Eco-physiological Studies in a Tropical Evergreen Forest Ecosystem
(OF NELLIAMPATHY AREA, IN KERALA)

BY
S. SHEIK HYDER HUSSAIN

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Eco-physiological studies in a tropical evergreen forest ecosystem of Nelliampathy area, in Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or society.

Place : Vellanikkara

Date :

(S.Sheik Hyder Hussain)

CERTIFICATE

Certified that this thesis, entitled "Eco-physiological studies in a tropical evergreen forest ecosystem of Nelliampathy area, in Kerala" is a record of research work done independently by Sri. S. Sheik Hyder Hussain under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Place : Vellanikkara

Date : 17. 6. 1991

Dr. Luckins C. Babu
Associate Professor and
Chairman, Advisory
Committee,
College of Forestry,
Kerala Agricultural
University. Vellanikkara.

Approved by :

Chairman

Dr. Luckins C. Babu

Members

1. Dr. C. C. Abraham

2. Dr. N. K. Vijayakumar

3. Dr. K. C. George

External Examiner

CONTENTS

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1. INTRODUCTION

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The physiological ecology of tropical vegetation in general and that of the rainforest in particular is poorly understood (Bazzaz, 1984). Several factors have contributed to this situation. That the forests have low accessibility, availability of accurate instrumentation for eco-physiological research is limited and that the physiological ecologists are concentrated in the temperate zone are the important ones.

Ecologists have long recognised the dynamic nature of tropical forests. They have viewed the forest as a patchwork of gaps in various stages of succession (Richards, 1952). Gap size, shape, and orientation determine the gap environment, especially with regard to light and its distribution within the gap. Thus, environmental gradients are extremely complex, and simple discrete concentric circles of environments are highly unlikely. The eco-physiological activities of plants will be influenced by the heterogeneity of the gap environment in light, moisture, temperature etc.

Research activities in this field for the past two decades permit to predict about the eco-physiological characters of rainforests, however, much more work is required (Bazzaz, 1979) to rigorously test them before they are accepted as valid generalisations.

Most of the investigations carried out along these lines are restricted to South America and South East Asia (Ng, 1978; Mooney et at., 1980). For the Western Ghat region of South India one can refer to the work of Pascal(1988) only, wherein certain ecological parameters have been looked into. Thus, there is paucity in information relating to eco-physiological properties like light, temperature, soil moisture, humidity and nutrient availability of wet evergreen forests and there has been no attempts to record the changes due to modifications in the vegetation.

The present work is initiated to prepare a base for eco-physiological studies in humid forests of this region so as to create an awareness for further elaborate investigations on tropical forest eco-physiology which is an area of great relevance.

The objectives of the study are:

(a) to understand the structural and physiognomic characteristics of the ecosystems.

(b) to conduct a detailed vegetation analysis to reveal the peculiarities of the same.

(c) to evaluate the Leaf Area Index of the ecosystems.

(d) to monitor soil temperature, soil moisture and to record the phenological changes over an year.

(e) to assess the distribution of light at various levels of canopy and also relative availability of light to regeneration.

(f) while all the above investigations will be carried out in a typical undisturbed evergreen forest ecosystem, comparative observation on certain parameters like light, soil temperature and soil moisture will be carried out in disturbed areas like,

1. selection felled area
2. cardamom plantation

2. REVIEW OF LITERATURE

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Tropical wet evergreen forest - the miracle of biological ingenuity - is the end product of many millions of years of evolution during which the flora and fauna have gradually moulded the environment to suit their own requirements and since it is the result of intricately builded factors, this system is highly complex. The term "tropical rain forest" has been coined by Schimper (1898). The tropical wet evergreen forest are most studied from different angles and is least understood due to its complexity. No treatise on wet evergreen forest is, therefore, complete and publications concerning them are more or less isolated (Basha, 1987).

The forest ecosystem are sensitive to the precipitation, its reliability and seasonal distribution. The physiognomy and structure vary with rainfall patterns and is further modified by edaphic, orographic, biotic and historical influences (UNESCO, 1978).

The canopy of tropical rainforest is often considered to be layered or stratified and different forest formations have different numbers of strata. The classic view of layering in tropical lowland evergreen rainforests is into five strata, A-E (Whitmore, 1984). The A stratum comprises the top layer of the biggest trees. which commonly stand as isolated or grouped emergents above a continuous B layer, the main canopy. Under 'B' is a lower storey of trees, the C layer. The D layer is woody treelets and the E layer forests-floor herbs and small seedlings.

Whitmore (1984) has beautifully described the structure and physiognomy of tropical lowland evergreen rain forest in North-East as follows: "This is the most luxuriant of all plant communities and occurs under what are amongst the finest dry-land growing conditions found anywhere in the world. It is a lofty, dense, evergreen forest 45 m or more high, only occassionally less, characterised by the large number of trees which occur together. Gregarious dominants are uncommon and usually two-thirds or more of the upper canopy trees are of species individually not contributing more than one percent of the total numbers. This formation is regarded as having three layers: the top layer of individual or grouped giant emergent trees, over a main stratum at about 24-36 m, and with a smaller, shade-dwelling trees below that. Ground vegetation is often sparse, and mainly of small trees; herbs are uncommon. Some of the biggest trees have clear bole of 30 m and reach 4.5m girth, and may be deciduous or semi-deciduous without affecting the evergreen nature of the canopy as a whole."

Boles are usually almost cylindrical. Butterses are common. Cauliflory and ramiflory are common features. Pinnate leaves are frequent; laminae of mesophyll size predominate. Big woody climbers, mostly free-hanging, are frequent to abundant. Shade and sun epiphytes are occasional to frequent. Bryophytes are rare (Longman and Jenik, 1987). Basha (1987) has recorded over 22 species of epiphytes belonging to 5 families in a dead Poeciloneuron indicum in Silent Valley, India.

Several studies to understand the structure and physiognomy of tropical evergreen forest ecosystem in India have been done. Works of Rai (1981), Singh et al. (1984), Balasubramanyan (1987), Basha (1987) and Pascal (1988)are noteworthy.

Also, these forests are well known for the numerous very localized endemic species, and even genera, some of which are very rare. Vateria macrocarpa, an emergent tree species, belonging to Diptocarpaceae has been located only as a patch of few hundred hectares in Muthukulam in the whole of Western Ghats (Basha, 1987).

Fedorov (1966) concluded that (1) many entire plant families (with all their genera and species) and many very large genera are frequently confined within the limits of a tropical community. eg:- Dipterocarpaceae in the tropics of Asia, the rich genera of Lecythidaceae in South America, etc. (2) The lowest population density is characteristic both of the stratum of the outstanding or emergent trees and of the uppermost storey situated below it. The highest population density is observed in the lower strata.

Species diversity is a much used term in most descriptions of the rain forests, because many, but not all, tropical rain forests are extremely diverse in terms of species number. They are, therefore, of great value purely because of the genetic diversity they contain (Prance, 1982). The causes of this variation are complex and for the most part little studied and often defying critical scientific investigations (UNESCO, 1978). A number of theories to explain the co-existence of so many species have been proposed. Some place emphasis on biotic factors, others on environmental factors. Time, space, resources, competition and predation play important roles in explaining the biological diversity of the tropics (Mabberley, 1983).

New species arise from the reproductive isolation of sympatric population (Mayr, 1982). The factors triggering reproductive isolations can be mutations or recombination of genes, resulting either from internal genetic changes or induced by external physical environment. The levels of ultra-violet radiation in tropics, which can modify DNA, can induce a higher rate of mutation (Caldwell, 1981). Since the frequency of mutations will be higher, the rate of tropical speciation might consequently be greater, and it could be further enhanced by the spatial and temporal isolation possible within the complex and highly dynamic structure of the forest (Longman and Jenik 1987).

Regarding case studies on species richness, data from many areas are available. Costa Rica, a tiny country one-fifth of the size of Great Britain, alone possess 8,000 plant species compared with only 1,443 in Britain falling within temperate area (Campbell, 1989). Murca Peres (1953) on a five hectare(ha) forest in Amazonia recorded 224 species representing 136 genera and 52 families among 2607 trees of over 30 cm girth at breast height (gbh) . The poorest wet evergreen forests of Puerto Rico contain only 51 species in a total of 10 acres, while the richest in Regnum Johar Reserve contain 227 per ha. In Silent Valley (India), a quarter ha area easily contains 33 species out of 370 individuals of over 10 cm gbh. While at Muthikulam and Nelliampathy for the same extent of area 292 and 335 individuals were recorded (Basha, 1987) belonging to 33 species.

Climate plays a decisive role in determining the types of vegetation and their zonation (Pascal, 1988). The tropical zone between 23° 27' N and 23° 27' S covers about 40 percent of the earth's surface. Climatically, the tropics are a belt of varying width on either side of the climatic equator which deviates from geographic equator as a result of the distribution of the land and ocean surfaces and orographic influences (UNESCO, 1978). The tropics do not comprise a region of uniform climate, owing to the position of the continental masses, air-flow and sea-currents leading to wide variation in precipitation, relative humidity temperature, wind and vulnerability to violent storms (Mabberley, 1983). Koppen (1930) defined tropical lowland climates as having monthly averages of air temperature above 18°C and the subdivided the humid tropical climate into:

Aj Permanently wet rain forest: all months have sufficient precipitation;

Am seasonally humid or sub-humid evergreen rain forest, with a few months having arid characteristics;

Aw dry period in the winter of the corresponding hemisphere - sub-humid or xeromorphic forests, woodlands or savannas.

A serious limitation of Koppen's approach is that the moisture regime and the availability of water to the vegetation is not adequately defined by the water input from rain.

Critchfield (1966) classified five types of tropical climate: rainy tropics, monsoon tropics, wet and dry tropics, tropical semi-arid and arid climates. The first two types are having climax vegetation and the others consist of savannas, semi-desert or even desert depending upon the distribution of rainfall. The rainfall can be less than 400mm and up to 10,000 mm/year (Longman and Jenik, 1987). Whitmore (1984) analysed the climates of the tropical far east and concluded that in tropics, where temperature is high, the diurnal fluctuation is greater than the seasonal changes. Similar views have also been maintained by Richards (1952) and Longman Jenik (1987). There is no winter period associated with reduced day lengths in the tropics.

Basha (1987) compiled rainfall data for 12 years for Silent Valley and Muthikulam (in the Western Ghats) which varies from 2,260 mm to 4,544 mm per year. Average annual temperature in these stations ranged from $19.6^{o}C$ to $21.9^{o}C$. Pascal (1988) during his study concluded that the evergreen forest ecosystem of the Western Ghats is conditioned by an annual rainfall of more than 2,000 mm with dry seasons varying from 1 to 7 months which causes changes in the floristic compositions.

The relative humiditiy in permanently wet evergreen forest is taken for granted to be always high (Jordan, 1981).

It is very high (above 90 percent) during the monsoon and a decrease is observed during the dry season (Pascal, 1988). Meanwhile, in seasonally wet evergreen forest, a steep decrease (upto 30 percent) in relative humidity during peak summer months has been reported (Basha 1987).

Of the above-ground environmental factors affecting the life of tropical evergreen forest plants, light is undoubtedly the most variable, most complex, and least readily quantified. Descriptions of the light environment are only the first step towards understanding the light relations of tropical plants (Chazdon and Fetcher, 1984).

Leaf area index describes the size of the assimilatory apparatus of a plant and serves as a primary value for the calculations of other growth characteristics (Watson, 1952). Accurate leaf area measurements are critical for estimating fluxes of carbon, solar energy and water in forested ecosytem. Photosynthesis, transpiration, respiration and light interception can be directly related to leaf area (Jarvis and Leverenz, 1983) and these processes underlie correlation between leaf area index and productivity.

Several conventional methods, both direct and indirect, are available for estimating leaf area indices. Leaf area meters are available for use on broad leaf foliage either detached from the plant or attached to small branches. However, the lack of direct, non-destructive measurements of leaf area of entire large plants or of canopies continued to be a problem till recently.

The Research of Grier and Waring (1974), and others suggest that foliage biomass of a woody plant and the cross-sectional area of conducting tissue in the stem are highly correlated. Thus measurements confined to the stem can be used to estimate foliage area for the whole plant.

Without any destruction to forest, leaf area index can be assessed with an ultra-wide or 'Fish-eye' photograph and by using Plant Canopy Analyzer (LAI - 2000).

Phenology refers to the leaf fall, new flushing, flowering, fruiting etc. and as far as the evergreen species are considered, the data are quite inadequate. Precise data about the periodicities of flowering and fruiting are generally not available as most of the areas are not visited all around the year for atleast a few successive years (Balasubramanyan, 1987). However, case studies of Koelmeyer (1959), Ng and Loh (1974) and Hilty (1980) are noteworthy.

Litter plays a key role in the nutrient turnover of tropical evergreen forest (Whitmore, 1984). Quantitative measurements of nutrients in such ecosystems have been reviewed by Vitousek (1984), Proctor (1987) and Swamy (1989). Annual litterfall is an important pathway of mineral nutrient cycling in forest ecosystems (Proctor, 1987). While the periodicity of litterfall is influenced by climatic variations (Pascal, 1988), the quantum depends on the type and structure of the ecosystem.

Nutrients enter the ecosystem with the rain, deposition of dust and aerosols, by fixation by microorganisms (in the case of nitrogen) above and below ground, and (except for nitrogen) by weathering of the rock. In an ecosystem, the above ground nutrients (total plant community above the ground and the dead organic matter) and the below ground nutrients (roots and other exchangable cations) form the nutrient pools. Assessing the above ground nutrients requires proper sampling. Rainforests are so rich in species (Proctor et al., 1983) and there are such large interspecific differences in chemical composition. Grubb and Edwards (1982) state that genuine representative samples are impossible to obtain. This means that leaves (which are usually collected)cannot be used as indicators of the nutrients concentrations (Grubb and Edwards 1982) and hence similar sampling problem occur here also. The measurment of inorganic nutrients in the soil involves the problem that the amount estimated by chemical analysis are not necessarily a measure of those available to plants(Proctor 1987).

The nutrient capital of a tropical humid forest ecosystem has always been referred to be predominantly present in the vegetation rather than in soil (Golley and Richardson, 1977) But Proctor (1987) has reported that it need not be true for all forest ecosystems. Sankar (1990), using values from total soil nutrient analysis, has confirmed that the soil capital may contain over 85 percent of the nutrient stocks (N,P,K,Ca and Mg) of the ecosystem.

There are still few data sets on atmospheric influx. When the available data were correlated, (Nye and Greenland, 1960; Jordan et al., 1980; Manokaran, 1980; Jordan, 1982; Servant et al., 1984; Brinkmann, 1985) they show considerable variation between nutrients and sites. The causes of inter-site variation include different amounts of precipitation and differing proximity to the sea, where onshore winds may enhance magnesium (as well as sodium) (Brasell and Sinclair, 1983).

Nutrient input can also be influenced by smoke. Kellmann et al. (1982) found evidence that volcanic activity 300 Km distant resulted in an increase in nutrient input eventhough their measurement site was well beyond the normal ash fall zone.

Epiphytes play a major role in atmospheric nutrient capture (Benzing, 1983). Baillie and Ashton (1983) suggested that less labile form of elements may be supplied by rock weathering and this influences vegetation composition in rainforests. Dudgeon (1984) has given an account of various processes in tropical streams which help return forest nutrients lost in them.

Proctor (1987) reviewed the literature and concluded that nutrient cycling in little disturbed tropical rainforests is immensely complicated and so far the results we do have are nothing more than glimpses at some aspects of the processes in a few of them.

Some of the estimations done are given below. Sylvester-Bradley et al. (1980) estimated that annual nitrogen inputs to Amazonian rainforests via noduled legumes are 1.5-2.5 Kg/ha in forests on oxisols, 20 Kg/ha in Campina vegetation on ultisols, and over 240 Kg/ha on fertile 'Varzea' soils. Proctor (1987) has summarized the information on small litter fall. The recorded amounts of small litterfall in studies from lowland rainforests vary from 3.4 t/ha/yr [in the Western Ghats in India (Rai and Proctor 1986)] to 15.1 t/ha/yr in a Rhizophora Mangrove in Malaya (Proctor, 1984). Nutrient contents of small litter fall vary grately and the following ranges have been recorded (from Proctor, 1984): nitrogen 8-223; phospherus 0.4-18.2; Potassium 1.0-100; Calcium 7.7-372; Magnesium 1.1-64 t/ha/yr.

A common misconception is that decomposition in tropical forests is invariably rapid. Anderson ad Swift (1983) have shown that decomposition rates in tropical forests may be fast or relatively slow.

Since the mid 1970s interest has developed in total biomass utilization to provide a renewable energy source in place of oil. Biologists have taken over the concept of productivity and applied it to whole ecosystems in different parts of the world and to comparisons of natural ecosystems with cultivated crops. One basic biological interest behind the measurement of ecosystem productivity is that, if it is possible to estimate both the total dry weight of the community at any moment and also the rate of change, these can be converted into energy units to give a measure of the rate of energy flow through the system as well as the amount stored (Whitmore, 1984).

The standing crop is the biomass or total amount of living organic matter present at any time. The rates of biomass production is higher in tropical than in temparate forests, especially in the formation of foliage and twigs in the crowns, and also under favourable condition in the production of wood (Golley, 1983). [About 5 t/ha of dry organic matter is released for decomposition each year in the tropical forest which was found to be 5 times greater than the average for temperate zone forests]. Medina and Klinge (1983), also found that tropical forest had a much greater biomass in wood and leaves than its temperate broad leaved partner (shown below).

Forest	Place	Above ground Biomas wood(t/ha)	Leaves (t/ha)
1. 46 years *Fagus* forest	Denmark	129	2.7
2. Lowland dipterocarp forest	Pasoh, Malayasia.	414	7.6

According to a summary by Golley (1983), plant biomass figures for tropical forest ecosystem are the highest in the world, averaging about 415 t/ha. The total ranged from 350 to 550 t/ha, with an exceptional record of 1185 for riverine forest in Panama. Lower values quoted were found in swampy or dry conditions. Sankar (1990) has reported the biomass of the evergreen forest at Nelliampathy to be 511 ton/ha.

Next to climate, soils are the second powerful factor controlling both the distribution and composition of tropical forests (Whitmore, 1984). Many attempts to classify the diversity of tropical soils have been made. A unified international scheme has been achieved by the authors of the - Soil Map of the World (FAO/UNESCO 1968). Close relationship between rainfall, soil and forest composition were clearly demonstrated by Ahn (1961) during his studies at Ghana.

It has long been recognized that rainforests occur over a wide range of soils. Proctor et al (1983) have correlated soil analyses from a range of rainforests and demonstrated that some are on nutrient-poor soils, others on nutrient-rich soils. This makes generalization about rainforest soils difficult to sustain. For example, there is a frequently expressed view that Amazonian soils are unusually infertile, yet the data in Camargo and Falesi (1975), Guerro (1975) and Proctor et al. (1983) do not support this for at least some of the soils of that region.

In Northwest Columbia, chemical comparisons were made between the leaves, epiphytes, litter and soil at six places to know whether the differences in soils under typical lowland rainforest reflected in the species composition of the forest (Golley and Richardson, 1977). There were significant differences in soil composition, but in the vegetable material, only potassium and calcium levels differed. There was a loose correspondence between soil and geological substrata but apparently little between soil and vegetation. In rainforests of Australia, there seem to be good correlation between distribution of forest types and nutrient concentrations, particularly potassium, nitrogen, phosphorus and calcium (Harcombe, 1980).

Basha (1987) has concluded that soils in the wet evergreen forests of Kerala Western Ghats are subject to drastic modifications due to disturbances. The changes range from absolute physical loss of soil through denudation processes to depletion in nutrients and organic matter. That the wet evergreen forest soils are more fragile than their counterparts in drier climate has been recorded in the Western Ghats (Alexander et al., 1986).

The status of natural regeneration is controlled by environmental factors and also flowering and fruiting, biology of individual species, the efficiency of their seed dissemination mechanism and prevalence of seed trees (Nair, 1961). In certain cases, regeneration is affected by biotic interactions (Balasubramanyan, 1987).

3. STUDY AREA AND METHODS

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3.1. STUDY AREA

The investigations were carried out in Pothumala (Fig. 1) of Nelliampathy Range, Nemmara Forest Division (10^{o} 25' - 10^{o} 30' N and 76^{o} 35' - 76^{o} 45' E). This area was chosen as it embodes undisturbed evergreen forests, selection felled forests and cardamom plantations adjacent to one another. The area is situated on the Western Ghats at an elevation of 1000 m. The site enjoys an average annual rainfall (12 years) of 3660 mm (Basha 1987).

3.1.1. Site Selection

3.1.1.1. Undisturbed Evergreen Forest: The undisturbed forests were surveyed and a typical plot of one hectare was selected (Plate 1). Within this plot, an experimental area of 50 x 50m was demarcated and subplots of 10 x 10m established. All observations and enumerations were carried out within this plot.

3.1.1.2. Selection felled Evergreen Forest: A part of the evergreen forests in the area has been subjected to selection felling system for a period of seven years up to 1986. Selection felling system envisages the removal of mature, usually the oldest or largest trees and follows a felling cycle with a minimum number of trees to be removed per

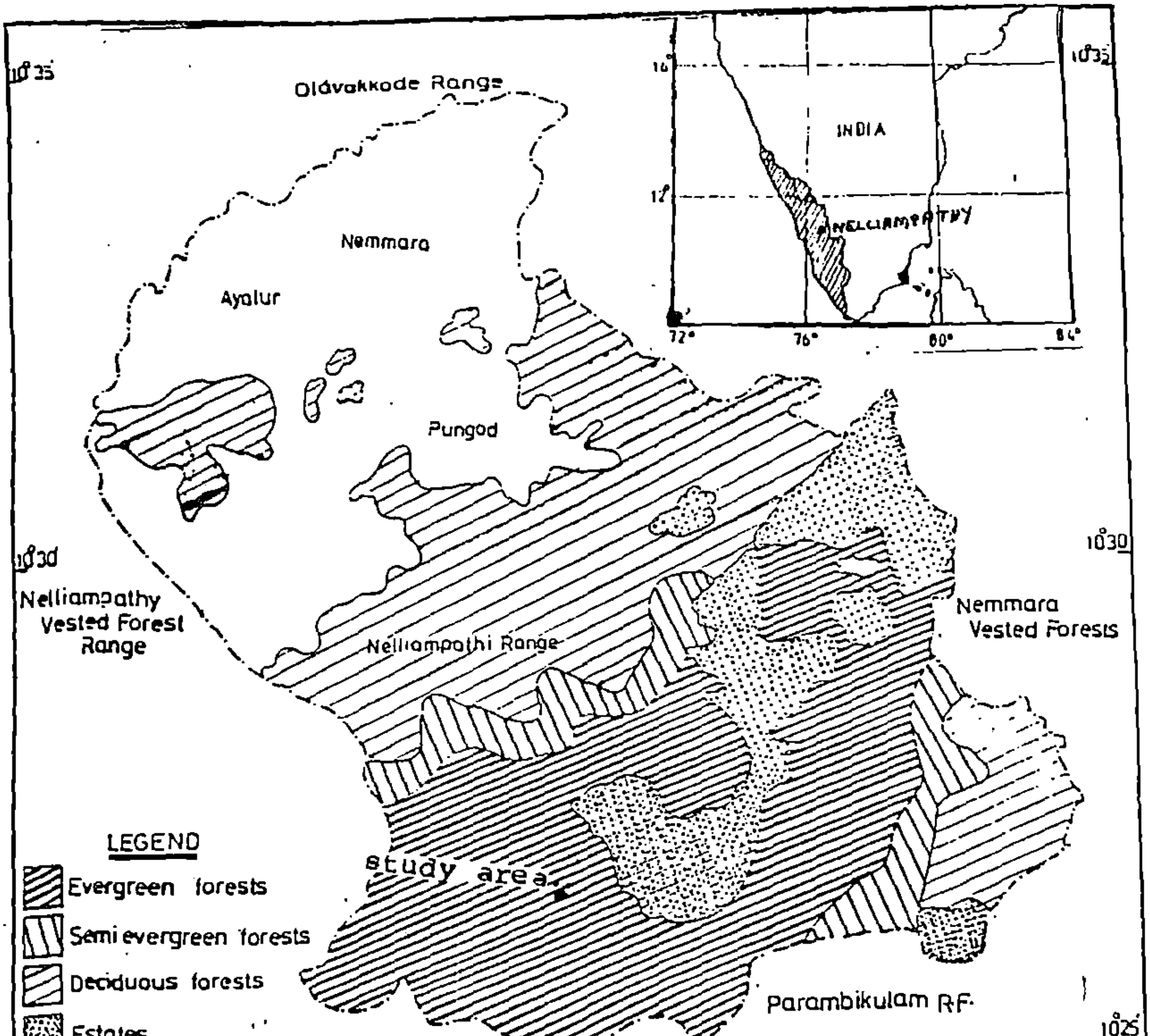


Fig. 1 Location map

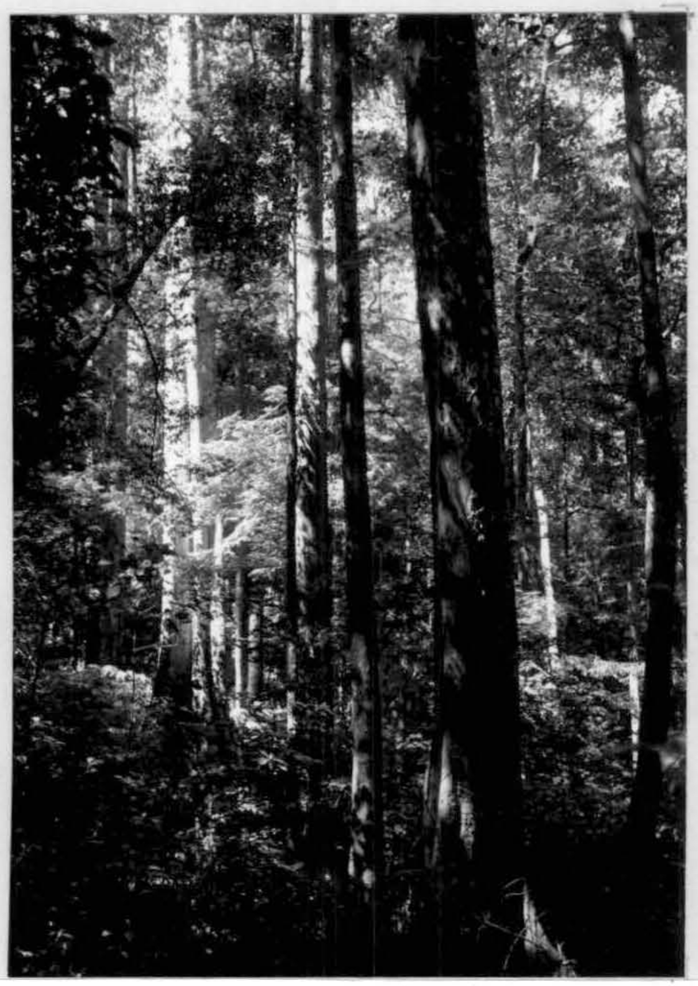


Plate 1. Undisturbed evergreen forest plot

hectare. At present six trees/ha are removed. A plot of 50 x 50 m (Plate 2) was surveyed and demarcated in this area and subplots of 10 x 10 m were established.

3.1.1.3. Cardamom plantation: The Kerala Forest Development Corporation has established a cardamom plantation in the 1980 selection felled area. Trees of smaller diameter were removed prior to cardamom planting for enhancing the light availability to the crop (Plate 3). Here also, a plot of 50 x 50m was surveyed and demarcated and subplots of 10 x 10m were established.

3.2. METHODOLOGY

3.2.1. Structure and Physiognomy

All trees $\geq$ 30 cm girth at breast height (gbh) were enumerated, identified and measurements conducted. The distribution of trees in the three tiers viz., emergent (>30 m height), middle (15-30 m height) and lower (<15 m height) was arrived at. The trees in each plot were categorised into girth classes viz., 30-60, 61-90, 91-120, 121-150, 151-180, 181-210, 211-240, 241-270, 271-300 and >300 cm . The number of trees in each girth class for the three different plots were arrived at. Profile diagrams (Richards, 1952) were prepared for each experimental plot.

Plate 2. Selection felled evergreen forest plot

Plate 3. Cardamom Plantation

3.2.2. Phytosociological Analysis

To conduct a phytosociological analysis (vegetational analysis), the following information was gathered from the three sites and from 25 subplots within each site.

$$\text{Relative Density (RD)} = \frac{\text{No. of individuals of the species}}{\text{Total No. of individuals in the plot}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency}}{\text{Total Frequency}} \times 100 \quad \text{where,}$$

$$\text{Frequency} = \frac{\text{The No. of subplots where the species is present}}{\text{Total number of subplots}}$$

$$\text{Relative Basal Area (RBA)} = \frac{\text{Basal area of the species}}{\text{Basal area of all the species}}$$

3.2.2.1. **Importance Value Index:** It is computed by adding the figures of RF, RD and RBA. The importance Value Index (IVI) gives the total picture or the sociological structure of a species in a community. IVI of species and families was calculated.

3.2.2.2. **Floristic diversity:** For understanding floristic richness and species diversity Simpson's Index was used. Simpson's Index is derived using the formula,

$$D = 1 - \quad_{i=1} \left(\frac{\quad}{N} \right)^2$$

where

ni - is the number of individuals of each species

N - is the total number of individuals in the plot

S - is the number of species in the plot.

3.2.3. <u>Leaf Area</u>

The leaves of important tree species were collected and areas calculated on LICOR Area meter. The leaves were classified according to the leaf area (Table 1) as per Givnish (1984).

Table 1. Classification of leaves according to leaf area

Leaf area (Sq.cm)	Category
0.00 - 0.25	Leptophyll
0.25 - 2.25	Nanophyll
2.25 - 20.25	Microphyll
20.25 - 45.00	Notophyll
45.00 - 182.25	Mesophyll
182.25 - 1640.25	Macrophyll
above 1640.25	Magaphyll

3.2.4. Leaf Area Index

Leaf Area Index of the three experimental plots was determined using Plant Canopy Analyser LAI-2000 following the instruction manual. LAI-2000 calculates Leaf Area Index (LAI) and other canopy structure attributes from measurements made with a "fish-eye" optical sensor. Measurements made above and below the canopy are used to determine light interception by the canopy, from which LAI is computed using a model of radiative transfer in vegetative canopies (LAI-2000 Plant Canopy Analyser, 1990).

3.2.5. Microclimate

3.2.5.1. Air Temperature and Humidity: Daily maximum and minimum air temperature and relative humidity of the study area was measured using an automatic monthly hygrothermograph (Weathermeasure, USA). The data was tabulated on a monthly basis, indicating maxima and minima and mean average.

3.2.5.2. Rainfall: Rainfall data for the experimental period was collected from the rain-guage established by Kerala Forest Development Corporation at Pothumala cardamom plantation.

Ombrothermic diagram:- Monthly rainfall was plotted against monthly mean temperature to arrive at the ombrothermic diagram. The same helps to derive the length of the dry season.

3.2.5.3. Light: Light measurements were conducted using a Lux meter LICOR 2000. The incidence of light was measured at the ground level, 10 m, 20 m, 30m and above the canopy to understand the vertical stratification of the same. This was carried out at nine locations in the undisturbed evergreen forest plot only. Further, horizontal stratification of light intensity was determined at 180 systematically located sample points in a subplot of 20 x 9 m in each experimental area. These lux readings were stratified into five classes viz., 0-1000, 1001-5000, 5001-10000, 10001-20000 and above 20000 lux and a light distribution map was prepared. The area under each category was determined using an area meter and percentage distribution under each was determined.

3.2.5.4. Soil Temperature: Soil temperature was measured using soil thermometers. The temperature was measured at nine locations in each plot at a depth of 10 cm during a fixed hour of the day (12 noon). Monthly measurements were made for a period of 12 months.

3.2.5.5. Soil Moisture: Soil moisture was determined using the gravimetric method. Nine samples were collected from each plot in every month from a depth of 20 cm and transferred to the laboratory in airtight containers. The samples were oven-dried (105 ^{o}C) till constant weight, in a hot air oven. Soil moisture content was calculated using the equation,

$$\text{Soil Moisture} = \frac{(\text{Wet weight} - \text{Oven dry weight})}{\text{Oven dry weight}} \times 100$$

Samples were collected monthly for a period of 12 months.

The soil moisture of each month was compared with the Maximum Water Holding Capacity (MWHC) of the soil. The MWHC was arrived at by permitting a soil column of known weight to absorb water and the water retained was measured by reweighing. MWHC was calculated using the formula.

$$\text{MWHC} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

The results are expressed in mm.

3.2.6. <u>Phenology</u>

3.2.6.1. Observations: Periodic observations were conducted to determine the flowering, fruiting and leaf fall of different tree species in the study plots.

3.2.6.2. Quantification of Leaf Litterfall: Litterfall was measured in each plot (nine replicates) for a period of 12 months. 1 x 1 m quadrats were permanently demarcated on ground and litter was collected. The same was oven-dried ($60^{o}C$) and weighed.

3.2.6.3. Nutrient Input Through Leaf Litterfall: Nutrient (N, P, K, Ca and Mg) concentrations were analysed in composite litter samples and the annual nutrient input through litterfall was estimated.

N was analysed by Micro Kjeldahl digestion while P, K, Ca, and Mg were determined in samples after dry ashing. P was determined by phospho-molybdic reagent, K by flame photometry, Ca and Mg by titration with EDTA (Jackson, 1973).

3.2.7. Soil Nutrients

Soil samples were collected from 0 - 20 cm (surface) layer at four locations from the three experimental plots. The samples from identical plots were pooled for analysis. One soil profile up to 100 cm was dug and soil samples collected from 0 - 20, 20 - 40, 40 - 60, 60 - 80 and 80 - 100 cms. The samples were air dried and passed through a 2 mm sieve. Soil material <2 mm was subjected to the following chemical analyses. Total N was determined by Micro Kjeldahl digestion method. Extractable P was determined with Bray II extractant, K with flame photometer, and Ca and Mg using EDTA (Jackson, 1973).

3.2.8. Regeneration

The status of regeneration in undisturbed evergreen forest, selection felled evergreen forest and cardamom plantation was looked into. Regeneration survey was conducted in each experimental area in five subplots of 10 x 5 m. The species were classified into:

1. Unestablished seedlings - less than 40 cm height
2. Established seedlings - 40 to 100 cm height
3. Advanced growth - over 100 cm height but below 10 cm gbh
4. Saplings - young trees above 10 cm gbh but below 30 cm gbh

4. RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Structure and Physiognomy

4.1.1. Physiognomy

The tropical wet evergreen forests show remarkable physiognomic features in stratification, girth classes, presence of trees with various features etc. The present study focuses on the various facets of physiognomic features of the evergreen forest in the study area.

Though all the trees in the forest show many features in common, each stratum has a distinctive physiognomy (Richards, 1952). The special characteristics of different structural features are:

Trunk: Nature of the trunk is one of the most striking characteristics of the trees. The trees in the upper storey have mainly long, unbranched, columnar and gradually tapering smooth trunks reaching to almost 2/3 of their height. The following species are good examples *Cullenia exarillata*, (Plate 4), *Palaquium ellipticum*, *Mesua ferrea* etc. The absence of branches in the bole may be due to thick surrounding growth and competition from neighbouring trees for light (Richards, 1952). The above species show branching on the boles when they remain in the 1st and 2nd storeys and branches fall off by natural pruning when they grow and attain top canopy status.

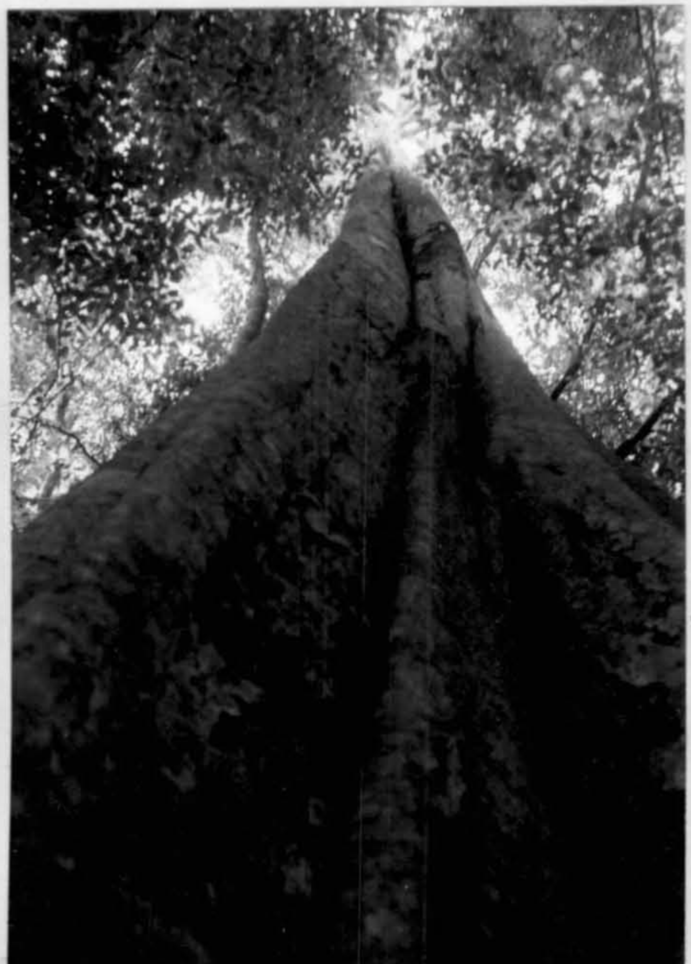


Plate 4. Trunk of Cullenia exarillata

The trees in the second storey and first storey also show cylindrical shaped boles but the bole length and crown length are almost equal. Fluting in the bole, another ecological character, is noticed in certain species (Drypetes wightii). It is more often genetic than due to other reasons (Basha, 1987).

Crown: Emergent species like Palaquium ellipticum, Cullenia exarillata and Mesua ferrea show umbrella shaped crowns tending to become slightly conical. Irregular crown is observed in Syzigium cuminii. The crown shape of the emergent trees is largely controlled by the height of the tree in relation to the other surrounding trees. When these trees are in the second and first storeys, they develop characteristic candle flame shaped structure.

Branching pattern: Different branching patterns have been observed. Branching of top canopy species is mostly acute to the main stem. In the first and second storeys the trees show varying forms of branching from acute to horizontal and even obtuse.

Coppicing: Most of the trees give out coppice shoots when the main trunk is either destroyed due to felling or wind fall. Artocarpus heterophyllus and Actinodaphne malabaricum are the prominent coppicing species in the study area.

__Bark and Blaze__: The bark and blaze features of important tree species in the study area are given in Table 2. Thus, it can be seen that there is variation in bark thickness, colour and surface features.

Table 2. Bark Characteristics of different tree species

Species	Characters
1. *Cullenia exarillata*	Smooth and brownish, comes out as flakes, 8 - 12mm thick.
2. *Drypetes wightii*	Greenish to whitish, 5mm thick, smooth.
3. *Holigarna arnottiana*	Brown to whitish, 5-8mm thick, a colourless juice oozes out slowly when blazed which turns black.
4. *Mesua ferrea*	Pale brown, scaling off, latex colourless and sticky, 10-12mm thick.
5. *Palaquium ellipticum*	Slight reddish brown, 10-15mm thick, milky white juice when cut.

__Buttresses__: Buttresses are generally considered as organs of anchorage. They may be in the form of 'stilt roots' or plank buttresses and their ecological significance is very important. *Palaquium ellipticum*, *Mesua ferrea*, *Cullenia exarillata* are famous for their plank buttresses.

Cauliflory and ramiflory: One of the striking features in the wet evergreen forests is the formation of floral parts on the main trunk(cauliflory) and branches (ramiflory). In the study area, Artocarpus heterophyllus exhibits cauliflory, while Cullenia exarillata, ramiflory.

Profile diagrams: The profile diagrams of the three experimental plots viz. undisturbed evergreen forest, selection felled evergreen forest and cardamom plantation are given in Figs. 2,3 and 4 respectively.

The profile diagram of the undisturbed evergreen forest (Fig. 2) reveals that emergents are common. The tallest tree is Palaquium ellipticum (41 m). Second and first storey trees are more or less equally distributed. At the same time the profile diagram of the selection felled plot (Fig. 3) shows that there is a reduction in the number of emergent trees due to felling operations. Further, due to felling damages, the second storey is represented feebly (Table 3) while fresh openings in the canopy have resulted in a grater number of trees of the first storey. The profile diagram of the cardamom plantation (Fig. 4) reveals the drastic changes in the structure of the ecosystem. There has been a reduction in the number of trees belonging to all categories.

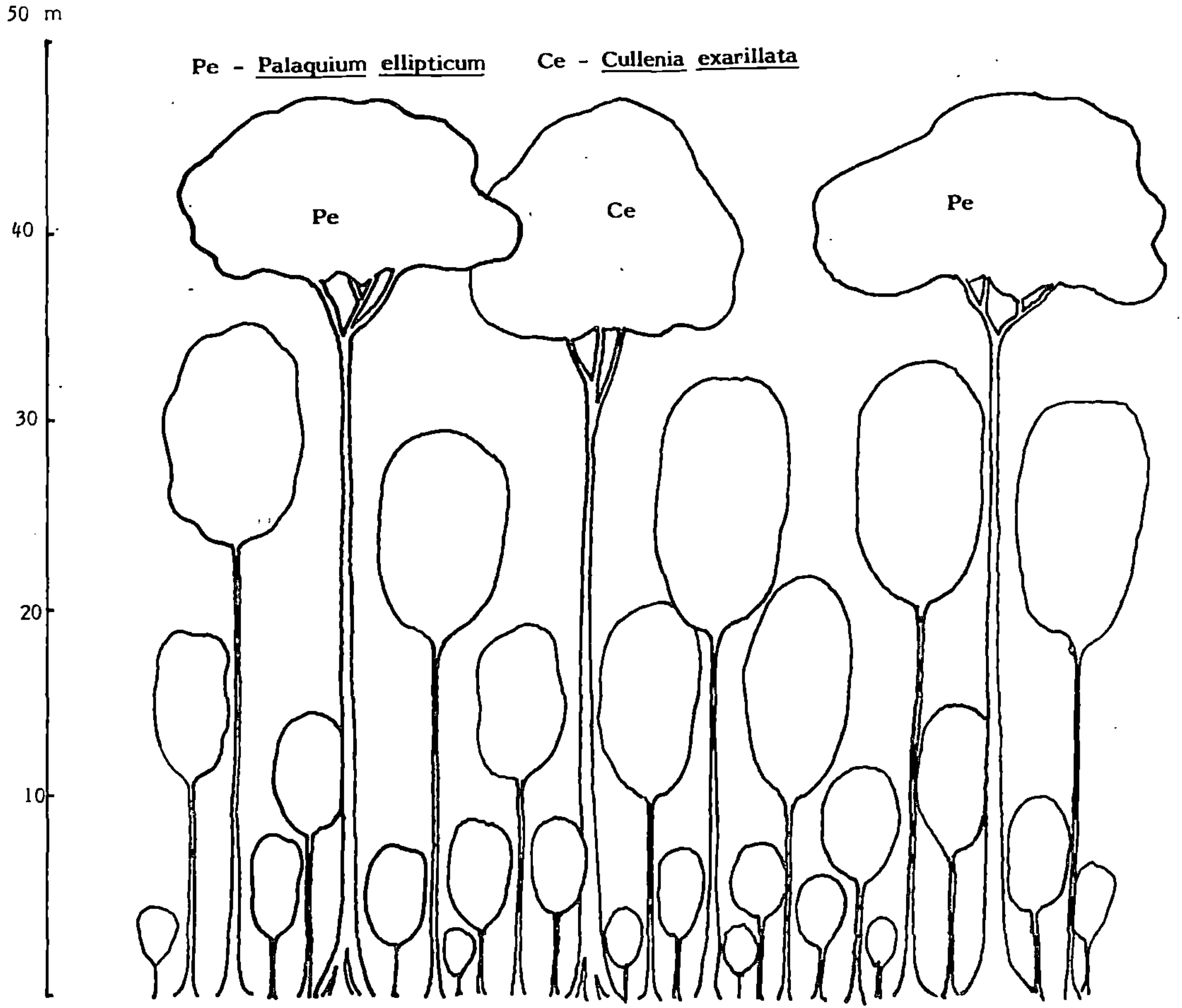


Fig.2 Profile diagram of vegetation in the undisturbed evergreen forest at Nelliampathy (5x50 m)

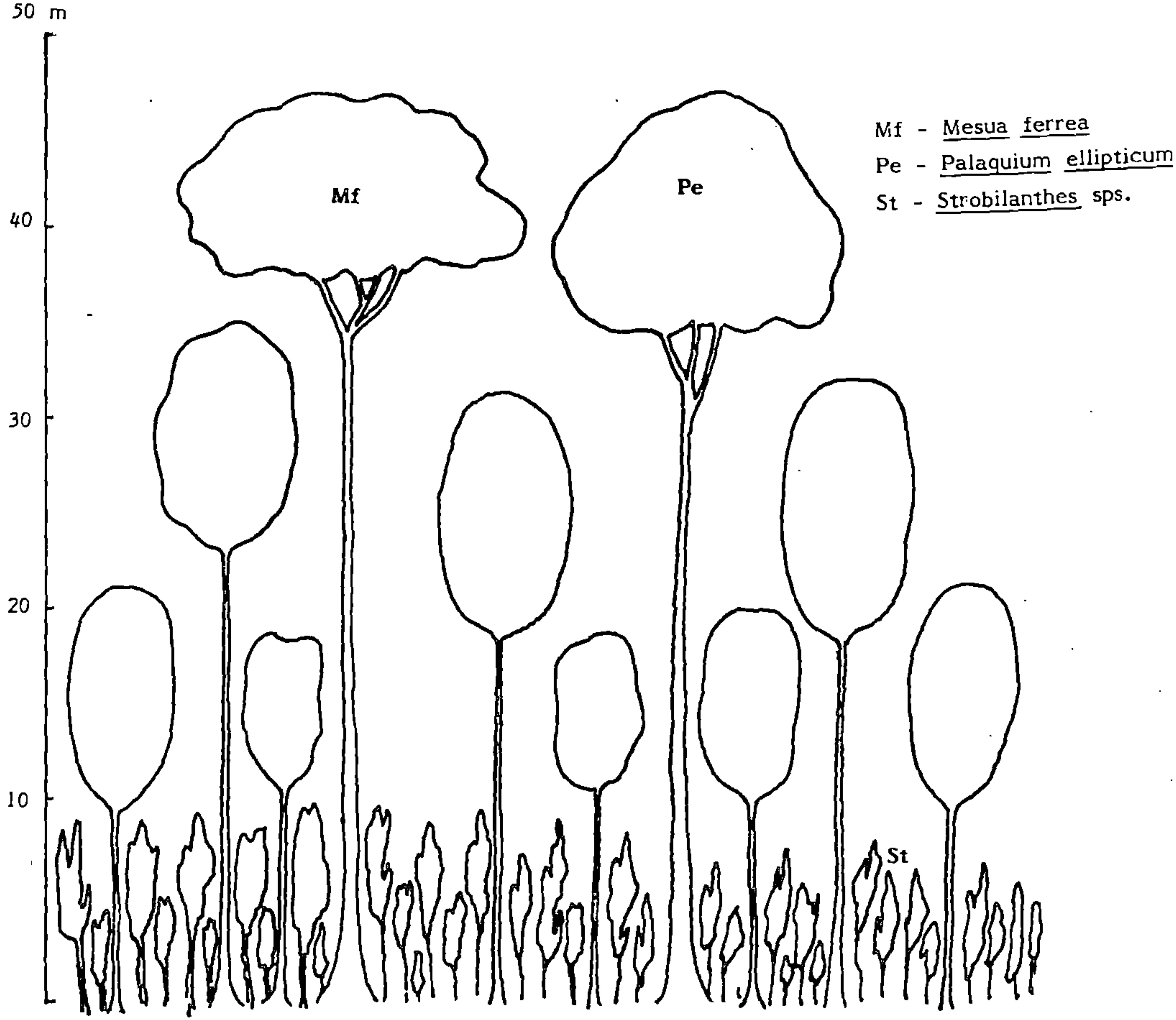


Fig.3 Profile diagram of vegetation in the selection felled evergreen forest at Nelliampathy (5 x 50 m)

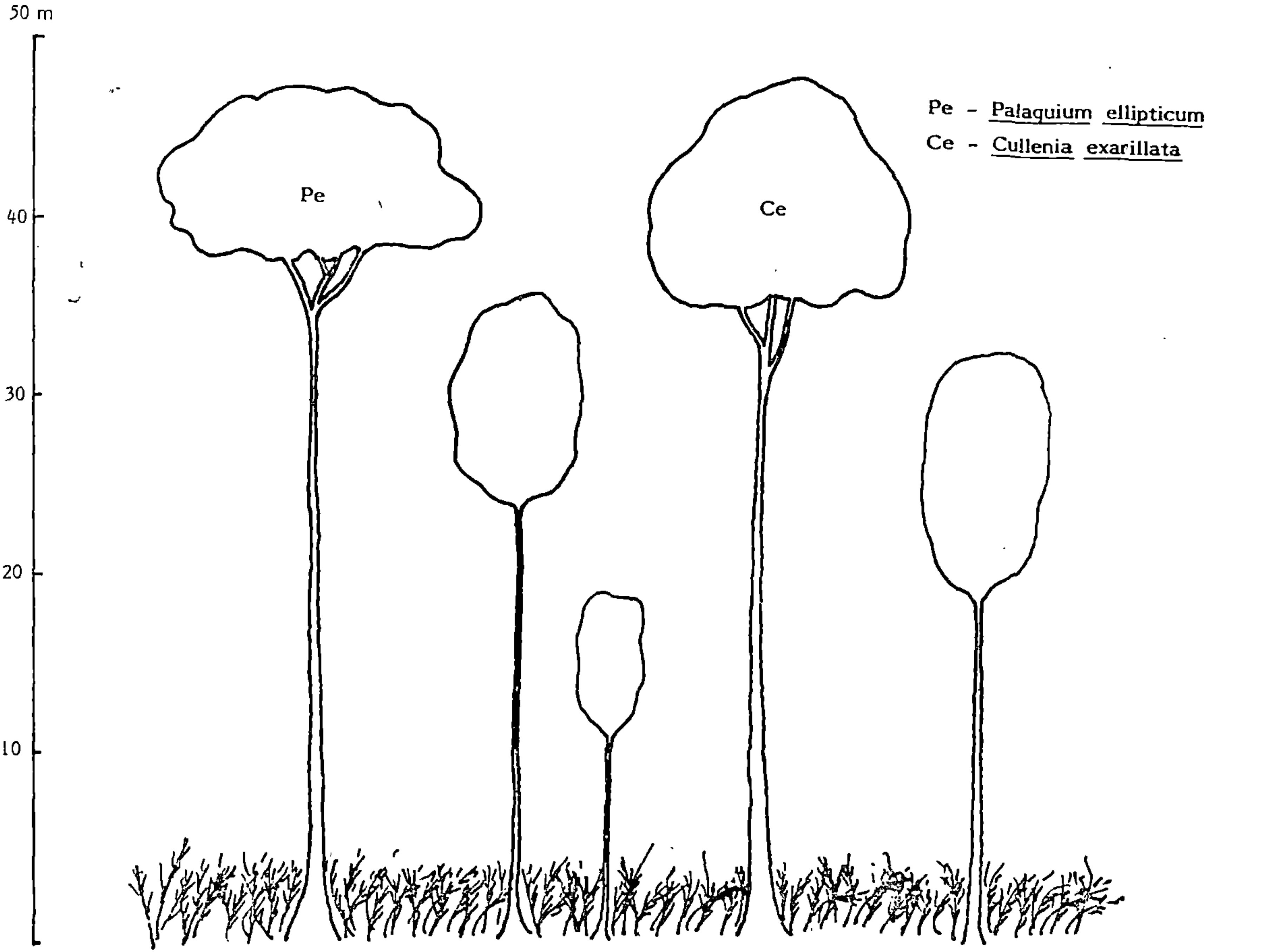


Fig.4 Profile diagram of vegetation in the cardamom plantation at Nelliampathy (5 x 50 m)

<u>Stratification</u>: That the evergreen forest comprises trees of different heights arranged in 3 to 4 tiers is well known (Richards, 1952). The results of the stratification of trees into three storeys in the study plots are given in Table 3. It is evident from the same that in the undisturbed plot all storeys are well represented, while in the selection felled plot there is a reduction in the number of species in the second and third storeys due to felling operations. The first storey is predominantly represented due to the effect of gaps and rapid growth of sapling to the next height class.

Table 3. Percentage distribution of individuals occupying different tiers in the experimental plots

Experimental plots	Number of individuals	Percentage distribution		
		First storey	Second storey	Third Storey
Undisturbed evergreen	177	40.7	24.8	34.5
Selection felled	95	56.8	14.7	28.5
Cardamom plantation	59	22	39	39

First storey - upto 15m

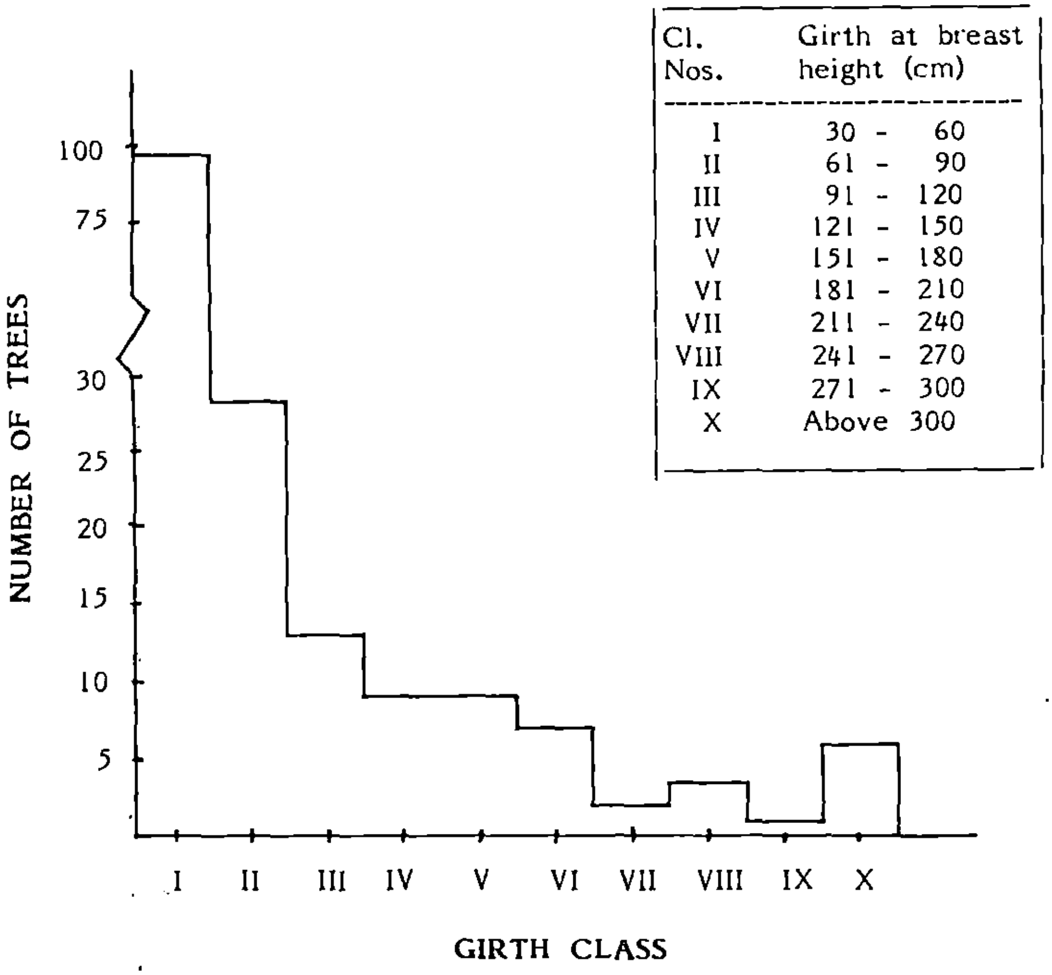
Second storey - 15 to 30m

Third storey - above 30m

Table 4. List of trees in various girth classes in the undisturbed evergreen forest plot.

Plot size 50 x 50 m

Sl No.	Species	Girth class (cm)											
		30-60	61-90	91-120	121-150	151-180	181-210	211-240	241-270	271-300	>300	Total	%
1	_Palaquium ellipticum_	15	7	8	5	5	6	-	1	-	2	49	27.60
2	_Drypetes wightii_	20	9	3	-	-	-	-	-	-	-	32	18.10
3	_Gomphandra coriacea_	23	-	-	-	-	-	-	-	-	-	23	13.00
4	_Cullenia exarillata_	7	4	2	1	2	-	1	1	-	3	21	11.90
5	_Mesua ferrea_	8	3	-	-	1	1	1	-	-	1	15	8.50
6	_Meiogyne pannosa_	11	-	-	-	-	-	-	-	-	-	11	6.20
7	_Dimocarpus longan_	5	-	-	-	1	-	-	-	-	-	6	3.40
8	_Agrostistachys borneensis_	5	-	-	-	-	-	-	-	-	-	5	2.80
9	_Myristica dactyloides_	-	1	-	1	-	-	-	1	-	-	3	1.70
10	_Holigarna arnottiana_	-		-	1	-	-	-	1	-	-	2	1.10
11	_Macaranga peltata_	-	1	-	1	-	-	-	-	-	-	2	1.10
12	_Garcinia morella_	1	1	-	-	-	-	-	-	-	-	2	1.10
13	_Phoebe lanceolata_	2		-	-	-	-	-	-	-	-	2	1.10
14	_Cinnamomum malabathrum_	-	-	-	-	-	-	-	-	1	-	1	0.60
15	_Actinodaphne malabarica_	-	1	-	-	-	-	-	-	-	-	1	0.60
16	_Drypetes malabarica_	-	1	-	-	-	-	-	-	-	-	1	0.60
17	_Debregeasia longifolia_.	1		-	-	-	-	-	-	-	-	1	0.60
	Total	98	28	13	9	9	7	2	4	1	6	177	
	%	55.4	15.8	7.3	5.1	5.1	3.9	1.1	2.3	0.6	3.4		



Cl. Nos.	Girth at breast height (cm)
I	30 - 60
II	61 - 90
III	91 - 120
IV	121 - 150
V	151 - 180
VI	181 - 210
VII	211 - 240
VIII	241 - 270
IX	271 - 300
X	Above 300

Fig.5 Distribution of trees in various girth classes in undisturbed evergreen forest plot

In the cardamom plot the fir t storey is feebly represented. The reason for this n be attributed to excessive removal of understorey ..opy and absence of saplings which can shift to the next height class.

4.1.2 Vegetational structure

The distribution of trees in various girth classes is given in Tables 4, 5 and 6. It reveals that the typical smooth curve for normal forest is available only in the undisturbed evergreen forest (Fig. 5). Girth classes below 60cm are of high order with a descending number of individuals in higher classes in this plot. As the plot was not subjected to operations, higher girth classes especially above 180cm are well represented. Palaquium ellipticum, Cullenia exarillata and Mesua ferrea are represented in most of the girth classes. Second storey species like Drypetes wightii, Myristica dactyloides, Dimocarpus longan etc. are available in girth classes less than 120 cm. The first storey species are restricted to girths below 90cm.

Compared to the undisturbed plot, the selection felled area does not possess a typical smooth curve (Fig. 6) in girth class distribution. Here girth classes above 180 cm are represented weakly. Moreover, the number of trees in the 61-90cm girth class in as low as nine while the same is 28

Table 5. List of trees in various girth classes in selection felled evergreen forest plot

Plot size 50 x 50 m

Sl No.	Species	Girth class (cm)											
		30-60	61-90	91-120	121-150	151-180	181-210	211-240	241-270	271-300	>300	Total	%
1	*Mesua ferrea*	3	3	5	2	2	3		2	1		21	22.10
2	*Palaquium ellipticum*	6		2	2	3	2	1	2		1	19	20.00
3	*Agrostistachys borneensis*	14	1									15	15.70
4	*Drypetes wightii*	7	4		1							12	12.60
5	*Gomphandra coriacea*	6										6	6.30
6	*Cullenia exarillata*				1			1	1	1	1	5	5.20
7	*Dimocarpus longan*	3		1								4	4.20
8	*Meiogyne pannosa*	4										4	4.20
9	*Myristica dactyloides*			2								2	2.10
10	*Drypetes malabarica*	2										2	2.10
11	*Dysoxylum malabaricum*										1	1	1.10
12	*Holigarna arnottiana*							1				1	1.10
13	*Artocarpus heterophyllus*				1							1	1.10
14	*Trichilia connaroides*		1									1	1.10
15	*Actinodaphne malabarica*	1										1	1.10
	Total	46	9	10	7	5	5	3	5	2	3	95	
	%	48.5	9.5	10.5	7.4	5.2	5.2	3.2	5.2	2.1	3.2		

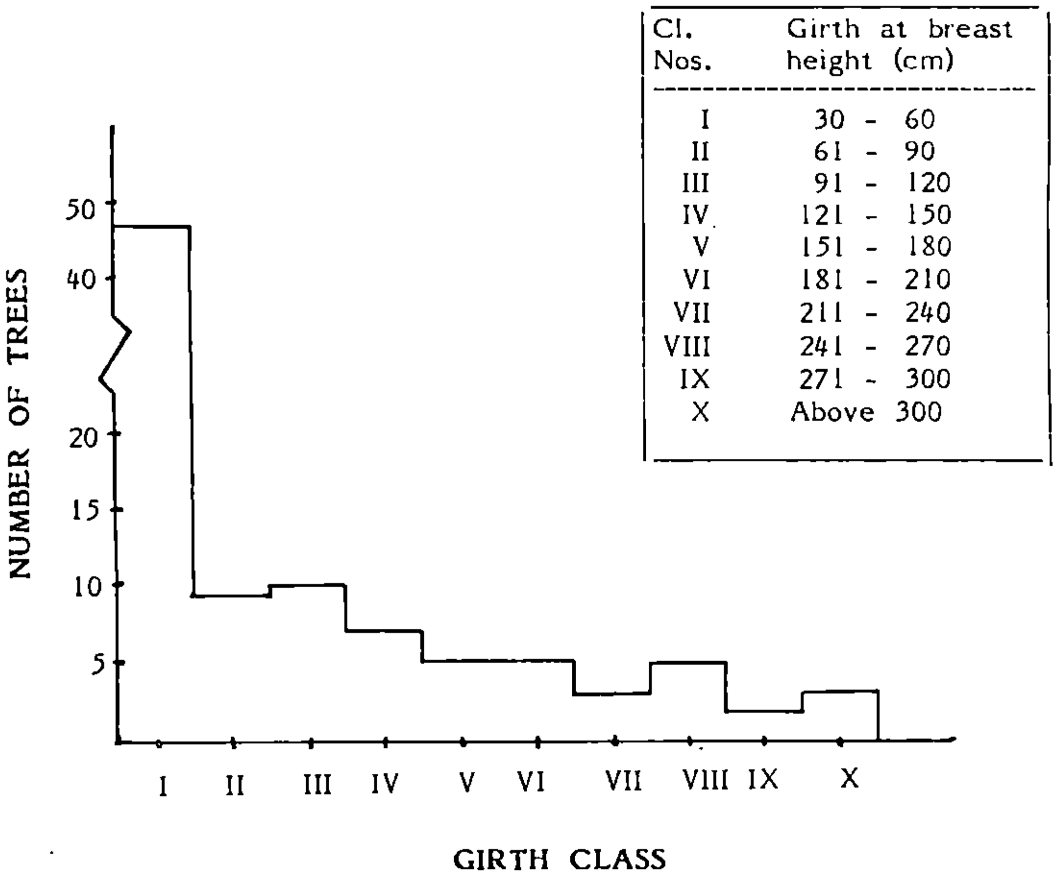


Fig.6 Distribution of trees in various girth classes in selection felled evergreen forest plot

for the undisturbed plot. This can be attributed to the damages caused to the smaller trees during felling operations. Balasubramanyan (1987) has recorded that the selection felling process can damage upto 60 percent of the standing crop. Emergent trees like Mesua ferrea and Palaquium elliptium are represented in most of the girth classes(Table 5). Strikingly there is not a single individual of Cullenia exarillata in girth classes below 120 cm. Second storey species like Drypetes wightii, Dimocarpus longan and Agrostistachys borneensis are present in girth classes below 150cm. Only 13 trees could be identified with gbh above 180cm while 20 trees of this category were found in the undisturbed evergreen plot.

The stem analysis of trees in the cardamom plantation presents a totally different picture (Fig. 7). Here a drastic reduction is observed in lower girth classes (ie) below 90cm. This is due to the removal of smaller trees for opening up canopy and while these were 98 and 46 individuals in the 30-60cm class in undisturbed and selection felled evergreen plots respectively, only seven could be identified in the cardamom plantation. No species was found distributed in all the girth classes pointing to the strong abnormality of the forest.

Table 6. List of trees in various girth classes in the cardamom plot.

Plot size 50 x 50 m

Sl No.	Species	Girth class (cm)											
		30-60	61-90	91-120	121-150	151-180	181-210	211-240	241-270	271-300	>300	Total	%
1	*Palaquium ellipticum*		4	5	2	3	5	4	1			24	40.60
2	*Cullenia exarillata*		2	5		3				1	1	12	20.30
3	*Mesua ferrea*			2		1	1	1	1		2	8	13.60
4	*Agrostistachys borneensis*		5									5	8.50
5	*Drypetes wightii*	2	1									3	5.10
6	*Macaranga peltata*	2										2	3.40
7	*Actinodaphne malabarica*						1					1	1.70
8	*Myristica dactyloides*						1					1	1.70
9	*Phoebe lanceolata*	1										1	1.70
10	*Gomphandra coriacea*	1										1	1.70
11	*Meiogyne pannosa*	1										1	1.70
	Total	7	12	12	2	7	8	5	2	1	3	59	
	%	11.9	20.3	20.3	3.4	11.9	13.6	8.5	3.4	1.7	5.0		

Cl. Nos.	Girth at breast height (cm)
I	30 - 60
II	61 - 90
III	91 - 120
IV	121 - 150
V	151 - 180
VI	181 - 210
VII	211 - 240
VIII	241 - 270
IX	271 - 300
X	Above 300

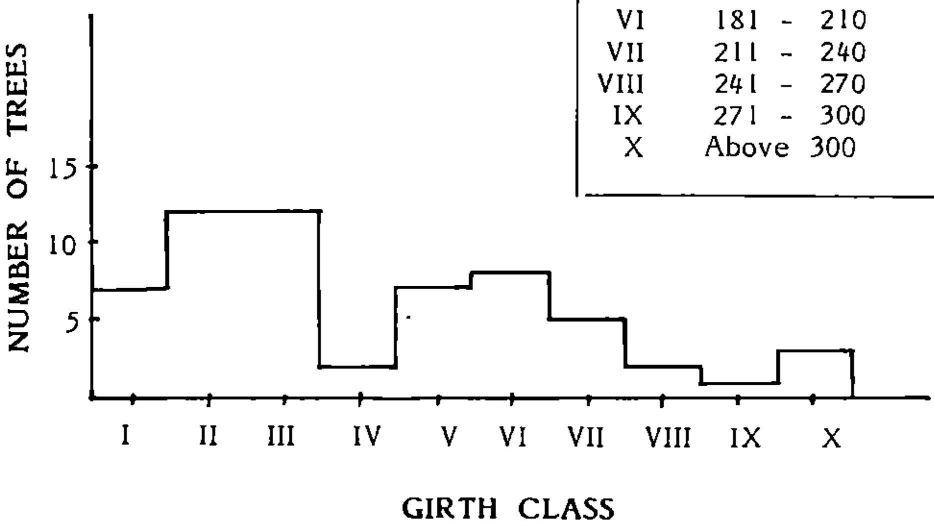


Fig.7 Distribution of trees in various girth classes in cardamom plot

4.2. Phytosociological Analysis

It was found that 17 species spread over 177 individuals (above 30cm gbh) were present in the undisturbed evergreen forest plot (Table 7). Data on relative density, relative frequency and relative basal area together forming Important value index (IVI) reveal the dominance of *Palaquium ellipticum* and *Cullenia exarillata*. A second storey species, *Drypetes wightii* follows with an IVI of 40.14 Basha (1987), Balasubramanyan (1987) and Sankar (1990) have arrived at the predominance of *Palaquium*-*Cullenia* association for the evergreen forest of Nelliampathy.

It is found that *Mesua ferrea* occupies the dominant position according to IVI in the selection felled plot (Table 8). This species was at the fourth position in the undisturbed evergreen plot. The shift in the position of *Mesua* can be attributed to the selective removal of *Palaquium* and *Cullenia* with a gbh above 180cm. Only 15 species distributed over 95 individuals were recorded from this plot. *Mesua* is followed by *Palaquium ellipticum*., a second storey species *Agrostistachys borneensis* and *Cullenia exarillata* in the IVI table. The change in number of individuals per unit area is due to selection felling.

Table 7. Vegetational analysis in the undisturbed evergreen forest plot

Sl. No.	Species	No. of individuals	RD	RF	RBA	IVI
1.	Palaquium ellipticum	49	27.68	19.47	34.02	81.17
2.	Cullenia exarillata	21.	11.87	12.39	31.19	55.45
3.	Drypetes wightii	32	18.08	16.82	5.24	40.14
4.	Mesua ferrea	15	8.48	8.85	11.75	29.08
5.	Gomphandra coriacea	23	13.00	14.16	1.57	28.73
6.	Meiogyne pannosa	11	6.21	8.85	0.65	15.71
7.	Dimocarpus longan	6	3.39	4.43	1.53	9.35
8.	Myristica dactyloides	3	1.70	2.66	3.95	8.31
9.	Holigarna arnottiana	2	1.13	1.77	3.82	6.72
10.	Agrostistachys borneensis	5	2.83	2.66	3.95	8.31
11.	Cinnamomum malabathrum	1	0.56	0.88	3.65	5.09
12.	Macaranga peltata	2	1.13	1.77	1.00	3.90
13.	Garcinia morella	2	1.13	1.77	0.42	3.32
14.	Phoebe lanceolata	2	1.13	0.88	0.11	2.12
15.	Actinodaphne malabarica	1	0.56	0.88	0.34	1.78
16.	Drypetes malabarica	1	0.56	0.88	0.21	1.64
17.	Debregeasia longifolia	1	0.56	0.88	0.09	1.53
	Total	177	100	100	100	300

Abbreviations used:

RD - Relative density
RF - Relative frequency
RBA - Relative basal area
IVI - Importance value index

Table 8. Vegetational analysis in the selection felled evergreen forest plot

No.	Species	No. of individuals	RD	RF	RBA	IVI
1.	*Mesua ferrea*	21	22.11	22.78	29.58	74.47
2.	*Palaquium ellipticum*	19	20.00	16.45	29.33	65.48
3.	*Agrostistachys borneensis*	15	15.79	13.92	2.14	31.85
4.	*Cullenia exarillata*	5	5.26	6.33	19.73	31.32
5.	*Drypetes wightii*	12	12.63	12.66	3.38	28.67
6.	*Gomphandra coriacea*	6	6.32	6.33	0.60	13.25
7.	*Dimocarpus longan*	6	3.39	4.43	1.53	10.37
8.	*Dysoxylum malabaricum*	1	1.05	1.27	7.63	9.95
9.	*Meiogyne pannosa*	4	4.21	0.50	5.06	9.77
10.	*Holigarna arnottiana*	1	1.05	1.27	3.39	5.71
11.	*Myristica dactyloides*	2	2.11	2.53	0.82	5.46
12.	*Drypetes malabarica*	2	2.11	2.53	0.32	4.96
13.	*Artocarpus heterophyllus*	1	1.05	1.27	1.16	3.48
14.	*Trichilia connaroides*	1	1.05	1.27	0.22	2.54
15.	*Actinodaphne malabarica*	1	1.05	1.27	0.10	2.42
	Total	95	100	100	100	300

Abbreviations used:

RD - Relative density
RBA - Relative basal area
RF - Relative frequency
IVI - Importance value index

Table 9. Vegetational analysis in the cardamom plot

No.	Species	No. of indivi-duals	RD	RF	RBA	IVI
1.	Palaquium ellipticum	24	40.68	29.54	43.84	114.06
2.	Cullenia exarillata	12	20.34	18.19	21.18	59.71
3.	Mesua ferrea	8	13.56	18.19	27.30	59.05
4.	Agrostistachys borneensis	5	8.48	11.36	1.69	21.53
5.	Drypetes wightii	3	5.09	6.82	0.68	12.59
6.	Macaranga peltata	2	3.40	4.55	0.27	8.22
7.	Actinodaphne malabarica	1	1.69	2.27	2.32	6.28
8.	Myristica dactyloides	1	1.69	2.27	2.23	6.19
9.	Phoebe lanceolata	1	1.69	2.27	0.20	4.16
10.	Gomphandra coriacea	1	1.69	2.27	0.15	4.11
11.	Meiogyne pannosa	1	1.69	2.27	0.14	4.10
	Total ..	59	100	100	100	300

There is a further reduction of the number of individuals with gbh above 30cm in the cardamom plot (Table 9). The cardamom plantation was established in 1980 after selection felling of trees above 180cm gbh(six trees/ha) and further removal of trees in the first and second storeys. This operation is carried out to enable penetration of light through the canopy to the understorey of cardamom. Thus in the plot of 0.25 hectare only 59 individuals (above 30cm gbh) are available as compared to 95 and 177 in selection felled and undisturbed evergreen forest respectively. Palaquium ellipticum, Cullenia exarillata and Mesua ferrea dominate the IVI table (Table 9), while second storey species namely Agrostistachys borneensis, Drypetes wightii and Gomphandra coriacea are relegated to the background. The number of species per unit area is also less (11/0.25 ha) when compared to the other two plots.

4.2.1 Importance value indices of families

It is found that four families, Sapotaceae, Clusiaceae, Bombacaceae and Euphorbiaceae dominate in the IVI in all the three plots (Table 10). The selection felled plot has an IVI dominated by Clusiaceae which is due to the relative increase in Mesua ferrea as a result of the selective removal of Cullenia exarillata (Bombacaceae) and Palaquium ellipticum(Sapotaceae). Although maximum number of species is available for Euphorbiaceae (4) and Lauraceae(2) in all the plots, their low position in the IVI table can be attributed to relatively small basal areas. Similar results have been obtained by Basha (1987) for the same area and Pascal(1988) for Attappady area in Palghat.

Table 10. Important value indices of families in the experimental plots

Sl. No.	Family	IVI		
		Undisturbed evergreen	Selection felled	Cardamom plantatio
1.	Sapotaceae	81.17	65.78	114.06
2.	Bombacaceae	55.45	31.32	59.71
3.	Euphorbiaceae	51.63	65.48	42.34
4.	Clusiaceae	32.40	74.47	59.05
5.	Icacenaceae	28.73	13.25	4.11
6.	Anonaceae	15.71	9.77	4.10
7.	Myristicaceae	13.40	5.46	6.19
8.	Sapindaceae	9.35	10.37	---
9.	Anacardiaceae	6.73	5.71	---
10.	Lauraceae	3.90	2.42	10.44
11.	Urticaceae	1.53	---	---
12.	Meliaceae	---	12.49	---
13.	Moraceae	---	3.48	---

4.2.2 Floristic diversity

The tropical wet evergreen forests are well known for their floristic diversity (Foggie, 1960). Dominance of single species has never been encountered (Ashton, 1964). The investigations revealed that the species diversity is high in the undisturbed evergreen and selection felled evergreen forest plots (Table 11).

Table 11. Floristic diversity in the experimental plots.

Experi-mental plots	Surface area (Sq.m)	No. of individuals(N) (girth >30cm)	No. of species(S) (girth>30cm)	N/S	Simpson's Index
Undisturbed evergreen	2500	177	17	10.4	0.85
Selection felled evergreen	2500	95	15	6.3	0.86
Cardamom plantation	2500	59	11	5.[illegible]	0.76

Basha (1987) has recorded a Simpson's Index of 0.87 for the same area. A minimal increase in the diversity value (by 0.01) in the selection felled plot when compared to undisturbed evergreen forest may be attributed to the removal of <u>Palaquium</u> and <u>Cullenia</u> whose numbers are appreciably more in the vegetation. Removal of both over storey and understorey vegetation has brought down the diversity index in cardamom plantat: n. It is to be noted here that the understorey comprises more species but represented by few numbers, while 3 - 4 species tend to dominate in the overstorey.

4.2.3 Presence and absence of species

The results of this study is given in Table 12. Altogether 20 species of trees(above 30cm gbh) were present in the three plots. Of this 17 could be located in the undisturbed, 15 in the selection felled and 11 in the cardamom plots. Palaquium ellipticum, Cullenia exarillata, Mesua ferrea, Drypetes wightii, Gomphandra coriacea, Myristica dactyloides, Meiogyne pannosa, Actinodaphne malabarica etc. were common to all the plots.

4.2.4 Distribution of species within families

The results given in Table 13 reveal the presence of 13 families in the study area of which 11 area present in the undisturbed plot, 12 in the selection felled plot while only eight are available in the cardamom plot. The low family diversity in the cardamom plot is attributed to the removal of both understorey and overstorey vegetation.

Table 12. Presence and absence of tree species within families in the three experimental plots

Sl. No.	Species	Family	undisturbed evergreen plot	Selection felled plot	Cardamom plantation
1.	Palaquium ellipticum	Sapotaceae	x	x	x
2.	Cullenia exarillata	Bombacaceae	x	x	x
3.	Mesua ferrea	Clusiaceae	x	x	x
4.	Myristica dactyloides	Myristicaceae	x	x	x
5.	Drypetes wightii	Euphorbiaceae	x	x	x
6.	Gomphandra coriaceae	Icacinaceae	x	x	x
7.	Meiogyne pannosa	Anonaceae	x	x	x
8.	Agrostistachys borneensis	Euphorbiaceae	x	x	x
9.	Actinodaphne malabarica	Lauraceae	x	x	x
10.	Dimocarpus longan	Sapindaceae	x	x	...
11.	Holigarna arnottiana	Anacardiaceae	x	x	...
12.	Drypetes malabarica	Euphorbiaceae	x	x	...
13.	Macaranga peltata	Euphorbiaceae	x	...	x
14.	Phoebe lanceolata	Lauraceae	x	...	x
15.	Garcinia morella	Clusiaceae	x	...	...
16.	Cinnamomum malabathrum	Myristicaceae	x	...	...
17.	Debregeasia longifolia	Urticaceae	x	...	...
18.	Dysoxylum malabaricum	Meliaceae	...	x	...
19.	Artocarpus heterophyllus	Moraceae	...	x	...
20.	Trichilia connaroides	Meliaceae	...	x	...

Table 13. Distributi‹ ›f tree species within families in the experim .al plots

Sl. No.	Family	Number of species		
		Undisturbed evergreen	Selection felled evergreen	Cardamom plantation
1.	Euphorbiaceae	4	3	3
2.	Lauraceae	2	1	2
3.	Myristicaceae	2	1	1
4.	Clusiaceae	2	1	1
5.	Bombacaceae	1	1	1
6.	Sapotaceae	1	1	1
7.	Anonaceae	1	1	1
8.	Icacenaceae	1	1	...
9.	Anacardiaceae	1	1	...
10.	Meliaceae	...	2	...
11.	Sapindaceae	1	1	...
12.	Moraceae	...	1	...
13.	Urticaceae	1	...	...
	Total	17	15	11

Basha(1987) has recorded 18 families in a plot of (50 x 50m) undisturbed evergreen forest in the same area taking into consideration all trees above 10cm gbh. Further it can be seen that Euphorbiaceae, Lauraceae and Myristicaceae contain maximum number of species.

4.3 Leaf Area

Givnish(1984) classified the leaves according to their area (Table 1). Based on this, the leaf area of important trees in the study area was classified and the data is presented in Table 14.

Table 14. Leaf area of important tree species in the experimental plots

Sl. No.	Species	Leaf area (Sq.cm)	Type of leaf
1.	*Palaquium ellipticum*	36.61	Notophyll
2.	*Dysoxylum malabaricum*	40.29	Notophyll
3.	*Holigarna arnottiana*	27.51	Notophyll
4.	*Meaua ferrea*	49.54	Mesophyll
5.	*Cullenia exarillata*	93.18	Mesophyll
6.	*Meiogyne pannosa*	10.61	Microphyll
7.	*Drypetes wightii*	21.73	Notophyll
8.	*Dimocarpus longan*	40.75	Notophyll
9.	*Drypetes malabarica*	56.77	Mesophyll
10.	*Cinnamomum malabathrum*	81.62	Mesophyll
11.	*Myristica dactyloides*	90.84	Mesophyll
12.	*Actinodaphne malabarica*	115.78	Mesophyll
13.	*Agrostistachys borneenss*	119.74	Mesophyll
14.	*Macaranga peltata*	228.59	Macrophyll

Of the five top canopy species, three viz., Palaquium ellipticum, Dysoxylum malabaricum and Holigarna arnottiana possess notophyllous leaves while two species - Cullenia exarillata and Mesua ferrea mesophyllous. In the understorey five species have mesophyll leaves two notophyll and one microphyll. The pioneer species colonising the gaps, Macaranga peltata, has macrophyllous leaves. This conforms to the general theory that in the rainforest individual leaf area decreases with the height of the canopy that species is occupying, and plays an important role in the partitioning of light (Givnish, 1984).

4.4 Leaf Area Index

The results given in Table 15 clearly indicate that there is an increase in Leaf area index (LAI) from cardamom plantation to undisturbed evergreen forest.

Table 15. Leaf Area Indices (LAI) of the vegetation in the experimental plots

Sl. No.	Experimental plots	LAI
1.	Undisturbed evergreen	4.61
2.	Selection felled evergreen	3.68
3.	Cardamom plantation	2.40

The values of LAI as measured by the Canopy Analyzer are under estimated. Such a phenomenon has been reported by Gower and Norman(1990). They further found that this instrument can be successfully used in forest settings using a correction factor, which is based on shoot morphology. They determined the correction factor to be 1.48 for European larch to 1.67 for Norway spruce which has to be multiplied with LAI 2000's results.

Publications on LAI for tropical evergreen forest indicate the same to be 8.4 (Ogava et al, 1965), 8.9 (Edwards and Grubb, 1977), 9 (Kato et al; 1978), while Swamy (1989) has reported a LAI of 14.17 for evergreen forest of Karnataka, India.

Our figure of 4.61 for undisturbed evergreen forest plot in Nelliampathy if multiplied by the correction factor can yield comparable results. It is to be stressed here that the compensation factor for such types of ecosystem has to be arrived at. The reduction in LAI with disturbances in the form of selection felling and raising of cardamom plantation by opening up the canopy follows the same trend as in basal area, litter production and other parameters. As in all cases, undisturbed evergreen forest possesses the maximum LAI (4.61) and cardamom plantation the least(2.40) while the selection felled plot has a figure in between (3.68).

4.5 Microclimate

4.5.1 Air temperature and humidity

The data pertaining to air temperature and relative humidity are presented in Table 16. The monthly mean temperature did not go below 17 ^{o}C as expected for regions with such a type of vegetation.

Table 16. Air temperature, humidity and rainfall in the study area during 1989

MONTH	TEMPERATURE (^{o}C)			RELATIVE HUMIDITY			RAINFALL (mm)
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	
January	24	9	17.10	100	32	71	15.2
February	27	8	18.60	95	28	56	0.0
March	26	10	19.40	90	22	65	22.4
April	27	16	21.40	88	40	63	51.3
May	24	15	20.20	95	72	85	129.6
June	22	16	18.00	100	74	93	646.0
July	24	16	18.00	95	78	88	1085.5
August	21	16	18.00	95	72	87	478.5
September	23	16	18.30	95	72	86	261.4
October	21	15	17.80	90	70	86	292.1
November	23	15	19.30	90	50	76	20.0
December	23	12	19.40	90	52	77	1.0

The coolest month was January with a monthly average temperature of 17.1 °C. But the lowest temperature of 8 °C was recorded in February. Pascal (1988) has recorded an absolute minimum temperature of 9 °C while reporting on the bioclimate of Western Ghats. February, March and April constituted the hottest period with a maximum temperature of 26 to 27 °C. With the onset of monsoons, the maximum temperature fell to about 22-24 °C. There was no significant variation in the monthly mean temperature. The diurnal variation of temperature varied from 5 to 19 °C. The lowest diurnal variation was observed in August. It was high during November to March. This is the time when flowering and leaf fall are at their peak. The possibility of an effect of small changes in temperature on plants, animals and people has been reported (Longman and Jenik, 1987). Cachan and Duval (1963), have recorded a diurnal variation of 10.8 °C in the rainforests of Ivory Coast.

The results of the observations on relative humidity (RH) are also presented in Table 16. As expected for humid tropical climates, the maximum RH was always above 90 percent throughout the year. But during the dry season a steep fall in minimum RH was observed. It came down to 22 percent in March and was in the range of 32 to 40 percent during January to April. Consequently large water vapour pressure deficits occur at this level (Aoki et al., 1974) and is responsible for enhanced litterfall. This very low RH coupled with high air temperatures and low soil moisture content (Table 19) play a vital role in the growth and functioning of this ecosystem (Pascal, 1988). Low RH values were reported for the same period in Nelliampathy earlier (Basha, 1987).

4.5.2 Rainfall

The area recorded a rainfall of 3003mm during the study period (Table 16). Bulk of the rainfall occurred during the post-summer months of June to September (82 percent), the north-east monsoon from October to December contributed 10 percent, the pre-monsoon thunder showers from April to May six percent and the dry season from January to March two percent. Basha (1987) while compiling the rainfall data for Nelliampathy has arrived at more or less the same picture. He reported that out of a total annual rainfall of 3661mm, the south-west monsoon accounted for 76.6 percent, the retreating monsoon (north-east) 14.1 percent, the pre-monsoon thunder showers 7.4 percent and the dry season 1.9 percent.

There is a significant variation in total annual rainfall in the area. The rainfall varied from 2431mm in 1987 to 1833mm in 1988. This variation also affects the functioning of the forest ecosystem.

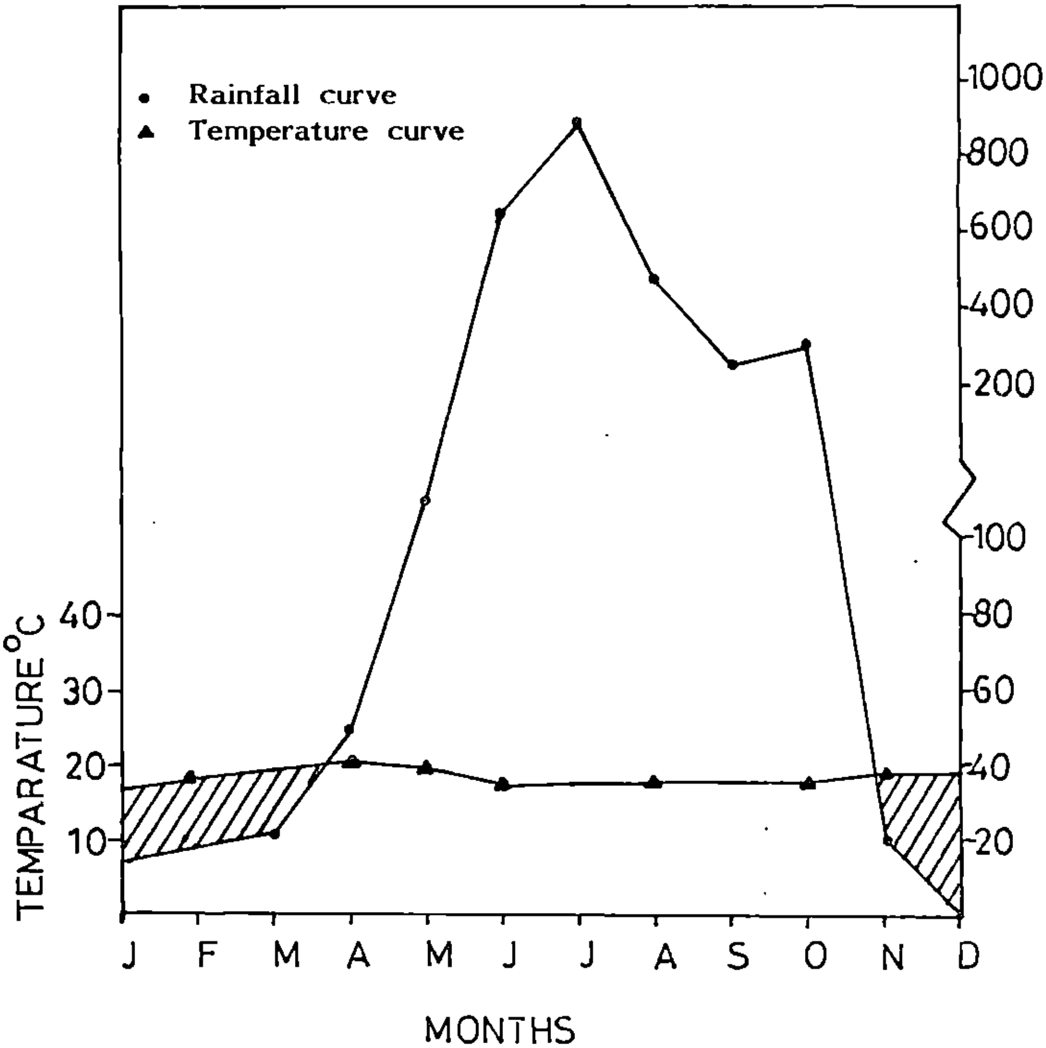


FIG .8 OMBROTHERMIC DIAGRAM OF STUDY AREA

Ombrothermic diagram: By plotting mean monthly temperature against rainfall an ombrothermic diagram of the study area was arrived at (Fig. 8). The shaded areas represent the dry season where average temperatures stand above the precipitation. Thus the study area has a dry season of four months extending from December to March. This indicates that the ecosystem represents a seasonal rain forest (monsoon evergreen forest) and the maintenance of such a system is affected by high rainfall of 3000mm. Walters (1971) has reported that even in areas with a dry season of three to four months, rainforests can develop, given the rainfall exceeds 2500 mm.

4.5.3 Light

The vertical distribution of light was measured only in the undisturbed evergreen plot and the result is given in Fig. 9. The upper tree layer, with the fully exposed emergent trees receive 100 percent of the light. In subsequent layers below the canopy light is markedly reduced. At 30m height only 60 percent of the radiant energy is received. Lower down at 20 m only 30 percent, while at 10 m only 15 percent of illuminance is observed. At the ground level minimum light supply is available amounting to 10 percent of the total light.

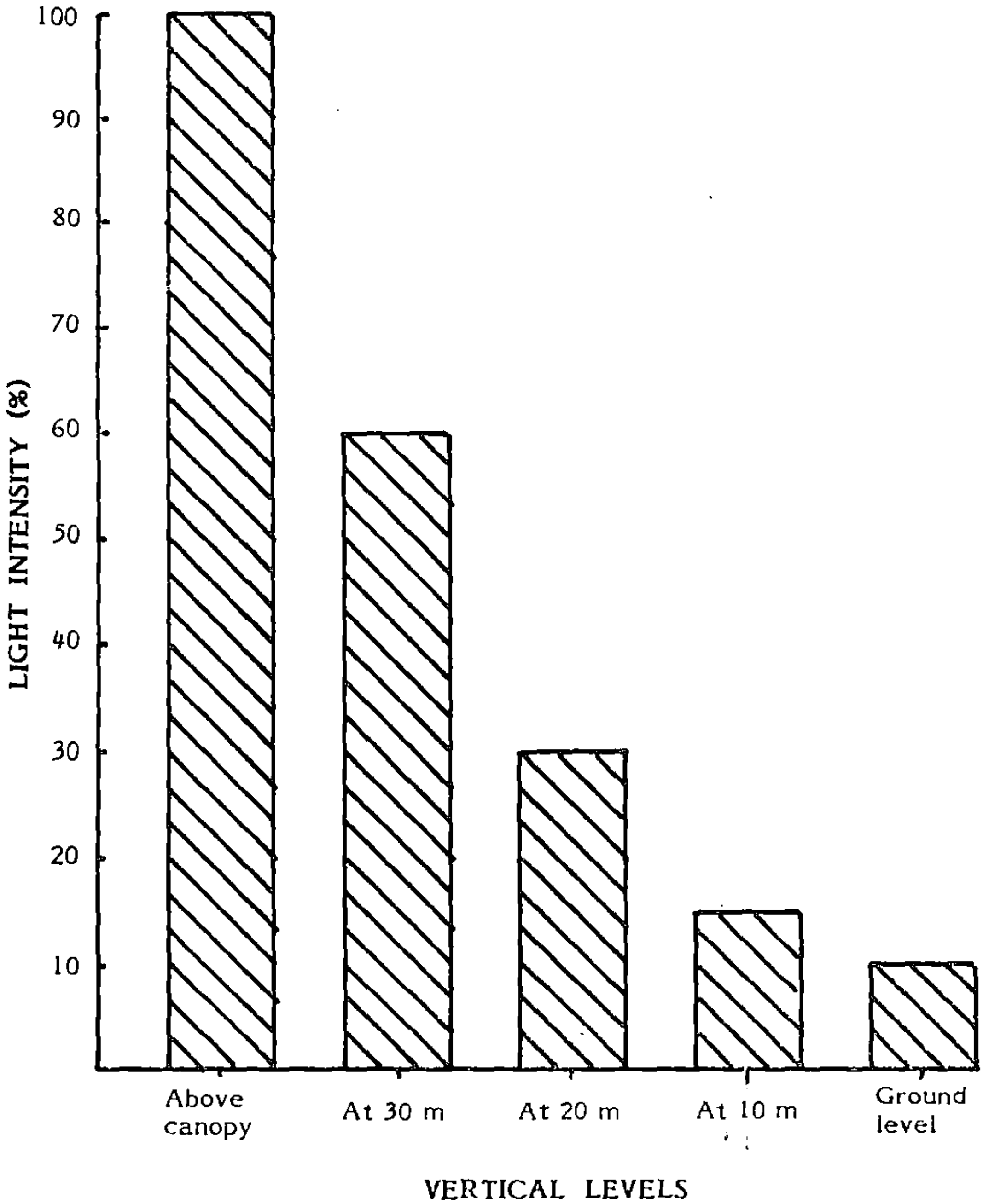


Fig.9 Vertical distribution of light in the undisturbed evergreen forest plot

Allen *et al* (1972) working in Pasoh, Malaysia and Costa Rica respectively have arrived at similar vertical profiles for the light environment. Richards (1983) terms the illuminated part of the canopy as euphotic layer while the areas with decreased illuminance as oligophotic layer. The minimal light supply near the ground surface in the evergreen forest plot under consideration is reflected in the low development of understorey plant biomass.

Since tropical forests are three-dimensional structures, their patterns of radiation and illuminance vary horizontally also (Longman and Jenik, 1987). The distribution of light in the study plots is illustrated in Figures 10, 11 and 12. It is clearly observed that the undisturbed evergreen forest recorded maximum area with light intensities less than 1000 lux (14.9 percent) while the cardamom plantation did not possess even a single sq.m of this dark phase (0 percent). The selection felled plot occupied a middle position with 6.3 percent of the area belonging to this category of illuminance.

The undisturbed evergreen forest had 58 percent of the area under the illuminance category 1001 to 5000 lux suggesting that the dim phase is the most prominent. At the same time the selection felled plot possessed 41 percent while the cardamom plantation 14.5 percent of the area respectively under this category.

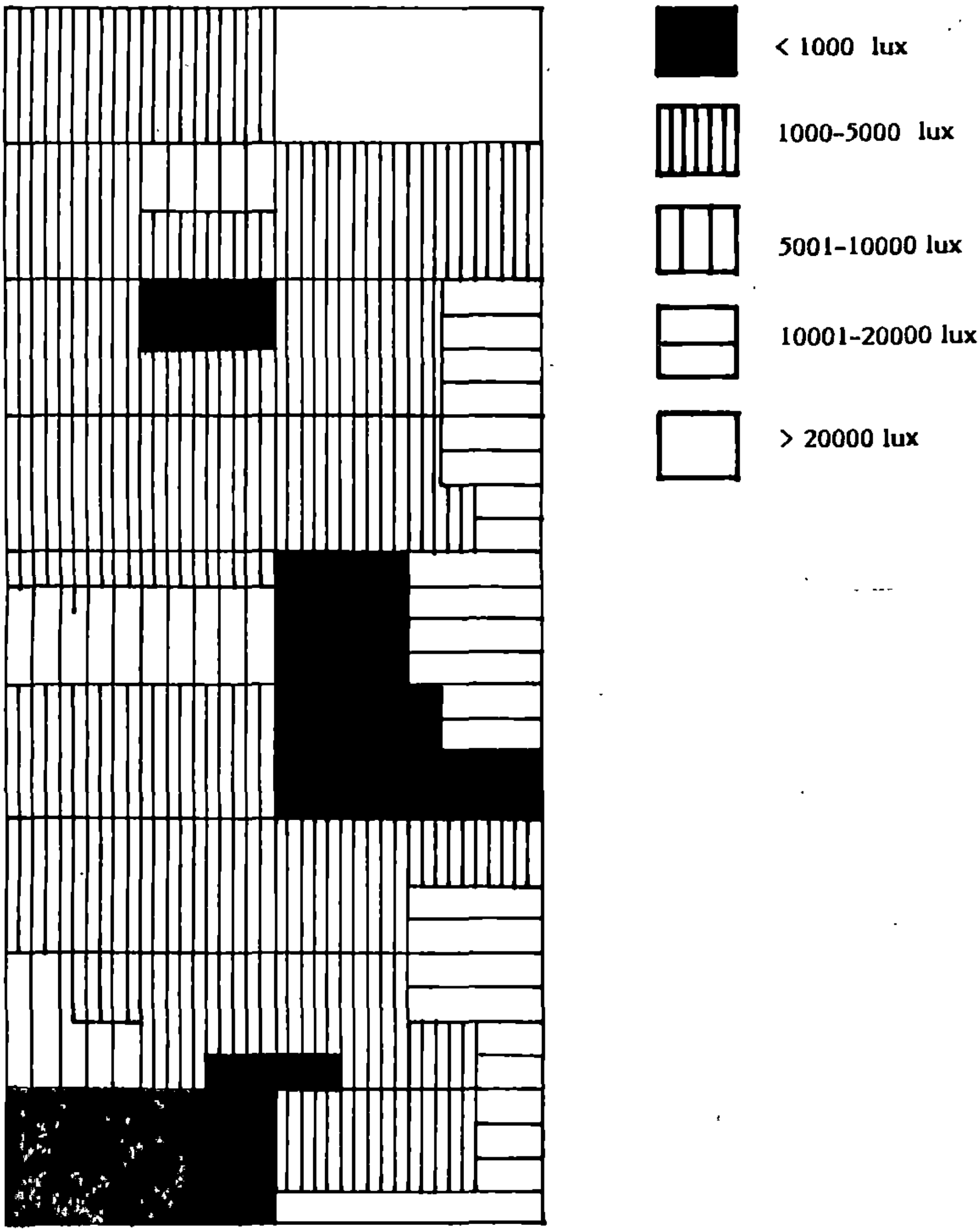


Fig.10 Horizontal distribution of light in the undisturbed evergreen forest plot (20 x 9 m)

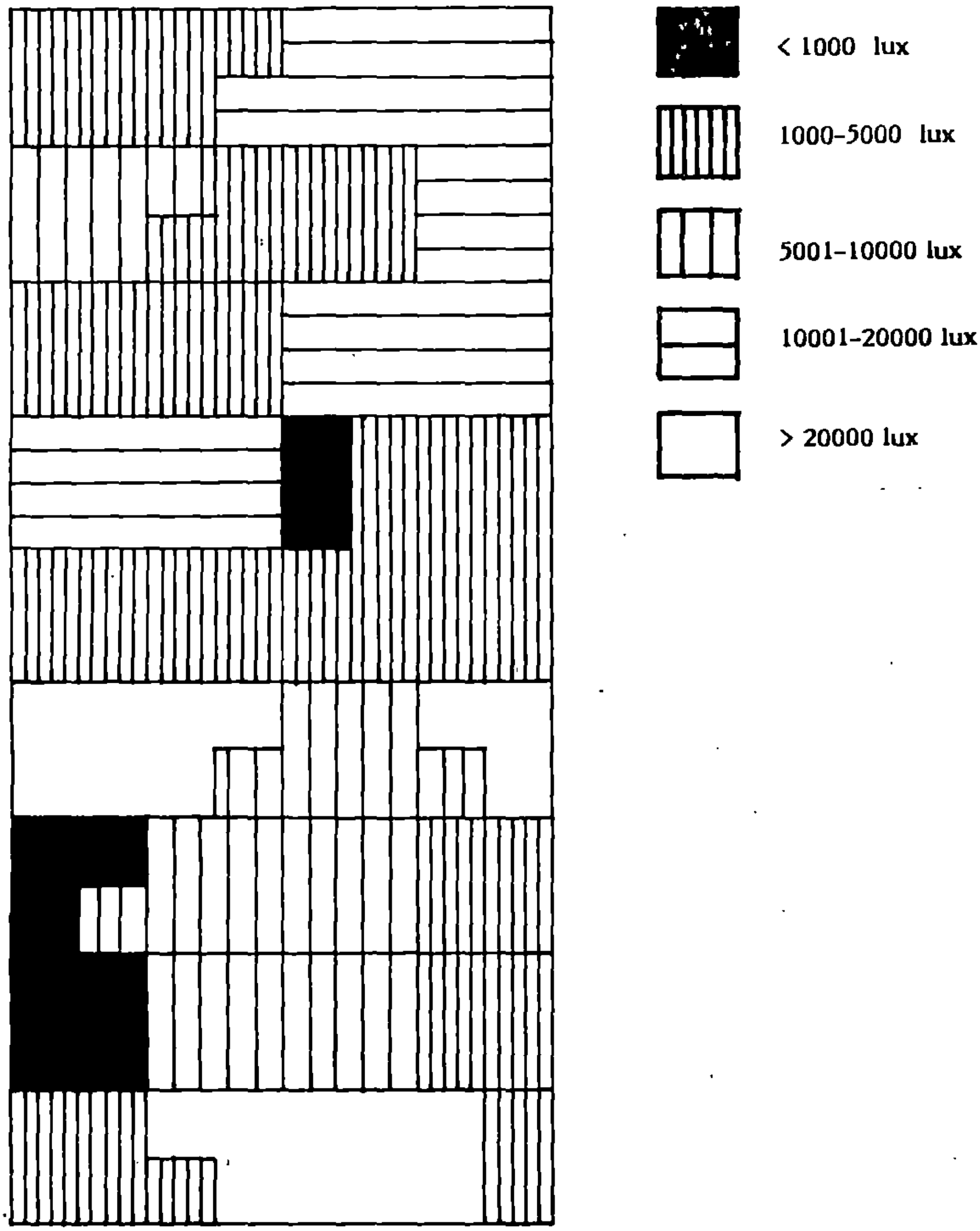


Fig.11 Horizontal distribution of light in the selection felled evergreen forest plot (20 x 9 m)

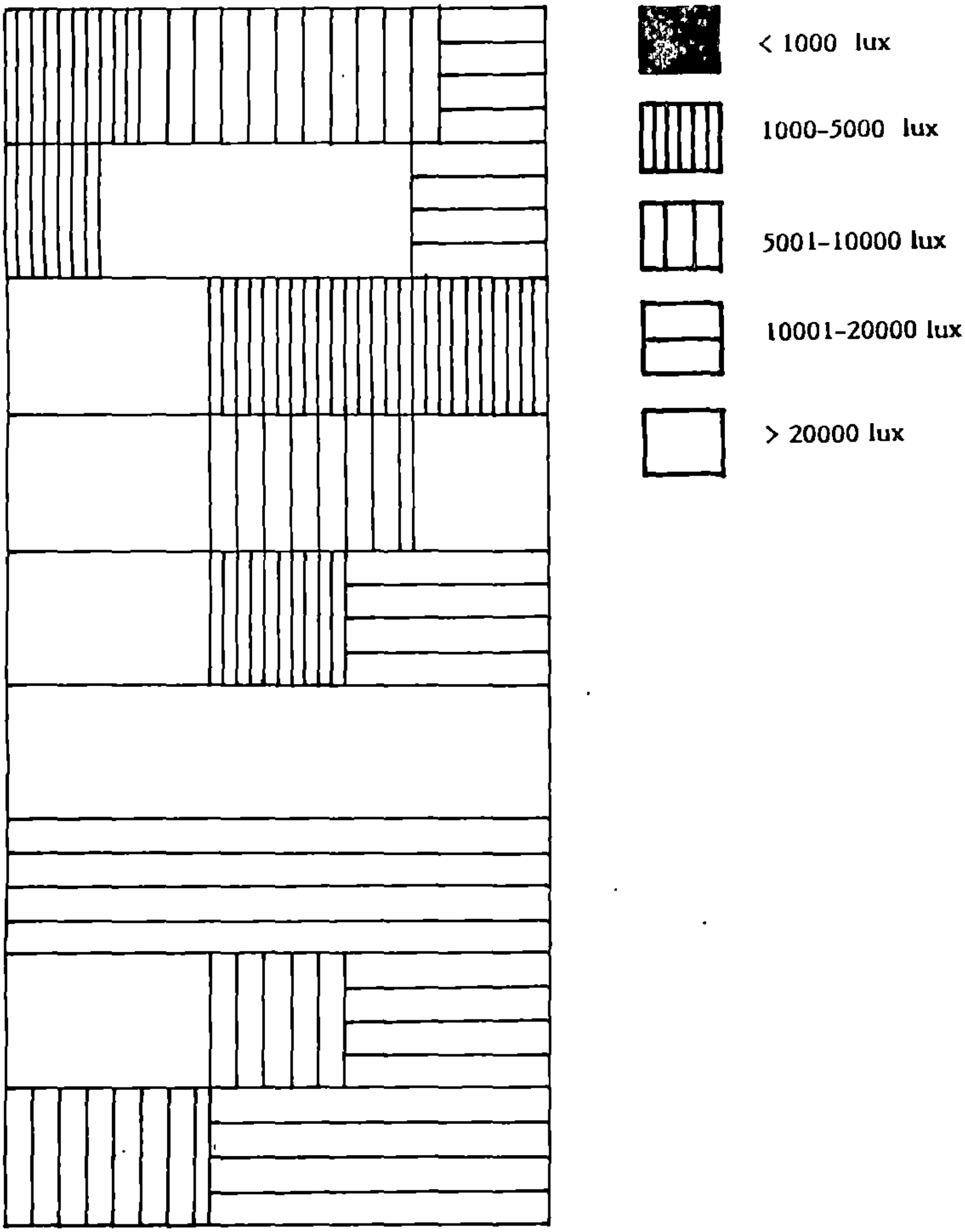


Fig.12 Horizontal distribution of light in the cardamom plot (20 x 9 m)

The next category of light intensity (5001 to 1000 lux) was observed in 7.7, 19.4 and 17.4 percent of the area of the undisturbed evergreen forest, selection felled forest and cardamom plantation respectively.

The category of higher illuminance (10001 to 20000 lux) was available in 13.5, 20.1 and 31.3 percent of the area in undisturbed, selection felled forests and cardamom plantation respectively. Open areas with maximum light phase (above 20000 lux) was the highest in cardamom plantation (36.8 percent). As expected the undisturbed plot had only 5.6 percent of the area under this category while the selection felled 13.2 percent.

It is evident from the above that undisturbed forest has minimum light intensities while opened up cardamom plantation possesses maximum. The selection felled plot where the disturbance has been minimal in the form of removal of six trees/ha occupies the middle position. Enumeration of the canopy area in these plots substantiates the above observation. It was found that (Table 17) the undisturbed plot possessed a crown area of 694 m^2, while the cardamom plantation had only 442 m^2 of crown area on a surface area of 500 m^2. The selection felled plot contained a crown area of 576m^2 for the same surface area.

Table 17. Crown area of trees in the experimental plots [50 x 10m]

Sl. No.	Experimental plot	Canopy coverage (Sq.m)
1.	Undisturbed evergreen	694
2.	Selection felled evergreen	576
3.	Cardamom plantation	442

Light environment in forest is controlled by the structure of the canopy. The canopy gaps which are highly variable produce a mosaic of light conditions. The presence of large gaps, artificially created in the cardamom plantation is responsible for relatively high light values. Denslow (1980), Barton and Redhead (1982) have stated that much of the variability in light conditions can be attributed to the canopy gap size.

4.5.4 Soil temperature

The monthly soil temperature in the three plots under study is given in Table 18 and illustrated in Figure 13. In the undisturbed evergreen forest maximum soil temperature was observed in the month of April (21.7°) and minimum in the month of September (17.6°C). There was a gradual increase in soil temperature from December to April and the same stabilised during the monsoons. In the selection felled plot also maximum soil temperature was observed in the month of April (22.6°C) and minimum in the month of September (18.4°C). The cardamom plot also followed the same pattern with a maximum of 26.3°C (April) and a minimum of 21.3°C (September).

There was considerable variation between the soil temperatures recorded in the undisturbed evergreen plot and cardamom plantation. There was a 4.6°C difference in April and 3.5°C in September. The selection felled plot had more or less the same soil temperature as in the undisturbed one.

Table 18. Monthly soil temperature (Centigrade) in the experimental plots

Experimental plots	Months											
	Jan 89	Feb 89	Mar 89	Apr 89	May 89	Jun 89	Jul 89	Aug 89	Sep 89	Oct 89	Nov 89	Dec 89
Undisturbed evergreen plot	18.9	19.5	21.4	21.7	21.0	19.9	19.1	19.2	17.6	18.2	19.1	18.9
Selection felled plot	19.3	19.8	21.7	22.6	21.6	20.7	19.7	19.2	18.4	19.2	19.4	19.1
Cardamom plot	23.4	23.8	25.7	26.3	25.0	23.4	22.0	22.4	21.3	22.1	23.2	23.2

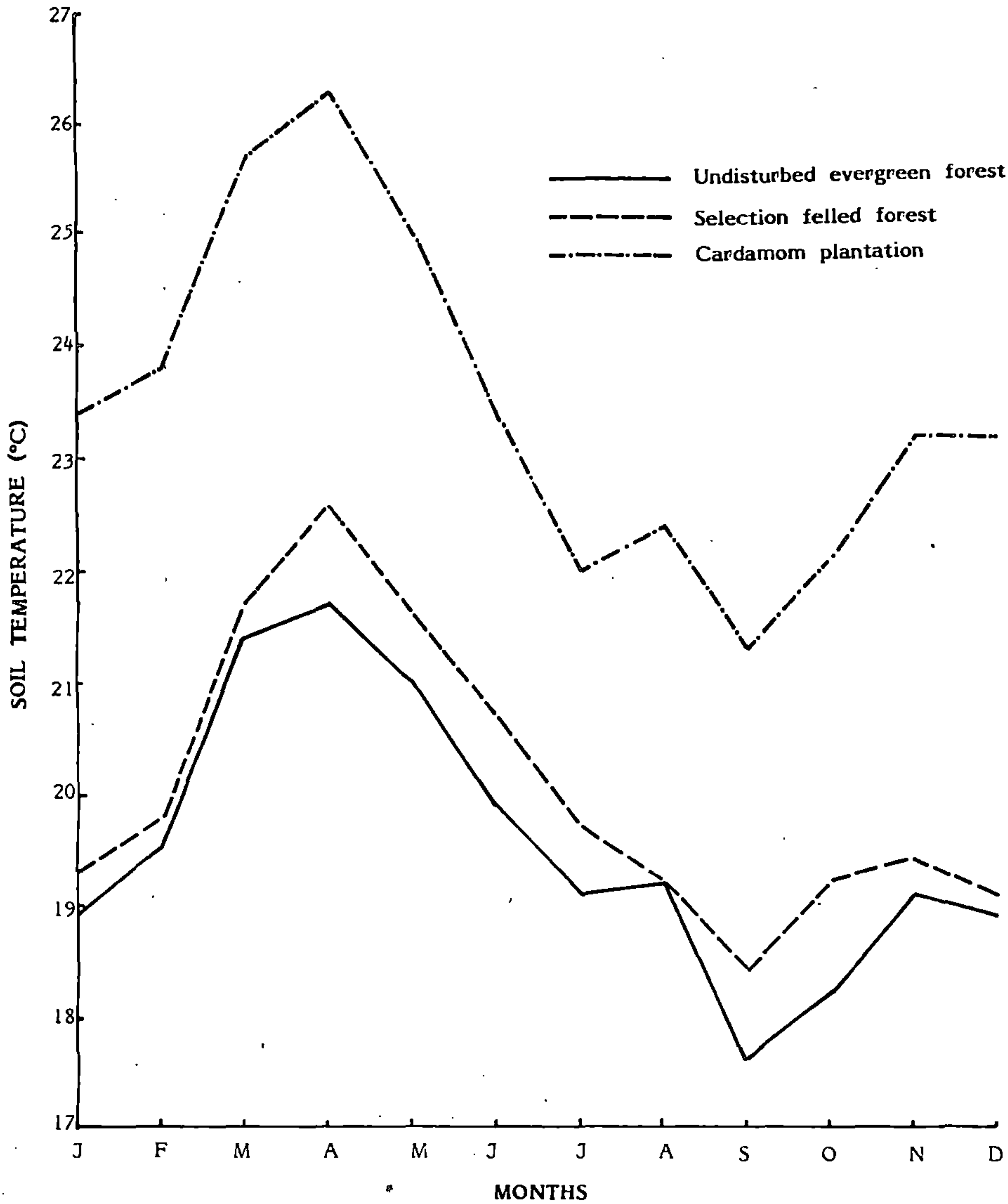


Fig.13 Monthly soil temperature in the experimental plots

The openings in the canopy of the cardamom plot is responsible for higher soil temperatures in this system. This observation is confirmed by the horizontal distribution pattern of light (Fig. 12) and also the soil moisture content (Table 19) in the cardamom plot. Balasubramanyan (1987) has recorded higher soil temperatures in freshly selection felled plots compared to undisturbed ones and has related the same to opening of the canopy.

In the present study, soil temperatures in the undisturbed evergreen forest and the selection felled plot did not have significant variation. This is due to the fact that this plot was put under selection felling in 1985 and a thick undergrowth of Strobilanthes sps. (Plate 5) developed covering the openings. The same must have been responsible for mitigating the effects of canopy opening as far as soil temperature is concerned.

4.5.5 Soil Moisture

The results of the measurements of soil moisture (20 cm depth) are given in Table 19 and Fig. 14. Soil moisture content was lowest in the month of April in undisturbed evergreen (24mm) and selection felled plots (24mm). But in the cardamom plantation the lowest value (19mm) for soil moisture was observed in March. With the onset of monsoon in

May, a progressive increase in soil moisture was observed. July, August and September were the months with maximum soil moisture content. From October onwards the value of soil moisture declined reaching a minimum by March-April.

The results reveal that there is not much variation in the soil moisture content between undisturbed and selection felled evergreen forests. Although, the canopy of the latter has been opened, thick undergrowth of Strobilanthes must have served as a moisture conserving factor. Further there was not a significant difference between the above plots and cardamom plantation in soil moisture content during the peak monsoon period from June to September.

Table 19. Monthly soil moisture (mm) in the experimental plots (20 cm depth)

Experimental plots	Months											
	Jan 89	Feb 89	Mar 89	Apr 89	May 89	Jun 89	Jul 89	Aug 89	Sep 89	Oct 89	Nov 89	Dec 89
Undisturbed evergreen	31	28	26	24	33	41	52	56	56	42	40	37
(Deficit)	13	16	18	20	11	3	--	--	--	2	4	7
Selection felled	32	27	25	24	31	42	48	54	56	40	38	36
(Deficit)	12	17	19	20	13	2	--	--	--	4	6	8
Cardamom	24	21	19	22	28	43	50	54	55	38	33	27
(Deficit)	20	23	25	22	16	1	--	--	--	6	11	17

n=9

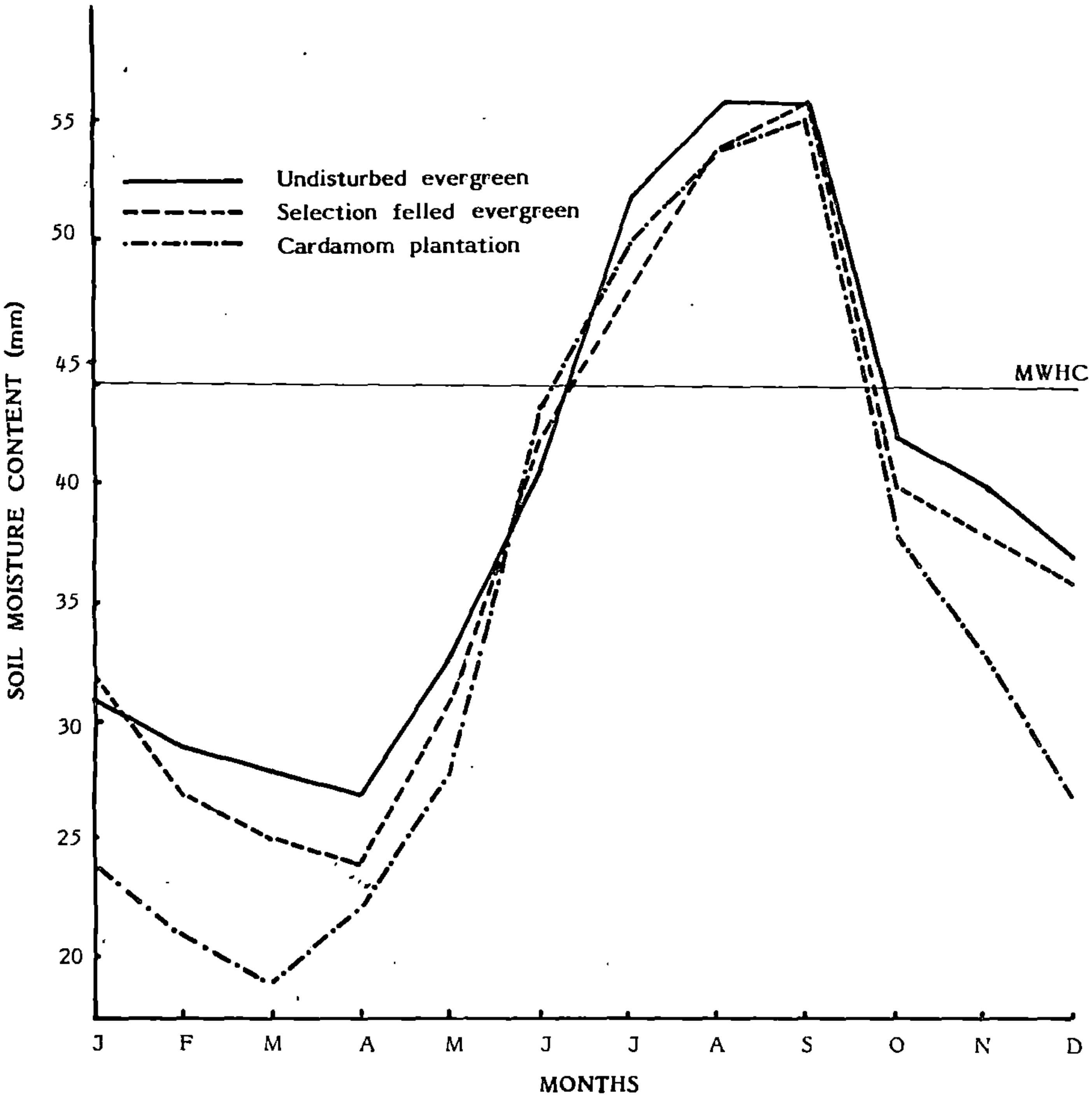


Fig.14 Monthly soil moisture content in the three experimental plots

With the onset of dry season, significant differences were observed indicating the roll of overstorey in moisture conservation. These results are substantiated by the studies on light and soil temperature.

If rainfall is the main factor controlling the geographical distribution of rainforests (Walters, 1971), soil moisture is dominant in determining local patterns of forest types (Longman and Jenik, 1987). Although the type of vegetation (evergreen forest) is the same in the three study plots, the difference in soil moisture is attributed to vegetation disturbances rather than texture of the soil (Schulz, 1960).

There is a strong belief that rainforests occur only in continuously moist locations (Schimper, 1898). On the contrary, wet evergreen forests (rainforests) are found to occur in seasonal climates also (Koppen, 1930) and the total rainfall is attributed to be the main factor (Walters, 1971). The maximum water holding capacity (MWHC) of the soils in the study area was found to be 44mm (Fig. 14). Taking this factor into consideration it can be noticed that only during five months in a year the soil moisture content is above or nearly equal to the maximum water holding capacity while during seven months it is below the same (The soil moisture is above water holding capacity due to continuous rain in the period). Maximum soil moisture deficit is observed in February to April for undisturbed evergreen and selection felled plots while in cardamom it is from December to May. This is the period when the forest is phenologically active with gregarious flowering and copious litterfall (Table 20 and Table 21). Unlike continuously wet rainforests which are species-wise more diverse but phenologically less active, seasonal forests are poorer species-wise while being extremely dynamic phenologically (Basha, 1987).

4.6 Phenology

4.6.1 Phenological Observations

Phenology refers to the periods of leaf fall, flowering and fruiting and plays a key role in maintaining the equilibrium of the ecosystem. The results of the phenological observations (Table 20) conducted for a period of 12 months in the study area indicates that flowering of dominant species occurs during the dry season January-March. Subsequently fruiting is towards the monsoons to provide favourable conditions for germination. It is well known that the seeds of tropical evergreen forest trees have very short viability period. The leaf fall is observed through out the year with maximum in the dry season which is evidenced by the results on quantification of litterfall.

Table 20. Phenological observations

Sl. No.	Species	Flowering	Fruiting	Leaf fall
1.	Artocarpus heterophyllus	Feb-Mar	Apr-Jun	Peak in Mar-Apr
2.	Cinnamomum malabathrum	Dec-Mar	Sep-Dec	-do-
3.	Cullenia exarillata	Jan-Mar Oct-Nov	May-Aug Feb-Mar	-do-
4.	Dimocarpus longan	Jan-Feb and Jun	Jul-Aug and Dec	-do-
5.	Drypetes malabaricum	Feb-Apr	May-Jul	-do-
6.	Dysoxylum malabaricum	Feb-Mar	Jun-Au	-do-
7.	Holigarna arnottiana	Jan-Feb	Jul-Au	-do-
8.	Macaranga peltata	Jan	Mar	-do-
9.	Mesua ferrea	Feb-May	Apr-Ma	-do-
10.	Palaquium ellipticum	Jan-Mar	Jun-Ju	-do-
11.	Agrostistachys borneensis	Jan-Feb	Mar-Ap	-do-
12.	Myristica dactyloides	Aug-Oct	Nov-Ja	-do-

4.6.2 Quantification of leaf litterfall

The results of the studies pertaining to litterfall (Table 21) reveal that maximum litterfall is observed during February, March and April regardless of the ecosystem under consideration (Fig. 15). This is effected by high air

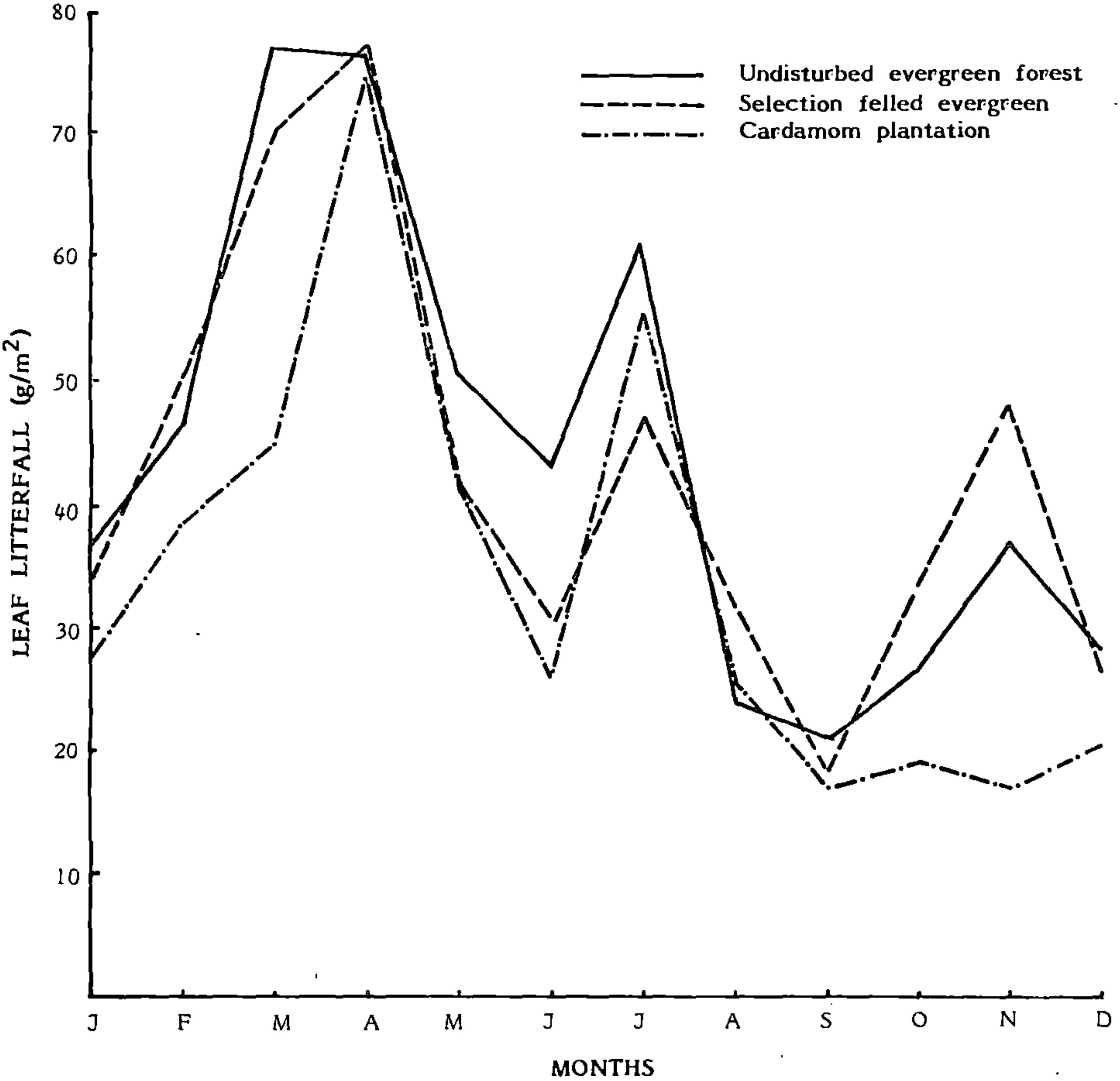


Fig.15 Monthly leaf litterfall in the experimental plots

Table 21. Leaf litter fall in the experimental plots (g/sq.m)

Experimental Plots	Months												Total Litter fall (Kg/ha/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Undisturbed evergreen Forest	36.7	46.6	76.9	76.6	50.5	43.3	60.9	23.9	21.0	26.8	36.9	28.4	5280
Selection felled Forest	33.9	50.3	70.5	77.3	41.3	30.5	47.1	31.7	18.2	33.4	48.4	26.7	5093
Cardamom Plantation	27.4	38.3	45.1	74.5	41.7	26.0	55.5	25.7	17.2	19.1	17.2	20.6	4080

n=9

temperature, low relative humidity (Table 16) and also soil moisture content (Table 19). The leaf litterfall during these months accounts for almost 38 percent of the total litterfall. An unexpectedly high leaf fall in the month of July (Table 21) is the result of a gale storm which struck the area. Leaf fall during the monsoons (May to September) is variable but low compared to that of the dry season. All species shed their leaves heavily during the dry season, but being evergreen the forest always has a cover, only it is less during these period.

There is a significant variation in the total litterfall among the three ecosystems under consideration. An analysis of variance (Table 22) confirms the statement.

But the interaction between vegetations and period is feeble but the variation between months is significant.

Table 22. Analysis of variance of leaf litter fall in the experimental plots

F1 -- VEGETATION (3 types)

F2 -- PERIODS (12 months)

Source of variation	Sum of squares	Degree of freedom	Mean Square	F	Significance of F
F1 Vegetation	6196.421	2	3098.211	12.669**	
F2 Period	88552.071	11	8050.188	32.918**	
F1 x F2	8894.682	22	404.304	1.653	
Explained	103643.17	35	2961.234	12.109	
Residual	70431.402	288	244.553		
Total	174074.57	323	538.931		

** Significant at 0.01%

This observation is confirmed by the variation in total leaf litterfall for twelve months in the plots while undisturbed forest recorded a leaf fall of 5280 kg/ha/yr, the cardamom plantation produced 4080 kg/ha/yr. The selection felled area occupied a middle position with 5093 kg/ha/yr.

The values for the three ecosystems are similar to those obtained in Brazil (Klinge and Rodriguez, 1968), Columbia (Foster and de las Salas, 1976), French Guiana (Puig, 1979), Attappady in South India (Pascal, 1988). The litterfall recorded by Rai (1981) for Karnataka, India is lower (3000 to 4000 kg/ha/yr). Pascal (1988) has attributed this to lower basal areas in plots investigated by Rai. Chandrasekhara (personal communication) working in the same area as the present investigation has arrived at a litterfall figure of 14000 kg/ha/yr. The reasons for this overestimation may be attributed to not only differences in methodology and tree parameters but also to adverse climatic conditions during the study period of the investigator. During 1987-88, there was a drought and the total annual rainfall in Nelliampathy was less than 2000mm. On the contrary, during the present work (1989), the rainfall was over 3000mm.

This observation permits us to deduce that the variations in litterfall in the three plots of the present study is due to the differences in the basal area. Our enumerations reveal that the undisturbed plot has the maximum basal area of 73.2 sq.m/ha while the cardamom plantation only 49.2 sq.m/ha. The selection felled area possessed a basal area of 54.08 sq.m/ha.

4.6.3 Nutrient input through leaf litterfall

The concentration of nutrients in the litterfall shows (Table 23) that calcium and nitrogen are the dominant nutrients while the content of phosphorus is the lowest.

Table 23. Concentration of nutrients in leaflitter *

Nutrient	Concentration (mg/kg)
N	7400
P	288
K	3100
Ca	10900
Mg	3800

* Samples for 12 months were composited before analysis.

Herrera (1979) has found that nitrogen and calcium are the dominant nutrients in the litter of Amazon forest. High amounts of calcium in the litter of the study area has been reported by Sankar (1990).

The results of nutrient input through litterfall indicate that maximum nutrient input for nitrogen, phosphorus, potassium, calcium and magnesium is observed in the undisturbed evergreen forest and least for the cardamom plantation (Table 24).

Table 24. Annual input of nutrients through litterfall in the expe: ..ental plots (kg/ha)

Experimental plots	Total litterfall	Annual input				
		N	P	K	Ca	Mg
Undisturbed evergreen plot	5280	39.07	1.52	16.37	57.55	20.06
Selection felled evergreen	5093	37.69	1.47	15.79	55.51	19.35
Cardamom plantation	4080	30.19	1.18	12.65	44.47	15.50

The selection felled plot occupies a middle position. This difference in nutrient input is governed by the difference in the quantum of annual litterfall.

4.7 Soil Nutrients

The depth-wise nutrient status of soil is given in Table 25. The concentration of all nutrients is highest in the surface layer. This confirms the premise that nutrients are more available in the uppermost layer in tropical soils which is the result of the humus content in the same (Sanchez, 1976). With depth there is a lowering in the concentration of all nutrients.

Table 25. Soil nutrient concentration (profile) in the undisturbed evergreen forest plot.

Depth (cm)	Nutrient (mg/kg)				
	N	P	K	Ca	Mg
00 - 20	2300	16	110	930	200
20 - 40	1800	9	95	740	155
40 - 60	1255	7	60	405	75
60 - 80	2100	6	45	400	45
80 - 100	1900	6	43	360	30

n = 1

Typical to tropical ferralitic soils, the group to which the soils in the study area belong (Basha, 1987), the available phosphorus content is very low. The level of available calcium is higher than that of available potassium, although the values for total potassium are reported to be higher than total calcium for these soils (Sankar, 1990). This shows that calcium is more mobile than potassium.

The comparative soil analytical data for the three plots is presented in Table 26. The highest values for all nutrients is in soils of the undisturbed evergreen forest and the lowest for the cardamom plantation. The selection felled plot occupies a middle portion. As litter is a major contributor in the nutrient inputs to the ecosystem

Table 26. Soil nutrient content in surface layer (0 - 20cm) in the experimental plots

Experimental plots	Nutrient (mg/kg)				
	N	P	K	Ca	Mg
Undisturbed evergreen plot	2300	16	110	930	200
Selection felled evergreen plot	2070	14	100	865	185
Cardamom plantation	1750	12	85	710	150

(Proctor, 1987), these differences in soil nutrient status are in confirmation with the litterfall data from the respective plots (Table 21).

4.8 Regeneration

In certain cases, like in the present study regeneration is affected by biotic interactions. The results reveal extremely diverse status, both qualitative and quantitative, of regeneration in the three plots. The results given in Table 27 reveal that the four types of regenerating forms (unestablished seedlings, established seedlings, advance growth and saplings) are available for six species out of sixteen in the undisturbed evergreen plot.

Table 27. Regeneration in the undisturbed evergreen forest plot

Sl. No.	Species	Number of seedlings					
		Unestablished	Established	Advance growth	Sapling	Total	Percentage
1.	*Palaquium ellipticum*	89	6	1	1	97	38.6
2.	*Mesua ferrea*	17	14	1	1	33	13.1
3.	*Persea macrantha*	12	7	2	1	22	8.8
4.	*Syzigium cuminii*	9	7	3	...	19	7.6
5.	*Dimocarpus longan*	8	6	3	...	17	6.8
6.	*Actinodaphna malabarica*	10	4	1	2	17	6.8
7.	*Phoeba lanceolata*	7	3	1	1	12	4.8
8.	*Trichilia connaroidies*	4	1	2	1	8	3.1
9.	*Cinnamomum malabathrum*	...	3	1	...	4	1.6
10.	*Drypetes wightii*	2	...	1	1	4	1.6
11.	*Vernonia arborea*	...	1	3	...	4	1.6
12.	*Meiogyne pannosa*	1	1	1	...	3	1.2
13.	*Gomphandra coriancea*	1	1	...	...	2	0.8
14.	*Holigarna arnottiana*	...	...	1	...	1	0.4
15.	*Dysoxylum malabaricum*	...	...	1	...	1	0.4
16.	*Drypetes malabarica*	...	1	...	...	1	0.4
	Total	163	57	22	9	251	100
	Percentage	64.5	22.7	9.2	3.6		

The most dominant among the regenerating tree species is Palaquium ellipticum followed by Mesua ferrea, Persea macrantha, Dimocarpus longan, Actinodaphne malabarica and phoebe lanceolata. The association in this plot, although is Palaquium-Cullenia (according to IVI Table 7), the regeneration of Cullenia exarillata is low. In its position a new species for the plot, but not for the area, Persea macrantha has appeared indicating the everchanging composition of the forest but maintaining equilibrium (Brokaw and Scheiner, 1989). The undisturbed plot presents a normal regeneration status (Plate 1) for such type of ecosystems in the Western Ghats (Basha, 1987; Pascal 1988).

Further, seedlings of certain light demanding species, seed trees of which were absent in the plot could be observed. Vernonia arborea an Asteraceae tree member which is a colonizer in gaps was observed especially in areas with light intensity above 20000 lux. The seedlings of certain species were absent although members above 30 cm gbh could be located during the vegetation survey. These are Agrostistachys borneensis, Macaranga peltata, Garcinia morella, Debregeasia longifolia and Myristica dactyloides. It is worth mentioning that the seed bearers for the first four species were absent in the plot and also they were represented feebly in the undisturbed evergreen forest plot.

The regeneration survey revealed that 64.9% belong to the category of unestablished seedlings, 22.72% established, 8.80% to advance growth and 3.60% to saplings indicating the mortality during natural succession.

In the selection felled plot, the normal regeneration was hampered by the gregarious growth of the shrub *Strobilanthes* sps. (Plate 5). The gaps produced by the selection felling operations in 1985 have been totally colonised by this species, the flowering of which was recorded in 1986. Enumerations were not carried out for seedlings and saplings of tree species since they were almost, absent and *Strobilanthes* sps. belongs to the category of a tall shrub (4 to 5 m in height - Plate 5).

The cardamom plot presents an extremely interesting case of regeneration status for evergreen forest species when the area is subjected to plantation operations. Regeneration of 11 species were observed and all of them belonged to the category - unestablished seedlings (Table 28). The most dominant species was *Palaquium ellipticum*. Seedlings of light demanders like *Macaranga peltata*, *Toona celiata* and *Garcinia morella* were also available. The absence of members belonging to successive categories is the result of continuous weeding and other cultural operations carried out for cardamom (Plate 6).

Plate 5. Gregarious regeneration of Strobilanthes sp. (4 to 5 m in height)

Table 28. Regeneration in the Cardamom plot

Sl. No.	Species	Number of seedlings					
		Unestablished	Established	Advance growth	Sapling	Total	Percentage
1.	Palaquium ellipticum	25	Nil	Nil	Nil	25	30.0
2.	Phoebe lanceolata	18	...	...	...	18	21.7
3.	Syzigium cuminii	10	...	...	...	10	12.1
4.	Actinodaphne malabarica	8	...	...	...	8	9.7
5.	Macaranga peltata	6	...	...	...	6	7.3
6.	Holigarna arnottiana	4	...	...	...	4	4.8
7.	Toona ciliata	4	...	...	...	4	4.8
8.	Persea macrantha	4	...	...	...	4	4.8
9.	Garcinia morella	2	...	...	...	2	2.4
10.	Meiogyne pannosa	1	...	...	...	1	1.2
11.	Drypetes wightii	1	...	...	...	1	1.2
	Total	83	Nil	Nil	Nil	83	100

Thus the normal succession of evergreen forest tree species in the cardamom plot is hampered. This poses a threat to the status of the canopy cover in the plantation in the future.

Plate 6. Hampered regeneration in cardamom plot due to cultural operations.

5. CONCLUSION

CONCLUSION

The evergreen forest ecosystem shows all physiognomic features typical to such formations. This is illustrated by the shape and size of trunks, crown; colour and blaze of bark; branching pattern; coppicing power; buttressing; cauliflory and ramiflory. These features are present in the undisturbed, selection felled and cardamom areas. With regard to stratification, the plots show striking differences. If the all storeys are well represented in the undisturbed evergreen forest plot, in the selection felled plot there is a reduction in the number of trees of the third storey with an increased proportion of the same in the first storey. In the cardamom plot due to extension removal of smaller trees, the first storey is feebly represented.

The distribution of trees in various girth classes is normal (L-shaped curve) in undisturbed while atypical in the selection felled plot due to removal of trees above 180cm gbh. The curve was extremely abnormal in the cardamom plantation with very weak representation in the smaller and larger girth classes. Thus there is a drastic change in the evergreen forest structure when the same is converted to a cardamom plantation.

Analysis of vegetation (phytosociology) reveals that the species association according IVI in the undisturbed plot is Palaquium-Cullenia. The same association is met in the cardamom plot also. This is the dominant species association for the area. But in the selection felled plot there is a predominance of Mesua and a Mesua-Palaquium association. This change from normality is attributed to the preferential removal of Palaquium and Cullenia during the selection felling.

Of the 20 species of trees (above 30 cm gbh) available in the study area, 17 were present in the undisturbed, 15 in the selection felled and only 11 in the Cardamom plots. The species diversity index (Simpson's index) was 0.85 and 0.86 for undisturbed and selection felled respectively showing moderately high diversity. The Index was only 0.76 in the cardamom plot rendering it poor floristically. The most important families met within the area are Sapotaceae, Bombacaceae, Clusiaceae and Euphorbiaceae.

Four Categories of leaves (according to area) could be observed in the study plots. Predominantly the canopy species possess notophyllous leaves while the under storey ones mesophyllous. Early successional species Macaranga peltata has macrophyllous leaves while Meiogyne pannosa microphyllous.

The undisturbed evergreen plot has the maximum LAI and the cardamom has the minimum while the selection felled occupies the middle position showing the degree of destruction.

The average monthly temperature did not go below 17 ^{o}C revealing the suitability of the climate for such types of ecosystems. The absolute minimum recorded was 8 ^{o}C in February while the maximum 27 ^{o}C in April. The monthly average humidity varies from 55.1 to 93.3 percent. The maximum humidity experienced during the study period was 100 percent in January and June with above 90 percent in all other months. A minimum humidity of 22 percent was recorded in March. This permits us to conclude that humidity and temperature can vary drastically (diurnal) in seasonally wet evergreen forest areas.

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Eco-physiological Studies in a Tropical Evergreen Forest Ecosystem

(OF NELLIAMPATHY AREA, IN KERALA)

BY
S. SHEIK HYDER HUSSAIN

ABSTRACT OF THE THESIS

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ABSTRACT

Eco-physiological studies in a tropical evergreen forest ecosystem of Nelliampathy area, in Kerala

The physiological ecology of tropical vegetation in general and that of evergreen forest in particular is poorly understood. As regards to South Indian forest ecosystems studies on these lines are virtually absent. The present investigation attempts to generate some basic information on ecological aspects of evergreen forests and also to identify the changes caused by human interference. The study was carried out in three locations adjacent to the Nelliampathy tract representing undisturbed and selection felled evergreen forests and cardamom plantation.

In each of these three ecosystems, 50x50m plots were established in most typical sites of one hectare and the vegetation, structure, phytosociology and floristics were analysed. Estimation of leaf area index, leaf litter and nutrient input through litter, soil nutrients and natural regeneration was carried out. Monthly measurements of micrometeorological parameters namely, air temperature, relative humidity, rainfall soil temperature and soil moisture were taken. Light environment was studied both in vertical and horizontal profiles.

The evergreen forest ecosystem presented diverse physiognomic features exemplified by size of trunks, crown, branching pattern, coppicing power, buttressing, colour and blaze of bark, cauliflory and ramiflory. The disturbance to the ecosystem by way of selection felling and/or raising of cardamom in the understorey has caused drastic changes in the structure. There is marked difference in the distribution of trees among the three storeys and also in various girth classes.

The dominant species association, as indicated by the Importance Value Index is *Palaquium ellipticum* - *Cullenia exarillata* in the undisturbed and cardamom plots, while it is *Mesua ferrea* - *Palaquium ellipticum* in the selection felled plot. Of the 20 species of trees (≥30 cm girth at breast height), 17 were present in the undisturbed, 15 in the selection felled and 11 in the cardamom plot. The index of species diversity was 0.85 and 0.86 for undisturbed and selection felled areas respectively, with the cardamom plot possessing an index of 0.76. The most important plant families occurring in the area are Sapotaceae, Bombacaceae, Clusiaceae and Euphorbiaceae.

The undisturbed evergreen plot has the maximum leaf area index and the cardamom plot the minimum, while the selection felled area occupies the median position as a result of the varying degrees of canopy removal. The vertical distribution of light reveals that while 60 percent radiant energy is received at 30m height, 30 percent at 20m and 15 percent at 10m, only 10 percent is available at the ground level. There is a striking difference in the horizontal distribution of light categorised into varying intensities among the three plots which is affected by the disturbances in the canopy.

The monthly soil temperature did not vary between the undisturbed and selection felled plots, while it was higher in the cardamom plot. A reverse trend was observed in the case of soil moisture with the undisturbed plot having maximum soil moisture. The ecosystems under consideration are phenologically active due to the dry spell and flowering of most species occurs in January-March. While fruiting is towards the monsoon period, maximum leaf fall takes place during the summer. There is significant variation in the total annual litterfall among the three ecosystems with the undisturbed plot occupying the top position and the cardamom plot the bottom. The same trend is followed with regards to the input of N,P,K, Ca and Mg though leaflitter into the ecosystem. The highest value for soil nutrients (0-20cm) was estimated in the undisturbed plot and least in the cardamom plot.

Natural regeneration was normal in the undisturbed evergreen forest, almost absent in the selection felled plot due to the invasion of Strobilanthes sps., while only unestablished seedlings were available in the cardamom plot due to successive weeding operations.

The study reveals that slight and heavy modifications in the evergreen forest ecosystem brings about significant changes in structure, floristics, microclimatic environment and features relating to the functioning of the system, namely, nutrient input and regeneration.