>Clausena dentata</i> (Willd.) Roem. & Schult.	Rutaceae		+	+
<i>C. indica</i> (Dalz.) Oliver	Rutaceae		+	+
<i>Clerodendrum serratum</i> (L.) Moon	Verbenaceae	+	+	+
<i>C. viscosum</i> Vent.	Verbenaceae		+	+
<i>Cocculus laurifolius</i> DC.	Menispermaceae		+	+
<i>Croton lacciferus</i> L.	Euphorbiaceae		+	+
<i>Cryptocarya lawsonii</i> Gamble	Lauraceae			+
<i>C. neilgherrensis</i> Meissn.	Lauraceae		+	+
<i>Cullenia exarillata</i> A. Robyns	Bombacaceae			+
<i>Daphniphyllum neilgherrense</i> (Wt.) Rosenth.	Euphorbiaceae		+	+
<i>Debregeasia longifolia</i> (N. Burman) Wedd.	Urticaceae		+	+
<i>Dimocarpus longan</i> Lour.	Sapindaceae	+	+	+

Diospyros neilgherrensis (Wt.) Kosterm.	Ebenaceae		+	+
D. ovalifolia Wt.	Ebenaceae		+	+
D. sylvatica Roxb.	Ebenaceae		+	+
Ehretia canarensis (Clarke) Gamble	Boraginaceae			+
Elaeocarpus ferrugineus Wt.	Elaeocarpaceae			+
E. munronii (Wt.) Masters	Elaeocarpaceae			+
E. serratus L.	Elaeocarpaceae			+
E. tuberculatus Roxb.	Elaeocarpaceae			+
Epiprinus mallotiformis (M. Arg.) Croizat	Euphorbiaceae			?
Eugenia thwaitesii Duthie	Myrtaceae			+
Euodia lunu-ankenda (Gaertn.) Merr.	Rutaceae			+
Euonymus crenulatus Wall. ex Wt. & Arn.	Celastraceae			+
Eurya nitida Korthals	Theaceae			+
Fagraea ceilanica Thunb.	Loganiaceae			+
Ficus hispida L.f.	Moraceae			+
F. microcarpa L.f.	Moraceae		+	+
F. mollis Vahl	Moraceae			?
F. nervosa Heyne ex Roth	Moraceae			+
F. racemosa L.	Moraceae		+	+
F. talbotii King	Moraceae		+	+
F. tsjahela N. Burman	Moraceae		+	+
F. virens Aiton	Moraceae		+	+
Garcinia spp.	Clusiaceae			+
Gaultheria fragrantissima Wall.	Ericaceae			+
Glochidion neilgherrense Wt.	Euphorbiaceae		+	+
G. pauciflorum Gamble	Euphorbiaceae			+
G. velutinum Wt.	Euphorbiaceae			+
Gnidia glauca (Fresen.) Gilg	Thymelaeaceae			+
Gordonia obtusa Wall. ex Wt. & Arn.	Theaceae			+
Holigarna spp.	Anacardiaceae			+
Hydnocarpus alpina Wt.	Flacourtiaceae			+
Ilex denticulata Wall.	Aquifoliaceae			+
I. wightiana Wall.	Aquifoliaceae			+
Isonandra perrottetiana DC.	Sapotaceae			+
Ixora notoniana Wall. ex G. Don	Rubiaceae			+
Knema attenuata (J. Hk. & Thw.) Warb.	Myristicaceae			+
Lasianthus acuminatus Wt.	Rubiaceae			+
L. venulosus Wt.	Rubiaceae			+
Leea asiatica (L.) Ridsdale	Leeaceae			+
Ligustrum perrottetii A. DC.	Oleaceae		+	+
L. roxburghii Cl.	Oleaceae			+
Litsea deccanensis Gamble	Lauraceae			+
L. floribunda (Bl.) Gamble	Lauraceae			+
L. oleoides (Meissn.) J. Hk.	Lauraceae			+
L. stocksii J. Hk.	Lauraceae			+
L. wightiana J. Hk.	Lauraceae			+
Lonicera ligustrina Wall.	Caprifoliaceae			+
Macaranga peltata (Roxb.) M. Arg.	Euphorbiaceae			+
Maesa indica (Roxb.) DC.	Myrsinaceae		+	+
Mahonia leschenaultii Takeda	Berberidaceae			+
Mallotus intermedius (Baillon) Balak.	Euphorbiaceae		+	+
M. philippensis (Lam.) M. Arg.	Euphorbiaceae		+	+
M. stenanthus (Lam.) M. Arg.	Euphorbiaceae			+
M. tetracoccus (Roxb.) Kurz	Euphorbiaceae			+
Mangifera indica L.	Anacardiaceae		+	+
Meiogyne pannosa (Dalz.) Sinclair	Annonaceae			+
Melicope indica Wt.	Rutaceae			+
Meliosma pinnata (Roxb.) Walp.				
ssp. arnottiana (Walp.) Beus.	Sabiaceae			+
M. simplicifolia (Roxb.) Walp.				
ssp. pungens (Walp.) Beus.	Sabiaceae			+
Memecylon lushingtonii Gamble	Melastomataceae		+	+
M. talbotianum Brandis	Melastomataceae			?
Mesua ferrea L.	Clusiaceae			+
Meyna laxiflora Robyns	Rubiaceae			+

Michelia champaca L.	Magnoliaceae		+	+
M. nilagirica Zenk.	Magnoliaceae			+
Microtropis microcarpa Wt.	Celastraceae			+
M. ovalifolia Wt.	Celastraceae			+
M. ramiflora Wt.	Celastraceae			+
Millettia eriocarpa Dunn	Annonaceae	+	+	
Murraya koenigii (L.) Spreng.	Rutaceae		+	+
M. paniculata (L.) Jack.	Rutaceae		+	+
Myristica dactyloides Gaertn.	Myristicaceae		+	+
Neolitsea zeylanica (Nees) Merr.	Lauraceae	+	+	+
Neopeltandra longipes Gamble	Euphorbiaceae		+	?
Nilgiranthus barbatus (Nees) Brem.	Acanthaceae		+	+
N. foliosus (Wt.) Brem.	Acanthaceae		+	+
N. heyneanus (Nees) Brem.	Acanthaceae		+	+
Nothapodytes foetida (Wt.) Sleumer	ICACINACEAE		+	+
Nothopogon beddomei Gamble	Anacardiaceae	+	+	+
Olea glandulifera Wall. ex G. Don	Oleaceae	+	+	+
Palaquium ellipticum (Dalz.) Baillon	Sapotaceae		+	+
Pavetta indica L.	Rubiaceae	+	+	+
Persea macrantha (Nees) Kosterm.	Lauraceae	+	+	+
Phoebe paniculata Nees	Lauraceae	+	+	+
P. wightii Meissn.	Lauraceae			+
Photinia notoniana Wt. & Arn.	Rosaceae			+
Pittosporum neelgherrense Wt. & Arn.	Pittosporaceae		+	+
P. tetraspermum Wt. & Arn.	Pittosporaceae			+
P. wightii Mukerjee	Pittosporaceae		+	+
Prunus ceylanica (Wt.) Miq.	Rosaceae		+	+
Psychotria bisulcata Wt. & Arn.	Rubiaceae		+	+
P. elongata (Wt.) J. Hk.	Rubiaceae		+	+
P. nigra (Gaertn.) Alston	Rubiaceae		+	+
P. nilgiriensis Def. & Gaug.	Rubiaceae			+
Rapanea wightiana (Wall. ex DC.) Mez.	Myrsinaceae		+	+
Rauwolfia densiflora (Wall.) Benth. ex J. Hk.	Apocynaceae		+	+
Rhododendron nilagiricum Zenk.	Ericaceae			+
Rhodomyrtus parviflora Alston	Myrtaceae			+
Salix tetrasperma Roxb.	Salicaceae		+	+
Schefflera capitata (Wt. & Arn.) Harms	Araliaceae		+	+
S. racemosa Harms	Araliaceae			+
S. rostrata Harms	Araliaceae			+
S. rostrata (Wt.) Harms	Araliaceae			+
var. micrantha (Clarke) Mahesh.	Araliaceae		+	+
Scolopia crenata (Wt. & Arn.) Clos.	Flacourtiaceae	+	+	+
Securinega virosa (Willd.) Baillon	Euphorbiaceae		+	+
Solanum giganteum Jacq.	Solanaceae		+	+
S. robustum Wendl.	Solanaceae		+	+
Sterculia guttata Roxb. ex DC.	Sterculiaceae	+	+	+
Symplocos cochinchinensis (Lour.) Moore				
ssp. laurina (Retz.) Noot.	Symplocaceae		+	+
S. foliosa Wt.	Symplocaceae		+	+
S. pendula Wt.	Symplocaceae			+
S. spicata Roxb.	Symplocaceae			+
Syzygium calophyllifolium Walp.	Myrtaceae			+
S. cumini (L.) Skeels	Myrtaceae	+	+	+
S. densiflorum Wall. ex Wt. & Arn.	Myrtaceae		+	+
S. gardneri Thw.	Myrtaceae		+	+
S. hemisphericum (Walp.) Alston	Myrtaceae		+	+
S. malabaricum (Bedd.) Gamble	Myrtaceae		+	+
S. montanum Gamble	Myrtaceae			+
Tarenna asiatica (L.) Schumann	Rubiaceae	+	+	+
Toona ciliata M. Roem.	Meliaceae		+	+
Trema orientalis (L.) Bl.	Ulmaceae		+	+
Trichilia connaroides (Wt. & Arn.) Benth.	Meliaceae		+	+
Turpinia nepalensis Wall.	Staphyleaceae			+
Vaccinium leschenaultii Wt.	Vacciniaceae			+
V. neilgherrense Wt.	Vacciniaceae			+
Vernonia monosis C.B. Clarke	Asteraceae		+	+

<i>Viburnum coriaceum</i> Bl.	Caprifoliaceae		+	+
<i>V. hebanthum</i> Wt. & Arn.	Caprifoliaceae			+
<i>V. punctatum</i> Buch.-Ham. ex D. Don	Caprifoliaceae		+	+
<i>V. erubescens</i> Wall.	Caprifoliaceae			+
<i>Villebrunea integrifolia</i> Gaud.	Urticaceae		+	+
<i>Vitex altissima</i> L.f.	Verbenaceae	+		+
<i>Wendlandia thyrsoides</i> (Roem. & Schult.) Steud.	Rubiaceae	+	+	+
<i>Xantolis tomentosa</i> (Roxb.) Raf.	Sapotaceae	+	+	+
<i>Ziziphus rugosa</i> Lam.	Rhamnaceae	+	+	+
Climbers				
<i>Caesalpinia decapetala</i> (Roth) Alston	Fabaceae (Caesalpinioideae)		+	+
<i>Calamus gamblei</i> Becc.	Arecaceae		+	+
<i>Carissa inermis</i> Vahl	Apocynaceae		+	+
<i>Cayratia</i> sp.	Vitaceae		+	+
<i>Celastrus paniculatus</i> Willd.	Celastraceae	+	+	+
<i>Derris heyneana</i> (Wt. & Arn.) Benth.	Fabaceae (Faboideae)		+	
<i>Diptoclisia glaucescens</i> (Bl.) Diels	Menispermaceae	+	+	+
<i>Elaeagnus kologa</i> Schlecht.	Elaeagnaceae	+	+	+
<i>Entada pursaetha</i> DC.	Fabaceae (Mimosoideae)		+	
<i>Ficus laevis</i> Bl. var. <i>macrocarpa</i> (Miq.) Comer	Moraceae		+	
<i>Gardneria ovata</i> Wall.	Loganiaceae		+	+
<i>Gnetum ula</i> Brogn.	Gnetaceae	+	+	+
<i>Hiptage benghalensis</i> (L.) Kurz	Malpighiaceae	+	+	+
<i>Jasminum azoricum</i> L.	Oleaceae	+	+	+
<i>J. rottlerianum</i> DC.	Oleaceae		+	+
<i>Mezoneuron cucullatum</i> (Roxb.) Wt. & Arn.	Fabaceae (Caesalpinioideae)		+	+
<i>Piper hymenophyllum</i> Miq.	Piperaceae	+	+	+
<i>Rubus fairholmianus</i> Gard.	Rosaceae		+	+
<i>R. niveus</i> Thunb.	Rosaceae		+	+
<i>Scutia myrtina</i> (Burm.f.) Kurz	Rhamnaceae	+	+	+
<i>Smilax perfoliata</i> Lour.	Smilacaceae	+	+	+
<i>Toddalia asiatica</i> (L.) Lam. var. <i>floribunda</i> (Wall.) Gamble	Rutaceae		+	+
<i>Uvaria narum</i> (Dunal) Wall. ex Wt. & Arn.	Annonaceae	+	+	+
<i>Zanthoxylum tetraspermum</i> Wt. & Arn.	Rutaceae		+	+

VEGETATION MAP OF THE BILIGIRIRANGAN HILLS

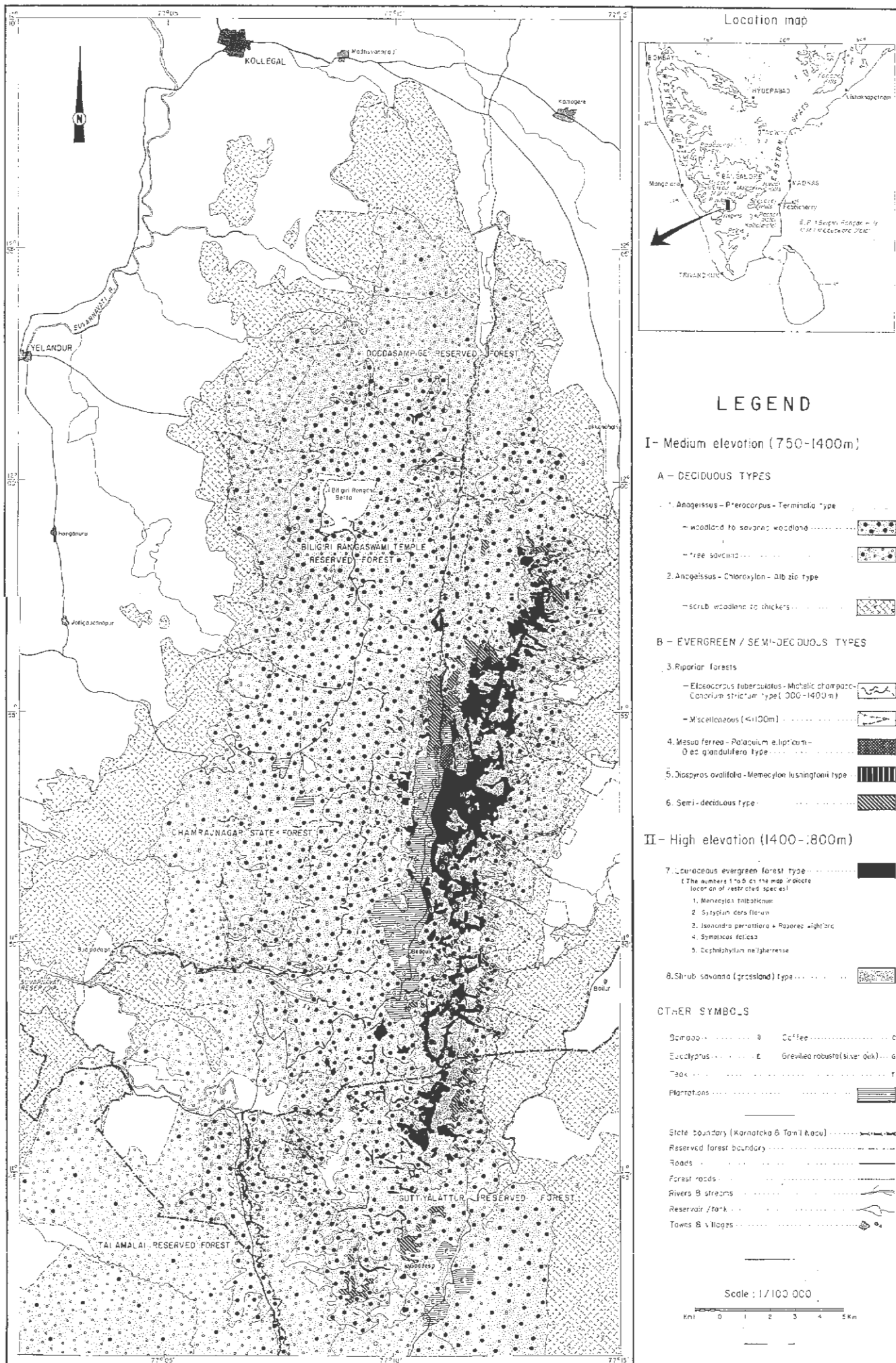
BY

B. R. RAMESH

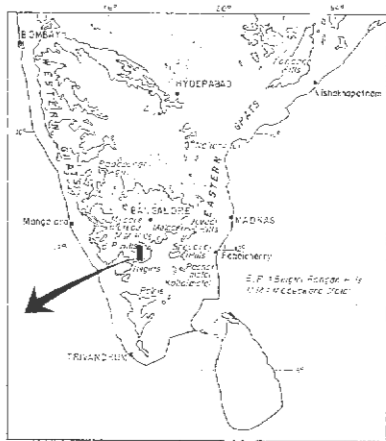
DRAWN BY W. KESSAVANE

FRENCH INSTITUTE, PONDICHERY

FRENCH INSTITUTE, PONDICHERY, 1989



Location map



LEGEND

I - Medium elevation (750-1400m)

A - DECIDUOUS TYPES

- 1. Anogeissus - Pterocarpus - Terminalia type
 - woodland to savanna woodland
 - tree savanna
- 2. Anogeissus - Chloroxylon - Albizia type
 - scrub woodland to thickets

B - EVERGREEN / SEMI-DECIDUOUS TYPES

- 3. Riparian forests
 - Elaeagnus tuberculata - Michelia champaca - Canarium strictum type (300-1400 m)
 - Miscellaneous (<1100m)
- 4. Mesua ferrea - Paladium ellipticum - Dec. glandulifera type
- 5. Diospyros ovalifolia - Memecylon lushingtonii type
- 6. Semi-deciduous type

II - High elevation (1400-1800m)

- 7. Coniferous evergreen forest type
 - (The numbers 1 to 5 on the map indicate location of restricted species)
 - 1. Meneglyia trilobatum
 - 2. Systylin ceras florum
 - 3. Isanandra perrottiana + Razaea wightii
 - 4. Symlocos falcata
 - 5. Cephaelis thymifera
- 8. Shrub savanna (grassland) type

OTHER SYMBOLS

- Bamboo
- Eucalyptus
- Teak
- Plantations
- Coffee
- Grevillea robusta (silver oak)
- Roads
- Forest roads
- Rivers & streams
- Reservoir / tank
- Towns & Villages

Scale : 1/100 000

