ECOPHYSIOLOGICAL STUDIES IN DISTURBED FOREST ECOSYSTEM: A CASE STUDY AT PATTIKKAD

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Forestry

Faculty of Agriculture
Kerala Agricultural University

COLLEGE OF FORESTRY
Vellanikkara - Thrissur

1993

DECLARATION

I hereby declare that the thesis entitled Ecophysiological studies in disturbed forest ecosystem: A case study at Pattikkad 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 any other similar title, of any other university or society.

Vellarikkara,
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CERTIFICATE

Certified that the thesis entitled **Ecophysiological studies in disturbed forest ecosystem: A case study at Pattikkad** is a bonafide record of research work done by **Mr. P.O. Nameer**, (91-17-04) 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.

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We, the undersigned, members of the Advisory Committee of **Mr. P.O. Nameer**, a candidate for the degree of Master of Science in Forestry, agree that the thesis entitled **Ecophysiological studies in disturbed forest ecosystem: A case study at Pattikkad** may be submitted by Mr. P.O. Nameer 91-17-04 in partial fulfilment of the requirement for the degree.

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ACKNOWLEDGEMENTS

It is a great privilege to express my deep sense of gratitude to Dr. P.K. Asokan, Chairman of Advisory Committee and Associate Professor, College of Forestry, Kerala Agricultural University, for his accurate planning, introspective guidance, constructive suggestions, keen interest, co-operation and useful criticism in executing the present work and the preparation of the thesis.

It is with great respect and devotion, I place on record my deep sense of gratitude and indebtedness to Dr. S. Sankar, Co-Chairman, Advisory Committee and Scientist-in-charge, Division of Soil Science and Division of Agroforestry-cum-Publicity, Kerala Forest Research Institute (KFRI), for the erudite guidance, unflagging enthusiasm, and unstinted support, constant evaluation, right from the inception of the work to the preparation of the manuscript and has left in deliable mark on the whole work.

My sincere thanks to Dr. C.C. Abraham, former Special Officer, College of Forestry and Dr. Luckin C. Babu, Associate Professor, College of Forestry for rendering propitious support for the successful completion of the work.

I place on record my sincere gratitude to Dr. S. Chand Basha, I.F.S., Director, KFRI for allowing me to avail the various facilities in the Institute.

I place on record my deep sense of gratitude to Dr. Pouchpadas, Director, French Institute, Pondichery (FIP), and Dr. G. Bourgorne (FIP) for allowing me to use the facilities at FIP. I am also grateful to other FIP Scientists - Dr. F. Obein, Mr. Regis Lan franchi, Mr. Aravazhi, Dr. Silanjan, Mr. Parthiba, Dr. Dario, Dr. Garrigues, Dr. Ramesh, Severine, Ann-Marie, Isabell, Alex, Julie and Catherine for their warmth, hospitality and facilities provided during my stay at FIP.

I am extremely grateful to Dr. U.M. Chandrashekhara, and Dr. N. Sashidharan, of KFRI, for the authentic identification of the plants, Dr. Jose Kallarikkal (KFRI) for the analysis of leaf area index and light, Dr. J.K. Sharma (KFRI) for the leaf area measurements.

My profound thanks are due to Mohankumar, K., Santhoshkumar, S., Hari Narayan, M.K., Sanal Kumar, M.G., Ajitha, S. and Jayasree, P.P. of Soil Science Division, KFRI, for their timely and earnest help.

I have no words to express my sincere gratitude to Mr. P.C. Anil and Mr. M. Pradeepkumar who had helped me in the field and in the lab and for the fruitful discussions that we had over the cup of tea.

Among the colleagues I am extremely grateful to Mr. Suman Jacob George, who had helped me with the data analysis and for the useful discussions. My profound thanks are also to M/s E.V. Anoop, A.V. Santhoshkumar, A. Jayamadhavan, V. Jamaludheen, S. Gopakumar, T.K. Kunhamu and T.R. Vinod for their help and constant support throughout.

I would not have completed my field work but for the help of Mr. Varghese and Mr. K.B. Sajeevkumar. I really appreciate the technical skill and perseverance with which they meticulously carried out my instructions in the field.

My profound appreciation to Mr. O.K. Ravindran, PEAGLES, Mannuthy for the care and interest he has taken in typing the manuscript.

Above all the moral support and constant encouragements extended by my parents and other family members are gratefully acknowledged with deep sense of gratitude.

P.O. NAMEER

CONTENTS

LIST OF TABLES

LIST FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

The tropical regions are endowed with a remarkably high level of biological diversity and habitat heterogeneity, there are roughly twice as many species in tropical regions as temperate ones (Singh and Singh, 1992). However, many tropical ecosystems are fragile, being precariously balanced with the prevailing environment. Almost three quarter of humanity resides in the tropics and currently the population is increasing at the rate of about 2.5 per cent annually, generating tremendous pressure on various ecosystems. The development oriented anthropogenic activities are leading to degradation and alteration of ecosystems at a massive scale which in turn is contributing to global change.

The physiological ecology of tropical vegetation in general and that of 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 ecophysiological research is limited and that the physiological ecologists are concentrated in the temperate zone are the important ones.

Secondary forests, degraded zones and other human impacted areas comprise an increasingly large proportion of tropical lands. Such systems have received comparatively little attention, compared with 'natural' systems, and there is a growing need for improved scientific understanding on which the effective management of impacted systems including rehabilitation of degraded areas could be based. These systems may well hold the key for long-term solutions to human environment problems in tropics.

The current trends of degradation involve changes in composition and productivity that are adversely affecting the capacity of the systems to support vegetation cover and also human and other organisms. Recently Hussain (1991) has studied the difference in ecophysiological aspects of an evergreen forests, selection felled forest and cardamom plantations. Moist deciduous forests, which form over 50 per cent of the forest cover of the state and also occupy the buffer zone, between human populations and evergreen forests are experiencing the maximum impact from fire, grazing, green and dry manure removal, firewood cutting and collection of non-timber forest products. Degradation due to such disturbance is rampant and in the village-forest interface, where the forest cover is fast disappearing. In order to arrest or reverse these changes, we need to improve our understanding on the changes in the structural and functional properties of forests on disturbance, the critical limits beyond which forests do not recover after the disturbance factor is removed or the thrusholds of disturbance and the mechanisms that determine, the manner and the rates by which forest respond to recover from a disturbance.

Moist deciduous forests of Western Ghats are one of the least studied ecosystems. Practically the literature available regarding the impact of disturbance on the structure and functioning of the moist deciduous forests are few.

So the present investigation was carried out with the objectives to find out the floristic, structural, functional, physiological, edaphic and micrometeorological changes accompanying the degradation of a moist deciduous forest due to human interference.

Review of Literature

REVIEW OF LITERATURE

In India Moist Deciduous Forests (MDF) rank next to the Wet Evergreen Forests in extent. Kerala has approximately 2300 km^2 of MDF which accounts for more than 33 per cent of the total forest area in the state. The area under MDF has been under constant threat from human interference and the resulted degradation, mostly because of the pressure of growing population and human greed.

The consequence of ecosystem degradation and the importance of research in this area were realised only recently. So the literature available are limited especially with respect to tropical situations. The information available are reviewed here.

2.1 Taxonomy of Indian Deciduous Forests

Champion (1936), Chandrasekharan (1960), Champion and Seth (1968a)and Muller-Dombois and Ellenberg (1974) have given excellent reviews of vegetational classifications. Two dominant vegetation classification schemes are available for the Indian Subcontinent, the English school and the French school. The English school originally proposed by Schimper

(1903) was subsequently expanded by Stebbing (1922), Champion (1936) and later by Champion and Seth (1968b

The originator of the French scheme was Gaussen (1959) whose concepts were expanded and further applied to the Indian subcontinent by Gaussen et al. (1961a, 1961b, 1963a, 1963b, 1965a, 1965b, 1968a, 1968b, 1971, 1972, 1973, 1978) and Gadgil and Meher Homji (1982). At the regional level, the English school used the physiognomic and species composition criteria for the classification of forest types at first and second levels respectively, while the French school used the composition criterion at the first level and physiognomy at the second level.

The name Deciduous Forest was the contribution of Stebbing (1922). These forests were also known as Monsoon Forests (Schimper, 1903) and Deciduous Monsoon Forests (Stamp, 1926). Champion (1936), who was first to suggest a practical classification for the whole vegetation of British India, identified two formations under Deciduous Forests, viz., Tropical Moist Deciduous Forests Champ. and Tropical Dry Deciduous Forests Champ. The former was further subdivided into The South Indian Moist Deciduous Forests Champ. and the North Indian Moist Deciduous Forests Champ.

In Kerala we have only South Indian Moist Deciduous Forests, as is evident from the regional prefix.

The French school classified the Indian vegetation into 29 communities based on species composition as depicted in the 12 vegetation maps of the Indian subcontinent (Gaussen *et al.*, 1961-1978). Puri *et al.* (1983) equated the French School's series *Tectona* - *Dillenia* - *Lagerstroemia lanceolata* - *Terminalia paniculata* with South Indian Moist Deciduous Forests.

2.2 Vegetation

2.2.1 Succession

Decades of observational and experimental studies have revealed tremendous variation in patterns and processes by which species enter, develop and depart from a community. There have been numerous, often divergent, approaches to a general unifying theory of succession (Clements, 1916; Odum, 1969; Drury and Nisbet, 1973; Horn, 1974; Whittaker and Niering, 1975).

Early concepts (Clements, 1916) assume that following a disturbance, a community will regenerate a resemblance of itself by an orderly and predictable series of species replacements. This assumption allows a deterministic, "single pathway" prediction of succession. Odum (1969) similarly views succession as a process of ecosystem development. The JABOVA model (Botkin et al., 1972) observes successional changes on an individual tree basis by considering competition, environmental growth rate and survival characteristics. A slightly different approach was taken by Horn (1974). He observed for each individual tree in the canopy, the understory species that may replace it, and assigned a probability for that event. The replacement probabilities were used to predict the successional changes. Alternatively, Whittaker (1975) characterizes succession by developmental trends, that is characteristics of ecosystem that change through succession. These include species diversity, productivity, biomass and nutrient stock. The three models of Conell and Slayter (1977) describes succession in terms of species facilitation, tolerance and inhibitive properties.

2.2.2 Patterns of succession after disturbance

The ecological literature is rich, with descriptions of how the vegetation in many regions varies in sequence overtime following a major disturbance (Whitehead, 1982; Smith and Goodman, 1987; Archer et al., 1988; Whittaker et al., 1989). The earlier concepts of plant succession deal with disturbance on a general way with emphasis on replacement sequence (Clements, 1916). Plant succession models driven by normal or natural disturbance periodicities and/or altered inter disturbance were developed by several workers (Noble and Slatyer, 1977; Kessel, 1979; Cattelino *et al.*, 1979). Classical work of Whittaker *et al.* (1989) on succession in Karakatu Islands reveals the variation in sequence of succession after a disturbance.

Yet despite the variability inherent in this complex process, two patterns are commonly described for secondary succession series (1) most species either survive disturbance or colonize shortly thereafter, and (2) long term changes in composition occurs through gradual expansion and decline of species, rather than recruitment and replacement.

A large increase in above ground biomass with age upto 20 years have been noted by Bartholomew and Meyer (1953). In a study on succession after slash and burn agriculture herbs and perennial grasses like *Dendrocalamus strictus* have been reported to appear first after abandonment. Fast growing woody species were found to be common after nearly one year. The distribution of early colonizers were due to chance distribution of seeds, both in the soil and dispersed onto the site immediately following the disturbance. The distribution has also been reported through root suckers and stumps/coppice

(Ewel *et al.*, 1981; Ramakrishnan *et al.*, 1981, Uhl *et al.*, 1982).

Saxena and Ramakrishnan (1984) found that the early stages of secondary succession following the burning tended to conform closely to "initial floristic' composition of Egler (1954) under shorter 'jhum' cycles but followed 'relay floristic model' of Clements (1916) and Odum (1969) for longer 'jhum' cycles. On an abandoned shifting cultivators field in South Central Africa, species diversity was found least after four years of disturbance (Stromgaard, 1986). The detailed vegetation analysis of succession after cessation of shifting cultivation by Rao and Ramakrishnan (1987) shows that the standing biomass contribution by ruderal (R-) strategists (herbs) reduce drastically as fallow age increases, while competitive (C-) strategists (bamboo and perennial weeds) and stress-tolerant (S-) strategists (tree and shrubs) contributed more. Thus the succession involves a C-S-R strategy of Grime (1979a). In an abandoned fallow area of Venezuala it was estimated that mature forest basal area and biomass would be achieved in only 190 years (Saldarriaga *et al.*, 1988).

Recolonization of vegetation taking place after slash and burn agriculture in wet tropical lowlands usually start with rapid soil coverage by a mixture of weedy herbacious plants and vines. In the distribution of vegetation along with other factors, pre-disturbance coverage in the soil is very important. Number of species and biomass increases constantly for the first few years. The vegetation will be comparable to that supported by the area before slash and burn agriculture after a long time.

The adaptive patterns shown by early successional species on a clearfelled area have been reported by Salisbury (1929). He reported about copious production of offsprings by early successional species and lavish provisioning of fewer offsprings by later species. Raynal and Bazzaz (1973) found that species with light weight and highly mobile seeds often invade a recently disturbed ecosystem, whereas species with heavier seeds, often animal disseminated, usually enter the succession at later stages. Harper and White (1974) reported that in a recently clearfelled area the early species colonizing were able to adopt an exploitative strategy and were able to attain dominance. In a study conducted in Amazon forest it was found out that many of the more mature trees in secondary forest were of coppice in origin. It also suggested that the best represented families may be intrinsically better at coppice regeneration (Gentry, 1978).

Development of canopy stratification during early succession after felling was studied in a northern hardwood forest. It was reported that intolerant species tended to be indeterminate in growth had a fast growth rate and grew up longer during growing season. Tolerant species tended to be determinate in growth form, had slower growth rates (Bicknell, 1982). In a study conducted in a dipterocarp forest, shade of pioneer species was found to be necessary for subsequent dipterocarp regeneration (Rosario, 1982). Tree density decreased in a cleared forest land in Ghana during the initial stages of succession after clear-felling. One or two of the primary species continued to appear every year (Swaine and Hall, 1983). Early successional species like Macaranga sp., and Musanga sp., dominated in a clear-felled rainforest in Nigeria (Okali and Adams, 1987).

Certain intrinsic property of plants help them to establish on disturbed ecosystems. Early successional species can seldom reproduce locally and must invade recent openings, grow and mature quickly and disperse widely and abundantly to increase the likelihood of reaching new openings.

Successional pattern also depends on the canopy gap. Perhaps the most important effect of canopy gap opening is an increase in the duration and intensity of direct sunlight reaching the lower strata of the forest (Chazdon and Fetcher, 1984). Apart from this, the root competition decreases significantly (Richards, 1952) and the nutrient availability increases considerably (Schulz, 1960). Depending upon the degree of disturbance the vegetation structure alters significantly. Based on the response to the species to the canopy gaps, they have been categorized into three groups (Whitmore, 1984).

Some species will only grow in very large canopy openings (Brokaw, 1985). Like ruderal species, large gap species require high light intensity and temperatures of large gaps for germination and seedling establishment. Early growth is rapid and saplings are able to reach the upper forest strata during the life time of a single gap. This growth pattern may in part account for the scarcity of sapling size classes in these species and the absence of classic L-shaped size-frequency distribution in their populations (Baur, 1968; Hartshorn, 1980; Hubbel and Foster, 1988).

Small gap species are able to survive understorey light conditions owing to low respiration and low light requirements at saturation, but they are dependent on some canopy opening for substantive growth and reproduction (Baur, 1968; Richards, 1952, Whitmore, 1985).

The amount and duration of light are important determinants of establishment success. Tree species can be arrayed along a continuum of adaptive responses to the availability and duration of incident radiation. Species and successional processes characteristic of very large clearings and repeatedly disturbed areas are different from those of large but short-lived gaps.

Succession patterns after disturbance have been a well studied parameter in the tropics. However, such studies in the Western Ghats is very few.

2.3 Regeneration

The observation on the processes of natural regeneration over many decades had contributed a vast store of knowhow of silvicultural practices in forests management (Nair, 1961; Swarupanandan and Sashidharan, 1992).

2.3.1 Process and phases of natural regeneration

All populations are under the flux of two vital but opposite process, viz., growth and death. Regeneration leads to increase in population number (Krebs, 1972). Different kinds of organisms have different kinds of regenerative strategies (Grime, 1979b). Of these, forest trees, by and large, have seed based regenerative strategies, although some species show a certain degree of vegetative regeneration.

Adequate seed supply effective dispersal, good viability and longevity of seeds, successful establishment of seedlings and good conversion to mature trees are all unavoidable for a sustained forest management. Therefore the population structure at each of these life stages, viz., flowering, fruiting, seed dispersal, germination, establishment and the conversion to adult trees determine the structure of mature tree populations. The characteristic regeneration pattern of individual species and forest types are therefore, compromises between the real regeneration potential and the pressure offered by constraints (Fox, 1976).

2.3.1.1 Flowering

In the tropics flowering and fruiting of forest trees are quite often not regular. These irregularities affect regeneration (Dhamanijayakul, 1981).

Flowering phenology of many forests trees, especially the evergreen forests have been studied in the tropics (Holttum, 1931; Holmes, 1956, Koelmeyer, 1959; Medway, 1972, Cockburn, 1975, Ng, 1977; Ng, 1981).

Flowering includes floral bud initiation, development, blooming and floral persistence (Borchert, 1983; Rathcke and Lacey, 1985). Except for a few crop species, forest trees have not been studied on bud initiation, development and blooming.

2.3.1.2 Fruiting

Fruiting includes fruit initiation, growth, ripening fruitfall and the presentation of fruits (seeds) to disperse (Rathcke and Lacey, 1985). Generally flowering periodicities are reflected in fruiting. But, a tree flowering profusely need not always fruit. Bawa et al. (1985) shown that in *Hymmenaea courbanil* (Fabaceae) although flowering take place annually, fruiting is abundant only once in five years. They have also reported abortion of flowers and immature fruits ranging between 1 to 100 per cent.

The predator-seed crop relation has been studied in detail. Janzen (1974, 1978) argues that most seeding in Dipterocarps is a result of predator satiation achieved by individual trees. The time taken by fruits and seeds to mature varies from few weeks to several months (Ng and Loh, 1974). Time of ripening of fruits and seeds are known to be correlated with the zoochorous dispersal in some trees (Smythe, 1970).

Indian literature on forest tree phenology is extremely sparse, although a few studies are available (Krishnaswamy and Mathauda, 1960; Kaul and Raina, 1980; Boojh and Ramakrishnan, 1981; Khosla et al., 1982; Shrivasthava, 1982; Shukla and Ramakrishnan, 1982, Ralhan *et al.*, 1985, Basha, 1987; Hussain, 1991).

2.3.1.3 Dispersal

The place of production of seeds does not have the carrying capacity to grow and sustain them (Gadgil, 1971). Thus competition is avoided by dispersing seeds even at the danger of casualties. The mechanism of dispersal involves wind, water and frugivory (Ridley, 1930). In wet forests seeds of more than 50 per cent of the trees are dispersed by sarcochorus means (eaten by animals) (Dansereau and Lems, 1957). While, the dry forests show a greater percentage of wind dispersal (Baker *et al.*, 1983).

2.3.1.4 Seed predation

Predation is an important factor controlling the viable seed population. Predators can affect the seed population by feeding on photosynthetic tissues, flowers and directly on fruits and seeds. Predation can either be predispersal or post dispersal. There are instances of upto 40 per cent seed predation by rodents (Synnott, 1973). Generally predation decreases with distance from seed tree or with poor seed density. Janzen (1971) suggested a predator escape hypothesis according to which plants escape from predation by immediate germination (Nair, 1961), building up a seedling bank (Grime, 1979b or by satiating them (Howe and Smallwood, 1982).

2.3.1.5 Dormancy

Dispersed seeds generally show a period of rest termed 'dormancy' (Harper, 1977). Seeds of trees of mature phase in wet forests are generally not dormant (Tang and Tamari, 1973) while those of other species extend from two weeks to three years (Mensbruge, 1966). Most species of evergreen forests lack dormancy (Hoi, 1972).

2.3.1.6 Soil seed bank

All the seeds do not germinate as soon as they are dispersed. A good percentage move a few centimetres down the soil. These form a 'seed bank' contributing viable plants on germination. Keay (1960) has given a review of forest seed banks.

The limited investigations on seed bank beneath tropical forests indicate the prevalence of seeds of secondary species (Symington, 1933; Keay, 1960, Guevara and Gomez-Pompa, 1972; Liew, 1973; Hopkins and Graham, 1983; Enright, 1985). However, the importance of viable soil-seed banks in forest regeneration has been questioned by Whitmore (1983) and Putz (1983) in view of the reported absence of soil seed bank in many tropical rain forest (Ng, 1983, Ladbrach and Humberto Mazuera, 1985).

2.3.1 7 Stand structure

In tropical seasonal forests canopy species, lianas and the pioneer species show a unimodial pattern of germination. On the contrary that of understorey and shade tolerant species germination is throughout the rainy season, without a peak in any of the months (Garwood, 1983).

Size class reflects age and therefore, size structure of populations proxies the dynamics of size conversion in the past. To a certain extend it also tells about the future of the stand (Buell, 1945; Harper, 1977).

Distribution of size classes is the most studied parameter. Nevertheless comparison of data is very much difficult owing to differences in lower size limit, the class intervals and units of measurements (UNESCO, 1978b). Size class distributions were studied for most forest types. Each forest type shows wide variability in stand structure. Some forest types are richer in large stems (>60 cm dbh) than others (Rollet, 1962; Nicholson, 1965), owing to the behaviour of certain species and partly due to the history of stands.

Stand structure always tends to be exponential especially in a semilogarithmic graph (UNESCO, 1978a). When the limit of size class goes further and further down, the graph develops a concavity thus diverging from the exponential model. According to the exponential model the sum of stems larger than a given diameter is equal to the number of stems in the immediate lower class. When the quotient (survival probability) is greater than 0.5 the conversion from one class to another increases (Wyatt-Smith, 1963). Meyer (1952) theorizes that structure of forests over any large area approaches a balanced condition where the quotient of population size in two successive size (diameter) classes approaches a constant value. This ideal state is never observed although stands tend towards it (Harper, 1977). Moreover, the situation can be very much worsened by disturbance, which results in broken lines in graphs (UNESCO, 1978a). Population structure of most tree species show strongly skewed L-shaped graphs while others show an exponential model. Some erratic species show normal distribution. Semilogarithmic graphs show upward or downward concavity indicating sharp decrease in the survival probability of lowermost or uppermost classes (Krebs, 1972, UNESCO, 1978a).

Indian literature on regeneration dynamics of the deciduous forests are widely segmented. A brief review may be found in Champion and Seths (1968b) monograph of Indian Silviculture. Chengappa (1937, 1944) has made detailed studies on the regeneration of Andaman forests. Brief notes on phenology, eye view estimates of regeneration status and seedling establishment of individual species are compiled by Troup (1921). Studies on regeneration and the different stages of regeneration are almost lacking as far as Western Ghats are concerned. The only study on regeneration dynamics from Western Ghats is by Swarupanandan and Sashidharan (1992).

2.4 Nutrient cycling

Litter plays a fundamental role in the cycling of nutrients and in the transfer of energy between plants and soil, functioning as fuel for the nutrient cycles in the uppermost layers of the soil (Medwecka-Kornas, 1970). The importance of the detrital pathway to the overall ecosystem productivity and nutrient cycling has long been recognized and is reflected in the voluminous literature on this subject matter (see reviews by Bray and Gorham, 1964; Cole and Rapp, 1981; Waring and Schlesinger, 1985 and Vogt et al., 1986). Litterfall, decomposition and turnover rates have been reported from diverse ecosystems. Van Cleve and Norman (1978) from higher altitudinal forests of Alaska, Lamb (1985) from Australian eucalypts forests, Das and Ramakrishnan (1985) from subtropical *Pinus kesiya* of north east India, Stohlgren (1988) in the Sierran mixed coniferous forests. Harmon et al. (1990) from a picea/tuga forest, Chandrashekara (1991) for an evergreen forests, before and after gap formation, of western ghats, Hussian (1991) again for an evergreen forests, of western ghats, Kumar and Deepu (1992) for the moist deciduous forests of western ghats. A vast majority of the works cited are however, from temperate and/or monoculture stands and only a few reports are from tropical forests.

2.4.1 Litter production rates

Litter represents an input-output mechanism for mineral nutrients and organic matter. The amount of detritus or litter produced vary markedly among ecosystems and a number of factors appear to control this parameter.

Bray and Gorham (1964) have shown that an inverse relationship exists between the total amount of litter produced per year and the latitude of the locality. Das and Ramakrishnan (1985) reported that for a *Pinus kesiya* stand by North-East India, the total litter production ranged from 6663 to 8984 kg^{-1} ha^{-1} yr^{-1}, while the needle litter ranged from 6383 to 6908 kg ha^{-1} yr^{-1}, lower than the values projected by Bray and Gorham (1964). For a secondary successional stand on well-obtained uplands of the East Gulf Coastal Plain of Mississippi, Hinesley et al. (1991) suggested that foliage litter mass was in conformity with the Bray and Gorham's hypothesised values. Nevertheless, the proportion of reproductive parts were lower than the values reported by Cromack and Monk (1975), Grizzard *et al*. (1976) and Rolfe (1975).

Annual litter production in warm temperate forests range from 5 to 7 t ha^{-1} yr^{-1}, but can be as high as 18 t ha^{-1} yr^{-1} (Bray and Gorham, 1964, Rodin and Bazilevich, 1975). Values reported for tropical forest formations vary widely 5.5 to 14.8 t ha^{-1} yr^{-1} (Bray and Gorham, 1964), 7 t ha^{-1} yr^{-1} (Cornforth, 1970), 9.4 t ha^{-1} yr^{-1} (Bernhard, 1970), 11.4 t ha^{-1} yr^{-1} (Golley *et al*., 1975), 8.8 to 12 t ha^{-1} yr^{-1} (Proctor *et al*., 1983), 7.3 to 10.5 t ha^{-1} yr^{-1} (Spain, 1984). In India, Singh and Ramakrishnan (1982) and Boojh and Ramakrishnan (1982) have reported annual litter production values as 5.5 t ha^{-1} yr^{-1} and 9 t ha^{-1} yr^{-1} respectively for the North East Indian tropical evergreen forests.

The annual litter production values reported for evergreen forests of Western Ghats also vary widely 3.4 to 4.2 t ha^{-1} yr^{-1} (Rai, 1981; Rai and Procter, 1986), 8.5 t ha^{-1} yr^{-1} (Pascal, 1988) 17.5 t ha^{-1} yr^{-1} (Chandrashekara, 1991), Hussain (1991), 5.3 t ha^{-1} yr^{-1}. Kumar and Deepu reported 12.2 to 14.4 t ha^{-1} yr^{-1} as the annual litter production for a Moist Deciduous forests of Western Ghats

Depending on an array of factors such as lattitude, altitude, stand density and species the amount of litterfall varies widely but it remains as the primary source of nutrient recharge into any ecosystem.

2.4.2 Seasonal variation in litterfall

Lansdale (1988) analysed the total litterfall from 389 forest sites throughout the world using multiple regression analyses considering lattitude, altitude as predictor variables.

In deciduous plantations maximum litter fall was recorded during summer months (Gosh et al., 1982, Kikuzawa et al., 1984). While in deciduous stands in the temperate regions of Northern hemisphere the litterfall normally is concentrated in the autumn with a pronounced peak during October-November (Viro, 1955; Anderson, 1970). Pascal (1988) reported the peak litterfall period as at the end of dry and beginning of the rainy season for the evergreen forests of Attappadi, Western Ghats, where as Chandrashekara (1991) reported a bimodial pattern of litterfall with a major peak during the rainy season of June-September and a smaller peak during the dry post-monsoon period of December-January, for the evergreen forests of Nelliampathies, Western Ghats. Pokhriyal et al. (1989) made a detailed analysis of the leaf emergence and shedding behaviour in *Populas deltoides* at Dehradun. They found that almost 90 per cent of the leaves were shed during October-December. Kumar and Deepu (1992) observed that litterfall followed a monomodial distribution pattern with a peak during the dry period from November-December to March-April.

In short, chronosequencial variations in litterfall are generally observed.

2.4.3 Litter decomposition

Litter decomposition is an important mechanism of nutrient cycling in tropical forest ecosystems. The rates and pathways of litter decomposition are determined by quantitative and qualitative composition of the decomposer community, their physical environment and the biochemical quality of the substrate (Swift *et al.*, 1979).

Litter disappearance rates have been determined for a wide variety of litter types throughout the world. Cold temperate forests are characterised by slow decomposition and mineralisation of organic matter and nutrients (Jenny *et al.*, 1949, Makarenko and Atkin, 1976), while the warmer or more mesic regions, the forest floor accumulation of nutrients and organic matter are generally lower. It is estimated that needles of *Pinus silvestris* spent about six months in the 'L' layer of the soil profile and two years in the F_1 and seven years in the F_2 layer before being humified (Kendrik, 1959). But decomposition rates were markedly higher for tropical forests, ranging from 0.45 to 1.5 per cent per day (Laudelout and Mayer, 1954). In temperate forests the rates are comparatively higher for broad leaved species as compared to conifers (Bray and Gorham, 1964).

In the tropics the decomposition co-efficients (litter fall/stored litter at a given time) obtained also vary widely. Jenny et al. (1949) got decomposition co-efficient values 0 61 to 1.69 for a broadleaved rainforest in Columbia; Hopkins (1966) reported 2.37 for moist evergreen forest in Nigeria, Bernhard Riversat (1972) obtained values which ranged from 3.3 to 4.2 for evergreen forests of Ivory Coast; Kling (1973) reported 1.3 for a Terra firme forest in Brazil where as Franken (1979) reported 1.9 for a riverine forest in Brazil, Puig (1979) got 2.17 for the rainforest of French Guyana; for a Malaysian lowland rainforest Tsai (1975) obtained a value of 2.4. However, for the evergreen forests of Attappadi, Southern Western Ghats, Pascal (1988) reported a decomposition co-efficient of 0.66. Chandrashekara (1991) observed an annual leaf litter decomposition rate of 80 to 100 per cent for the evergreen forests of Nelliampathy, Western Ghats.

Deciduous tree litter usually decompose more rapidly but considerable variation occur between different species. The time required for complete disappearance of original biomass ranged from five to eight months (Kumar and Deepu, 1992). Sankaran (1993) reported a weight loss of 96 per cent teak and 94 per cent for eucalypts, over a period of 18 months.

2.4.4 Factors affecting litter decay

2.4.4.1 Resource quality

Several workers have found a strong negative relationship between initial lignin/nitrogen and the mass disappearance rates of litter (Aber and Melillo, 1982, Taylor et al., 1989). Aber and Melillo (1982) studied the nitrogen immobilization occurred in litter with highest lignin and nitrogen contents. Carbon-nitrogen ratio of the litter has been reported to be a good predictor of decomposition rates (Meentemeyer, 1978; Taylor et al., 1989).

Initial low N concentrations resulted in high maximum litter accumulation, low levels of P in forest litter also resulted in a slower rate of nutrient release (Gholz et al., 1985). Stohlgren (1988) found that the species with the lowest initial concentration of N, P, K, Ca, Mg and Mn retained the greatest proportion of nutrients after six years, in a Sierran mixed conifer forest.

In terrestrial ecosystems leaf litter decay is regulated by an array of factors besides the biochemical quality of the litter. Environmental conditions such as temperature and moisture supply can play a vital role in deciding decay rates (Singh and Gupta, 1977; Pastore and Post, 1977).

2.4.5 Nutrient dynamics of decomposing litter

The concentrations of N increased sharply over the one year period for *Pinus banksiana*, *Betula papyrifera*, *Populus tremuloides* and *Quercus ellipsoidalis* (Bockeim *et al.*, 1991), and six tropical deciduous species (Kumar and Deepu, 1992). But the concentration of P remained constant for about the first 250 days and then increased, while K concentration declined over the one year period. Many studies have reported that K and Mg as the most readily released nutrients and that N on the most slowly released macronutrient (Gosz *et al.*, 1973, Staaf, 1980).

Studies on leaf decomposition have shown the reduction of carbon as the reason for the apparent increase in concentration of many elements. For N, however, microbial fixation of atmospheric nitrogen, through fall, stemflow and translocation of N are also important (Bocock, 1963).

2.4.6 Nutrient cycling following disturbance

Vegetation regrowth following disturbance eventually reduces soil temperature and run off and reestablished relatively closed nitrogen and phosphorus cycles (Marks and Bormanu, 1972), and the forest floor eventually becomes a net sink of organic matter and nutrients (Covington, 1981). A rapid biomass, and nutrient accumulation occurs relatively early in succession (Vitousek and Reiners, 1975, Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983). Nutrient limitation can occur as a result of (a) decreased supply of nutrients, (b) increased demand for than, and (c) accumulation of nutrients in the biomass (Aber et al., 1982, Fisher et al., 1982). In the later phases of succession the growing plants become more conservative in their use of limiting nutrients and such plants either operate with lower nutrient concentrations in active leaves (Birk, 1983) or retranslocate nutrients more effectively from senescing leaves (Miller et al., 1976, Turner, 1981). This relatively efficient use of nutrients of trees causes litter produced by such trees to have high carbon/nitrogen ratio (Vitousek, 1982). High ratio, in turn, cause increased nutrient limitation to decomposers, immobilization of nutrients, decreased nutrient availability to plants, and decreased losses from the whole system (Vitousek et al., 1982) Thus, in general, during secondary succession the nutrient availability decreases with period and the nutrient use efficiency of the vegetation increases, as also observed by Grime (1979b) and Miller (1981).

Regarding litterfall and decomposition few studies have been done in Western Ghat region. Moreover, three out of the four important works are on evergreen forests.

2.5. Ecophysiology

2.5.1 Light utilization

2.5.1.1 Canopy influence on solar spectral characteristics

Plant canopies effect both quality and quantity of light. Under a canopy, the photonfluence rate gets attenuated to varying degrees (Hart, 1988). Light on absorption by photosynthetic pigments undergoes alternation in the red infrared ratio (Hart, 1988). The spectral environment in a canopy is further complicated by sunflecks, where light enters through gap in the canopy (Holmes. 1981). Whitmore and Wang (1959) observed that roughly half the total energy in a low land tropical rainforest in Singapore are due to sunflecks.

Alterations in the composition of short-wave radiations penetrating plant canopy indicates minimal changes in spectral components during noon and maximum changes during sunrise and sunset (Daynard, 1969). Comparing four forest types and two shrub vegetation types in the Netherlands Stoutjesdijk (1972) observed that leaf canopies transmitted very little radiations in the photosynthetically active wavelength and a larger amount of longer wavelength. Stoner et al. (1978) who modelled irradiance within vegetation in Betula alba canopies of northern lattitudes showed that photosynthetically active radiation profile was influenced by foliage area, foliage reflectance and foliage angle.

2.5.1.2 Canopy influence on attenuation of solar irradiation

Plant foliage apart from bringing qualitative changes to the solar spectrum, plays an important part in the quantitative reduction of the incoming radiation. Light measurements at a height of one meter, under a 100-140 year old stand of Pinetum polytrichosum, P. equisetososphagnosum and P. fruitiososphagnosum, showed a reduction of two to six per cent light infiltration during summer compared to winter. Difference between solar radiation under canopy and in the open decreased with increasing cloud cover (Izotov, 1966; Brasseur and Sloover, 1973). Photometric evaluation of the radiation regime under a forest canopy in Sakhalin, Russia showed that maximum photosynthetically active radiations were from noon to 15 hours local solar time under stands of fir, birch, spruce and larch of different densities and ages. Under dense canopy (density index : 1-0.8) photosynthetically active radiation increased six to seven folds. Photosynthetically active radiation under the canopy of birch stand was five times more than that under spruce/fir stand of equal density (Klinstov, 1976). Solar radiation under <u>Cryptomeria japonica</u> stand managed on group selection system was 40-50 per cent higher than an unmanaged stand (Fujimoto, 1973)

Relative light intensity under a <u>Fagus sylvatica</u> stand was 11 to 20 per cent to that in the open during spring and two to three per cent in summer (Draskovits, 1975). In a tropical dry evergreen forest of Thailand (Yoda <u>et al</u>., 1983) noted that the relative illuminance decreased linearly with height. The curve could be split into three segments. The first segment represented the 20 to 31 m layer which intercepted about 90 per cent of the incident light, while second layer with fewer leaves, intercepted negligible amount of light.

Solar radiation and relative transmission within the canopy tended to reach maximum when the sun reached its maximum altitude (Fujimoto, 1973).

Of the above ground environmental factors affecting the life of the 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 relation of tropical plants (Chazdon and Fetcher, 1984).

2.5.2 Leaf area index

Leaf Area Index (LAI) describes the size of the assimilatory apparatus of a plant and serves as a primary value for the calculation of other growth characteristics (Watson, 1952). LAI is critical for estimating fluxes of carbon, solar energy, and water in forested ecosystems, photosynthesis, transpiration, respiration and light interception can be directly related to leaf area (Gholz et al., 1976; Jarvis and Leverenz, 1983) and these processes underlie correlation between leaf area index and productivity (Gholz, 1982; Schroeder et al., 1982).

Leaf area is preferred to leaf biomass as a measure of leaf amount because leaf mass changes from top to bottom of the canopy (Lewandowska and Jarvis, 1977; Nygras and Kellomaki, 1983) and varies seasonally and with leaf age (Smith et al., 1981).

An emperical relationship between sapwood area and foliage area might be expected because they jointly accommodate water movement in trees. In fact,Ritchter (1973) suggested that total waterflow through all roots, stem, branches and leaves is equal. While it is generally known that heartwood does not contribute to water transport. Swanson (1966) found that the entire sapwood of the conifer stems actively transports water. Thus, the high correlation that Grier and Waring (1974) found between sapwood area and foliar weight is not surprising. Kaufmann and Treondle (1981); Marshall and Waring (1986); Long and Smith (1989), and Magnire and Hann (1989) have pointed out that this relationship is species specific. LAI can be measured, without any destruction to forest with an ultra-wide or 'fish'eye' photograph and by using Plant Canopy Analyzer (LAI-2000, 1990).

Ecophysiological parameters of natural forests of western ghat region is perhaps the least studied parameter and the only study in this aspect pertains to that of evergreen forests (Hussain, 1991).

Although research on tropical forest ecosystems have been going on for past one century all over the world, Western Ghats, one the Subcontinent's three richest tropical moist forest areas, started receiving attention only very recently and is evident from literature. Basic ecological studies pertaining to structure and function of the forest ecosystems are highly essential to evolve ecologically sound management procedures and for long term conservation of this fragile ecosystem.

Study Area and Methods

STUDY AREA AND METHODS

3.1 Study area

3.1.1 Location

The present study was carried out at Pattikkad Range of Peechi-Vazhani Wildlife Sanctuary (between 76°15' and 76°27E longitude and 10°30' and 10°42' N latitude) in Trichur Forest Division (Fig.1). The sanctuary covers an area of about 125 km^2, which includes 500 ha of mixed plantation of teak and bombax (Menon and Balasubramanyan, 1985).

3.1.2 Climate

The area enjoys a warm humid climate characteristic of the region. The main sources of atmospheric precipitation are the south-west and north-east monsoons. The greater portion of the rain (78.82 per cent) is from south-west monsoon, between June and September. The rainfall for the period from May 92 to April 93 is 3034.5 mm. As shown in the Fig.2, the mean monthly maximum temperature for the same period (May 92 to April 93) varied from 30.2°C (July) to 38.3°C (March) and mean monthly minimum temperature varied from 19.1°C (January) to 23.9°C (April). The mean monthly maximum humidity varies from 92 per cent (July) to 76 per cent (April-May) and mean monthly

Fig.1 Map of the Peechi-Vazhani Wildlife Sanctuary, showing the study plots

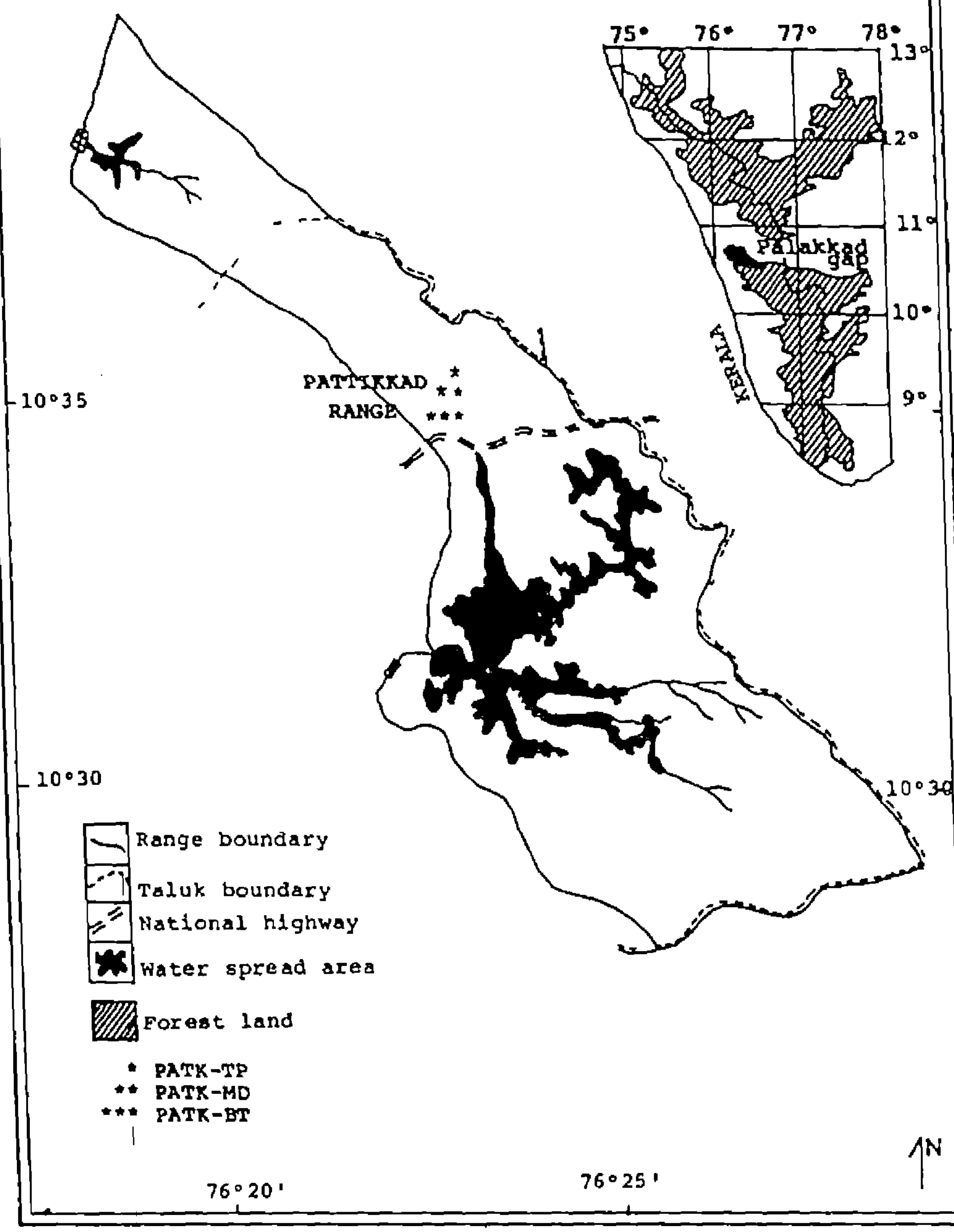
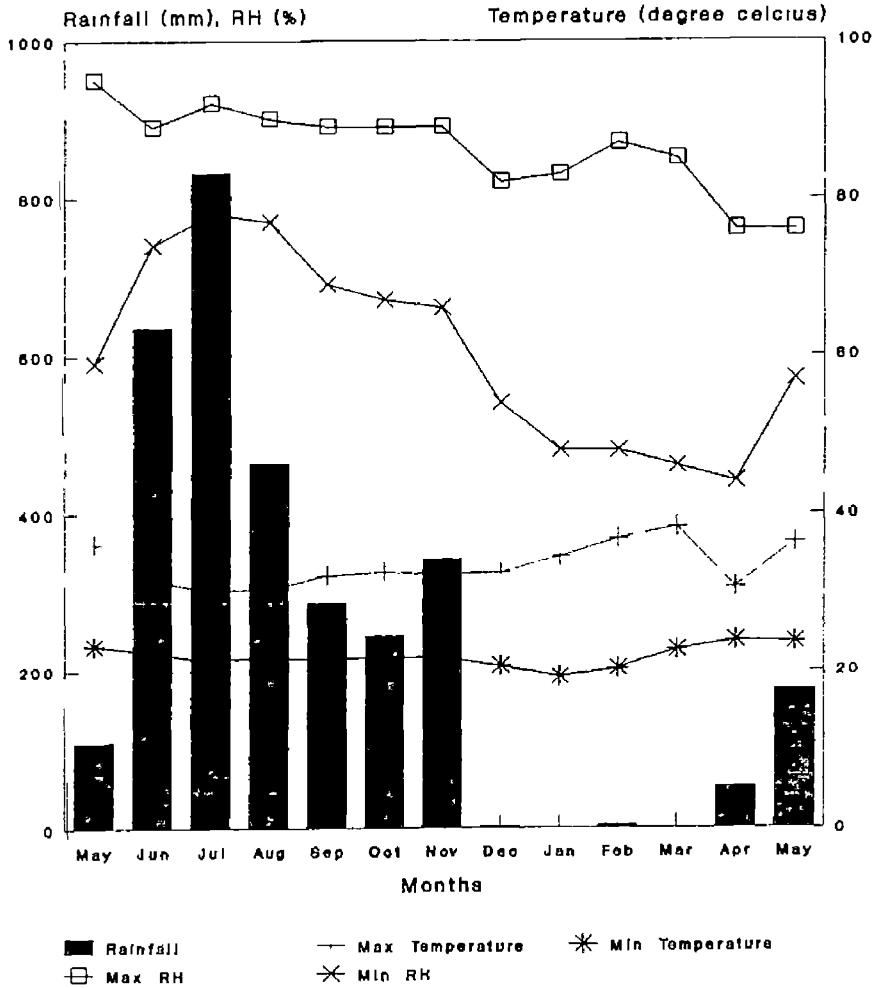


Fig. 2 Weather parameters for the experimental period (May, 1992 to May, 1993).



minimum humidity varies from 78 per cent (July) to 44 per cent (April).

3.1.3 Physiography

Physiographically the whole Thrissur Forest division is distinguishable into five blocks. (Swarupanandan and Sashidharan, 1992). Because of highly rugged, undulating physiography all kinds of aspects are met with. Nevertheless, the area is well-drained with two west flowing rivers, Wadakkancherry river and Manali river. Two irrigation projects are present namely, Peechi and Vazhani, irrigating the agricultural lands towards the west.

3.1.4 Geology, rock and soil

The predominant parent material seen is of metamorphic rocks of the gneiss series, weathering in large sheet, especially on the upper elevations. However, on the lower slopes the rocks tend to become lateritic. Occasionally on the higher areas exposed banks show the occurrence of lateritic parent material (Swarupanandan and Sashidharan, 1992). Owing to active weathering the ground is very much bouldary, especially in the moist deciduous forest areas. The soil is blackish or reddish and loamy.

3.2 Methods

A reconnaissance survey was done at Pattikkad and Machad Ranges of Peechi-Vazhani Wildlife Sanctuary with an objective of identifying three locations for establishment of plots. Three plots namely, highly disturbed (PATK-BT), partially disturbed (PATK-MD) and more or less undisturbed (PATK-TP) (Plates 1, 2 and 3 respectively) have been identified taking into consideration the proximity to human settlement.

3.2.1 Plot establishment

After identifying the location, the plot was established. This was done with the help of compass, plastic ropes, survey chain, tapes and serially numbered pegs. After laying out a plot of 100 m x 100 m (10,000 m^2) it was subdivided into quadrats having size 10 m x 10 m (100 m^2). Each quadrat was also demarcated using pegs, on which X-axis and Y-axis are marked. The experimental layout of the plot is given in Fig.3.

3.2.2 Vegetation

All plants, $\geq$10 cm girth at breast height (1.3 m) in each quadrat, were identified species-wise, serially numbered on two sides (using paint) of the tree and for smaller shrubs

Fig. 3 Experimental layout

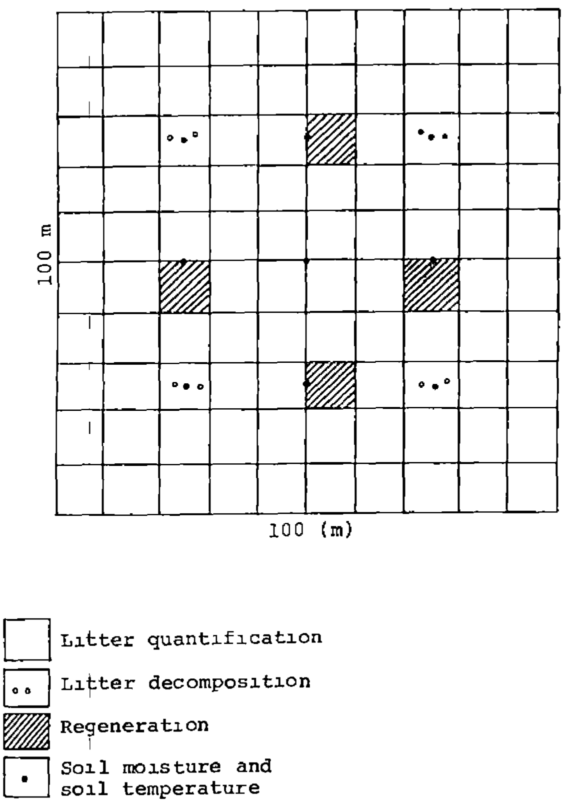
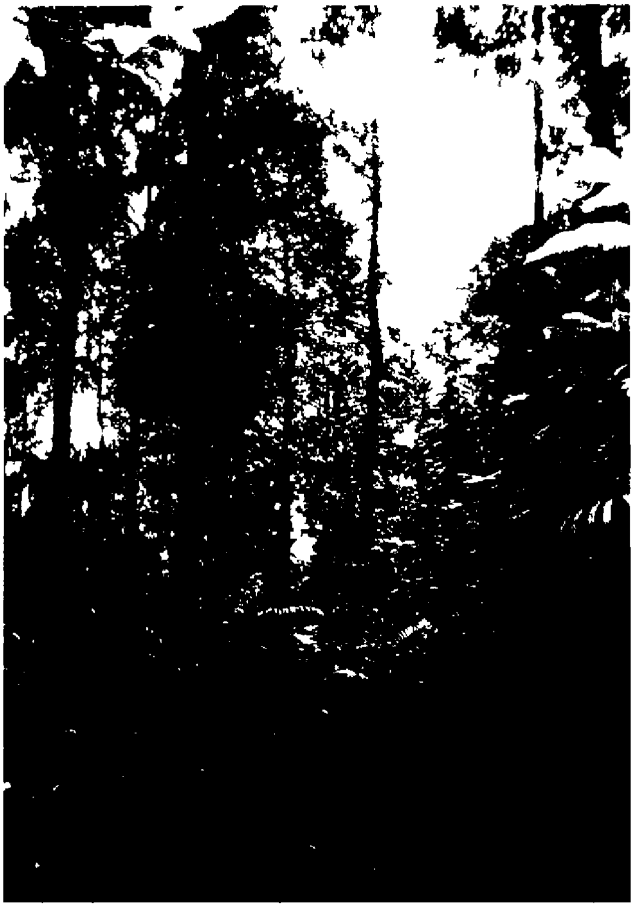


Plate 1 General view of the highly disturbed (PATK-LT) plot

Plate 2 General view of the partially disturbed (PATK-MT) plot

Plate 3 General view of the undisturbed (PACK-TP) plot



numbered tags were tied to the branch. Tree measurements viz., girth at breast height and total height of the tree were also recorded.

3.2.2.1 Phytosociological analysis

The Importance Value Index (IVI) of Curtis, 1950 and Curtis and McIntosh (1951) takes into consideration the number of individuals (density) belonging to each species, their basal area (dominance) and distribution (frequency) in the plot To calculate IVI the method described by Cain *et al* (1956) was followed

Density n_i - number of individuals of species 'i'

Relative Density rD - $\frac{n_i}{N} \times 100$

where, 'N' is total number of individuals in the plot

Dominance d_i sum of the basal areas (at 1 3) of individuals of same species

Relative dominance rd - $\frac{d_i}{d} \times 100$, where

d is the basal area of the plot

Frequency f_i - $\frac{C_i}{C} \times 100$

Where C_i = number of squares where the species is present

and C = total number of squares studied

Relative frequency, rF $= \frac{f_i}{F} \times 100$, where F f_i

Thus IVI of each species = r D + rd + r F and the value varies from 0 to 300.

The IVI for each botanical families were also calculated by adding the IVI of the different species of the same family found in the plot.

3.2.2.2 Floristic diversity

A number of indices have been suggested for the measurement of floristic diversity

a Simpon's index

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

where n_i - number of individuals of species 'i'

N - total number of individuals in the plot

S number of species in the plot

b. Shannon-Wiener's index (H')

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

where, n_i, N and S denote same as above and 3.3219 corresponds to the conversion factor from $\log_2$ to $\log_{10}$.

3 2.2 3 Profile diagram

The profile diagram is a physical, size to scale pictorial transectional representative segment of forest stand (Richards, 1952). A strip of 10 m x 30 m was demarcated in each plot. A linear representation of this strip was made in a size to scale graph ignoring the width of the strip The position of each tree was marked on the line. The total height of the tree was measured and also the crown shape From these pictorial and quantitative data obtained, the profile diagram was synthesised keeping the measurements to scale

3.2.3 Regeneration

Four quadrats were selected, in each plot, randomly and all plants less than 10 cm in girth were identified species wise and tagged The height and the girth of these plants were measured and classified into,

Unestablished seedlings	-	<40 cm height
established seedlings	-	40-100 cm height
advanced growth	-	100 cm in height but <3 cm gbh
saplings	-	3-10 cm gbh,

according to Basha (1987).

This was done in 1992 May, and in 1993 May these quadrats were reenumerated.

3.2.4 Litter dynamics

3 2.4.1 Litter quantification

Litter quantification was carried out by collecting sample litter in specially made litter traps at monthly intervals. Circular litter traps having dimension of 80 cm diameter were used (Plate 4). Each trap had a collection area of 0.50 m^2 The traps were made out of bamboo and were kept above three wooden stakes on forest floor. The basket was about 30 cm above the ground level. In each plot 100 litter traps were kept, in such a way that each quadrat had one trap each in it Each of these traps was numbered The litter collected in each trap was transformed into numbered plastic bags, which was taken to lab, sorted for leaves, bark and twigs and reproductive parts and oven dried weight was estimated. Quantitative phenological observation, number and species of flowers and fruits in each basket, was also done. Litter collections were made for a one year period from 1st June, 1992 to 31 May 1993.

3.4.4.2 Litter decomposition

Standard litter bag technique (Bocock and Gilbert,

Plate 4 Litter traps

Plate 5 Litter decomposition bags

1957) was adopted for characterising litter decomposition dynamics. Top layer of the ground litter was collected from each plot. The collected samples were air dried for 48 hours. Fifty gram litter samples were placed in litter bags having a dimension of 30 cm x 20 cm, made out of 4 mm nylon wire mesh. Representative sample from each plot was collected in triplicate to estimate the litter moisture content at the time of transferring the samples to the litter bags. The bags were placed in the litter layer on the forest floor (Plate 5). In each plot 48 bags were kept (four replicates each for 12 months)

At monthly intervals starting from 1st June 1992 to 31 May 1993, residual mass from the litter bags were retrieved by carefully removing the soil and other materials getting accumulated over the bags and returned them to laboratory. The bag to be withdrawn each month was decided randomly. After removing the extraneous materials like large arthropods, fine roots and soil, and washing in running cold water, the oven dry weights were arrived at.

The model for constant potential weight loss (Olson, 1963) represented by the equation,

$$X/X^{o} = e^{-kt}$$

where,

X = the weight remaining at time t,

X^o = the original mass

e = the base of natural logarithm

k = the decay rate co-efficient

t = time

This equation was fitted on mass disappearance data. Half lives ($t_{0.5}$) of decomposing litter were estimated from the 'k' values using the equation.

$$t_{0.5} = \ln (0.5)/-k$$
$$= 0.693/+k$$ (Bockheim *et al.*, 1991)

3.2.4.3 Nutrient input through litters

The representative litter samples were collected from all the three experimental plots and nutrient status of litter was estimated for nitrogen, phosphorus, potassium, calcium and magnesium.

3.2.5 Phenology

henological observations were made on a monthly basis on trees having a girth of ≥30 cm at breast height. A total of 188 trees in 20 species, in the bottom and middle plots were kept under observation. (The trees of top plot were avoided as enough sample size of any one of the species was not available in most of the cases). All these 188 trees were numbered and marked. The observations were made with the help of 10 x 40 super Zenith binocular.

3.2.6 Ecophysiology

3.2.6.1 Leaf area

Twenty five leaves each of 10 important species (based on IVI) in each plot were collected and the leaf area of individual species estimated using LICOR area meter. The leaves were then classified into heptophyll (0-0.25 cm^2) nanophyll (0.25-2.25 cm^2), microphyll (2.25-20.25 cm^2), notophyll (20.25-45.00 cm^2), mesophyll (45.00-182.25 cm^2), macrophyll (182.25-1640.25 cm^2) and megaphyll (> 1640.25 cm^2), according to Givnish (1984).

3.2.6.2 Leaf Area Index

LAI of the three experimental plots were determined using Plant Canopy Analyser (LICOR, USA model LAI-2000). Measurements were taken in a wide open area, to represent the above canopy reading and the below canopy readings were recorded from ten random locations in each plot. The calculated LAI values were read out from the instrument.

3.2.6.3 Light

Light measurements were taken using line quantum censor during May 1993, at 10 random locations in each plot.

3.2.7 Soil

3.2.7.1 Soil sample collection

Soil samples were collected from the three plots during May 1993. From each plot 3 samples each were collected from four random locations, at 0-20, 20-40 and 40-60 cm depths. Samples were air dried for 48 hours. The total air dry weight of the sample was estimated, then crushed and sieved using 2 mm sieve. The gravel thus obtained was also weighed to estimate the percentage of gravel in the soil.

3.2.7.2 Soil pH

Soil pH was estimated using a pH meter. The mean values for each layer in each plot was calculated.

3.2.7.3 Nutrient composition of the soil

Nitrogen is determined by Micro-Kjelhal digestion method. Extractable P is determined with Bray extractant, K with flame photometer (Jackson, 1973). Organic carbon was determined using potassium dichromate method.

3.2.8 Micrometeorology

3.2.8.1 Soil moisture

Soil samples were collected from nine locations from three experimental plots and soil moisture was estimated gravimetrically on a monthly basis for a period of 12 months.

3.2.8.2 Soil temperature

Monthly soil temperature (at 5 cm depth) measurements were done using soil thermometer which was kept in the middle of the plot.

Results

RESULTS

4.1 Vegetation

4.1.1 Floristic richness

The floristic data of the highly disturbed (PATK-BT) area is presented in Table 1. Floristically the highly disturbed plot has got 28 species in 19 families. Acacia intsia was the only liana present in this plot. The important tree species in this plot were Xylia xylocarpa, Bombax ceiba, Lagerstroemia microcarpa, Terminalia crenulata, and Tectona grandis (Table 1, Fig.4). Out of the 28 species present in this plot Chionanthus leprocarpa was the only evergreen (3 per cent) species.

The partially disturbed (PATK-MD) has 51 species in 24 families. Acacia intsia, Bridelia scandens, Butea parviflora, Calicopteris floribunda, Ixora brachiata, Olax scandens and Ziziphus oenoplea were the lianas present. The important tree species were Xylia xylocarpa, Wrightia tinctoria, Terminalia paniculata and Grewia tiliifolia (Table 2 and Fig.5). There were 10 evergreen (20 per cent) species in this plot.

The undisturbed plot (PATK-TP) has got 142 species in 48 families. Eighteen lianas were present in this plot.

Eighty seven per cent of the species were evergreen in nature. The important tree species were *Aglaia lawii*, *Spondias pinnata*, *Dimocarpus longan* and *Pterospermum reticulatum* (Table 3 and Fig.6).

4.1.2 Floristic diversity

The Importance Value Index (IVI) of *Xylia xylocarpa* was the maximum (50.6) at PATK-BT, followed by *Bombax ceiba* (32.59) and *Lagerstroemia microcarpa* (31.91) (Table 1). Eleven species at PATK-BT have IVI more than 5; ten of them exceed 10 and five species have more than 20 (Table 1).

At PATK-MD also, *Xylia xylocarpa* has maximum IVI (60.86), followed by *Wrightia tinctoria* (46.39) and *Terminalia paniculata* (33.25) (Table 2). Here again 11 species have IVI more than five, eight of them exceed 10 and five species have more than 20 (Table 2).

At PATK-TP *Aglaia lawii* has maximum IVI (18.96) followed by *Spondias pinnata* (15.54) and *Dimocarpus longan* (15.47) (Table 3). Fifteen species have IVI more than 5, five of them exceed ten and none more than 20 (Table 3).

Of the 28 species at PATK-BT, 12 have been represented just once and seven of them, twice. The highest relative densities were those of *Bombax ceiba* (14.29%), *Xylia xylocarpa*

Table 1. Importance Value Index of species at highly disturbed (PATK-BT) plot

	A	B	C
1	SPECIES	IVI	FAMILIES
2	Xylia xylocarpa	50,60	MIMOSACEAE
3	Bombax ceiba	32,59	BOMBACACEAE
4	Lagerstromia microcarpa	31,91	LYTHRACEAE
5	Terminalia crenulata	23,74	COMBRETACEAE
6	Tectona grandis	21,88	VERBENACEAE
7	Terminalia paniculata	18,17	COMBRETACEAE
8	Wrightia tinctoria	17,27	APOCYNACEAE
9	Bambusa arundinaceae	15,89	POACEAE
10	Lannea coromandelica	14,38	ANACARDIACEAE
11	Grewia tilifolia	13,78	TILIACEAE
12	Terminalia bellarica	7,22	COMBRETACEAE
13	Haldina cordifolia	4,50	RUBIACEAE
14	Sterculia guttata	4,46	STERCULIACEAE
15	Acacia intia	4,18	MIMOSACEAE
16	Cassia fistula	4,18	CAESALPINIACEAE
17	Ziziphus mauritiana	4,18	RHAMNACEAE
18	Mitragyna parviflora	4,17	RUBIACEAE
19	Bridelia retusa	3,60	EUPHORBIACEAE
20	Ficus asperima	3,16	MORACEAE
21	Dillenia pentagyna	2,81	DILLENIACEAE
22	Unidentified	2,80	
23	Dalbergia paniculata	2,78	FABACEAE
24	Pterocarpus marsupium	2,40	FABACEAE
25	Meliusa tomentosa	2,36	ANNONACEAE
26	Sterculia urens	1,40	STERCULIACEAE
27	Emblica officionalis	1,40	EUPHORBIACEAE
28	Chionanthus leprocarpus	1,39	OLEACEAE
29	Streblus asper	1,39	MORACEAE
30	Holarrhena pubescens	1,39	APOCYNACEAE
31		300,02	

Table 2 Importance Value Index of species at partially disturbed (PATK-MD) plot

	A	B	C
1	SPECIES	FAMILIES	IVI
2	Xylia xylocarpa	MIMOSACEAE	60.86
3	Wrightia tinctoria	APOCYNACEAE	46.39
4	Terminalia paniculata	COMBRETACEAE	33 25
5	Helicteres isora	STERCULIACEAE	22 53
6	Grewia tiliifolia	TILIACEAE	20.36
7	Bambusa arundinacese	POACEAE	17.39
8	Dillenia pentagyna	DILLENIACEAE	15.83
9	Lagerstroemia microcarpa	LYTHRACEAE	12.46
10	Holarrhena pubescens	APOCYNACEAE	8 36
11	Randia dumetorum	RUBIACEAE	7.51
12	Naringi crenulata	RUTACEAE	7.05
13	Dalbergia aissoides	FABACEAE	4 11
14	Albizia odoratissima	MIMOSACEAE	4.01
15	Meliusa tomentosa	ANNONACEAE	3 46
16	Bridelia retusa	EUPHORBIACEAE	2 83
17	Bombax ceiba	BOMBACACEAE	2 12
18	Calicopteris floribunda	COMBRETACEAE	1.90
19	Melia dubia	MELIACEAE	1 76
20	Dalbergia paniculata	FABACEAE	1 73
21	Spondias pinnata	ANACARDIACEAE	1.42
22	Schleichera oleosa	SAPINDACEAE	1.42
23	Symplocos sp	SYMPLOCACEAE	1 42
24	Terminalia crenulata	COMBRETACEAE	1.38
25	Ziziphus oenoplea	RHAMNACEAE	1.38
26	Ziziphus mauritiana	RHAMNACEAE	1.36
27	Lannea coromandelica	ANACARDIACEAE	1.28
28	Sterculia guttata	STERCULIACEAE	1.28
29	Ficus sp	MORACEAE	1 01
30	Emblica officinalis	EUPHORBIACEAE	0.97
31	Mallotus philippensis	EUPHORBIACEAE	0.97
32	Mitrgyna parviflora	RUBIACEAE	0 93
33	Cassia fistula	CAESALPINIACEAE	0 92
34	Strychnos nux_vomica	LOGANIACEAE	0 91
35	Acacia intia	MIMOSASEAE	0 91
36	Paglanthia dichotoma	APOCYNACEAE	0 61
37	Butea parviflora	FABACEAE	0 52
38	Canthium dicoccum	RUBIACEAE	0.52
39	Stereospermum chelonoides	BIGNONIACEAE	0.49
40	Ficus dalhousiae	MORACEAE	0 48
41	Ficus asperima	MORACEAE	0 47
42	Terminalia bellarica	COMBRETACEAE	0.46
43	Antidesma acidum	EUPHORBIACEAE	0.46
44	Aglaia simplicifolia	MELIACEAE	0.45
45	Turraea villosa	MELIACEAE	0.45
46	Allophylus cobbe	SAPINDACEAE	0 45
47	Clerodendron viscosum	VERBINACEAE	0 45
48	Bridelia scandens	EUPHORBIACEAE	0.45
49	Dalbergia latifolia	FABACEAE	0 45
50	Ixora brachiata	RUBIACEAE	0 45
51	Pterospermum reticulatum	STERCULIACEAE	0 45
52	Olax scandens	OLACACEAE	0 45
53	Unidentified		0 45
54			299 98

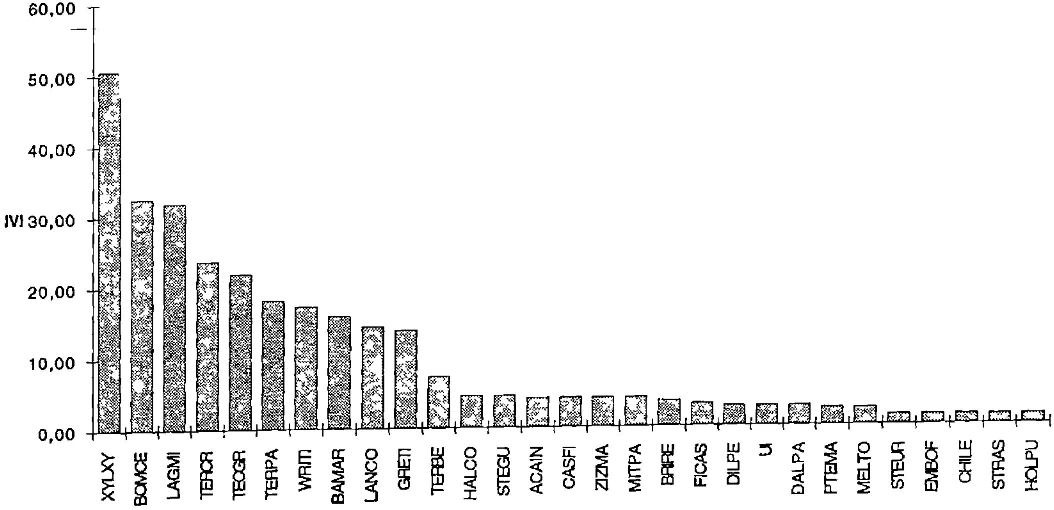
Table 3 Importance Value Index of species at undisturbed (PATK-TP) plot

	A	B	C
1	SPECIES	FAMILY	IVI
2	Aglaia lawii	MELIACEAE	18 96
3	Unidentified		16.65
4	Spondias pinnata	ANACARDIACEAE	15.54
5	Dimocarpus longan	SAPINDACEAE	15.47
6	Pterospermum reticulatum	STERCULIACEAE	11.02
7	Lagerstroemia microcarpa	LYTHRACEAE	9 18
8	Scleropyrum pentandrum	SANTALACEAE	8 37
9	Vitex altissima	VERBENACEAE	7.96
10	Diospyros paniculata	EBENACEAE	7 80
11	Erythrina stricta	FABACEAE	7.60
12	Wrightia tinctoria	APOCYNACEAE	7 59
13	Diospyros bourdillonii	EBENACEAE	6.73
14	Diospyros hirsuta	EBENACEAE	6 52
15	Cynometra travancorica	CAESALPINIACEAE	6.31
16	Bambusa arundinaceae	POACEAE	6 22
17	Diospyros cremenata	EBENACEAE	5.80
18	Randia dumetorum	RUBIACEAE	4.76
19	Euodia lunu ankenda	RUTACEAE	4 65
20	Dimorphocalyx beddomei	EUPHORBIACEAE	4.65
21	Memecylon terminale	MELASTOMATACEAE	4 36
22	Hunteria zelanica	APOCYNACEAE	4.19
23	Atalantia wightii	RUTACEAE	4.15
24	Syzygium cuminii	MYRTACEAE	4.00
25	Diospyros humilis	EBENACEAE	3.85
26	Pagiantha dichotoma	APOCYNACEAE	3.35
27	Blachia denudata	EUPHORBIACEAE	3.29
28	Mallotus stenanthus	EUPHORBIACEAE	3 14
29	Tetrameles nudiflora	DATISCACEAE	3 13
30	Radermachera xylocarpa	BIGNONIACEAE	3.06
31	Celtis philippensis	ULMACEAE	2.53
32	Aglaia indica	MELIACEAE	2.29
33	Canthium dicoccum	RUBIACEAE	2 27
34	Casearia ovata	FLACOURTIACEAE	2 16
35	Melia dubia	MELIACEAE	2.04
36	Cleidion spiciflorum	EUPHORBIACEAE	2.04
37	Dalbergia horrida	FABACEAE	2.02
38	Memecylon edule	MELASTOMATACEAE	2.01
39	Xanolelis	SAPOTACEAE	1.99
40	Lepisanthes decipiens	SAPINDACEAE	1 98
41	Bombax ceiba	BOMBACACEAE	1.96
42	Strychnos	LOGANIACEAE	1.91
43	Casearia rubesence	FLACOURTIACEAE	1 78
44	Olea dioica	OLEACEAE	1.69
45	Litsea stocksii	LAURACEAE	1.68
46	Connarus ritchiei	CONNARACEAE	1.65
47	Diospyros montana	EBENACEAE	1.54
48	Atalantia racemosa	RUTACEAE	1.49
49	Kingiodendron pinnatum	CAESALPINIACEAE	1 42
50	Artabotrys zeylanicus	ANNONACEAE	1 40
51	Diospyros oocarpa	EBENACEAE	1.40

	A	B	C
52	Croton malabaricum	EUPHORBIACEAE	1,38
53	Diospyros buxifolia	EBENACEAE	1,35
54	Litsea laevigata	LAURACEAE	1,19
55	Nothopegia beddomei	ANACARDIACEAE	1,19
56	Naringi crenulata	RUTACEAE	1,15
57	Reinwardtiodendron anamalainse	MELIACEAE	1,12
58	Leptonychia moacurroides	STERCULIACEAE	1,12
59	Cinnamomum zelanicum	LAURACEAE	1,08
60	Cynometra tomentosa	CAESALPINIACEAE	1,07
61	Walsura trifolia	MELIACEAE	0,96
62	Dimorphocalyx bourdilloni	EUPHORBIACEAE	0,95
63	Sterculia guttata	STERCULIACEAE	0,86
64	Beilschmiedia bourdilloni	LAURACEAE	0,85
65	Mussanda laxa	RUBIACEAE	0,82
66	Drypetes malabarica	EUPHORBIACEAE	0,81
67	Holarrhena pubescens	APOCYNACEAE	0,80
68	Vepris bilocularis	RUTACEAE	0,79
69	Myristica	MYRISTICACEAE	0,76
70	Herpullia arborea	SAPINDACEAE	0,75
71	Chrysophyllum lanceolatum	SAPOTACEAE	0,74
72	Strombosia ceylanica	OLACACEAE	0,72
73	Actinodaphne bourdillonii	LAURACEAE	0,67
74	Jasminum rottlerianum	OLEACEAE	0,67
75	Meiogyne pannosa	ANNONACEAE	0,65
76	Diospyros ovalifolia	EBENACEAE	0,64
77	Ficus nervosa	MORACEAE	0,63
78	Hydnocarpus pentandra	FLACOURTIACEAE	0,61
79	Blachia umbellata	EUPHORBIACEAE	0,60
80	Murraya paniculata	RUTACEAE	0,59
81	Symplacos	SYMPLOCACEAE	0,58
82	Orophea uniflora	ANNONACEAE	0,58
83	Flacourtia montana	FLACOURTIACEAE	0,57
84	Derris heyneana	FABACEAE	0,56
85	Persea macrantha	LAURACEAE	0,56
86	Croton caudatus	EUPHORBIACEAE	0,53
87	Alangium salvifolium	ALANGINACEAE	0,53
88	Syzygium laetum	MYRTACEAE	0,53
89	Aglaia elaeagnoidea	MELIACEAE	0,53
90	Bridelia retusa	EUPHORBIACEAE	0,52
91	Alstonia scholaris	APOCYNACEAE	0,51
92	Capparis cleghornii	CAPPARIDACEAE	0,50
93	Glochidion johnstonei	EUPHORBIACEAE	0,50
94	Apodytes beddomei	ICACINACEAE	0,48
95	Actinodaphne malabarica	LAURACEAE	0,47
96	Litsea floribunda	LAURACEAE	0,47
97	Garcinia xanthochymus	CLUSIACEAE	0,46
98	Glochidion malabaricum	EUPHORBIACEAE	0,45
99	Casearia bourdillonii	FLACOURTIACEAE	0,44
100	Cassia fistula	CAESALPINIACEAE	0,43
101	Capparis moonii	CAPPARIDACEAE	0,42
102	Dysoxylum binectariferum	MELIACEAE	0,42

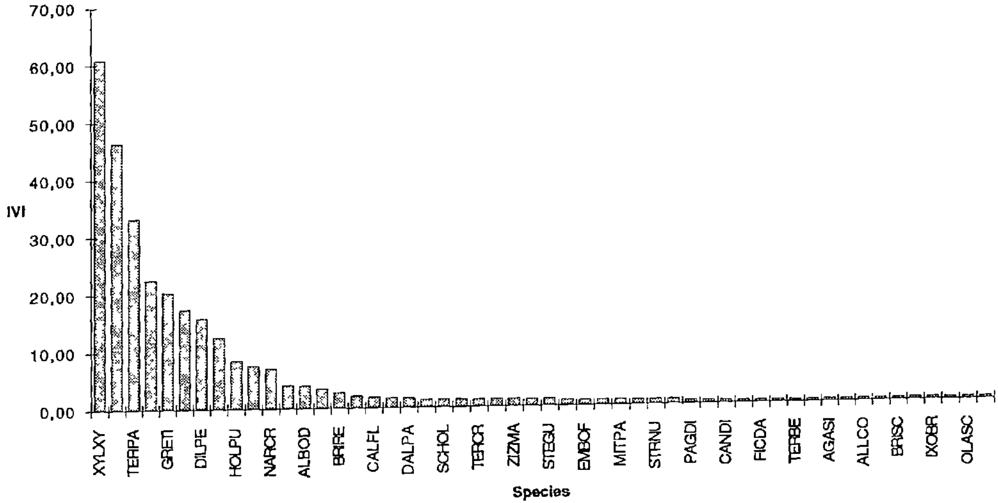
	A	B	C
103	Myristica malabarica	MYRISTICACEAE	0,41
104	Careota urens	PALMAE	0,41
105	Dimorphocalyx lawii	EUPHORBIACEAE	0,40
106	Turpinia malabarica	STAPHYLEACEAE	0,40
107	Alseodaphne semecarpifolia	LAURACEAE	0,39
108	Clausena heptaphylla	RUTACEAE	0,39
109	Dysoxylum malabaricum	MELIACEAE	0,37
110	Xanthophyllum arnottianum	XANTHOPHYLLACEAE	0,37
111	Diospyros sp	EBENACEAE	0,37
112	Pterospermum rubiginosum	STERCULIACEAE	0,36
113	Dillenia pentagyna	DILLENIACEAE	0,31
114	Ziziphus oenoplea	RHAMNACEAE	0,29
115	Derris sp	FABACEAE	0,28
116	Aglaia barberi	MELIACEAE	0,28
117	Unona viridifolia	ANNONACEAE	0,28
118	Sapindus laurifolius	SAPINDACEAE	0,28
119	Turrea villosa	MELIACEAE	0,28
120	Zanthoxylum rhetsa	RUTACEAE	0,28
121	Pajanelia longifolia	BIGNONIACEAE	0,28
122	Acacia intia	MIMOSASEAE	0,28
123	Salacia beddomi	HIPPOCRATIACEAE	0,27
124	Mussanda glabrata	RUBIACEAE	0,27
125	Acacia concinna	MIMOSASEAE	0,27
126	Ancistrocladus heyneanus	ANCISTROCLADEACEAE	0,27
127	Capparis rheedei	CAPPARIDACEAE	0,27
128	Gomphandra tetandra	ICACINACEAE	0,27
129	Hydnocarpus alpina	FLACOURTIACEAE	0,27
130	Chionanthus malabarica	OLEACEAE	0,27
131	Aphananthe cuspidata	ULMACEAE	0,27
132	Mallotus beddomei	EUPHORBIACEAE	0,27
133	Aporosa lindleyana	EUPHORBIACEAE	0,27
134	Salacia oblonga	HIPPOCRATIACEAE	0,27
135	Mallotus distans	EUPHORBIACEAE	0,27
136	Dimorphocalyx sp	EUPHORBIACEAE	0,27
137	Schleichera oleosa	SAPINDACEAE	0,27
138	Hibiscus surrattensis	MALVACEAE	0,27
139	Lepisanthus erecta	SAPINDACEAE	0,27
140	Mallotus philippensis	EUPHORBIACEAE	0,27
141	Grewia sp	TILIACEAE	0,26
142	*dead		4,07
143			299,99

Fig. 4 Distribution of species according to Importance Value Index at highly disturbed (PATK-BT) plot



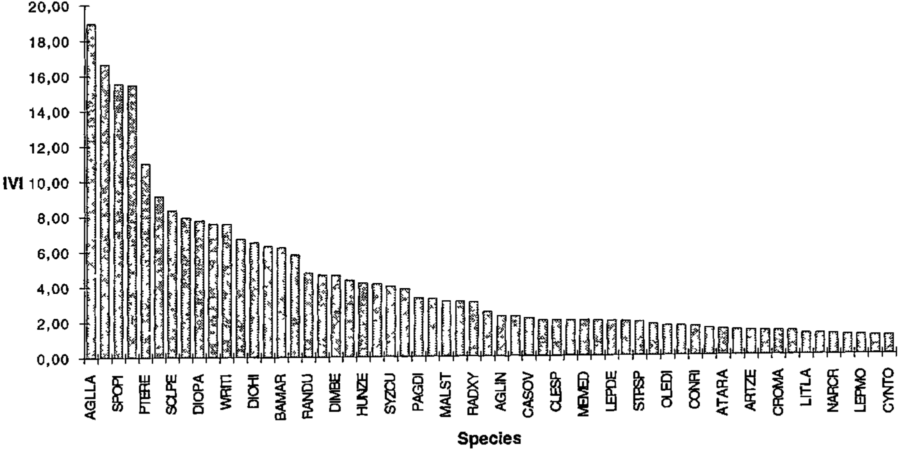
* Expansions of the abbreviations are given in Appendix-I

Fig. 5 Distribution of species according to Importance Value Index at partially disturbed (PATK-MD) plot



* Exapansions of the abbreviations are given in Appendix-I

Fig. 6 Distribution of species according to Importance Value Index at undisturbed (PATK-TP) plot



* Expansions of the abbreviations are given in Appendix-I

(12.34), Tectona grandis (9.09) and Wrightia tinctoria (9.09). These four species by themselves constituted 44.81 per cent of the trees (Table 4).

Of the 51 species at PATK-MD, 21 have been represented just once and ten of them, twice. The highest relative densities were those of Wrightia tinctoria (25.37%), Xylia xylocarpa (14.07%), Helicteres isora (11.67%) and Bambusa arundinaceae (8.89%). These four species by themselves constituted 60 per cent of the trees (Table 5).

Of the 142 species at PATK-TP, 58 have been represented just once and 24 of them, twice. The highest relative densities were those of Aglaia lawii (7.82%), Dimocarpus longan (5.44%), Scleropyrum pentandrum (4.42) and Spondias pinnata (3.85%). These four species by themselves accounted 21.53% of the trees (Table 6).

Nearly 62 per cent of individuals at the highly disturbed (PATK-BT) plot comes in the 0-5 IVI class (Table 7, Fig.7). In the partially disturbed (PATK-MD) plot 0-5, IVI class accounts for 78 per cent (Table 8, Fig.8) and the undisturbed (PATK-TP) plot has 89 per cent of individuals in the 0-5, IVI class (Table 9, Fig.9).

The IVI of families are given in Tables 10, 11 and 12. Mimosaceae (54.78), Combretaceae (49.13), Bombacaceae (32.59)

Table 4. Phytosociological analysis in the highly disturbed (PATK-BT) plot

	Species	Density	Basal area	Relative frequency	Relative basal area	Relative density	Importance value index
1.	Xylia xylocarpa	19.00	4.40	12.50	25.75	12.34	50.58
2.	Bombax ceiba	22.00	0.87	13.24	5.09	14.29	32 61
3.	Lagerstroemia microcarpa	10.00	3.09	7.35	18.08	6.49	31.93
4.	Terminalia crenulata	10.00	1.82	6.62	10.65	6.49	23.76
5.	Tectona grandis	14.00	1.04	7.35	6.09	9.09	22.53
6.	Terminalia paniculata	7.00	1.45	5.15	8.48	4.55	18.18
7.	Wrightia tinctoria	14.00	0.02	8.82	0.12	9.09	18.03
8.	Bambusa arundinaceae	13.00	0.02	7.35	0.12	8.44	15.91
9.	Lannea coromandelica	7.00	0.93	4.41	5.44	4.55	14.40
10.	Grewia tiliifolia	6.00	1.06	3.68	6.20	3.90	13.77
11.	Terminalia bellirica	2.00	0.76	1.47	4.45	1.30	7.22
12	Haldina cordifolia	1.00	0.53	0.74	3.10	0.65	4.49
13	Sterculia guttata	2.00	0.29	1.47	1.70	1.30	4.47
14.	Cassia fistula	3.00	0.00	2.21	0.00	1.95	4.15

Contd.

Table 4 (Contd.)

15.	*Mitragyna parviflora*	3.00	0.00	2.21	0.00	1.95	4.15
16.	*Bridelia retusa*	2.00	0.14	1.47	0.82	1.30	3.59
17.	*Ficus asperima*	2.00	0.07	1.47	0.41	1.30	3.18
18.	Unidentified	2.00	0.01	1.47	0.06	1.30	2.83
19.	*Dillenia pentagyna*	1.00	0.24	0.74	1.40	0.65	2.79
20.	*Acacia intsia*	2.00	0.00	1.47	0.00	1.30	2.77
21.	*Dalbergia paniculata*	2.00	0.00	1.47	0.00	1.30	2.77
22.	*Miliusa tomentosa*	1.00	0.17	0.74	0.99	0.65	2.38
23.	*Pterocarpus marsupium*	1.00	0.17	0.74	0.99	0.65	2.38
24.	*Emblica officionalis*	1.00	0.00	0.74	0.00	0.65	1.38
25.	*Chionanthus leprocarpa*	1.00	0.00	0.74	0.00	0.65	1.38
26.	*Ziziphus mauritiana*	1.00	0.00	0.74	0.00	0.65	1.38
27.	*Holarrhena pubescens*	1.00	0.00	0.74	0.00	0.65	1.38
28.	*Ziziphus nemmlaria*	1.00	0.00	0.74	0.00	0.65	1.38
29.	*Streblus asper*	1.00	0.00	0.74	0.00	0.65	1.38
30.	*Ziziphus oenoplea*	1.00	0.00	0.74	0.00	0.65	1.38
31.	*Sterculia urens*	1.00	0.00	0.74	0.00	0.65	1.38
		154.00	17.08				

Table 5 (Contd.)

15	*Bridelia retusa*	2.00	0.53	0.52	2.05	0.37	2.95
16	*Bombax ceiba*	3.00	0.15	0.79	0.58	0.56	1.92
17	*Calicopteris floribunda*	4.00	0.03	1.05	0.12	0.74	1.90
18	*Melia dubia*	1.00	0.34	0.26	1.32	0.19	1.76
19	*Dalbergia paniculata*	3.00	0.10	0.79	0.39	0.56	1.73
20	*Schleichera oleosa*	3.00	0.02	0.79	0.08	0.56	1.42
21	*Spondias pinnata*	3.00	0.02	0.79	0.08	0.56	1.42
22	*Symplacos* sp.	3.00	0.02	0.79	0.08	0.56	1.42
23	*Ziziphus mauritiana*	3.00	0.01	0.79	0.04	0.56	1.38
24	*Ziziphus oenoplea*	3.00	0.01	0.79	0.04	0.56	1.38
25	*Terminalia crenulata*	1.00	0.24	0.26	0.93	0.19	1.38
26	*Stereospermum chelonoide*	2.00	0.11	0.52	0.43	0.37	1.32
27	*Lannea coromandelica*	2.00	0.07	0.52	0.27	0.37	1.16
28	*Ficus* sp.	2.00	0.03	0.52	0.12	0.37	1.01
29	*Mallotus philippensis*	2.00	0.02	0.52	0.08	0.37	0.97
30	*Mitrgyna parviflora*	2.00	0.01	0.52	0.04	0.37	0.93
31	*Cassia fistula*	2.00	0.01	0.52	0.04	0.37	0.93

Contd.

Table 5 (Contd.)

32	*Emblica officinalis*	2.00	0.01	0.52	0.04	0.37	0.93
33	*Strychnos nuxvomica*	2.00	0.00	0.52	0.00	0.37	0.89
34	*Acacia intia*	2.00	0.00	0.52	0.00	0.37	0.89
35	*Pagianthia dichotoma*	1.00	0.04	0.26	0.15	0.19	0.60
36	*Butea parviflora*	1.00	0.02	0.26	0.08	0.19	0.52
37	*Canthium dicoccum*	1.00	0.02	0.26	0.08	0.19	0.52
38	*Ficus asperima*	1.00	0.01	0.26	0.04	0.19	0.49
39	*Ficus dalhousiae*	1.00	0.01	0.26	0.04	0.19	0.49
40	*Sterculia guttata*	1.00	0.01	0.26	0.04	0.19	0.49
41	*Olax scandens*	1.00	0.00	0.26	0.00	0.19	0.45
42	*Unidentified*	1.00	0.00	0.26	0.00	0.19	0.45
43	*Pterospermum reticulatum*	1.00	0.00	0.26	0.00	0.19	0.45
44	*Ixora brachiata*	1.00	0.00	0.26	0.00	0.19	0.45
45	*Terminalia bellarica*	1.00	0.00	0.26	0.00	0.19	0.45
46	*Aglaia simplicifolia*	1.00	0.00	0.26	0.00	0.19	0.45
47	*Allophylus cobbe*	1.00	0.00	0.26	0.00	0.19	0.45
48	*Antidesma acidum*	1.00	0.00	0.26	0.00	0.19	0.45

Contd.

Table 5 (Contd.)

49	Dalbergia latifolia	1.00	0.00	0.26	0.00	0.19	0.45
50	Turraea villosa	1.00	0.00	0.26	0.00	0.19	0.45
51	Bridelia scandens	1.00	0.00	0.26	0.00	0.19	0.45
52	Clerodendron viscosum	1.00	0.00	0.26	0.00	0.19	0.45
		540.00	25.82				

Table 6. Phytosociological analysis in the undisturbed (PATK-TP) plot

Sl. No.	Species	Density	Basal area	Relative frequency	Relative basal area	Relative density	Importance
1	Aglaia lawii	69.00	1.18	5 94	5.30	7.82	19 06
2	Unidentified	49.00	1.24	5.65	5.57	5.56	16.77
3	Spondias pinnata	34.00	1.57	4.75	7.05	3.85	15.66
4	Dimocarpus longan	48.00	1.13	5.05	5.07	5 44	15.57
5	Pterospermum reticulatum	24.00	1.18	2.82	5.30	2.72	10.84
6	Lagerstroemia microcarpa	13.00	1.34	1.78	6.02	1.47	9.27
7	Scleropyrum pentandrum	39.00	0.20	3.12	0.90	4.42	8.44
8	Vitex altissima	17.00	0.89	2.08	4.00	1.93	8.00
9	Diospyros paniculata	23.00	0.64	2.38	2.87	2.61	7.86
10	Erythrina stricta	12.00	1.04	1.63	4.67	1.36	7.66
11	Wrightia tinctoria	29.00	0.37	2.53	1.66	3.29	7.47
12	Euodia lunu-ankenda	14.00	0.69	2.08	3.10	1.59	6.76
13	Diospyros bourdillonii	18.00	0.56	2.08	2.51	2.04	6.63

Contd.

14	Dıospyros hırsuta	29.00	0.17	2.53	0.76	3.29	6.58
15	Cynometra travancorıca	28.00	0.11	2.67	0.49	3.17	6.34
16	Bambusa arundınaceae	32.00	0.06	2.38	0.27	3.63	6.27
17	Dıospyros cremenata	16.00	0.43	2.08	1.93	1.81	5.82
18	Randıa dumetorum	18.00	0.18	1.93	0.81	2.04	4.78
19	Dımorphocalyx beddomeı	15.00	0.26	1.63	1.17	1.70	4.50
20	Memecylon termınale	16.00	0.07	2.23	0.31	1.81	4.36
21	Hunterıa zelanıca	12.00	0.34	1 34	1.53	1.36	4.22
22	Atalantıa wıghtıı	14.00	0.21	1.63	0.94	1.59	4.16
23	Syzygium cuminıi	2.00	0.78	0.30	3.50	0.23	4.03
24	Dıospyros humılıs	3.00	0.72	0.30	3.23	0.34	3.87
25	Pagıantha dıchotoma	9.00	0.23	1.34	1.03	1.02	3.39
26	Tetrameles nudıflora	2.00	0.59	0.30	2.65	0.23	3.17
27	Mallotus stenanthus	14.00	0.02	1.49	0.09	1.59	3.16
28	Radermachera xylocarpa	1.00	0.63	0.15	2.83	0.11	3.09
29	Blachıa denudata	17.00	0.07	0.74	0.31	1.93	2.98

Contd.

30	*Casearia ovata*	6.00	0.25	0.89	1.12	0.68	2.69
31	*Celtis philippensis*	5.00	0.28	0.74	1.26	0.57	2.57
32	*Aglaia indica*	5.00	0.22	0.74	0.99	0.57	2.30
33	*Canthium dicoccum*	7.00	0.13	0.89	0.58	0.79	2.27
34	*Bombax ceiba*	2.00	0.36	0.30	1.62	0.23	2.14
35	*Cleidion spiciflorum*	2.00	0.36	0.30	1.62	0.23	2.14
36	*Melia dubia*	4.00	0.26	0.45	1.17	0.45	2.07
37	*Dalbergia horrida*	8.00	0.05	0.89	0.22	0.91	2.02
38	*Xanoletis*	5.00	0.19	0.59	0.85	0.57	2.01
39	*Lepisanthes decipiens*	6.00	0.09	0.89	0.40	0.68	1.98
40	*Strychnos* sp	8.00	0.03	0.89	0.13	0.91	1.93
41	*Casearia rubesence*	5.00	0.11	0.74	0.49	0.57	1.80
42	*Olea dioica*	6.00	0.03	0.89	0.13	0.68	1.71
43	*Litsea stocksii*	6.00	0.03	0.89	0.13	0.68	1.71
44	*Connarus ritchiei*	6.00	0.02	0.89	0.09	0.68	1.66
45	*Diospyros montana*	2.00	0.23	0.30	1.03	0.23	1.56

Contd.

46	Atalantia racemosa	5.00	0.08	0.59	0.36	0.57	1.52
47	Kingiodendron pinnatum	5.00	0.03	0.74	0.13	0.57	1.44
48	Diospyros oocarpa	4.00	0.08	0.59	0.36	0.45	1.41
49	Artabotrys zeylanicus	5.00	0.02	0.74	0.09	0.57	1.40
50	Croton malabaricum	5.00	0.02	0.74	0.09	0.57	1.40
51	Diospyros buxifolia	3.00	0.13	0.45	0.58	0.34	1.37
52	Memecylon edule	5.00	0.01	0.74	0.04	0.57	1.35
53	Litsea laevigata	5.00	0.01	0.59	0.04	0.57	1.21
54	Nothopegia beddomei	3.00	0.09	0.45	0.40	0.34	1.19
55	Naringi crenulata	6.00	0.01	0.45	0.04	0.68	1.17
56	Reinwardtiodendron anamalainse	4.00	0.02	0.59	0.09	0.45	1.14
57	Cinnamomum zelanicum	5.00	0.02	0.45	0.09	0.57	1.10
58	Leptonychia moacurroides	5 00	0.02	0.45	0.09	0.57	1.10
59	Cynometra tomentosa	2.00	0.12	0.30	0.54	0.23	1.06
60	Dimorphocalyx bourdillon	4.00	0.05	0.30	0.22	0.45	0.98
61	Walsura trifolia	3.00	0.04	0.45	0.18	0.34	0.97

Contd.

62	Sterculia guttata	1.00	0.14	0.15	0.63	0.11	0.89
63	Beilschmiedia bourdillon	3.00	0.02	0.45	0.09	0.34	0.88
64	Drypetes malabarica	3.00	0.04	0.30	0.18	0.34	0.82
65	Vepris bilocularis	2.00	0.06	0.30	0.27	0.23	0.79
66	Holarrhena pubescens	3.00	0.00	0.45	0.00	0.34	0.79
67	Herpullia arborea	1.00	0.11	0.15	0.49	0.11	0.76
68	Myristica	1.00	0.11	0.15	0.49	0.11	0.76
69	Chrysophyllum lanceolatu	1.00	0.11	0.15	0.49	0.11	0.76
70	Strombosia ceylanica	2.00	0.04	0.30	0.18	0.23	0.70
71	Actinodaphne bourdillonii	2.00	0.07	0.15	0.31	0.23	0.69
72	Jasminum rottlerianum	3.00	0.01	0.30	0.04	0.34	0.68
73	Diospyros ovalifolia	1.00	0.09	0.15	0.40	0.11	0.67
74	Meiogyne pannosa	2.00	0.03	0.30	0.13	0.23	0.66
75	Memecylon sp.	4.00	0.01	0.15	0.04	0.45	0.65
76	Blachia umbellata	1.00	0.08	0.15	0.36	0.11	0.62
77	Ficus nervosa	1.00	0.08	0.15	0.36	0.11	0.62
78	Hydnocarpus pentandra	2.00	0.02	0.30	0.09	0.23	0.61

Contd.

79	*Apodytes beddomei*	2.00	0.02	0.30	0.09	0.23	0.61
80	*Murraya paniculata*	2.00	0.01	0.30	0.04	0.23	0.57
81	*Symplacos*	2.00	0.01	0.30	0.04	0.23	0.57
82	*Orophea uniflora*	2.00	0.01	0.30	0.04	0.23	0.57
83	*Capparis moonii*	2 00	0.01	0.30	0.04	0.23	0.57
84	*Flacourtia montana*	2.00	0.01	0.30	0.04	0.23	0.57
85	*Mosanda laxa*	2.00	0.01	0.30	0.04	0.23	0.57
86	*Persea macrantha*	2.00	0.01	0.30	0.04	0.23	0.57
87	*Bridelia retusa*	1.00	0.06	0.15	0.27	0.11	0.53
88	*Syzygium laetum*	1.00	0.06	0.15	0.27	0.11	0.53
89	*Aglaia elaeagnoidea*	1.00	0.06	0.15	0.27	0.11	0.53
90	*Alstonia scholaris*	1.00	0.06	0.15	0.27	0.11	0.53
91	*Zanthoxylum rhetsa*	2.00	0.00	0.30	0.00	0.23	0.52
92	*Croton caudatus*	2.00	0.00	0.30	0.00	0.23	0.52
93	*Glochidion johnstonei*	1.00	0.05	0.15	0.22	0.11	0.49
94	*Capparis cleghornii*	3.00	0.00	0.15	0.00	0.34	0.49
95	*Garcinia xanthochymus*	1.00	0.05	0.15	0.22	0.11	0.49

Contd.

96	*Actinodaphne malabarica*	1.00	0.05	0.15	0.22	0.11	0.49
97	*Litsea floribunda*	1.00	0.05	0.15	0.22	0.11	0.49
98	*Glochidion malabaricum*	1.00	0.04	0.15	0.18	0.11	0.44
99	*Casearia bourdillonii*	1.00	0.04	0.15	0.18	0.11	0.44
100	*Cassia fistula*	1.00	0.04	0.15	0.18	0.11	0.44
101	*Derris heyneana*	2.00	0.01	0.15	0.04	0.23	0.42
102	*Myristica malabarica*	1.00	0.03	0.15	0.13	0.11	0.40
103	*Dysoxylum binectariferum*	1.00	0.03	0.15	0.13	0.11	0.40
104	*Dysoxylum malabaricum*	1.00	0.03	0.15	0.13	0.11	0.40
105	*Xanthophyllum arnottianum*	1.00	0.03	0.15	0.13	0.11	0.40
106	*Turpinia malabarica*	1.00	0.03	0.15	0.13	0.11	0.40
107	*Dimorphocalyx lawii*	1.00	0.03	0.15	0.13	0.11	0.40
108	*Careota urens*	1.00	0.03	0.15	0.13	0.11	0.40
109	*Alseodaphne semecarpifolia*	2.00	0.00	0.15	0.00	0.23	0.38
110	*Clausena heptaphylla*	2.00	0.00	0.15	0.00	0.23	0.38
111	*Diospyros* sp.	1.00	0.02	0.15	0.09	0.11	0.35
112	*Pterospermum rubiginosum*	1.00	0.02	0.15	0.09	0.11	0.35

Contd.

113	Ziziphus oenoplea	1.00	0.01	0.15	0.04	0.11	0.31
114	Dillenia pentagyna	1.00	0.01	0.15	0.04	0.11	0.31
115	Derris sp	1.00	0.01	0.15	0.04	0.11	0.31
116	Salacia beddomi	1.00	0.00	0.15	0.00	0.11	0.26
117	Aporosa lindleyana	1.00	0.00	0.15	0.00	0.11	0.26
118	Dimorphocalyx sp.	1.00	0.00	0.15	0.00	0.11	0.26
119	Hibiscus surrattensis	1.00	0.00	0.15	0.00	0.11	0.26
120	Mallotus philippensis	1.00	0.00	0.15	0.00	0.11	0.26
121	Turrea villosa	1.00	0.00	0.15	0.00	0.11	0.26
122	Sapindus laurifolius	1.00	0.00	0.15	0.00	0.11	0.26
123	Aphananthe cuspidata	1.00	0.00	0.15	0.00	0.11	0.26
124	Elangium salvifolium	1.00	0.00	0.15	0.00	0.11	0.26
125	Unona viridifolia	1.00	0.00	0.15	0.00	0.11	0.26
126	Chionanthus malabarica	1.00	0.00	0.15	0.00	0.11	0.26
127	Ancistrocladus heyneanus	1.00	0.00	0.15	0.00	0.11	0.26
128	Mussanda glabrata	1.00	0.00	0.15	0.00	0.11	0.26
129	Hydnocarpus laurifolius	1.00	0.00	0.15	0.00	0.11	0.26

Contd.

130	Capparis rheedei	1.00	0.00	0.15	0.00	0.11	0.26
131	Alangium salvifolium	1.00	0.00	0.15	0.00	0.11	0.26
132	Pajanelia longifolia	1.00	0.00	0.15	0.00	0.11	0.26
133	Aglaia barberi	1.00	0.00	0.15	0.00	0.11	0.26
134	Schleichera oleosa	1.00	0.00	0.15	0.00	0.11	0.26
135	Lepisanthus erecta	1.00	0.00	0.15	0.00	0.11	0.26
136	Mussanda laxa	1.00	0.00	0.15	0.00	0.11	0.26
137	Mallotus beddomei	1.00	0.00	0.15	0.00	0.11	0.26
138	Grewia sp.	1.00	0.00	0.15	0.00	0.11	0.26
139	Acacia intsia	1.00	0.00	0.15	0.00	0.11	0.26
140	Acacia concinna	1.00	0.00	0.15	0.00	0.11	0.26
141	Salacia oblonga	1.00	0.00	0.15	0.00	0.11	0.26
142	Gomphandra tetandra	1.00	0.00	0.15	0.00	0.11	0.26
143	Mallotus distans	1.00	0.00	0.15	0.00	0.11	0.26
		882	22.25				

Table 7. Number of species in each IVI class at highly disturbed (PATK-BT) plot

	IVI-Class	No. of species	Percentage
1.	0-5	18	62.07
2.	5-10	1	3.45
3.	10-15	2	6.90
4.	15-20	3	10.34
5.	20-25	2	6.90
6.	25-30	0	0.00
7.	30-35	2	6.90
8.	35-40	0	0 00
9.	40-45	0	0.00
10.	45-50	0	0.00
11.	50-55	1	3.45
	Total	29	100.00

Table 8. Number of species in each IVI class at partially disturbed (PATK-MD) plot

	IVI-Class	No. of species	Percentage
1.	0-5	41	78.85
2.	5-10	3	5.77
3.	10-15	1	1.92
4.	15-20	2	3.85
5.	20-25	2	3.85
6.	25-30	0	0.00
7.	30-35	1	1.92
8.	35-40	0	0.00
9.	40-45	0	0.00
10.	45-50	1	1.92
11.	50-55	0	0.00
12.	55-60	0	0.00
13.	60-65	1	1.92
	Total	52	100.00

Table 9. Number of species in each IVI class at undisturbed bed (PATK-TP) plot

	IVI-Class	No. of species	Percentage
1.	0-5	124	89.2086331
2.	5-10	11	7.91
3.	10-15	1	0.72
4	15-20	3	2.16
	Total	139	100.00

Fig. 7 Number of species per IVI classes at highly disturbed (PATK–BT) plot

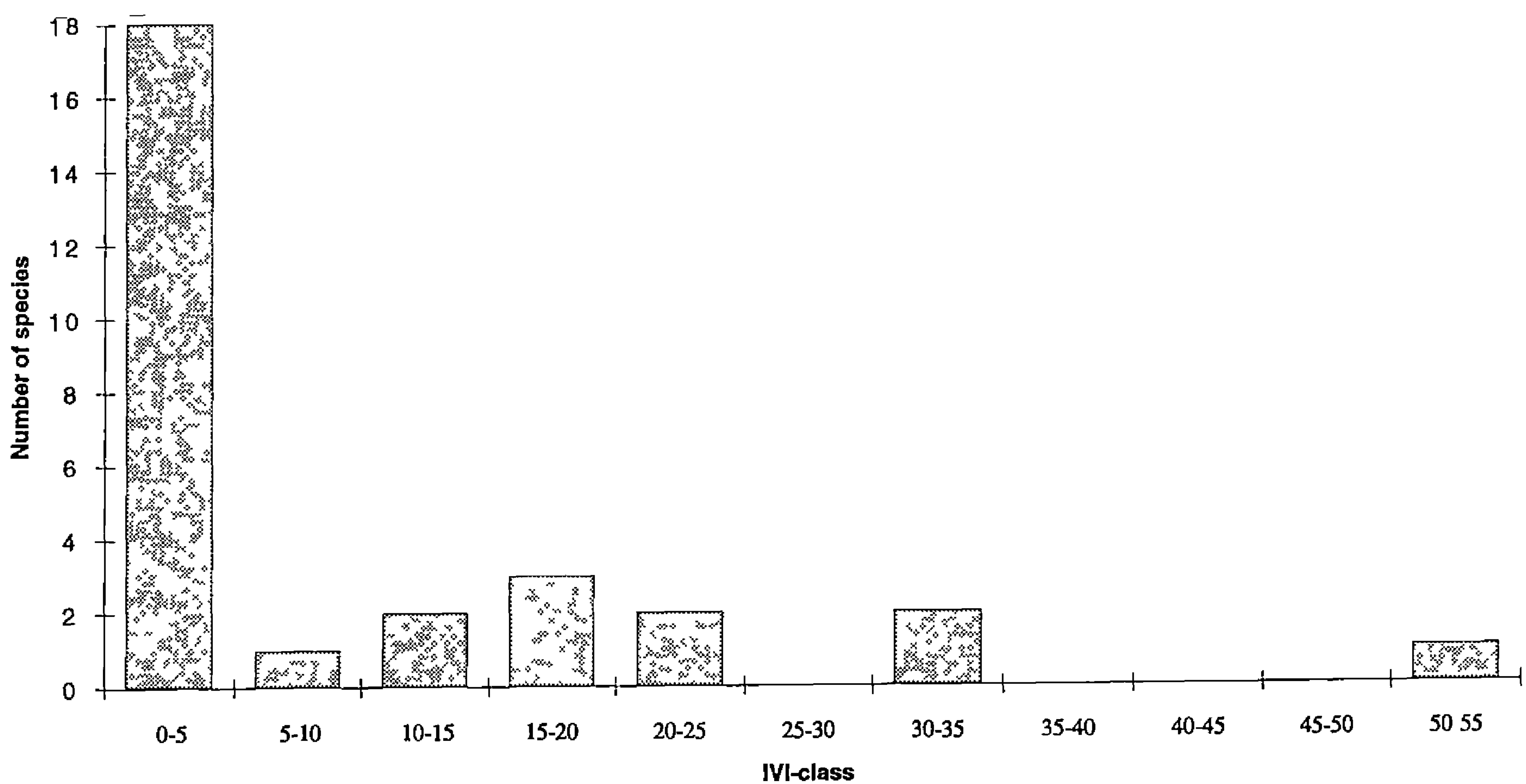


Fig. 8 Number of species per IVI classes at partially disturbed (PATK-MD) plot

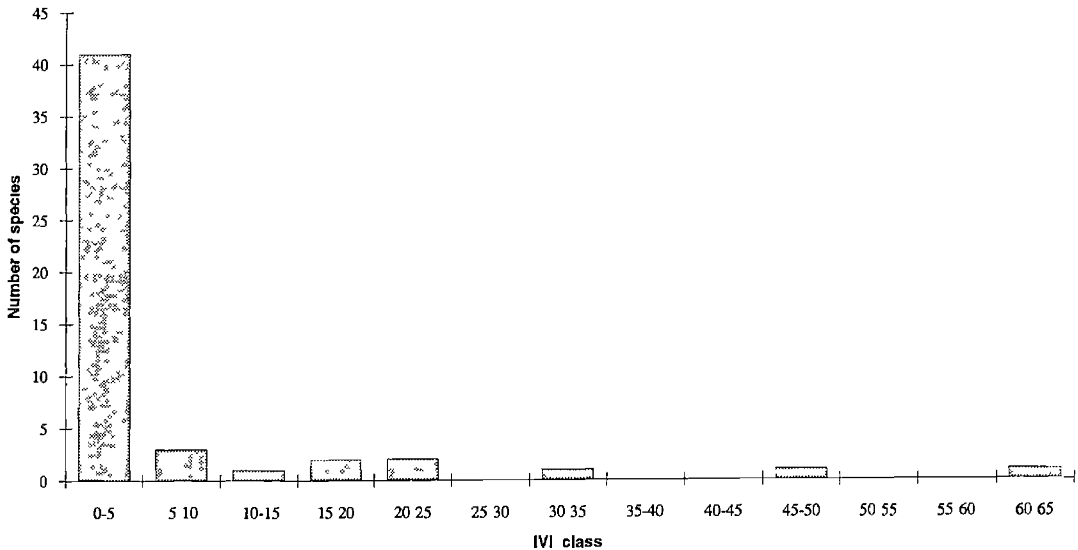
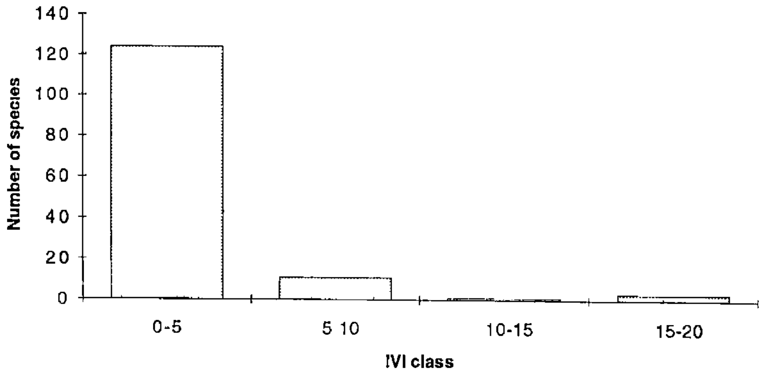


Fig. 9 Number of species per IVI classes at undisturbed (PATK–TP) plot



and Lythraceae (31.39) were the four important families at PATK-BT (Table 10). Nine families have IVI more than 10, five of them have more than 20 and four exceed 30.

Mimosaceae (65.77), Apocynaceae (55.36), Combretaceae (36.99) and Tiliaceae (20.36) were the four important families at PATK-MD (Table 11). Seven families have an IVI more than 10, four of them have more than 20 and three of them exceed 30.

Ebenaceae (36), Meliaceae (27.25), Euphorbiaceae (20.59) and Sapindaceae (19) are the four important families at PATK-TP (Table 12). Here ten families have an IVI more than 10, but only three of them have an IVI of more than 20 and first one family has an IVI more than 30.

Indices of diversity for all the three plots are given in Table 13. Simpson's index showed that out of the 100 pairs taken at random, eight were composed of individuals of same species at PATK-BT, 12 individuals for PATK-MD and only three individuals of same species for PATK-TP.

Shannon-Weiner's index also followed a similar trend between the three plots with values 4.16, 3.91 and 5.97 for PATK-BT, PATK-MD and PATK-TP respectively.

Table 10. Importance Value Index of families at highly disturbed (PATK-BT) plot

	A	B	C
1	FAMILIES	NO OF SPECIES	IVI OF FAMILIES
2	MIMOSACEAE	2	54,78
3	COMBRETACEAE	3	49,13
4	BOMBACACEAE	1	32,59
5	LYTHRACEAE	1	31,39
6	VERBENACEAE	1	21,88
7	APOCYNACEAE	2	18,68
8	POACEAE	1	15,89
9	ANACARDIACEAE	1	14,38
10	TILIACEAE	1	13,78
11	RUBIACEAE	2	8,53
12	STERCULIACEAE	2	5,86
13	FABACEAE	2	5,18
14	EUPHORBIACEAE	2	5
15	MORACEAE	2	4,55
16	CAESALPINIACEAE	1	4,18
17	RHAMNACEAE	1	4,18
18	DILLENIACEAE	1	2,81
19	UI	2	2,8
20	ANNONACEAE	1	2,36
21	OLEACEAE	1	1,39
22			299,3506554

Table 11. Importance Value Index of families at partially disturbed (PATK-MD) plot

	A	B	C
1	FAMILIES	NO OF SPECIES	IVI OF FAMILIES
2	MIMOSACEAE	3	65,77
3	APOCYNACEAE	3	55,36
4	COMBRETACEAE	4	36,99
5	TILIACEAE	1	20,36
6	POACEAE	1	17,39
7	DILENIACEAE	1	15,83
8	LYTHRACEAE	1	12,46
9	RUBIACEAE	4	9,42
10	RUTACEAE	1	7,05
11	FABACEAE	4	6,81
12	EUPHORBIACEAE	5	5,69
13	ANNONACEAE	1	3,46
14	RHAMNACEAE	2	2,74
15	ANACARDIACEAE	2	2,7
16	MELIACEAE	3	2,67
17	BOMBACACEAE	1	2,12
18	MORACEAE	3	1,97
19	SAPINDACEAE	2	1,87
20	STERCULIACEAE	2	1,73
21	SYMPLOCACEAE	1	1,42
22	CAESALPINIACEAE	1	0,92
23	LOGANIACEAE	1	0,91
24	BIGNONIACEAE	1	0,49
25	VERBENACEAE	1	0,45

Table 12 Importance Value Index of families at undisturbed (PATK-TP) plot

	A	B	C
1	FAMILIES	NO OF SPECIES	IVI OF FAMILY
2	EBENACEAE	10	36
3	MELIACEAE	10	27,25
4	EUPHORBIACEAE	18	20,59
5	SAPINDACEAE	6	19
6	ANACARDIACEAE	2	16,73
7	Unidentified	48	16,65
8	APOCYNACEAE	5	16,44
9	RUTACEAE	8	13,49
10	STERCULIACEAE	4	13,37
11	FABACEAE	4	10,46
12	CAESALPINIACEAE	4	9,23
13	LYTHRACEAE	1	9,18
14	SANTALACEAE	1	8,37
15	VERBINACEAE	1	7,96
16	LAURACEAE	9	7,36
17	RUBIACEAE	2	7,03
18	MELASTOMATACEAE	2	6,37
19	POACEAE	1	6,22
20	FLACOURTIACEAE	6	5,84
21	MYRTACEAE	2	4,53
22	*dead	18	4,07
23	BIGNONIACEAE	2	3,34
24	DATISCACEAE	1	3,13
25	ANNONACEAE	4	2,91
26	ULMACEAE	2	2,8
27	SAPOTACEAE	2	2,73
28	BOMBACACEAE	1	1,96
29	OLEACEAE	2	1,96
30	LOGANIACEAE	1	1,91
31	CONNARACEAE	1	1,65
32	CAPPARIDACEAE	3	1,19
33	MYRISTICACEAE	2	1,17
34	RUBIACEAE	2	1,09
35	ICACINACEAE	2	0,75
36	OLACACEAE	1	0 72
37	OLEACEAE	1	0,67
38	MORACEAE	1	0,63
39	SYMPLOCACEAE	1	0,58
40	MIMOSASEAE	2	0,55
41	HIPPOCRATIACEAE	2	0,54
42	ALANGINACEAE	1	0,53
43	CLUSIACEAE	1	0,46
44	PALMAE	1	0,41
45	STAPHYLEACEAE	1	0,4
46	XANTHOPHYLLACEAE	1	0,37
47	DILLENIACEAE	1	0,31
48	RHAMNACEAE	1	0,29
49	ANCISTROCLADACEAE	1	0,27
50	MALVACEAE	1	0,27
51	TILIACEAE	1	0,26
52			299,99

Table 13. Floristic diversity in the three experimental plots at Pattikkad

Site code	Area (m^2)	Number of species (S)	Number of individuals (N)	N/S	Simpson's index	Shannon-Wiener's index		
						H'	H max	E=H'/H max
PATK-BT	10,000	31	154	4.97	0.92	4.16	4 95	0.84
PATK-MD	10,000	52	540	10.40	0.88	3.91	5.70	0.69
PATK-TP	10,000	143	882	6.17	0.97	5.97	7.16	0.83

4.1.3 Structure

4.1.3.1 Stratification

The percentage distribution of individuals occupying different tiers in the experimental plots showed that first storey (<15 m) individuals were well represented in the undisturbed (PATK-TP) plot and the percentage of individuals in the first storey decreases as we go to partially disturbed (PATK-MD) and highly disturbed (PATK-BT) plots (Table 14). It was also evident from the table that third storey was poorly represented in the three experimental plots.

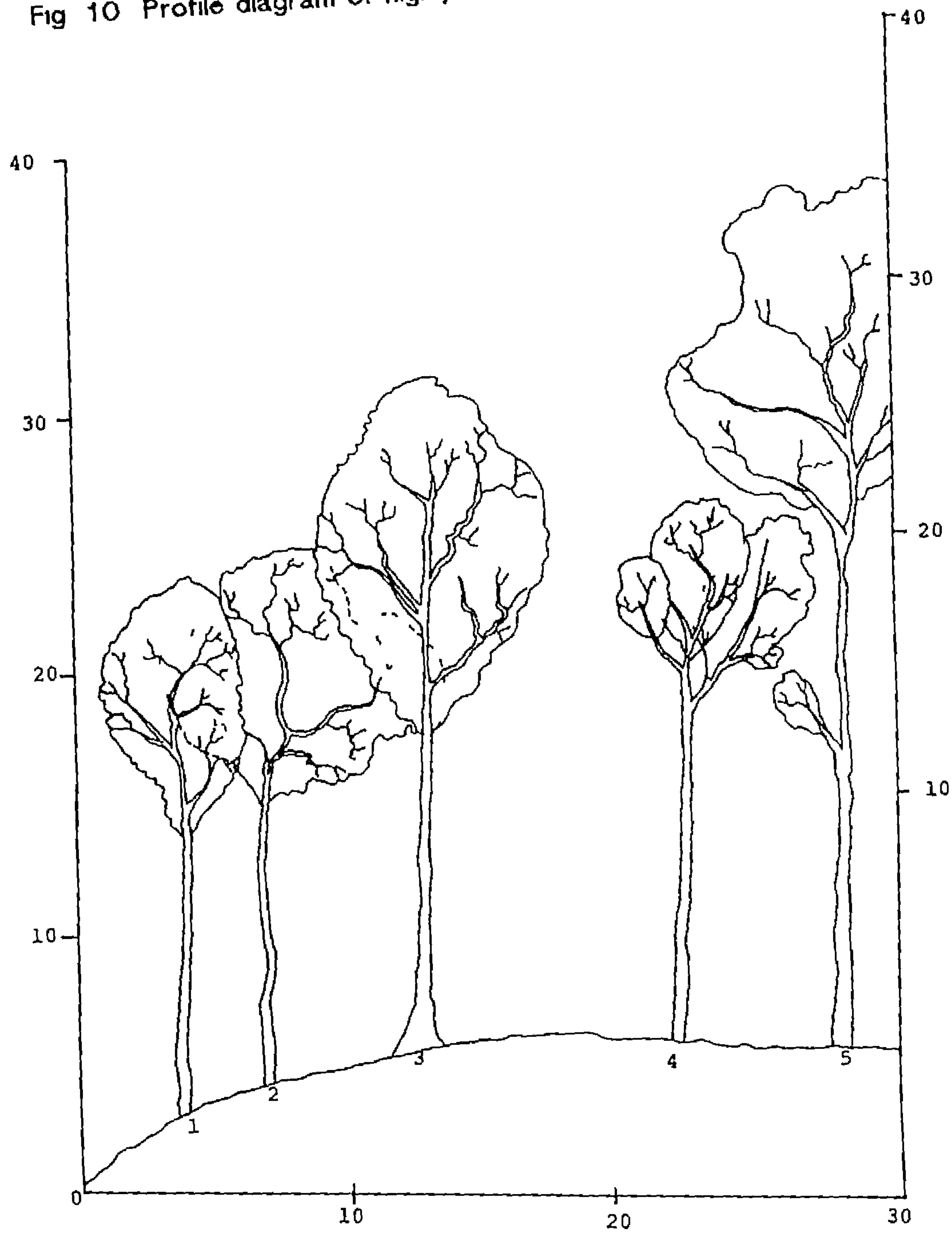
4.1.3.2 Profile diagram

The profile diagrams of the three experimental plots are shown in Figs. 10 to 12. Profile diagram shows that the undisturbed plot (PAPK-TP) has the maximum density of individuals. The regenerating community is also well represented at PATK-TP (Fig.12). With disturbance there is a shift in the forest structure which can be observed in the profile. In the disturbed plots the lower categories of the vegetation are poorly represented (Figs. 10 and 11). Plates 1, 2 and 3 also show a similar pattern.

Table 14. Percentage distribution of individuals occupying different tiers in the experimental plots

Experimental plots	Number of individuals	Percentage distribution		
		First (<15m)	Second Storey (15-30m)	Third Storey >30 m
Highly disturbed (PATK-BT)	154	56.49	34.35	9.16
Partially disturbed (PATK-MD)	540	75.52	14.46	13.01
Undisturbed (PATK-TP)	882	83.33	14.74	1.92

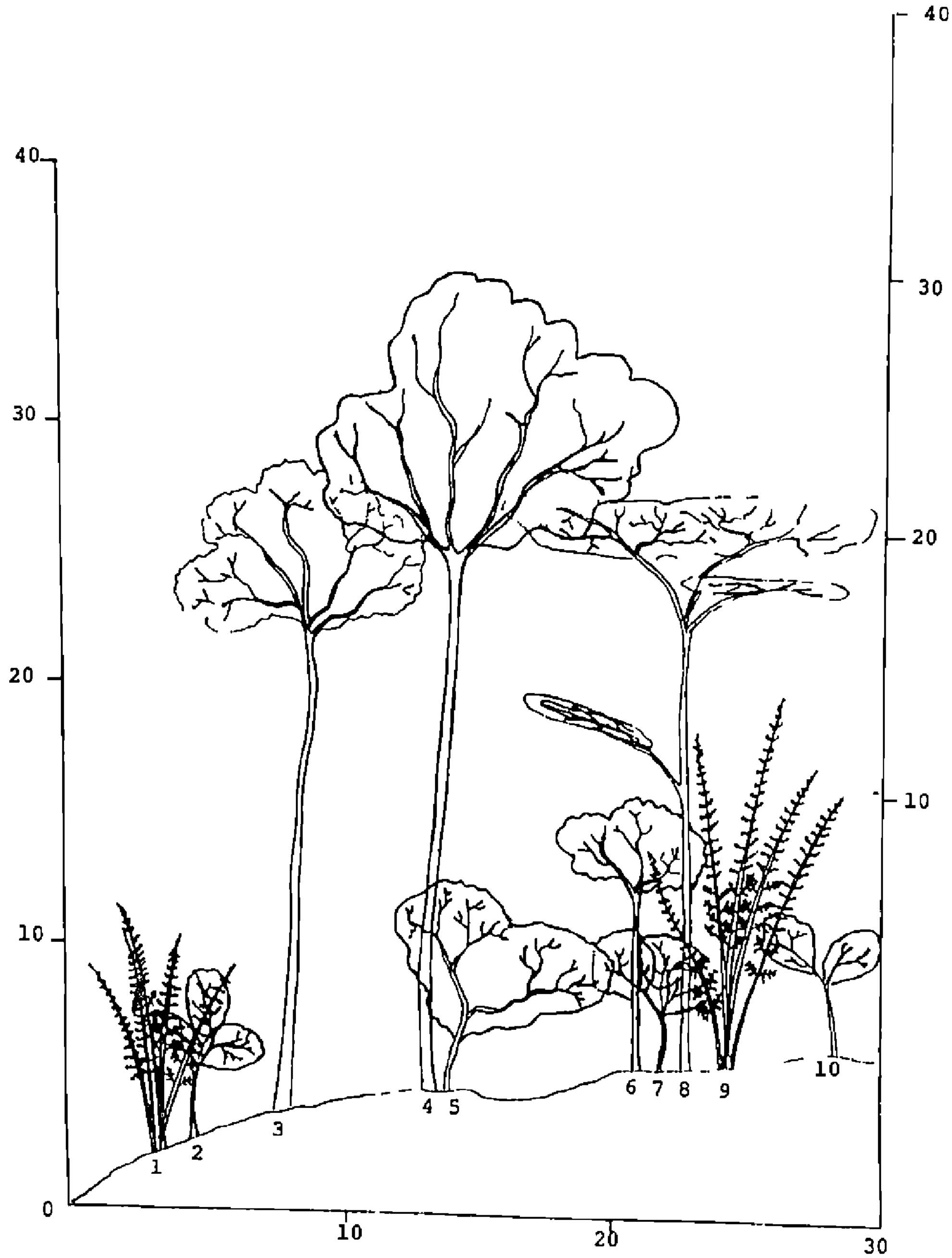
Fig 10 Profile diagram of highly disturbed (PATK-BT) plot (10m x 30m)



1. LAGMI 2. TERPA 3. LAGMI 4. XYLXY 5. XYLXY

* Expansions of the abbreviations are given in Appendix-I

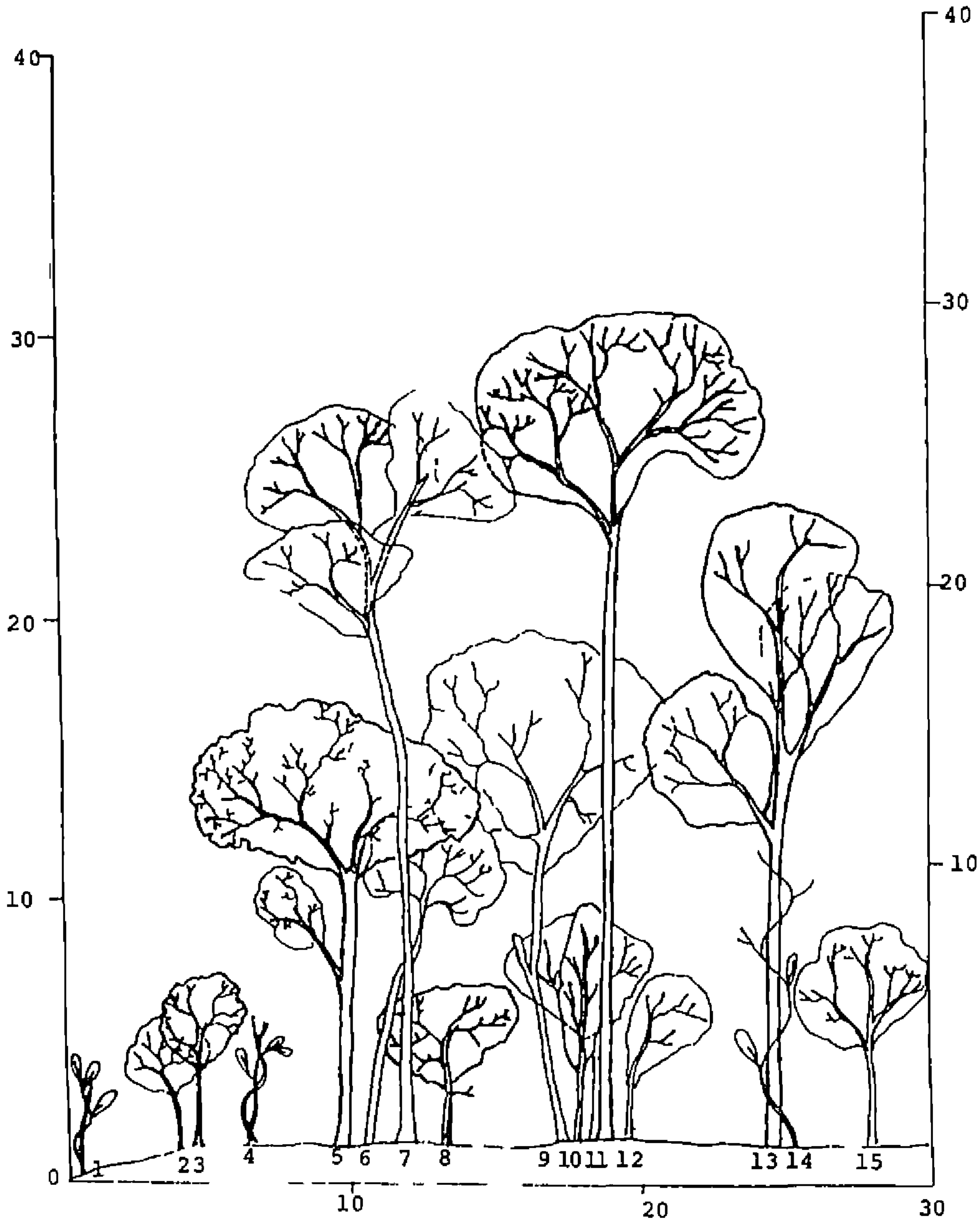
Fig. 11 Profile diagram of partially disturbed (PATK-MD) plot (10m x 30m)



1. BAMAR 2. WRITI 3. LANCO 4. XYLXY 5. WRITI
6. TERPA 7. WRITI 8. TERPA 9. BAMAR 10. XYLXY

* Expansions of the abbreviations are given in Appendix-I

Fig 12 Profile diagram of undisturbed (PATK-TP) plot (10m x 30m)



1. STRSP	4. ARTZE	7. CLESP	10. ACTBO	13 DIMLO
2. EUOLU	5. DIOCR	8. CINZE	11. HUNZE	14 CONRI
3. LITLA	6 OLEDI	9. AGLLA	12 AGLLA	15. CYNTR

* Expansions of the abbreviations are given in Appendix-I

4.1.3.3 Height diameter relationships

Height-diameter relationships for all individuals of girth >10 cm following Oldeman's (1974) method for PATK-BT, PATK-MD and PATK-TP are given in Fig.13, 14 and 15 respectively.

The set of the future (left of the line H=100 D) was very few at PATK-BT (Fig 13). It also showed a substantial reduction of individuals having diameter 9 cm to 40 cm and height 5 m to 20 m.

At PATK-MD, also the set of the future was poorly represented (Fig.14). Here also there was a reduction in the frequency of individuals having diameter 10 cm to 30 cm and height 7 m to 20 m. Few dead or badly damaged trees were present in this plot.

The set of the future was better represented at PATK-TP (Fig.15). Here also dead or badly damaged trees were present. The adequate representation of individuals show less disturbance at PATK-TP.

4.1.3.4 Girth distribution

The girth class frequency distribution of individuals at PATK-BT, PATK-MD and PATK-TP are given in Fig.16, 17 and 18 respectively.

Fig. 13 Height-diameter relationships at highly disturbed (PATK-8T) plot

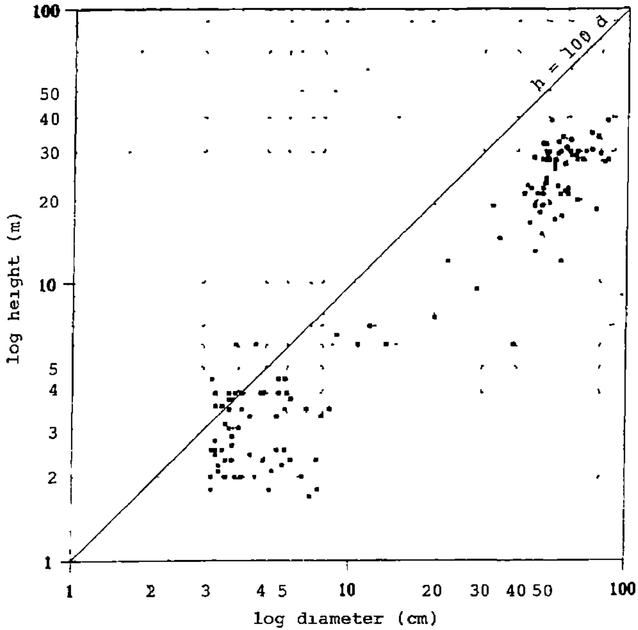


Fig. 14 Height-diameter relationships at partially disturbed (PATK-MD) plot

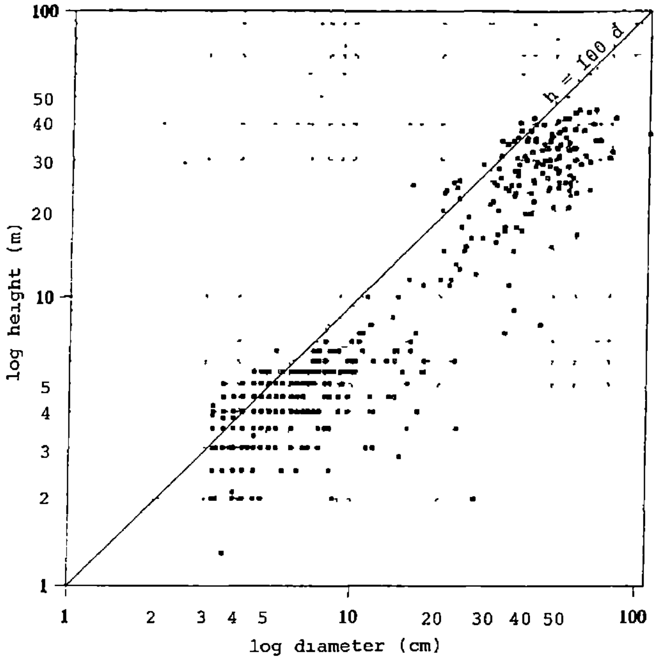
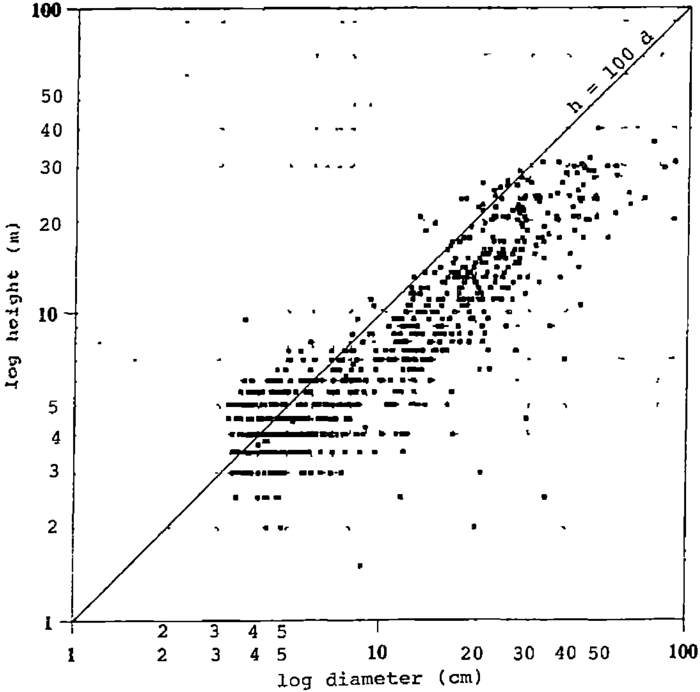


Fig. 15 Hieght-diameter relationships at undisturbed (PATK-TP) plot



Girth class frequency distribution of PATK-BT, presented in Fig.16 showed that lower size classes (upto 30 cm) account for nearly 50 per cent of the total individuals. Individuals having girth 50 cm to 150 cm were poorly represented in this plot.

Girth class frequency distribution of individuals at PATK-MD is presented in Fig.17. Lower size class, upto 50 cm girth individuals accounted for 70 per cent of the total population. At PATK-MD the girth class distribution followed more or less an inverse 'J' pattern indicating less disturbance. Though a lone tree has a girth of 340 cm, other individuals are <260 cm in girth.

The girth class frequency distribution of individuals at PATK-TP is given in Fig.18. Here also lower size class individuals upto 60 cm girth accounted for 70 per cent of the total population. At PATK-TP, the girth class frequency distribution follows an inverse 'J' pattern indicating that the structure of the forest is in a stable state. However trees having girth of >160 cm accounted for 2 per cent only. The maximum girth of an individual was 285 cm.

4.1.3.5 Height distribution

The height class frequency distribution of individuals at PATK-BT, PATK-MD and PATK-TP are presented in Figs.19 to 21.

Fig. 17 Girth class frequency distribution of individuals at partially disturbed (PATK-MD) plot, in percentage

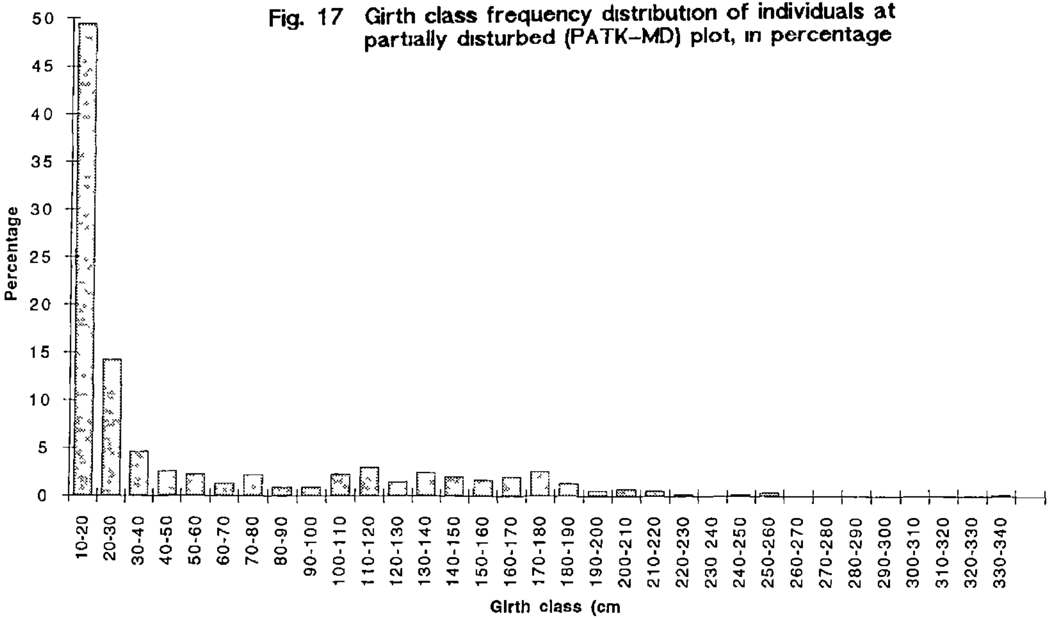
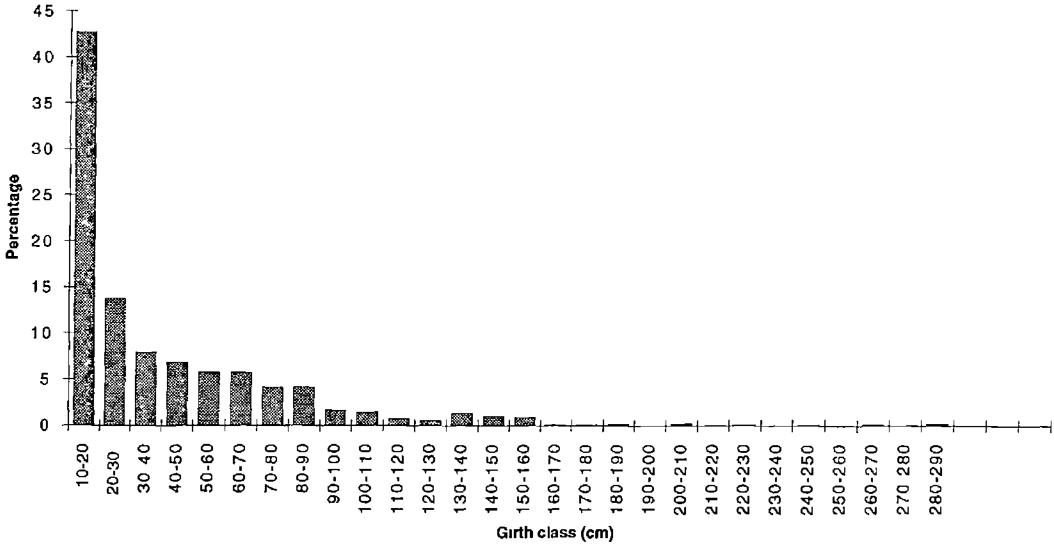


Fig. 18 Girth class frequency distribution of individuals at undisturbed (PATK-TP) plot, in percentage



The phenomena were similar to those observed for girth. Nearly 50 per cent of individuals have a height of <8 m (Fig.19). Height class from 8 to 18 m, as well as from 24 to 28 were poorly represented at PATK-BT.

It was observed that nearly 65 per cent of the total individuals have <8 m in height (Fig.20). Height class from 8 to 24 m are poorly represented at PATK-MD.

Height class frequency distribution of the individuals at PATK-TP, also followed an inverse 'J' pattern (Fig.21), once again indicating that the structure of the forest is in a state of equilibrium at PATK-TP.

4.2 Regeneration

The frequency of individuals having a girth <10 cm in 400 m^2 area at PATK-BT is given in Table 15. The plants have been classified into, unestablished seedlings, established seedlings, advanced growth and saplings as per Basha (1987). The density of regenerating individuals was 3825 per ha with 1525 unestablished seedlings, 1325 established seedlings, 675 advanced growth and 300 saplings.

Xylia xylocarpa accounted for 26 per cent of total regenerating community at PATK-BT, and was followed by *Wrightia tinctoria*, *Holarrhena pubescens*, *Bambusa arundinacea*

Fig. 19 Height class frequency distribution of individuals at highly disturbed (PATK-BT) plot, in percentage

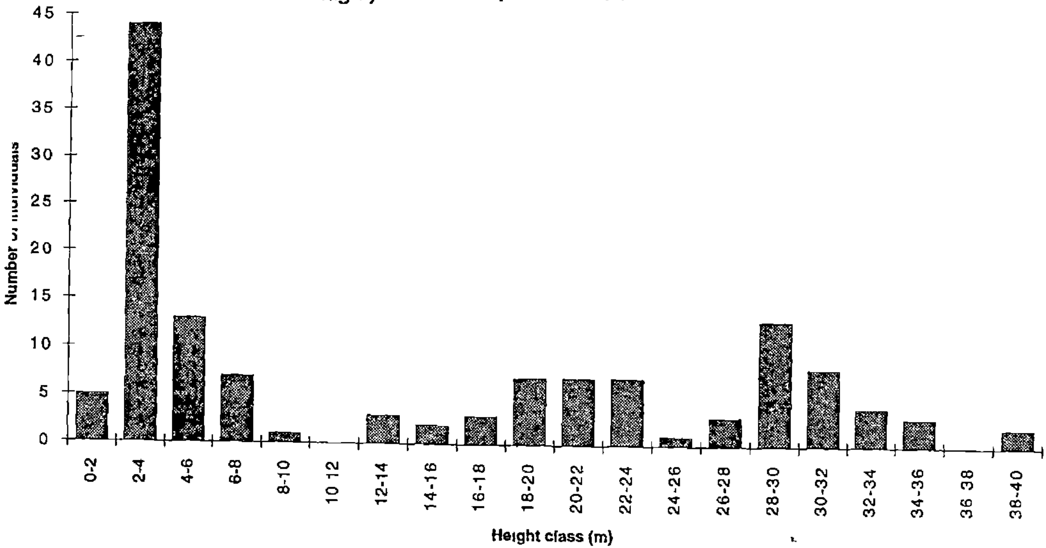


Fig. 20—Height class frequency distribution of individuals at partially disturbed (PATK-MD) plot, in percentage

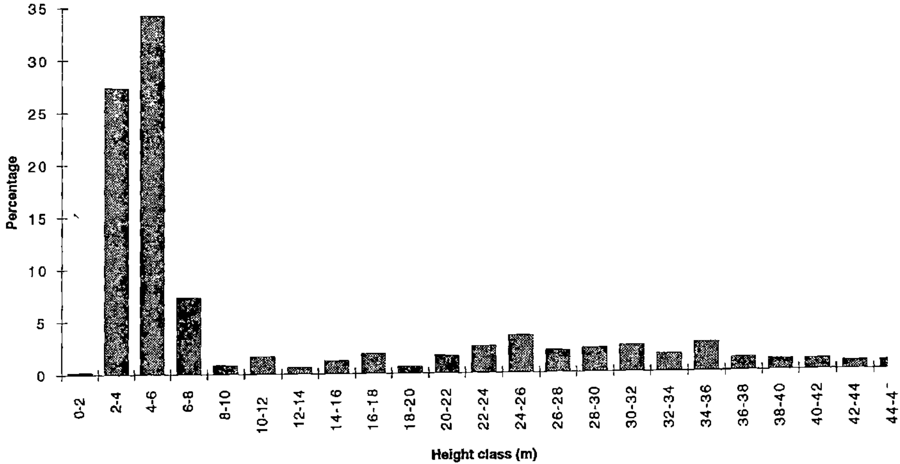


Fig. 2 1 Height class frequency distribution of individuals at undisturbed (PATK-TP) plot, in percentage

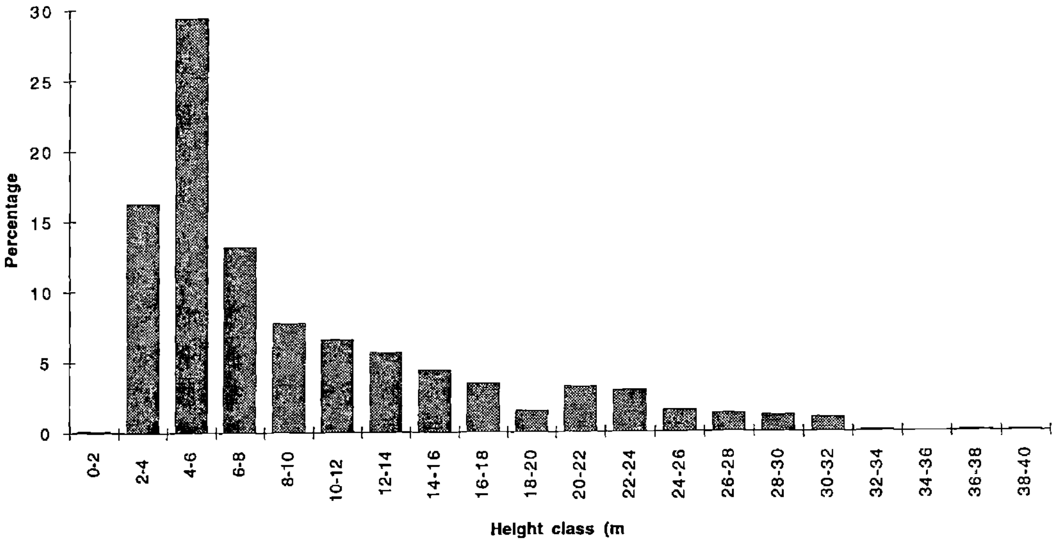


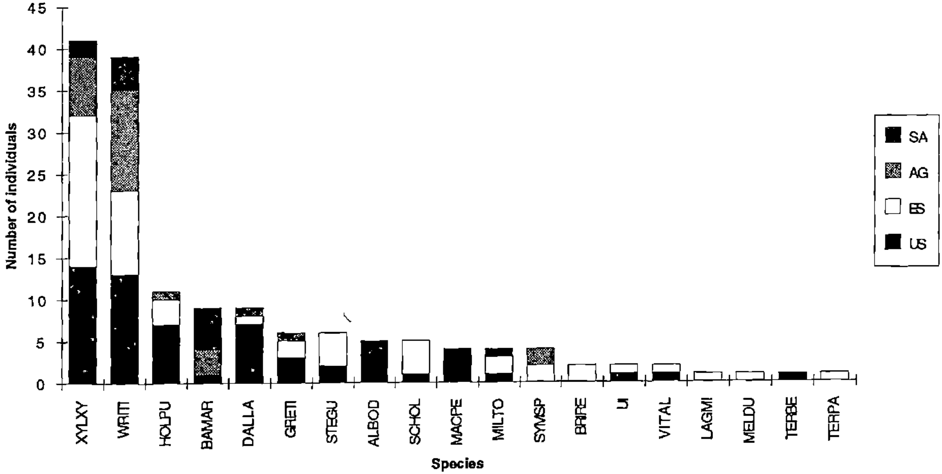
Table 15. Regeneration pattern in the highly disturbed (PATK-BT) plot (Plot size 400 m^2)

Species	Number of seedlings				Total
	Unesta-blished seedlings	Establi-shed seedlings	Advanced growth	Saplings	
1. *Xylia xylocarpa*	14	18	7	2	41
2. *Wrightia tinctoria*	13	10	12	4	39
3. *Holarrhena pubescens*	7	3	1	-	11
4. *Bambusa arundinaceae*	1	-	3	5	9
5. *Dalbergia latifolia*	7	1	1	-	9
6. *Grewia tiliifolia*	3	2	1	-	6
7. *Sterculia guttata*	2	4	-	-	6
8. *Albizia odoratissima*	5	-	-	-	5
9. *Schleichera oleosa*	1	4	-	-	5
10. *Macaranga peltata*	4	-	-	-	4
11. *Miliusa tomentosa*	1	2	-	1	4
12. *Symplacos* sp.	-	2	2	-	4

Contd.

Species	Number of seedlings				Total
	Unestablished seedlings	Established seedlings	Advanced growth	Saplings	
13. *Bridelia retusa*	-	2	-	-	2
14. UI	1	1	-	-	2
15. *Vitex altissima*	1	1	-	-	2
16. *Lannea coromandelica*	-	1	-	-	1
17. *Melia dubia*	-	1	-	-	1
18. *Terminalia bellirica*	1	-	-	-	1
19. *Terminalia paniculata*	-	1	-	-	1
	61	53	27	12	153

Fig. 22 Species frequency distribution of unestablished seedlings to saplings at highly disturbed (PATK-BT) plot



* Expansions of the abbreviations are given in Appendix-I

and Dalbergia latifolia (Table 15, Fig.22). Figure 22 also show that Xylia xylocarpa, Wrightia tinctoria, Holarrhena pubescens, Dalbergia latifolia, Grewia tiliifolia and Miliusa tomentosa show conversion from one regeneration class to other. However, Bridelia retusa, Lagerstroemia microcarpa, Melia dubia and Terminalia paniculata were represented only as established seedlings and Terminalia bellirica as unestablished seedling.

The frequency of individuals having a girth <10 cm in 400 m^2, at PATK-MD is shown in Table 16. The density of the regenerating individuals was 5045 per hectare, with 1800, unestablished seedlings, 2300 established seedlings, 550 advanced growth and 425 saplings

Xylia xylocarpa accounted for 20 per cent of the total regenerating community at PATK-BT, and was followed by Grewia tiliifolia, Wrightia tinctoria and Terminalia paniculata (Table 16, Fig.23). Figure 23 also showed that conversion from one regeneration class to other is clearly taking place in the case of Xylia xylocarpa, Grewia tiliifolia. However, Dalbergia latifolia, Symplacos sp. and Clerodendron viscosum were represented only in established seedling state and Albizzia odoratissima and Lannea coromandelica only as unestablished seedling stage.

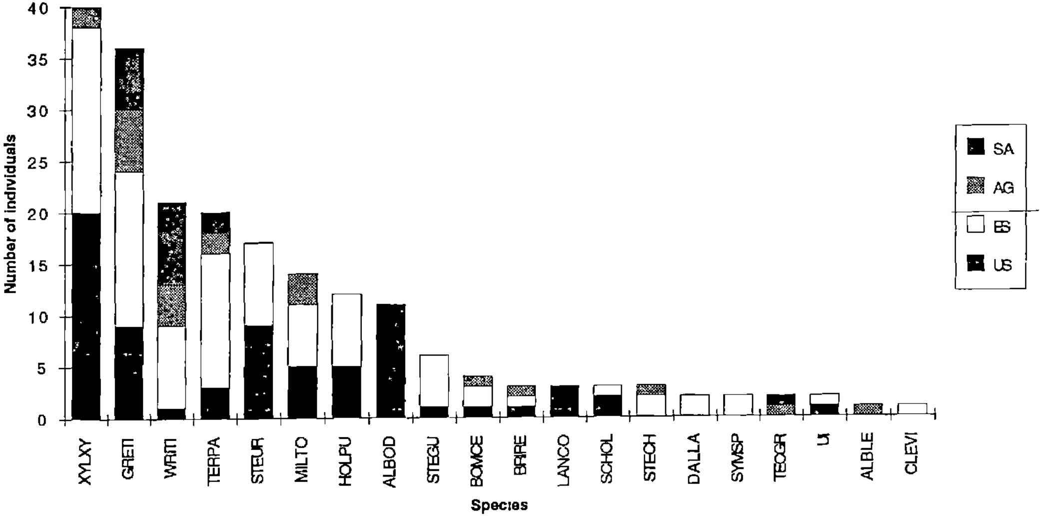
Table 16. Regeneration pattern in the partially disturbed (PATK-MD) plot (plot size 400 m^2)

Species	Number of seedlings				Total
	Unestablished seedlings	Established seedlings	Advanced growth	Saplings	
1. *Xylia xylocarpa*	20	18	2	-	40
2. *Grewia tiliifolia*	9	15	6	6	36
3. *Wrightia tinctoria*	1	8	4	8	21
4. *Terminalia paniculata*	3	13	2	2	20
5. *Sterculia urens*	9	8	-	-	17
6. *Miliusa tomentosa*	5	6	3	-	14
7. *Holarrhena pubescens*	5	7	-	-	12
8. *Albizia odoratissima*	11	-	-	-	11
9. *Sterculia guttata*	1	5	-	-	6
10. *Bombax ceiba*	1	2	1	-	4
11. *Bridelia retusa*	1	1	1	-	3
12. *Lannea coromandelica*	3	-	-	-	3

Contd.

Species	Number of seedlings				Total
	Unestablished seedlings	Established seedlings	Advanced growth	Saplings	
13. *Schleichera oleosa*	2	1	-	-	3
14. *Stereospermum chelenoides*	-	2	1	-	3
15. *Dalbergia latifolia*	-	2	-	-	2
16. *Symplacos* sp.	-	2	-	-	2
17. *Tectona grandis*	-	-	1	1	2
18. UI	1	1	-	-	2
19. *Albizia lebbeck*	-	-	1	-	1
20. *Clerodendron viscosum*	-	1	-	-	1
	72	92	22	17	203

Fig. 23 Species frequency distribution of unestablished seedlings to saplings at partially disturbed (PATK-MD) plot



* Expansions of the abbreviations are given in Appendix-I

In the undisturbed plot (PATK-TP) frequency of individuals having a girth of <10 cm was 26,500 per hectare, with 4000 unestablished seedlings, 10,000 established seedlings 9500 advanced growth and 3000 saplings (Table 17).

The distribution pattern of unestablished seedlings, established seedlings, advanced growth and saplings at PATK-BT, PATK-MD and PATK-TP is shown in Fig.24, Table 17.

4.3 Litter dynamics

4.3.1 Litter fall

The total litter fall and the contribution from various litter parts are given in Tables 18 to 20 for PATK-BT, PATK-MD and PATK-TP respectively.

The total litter production was 6.14 t ha^{-1} for PATK-BT. The leaves accounted for 83.6 per cent, bark and twigs for 8.3 per cent and reproductive parts for 8.08 per cent (Table 18). The litter fall at PATK-BT followed a monomodial distribution pattern (Fig.25) with a conspicuous peak during the period from November to February.

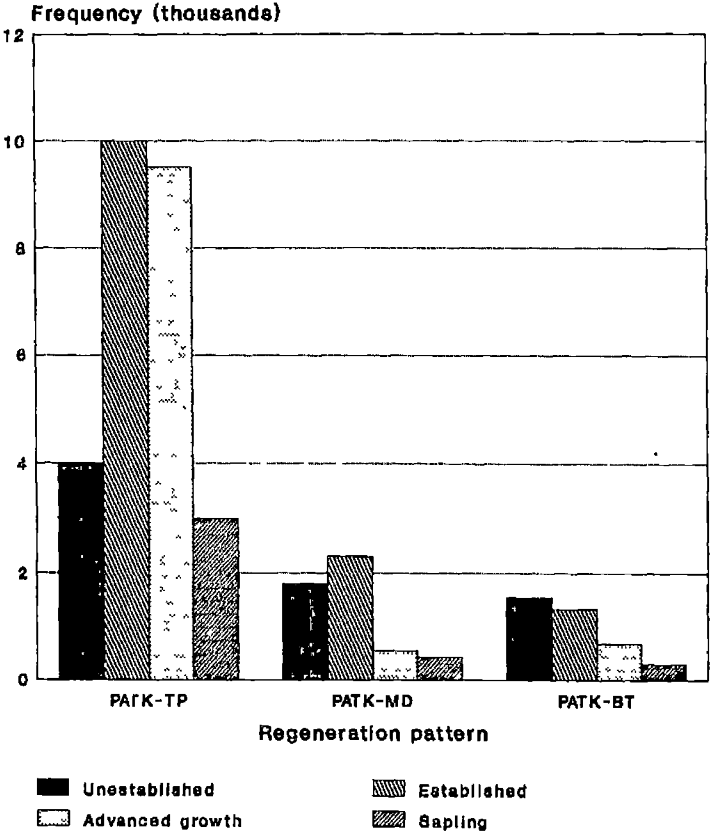
The total litter production was 8.66 t ha^{-1} at PATK-MD. The leaves accounted for 86.3 per cent, twigs and bark 9.0 per cent and reproductive parts 4.7 per cent (Table 19). The litterfall at PATK-MD followed a monomodial distribution

Table 17. The frequency of unestablished seedlings to saplings in the three experimental plots

Plot	Number of seedlings per hectare				Total
	Unestablished seedlings	Established seedlings	Advanced growth	Saplings	
Undisturbed (PATK-TP)	4000 (15)	10000 (38)	9500 (36)	3000 (11)	26500
Partially disturbed (PATK-MD)	1800 (36)	2300 (45)	550 (11)	425 (8)	5045
Highly disturbed (PATK-BT)	1525 (40)	1325 (35)	675 (18)	300 (8)	3825

Figures in parenthesis show the percentage

Fig.24 The distribution of seedling community in the three plots



pattern (Fig.26) with a conspicuous peak during the period from November to February.

The total litter production at PATK-TP was 6.89 t ha^{-1}. The leaves accounted for 86 per cent, followed by twigs and barks (10.3 per cent) and reproductive parts (3.6 per cent) (Table 20). The litter fall at PATK-TP followed a bimodial distribution (Fig.27) with one peak from October to December and a second peak in February. The phenology of litter production at PATK-BT, PATK-MD and PATK-TP is shown in Figs. 28 to 30.

At PATK-BT heavy leaf fall was observed during November to March (Fig.28). Fruit fall also started from November (end of the monsoon) and continued till June (beginning of monsoon).

At PATK-MD heavy leaf fall was observed during November to March (Fig.29). Fruit fall started from December and continued till June.

At PATK-TP leaf fall was more or less uniform over the months, except in December and February (Fig.30). Here the fruit fall commences with the onset of monsoon in June and continues till January.

A negative correlation between the leaf fall and soil

Table 18. Annual litter production at highly disturbed (PATK-BT) plot

Month	Leaves ($t\ ha^{-1}$)	Bark & Twig ($t\ ha^{-1}$)	Fruit & flower ($t\ ha^{-1}$)	Total ($t\ ha^{-1}$)
Jun. '92	0.08 (25.32)	0.14 (43.81)	0.10 (30.87)	0.33
Jul. '92	0.11 (60.57)	0.07 (34.710	0.01 (4.72)	0.19
Aug. '92	0.10 (83.03)	0.02 (13.67)	0.00 (3.31)	0.12
Sep. '92	0.14 (75.29)	0.04 (22.82)	0.00 (1.89)	0.19
Oct. '92	0.12 (81.69)	0.02 (12.08)	0.01 (6.23)	0.15
Nov. '92	0.20 (78.68)	0.02 (9.54)	0.03 (11.78)	0.25
Dec. '92	0.56 (87.66)	0.04 (5.54)	0.04 (6.81)	0.63
Jan. '93	1.04 (82.77)	0.04 (3.11)	0.18 (14.12)	1.26
Feb. '93	1.81 (96.44)	0.01 (0.72)	0.05 (2.83)	1.87
Mar. '93	0.64 (87.67)	0.04 (5.25)	0.05 (7.08)	0.73
Apr. '93	0.15 (50.79)	0.10 (35.68)	0.04 (13.54)	0.29
May '93	0.05 (38.74)	0.05 (42.23)	0.02 (19.03)	0.12
Total	5.00 (83.62)	0.59 (8.30)	0.55 (8.08)	6.14 (100.00)

Figures in parenthesis show the percentage

Table 19. Annual litter production at partially disturbed (PATK-MD) plot

Month	Leaves (t ha^{-1})	Bark & Twig (t ha^{-1})	Fruit & flower (t ha^{-1})	Total (t ha^{-1})
Jun '92	0.12 (41.05)	0.11 (38.98)	0.06 (19.97)	0.29
Jul. '92	0.15 (55.48)	0.11 (42.64)	0.01 (1.89)	0.27
Aug. '92	0.15 (82.62)	0.03 (15.46)	0.00 (1.92)	0.18
Sep. '92	0.14 (79.11)	0.03 (19.32)	0.00 (1.57)	0.17
Oct. '92	0.13 (69.69)	0.04 (21.87)	0.02 (8.45)	0.19
Nov. '92	0.23 (73.50)	0.08 (24.53)	0.01 (1.97)	0.32
Dec. '92	0.02 (81.47)	0.20 (15.77)	0.03 (2.77)	1.25
Jan. '93	0.94 (95.04)	0.02 (1.94)	0.03 (3.02)	0.99
Feb. '93	3.14 (96.23)	0.04 (1.32)	0.08 (2.45)	3.26
Mar. '93	1.07 (91.29)	0.01 (0.97)	0.09 (7.73)	1.17
Apr. '93	0.23 (73.42)	0.02 (7.90)	0.06 (18.68)	0.31
May '93	0.16 (61.81)	0.07 (28.55)	0.03 (9.65)	0.26
Total	7.47 (86.28)	0.78 (8.96)	0.41 (4.73)	8.66 (100.00)

Figures in parenthesis show the percentage

Table 20. Annual litter production at undisturbed (PATK-TP) plot

Month	Leaves ($t\ ha^{-1}$)	Bark & Twig ($t\ ha^{-1}$)	Fruit & flower ($t\ ha^{-1}$)	Total ($t\ ha^{-1}$)
Jun. '92	0.32 (55.17)	0.22 (37.93)	0.05 (8.62)	0.58
Jul. '92	0.22 (68.75)	0.06 (18.75)	0.04 (12.5)	0.32
Aug. '92	0.35 (87.51)	0.04 (10.00)	0.01 (2.50)	0.40
Sep. '92	0.26 (89.66)	0.02 (6.90)	0.01 (3.50)	0.29
Oct. '92	0.27 (77.14)	0.06 (17.14)	0.01 (2.90)	0.35
Nov. '92	0.53 (86.88)	0.06 (9.83)	0.02 (3.27)	0.61
Dec. '92	1.16 (87.20)	0.12 (9.02)	0.04 (3.01)	1.33
Jan. '93	0.72 (91.14)	0.04 (5.06)	0.04 (5.06)	0.79
Feb. '93	1.25 (98.43)	0.02 (1.58)	0.00 (0.00)	1.27
Mar. '93	0.38 (97.44)	0.01 (2.56)	0.00 (0.00)	0.39
Apr. '93	0.21 (84.00)	0.03 (12.00)	0.01 (4.00)	0.25
May '93	0.28 (87.50)	0.04 (12.50)	0.00 (0.00)	0.32
Total	5.93 (86.11)	0.71 (10.31)	0.25 (3.61)	6.89 (100.00)

Figures in parenthesis show the percentage

Fig. 25 Annual litter production at highly disturbed (PATK-BT) plot

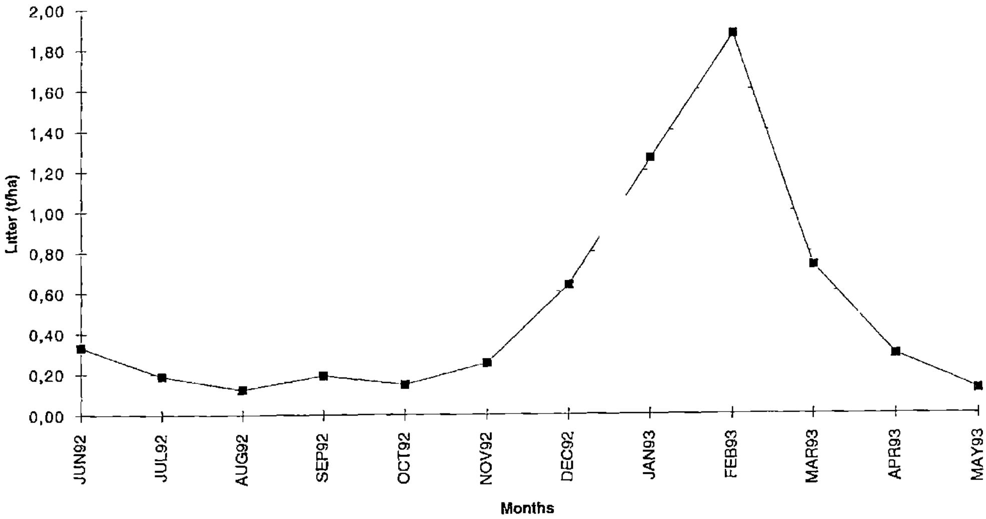


Fig. 26 Annual litter production at partially disturbed (PATK-MD) plot

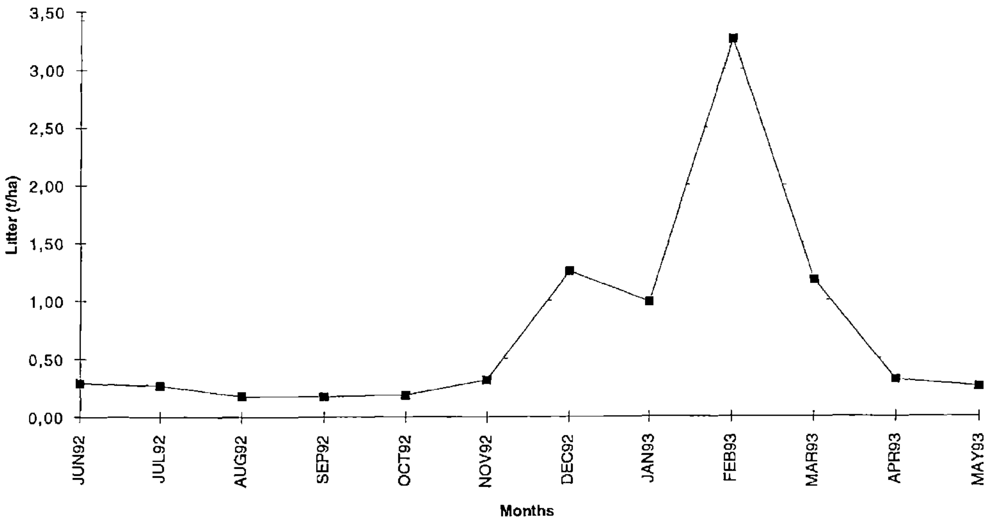


Fig. 27 Annual litter production at undisturbed (PATK-TP) plot

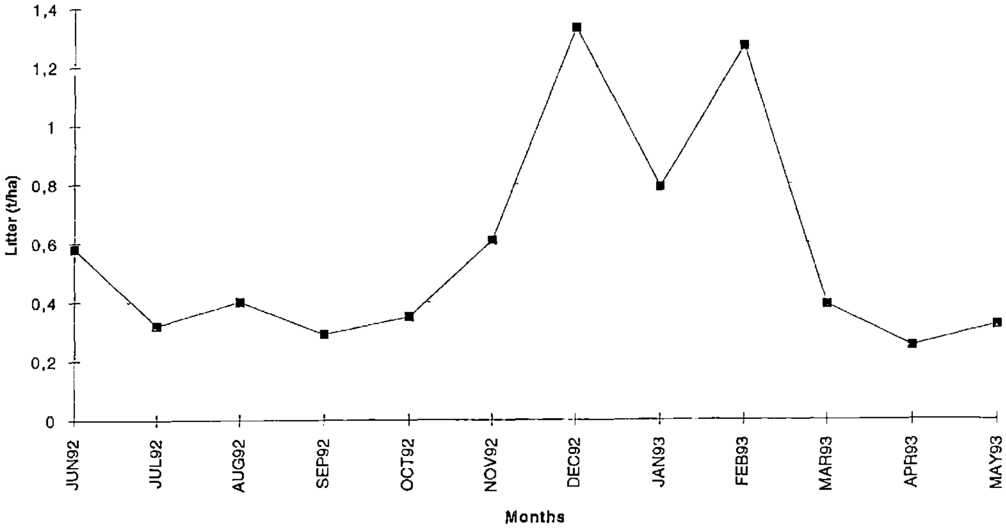


Fig. 29 Contribution of various components of litter at partially disturbed (PATK-MD) plot

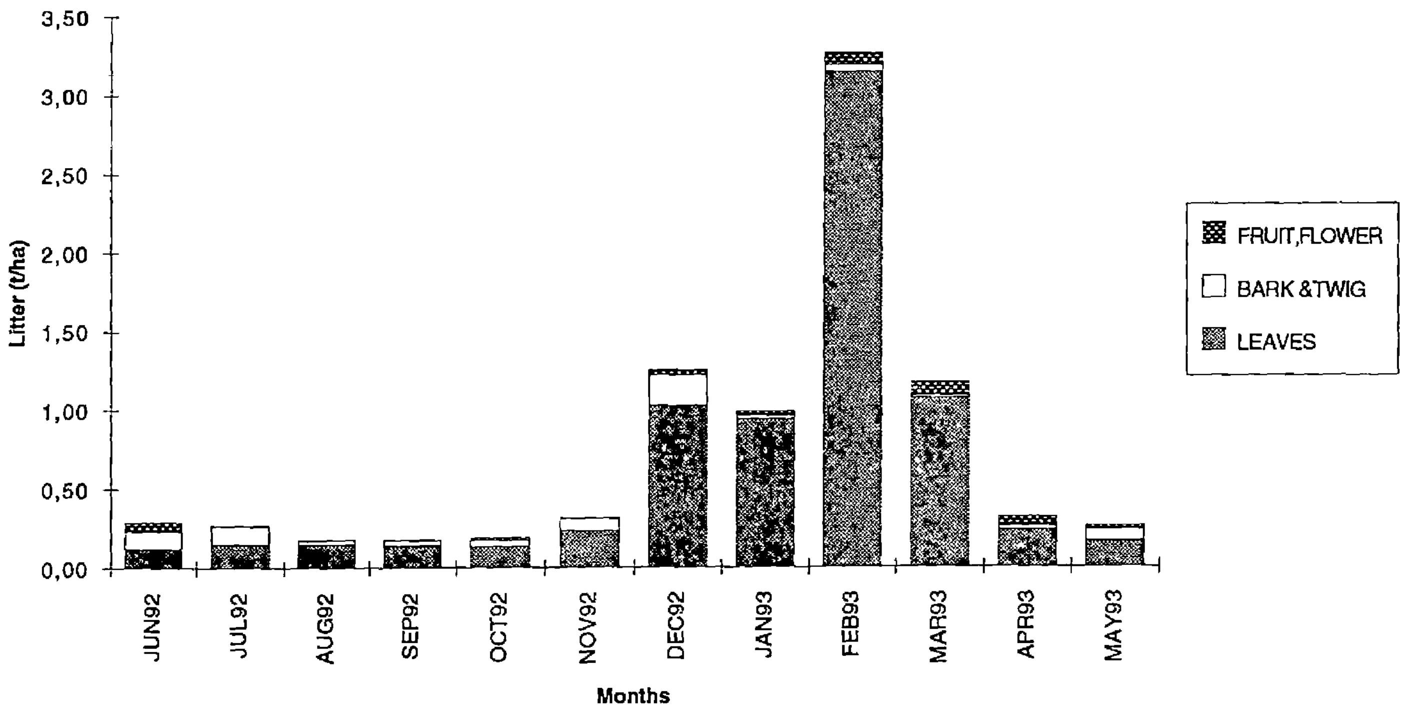
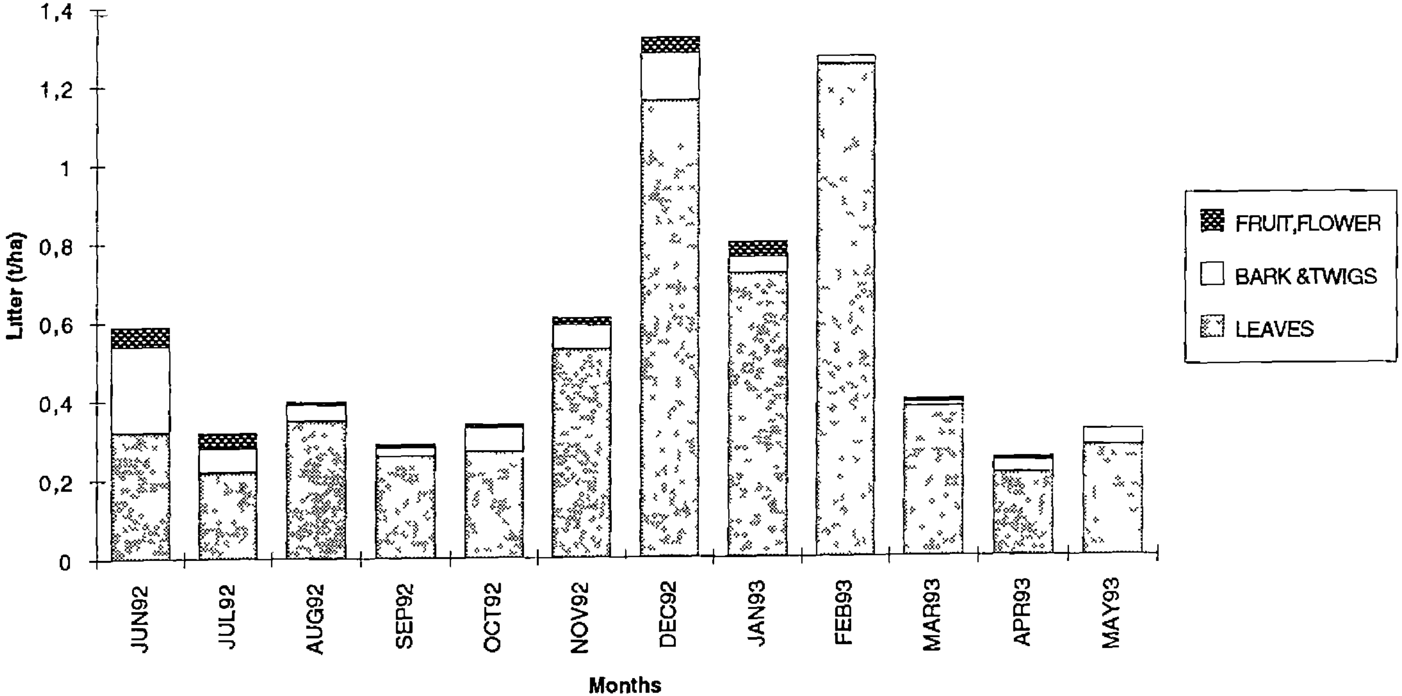


Fig. 30 Contribution of various components of litter at undisturbed (PATK–TP) plot



moisture was observed in all three areas under study, viz , PATK-BT, PATK-MD and PATK-TP (Figs.31 to 33). When the soil moisture decreased the leaf fall increased. However, in February though the soil moisture increased the litter fall also showed a higher value. This is an artifact, caused due to the drizzle on the day of the soil sample collection for soil moisture estimation.

4.3.2 Litter decomposition

Results of the litter decomposition studies revealed that the mass remained in the litter bags decreased linearly with time for PATK-BT, PATK-MD and PATK-TP (Table 21, Fig.34). The regressions describing decay rates over time were highly significant at all the three locations, with r^2 values of 0.89, 0.87 and 0.92 for PATK-BT, PATK-MD and PATK-TP respectively (Table 22).

Decomposition was characterised by an initial fast rate of disappearance, followed by a subsequent slower rate (Fig.34). For instance the percentages of litter mass remaining at the end of the second month were 62.2 per cent, 76.4 per cent and 71.4 per cent for PATK-BT, PATK-MD and PATK-TP respectively.

The monthly decay rate co-efficients (K) for the three plots are given in Table 22. It showed that PATK-BT has got a

Fig. 3.1 Annual litter production and soil moisture at highly disturbed (PATK-BT) plot

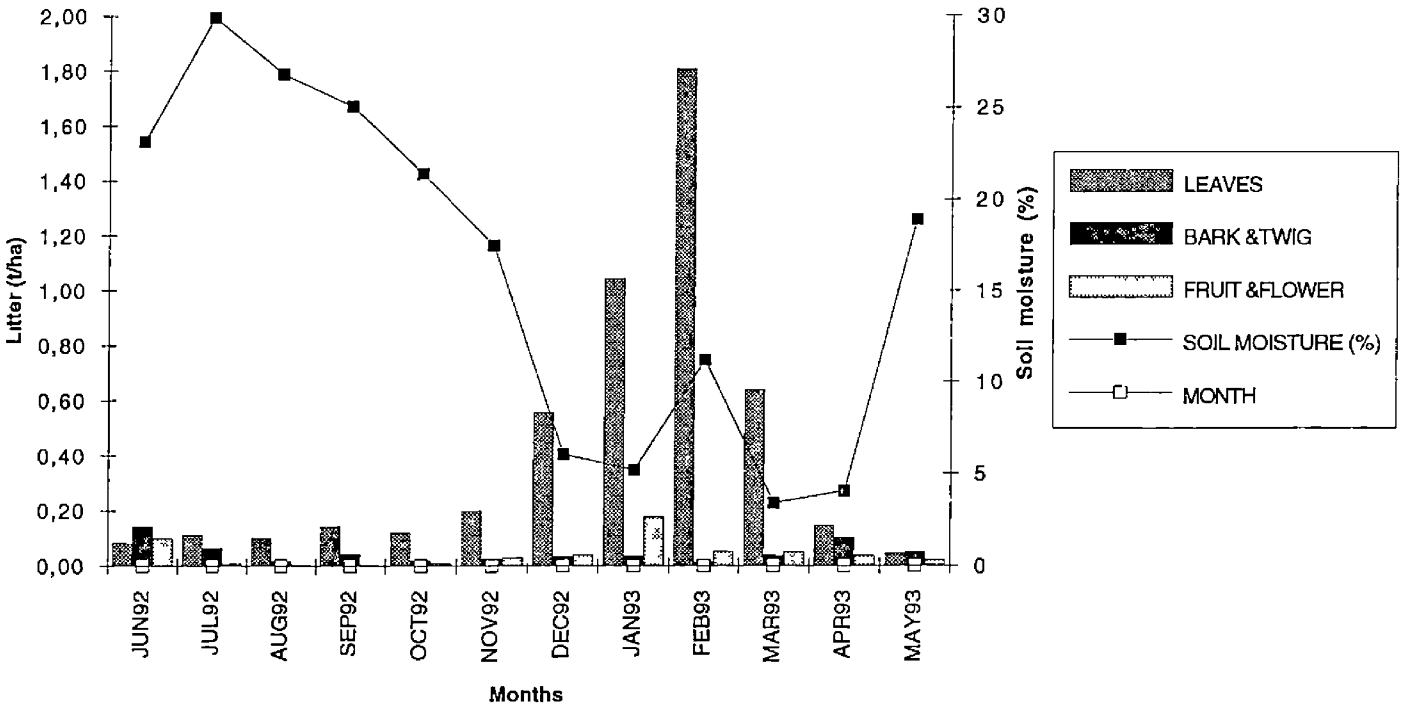


Fig. 32 Annual litter production and soil moisture at partially disturbed (PATK-MD) plot

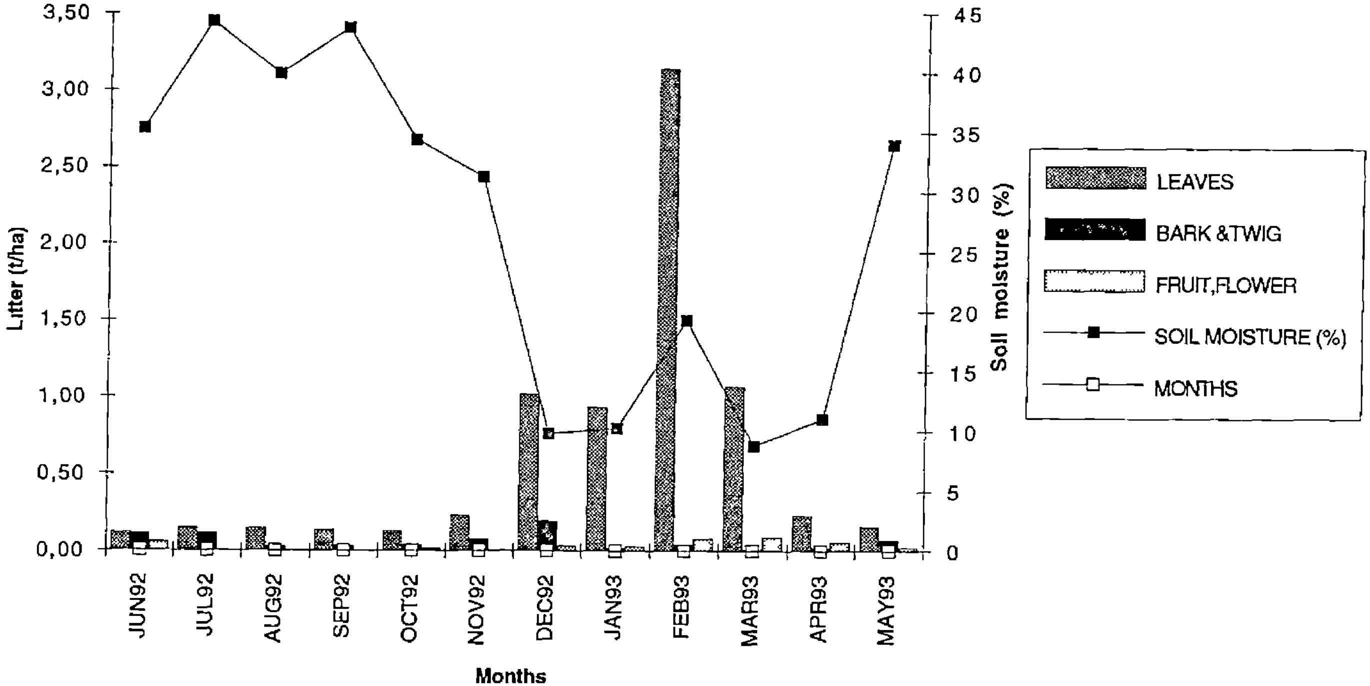


Fig. 33 Annual litter production and soil moisture at undisturbed (PATK-TP) plot

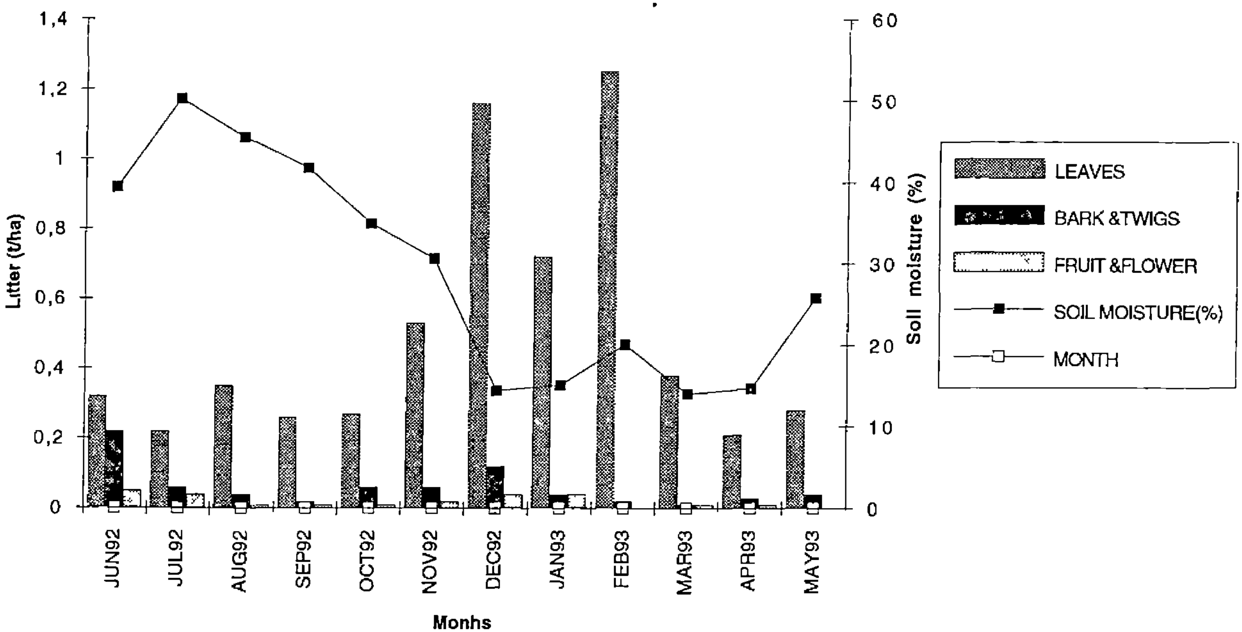


Fig. 33 Annual litter production and soil moisture at undisturbed (PATK-TP) plot

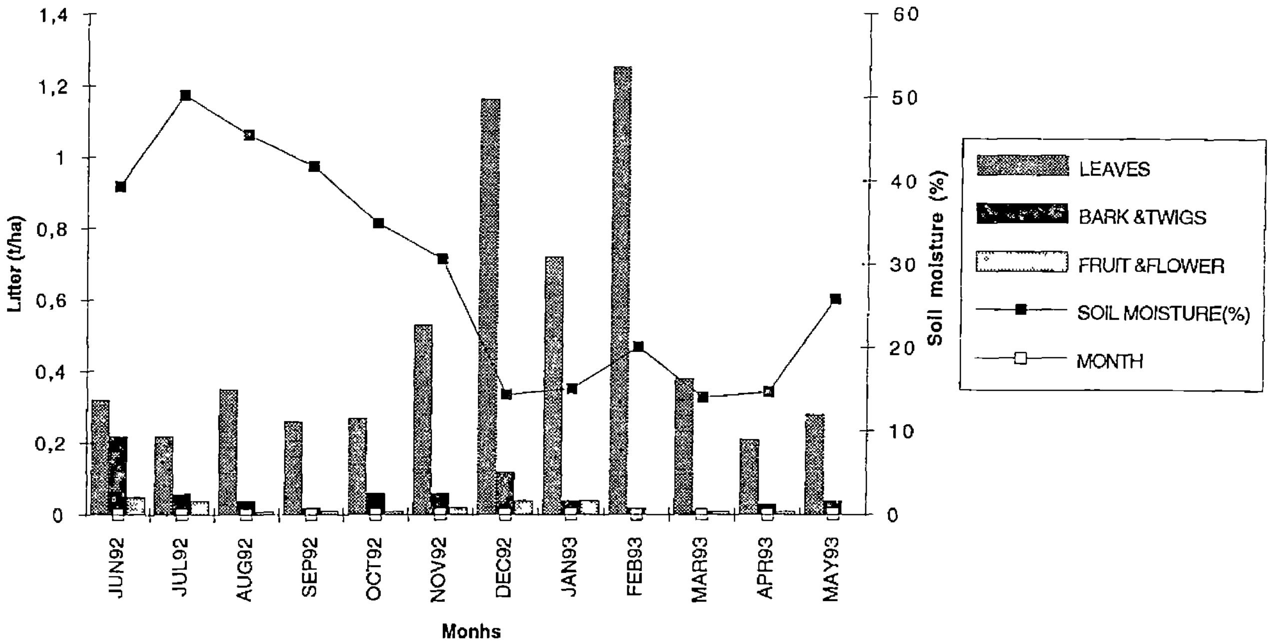


Table 21. Mass remaining in the litter bags at the three experimental sites

Month	Mass reduction (g)		
	highly disturbed (PATK-BT)	Partially disturbed (PATK-MD)	Undisturbed (PATK-TP)
June '92	31.14	38.21	35.71
July	25.05	33.24	30.39
August	15.97	24.42	28.85
September	15.49	20.94	21.64
October	11.16	19.28	15.81
November	9.52	18.37	15.77
December	8.43	15.03	14.84
January '93	4.51	14.72	12.35
February	4.28	10.12	10.75
March	4.01	9.37	9.26
April	3.76	9.04	8.32
May	3.45	8.81	7.93

(Initial weight = 50 g)

Fig.34 Decomposition models at the three experimental plots

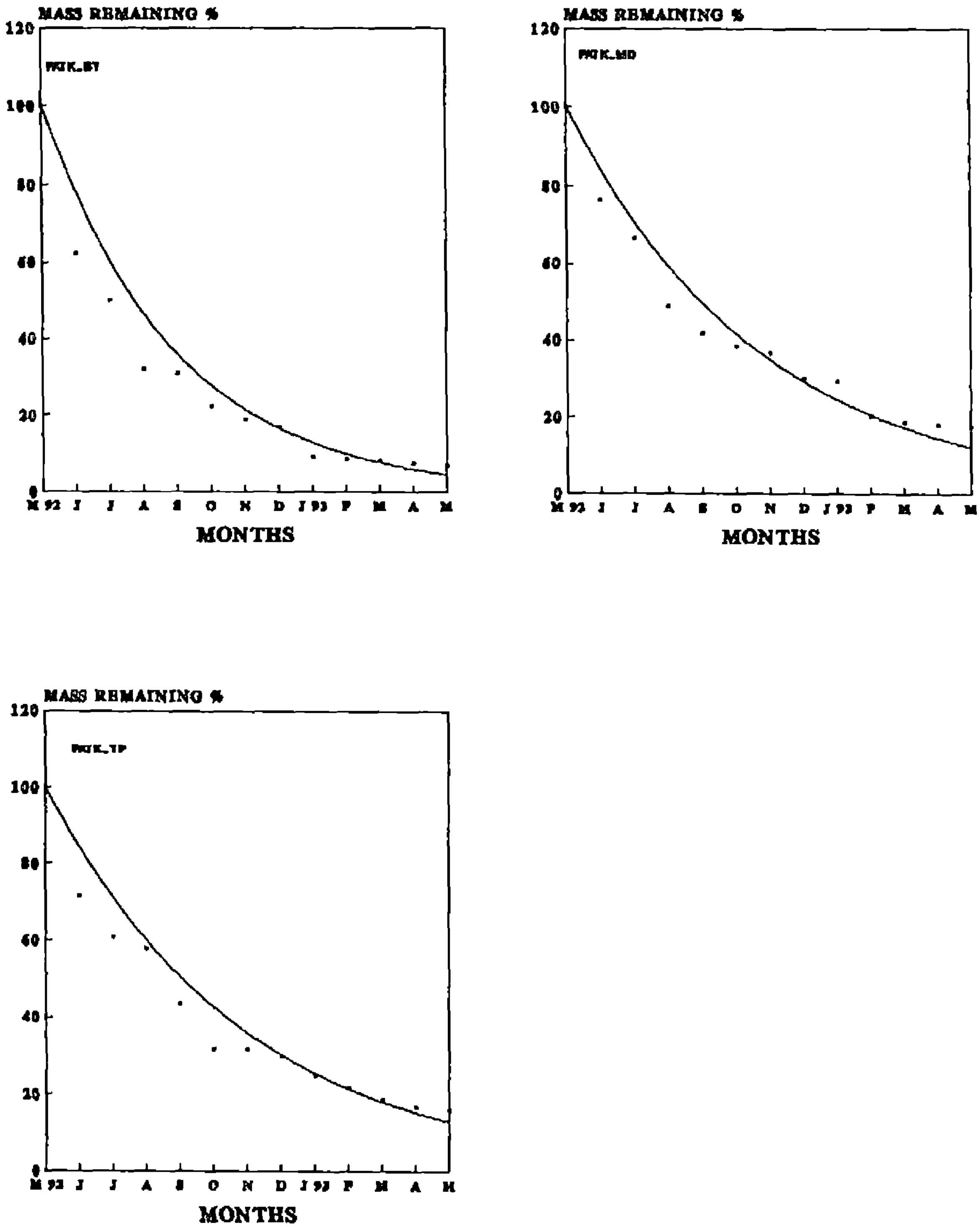


Table 22. Decay rate co-efficient and half life of decomposing litter at the three experimental plots

Plot		K	r^2	S.E.E.	Half life (t 0.5) months	n
Highly disturbed	(PATK-BT)	0.2569	0.899	0.246	2.67	13
Partially disturbed	(PATK-MD)	0.1752	0.871	0.180	3.85	13
Undisturbed	(PATK-TP)	0.1711	0.920	0.146	4.08	13

higher decay rate co-efficient (0.26) followed by PATK-MD (0.18) and, PATK-TP (0.17), which has the lowest. The half life (months) also followed a similar pattern for the three plots (Table 22).

4.3.3 Nutrient input through litter

The amount of N, P, K, Ca and Mg added to the system at the different experimental plot (PATK-BT, PATK-MD and PATK-TP) are given in Table 23.

4.4 Phenology

The results of the phenological observations conducted for a period of 12 months on 15 moist deciduous species is presented in Table 24. Generally the leaf fall occurs during the dry season (February to April months). Flowering normally commence along with the leaf fall or before and is immediately followed by fruiting.

4.5 Ecophysiology

4.5.1 Light

The distribution of light at the three areas (Table 25) showed that PATK-BT has recorded maximum light infiltration followed by PATK-MD and PATK-TP.

Table 23. Nutrient concentration (kg ha^{-1}) in litter at the different experimental plots

	N	P	K	Ca	Mg
PATK-BT	56.50	2.14	19.29	83.37	29.63
PATK-MD	62.35	2.60	19.92	93.87	45.03
PATK-TP	43.59	1.78	14.12	66.44	31.31

Table 24. Phenology of 15 important tree species at Pattikkad

Sl. No.	Species	Leaf fall	Flowering	Fruiting
1.	*Albizzia odoratissima*	April-May	May-June	Jan-Mar.
2.	*Alstonia scholaris*	Mar-April	Dec-Jan	Jan-Feb
3.	*Bombax ceiba*	Feb-Mar	Feb-Mar	Apr-May
4.	*Dillenia pentagyna*	Mar-Apr	Mar-Apr	Apr-May
5.	*Dalbergia sissoides*	Feb-Mar	Feb-Apr	Apr-May
6.	*Grewia tiliifolia*	Mar-Apr	Mar-May	May-July
7.	*Haldina cordifolia*	Mar-Apr	May-June	Nov-Jan
8.	*Lagerstroemia microcarpa*	Mar-Apr	June-Aug	Nov-Feb
9.	*Melia dubia*	Feb-Mar	Jan-Feb	Jan-Mar
10.	*Tectona grandis*	Mar-Apr	June-Aug	Nov-Jan
11.	*Terminalia bellirica*	Feb-Mar	Mar-May	July-Nov
12.	*Terminalia crenulata*	Feb-Mar	May-July	Nov-Feb
13.	*Terminalia paniculata*	Feb-Mar	Oct-Dec	Jan-Mar
14.	*Tetrameles nudiflora*	Mar-Apr	Feb-Apr	Apr-May
15.	*Xylia xylocarpa*	Mar-Apr	Feb-Apr	May-July

Table 25. Intensity of light in the three experimental plots at Pattikkad (μmol m^{-2} s^{-1})

Sl. No.	Highly disturbed (PATK-BT)	Partially disturbed (PATK-MD)	Undisturbed (PATK-TP)
1.	148.10	75.90	14.81
2.	136.20	54.71	3.10
3.	163.60	128.30	10.54
4.	122.20	134.60	12.92
5.	236.00	76.92	183.10
6.	50.89	345.70	9.19
7.	128.20	104.90	35.45
8.	129.40	174.60	32.63
9.	135.20	58.65	105.40
10.	154.40	55.89	37.09
$\bar{X}$	140.42	121.02	44.42

4.5.2 Leaf area index

The leaf area index recorded (Table 26) showed that PATK-TP had maximum LAI of 4.04 followed by PATK-MD (1.11) and PATK-BT (1.06).

4.5.3 Leaf area

The leaf area of ten important species each from PATK-BT, PATK-MD and PATK-TP were shown in Tables 27 to 29. At PATK-BT (Table 27) 70 per cent leaves belonged to the mesophyllous class, 20 per cent macrophyllous and 10 per cent notophyllous, whereas at PATK-MD (Table 28), 60 per cent belonged to mesophyllous, 20 per cent macrophyllous. Notophyllous and nanophyllous leaves accounted for 10 per cent each. However, at PATK-TP (Table 29) 50 per cent belonged to notophyllous, 40 per cent mesophyllous and 10 per cent microphyllous.

4.6 Soil

The physico-chemical properties of the soil in the three experimental plots is presented in Table 30. The percentage of gravel is maximum at the highly disturbed (PATK-BT) plot and minimum at undisturbed (PATK-TP) plot. The soil is more acidic in the undisturbed (PATK-TP) plot and the acidity is very low in the highly disturbed (PATK-MD) plot.

Table 26. Leaf area index (LAI) of the vegetation in the three experimental plots at Pattikkad

Sl.No.	Experimental plots	LAI
1.	Highly disturbed (PATK-BT)	1.06
2.	Partially disturbed (PATK-MD)	1.11
3.	Undisturbed (PATK-TP)	4.04

(n = 10)

Table 27. Leaf area (cm^2) of ten important species (according to IVI) at highly disturbed (PATK-BT) plot in Pattikkad

Sl.No.	Species	Type of leaf	Leaf area (cm^2)
1.	*Wrightia tinctoria*	notophyll	38.06
2.	*Lagerstroemia microcarpa*	mesophyll	47.03
3.	*Xylia xylocarpa*	mesophyll	51.24
4.	*Bombax ceiba*	mesophyll	52.30
5.	*Lannea coromandelica*	mesophyll	73.04
6.	*Terminalia paniculata*	mesophyll	88.81
7.	*Terminalia crenulata*	mesophyll	92.08
8.	*Terminalia bellirica*	mesophyll	163.16
9.	*Grewia tiliifolia*	macrophyll	210.97
10.	*Tectona grandis*	macrophyll	497.21

n = 25

Table 28. Leaf area (cm^2) of ten important species (according to IVI) at partially disturbed (PATK-MD) plot in Pattikkad

Sl.No.	Species	Type of leaf	Leaf area (cm^2)
1.	Albizzia odoratissima	nanophyll	38.00
2.	Wrightia tinctoria	notophyll	38.06
3.	Lagerstroemia microcarpa	mesophyll	47.03
4.	Xylia xylocarpa	mesophyll	51.24
5.	Terminalia paniculata	mesophyll	88 81
6.	Holarrhena pubescens	mesophyll	95.50
7.	Helicteres isora	mesophyll	155.06
8.	Miliusa tomentosa	mesophyll	175.70
9.	Grewia tiliifolia	macrophyll	210.97
10.	Dillenia pentagyna	macrophyll	679.47

n = 25

Table 29. Leaf area (cm^2) of ten important species (according to IVI) at undisturbed (PATK-TP) plot in Pattikkad

Sl.No.	Species	Types of leaf	Leaf area (cm^2)
1.	*Dimocarpus longan*	microphyll	19.29
2.	*Spondias pinnata*	microphyll	19.29
3.	*Aglaia lawii*	notophyll	22.64
4.	*Scleropyrum pentandrum*	notophyll	26.41
5.	*Diospyrous hirsuta*	notophyll	34.73
6.	*Wrightia tinctoria*	notophyll	38.06
7.	*Vitex altissima*	notophyll	43.67
8.	*Lagerstroemia microcarpa*	mesophyll	47.03
9.	*Pterospermum reticulatum*	mesophyll	56.34
10.	*Erythrina stricta*	mesophyll	95.58

n = 25

Table 30. Physico-chemical properties of soil in the three experimental plots at Pattikkad

	% of gravel	pH	Org. C (%)	N (ppm)	P	K (ppm)
PATK-BT						
0-20	33.53	6.14	1.98	1300	6	230
20-40	39.89	6.14	1.27	760	3	196
40-60	23.61	6.13	0.89	550	NA	196
PATK-BT						
0-20	30.79	5.73	2.15	1800	12	350
20-40	30.95	5.86	1.53	1250	7	303
40-60	26.52	5.64	1.28	700	3	207
PATK-TP						
0-20	22.69	5.57	2.98	2400	16	218
20-40	23.94	5.51	1.55	1900	8	137
40-60	23.87	5.56	1.40	1120	6	155

(n = 4)

Organic carbon is maximum in the undisturbed (PATK-TP) plot followed by partially disturbed plot (PATK-MD) and highly disturbed (PATK-BT) plot.

4.7 Micrometeorology

4.7.1 Soil moisture

Variation in the soil moisture at the experimental plots is presented in Table 31. The undisturbed (PATK-TP) plot consistantly recorded the maximum soil moisture for all the months over the year. The soil moisture was the lowest in the highly disturbed (PATK-BT) plot.

4.7.2 Soil temperature

Variation in the soil temperature at the three experimental plots is presented in Table 32. The highly disturbed (PATK-BT) plot consistantly recorded the maximum temperature for all the months over the year. The soil temperature was the lowest in the undisturbed (PATK-TP) plot.

The relationship between soil moisture and soil temperature at PATK-BT, PATK-MD and PATK-TP are shown in Figs.35 to 37. It clearly shows that as the soil temperature increases, the soil moisture decreases in all the three plots. Soil temperature did not vary considerably over the months, where as soil moisture varies considerably over the months in all the experimental plots (Figs.35 to 37).

Table 31. Soil moisture (%) at the different experimental plots in Pattikkad

Months	PATK-BT	PATK-MD	PATK-TP
June 1992	23.12	35.36	36.36
July	29.91	44.31	50.19
August	26.78	39.91	45.47
September	25.05	43.72	41.73
October	21.37	34.38	34.89
November	17.44	31.28	30.59
December	6.06	9.81	14.36
January 1993	5.20	10.25	15.07
February	11.21	19.27	20.04
March	3.40	8.80	14.00
April	4.07	11.02	14.71
May	18.90	34.00	25.75

(n = 9)

Table 32. Soil temperature (°C) at the different experimental plots in Pattikkad

Months	PATK-BT	PATK-MD	PATK-TP
June 1992	25.0	24.0	23.0
July	25.0	23.0	22.0
August	26.5	24.0	22.5
September	26.5	24.5	23.0
October	28.0	25.5	23.5
November	27.0	25.5	22.5
December	29.0	26.0	23.5
January 1993	31.5	28.0	22.5
February	33.0	28.5	25.0
March	35.0	32.0	27.0
April	36.0	30.5	28.0
May	28.0	26.5	26.0

Fig. 35 Monthly means of soil moisture and soil temperature at highly disturbed (PATK-BT) plot

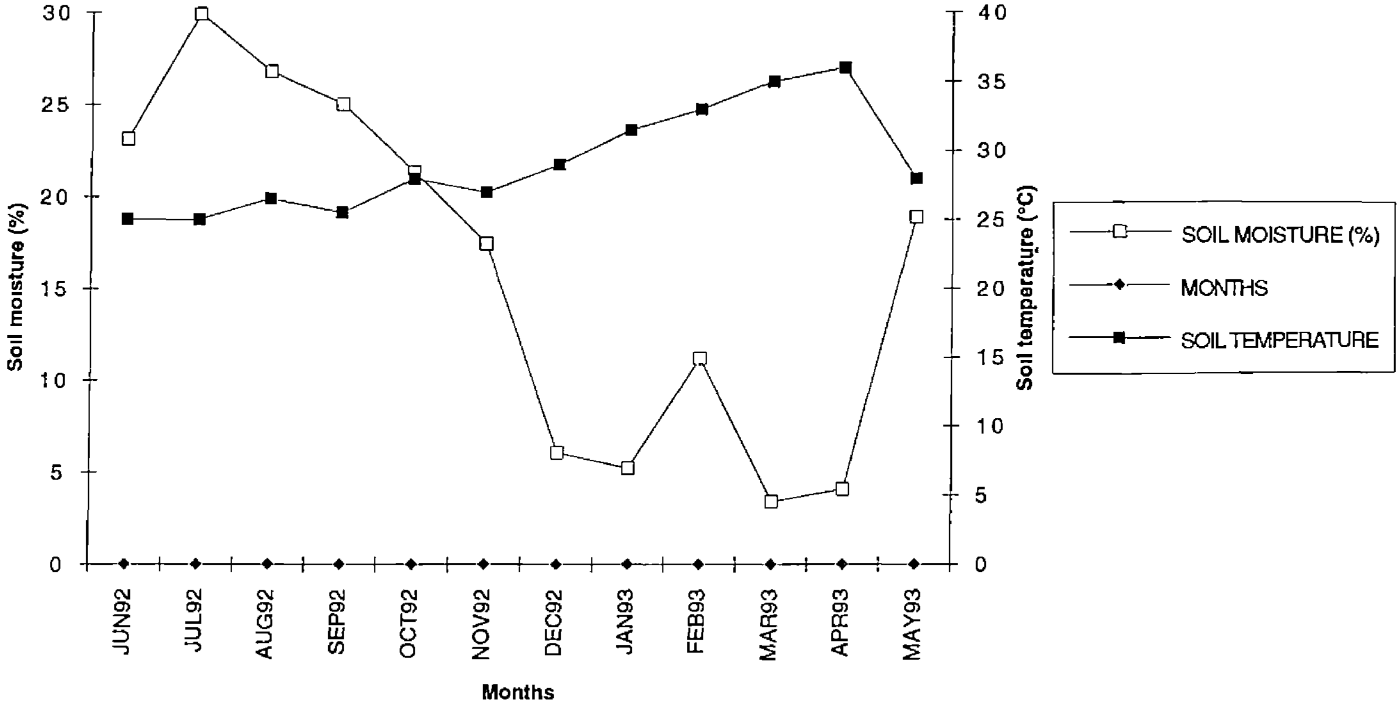


Fig. 36 Monthly means of soil moisture and soil temperature at partially disturbed (PATK-MD) plot

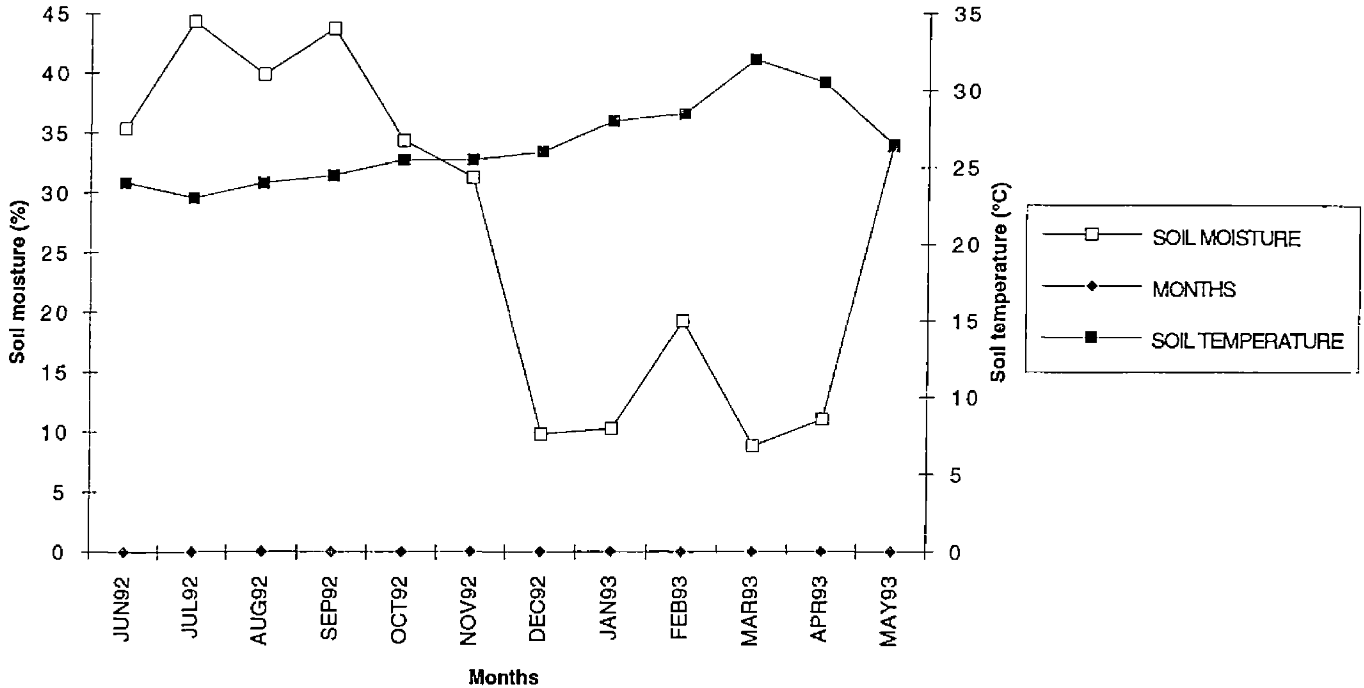
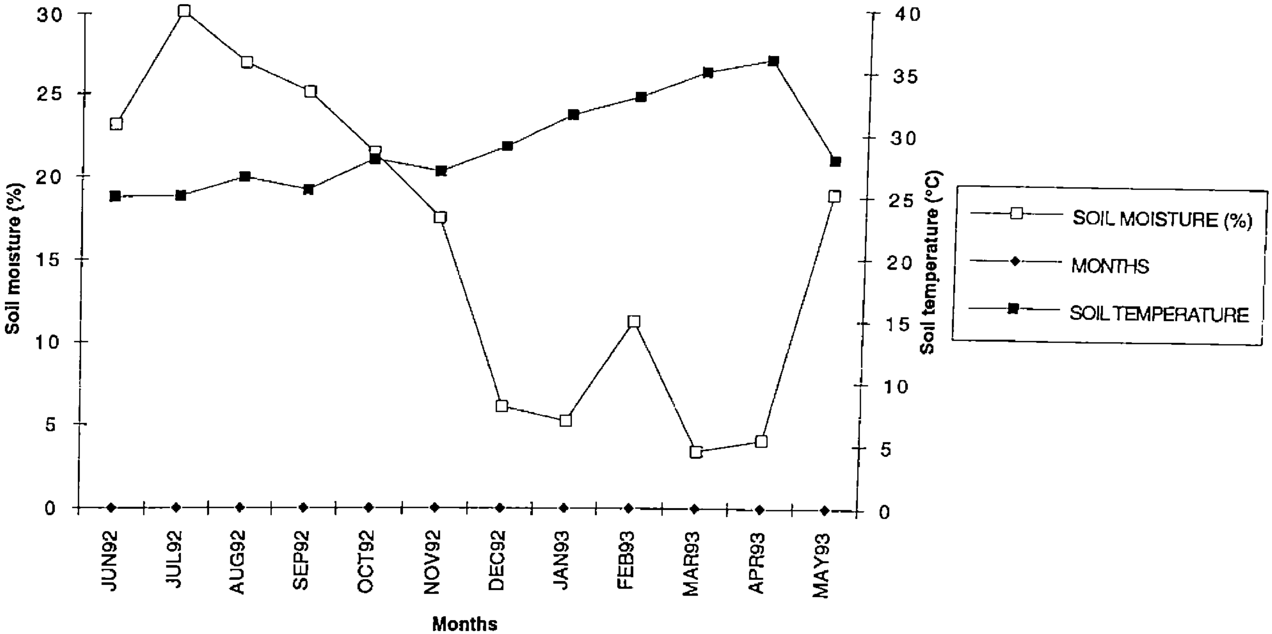


Fig. 37 Monthly means of soil moisture and soil temperature at undisturbed (PATK-TP) plot



Discussion

DISCUSSION

5.1 Vegetation

5.1.1 Floristic richness and diversity

Floristically the undisturbed plot (PATK-TP) is the richest in density (882), number of species (143) and diversity (Simpson's = 0.97, and Shannon-Weiner's = 5.97) (Table 13). Eighty seven per cent of the species at PATK-TP are evergreen in nature. This could be due to less anthropogenic pressure at PATK-TP. As a result, the moist deciduous forest gradually transforms to a semievergreen forest. Pascal (1988) has pointed out that if a moist deciduous forest is protected against biotic interferences it would be transformed to semi-evergreen, which if further protected will become an evergreen forest.

The highly disturbed plot (PATK-BT) has a vegetation association of *Xylia xylocarpa* - *Lagerstroemia microcarpa* - *Terminalia crenulata* whereas the partially disturbed plot (PATK-MD) has a vegetation association of *Xylia xylocarpa* - *Terminalia paniculata* - and *Grewia tiliifolia*. Similar vegetation associations have been reported for the moist deciduous forests of Thrissur forest Division by Menon and Balasubramanyan (1985).

5.1.2 Vegetation structure and Sylvigenesis

In a normally growing tropical forest, the set of the future and set of the present must be more or less equally represented. At PATK-TP (Fig.15) the set of the future and set of the present are well represented indicating that the vegetation is in a stable state. In the other two plots, PATK-BT and PATK-MD (Figs.13 and 14), it can be seen that the set of the future is poorly represented. It may also be noted that there is a considerable reduction in the number of individuals in the diameter class, 8 to 40 cm and height class, 5 to 20 m. This could be due to the preferential removal of individuals of the above said height class and girth class.

Oldeman (1974, 1990) while characterising the tropical wet evergreen forests has classified the floristic elements of an ecosystem into set of the future (trees on the left of line h = 100 d) set of the present (trees falling n the right of line h = 100 d) and set of the past (senescent and badly damaged trees). Halle et al. (1978) explains it as "the homeostatic forest plot can be thought of as a banquet at which three groups attempt to dine: the set of the present are successful but eat themselves to death on the abundant resources made available, the set of the future sit hungrily at the kitchen door hoping for a vacated place, the trees of the past are elderly, decrepit dying beggars chased away from every dish".

In a balanced unevenaged forest the number of individuals in the lower girth classes is usually large and the number in the higher size classes would decrease progressively. Consequently the size class frequency distribution would show an inverse 'J' or 'L' pattern (Pascal, 1988). Such kind of a balanced, inverse 'J' distribution pattern for girth class as well as height class is clearly depicted in the undisturbed (PATK-TP) plot (Figs.18 and 21). PATK-BT and PATK-MD do not portray an inverse 'J' distribution pattern both for girth class and for height class. There is a substantial reduction in the number of individuals having girth of 40-140 cm (Figs.16 and 17) and height 8 to 24 (Figs. 19 and 20). This also might be due to the anthropogenic interference.

5.1.3 Stratification

The results of the stratification of the trees (Table 14) showed that the moist deciduous plots consist of trees belonging to two tiers only (First storey and second storey).

The third storey (>30 m height) is poorly represented and this clearly points to the structural difference between evergreen and deciduous ecosystems. Tropical forests as a rule comprise trees of different heights arranged in three to four tiers. This is especially true for rain and evergreen forests (Richards, 1952). Among the plots, the percentage of individuals belonging to the first storey is least in the highly disturbed plot. This is due to the preferential removal of saplings and advanced growth for using as green manure by the resident populations. It may be noted that the local population exerts a tremendous pressure on the forests. They cut and remove the young regenerating plants, for sale to the farmers living around the forest. It is used as green manure.

5.1.4 Profile diagram

The vertical and horizontal composition of a forest is well represented by the profile diagram (Richards, 1952). The profile diagram of the undisturbed plot reveals that although emergents are represented feebly, the second and first storeys are more or less fully stocked. With disturbance, there is a reduction in the number of individuals in the first storey. In the highly disturbed plot, more individuals of second storey are present when compared to partially disturbed and undisturbed. The third storey is almost absent in the undisturbed plot. This may be due to the absence of mature moist deciduous trees, while the evergreen are still in the building up phase i.e., the undisturbed plot is in the transformation stage from a moist deciduous patch to an evergreen patch.

5.2 Regeneration

Results of regeneration data given in Table 17 reveal that the undisturbed plot possesses more numbers of all categories of regneration than the partially disturbed and highly disturbed plots (5 to 7 times). The presence of large number of plants in the seedlings stage and subsequent mortality of these seedlings as they transform to higher classes have been reported by Nair, 1961 and Swarupanandan and Sashidharan, 1992. Among the categories, advanced growth is represented in the undisturbed plot in a normal fashion. It is to be deduced that unestablished and established seedlings are removed during green manure collection, while advanced growth and saplings are collected for other purposes such as, props and firewood. Thus the regeneration aspect of a forest which is the key to the sustainability of the system is threatened by human interferences.

5.3 Litter dynamics

5.3.1 Litterfall

The present study indicated profound seasonal variations in detritus fall. Leaf shedding was heavy during the dry period ranging from November to April at all the three experimental plots. Tree water stress is a cardinal aspect of the dry seasons, where moisture availability is limited and temperature shoots up. Moore (1980) reported that water stress triggers *de novo* synthesis of abscissic acid in the foliage of plants, which in turn, can stimulate senescence of leaves and other parts. Hence changes in the endogenous hormonal balance can be a plausible explanation for the peak litterfall during summer months.

Study on the phenology of litterfall in moist deciduous natural forests are generally rare from Eastern Hemisphere. Nevertheless, available reports concerning deciduous plantations clearly indicate that deciduous species yield maximum litter during summer months (Ghosh *et al*., 1982, Kikuzawa *et al*., 1984). Pascal (1988) working on the wet evergreen forests of Attappadi region of Western Ghats, indicated that the rhythm of leaf was characterised by heavy fall during the dry season.

The annual addition of detritus through litterfall expressed as t ha^{-1} $year^{-1}$ ranged from 6.14 t ha^{-1} to 8.66 t ha^{-1} for the disturbed areas (PATK-BT and PATK-MD). This value is comparable with litter fall value predicted from Bray and Gorham's (1964) inverse relationship between total detritus production per year and latitude of a region (estimated value for 10°N latitude: 9.8 t ha^{-1} $year^{-1}$), and litter production rate (5.5 - 15.3 t ha^{-1} $year^{-1}$) reported by William and Gray (1974).

Kumar and Deepu (1992) reported a litter fall of 12.2 to 14.4 t ha^{-1} $year^{-1}$ for the moist deciduous forests of Thrissur Forest Division. The higher value they got than the present study could be due to difference in the methodology. While they used only 63 litter traps (each trap having a collection area of 0.2 m^2) for the litter quantification, in the present study we used 300 traps, each trap having a collection area of 0.5 m^2.

For the undisturbed plot (PATK-TP) the litter fall is 6.89 t ha^{-1} $year^{-1}$. This value is comparable with that obtained by Rai, 1981 and Pascal, 1988.

The mean annual litterfall rates at the three experimental locations appear to be directly related to stand basal area. This observation also contradicts the result obtained for Kumar and Deepu (1992). Stohlgren (1988) suggested that annual litterfall can be better predicted by a function derived from the individual tree basal area and live crown ratio.

5.3.2 Leaf litter decomposition

The mass disappearance rates in the present study were high on all the three sites, in comparison with values reported for temperate ecosystems. In this context the available literature on litter decomposition of different pine species were compiled by Das and Ramakrishnan (1985). Over 12 months decomposition periods, they reported annual decay rate co-efficients ranging from 0.307 to 0.46. Kumar and Deepu (1992) reported decay rate co-efficients for six moist deciduous species and the values ranged from 0.29 to 0.44. The decay rate co-efficients obtained for the present study is (0.17 to 0.26) is comparable with the values reported by Kumar and Deepu (1992). Kumar and Deepu (1992) studied the decomposition rates of six individual species at moist deciduous forests, whereas in the present study the litter collected from the forest floor which includes a mixture of different species in the ecosystem was used to study the decomposition rate. This might be one of the reason for the slower decomposition rate observed during the present study. The differences observed were also attributed to the profile and temporal dynamics of the decomposer population dynamics, especially of the macro-arthropods. In tropical forests, usually there is very little or no accumulation of litter, implying a fast turnover of organic matter in the soil. Changes in temperature and moisture have been related to decomposition rates (Woodwell and Dykeman, 1966; Agbim, 1987). William and Gray (1974) suggested that differences in temperature and moisture supply, their interactions and the higher activity of the decomposer organisms can, to a great extent, explain the large variations in litter decomposition rates existing between tropical and temperate regions.

Disturbance can alter the external environmental parameters. Pastor and Post (1986) postulated that this can increase litter decay rates. Thus the faster decay rates in the highly disturbed (PATK-BT) can be explained.

5.4 Phenology

The phenological observations conducted for a period of 12 months in the study area indicates that flowering of dominant species occurs during the dry season January-March (this is evidenced by the result of quantification of litterfall), when soil moisture is low and soil temperatures are high. This is in line with the general observation that trees flower during stress period (Kozlowski and Kramer, 1979 and Hilty, 1980). Subsequently fruiting is towards the monsoon to provide favourable conditions for germination. It is a well known fact that the seeds of tropical evergreen forests have very short viability period.

5.5 Ecophysiology

5.5.1 Light

The patterns of radiation and illuminance vary horizontally within and between the plots (Table 25). It is observed that undisturbed plot has the least amount of light at the ground level ($\bar{x}$ = 44.42, Table 25). This in turn is the result of the larger leaf area index in this plot (4.04) which is four times greater than the partially disturbed and highly disturbed plots. No much variation between the light availability at ground level has been observed between the partially disturbed and highly disturbed plots (121.02 and 140.42, respectively) (Table 25). This is corroborated by the more or less similar LAI of the above plots.

5.5.2 Leaf Area Index

The results of LAI estimation in the three experimental plots (Table 26) indicates that the undisturbed plot has the maximum LAI. The partially disturbed and highly disturbed plots posses nearly four times less LAI compared to the former. This is justified by the presence of more number of trees in the undisturbed plot (882) in relation to the partially disturbed (540) and highly disturbed (154) plots.

In values of LAI as measured by the Plant 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 that 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 forests of Karnataka, India. The above studies had been done by destructive sampling method.

Hussain (1991) while working with disturbed and undisturbed evergreen plots of Nelliampathy, estimated LAI using plant Canopy Analyzer, got more or less a similar value as that of the present study. The correction factor to be used while using Canopy Analyzer has not been standardised for the tropical forests. This could be one of the reason for the low LAI value obtained during the present study.

5.5.3 Leaf area

The leaf area of ten important species (according to IVI) from each plot is given in Tables 27 to 29. The leaf area of different species clearly indicates the nature of the forest. While in PATK-BT and PATK-MD plots (highly and partially disturbed) mesophyllous and macrophyllous leaves dominate, in PATK-TP (undisturbed) notophyllous leaves are met with more frequently. This is due to the occurrence of deciduous tree species in the highly disturbed and partially disturbed plot and the occurrence of evergreen trees in the undisturbed plot. As a rule evergreen forest trees have smaller leaf area for permitting filtration of light to the lower canopies while deciduous trees have mesophyllous and macrophyllous leaves (Richards, 1952; Whitmore, 1984; Oldeman, 1990).

5.6 Soil properties

The soils in the three plots belong to the broad group of Red Ferrallitic soils which are the most dominant in the region (Sankar, 1990). The results of the analysis are given in Table 30.

The content of gravel increases with the degree of disturbance and is caused by the erosional impact in more exposed areas. The soil reaction is more acidic (pH = 5.6) in the undisturbed plot, compared to partially disturbed (pH = 5.7 and highly disturbed (pH = 6.1). The higher acidic reaction may be due to the role of humic acids from decomposing litter which is mostly available in the undisturbed plot. This is confirmed by the presence of more organic carbon (2.93 per cent) in this plot compared to others. The same is true for other nutrients like nitrogen, potassium and phosphorus.

The disturbance in the vegetation in the form of removal, collection of green manure and litter is also reflected on the soil properties.

5.7 Micrometeorology

5.7.1 Soil moisture

The results of soil moisture (Table 31) estimation reveal that the undisturbed plot had more soil moisture than the other two during the 12 months of study. This is attributed to more canopy coverage (LAI) lesser soil temperature and better soil physical conditions. With disturbance the evaporation rates increase, resulting in lesser soil moisture. This can be one of the reasons for the predominance of evergreen species in the undisturbed plot (87 per cent) and only ten and three per cent in the partially disturbed and disturbed plots respectively.

5.7.2 Soil temperature

The monthly soil temperature (00-15 cm) layer is given in Table 32. The undisturbed plot showed a lower soil temperature when compared to the other two. While maximum temperatures were observed in the highly disturbed plot. Change in soil temperature and especially increasing trends due to vegetation disturbance in forest ecosystems have been reported earlier (Balasubramanyan, 1987; Hussain, 1991). This fact is confirmed by the lesser LAI of disturbed plots and the resultant intrusion of more light.

Summary

SUMMARY

The floristic, structural, functional, physiological, edaphic and micrometeorological changes accompanying the human interference and the resultant degradation were studied and the salient results are summarised below·

1. The moist deciduous forest tend to become a semi-evergreen forest if left undisturbed for several years.

2. While the disturbance increases the diversity of the forest decreases.

3. Structure of the forest is also adversely affected due to disturbance. The set of the future (regenerating community) is more or less absent in the disturbed plots. This is evidenced by the stratification of the forest ie. the first storey (<15 m height) is poorly represented in the disturbed plots.

4. Disturbance also adversely affects the regeneration of the forest. As the disturbance increases the regeneration is hampered.

5. Disturbance causes a reduction in the litter productivity.

6. Litterfall is positively correlated to stand basal area.

7. The decomposition rate of litter is higher in the disturbed plot. The low decay rate in the undisturbed plot can be due to the lower soil temperatures and higher soil moisture regimes.

8. The disturbance causes opening in the canopy, which in turn results in the greater availability of light and low leaf area index in the disturbed plots.

9. The content of gravel increases with the degree of disturbance. The soil is highly acidic in the undisturbed plot, due to the role of humic acids from decomposing litter. The nutrient status of the soil also is better in the undisturbed plot.

10. Disturbance causes more opening, which in turn result in the low soil moisture content and high soil temperature.

Overall there is a change in structure and functioning of the forest due to anthropogenic disturbance.

References

REFERENCES

Aber, J.D. and Melillo, J.M. 1982. Nitrogen immobilization in decaying hardwood leaf litter as a function of initial nitrogen and lignin content. Can. J. Bot. 60 2263-2269.

Agbim, N.N. 1987. Dry season decomposition of leaf litter from five common plant species of West Asia. Biol. Agric. Hortic. 4. 213-224.

Aber, J.D., Melillo, J.M. and Federer, C.A. 1982. Predicting the effects of rotation length, harvest intensity and fertilization on fiber yield from northern hardwood forests in New England. For. Sci. 28: 31-45.

*Andersson, F. 1970. Research in Scandanavian: Site Productivity Research. IEA/FE Project CPC-10, Rep. 2· 11-14.

Archer, S., Scifres, C., Bassham, C.R. and Maggio, R. 1988. Autogenic succession in subtropical savannah: Conversion of grassland to thorn woodland. Ecol. Monogr. 58 (2): 111-127.

Balasubramanyan, K. 1987. Impact of selection felling in a forest ecosystem in Kerala. Kerala Forest Research Institute, Peechi, South India. 65 pp.

Baker, H.G., Bawa, K.S., Frankie, G.W. and Opler, P.A. 1983. Reproductive biology of plants in tropical forests. In: Golley, F.G. and Leith, H. (Eds.). Tropical Rain Forest Ecosystems. Elsevier Scientific Publ. pp. 183-215.

*Bartholomew, W.V. and Mayer, J. 1953. Mineral nutrient immobilization under forest and grass fallow in the Yangambi (Belgian Congo) Region. Inst. Nat. Pour Etude Agron. 'de Congo Belgi'. Publ. 57: 1-27.

Basha, S.C. 1987. Studies on the Ecology of Evergreen Forests of Kerala with Special Reference to Silent Valley and Attappady. Ph.D. Thesis. Univ. of Kerala. Trivandrum. 232 p.

*Baur, G.N. 1968. The Ecological Basis of Rain Forest Management. For. Comm. Sudney.

Bawa, K.S., Bullock, S.H., Perry, D.R., Coville, R.E. and Grayum, M.H. 1985. Reproductive biology of tropical lowland forest trees. II. Pollination Systems. Am. J. Bot. 72 (3). 346-356.

Bazzaz, F.A. 1979. The physiological ecology of plant succession. Ann. Rev. Ecol. Syst. 10· 351-371.

Bazzaz, F.A. 1984. Dynamics of wet tropical forests and their species strategies. In: Medina, E., Mooney, H.A. and Vazquez-Yanee, C. (Eds.) Physiological Ecology of Plants of the Wet Tropics. Dr. Junk Publishers, Hague. pp. 233-243.

*Bernhard, F. 1970. Etude de la liti ere et de sa contribution au eyele des elements mineraux en forest ombrophite de Conte-do' Ivorie. Oecologia Pl., 5: 247-266.

Bicknell, S.H. 1982. Development of canopy stratification during early succession in northern hardwoods. For. Ecol. Manage 4 (1): 41-51.

Birk, E.M. 1983. Nitrogen availability, N cycling and N use efficiency on the Savanuah River Plant. Bull. Ecol. Soc. Am. 63 93.

Bockeim, J. G., Jepsen, E. A. and Heisey, D. M. 1991. Nutrient dynamics in decomposing leaf litter of four tree species on a sandy soil in north western Wisconsin. Can. J. For. Res. 21: 803-812.

Bocock, K.L. and Gilbert, O.J.W. 1957. The disappearance of leaf litter under different woodland conditions. Plant Soil, 9: 179-185.

Bocock, K.L. 1963. Changes in the amounts of dry matter, nitrogen, carbon and energy in the decomposing woodland leaf litter in relation to the activity of the soil fauna. J. Ecol. 52: 273-284.

Boojh, R. and Ramakrishnan, P.S. 1981. Phenology of trees in a subtropical evergreen montane forest in North-East India. Geo. Eco. Trop. 5: 189-209.

Boojh, R. and Ramakrishnan, P.S. 1982. Growth strategy of trees related to successional status. I. Architecture and extension growth. For. Ecol. Manage. 4: 359-374.

Borchert, R. 1983. Phenology and control of flowering in tropical trees. Biotropica. 15: 81-89.

Botkin, D.B., Janak, J.F. and Wallis, J.R. 1972. Some ecological consequencies of a computer model of forest growth. J. Ecology. 60: 849-872.

*Brasseur, F. and Sloover, J.R.De. 1973. Interception of total solar radiation and visible light in two forest communities in the Belgian. Haute. Ardenne. Bulletin de la Societe Royale de Botanique de Belique. 106 (2). 219-236.

Bray, J.R. and Gorham, E. 1964. Litter production in forests of the world. Adv. Ecol. Res. 2: 101-157.

Brokaw, N. 1985. Gap-phase regeneration in a tropical forest. Ecology. 66: 682-687.

Buell, J.H. 1945. The predation of growth in unevenaged timberstands on the basis of diameter distribution. Duke Univ. Sch. For. Bull. No.11.

Cain, St. A., Castro de Oliveira, Pires, J.M. and Silva, N.T.Da. 1956. Application of some phytosociological techniques to Brazilian rain forest. Am. J. Bot. 43· 911-941.

Cattelino, P.J., Noble, I.R., Slatyer, R.O. and Kessell, S.R. 1979. Predicting the multiple pathways of plant succession. Environ. Manage. 3: 41-50.

Champion, H.G. 1936. A preliminary survey of the forest types of India and Burma. Indian For. Rec. 1: 1-136.

Champion, H.G. and Seth, S.K. 1968 a. A Revised Survey of the Forest Types of India. Manager Publications, New Delhi.

Champion, H.G. and Seth, S.K. 1968 b. General Silviculture for India. Manager Publications, New Delhi.

Chandrashekara, U.M. 1991. Studies on the gap phase dynamics of a humid tropical forest. Ph.D. Thesis, submitted to Jawaharlal Nehru University, New Delhi. 148 p.

Chandrashekharan, C. 1960. Forest types of Kerala State. Diploma dissertation. Forest Research Institute and Colleges, Dehradun. Mimeo.

Chazdon, R.L. and Fetcher, N. 1984. Photosynthetic light environment in a low land tropical rain forest. J. Ecol. 72 (2)· 553-564.

Chengappa, B.S. 1937. Reproduction of the Andaman Forests. Indian For. 63. 16-29.

Chengappa, B.S. 1944. Andaman forests and their regeneration. Part 2. Indian For. 70: 339-351.

Clements, F.E. 1916. Plant succession: Ananlysis of the Development of Vegetation. Carnegie Inst. Washington, Publ. No. 242.

Cockburn, P.F. 1975. Phenology of dipterocarps in Sabah. Malay. For. 38. 160-170.

Cole, D.W. and Rapp, M. 1981. Element cycling in forest ecosystems. Dynamic Properties of Forest Ecosystems. Reichle, D.E. (ed.), Cambridge University Press, London.

Conell, J.H. and Slatyer, T. 1977. Mechanisms of succession in natural communities and their role in community stability and organisation. Am. Nat. 111: 1119-1144.

Cornforth, I.S. 1970. Leaf fall in a tropical rain forest. J. Appl. Ecol. 7: 603-608.

Covington, W.W. 1981. Changes in forest floor organic matter and nutrient content following clear cutting in northern hardwoods. Ecology. 62: 41-48.

Cromack, K. Jr. and Monk, C.D. 1975. Litter production, decomposition and nutrient cycling in a mixed hardwood watershed and a pine watershed. Mineral Cycling in South Eastern Ecosystems. Howell, F. G.; Gentry, J.B. and Smith, M.H. (eds.). U.S. Energy Research and Development Administration, Oak Ridge, TN., pp. 609-624.

Curtis, J.T. 1951. An upland forest continuum in the praire forest border region of Wisconsin. Ecology. 32. 476-496.

Curtis, J.T. and McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology. 31. 434-455.

*Dansereau, P. and Lems, K. 1957. The grading of types in plant communities and their ecological significance. Contr. Inst. Bot. Univ. Montreal. No. 71.

Das, A.K. and Ramakrishnan, P.S. 1985. Litter dynamics in khasi pine of North East India. For. Ecol. Manage. 10. 135-153.

Daynard, T.B. 1969. The quality of shortwave radiation within plant canopies. Can. J. Bot. 47 (12). 1984-1994.

Dhamanijayakul, D. 1981. The phenology of trees in dry evergreen forest and its application to timing for logging operation. For. Res. Bull. Fac. For. Ksasctsort Univ. No.64.

*Draskovits, R.M. 1975. Light intensity studies in beechwoods of different ages. Acta Botanica Acadenuae Scientiarum Hungaricae 21 (1/2) · 9-23.

Drury A.W.H. and Nisbet, I.C.T. 1973. Succession. J. Arnold Arbor. 54· 412-417.

Egler, F.E. 1954. Vegetation science concepts I. Initial floristic composition - a factor in old field vegetation development. Vegetatio. 4. 412-417.

Enright, N. 1985. Existance of a soil seed bank under rainforest in New Guinea. Aust. J. Ecol. 10: 67-71.

Ewel, J., Berish, C., Brown, B., Price, N. and Raich, J. 1981. Slash and burn impacts on a Costa Rican Wet Forest Site. Ecology. 62· 816-829.

Fisher, R.F., Gholz, H.C. and Pritchett, W.C. 1982. Nutrient limits to productivity after plantation establishment on the Coastal Plain region of the Southeastern U.S. Bull. Ecol. Soc. Am. 63: 181-182.

Fox, J.E.D. 1976. Constraints of the natural regeneration of tropical moist forest. For. Ecol. Manage. 1: 37-65.

Franken, M., Irinler, U. and Klinge, M. 1979. Litter fall in inundated, riverine and terra-firma forests of Central Amazonia. Trop. Ecol. 20: 225-235.

*Fujimoto, K. 1973. On growth of regeneration trees and environmental factors in selection forests (1) - Solar radiation measurements in the group stand of sugi. Bulletin of the Ethime University Forest. (10)· 19-31

Gadgil, M. 1971. Dispersal. population consequences and evolution. Ecology. 52· 253-261.

Gadgil, M. and Meher-Homji, V.M. 1982. Conserving India's biological diversity. Department of Environment, Govt. of India. Mimeo.

Gaussen, H. 1959. The vegetation maps. Trav. Sect. Sci. Tech. 1: 155-179.

Gaussen, H., Legris, P., Viart, M., Meher-Homjis, V.M., Sankaranarayanan, K.A., Dabholkr, M.V. and Gupta, R.K. 1961 a. Sheet Cape Comorin: International map of vegetation and environmental conditions. Trav. Sect. Sci. Tech. Hors. Ser. 2.

Gaussen, H., Legris, P. and Viart, M. 1961 b. Sheets Madras. *Trav. Sect. Sci. Tech. Hors. Ser.* 3.

Gaussen, H., Legris, P., Viart, M., Marlange, M. and Meher-Homji, V.M. 1963 a. Sheet Madras. *Trav. Sect. Sci. Tech. Hors. Ser.* 5.

Gaussen, H., Legris, P., Viart, M., Marlange, M. and Meher-Homji, V.M. 1963 b. Sheet Jagannath. *Trav. Sect. Sci. Tech. Hors. Ser.* 6.

Gaussen, H., Legris, P., Viart, M., Meher-Homji, V.M. and Labrow, L. 1965 a. Sheet Mysore. *Trav. Sect. Sci. Tech. Hors. Ser.* 11.

Gaussen, H., Legris, P., Viart, M., Meher-Homji, V.M. and Labrow, L. 1965 b. Sheet Bombay. *Trav. Sect. Sci. Tech. Hors. Ser.* 12.

Gaussen, H., Legris, P., Blasco, F., Meher-Homji, V.M. and Troy, J.P. 1968 a. Sheet Kathiawar. *Trav. Sect. Sci. Tech. Hors. Ser.* 14.

Gaussen, H., Legris, P., Blasco, F., Meher-Homji, V.M. and Troy, J.P. 1968 b. Sheet Satpura Mountains. *Trav. Sect. Sci. Tech. Hors. Ser.* 15.

Gaussen, H., Meher-Homji, V.M., Legris, P., Blasco, F., Gupta, R.K. and Troy, J.P. 1971. Sheet Rajasthan. *Trav. Sect. Sci. Tech. Hors. Ser.* 17.

Gaussen, H., Legris, P., Blasco, F., Meher-Homji, V.M. and Troy, J.P. 1972. Sheet Wainganga. *Trav. Sect. Sci. Tech. Hors. Ser.* 18.

Gaussen, H., Meher-Homji, V.M., Fontanel, J., Legris, P., and Pascal, J.P. 1978. Sheet Allahabad. Trav. Sect. Sci. Tech. Hors. Ser. 22.

*Gentry, A.H. 1978. Diversity and regeneration of the secondary forest of the Nat. Res. Inst. Amazonia. Acta. Amazon. **8** (1): 67-70.

Gholz, H.C. 1982. Environmental limits on aboveground net primary production, leaf area, and biomass in vegetation zones of the pacific Northwest, Ecology. **63**: 469-481.

Gholz, H.L., Fisher, R.F. and Pritchett, W.L. 1985. Nutrient dynamics in slash pine plantation ecosystems. Ecology. **66**. 647-659.

Gholz, H.L., Fitz, F.K. and Waring, R.H. 1976. Leaf area differences associated with old-growth forest communities in the Western Oregon Cascades. Can. J. For. Res. **6** (1): 49-57.

Ghosh, R.C., Kaul, O.N. and Subba Rao, B.K. 1982. Environmental effects of forests in India. Indian For. Bull. No.275. Controller of Publications, Government of India, New Delhi, 20 pp.

Givnish, T.J. 1984. Leaf and canopy adaptation in tropical forest. In. Medina, E., Mooney, H.A. and Vazgnez-Yanes, (Eds.). Physiological Ecology of Plants of Wet Tropics. pp. 51-84.

Golley, F.B., McGinnis, J.T., Clements, R.G., Guild, G.I. and Duever, M.J. 1975. Mineral Cycling in a Tropical Moist Forest Ecosystem. Univ. of Georgia Press, Athens.

Gosh, R.C., Kaul, O.N. and Subha Rao, B.K. 1982. Environmental Effects of Forests in India. Indian For. Bull. No. 275 Controller of Publications, New Delhi. pp. 20.

Gosz, J.R., Likens, G.E. and Bormann, F.H. 1973. Nutrient release from decomposing leaf and branch litter in the Hubbard Brook, New Hampshire. Ecol. Monogr. 43. 173-191.

Gower, S.T. and Norman, J.M. 1990. Rapid estimation of leaf area index in forest using LI-COR LAI-2000. Ecology. 3. 120-134.

Grier, C.C. and Waring, R.H. 1974. Conifer foliage mass related to sapwood area. For. Sci. 20· 205-206.

Grime, J.P. 1979 a. Regenerative strategies. In: Grime, J.P. (ed.). Plant Strategies and Vegetation Process. John Wiley and Sons, New York. pp. 79-122.

Grime, J.P. 1979 b. Plant Strategies and Vegetation Processes. John Wiley and Sons, Chichester. 222 p.

*Grizzard, T., Henderson, G.S., Clebsch, E.E.C. and Reichle, D.E. 1976. Seasonal nutrient dynamics of foliage and litterfall on Walker Branch Watershed, a deciduous forest ecosystem. Oak Ridge National Laboratory, Oak Ridge TN. ORNL/TM - 5254.

Guevara, S.S. and Gomez-Pompa, A. 1972. Seeds from surface soils in a tropical region of Veracruz, Mexico. J. Arnold Arbor. 53: 312-335.

Halle, F., Oldeman, R.A.A. and Tomlinson, P.B. 1978. Tropical Trees and Forests An architectural analysis. Springer-Verlag, Berlin, Heidelberg, New York. p.441.

Harmon, M.E., Baker, G.A., Spycher, G. and Greene, S.E. 1990. Leaf decomposition in young plantations of Acacia nilotica and Eucalyptus tereticornis in a highly alkaline soil. For. Ecol. Manage. 22. 59-69.

Harper, J.L. 1977. Population Biology of Plants. Academic Press. London.

Harper, J.L. and White, J. 1974. The demography of plants. Ann. Rev. Ecol. Syst. 15. 419-463.

Hart, J.W. 1988. Light and Plant Growth. Topics in Plant Physiology: I Series. M. Black and J. Cuapman (eds.), Unwin Hyman Ltd., London. p. 41.

Hartshorn, G.S. 1980. Neotropical forest dynamics. Biotropica. 12: 23-30.

Hilty, S.C. 1980. Flowering and fruiting periodicity in a premontane rainforest in Pacific Columbia. Biotropica. 12· 292-306.

Hinesley, L.E., Nelson, L.E. and Switzer, G.L. 1991. Weight and nutrient content of litter during secondary succession on well-drained uplands of East Gulf Coastal Plain in Mississippi. Can. J. For. Res. 21: 848-857.

*Hoi, L.V. 1972. Forest calendar and forestry seed saigon. Inst. Rech. Fore. 1972. 1-100.

Holmes, M.G. 1984. Light sources. Techniques in Photomorphogenesis. H. Smith and M.G. Holmes (eds.), 43-80. London. Academic Press.

Holmes, C.H. 1956. The natural regeneration of the wet and dry evergreen forests of Ceylon. Ceylon For. 2 (4): 18-31.

Hopkins, B. 1966. Vegetation of Olo-Kemiji forest reserves, Nigeria. IV. The litter and soil with special reference to their seasonal changes. J. Ecol. 54: 687-703.

Hopkins, M.S. and Graham, A.W. 1983. The species composition of soil seed banks beneath lowland rain forests in Nort Queensland, Australia. Biotropica. 15: 90-99.

Holttum, R.E. 1931. On periodic leaf change and flowering of trees in Singapore. Gard Bull. Singapore 5. 173-206.

Horn, H.S. 1974. Succession. In. Theoretical Ecology. Principals and applications, (ed). May, R.M. Blackwell Sci. Publ., Oxford. pp. 187-204.

Howe, H.F. and Smallwood, J. 1982. Ecology of seed dispersal. Ann. Rev. Ecol. Syst. 13: 201-228.

Hubbel, S.P. and Foster, R.B. 1988. Canopy gaps and the dynamics of a neotropical forest. In Plant Ecology (ed.). Crawley, M.J. Blackwell Scien. Publ., Oxford. pp.77-96.

Hussain, S.S.K. 1991. Eco-physiological studies in a tropical evergreen forest ecosystem, of Nelliampathy area, in Kerala. M.Sc. Thesis submitted to KAU, Vellanikkara, Kerala. 86 p.

*Izotov, V.F. 1966. Reduction of solar radiation by forest canopy in relation to weather. Fiziol. Rast. 13 (1) 168-170

Jackson, M.L. 1973. Soil Chemical Analysis. Pertance-Hall of India, New Delhi.

Janzen, D.H. 1971. Seed predation by animals. Ann. Res. Ecol. Syst. 2: 465-492.

Janzen, D.H. 1974. Tropical black-water rivers, animals and mast fruiting by the Dipterocarpaceae. Biotropica. 6 69-103.

Janzen, D.H. 1978 Seeding patterns of tropical trees. In. Tomlinson, P.B. and Zimmermann (eds.). Tropical Trees as Living Systems. Cambridge Uni. Press. Cambridge. pp. 83-128.

Jarvis, P.G. and Leverenz, J.W. 1983. Productivity of temperate, deciduous and evergreen forests. In. Lange, O.L., Nobel, P.S., Osmound, C.B. and Ziegler, H. (eds). Physiological Plant Ecology. Springler-Nerlag, New York, USA. pp. 237-280.

Jenny, H., Gessel, S.P. and Bingham, F.T. 1949. Comparative rates of decomposition of organic matter in temperate and tropical regions. Soil Sci. **68**· 419-432.

Kaul, V. and Raina, R. 1980. The phenology of woody angiosperms in Srinagar. Indian For. **106**: 94-101.

Kaufmann, M.R. and Troendle, C.A. 1981. The relationship of leaf area and foliage biomass to sapwood conducting area in four subalpine forest tree species. For. Sci. **27** (3) 477-482.

*Keay, R.W.J. 1960. Seed in forest soil. Nigeria For. Dept. Inform. Bull. N.S. 4. 1-12.

Kendrick, W.B. 1959. The time factor in decomposition of coniferous leaf litter. Can. J. Bot. 37· 907-912.

Kessell, S.R. 1976. Gradient modelling. A new approach to fire modelling and wilderness resource management. Environ. Manage. 1 (1): 39-48.

Kikuzawa, K., Asai, T. and Fukuchi, M. 1984. Leaf litter production in a plantation of Alnus inokumae. J. Ecol.25: 78-87.

Kikuzawa, K., Asai, T. and Fukuchi, M. 1984. Leaf litter production in a plantation of Alnus inokumae. J. Ecol., 72. 993-999.

Koelmeyer, K.O. 1959. The periodicity of leaf change and flowering in the principal forest communities of Ceylon. Ceylon For. 4. 157-189.

Kozlowski, T.T. and Kramer, P.J. 1979. Physiology of Woody Plants. Academic Press. New York. 384 p.

Klinge, H. 1977. Fine litter production and nutrient return to the soil in three natural forest stands of eastern Amazonia. Geol. Ecol. Trop. 1: 159-167.

*Klintsov, A.P. 1976. The radiation regime under forest canopy on sakhalin Lesovedenie (3). 31-36.

Krebs, C.J. 1972. Ecology. The Experimental Analysis of Distribution and abundance. Harper and Raw, New York.

Krishnaswamy, V.S. and Mathauda, G.S. 1960. Phenological behaviour of a few forest species at New Forest, Dehradun. Indian For. Rec. No. 9.

Kumar, B.M. and Deepu, J.K. 1992. Litter production and decomposition dynamics in moist deciduous forests of the Western Ghats in Peninsular India. For. Ecol. Manage. 50:181-201.

LAI, 2000. 1990. Plant Canopy Analyzer for Rapid Leaf Area Index Measurements. LI-COR INC. 4421, Nebaraska 68504. USA.

Lamb, R.J. 1985. Litterfall and nutrient turnover in two eucalypt woodlands. *Aust*. *J*. *Bot*. 33 1-14.

*Laudelout, M. and Mayer, J. 1954. Les cycles d'elements minerales et de matiere organique en foret equatoriale Congolaise. Proceedings of Fifth International Congress Soil Science. pp. 267-272.

Liew, T.C. 1973. Occurrence of seeds in virgin forest top soil with particular reference to secondary species in Sabah. *Malay*. *For*. **36**: 185-193.

Long, J.N. and Smith, F.W. 1989. Estimating leaf area of *Abies lasiocarpa* across ranges of stand and site quality. *Can*. *J*. *For*. *Res*. **19**· 930-932.

Lonsdale, W.M. 1988. Predicting the amount of litterfall in forests of the world. *Ann*. *Bot*. **61**(3). 319-324.

Magguire, D.A. and Hann, D.W. 1989. The relationship between gross irown dimensions and sapwood area at crown base in Dongles - Fir. *Can*. *J*. *For*. *Res*. **19**: 557-565.

*Makarenko, A.A. and Atkin, A.S. 1976. Formation and accumulation of litter in dry pine forests of Kazakh Hill country. *Soviet J*. *Ecol*. **1976**· 391-394.

Marks, P.L., and Bormann, R.H. 1972. Revegetation following forest cutting: mechanism for return to steady state nutrient cycling *Science*. **176**: 914-915.

Marshall, J.D. and Waring, R.H. 1986. Comparison methods of estimating leaf area index in old growth Dongles-fir. *Ecology*. **67**. 975-979.

Meentemeyer, V. 1978. Macroclimate and lignin control of litter decomposition rates. Ecology. 59 465-472.

Medwecka-Kornas, A. 1970. Litter production. Methods of Study in Soil Ecology. Phillipson, J. (Ed) UNESCO/IBP Geneve. pp.139-143.

Medway, L. 1972. Phenology of tropical rain forest in Malaya. Biol. J. Linn. Soc. 4· 117-146.

Menon, A.R.R. and Balasubramanyan, K. 1985. Species relation studies in moist deciduous forests of Trichur Forest Division (Kerala). KFRI Research Report No. 32. Kerala Forest Research Institute, Peechi

*Mensbruge, C. de la. 1966. La germination et les plantules des essences arborees de la foret dense humide de la cote d'inoire Nogent Sur-Mrne. Centre Technique Forestier Tropical (CTFT) Publ. No. 389.

Meyer, H.A. 1952. Structure, growth and gain in balanced unevenaged forests. J. For. 50: 85-92.

Miller, H.G. 1981. Forest fertilization Some guiding concepts. Forestry. 54: 157-167.

Miller, H.G., Cooper, J.M. and Miller, J.D. 1976. Effect of nitrogen supply on nutrients in litterfall and crown leading in a stand of Corsican pine. J. Appl. Ecol. 13· 233-248.

Mishra, B.K. and Ramakrishnan, P.S. 1983. Secondary succession subsequent to slash and burn agriculture and higher elevations of north-eastern India. II. Nutrient cycling. Acta Decological Oecol. Applic. 4 237-245.

Moore, T.C. 1980. Biochemistry and Physiology of Plant Hormones. Narosa Publishing house and Springer Verlag, New Delhi, 274 pp.

Muller-Dombois, D. and Ellenberg, H. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York.

Nair, P.N. 1961. Regeneration of moist tropical forests with special reference to Kerala. DAIFC Dissertation, Indian For. Coll., Dehradun.

Ng, F.S.P. 1977. Gregarions flowering of dipterocarps in Kepong, 1976. Malay. For. 44. 126-137.

Ng, F.S.P. 1981. Vegetative and reproductive phenology of dipterocarps. Malay. For. 44. 197-221.

Ng, F.S.P. 1983. Ecological principals of tropical lowland rainforest conservation. In. Sutton, S.L., Whitmore, T.C. and Chadwick, A.C. (eds). Tropical Forest Ecology and Management, Blackwell, Oxford. pp. 359-375.

Ng, F.S.P. and Loh, H.S. 1974. Flowering to fruiting periods of Malaysian trees. Malay. For. 37. 127-132.

Nicholson, D.I. 1965. A study of virgin forest near Sandakan North Borneo. In Proceedings of Synaposium on Ecological Research in Humid Tropies Vegetation, Kuching. UNESCO. pp. 67-87.

Noble, I.R. and Slatyer, R.O. 1977. Post-fire succession of plants in Mediterranean ecosystems. In. Proc. of Symp. on the environment consequences of fire and fuel management in Mediterranean climate ecosystem. U.S.D.A. For. Service Gen. Tech. Rep. No.3. pp.27-36.

Nygren, M. and Kellomaki, S. 1983. Effect of shading on leaf structure and photo-synthesis in young birch, Betula pennula Roth. and B. pubescens Ehrh. For. Ecol. Manage. 7 119-132.

Odum, E.P. 1969. Strategy of ecosystem development. Science. 164 262-270.

Okali, D.U.U. and Adams, B.A. 1987. Tree population change in treated rainforest at Omo Forest Reserve Nigeria. J. Trop. Ecol. 3 (4): 291-313.

Oldeman, R.A.A. 1974. L' architecture de la forit guayanaise. Me'm. ORSTOM. 73.

Oldeman, R.A.A. 1990. Forests. Elements of Silvology. Springer Verlag, Berlin etc. 264 pp.

Olson, J. S. 1963. Energy storage and balance of production and decomposers in eclogocal systems. Ecology. 44: 322-331.

Pascal, J.P. 1988. Wet Evergreen Forests of the Western Ghats of India. Ecology, Structure, Floristic composition and succession. Institut Francais de Pondicherry. 305 p.

Pastor, J. and Post, W M. 1986. Influence of climate, soil moisture, and succession on forest carbon and nitrogen cycles. Biogeochemistry 2. 3-27.

Proctor, J., Anderson, J.M., Chai, P. and Vallack, H.W. 1983. Ecological studies to four contrasting lowland rainforest types of Gunung Malu National Park. Sarawak. II. Litterfall, litterstanding crop and preliminary observations on herbivory. J. Ecol. 71. 261-283.

Pokhriyal, T.C., Pant, S.P. and Joshi, S.R. 1989. Leaf emergence and shedding behaviour of Populus deltoiodes. Indian For. 115 (1) 48-51.

*Puig, H. 1979. Production de litiere en foret Guyanaise resultats preliminaries. Extrait du Bull. de la Soc. d' Hist. Natur. de Toulouse Tome. 115, Fasc. 3-4 338-346.

Puri, G.S., Meher-Homji, V.M., Gupta, R.K. and Puri, S. 1983. Forest Ecology, Vol.I. 2nd ed. Oxford & IBH, New Delhi.

Putz, F.E. 1983. Treefall pits and mounds, buried seeds and the importance of soil disturbance to pioneer trees on Barro Colorado Island, Panama. Ecology. 64: 1069-1074.

Rai, S.N. 1981. Productivity of Tropical Rainforest of Karnataka. Ph.D. Thesis. University of Bombay, Bombay.

Rai, S.N. and Proctor, J. 1986. Ecological studies on four rainforests in Karnataka, India. I. Environment, structure, floristics and biomass. J. Ecol. 74 439-454.

Ralhan, P.K., Khanna, R.K., Singh, S.P. and Singh, J.S. 1985. Phenologicl characteristics of the tree layer of Kumaun Himalayan forests. Vegetatio. 60 113-120.

Ramakrishnan, P.S., Toky, O.P., Mishra, B.K. and Saxena, K.G. 1981. Slash and burn agriculture in North. Eastern India. In. Fire regimes and ecosystems properties of U.S. Dept. of Agric. Fore. Service General Tech. Report, Honolulu, Hawaii. pp.570-586.

Rao, K.S. and Ramakrishnan, P.S. 1987. Comparitive, analysis of the population dynamics of two bamboo species, Dendrocalamus hamittonii and Neohouzeua dulloa, on a successional environment. For. Ecol. Manage. 21: 177-189.

Rathcke, B. and Lacey, E.P. 1985. Phenological patterns of terrestrial plants. Ann. Res. Ecol. Syst. 16. 179-214.

Richards, P.W 1952. The Tropical Rain Forest. Cambridge Univ. Press. U.K.

Ridley, H.N. 1930. The dispersal of plants throughout the world. L. Reeve, London.

Ritchter, H. 1973. Frictional potential losses and total water potential in plants, a re-evaluation. J. Expt. Bot. 24 98-99.

*Rolfe, G.L. 1975. Nutrient fluxes in litter fall in a Central Illinois woodland. Ill. Agric. Exp. Stn. Dep. For. Res. Rep. No. 75-6.

*Rollet, B. 1962. Inventaire forestier de L'est Mekong. FAO Report No.1500. FAO.

Rosario, E.A. 1982. The ecological role of pioneer species in the natural regneration of logged-over dipterocarp forests. Canop. Inter. 8 (12): 5-8.

Saldarriaga, J.G., West, D.C., Thar, P.M.L. and Uhl, C. 1988. Long term chronosequence of forest succession in Upper Rio Negro of Colombia and Venzuela. J. Ecol. 76 (4). 938-958.

Salisbury, E.J. 1929. The bio-equipment of species in relation to competition. J. Ecol. 17: 197-222.

Sankar, S. 1990. Nutrient partitioning in an evergreen forest ecosystem. KFRI research report No.69, Peechi. South India.

Saxena, K.G. and Ramakrishnan, P.S. 1984. Herbaceous vegetation development and weed potential in slash and burn agriculture (Jhum) in North-East India. Weed Res. 24 135-142.

Schimper, AFW. 1903. Plant geography upon a physiological basis.

Schroeder, P.E., McCandlish, B., Waring, R.H. and Perry, D.A. 1982. The relationship of maximum canopy leaf area to forest growth in eastern Washington. Northwest Science. 56: 121-130.

Schulz, J.P. 1960. Ecological studies on rain forest in Northern Surinam. Verth. K. Ned. Akad. Wet , 53: 1-367.

Shankaran, K.V. 1993. Decomposition of leaf litter of albizia (Paraseriantes falcataria), eucalpt (Eucalyptus tereticornis) and teak (Tectona grandis) in Kerala, India. For. Ecol. Manage. 56 225-245.

Shrivasthava, R.K. 1982. A note on phenological observations on Aegle marmelos Correa. Indian For. 108: 593-595.

Shukla, R.P. and Ramakrishnan, P.S., 1982. Phenology of trees in a tropical humid forest in North Eastern India. Vegetatio. 49: 103-109.

Singh, J.S. and Gupta, S.R. 1977. Plant decomposition and soil respiration in terrestrial ecosystem. Bot. Rev. 43 (4) 449-528.

Singh, J. and Ramakrishnan, P.S. 1982. Structure and function of a subtropical humid forest of Meghalaya. I. Vegetation, biomass and its nutrients. Proc. Indian. Acad. Sci. (Plant Sci.), 91. 241-253.

Singh, K.P. and Singh, J.S. 1992. Tropical Ecosystems. Ecology and Management. Wiley Eastern Limited, New Delhi. p. 574.

Smith, R.B., Waring, R.H. and Perry, D.A. 1981. Interpretting foliar analysis from Dongles-fir as weight per unit of leaf area. Con. J. For. Res. **11**: 593-598.

Smith, T.M. and Goodman, P.S. 1987. Successional dynamics in an Acacia nilotica - Euclea divinorum savannah in Southern Africa. J. Ecol. 75 (3): 603-610.

Smythe, N. 1970. Relationship between fruiting seasons and seed dispersal methods in a neotropical forest. Am. Nat. **104**: 25-35.

Spain, A.W. 1984. Litterfall and the standing crop of litter in three tropical Australian rain forests. J. Ecol. 72: 947-961.

*Staaf, H. 1980. Release of plant nutrients from decomposing leaf litter in a south Swedish beech forest. Holarct. Ecol. 3: 129-136.

Stamp, L.D. 1926. Some aspects of vegetation survey in the tropics. In: Transley, A.C. and Chipps, T.F. (Eds). Aims and Methods of study of vegetation.

Stebbing, E.P. 1922. The forests of India. John Lane, London.

Stohlgren, T.J. 1988. Litter dynamics in two sierran mixed conifer forests. I. Litter fall and decomposition rates. Can. J. For. Res. 18: 1127-1135.

*Stoner, W.A., Miller, P.C. and Miller, P.M. 1978. A test of a model of irradiance with in vegetation canopies at Northern latitude. Artic Alpine Research 10 (4): 761-767.

*Stoutjesdijk, P. 1972. Spectral transmission curves of some types of leaf canopies with a note on seed germination. Acta Batanica Neerlandica 21 (3)· 185-191.

Stromgaard, P. 1986. Early secondary succession on abandoned shifting cultivators plot in Miombo of South Central Africa. Biotropica. 18 (2): 97-106.

Swaine, M.D. and Hall, J.B. 1983. Early succession on cleared forest land in Ghana. J. Ecol. 71 (2): 601-627.

Swanson, R.H. 1966. Seasonal course of transpiration of lodgepole pine and Engel mann spruce. In. Proceedings of International Symposium of Forest Hydrology. Swanson, R.H. (ed.), Pergamon Press, Oxford. pp. 417-432.

Swarupanandan, K. and Sashidharan, N. 1992. Regeneration studies on Some Important Trees in a Natural Moist Deciduous Forest Ecosystem. KFRI Research Report. Kerala Forest Research Institute, Peechi.

Swift, M.J., Heal, O.W. and Anderson, J.M. 1979. Decomposition in Terrestrial Ecosystems. Blackwell, Oxford, pp. 372.

Symington, L.F. 1933. The study of secondary growth on rainforest sites in Malaya. Malay. For. 12: 107-117.

*Synnott, T.J. 1973. Seed problems. NFRO Int. Symp. on Seed Processing, Bergen.

Tang, H.T. and Tamari, C. 1973. Seed description and storage tests of some dipterocarps. Malay. For. 36 38-53.

Taylor, B.R., Parkinson, D. and Parson, W.F.J. 1989. Nitrogen and ligin content as predictors of litter decay rates A microcosm test. Ecology. 70 (1) 97-104.

Toky, O.P. and Ramakrishnan, P.S. 1983. Secondary succession following slash and burn agriculture in Northeastern India. II. Nutrient cycling. J. Ecol. 71: 747-757.

Troup, R.S. 1921. The Silviculture of Indian Trees. volumes. Oxford Univ. Press, Oxford.

Turner, J. 1981. Nutrient cycling in an age sequence of Western Dougles fir stands. Ann. Bot. 48· 159-169

Uhl, C., Clark, H. and Clark, K. 1982. Successional patterns associated with slash and burn agrciculture in the Upper Rio Negro region of Amazon basin. Biotropica 14 (4): 249-254.

UNESCO, 1978 a. Organisation. In: Tropical Forest Ecosystems. pp. 112-142. UNESCO-UNEP, France.

UNESCO, 1978 b. The natural forest. plant biology, regeneration and tree growth. In: Tropical Forest Ecosystems. pp. 180-215. UNESCO-UNEP, France.

Van Cleve, K. and Noonan, L.L. 1975. Litterfall and nutrient cycling in the forest floor of birch and aspen stands in interior Alaska. Can. J. For. Res. 5· 626-39.

Viro, P. 1955. Prescribed burning in forestry. Comm. Inst. For. Fenn. 67 (7): 49.

Vitousek, P.M. 1982. Nutrient cycling and nutrient use efficiency. Am. Nat., 119: 553-572.

Vitousek, P.M., Gosz, J.R., Grier, C.C., Melillo, J.M. and Reiners, W.A. 1982. A comparitive analysis of potential nitrification and nitrate mobility in forest ecosystems. Ecol. Monogr. 52: 155-177.

Vitousek, P.M. and Reiners, W.A. 1975. Ecosystem succession and nutrient retention: A hypothesis. BioScience. 25: 376-381.

Vogt, K.A., Grier, C.C. and Vogt, D.J. 1986. Production, turnover and nutrient dynamics of above ground and below ground detritus of world forests. Adv. Ecol. Res. 15: 139-157.

Waring, R.H., Gholz, H.C., Grier, C.C. and Plummer, H.C. 1977. Evaluating stem conducting tissue as an estimator of leaf area in four woody angiospeoms. Can. J. For. Bot. 55: 1474-1477.

Waring, R.H. and Schlesinger, W.H. 1985. Forest Ecosystem: Concepts and Management, Academic Press, New York, pp. 181- 211.

William, S.T. and Gray, T.R.G. 1974. Decomposition of litter on the soil surface. In: C.H. Dikinson and G.J.E. Pugh (Eds), Biology of Plant Litter Decomposition. Academic Press, London, pp. 611-632.

Whitehead, D. 1982. Ecological aspects of natural and plantation forests. Commonw. For. Abs. 43 (10)· 615-624.

Whitmore, T.C. 1983. Secondary succession from seeds in tropical rain forests. Commonw. For. Abs. 44. 767-779.

Whitmore, T.C. 1984. Tropical Rain Forest of the Far East. 2nd Ed. Oxford University Press, 352 p.

Whitmore, T.C. 1985. Gap size and species richness in tropical rainforests. Commonw. For. Abs. 44. 767-779.

Whitmore, T.C. and Wang, V.K. 1959. Patterns of sunflecks and shade in tropical rain forest. Malay. Fore. 22 (1) 50-62.

*Whittaker, R.H. 1975. Functional aspects of succession in deciduous forest. In: (ed.) R. Tuxen. Sukzessionforschung Ber. Inst. Sympos. rinte. pp. 377-405.

Whittaker, R.J., Bush, M.B. and Richards, K. 1989. Plant recolonization and vegetation succession on the Karakatu islands, Indonesia. Ecol. Monogr. 59 (2). 59-123.

Whittaker, R.H. and Niering, W.A. 1975. Vegetation of Santa Catalina Mountains, Arizona V. Biomass production and diversity along the elevation gradient. Ecology. 771-790.

Woodwell, G.M. and Dykeman, W.R. 1966. Respiration of forest measured by CO_2 accumulation during temperature inversions. Science 154: 1031-1034.

Wyatt-Smith, J. 1963. Manual of malayan silviculture for inland forests. Malay. For. Res. No. 23.

*Yoda, K., Nishioka, M. and Dhanmanonda, P. 1983. Vertical and horizontal distribution of relative illuminance in the dry and wet seasons in a tropical dry-evergreen forest in Sakaert, NE Thailand. Jap. J. Ecol. 33 (1). 97-100.

Originals not seen

Appendices

Appendix-I

Species list - Pattikkad

Sl. No.	Species	Family	Species/ code
1.	Acacia concinna DC	MIMOSASEAE	ACACO
2.	Acacia intsia W. & A.	MIMOSASEAE	ACAIN
3.	Actinodaphne bourdillonii Gamb.	LAURACEAE	ACTBO
4.	Actinodaphne malabarica Balakr.	LAURACEAE	ACTMA
5.	Aglaia barberi Gamb.	MELIACEAE	AGLBA
6.	Aglaia elaeagnoidea (Juss.) Benth.	MELIACEAE	AGLEL
7.	Aglaia indica	MELIACEAE	AGLIN
8.	Aglaia lawii (Wt.) Saldh.	MELIACEAE	AGLLA
9.	Aglaia simplicifolia	MELIACEAE	AGLSI
10.	Alangium salvifolium Wang.	ALANGINACEAE	ALASA
11.	Albizia odoratissima (L.f.) Benth.	MIMOSACEAE	ALBOD
12.	Allophylus cobbe Bl.	SAPINDACEAE	ALLCO
13.	Alseodaphne semecarpifolia Nees	LAURACEAE	ALSSE
14.	Alstonia scholaris (L.) R.Br.	APOCYNACEAE	ALSSC
15.	Ancistrocladus heyneanus Wall.	ANCISTROCLADACEAE	ANCHE
16.	Antidesma acidum	EUPHORBIACEAE	ANTAC
17.	Aphananthe cuspidata (Bl.) Planch.	ULMACEAE	APHCU
18.	Apodytes beddomei Mast.	ICACINACEAE	APOBE
19.	Aporusa lindleyana (Wt.) Baill.	EUPHORBIACEAE	APOLI

20.	Artabotrys zeylanicus Hk. f.	ANNONACEAE	ARTZE
21.	Atalantia racemosa W. & A.	RUTACEAE	ATARE
22.	Atalantia wightii Tan.	RUTACEAE	ATAWI
23.	Bambusa arundinaceae Willd.	POACEAE	BAMAR
24.	Beilschmiedia bourdilloni Brand.	LAURACEAE	BEIBO
25.	Blachia denudata Benth.	EUPHORBIACEAE	BLADE
26.	Blachia umbellata Baill.	EUPHORBIACEAE	BLAUM
27.	Bombax ceiba L.	BOMBACACEAE	BOMCE
28.	Bridelia retusa (L.) Spreng.	EUPHORBIACEAE	BRIRE
29.	Bridelia scandens Gehrm.	EUPHORBIACEAE	BRISC
30.	Butea parviflora Roxb.	FABACEAE	BUTPA
31.	Calycopteris floribunda Lam.	COMBRETACEAE	CALFL
32.	Canthium dicoccum	RUBIACEAE	CANDI
33.	Capparis cleghornii Dunn.	CAPPARIDACEAE	CAPCL
34.	Capparis moonii W.	CAPPARIDACEAE	CAPMO
35.	Capparis rheedei	CAPPARIDACEAE	CAPRH
36.	Careota urens L.	PLMAE	CARUR
37.	Casearia bourdillonii	FLACOURTIACEAE	CASBO
38.	Casearia ovata	FLACOURTIACEAE	CASOV
39.	Casearia rubesence Dalz.	FLACOURTIACEAE	CASRU
40.	Cassia fistula L.	CAESALPINIACEAE	CASFI
41.	Celtis phlippensis (Planch.) Soepad.	ULMACEAE	CELPH
42.	Chionanthus leprocara (Bedd,)	OLEACEAE	CHILE

43.	*Chionanthus malabarica* (Wall. ex. G.D.	OLEACEAE	CHIMA
44.	*Chrysophyllum lanceolatum*	SAPOTACEAE	CHRLA
45.	*Cinnamomum zelanicum* Grac. ex Bl.	LAURACEAE	CINZE
46.	*Clausena heptaphylla* W & A.	RUTACEAE	CLAHE
47.	*Cleidion spiciflorum*	EUPHORBIACEAE	CLESP
48.	*Clerodendron viscosum*	VERBINACEAE	CLEVI
49.	*Connarus ritchiei* Hk.f.	CONNARACEAE	CONRI
50.	*Croton caudatus* Gies.	EUPHORBIACEAE	CROCA
51.	*Croton malabaricus* Bedd.	EUPHORBIACEAE	CROMA
52.	*Cynometra tomentosa*	CAESALPINIACEAE	CYNTO
53.	*Cynometra travancorica* Bedd.	CAESALPINIACEAE	CYNTR
54.	*Dalbergia horrida*	FABACEAE	DALHO
55.	*Dalbergia latifolia* Roxb.	FABACEAE	DALLA
56.	*Dalbergia paniculata* Roxb.	FABACEAE	DALPA
57.	*Dalbergia sissoides* Grah. ex Wt. et Arn.	FABACEAE	DALSI
58.	*Derris heyneana* Benth.	FABACEAE	DERHE
59.	*Derris* sp	FABACEAE	DERSP
60.	*Dillenia pentagyna* Roxb.	DILLENIACEAE	DILPE
61.	*Dimocarpus longan* Lour.	SAPINDACEAE	DIMLO
62.	*Dimorphocalyx beddomei*	EUPHORBIACEAE	DIMBE
63.	*Dimorphocalyx bourdilloni*	EUPHORBIACEAE	DIMBO
64.	*Dimorphocalyx lawii*	EUPHORBIACEAE	DIMLA

65.	Dimorphocalyx sp.	EUPHORBIACEAE	DIMSP
66.	Diospyros bourdillonii Brand.	EBENACEAE	DIOBO
67.	Diospyros buxifolia (Bl.) Hiern	EBENACEAE	DIOBU
68.	Diospyros cremenata	EBENACEAE	DIOCR
69.	Diospyros hirsuta	EBENACEAE	DIOHI
70.	Diospyros humilis Bourd.	EBENACEAE	DIOHU
71.	Diospyros montana Roxb.	EBENACEAE	DIOMO
72.	Diospyros oocarpa Thw.	EBENACEAE	DIOOO
73.	Diospyros ovalifolia W.	EBENACEAE	DIOOV
74.	Diospyros paniculata Dalz.	EBENACEAE	DIOPA
75.	Diospyros ghattensis	EBENACEAE	DIOGH
76.	Drypetes malabarica (Bedd.) Airy Shaw.	EUPHORBIACEAE	DRYMA
77.	Dysoxylum binectariferum (Roxb.) Hk.f.ex Bedd.	MELIACEAE	DYSBI
78.	Dysoxylum malabaricum Bedd. ex.Hiern	MELIACEAE	DYSMA
79.	Elangium salvifolium		
80.	Emblica officionalis Gaert.	EUPHORBIACEAE	EMBOF
81.	Erythrina stricta Roxb.	FABACEAE	ERYST
82.	Euodia lunu-ankenda (Gaert.) Merr.	RUTACEAE	EUOLU
83.	Ficus exasperata Vahl.	MORACEAE	FICEX
84.	Ficus dalhousiae Miq.	MORACEAE	FICDA
85.	Ficus nervosa Heyne ex. Roth.	MORACEAE	FICNE

86.	Ficus sp.	MORACEAE	FICSP
87.	Flacourtia montana Grah.	FLACOURTIACEAE	FLAMO
88.	Garcinia xanthochymus Hk.f.	CLUSIACEAE	GARXA
89.	Glochidion johnstonei Hk.f.	EUPHORBIACEAE	GLOJO
90.	Glochidion malabaricum Bedd.	EUPHORBIACEAE	GLOMA
91.	Gomphandra tetandra	ICACINACEAE	GOMTE
92.	Grewia sp.	TILIACEAE	GRESP
93.	Grewia tiliifolia Vahl.	TILIACEAE	GRETI
94.	Haldina cordifolia (Roxb.) Ridsd.	RUBIACEAE	HALCO
95.	Helicteres isora L.	STERCULIACEAE	HELIS
96.	Harpullia arborea (Blanco) Radlk.	SAPINDACEAE	HARAR
97.	Hibiscus surrattensis L.	MALVACEAE	HIBSU
98.	Holarrhena pubescens (Buch.-Ham.)	APOCYNACEAE	HOLPU
99.	Hunteria zelanica (Retz.) Gard.ex Thw.	APOCYNACEAE	HUNZE
100.	Hydnocarpus laurifolius	FLACOURTIACEAE	HYDLA
101.	Hydnocarpus pentandra (Buch.-Ham.) Oken	FLACOURTIACEAE	HYDPE
102.	Ixora brachiata Roxb.	RUBIACEAE	IXOBR
103.	Jasminum rottlerianum Wall.	OLEACEAE	JASRO
104.	Kingiodendron pinnatum (Roxb. ex DC Harms.	CAESALPINIACEAE	KINPI
105.	Lagerstroemia microcarpa Wt.	LYTHRACEAE	LAGMI
106.	Lannea coromandelica (Houtt.)Merr.	ANACARDIACEAE	LANCO

107.	Lepisanthes deficiens Radlk.	SAPINDACEAE	LEPDE
108.	Lepisanthes erecta	SAPINDACEAE	LEPER
109.	Leptonychia moacurroides Bedd.	STERCULIACEAE	LEPMO
110.	Litsea floribunda (Bl.) Gamb.	LAURACEAE	LITFL
111.	Litsea laevigata Gamb.	LAURACEAE	LITLA
112.	Litsea stocksii Hk.f.	LAURACEAE	LITST
113.	Mallotus beddomei Hk.f.	EUPHORBIACEAE	MALBE
114.	Mallotus distans M. Arg.	EUPHORBIACEAE	MALDI
115.	Mallotus philippensis (Lamk.) Muell.	EUPHORBIACEAE	MALPH
116.	Mallotus stenanthus M. Arg.	EUPHORBIACEAE	MALST
117.	Meiogyne pannosa	ANNONACEAE	MEIPA
118.	Melia dubia Cav.	MELIACEAE	MELDU
119.	Miliusa tomentosa (Roxb.) Sincl.	ANNONACEAE	MILTO
120.	Memecylon edule Roxb.	MELASTOMATACEAE	MEMED
121.	Memecylon sp.	MELASTOMATACEAE	MEMSP
122.	Memecylon terminale Dalz.	MELASTOMATACEAE	MEMTE
123.	Mitragyna parviflora	RUBIACEAE	MITPA
124.	Murraya paniculata	RUTACEAE	MURPA
125.	Mussaenda glabrata Hutch.	RUBIACEAE	MUSGL
125.	Mussaenda laxa Hutch.	RUBIACEAE	MUSLA
127.	Myristica sp.	MYRISTICACEAE	MYRSP
128.	Myristica malabarica Lamk.	MYRISTICACEAE	MYRMA
129.	Naringi crenulata	RUTACEAE	NARCR

130.	*Nothopegia beddomei* Gamble	ANACARDIACEAE	NOTBE
131.	*Olax scandens* Roxb.	OLACACEAE	OLASC
132.	*Olea dioica* Roxb.	OLEACEAE	OLEDI
133.	*Orophea uniflora* H.f. & T.	ANNONACEAE	OROUN
134.	*Pagianthia dichotoma* (Roxb.) Mark graf.	APOCYNACEAE	PAGDI
135.	*Pajanelia longifolia* (Wild.) K.	BIGNONIACEAE	PAJLO
136.	*Perséa macrantha* (Nees) Kosterm	LAURACEAE	PERMA
137.	*Pterocarpus marsupium* Roxb.	FABACEAE	PTEMA
138.	*Pterospermum reticulatum* Wt. et Arn.	STERCULIACEAE	PTERE
139.	*Pterospermum rubiginosum* Heyne ex Wt. et Arn.	STERCULIACEAE	PTERU
140.	*Radermachera xylocarpa* (Roxb.) K. Schum.	BIGNONIACEAE	RADXY
141.	*Reinwardtiodendron anamalainse* (Bedd.) Mabb.	MELIACEAE	REIAN
142.	*Salacia beddomei* Gamb.	HIPPOCRATIACEAE	SALBE
143.	*Salacia oblonga* Wall.	HIPPOCRATIACEAE	SALOB
144.	*Sapindus laurifolia* Vahl.	SAPINDACEAE	SAPLA
145.	*Schleichera oleosa* (Lour.) Oken	SAPINDACEAE	SCHOL
146.	*Scleropyrum pentandrum*	SANTALACEAE	SCLPE
147.	*Spondias pinnata* (L.f.) Kurz	ANACARDIACEAE	SPOPI
148.	*Sterculia guttata* Roxb.	STERCULIACEAE	STEGU
149.	*Sterculia urens* Roxb.	STERCULIACEAE	STEUR

150.	*Stereospermum chelonoides* (L.f.) DC.	BIGNONIACEAE	STECH
151.	*Streblus asper* Lour.	MORACEAE	STRAS
152.	*Strombosia ceylanica* Gard.	OLACACEAE	STRCE
153.	*Strychnos* sp.	LOGANIACEAE	STRSP
154.	*Strychnos nux-vomica* L.	LOGANIACEAE	STRNU
155.	*Symplacos* sp.	SYMPLOCACEAE	SYMSP
156.	*Syzygium cumini* (L.) Skeek.	MYRTACEAE	SYZCU
157.	*Syzygium laetum* (Ham.) Gandhi	MYRTACEAE	SYZLA
158.	*Tectona grandis* L.f.	VERBENACEAE	TECGR
159.	*Terminalia bellirica* (Gaert.) Roxb.	COMBRETACEAE	TERBE
160.	*Terminalia crenulata* Roth.	COMBRETACEAE	TERCR
161.	*Terminalia paniculata* Roth.	COMBRETACEAE	TERPA
162.	*Tetrameles nudiflora* R. Br.	DATISCACEAE	TETNU
163.	*Turpinia malabarica* Gamb.	STAPHYLEACEAE	TURMA
164.	*Turraea villosa* Benn.	MELIACEAE	TURVI
165.	*Unona viridifolia* Bedd.	ANONACEAE	UNOVI
166.	*Vepris bilocularis* (Wt. et Arn.) Engl. et Prantl.	RUTACEAE	VEPBI
167.	*Vitex altissima* L.f.	VERBINACEAE	VITAL
168.	*Walsura trifolia* (Juss.) Harms.	MELIACEAE	WALTR
169.	*Wrightia tinctoria* (Roxb.) R. Br.	APOCYNACEAE	WRITI
170.	*Xanoletis* sp.	SAPOTACEAE	XANSP
171.	*Xanthophyllum arnottianum*	XANTHOPHYLLACEAE	XANAR

172. *Xeromphis spinosa* (Thunb.) Kaey	RUBIACEAE	XERSP
173. *Xylia xylocarpa* (Roxb.) Taub.	MIMOSACEAE	XYLXY
174. *Zanthoxylum rhetsa* (Roxb.)	RUTACEAE	ZANRH
175. *Ziziphus mauritiana* Lamk.	RHAMNACEAE	ZIZMA
176. *Ziziphus oenoplia* Mill	RHAMNACEAE	ZIZOE
177. *Ziziphus nemmlaria*	RHAMNACEAE	ZIZNE

Appendix-II

Weather data at Peechi during the study period

Month	Year	Temperature Max.	Temperature Min.	RH % Max.	RH % Min.	Rain (mm)	Wind km/hr	Br.Sun hr/day
June	1992	31.50	22.30	89.00	74.00	634.80	8.70	1.40
July	1992	30.20	21.30	92.00	78.00	831.20	-1.00	0.70
August	1992	30.40	21.70	90.00	77.00	463.60	-1.00	2.20
September	1992	32.10	21.40	89.00	69.00	286.50	-1.00	3.60
October	1992	32.50	21.80	89.00	67.00	244.30	-1.00	4.40
November	1992	32.30	21.60	89.00	66.00	341.60	-1.00	4.60
December	1992	32.50	20.60	82.00	54.00	1.40	-1.00	7.50
January	1993	34.50	19.10	83.00	48.00	0.00	-1.00	7.20
February	1993	36.80	20.30	87.00	48.00	3.20	-1.00	9.00
March	1993	38.30	22.70	85.00	46.00	0.00	2.30	8.20
April	1993	30.60	23.90	76.00	44.00	52.10	1.80	8.60
May	1993	33.40	23.70	76.00	51.00	175.80	1.80	4.70

Source: Division of Plant Physiology, KFRI

ECOPHYSIOLOGICAL STUDIES IN DISTURBED FOREST ECOSYSTEM: A CASE STUDY AT PATTIKKAD

By

P. O. NAMEER

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Forestry

Faculty of Agriculture
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1993

... deciduous forests of Kerala are prone to comparatively more biotic interference, as it occupies a buffer zone between human population and evergreen forests. An ... at Pattikkad range of Peechi-Vazhani Wildlife ... Trichur Forest Division, ... of the present study were to ... the floristic, structural, functional, ... and micrometeorological changes ... al plots namely ... bed (PALK-MD) and ... identified taking into ... Each plot ... were subdivided into quadrats having ... frequency, density, basal ... index (IVI), diversity indices, height ... regeneration pattern, litter quantification ... phenology, leaf area, leaf area index ... on physico-chemical properties ... literature were recorded at ...

ABSTRACT

Moist deciduous forests of Kerala are prone to comparatively more biotic interference, as it occupies a buffer zone between human population and evergreen forests. An investigation was carried out at Pattikkad range of Peechi-Vazhani Wildlife Sanctuary, in Trichur Forest Division, Kerala. The objectives of the present study were to understand the floristic, structural, functional, physiological, edaphic and micrometeorological changes accompanying degradation. Three experimental plots namely highly disturbed (PATK-BT), partially disturbed (PATK-MD) and more or less undisturbed (PATK-TP) were identified taking into consideration the proximity to human settlement. Each plot had a size of 10000 m^2 and were subdivided into quadrats having 100 m^2 each and observations on frequency, density, basal area, Importance Value Index (IVI), diversity indices, height - diameter relationships, regeneration pattern, litter quantification, litter decomposition, phenology, leaf area, leaf area index, light infiltration, physico-chemical properties of soil, soil moisture and soil temperature were recorded at periodic intervals for an year.

The results indicate that the moist deciduous forest tend to become a semi-evergreen forest if left undisturbed for several years. The undisturbed (PATK-TP) plot recorded maximum density (882), in 143 species (48 families) whereas the density is only 154 in the highly disturbed (PATK-BT) plot. The number of species at PATK-BT is only 31 (19 families).

The species diversity is also very high in the undisturbed plot (Simpson's index = 0.97, Shannon-Weiner's index = 5.97) whereas the Simpson's index and Shannon-Weiner's index are 0.92 and 4.16 respectively for PATK-BT.

The height-diameter relationship clearly show that the set of the future is more or less absent in the disturbed plots. The regeneration survey reveals that the regenerating community is sparse in the disturbed plots. While the disturbed plots (PATK-BT and PATK-MD) had 3875 and 5045 seedlings per hectare the undisturbed (PATK-TP) plot had 26,500 seedlings per hectare.

The litter production was found to be positively correlated with basal area. The rate of litterfall ranged from 6.14 t ha^{-1} to 8.66 t ha^{-1} in the moist deciduous forests.

The decay rate was fastest in the disturbed (PATK-BT) plot ('K' value = 0.26) and slowest in the undisturbed (PATK-TP) plot ('K' value = 0.17).

The light infiltration to the forest floor was maximum in the highly disturbed (PATK-BT) plot (140.42 μ mol m^{-2} s^{-1}) and was least in the undisturbed (PATK-TP) plot (44.42 μ mol m^{-2} s^{-1}).

The PATK-TP had a leaf area index of 4.04 and that of PATK-BT was only 1.06.

While most of the leaves in the undisturbed plot belonged to notophyllous (leaf size = 20.25 cm^2 to 45.00 cm^2) type of leaves, that of disturbed plots were mesophyllous (leaf size = 45.00 cm^2 to 182.25 cm^2).

The physico-chemical properties of the soil were better in the undisturbed plot when compared to the disturbed plots. The gravel content was 23 to 33 per cent at PATK-BT whereas it was 22 to 23 per cent at PATK-TP. Soil was more acidic (pH 5.51 to 5.57) at PATK-TP, whereas at PATK-BT the pH varied from 6.13 to 6.14. The organic carbon at undisturbed (PATK-TP) plot ranged between 1.4 to 3 per cent while in the highly disturbed (PATK-BT) plot ranged from 0.9 to 2 per cent. N, P and K also followed a similar pattern.

The soil moisture was always maximum in the undisturbed (PATK-TP) plot. The soil moisture varied between 14 per cent (March) to 50 per cent (July). The soil moisture at the highly disturbed (PATK-BT) plot was always the minimum. The values varied between 3 per cent (March) to 30 per cent (July).

The undisturbed (PATK-TP) plot consistently recorded minimum soil temperature throughout the year when compared to the disturbed plots. The values varied between 22°C (July) to 28°C (April). Whereas in the highly disturbed (PATK-BT) plot the soil temperature was always high. The soil temperature recorded at PATK-BT ranged between 25°C (July) to 36°C (April)