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REGENERATION STUDIES ON SOME IMPORTANT TREES IN A NATURAL MOIST DECIDUOUS FOREST ECOSYSTEM

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Summary

Forest Resources are renewable only because they do regenerate. The pace at which older trees are replaced by younger ones is very much important in this respect. Regeneration dynamics thus, is one of the thrust areas of study in the management of natural forests.

In India *Tropical Moist Deciduous Forests* rank next to the *Tropical Dry Deciduous Forests* in extent. On the other hand, the *Moist Deciduous Forests (MDFs)* stand first in meeting the requirements of the people, as they yield timber trees of commerce like teak, sal, venteak, rosewood, *etc*.

Kerala has approximately 4,100 km^2 of *Moist Deciduous Forests* amounting to 43.6 percent of the State's total forest area. Regeneration is heavily deficient in these forests. Thus, the project was undertaken to investigate the causes of poor regeneration in these forests with special reference to the commercially important trees. In addressing the problem, the following questions were posed: To what extent is the paucity of regeneration in the *Moist Deciduous Forests?* Do the flowering and fruiting behaviour of the commercially important trees contribute to the paucity of their regeneration? What are the specifics of population dynamics in the early phases of sylvigenesis of these species? What processes limit the growth of natural regeneration populations below the desired levels?

Conventional phenological, demographic and phytosociological studies were conducted in the *South Indian Moist Deciduous Forests* of the Trichur Forest Division (Kerala) so as to answer the questions covering all phases of sylvigenesis. Qualitative phenological studies were conducted on 172 marked trees belonging to 18 tree species. Monthly observations of 10 phenological phases were made with the help of a binocular for three years. Quantitative phenological studies were conducted in a permanent plot by installing seventy five 1 m^2 litter traps. Regeneration survey was conducted in eight widely distributed 0.6 ha sample plots, so as to have a general idea of the seedling bank. Various parameters of the dynamics of seedling populations such as natality, mortality, survival, etc. were studied in two permanent plots by monitoring over 4,000 tagged seedlings for two years. In addition, for a period of one year the number of newly emerging tree seedlings were monitored in ninety 4 m^2 quadrats at fortnightly intervals, so as to get an idea of seed to new recruits ratio. Role of summer soil moisture depletion on seedling mortality was studied by monitoring the survival of tagged seedlings in thirty 20 m^2 plots during the summer months. Fate of 900 (>= 10 cm dbh) trees in the two permanent plots of 2 ha size were monitored for estimation of survival.

The average number of unestablished seedlings (<= 100 cm height) of comercially important species (stratum 1) obtained was over 3,000 ha^{-1} . This figure is quite satisfactory, on grounds parallel to that of *Evergreens*. On the other hand, the observed average stocking of established seedlings (height > 100 cm and dbh <= 10 cm; 239 ha^{-1}) was far below the required number (578 ha^{-1}). This denotes that actually the reproductive potential of the commercially important species is not low but is significantly mutilated by constraints operating during the movement to established seedling stage.

Population structure, *viz.*, the pattern of frequency distribution in the different size classes shows a strongly skewed L-shaped exponential curve for all the three tree strata. This indicates that mortality rates are maximum in the lower size classes and decrease with size classes up. There is a sharp decrease in the frequency of individuals in the size classes above 10 cm dbh in both the middle and lower strata, while in the upper stratum this flux is not very abrupt. However, a reduction of individuals in the size class > 10 cm and <=20 cm dbh (pole stage) of the upper stratum is very much obvious.

Semilogarithmic graphs of population structure of six dominant tree species *(Xylia xylocarpa, Lagerstroemia microcarpa, Grewia tiliifolia, Dillenia pentagyna, Terminalia paniculata* and *T. crenulata)* also showed the paucity of established seedlings. In *Lagerstroemia microcarpa*, poles were almost wanting.

From the results of phenological studies, flowering and fruiting periodicities of the commercially important trees in the MDFswere found to be regularly circannual. No gregarious flowering/ mast seed years or years without flowering and fruiting were also apparent for any of the commercially important trees. The number of flowers produced in a hectare of *MDFs* was estimated form the sample study as around 124 million. Of this, 56 million matured as fruits. Calculations of seed output using average number of seeds per fruit showed a very large number, 1156 million. Even ignoring the seeds of *Lagerstroemia microcarpa* and *Tetrameles nudiflora* which show very small percentages of germination, there were as many as 2.85 mill. seeds ha^{-1} yr^{-1}, which indeed is a large number. Newly emerging recruits of commercially important tree species were in the order of 10,000 ha-1 yr^{-1}. Although this is only a small fraction of the fruit/ seed output, the number is still very high and satisfactory, where the final result of sylvigenesis is not more than 200 trees ha-1. Hence, the reproductive potential of *MDFs* in terms of flower, fruit, seed and seedling production is in no way a limiting factor hindering ample regeneration.

Sumemer soil moisture depletion by itself is not a serious threat to regeneration. Experimental studies in protected sample plots showed that seedling mortality during the summer moths was no more than 10 to 20 percent. This was so presumably because, the thick litter carpet available on the ground during the summer months acted as a heat protective cover and prevented excessive moisture loss from soil.

Biotic factors were found to be the main causes responsible for the paucity of regeneration in the *Moist Deciduous Forests*. Recurring fire, grazing and browsing by goats and sheep, illicit cutting of saplings and poles, charcoal making *etc.* are the main reasons for the paucity of regeneration. Besides the biotic factors, competition offered by weeds, twiners and the less useful species also offer contraints but to a lesser extent. In some species intrinsic constraints also exist.

In areas where recurrent fire is common, this is the single largest factor causing paucity of regeneration in *Moist Deciduous Forests.* Because of the seasonal physiognomy, proximity to settlements and penetrability, *MDFs* are almost entirely (except perhaps a few protected areas) subject to fire every year. Recurrent fire, both intentional and unintentional, nullifies the reproductive potential by devastating the young seedlings. The probabilities of transition of regeneration form lower to higher size classes get diminished and from higher to lower size classes get amplified. Fire therefore always leads to retardation of the population of regeneration.

Moist Deciduous Forests have the seedling banks, the substrate required for the process of sylvigenesis to operate. But the latter gets arrested owing to fire. Thus, in areas where fire is fairly regular, it is largely responsible for the paucity of established seedlings (saplings).

Fire also reduces the seed source considerably. In general, the diaspores (fruits/ seeds) of the commercially important trees of the *MDFs* are larger than that of the weeds and other less useful trees. Therefore, they fail to enter the seed bank. Consequently they are burnt in the forest fire thus reducing the seed source.

Further, fire causes damages and also kills mature trees, which is the seed source for regeneration. Of the 900 trees (>=10 cm monitored, 28 percent (251) had fire burnt blisters or decay holes on the trunk/ collar region. Repeated ground fires burn the collar region of trees and over years the wood gets infected by decay causing fungi. The trees gradually get killed either by fungi or by wind fall.

Illicit cutting of saplings, poles and trees creates gaps in stands on the one hand and on the other distorts the population structure of individual species, again leading to arrested sylvigenesis. This in turn leads to poor regenerative potential.

The population of natural regeneration of the commercially less used species outnumber that of the useful species and offers strong competition to the latter. This is in addition to that contributed by weedy shrubs, twiners and lianas.

Some tree species have inherent intrinsic constraints. This is best exemplified by *Lagerstroemia microcarpa* where millions of seeds produced each year are practically sterile (with very low germination percentage) in the absence of a viable embryo.

Protection from biotic factors is the most important measure to be adopted for augmenting regeneration in *Moist Deciduous Forests*. Fire being the largest among the constraints to regeneration its control is of vital importance. Due to fire protection alone, populations of natural regeneration have shown significant increase in survival (85 percent) and transition probabilities to higher size classes. This is indicative of the fact that *MDFs* although deficient of ample regeneration are in no way irreparable. If proper protection is given they can still get back to uninterrupted sylvigenesis. In addition, grazing and browsing, illicit cutting, charcoal making, *etc*. need to be controlled.

In areas which are already degraded regeneration need to be augmented by enrichment planting. Present studies have shown higher fire survival (p=0.45) of seedlings in the size class 1–10 cm dbh. Hence, standardization of planting stock and technology with the lower half of this size class would be a better option in places where full fire protection measures cannot be enforced.

All causes of forest degradation such as fire, grazing, illicit cutting, *etc*. are anthropogenic in origin. Measures to check degradation therefore should take into consideration the sociological aspects of forest management. Due thoughts must be given to participatory management of forest resources, including the involvement of the local population.

Chapter 1

Introduction

For approximately half a century forestry research centred largely around plantation forestry. However, having experienced with the demerits of the homogeneous monocultural systems, in recent years forest management research has shown trends to conceive the idea of sustainable management of multiple resources conserving the rich natural diversity (Bawa and Krugman, 1986).

Precise knowledge of the intrinsic structure of the dynamics of ecosystems is a *sine qua non* in developing practical methods for sustainable management. Thus, research with the aim of acquiring basic information on ecosystem dynamics has been conducted in various parts of the world (Bawa, 1974; Frankie *et al.*, 1974a, 1974b; Janzen, 1978; Bawa,1979; Chan, 1981; Leigh *et al.*, 1982; Bawa, 1983; Sutton *et al.*, 1983; Bawa *et al.*, 1985a, 1985) and the process is continuing.

Regeneration is the process of sylvigenesis (= forest building; *cf.* Halle *et* al., 1978) by which trees and forests survive over time. Unlike homogeneous plantations, management of natural forests rely largely on natural regeneration. Successful management therefore depends on good natural regeneration of valuable species. Regeneration dynamics is one of the thrust areas for intensive research. The final goal of these research programmes should be to evolve methods to harmonise the rates of exploitation and regeneration.

Because of the fragile nature, *Evergreen Forests* received much attention on the above lines, but the *Moist Deciduous Forests* did not. The *Moist Deciduous Forests* are commercially much more important, as human dependence on this forest type is greater than that on the *Evergreens*. In fact, the problem of the *Moist Deciduous Forests* is much more acute than that of the *Evergreens,* the situation being complicated with a high degree of anthropogenic constraints.

Kerala has approximately 4,100 km^2 of *Moist Deciduous* Forests (Forest Survey of India, 1989) (Figure 1.1). They are the habitats for the most valuable timber species like rose wood (*Dalbergia latifolia* Roxb., *D. sissofdes* Grah. *ex* Wt. *et* Arn.), teak (*Tectona grandis* Linn. *f.),* irul (*Xylia xylocarpa* (Roxb.) Taub.), maruthi (*Terminalia crenulata* Roth, *T. paniculata* Roth), venteak (*Lagerstroemia microcarpa* Wt.), chadachi (*Grewia tiliifolia* Vahl), vaga (*Albizia odoratissima* (Linn. *f.*) Benth.), manjakkadambu (*Haldina cordifolia* (Roxb.) Ridsd.), *etc.* Regeneration

Figure 1.1 Distribution of *Moist Deciduous Forests* in Kerala. *A.* Compiled from Chandrasekharan (1962). B. Redrawn from Nair *et al.* (1984). The pronounced reduction in area by 1984 is due to the conversion of many areas into

is generally very poor and totally unsatisfactory for many of these commercially important tree species.

The first step in finding suitable solutions for the problem of regeneration is to identify the actual constraints involved. Identification of the constraints in turn requires a demographic assessment so as to locate the points of action of the constraints. As a matter of fact, the present study was undertaken so as to:

1. Get a general idea of regeneration dynamics of *South Indian Moist Deciduous Forests,* especially in Kerala.

2. Identify the constraints of regeneration specific to the commercially important species through phenological, demographic and phyto-sociological studies.

The Trichur Forest Division has a large junk of *Moist Deciduous Forests* and therefore, this area was selected for the study.

In forestry, generally the use of the term 'regeneration' is restricted to the lower size classes, especially seedlings. However, in the verbal form it is a cyclic process beginning with flowering and ending with the formation of adult trees, passing through fruits, seeds, seedlings, saplings and poles (P. N. Nair, 1961). Thus, in a wider sense the term applies to all life stages of the plant. Regeneration studies to be helpful in identifying the constraints must, therefore, embrace all the life stages. Thus, the different parameters studied in this connection were designed to address questions relating to the reproductive phase, regeneration phase and the mature tree phase. Since results and discussions on each of the silvic phases mentioned above are lengthy, they are dealt in separate chapters.

Chapter 2

Review of Literature

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Histroy of Regeneration Studies

The very birth of the science of forestry was as regeneration studies. The colonial powers in India were very much in need of teak for ship building, Shortage of teak and the need for its continuous supply led to the raising of first teak plantations in India and Burma (Stebbing, 1922). After the lapse of approximately 150 years, today this tradition of artificial regeneration and domestication of forest trees is well established as plantation forestry. Literature on this subject is enormous and has been precisely reviewed by Libby (1973) and Seymour *et al*. (1986).

While plantation forestry is an alternative measure to increase the turn over of yield of desired species it has the demerits of monocultures. Epidemic diseases and outbreak of pests are always associated with it. Moreover, plantations modify the natural vegetation completely. This led to the concept of managing the natural forests, keeping their original structure and diversity and using the techniques of natural regeneration. The practice of natural regeneration over many decades had contributed a vast store of know–hows of silvicultural practices in forest management (P. N. Nair, 1961; C. T. S. Nair, 1986).

Today, the concept of conservation in resource management is well established. Many international forums find their efforts to develop suitable methods for practicing the concept of sustained yield in forestry (Unesco, 1975). Therefore, the subject of natural regeneration is receiving greater attention. To take a brief retrospect, artificial regeneration (plantation forestry), natural regeneration, and the sustained yield concept are three phases of development in the history of forestry.

Natural Regeneration

Foresters and ecologists have contributed to the knowledge of regeneration dynamics of natural forests. Regeneration dynamics have been studied in both unmodified and modified forests of different latitudinal, longitudinal, altitudinal and typological specifications (Brooks, 1941; Ayliffee, 1952; Holmes, 1956; Webb *et al.*, 1972, Murray, 1981; Kahn, 1982; Heuveldop and Neumann, 1983; Burschel *et al.*, 1985; Venning, 1985 and many others). *Temperate Forests* and *Tropical Wet Evergreen Forests* are the ones best studied. Regeneration studies on selected species and specific categories of taxa are also numerous (Watt, 1919, 1923; Barnard, 1956; Khoon, 1981; Newbold *et al.*, 1981; Chaconsotelo, 1983; Dimitrov, 1984; Daly and Shankman, 1985; Drapier, 1985; Melnik, 1985; Morin, 1986; Szappanos, 1986; Bernier, 1987; Everard, 1987).

P. N. Nair (1961) has brought out a detailed review of the literature concerning the various aspects of natural regeneration. C. T. S. Nair **(1986)** has drawn a concise account of the silvicultural systems associated with natural regeneration. Fox (1976) has made a categorical review of constraints of natural regeneration. The vast store of literature on natural regeneration differs markedly in its content as the forest types themselves are and the factors and the processes involved in regeneration. Important aspects are reviewed hereunder, followed by synoptic review of pertinent studies on the *Deciduous Forests*.

Processes and Phases of Natural Regeneration

A number of reviews on the subject are already available. P. N. Nair (1961)has given a review of the subject on *Tropical Forests*. Unesco (1978 a, 1978 b) covered the subject at length.

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

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 sustainable forest management. Therefore, the population structure at each of these life stages, viz., adult trees, flower, fruit, seed, seedling, sapling, pole, *etc*. determine the structure of mature tree populations of the future. The characteristic regeneration pattern of individual species and forest types are therefore, compromises between the real regeneration potential and the pressure offered by the constraints (Fox, 1976).

Flowering

In the tropics flowering and fruiting of forest trees are quite often not regular. These irregylarities affect regeneration. For this reason, felling operations are to be based on the flowering and fruiting behaviour of the more important trees (Dhamanijayakul, 1981; P. N. Nair, 1961). In fact such phenological characteristics are being utilized for the management of *Dipterocarp Forests* in South East Asia.

A brief review of flowering of tropical plants was made by Bawa (1983). Flowering phenology of many forest trees, especially the *Evergreen Forests*, have been studied in the tropics (Holttum, 1931; Holmes, 1942a, 1942b; Koelmeyer, 1959; Pinto, 1970; Medway, 1972; Ng and Loh, 1974; Cockburn, 1976; Ng, 1977, 1981). Flowering phenology of a few ecosystems in toto had also been studied (Lee, 1971; Frankie *et al*., 1974a,

Flowering includes floral bud initiation, development, blooming and floral persistence (Borchert, 1983; Rathcke and Lacey, 1985). In a broader sense it also includes the study of breeding systems including floral biology. Of these, bud initiation, development and blooming are subjects of interest to physiologists and except for a few crop trees, forest trees have not been studied in this respect.

Not all the trees do flower and fruit in the same manner. Variation exists in frequency, time and duration of flowering and fruiting. It also varies with species, populations and ecosystems, and according to the climatic conditions (Bawa, 1983; Primack, 1985). The Costa Rican forests show a bimodal distribution of flowering frequencies (Baker *et al.*, 1983). The South East Asian Dipterocarps flower synchronously once in 5-13 years. This phenomenon is commonly termed as gregarious flowering (Medway. 1972; Janzen, 1974a). In most other trees annual flowering is the rule. Periodicities between these extremes are also known. These phenological patterns are very much related to competition of pollinators, pollinator activities and selection for life history traits (Bawa, 1983; Primack, 1985). The relationship between breeding systems (including anthecology = pollination ecology; Frankie *et al.*, 1974b; Baker *et al.*, 1983; Bawa *et al.*, 1985a) and incompatibility mechanisms (Bawa *et al.*, 1985b) of individual species are only being understood.

Fruiting/ Seeding

Fruiting/ seeding includes fruit initiation, growth, ripening, fruit fall and the presentation of fruits (seeds) to dispersers (Rathcke and Lacey, 1985). Janzen (1978) made a detailed review of seeding patterns for tropical trees. Generally flowering periodicities are reflected in fruiting. But, a tree flowering profusely need not always fruit. Size of the seed crops of any given individual for any two years need not be the same. For example, in *Hymmenaea courbanil* (Fabaceae) although flowering takes place annually, fruiting is abundant only once in five years. Abortion of flowers and immature fruits ranging between 1 to 100 percent have been recorded (Bawa *et al.*, 1985 b). In the West African *Parkia capertoniana* out of approximately 2,000 fertile flowers only 4-5 develop into fruits (Baker and Harris, 1957).

The predator-seed crop relation has been studied in some detail. Janzen (1974 a, 1974 b) argues that mast 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. Nevertheless a few studies are available on the subject (Krishnaswamy and Mathauda, 1960; Kaul and Raina, 1980; Boojh and Ramakrishnan, 1981; Khosla *et al.*, 1982; Shukla and Ramakrishnan, 1982; Shrivasthava, 1982; Ralhan *et al.*, 1985; Prasad and Hegde, 1986; Basha, 1987) .

Dispersal

The place of production of seeds does not have the carrying capacity to grow and sustain all of them (Gadgil, 1971). -Thus, competition is avoided by dispersing seeds even at the danger of casualties. The mechanism of dispersal involves wind, water, frugivorous birds and animals (Ridley, 1930, Pijl, 1969). In *Wet Forests* seeds of more than 60 percent of the trees are dispersed by sarcochorous means (eaten by animals; Danserau and Lems, 1957). While, the *Dry Forests* show a greater percentage of wind dispersal (Baker *et al.*, 1983).

The time of maturation and dispersal need not be the same. In *Pinus radiata* and *P. caribaea*, cones with seeds are retained on the trees for five or more years without loosing viability. Seed fall is maximum in the edges of forests (near clearings; Roe, 1967; Yocom, 1968). In closed stands on the other hand seed fall is highest at ***ca.*** 30 m from source (Cremer, 1965).

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. Both predispersal and postdispersal predation occur. There are instances of up to 40 % seed predation by rodents (Synnott, 1973) . In *Shorea ovalis* greater than 90 % seed predation due to insects has been recorded (Unesco, 1978 b). Seed collection from natural stands for various purposes also gives the same effect. 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 predation by satiating them (Howe and Smallwood, 1982). In the *Dipterocarp Forests* of Malaya seed years are widely spaced. The seeds escape predator threat by immediately germinating and building up a seedling bank (P. N. Nair, 1961; Grime, 1979).

Dormancy

Dispersed seeds generally show a period of rest termed 'dormancy' (of. 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 3 years (Mensbrugi, 1966). Most species *of Semievergreen Forests* lack seed dormancy (Hoi, 1972).

Seed Banks

Not all the seeds germinate as soon as they are dispersed. A good percentage move into the soil a few centimeters down. These form a 'seed bank'. Keay (1960) has given a review of forest seed banks and Whitmore (1983) has discussed the secondary succession of seeds in *Tropical Rain Forests.* Roberts (1981) and Cavers (1983) have made recent reviews of soil seed banks. There are excellent studies on seed banks of tropics (Symington, 1933; Liew, 1973; Hall and Swaine, 1980) and of higher latitudes (Kellman, 1970; Johnson, 1975).

Most studies indicate that seeds of dominant trees of the com–munities are either totally absent (Thompson and Grime, 1979) in the soil or they are poorly represented (Karpov, 1960). Generally the seed banks contain seeds of pioneer species. This non–correspondence of seed flora to the dominant tree flora is thought to be due to: 1. immigration of seeds by bird dispersal, and 2. quick loss of viability of seeds of dominant trees (Roberts, 1981).

Germination and Establishment

Dormancy is by far the chief factor determining the time of germination. Even in forests where there are two peak seasons of seed dispersal there is only one peak season for seed germination (Garwood, 1983 a), the peak being within,the first two months of the rainy (wet) season. In *Tropical Seasonal Forests* canopy species, lianas and the pioneer species show a unimodal pattern of germination. On the contrary in the case of understorey and shade tolerant species germination is throughout the rainy season, without a peak in any of the months (Garwood, 1983 b). Seedling emergence in canopy gaps peak 1-6 weeks prior to that in shaded understories (Garwood, 1983 a).

The conditions for germination and establishment of mature phase tree species are very much specialized (Gomez-Pompa *et al.,* 1972). In the life history of a plant highest mortality rates operate between flowering and seedling establishment (Wyatt-Smith, 1963). Mortality due to vagaries in rain fall, intense drought, herbivore predation and self thinning are recorded (Unesco, 1978b).

Conversion to Upper Size Classes

Trees are perennials with long life spans extending over hundreds of years. Therefore, studies on the conversion to higher size classes by following the life history of individuals in a given population of any given species or forest type for very long spans are totally lacking. However, size reflects age and therefore, size structure of 'populations proxies the dynamic of size conversions in the past. To a certain extent it also tells about the future of the stands (Buell, 1945; also of. Harper, 1977). Oliver and Larson (1990) have reviewed the subject of forest stand dynamics thoroughly. Seth (1974) and Satyamurthi (1 980) have refined the mathematical tools for the study of forest stand dynamics.

Distribution of size (diameter) classes is the most studied parameter. Nevertheless comparison of data is very much difficult owing to differen–ces in the lower size limit, the class intervals and units of measurement (Unesco, 1978 a) or because of limiting measurements to certain classes. Size class distributions were studied in most forest types, *viz., Low Land* and *Montane Evergreen Forests, Semideciduous Forests, Dry Deciduous Forests, Mangrove* and *Swamp Forests* (Beard, 1946; Rollet, 1952; Dawkins, 1958; Anderson, 1961; Rollet, 1962, 1974, *etc.; of.* Unesco, 1978a).

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; Pierlot, 1966), owing to the behaviour of certain species and partly due to the history of stands. In some gregarious *Dipterocarp Forests* this may be due to mast seed years.

Stand structure always tends to be exponential especially in a semilogarithmic graph (Unesco, 1978 a). 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, 1978 a).

Population structure of most tree species shows 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, 1978 a).

Yoda *etal*. (1963) have proposed the self thinning rule for even–aged single–species populations. According to this rule, individuals get eliminated owing to limitations of space and mass, *ie,* due to overcrowding and tied up organic matter and nutrients (Westoby, 1984). Bazzaz and Harper's (1976) arguments extend the applicability of the rule to mixed–aged and mixed–species stands. White (1974,1975, 1980,1981)has extended the rule to forest stands, explaining mortality and population structure.

Silvicultural Systems Associated with Natural Regeneration

Application oriented research concerning natural regeneration has contributed a series of silvicultural practices to the science of forestry. P. N. Nair (1961) and C. T. S. Nair (1986) have made excellent reviews of this topic. A very concise abstract is given below.

Three important silvicultural systems are known: 1. clear felling, 2. shelterwood system, and 3. selection system. The clear felling system involves a total removal of the trees leaving the seeds and seedlings to grow in order to give rise to a new generation of trees. This system is known from Malaya (Walton *et al.,* 1952; Barnard, 1955; Landon and Settan, 1957) and North Borneo (Walton, 1955; Nicholson, 1958).

The shelterwood system involves the gradual opening of the canopy so as to induce natural regeneration in forests. Various modifications of this system were practiced in African countries (Lancaster, 1952; Barnard, 1955), India (Chengappa, 1944; Kadambi, 1954; C. T. S. Nair, 1986,), areas of Bangladesh and Sri Lanka (Rosayro, 1954).

The selection system involves reducing part of the growing stock especially the commercially important species and favouring growth and regeneration. This system has many modifications and are practiced in West Africa, Sri Lanka, India (Kadambi, 1954) Pakistan, Burma, Philippines and Australia (P. N. Nair, 1961).

Studies on Moist Deciduous Forests

Broadly speaking, forested ecosystems can be recognized into three, *viz.*,the *Wet, Moist* and *Dry Forests*. Thirty three percent of the *Tropical and Subtropical Forests* are composed of *Moist Forests* (Murphy and Lugo, 1986). Compared to the *Wet Forests* the *Moist Forests* are poorly studied. Consequently, literature on the regeneration dynamics of these forest types are also but a few. Contributions of Rollet (1952, 1962) and Mooney (1961) on stand structure, Hubbel (1979) on diversity, FA0 (1955) on phenology, Gilbert (1938), Jones (1950, 1956) and Mensbrugi (196.6) on seed dormancy, germination and establishment *etc*. are notable.

Indian literature on the regeneration dynamics of the *Deciduous Forests* are widely segmented. A brief review may be found in Champion and Seth's (1968 b) 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, seedling establishment *etc*. of individual species were compiled by Troup (1921). Highly fragmented but very valuable information on the silviculture and various aspects of regeneration of the *Moist Deciduous Forests* are found distributed in the issues of two serial publications: (1) *Forest Research in India, Parts I and II* (1923-1961), published by the Governmnet of India, and (2) The *Annual Research Report of the Silviculture Division*, Kerala Forest Department.

Regeneration of rosewood (*Dalbergia latifolia;* Balasundaram *et al.*, 1979; Deshmukh, 1985), *Dipterocarpus* spp. (Thangam, 1982). sal *(Shorea robusta;* Bor, 1930; Champion, 1933; Chakravarthi, 1948; Chaudhuri, 1960; Bhatnagar, 1961; Sharma *et al.*, 1985), teak (*Tectona grandis;* Kadambi, 1957), irul (*Xylia xylocarpa;* Arora, 1960) have received much attention. Further details and specifics on the various aspects of regeneration of *Moist Deciduous Forests* and species are scattered in the various Forest Working Plans and phytosociological studies.

Chapter 3

Study Area

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Location and Area

The Western Ghats is discontinuous towards the south by a 22 km wide gap, the Palghat Gap. The forest formation in this region more or less conforms to the course of the Western Ghats. Thus, south of the Palghat Gap the forest land assumes a more or less T–shaped strip (Figure 3.1). The Trichur Forest Division is situated on the western half of the horizontal arm of this T–shaped portion of the Western Ghats. It is bordered by settlements and revenue lands all along the western, eastern and northern boundaries and by the Chalakkudy and Nemmara Forest Divisions along the south and south–east respecitively (Figure 3.2; George, 1963).

The Division falls wholly within the limits of the Trichur Revenue District of the Kerala State and lies between the latitudes 100 20' and 10^0 50' N and longitudes 75^0 95' and 76^0 30' E. As reconstituted in 1980, it comprises an area of approximately 328 km^2 of forests divided into four administrative blocks, viz. Wadakkanchery, Machad, Pattikkad and Peechi Ranges (of Figure 3.3). Of the above, the natural forests, the area of the present study constitutes approximately 204 km^2 spread over the Mukundapuram, Trichur and Thalappilly Taluks (Menon and Balasubramanyan, 1985).

Climate

The area shares 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 is from south–west nsoon which showers between June and September, especially during

Figure 3.2 Map of Trichur Revenue District showing the area and boundaries of Trichur Forest Division.

Figure 3.1. Forest map of South West India showing the location of Trichur Forest Division.

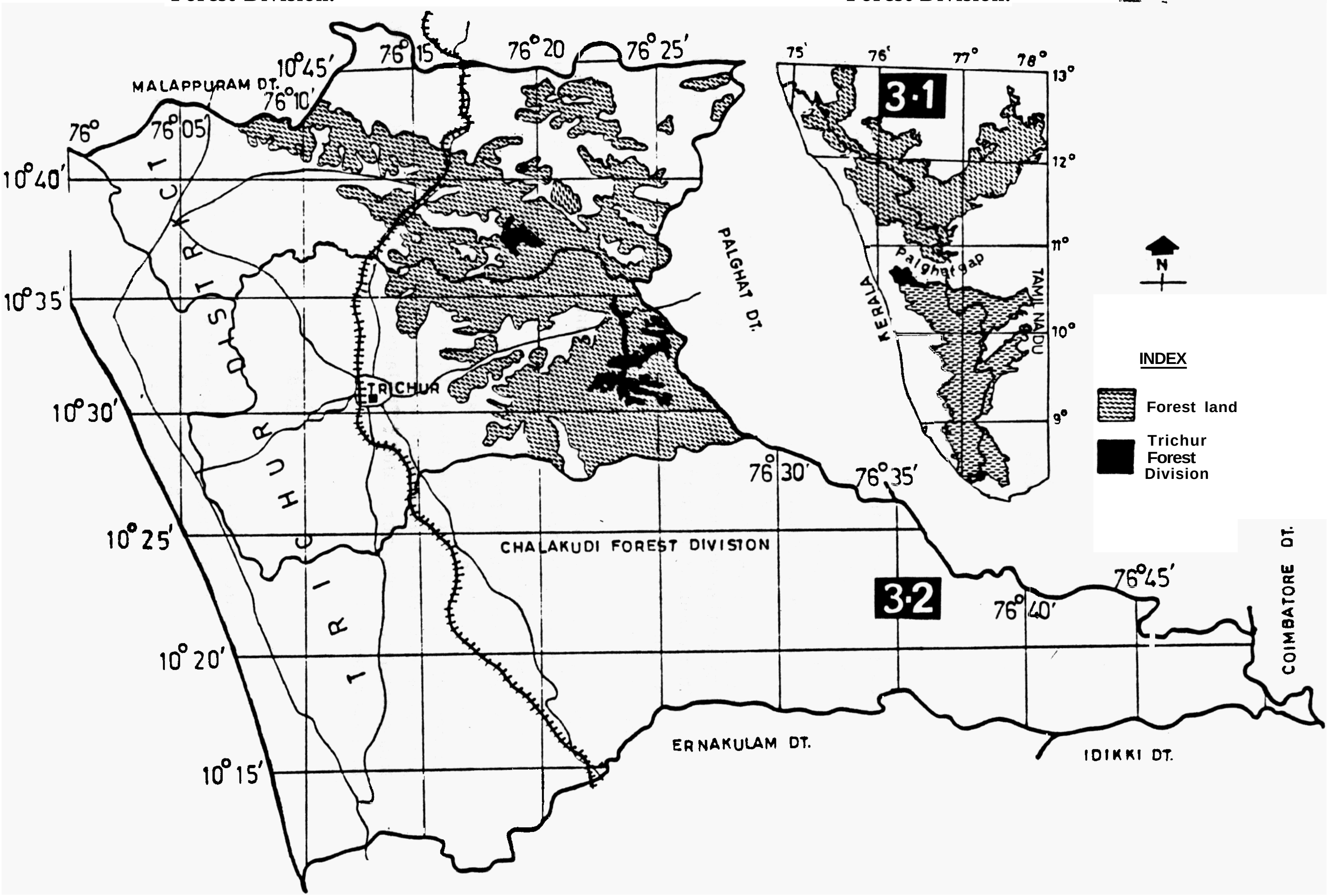
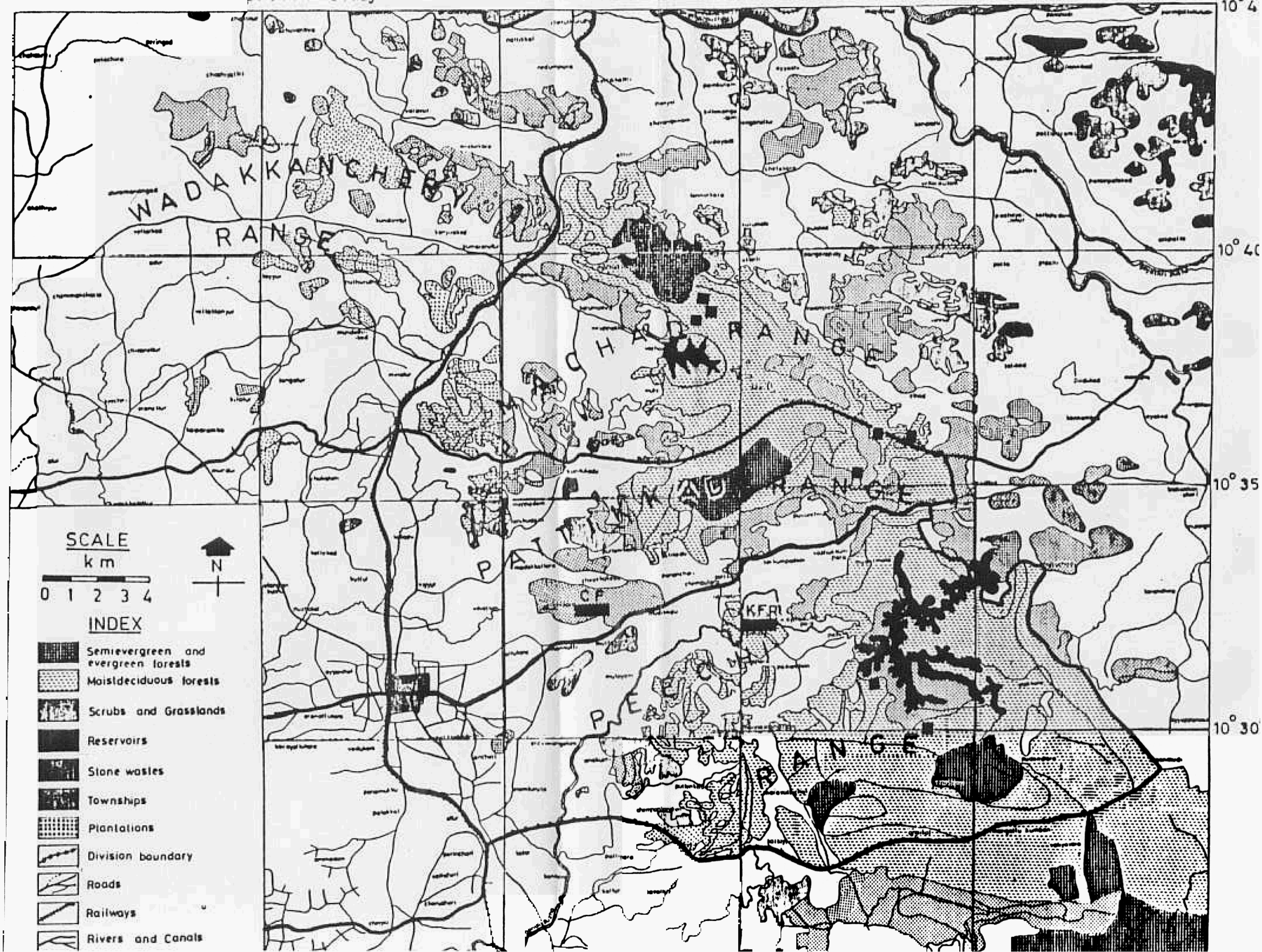


Figure 3.3Forest map of Trichur Forest Division showing the administrative blocks (Forest Ranges), forest areas and the sample plots (■) used in the present study.



June and July. The north–east monsoon showers during the later part of year between October and November. The . annual total for 10 years (1978-1987) ranged between 2,397 and 3,600 mm with the mean value being 2,793 mm. The details of distribution of precipitation for an average year (for the term of Meher-Homji, 1979), 1985, for Peechi (Trichur Forest Division) are given in Table 3.1.

The temperature extremes recorded for the past few years for Peechi were 18.9^0 C and 39.4^{0}C. The details of temperature fluctuations during 1985 are given in Table 3.1. The three months, March to May are the hottest. During December to early half of January, night temperature goes as far down to 18.9^{0}C.

The trade winds during the two monsoons are south–west and north–east respectively. During the months December to February, the forests on the eastern border receive warm winds coming through the Palghat Gap. A rare incident of cyclonic wind was also recorded for the Division during the year 1940.

Relative humidity is always greater than 55 % and attains 100 % during the rainy months. The statistics for 1985 for Peechi are given in Table 3.1.

Figure 3.4 is an ombrothermic graph for 1986 for Peechi. Generally May to October are wet months and November to April are dry.

Physiography

Physiographically the whole Division is distinguishable into five blocks:

1. The Machad Mala Ridge running along the north–west - south–east direction, flanked by the Chelakkara-Elanad Valley on the north and the Vazhani Valley on the south. This is the largest single block recognizable.

2. The Vellani Mala Ridge running east–west with Thanippadam and Pananchery Valleys on either side. This block is smaller in extent than the former and joins it by the western end.

Table 3.1 Statistic of climatic variables during an average year (1985) at Peechi.

Var	Stat	J	F	M	A	M	J	J	A	S	O	N	D
Temp. (°C)	Max	33.3	36.1	37.2	37.8	38.3	31.1	31.7	31.1	32.8	32.8	33.3	34.4
	Min	18.9	19.4	22.2	22.2	20.6	21.1	20.6	21.1	21.7	21.7	20.0	20.0
	Mean	25.8	27.8	30.7	30.7	29.4	25.5	25.2	25.7	27.0	26.6	26.7	27.9
Rain (mm)	Max	64.8	0.0	0.0	16.0	59.0	119.6	98.4	47.8	23.0	49.0	12.1	28.3
	Min	0.9	0.0	0.0	0.5	0.5	0.2	1.0	0.3	0.5	0.5	0.5	1.1
	Total	68.7	0.0	0.0	19.9	196.8	978.5	515.7	374.3	96.7	226.5	22.7	29.4
Rel. humid.	Max	96.0	91.0	96.0	97.0	96.0	100.0	100.0	96.0	95.0	98.0	96.0	98.0
	Min	29.0	29.0	17.0	32.0	49.0	72.0	73.0	76.0	62.0	58.0	47.0	42.0
	Mean	62.5	60.0	56.5	64.5	72.5	86.0	86.5	86.0	78.5	78.0	71.5	70.0

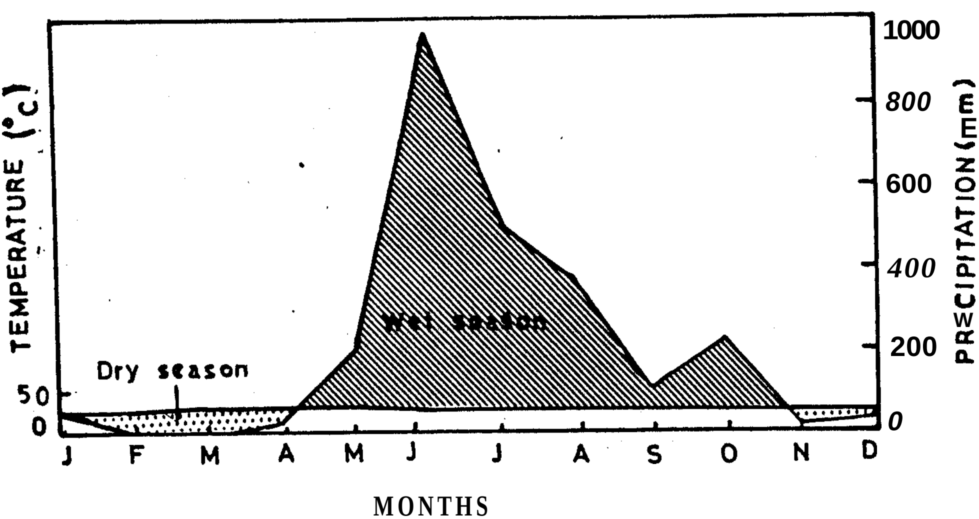


Figure 3.4 Ombrotherm for Peechi.

3. The low lying foot hills of the Machad Mala Ridge and the Vellani Mala Ridge along the west, north–west and north–east, where the elevation scarcely exceeds 200m . These hills are separated from the ridges because of the intrusion of human settlements and cultivation.

4. The many, more or less radiating ridges of the catchment of the Peechi Reservoir, and

6. The Anaikkal–Mangattu Komban Ridge running east–west, forming the northern flanks of the Chimoney Valley (Chalakkudy Forest Division) and holding the highest point (Ponmudi, 928 m) within the Division.

Because of the highly rugged, undulating physiography all kinds of aspects are met with. Nevertheless, the area is well drained with two west flowing rivers, Vadakkanchery River and Manali River. Two check–dams also exist, *viz.*, Peechi and Vazhani, which irrigate the agricultural lands along the west.

Geology and Rocks

The hills belong to the crystalline rocks of archean age comprising chiefly of charnockites, granites and granitic gneisses traversed by basic dykes (Geological Survey of India, 1976).

Vegetation

The forest land is recognizable into three: open blanks, plantations and natural forests. Of these, the natural forests comprise *Evergreen, Semievergreen and Moist Deciduous Forests.*

The dominant species in the *Evergreen Forests* are: *Calophyllum apetalum* Willd., *Dipterocarpus indicus* Bedd., *Mesua ferrea* Linn., *Palaquium ellipticum* (Dalz.) Baill., *Syzygium chavaran* (Bourd.) Gamb., ***S.* *gardneri*** Thw., *etc.*

The dominant species of the semievergreens are: *Artocarpus hirsutus* Lamk., *Bombax ceiba* Linn., *Lagerstroemia microcarpa* Wt., *Polyalthia* *fragrans* (Dalz.) Bedd., *Pterospermum reticulatum* Wt. et Arn., *Vitex altissima* Linn. f., *etc.* The details of the *Moist Deciduous Forests,* being the subject of the present study, are given in detail in a subsequent chapter.

Settlements

On the north, east and west, the Forest Division is surrounded by settlements. Hence, a well connected transportation network intercepts the forest land. The Cochin–Shoranur railway line bisects the Division into two east–west halves; likewise the national highway NH47 bisects it into two north–south halves. Some of the other important roads are: 1. Chelakkara-Elanad Rd., 2. Trichur-Ramavarmapuram-Vazhani Rd., 3. Trichur-Shoranur Rd., 4. Trichur–Mannamangalam Rd., and 6. Pattikkad -Peechi Rd.

People living immediately around the natural forests are highly dependent on the forests for agriculture, firewood, cattle grazing and smaller construction needs. The Malayas, the tribals at Velanganoor and Olakara are by tradition dependent on the forests for their livelihood.

Chapter 4

Moist Deciduous Forests of Trichur Forest Division: The Materials of Study

Contents **Page**

Typology

The term *'Moist Deciduous Forests' (MDFs)* denotes an aggregate forest type. This forest type is classified variously and the subdivisions received different names in different systems.

Champion (1936; English school) was the first to provide a practical classification of the *Tropical Deciduous Forests* of India, which was later revised by Champion and Seth (1968 a). The latter authors classified the *Tropical MDFs* of India into two: South *Indian MDF s* and *North Indian MDFs.* The *Moist Deciduous Forests* of the Trichur Forest Division belong to the former category. Puri *et al.* (1983) equated the *South Indian MDF s* with the Ser. *Tectona - Dillenia -Lagerstroemia - Teminalia paniculata of* Gaussen (1959) and Gaussen *et al.*(1961a, 1961 b, 1963a. 1963b, 1965a, 1965b, 1968a. 1968b, 1971, 1972, 1973, 1978) of the French school.

The *South Indian MDFs* comprise a large number of subdivisions. Presumably all these forest types exist in Kerala and Trichur Forest Division. The present studies were conducted in *Southern Moist Mixed Deciduous Forests.*

Distribution

Trichur Forest Division at present holds a total of 162 km^2 of natural *oist Deciduous Forests.* Distributed upto an elevation of 928 m above

MSL, these forests are a complex association of different kinds of habitats like reservoirs, man–made forests and natural forests. Along the upper reaches they form part of the insulation belt around the *Evergreen* and *Semievergreen Forests.* On the lower reaches they are surrounded by settlements and agricultural lands (Figure 4.1).

Soil

Soil and its properties vary considerably depending up on elevation and physiography of the land. Generally it is shallow, except on gentle slopes where it is moderately deep.

The soils belong to the group of red soils (oxisols) or red ferrallitic soils. They have originated from weathering of crystalline rocks like granite, gneisses and charnockites. The red colour of different intensities depend up on the content of Fe_2O_3, Al_2O_3 and SiO_2. The reddish brown colour of the surface soil turns reddish–yellow or yellowish–red with depth. The surface soil is generally sandy loam in texture and granular in structure while it becomes loamy and massive beneath. The absorbing capacity of the soils is low, except in the humus accumulative layer. Initial stages of laterization are observed where the soils are devoid of a vegetal cover and erosion is active (Sankar *et al.*, 1987).

In the permanent plot at Kalluchal, established for the regeneration studies, in the surface soil samples the gravel content ranged between 69 and 405 with a mean of 223 $\pm$ SD 72 g/kg and the finer particles ranged between 595 and 931 with a mean of 777 $\pm$ SD 72 g/kg. They were acidic (pH 5.8 $\pm$ SD 0.2) in reaction, medium in organic carbon content' (21.7'5 SD 4.7 g/kg), exchange acidity (33 $\pm$ 16 mg/kg) and exchangeable bases (163 $\pm$ SD 30 mg/kg) (Sujatha, 1989).

Physiognomy

During the wet season, because of the thick foliage the *Moist Deciduous Forests* mimics the *Evergreen Forests.* During this season their surface morphology is very much like that of the *Evergreen* Forests (Figure 4.2 A). However, during the dry season, in the *MDFs* trees shed their foliage and leave the vertical structure of the stands pellucid (Figures 4.2 B, 4.3 A & B).

Figure 4.1 The *Moist, Deciduous Forest* ecosystem with *Evergreen* and *Semievergreen Forests* in the upper reaches, the included reservoirs and catchments and the lower valleys with agricultural land and settlements (Peechi Forest Range, May, 1988).

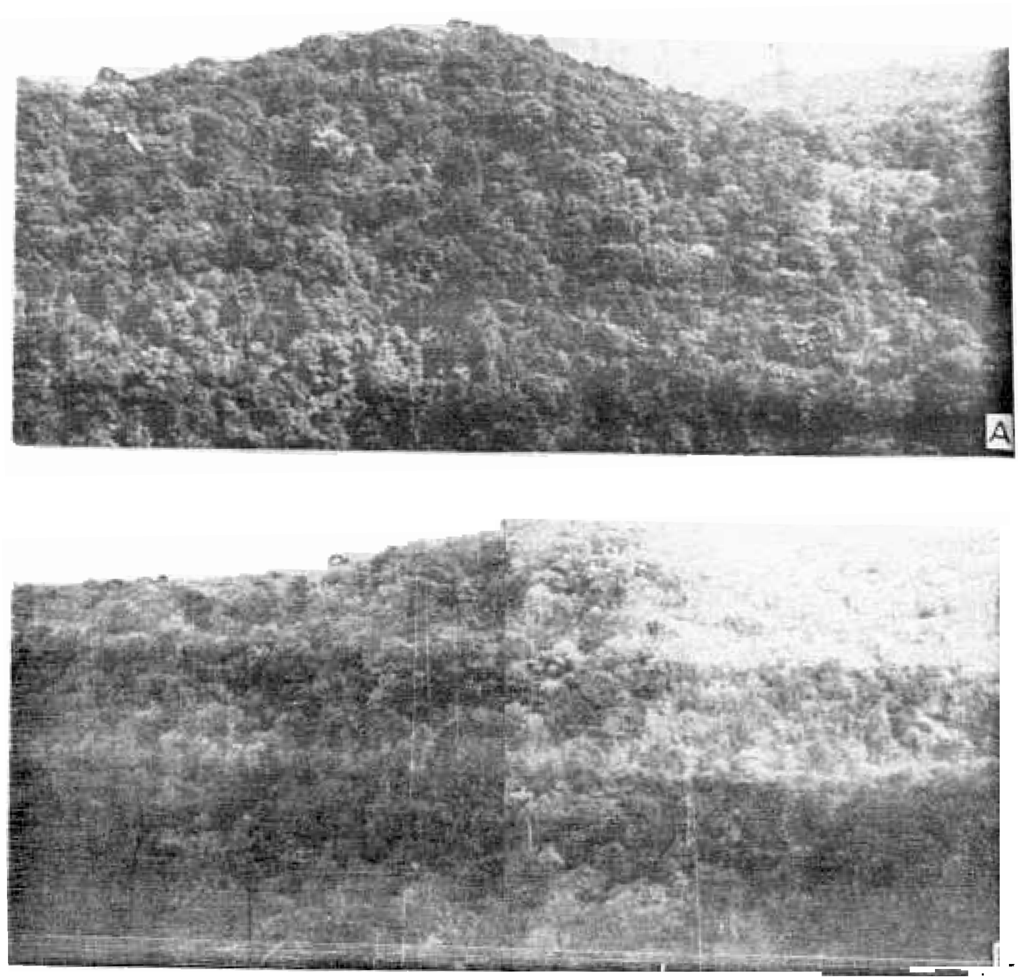


Figure 4.2 Physiognomy of the *Moist Deciduous Forest* during wet and dry seasons. A. Wet season (September). B. Dry season (April) – (Chathupara, Forest Range, 1988).

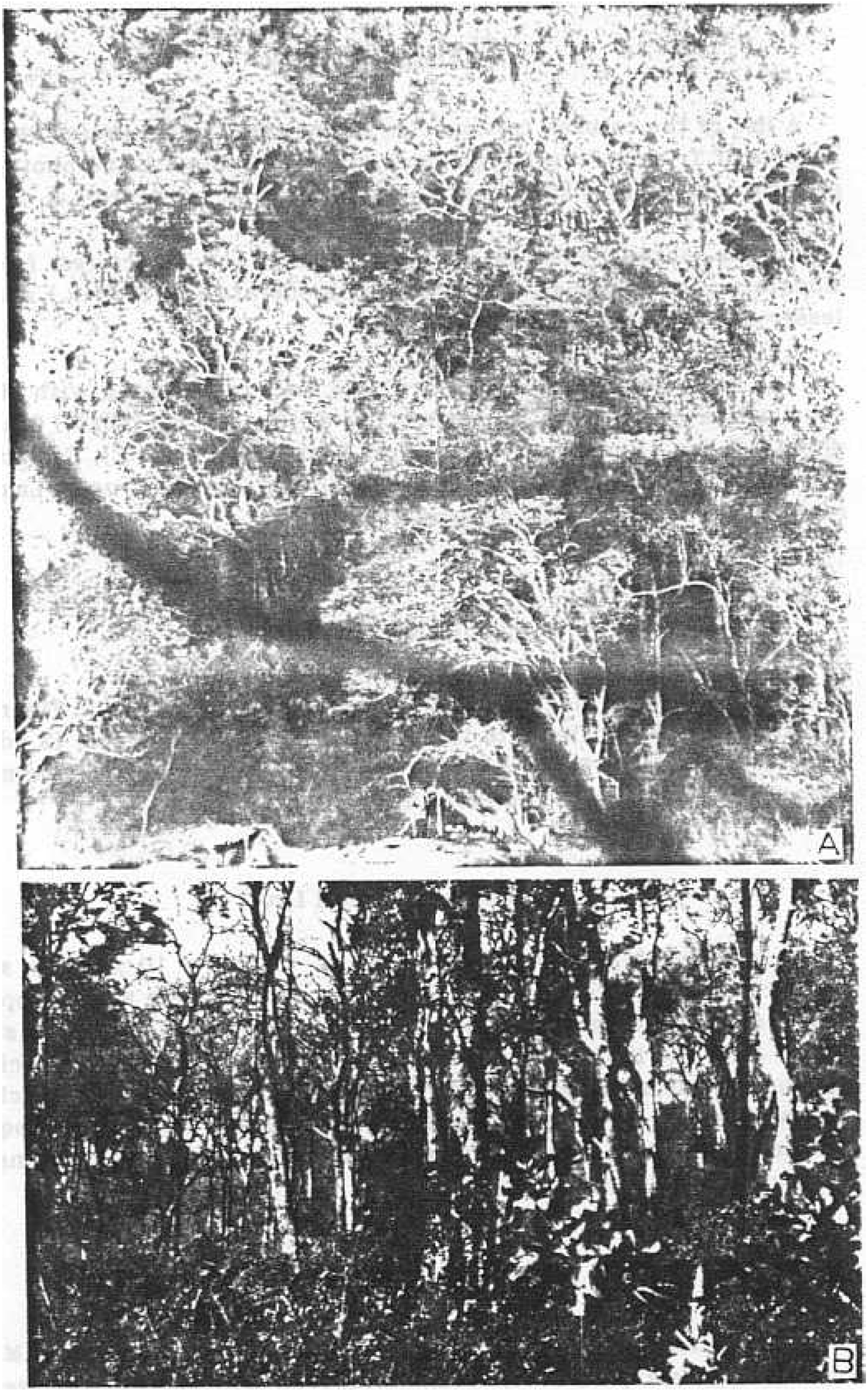


Figure 4.3 ***Moist Deciduous Forests*** **of Trichur Forest Division A. A view from above (Chathupara, Peechi Forest Range April, 1988). B. A view of the stand from below (Vazhani Machad Forest Range, April, 1988).**

Floristic Structure

A list of the common tree species encountered in the *Moist Deciduous* Forests of Trichur Forest Division is given in Table 4.1 and photographs of some commercially important species are given in Figure 4.4.

The shrub layer is mainly consisted of *Helicteres isora* L., *Eupatorium odoratum* L. (= *Chromolaena odorata* (L.) K. & R.) and to a lesser extent *Lantana camara* L.

The sylvan communities are also well represented with lianous species like *Acacia* spp. (*A. pennata* (L.) Willd., *A. torta* (Roxn.) Craib., *A. sinuata* (Lour.) Merr., *Butea parviflora* Roxb. (Figure 4.4 E), *Calycopteris floribunda* Lamk. *Dalbergia volubilis* Roxb., and *Zizyphus rugosa* Lam. (not represented in the profile diagrams).

Population Structure

Standard profile diagrams of two samples are represented in Figure 4.5. The trees are stratified into three, viz.,upper (1 st), middle (2 nd) and lower (3 rd) strata. The upper stratum is 25-35m in height, the middle between 18 to 25 m and the lower up to 10 m height.

Richness at Stratal Level

At stratal level species counts of trees >= 10 cm dbh shows significant differences between individual strata. There were 21 species in the upper stratum, 39 in the middle and only 4 in the lower strata (Table 4.1). The list of trees given in Table 4.1 shows that all species of the upper stratum are commercially very important, while most species of the middle and lower strata are less important. Thus, in subsequent sections of the text, the term upper stratum (stratum 1) is used instead of 'commercially important species'.

Dominance Structure

The area does not show any 'character species' association (Menon and Balasubramanyan, 1985). Dominant sylvan community of the 'medium

Table 4.1 List of tree species found in the different tree strata in the Trichur Forest Division.

Upper stratum (Stratum 1):

1 *Albizia odoratissima* (L. f.) Benth.
2 *Alstonia scholaris* (L.) R. Br.
3 *Bombax ceiba* L.
4 *B. insigne* Wall.
5 *Dalbergia sissoides* Wt. *et* Arn.
6 *Dillenia pentagyna* Roxb.
7 *Gmelina arborea* Roxb.
8 *Crewia tiliifolia* Vahl
9 *Haldina cordifolia* (Roxb.) Ridsd.
10 *Lagerstroemia microcarpa* Wt.
11 *Lannea coromandelica* (Houtt .) Merr.
12 *Melia dubia* Cav.
13 *Pterocarpus marsupium* Roxb.
14 *Radermachera xylocarpa* (Roxb.) Schum.
15 *Stereospermum colais* (Buch.) Mabb.
16 *Tectona grandis* L. *f.*
17 *Terminalia bellirica* (Gaert.) Roxb.
18 *T. crenulata* Roth
19 *T. paniculata* Roth
20 *Tetrameles nudiflora* R. Br.
21 *Xylia xylocarpa* (Roxb.) Taub.

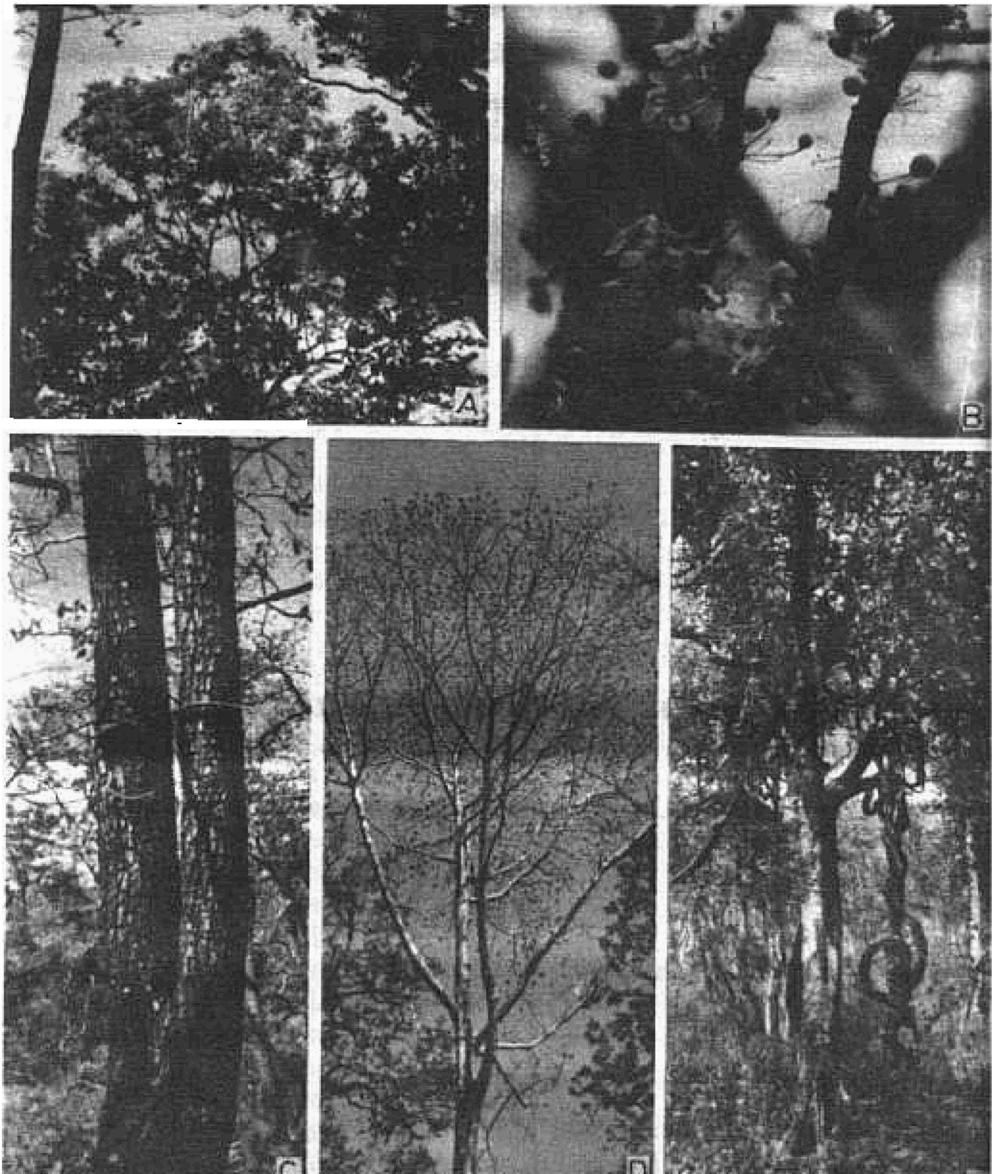
Middle Stratum (Stratum 2):

22 *Aporusa lindleyana* (Wt.) Baill.
23 *Artocarpus hirsuta* Lamk.
24 *Bauhinia racemosa* Lamk.
25 *Bridelia squamosa* Gerh.
26 *Carallia brachiata* (Lour.) Merr .
27 *Careya arborea* Roxb.
28 *Cassia fistula* L.
29 *Cleistanthus collinus* Hook. *f.*
30 *Cordia wallichii* G. Don .
31 *Dalbergia lanceolaria* L. f.
32 *Diospyros montana* Roxb.
33 *Emblica officinalis* Caert .
34 *Tabernaemontana heyneana* Wall. Wall.
35 *Ficus exasperate* Vahl
36 F. *drupacea* Thunb. var *pubescens* (Roth) Corner
37 *Garuga floribunda* Dcne.
38 *Hymenodictyon orixense* (Roxb.) Mabb .
39 *Litsea* sp.
40 *Mitragyna parvifolia* (Roxb.) Kunth.
41 *M. tubulosa* (Arn.) Havil.
42 *Macaranga peltata* (Roxb.) Muel1.-Arg.
43 *Hallotus philippensis* (Lamk.) Muell.-Arg.
44 *Miliusa tomentosa* (Roxb.) Sincl.
45 *Olea dioica* Roxb.
46 *Pajanelia longifolia* (Willd.) K. Schum.
47 *Persea macrantha* (Nees) Kosterm.
48 **Samanea saman* (Jacq.) Merr.
49 *Sapindus laurifolia* Vahl
50 *Schleichera oleosa* (Lour.)Oken
51 *Spondias pinnata* (L. f.) Kurz
52 *Sterculia guttata* Roxb.
53 S. *urens* Roxb.
54 *Streblus asper* Lour.
55 *Strychnos nux-vomica* L.
56 **Syzygium sp.*
57 *Trema orientalis* (L.) B1.
58 *Vitex altissima L. f,*
59 *Xeromphis spinosa* (Thunb,) Keay
60 *X. uliginosa* (Retz.) Mahesh.

Lower stratum (Stratum 3):

61 *Casearea wynadensis*
62 *Holarrhena pubescens* (Roth) DC
63 *Naringi crenulata* (Roxb.) Nicols.
64 *Wrightia tinctoria* (Roxb.) R Br.

* Bxotic or serievergreen irrigrants: seen only as seedlings.



A
B
C
D
E

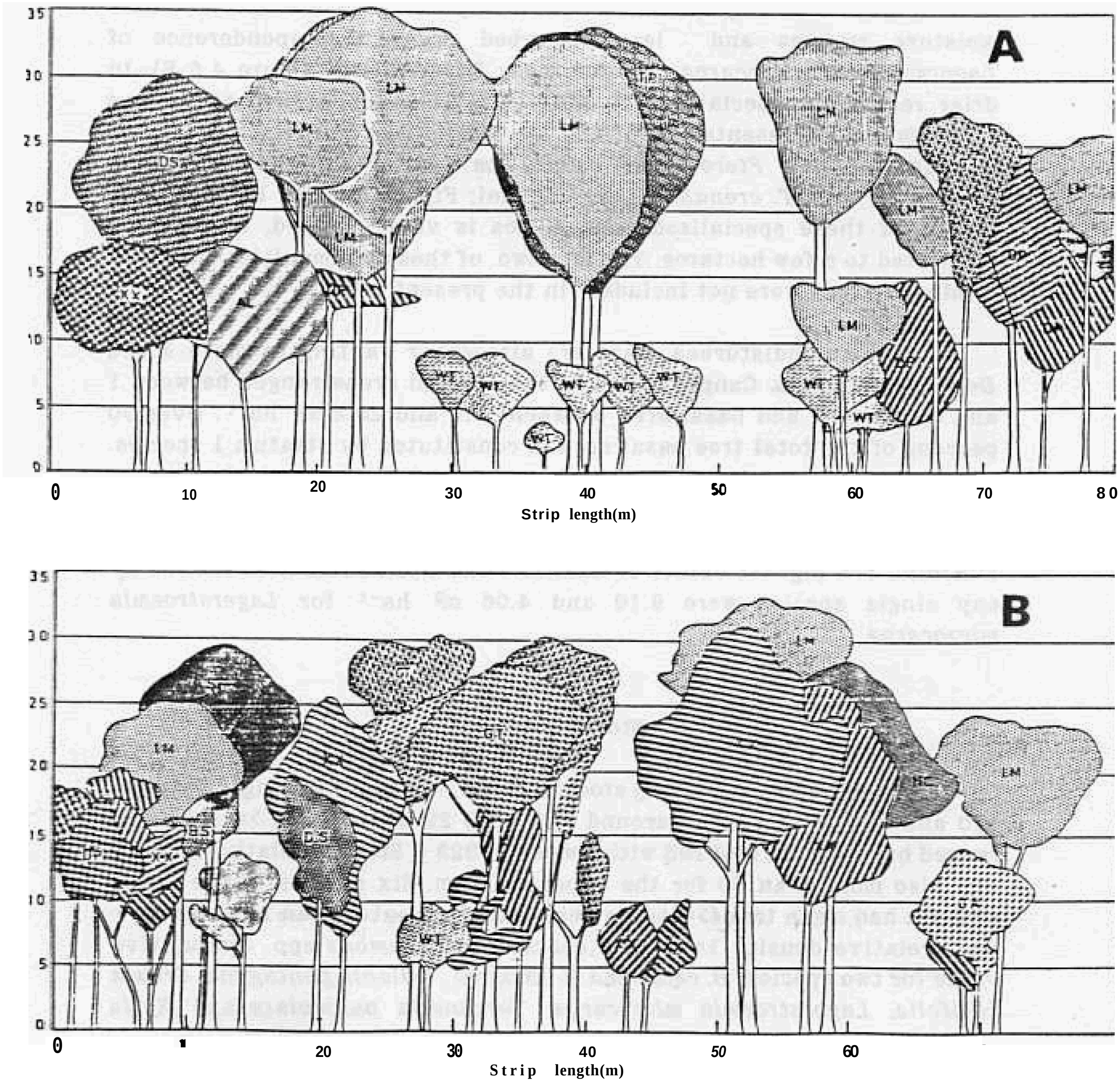


Figure 4.5 .Vegetation Profiles of selected sample localities. A. Karadippara. B.Kallucha1 (individuals >= 10 cm DBH of tree species alone depicted).

AL - *Alstonia scholaris*	LM - *Lagerstroemia microcarpa*
BS - *Bridelia squamosa*	XX - *Xylia xylocarpa*
DS - *Dalbergia sissoides*	WT - *Wrightia tinctoria*
GT - *Grewia*	

ranked association' is composed of species like *Xylia xylocarpa, Dillenia pentagyna, Tectona grandis, Grewia tiliifolia, Terminalia paniculata, T.crenulata and Lagerstroemia microcarpa* (Figure 4.6 A). In better moisture regimes and less disturbed areas a preponderence of *Lagerstroemia microcarpa* is seen. (*eg.:* Karadippara; Figure 4.6 B). In drier regimes, especially with underlying rock formations *Anogeissus latifolia* (a representative of the *Dry Deciduous Forests*) appears In assooiation with *Pterocarpus marsupium* (*eg.:* Pathrakkallu, Machad Range), or with *T. crenulsta (eg.:* Vazhani; Figure 4.6 C). However, the extent of these specialized communities is very limited, often being restricted to a few hectares. The last two of these communities and teak dominant areas were not included in the present study.

Totally undisturbed areas are altogether wanting in these *Mixed Deciduous Forests.* Canpopy gaps in the studied areas ranged between 1 and 30 percent and basal area between 4.4 and 28.2 m^2 ha^{-1}. Over 90 percent of the total tree basal area is constituted by stratum 1 species. The basal area constituted by the other two tree strata were insignificant. Four species had mean basal area > 1 m^2 ha^{-1}, the species being *Xylia xylocarpa, Terminalia paniculata, Lagerstroemia microcarpa,* and *Grewia tiliifolia***.** The highest values of maximum and mean basal area showed by any single species were 9.10 and 4.06 m^2 ha^{-1} for *Lagerstroemia microcarpa.*

Stocking Level

The per hectare growing stock of trees >=20 cm dbh ranged between 120 and 183, with a mean around 149 ± SD 22 while trees >= 1 cm dbh ranged between 522 and 186 with a mean of 323 ± SD 122. Relative density was also more than 60 for the upper stratum. Six species of the upper stratum had mean tree (>=10 cm dbh) density greater than 10 trees ha-1 and relative density >= 4. The species were *Bombax* spp. (cumulative value for two species: B. *ceiba* and *B.insigne),Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminslia panicula ta and Xylia xylocarpa.*

Stratawise, the upper stratum showed the highest mean Relative Importance Value (RIVI; RIVI = IVI/3; 169 ± SD 9); the actual values ranged between 58 and 82. Six species had RIVI >= 3. The species were *Bombax* spp. (cumulative values of two species: *B.ceiba* and *B. insigne), Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia panlculata* and *Xylia xylocarpa.* The highest values of maximum and

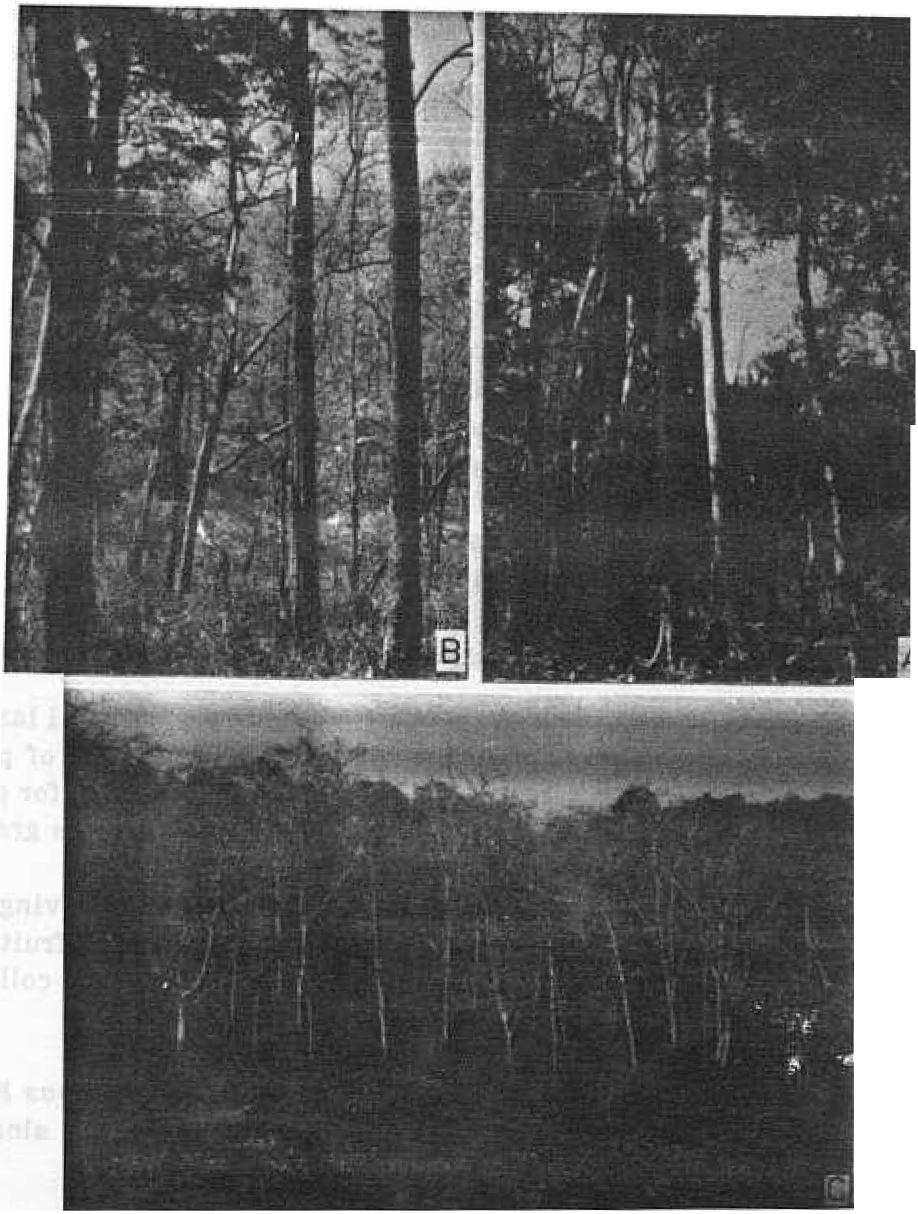


Figure 4.6 Species composition in the *Moist Deciduous Forests* of Trichur Division (continued). A. A stand with preponderance of *Lagerstroemia microcarpa* (Karadippara, Peechi Forest Range, April, 1988). B. *Xylia* - *Grewia* - *Dillenia* community (Vazhani, Machad Forest Range, April, 1988). C. *Anogeissus latifolia* - *crenulata* community (Vazhani, Machad Forest Range, April, 1988).

mean RIVI owned by any single species were 33 and 23 respectively, for *Xylia xylocarpa*. In addition to the upper stratum species, the lower stratum species *Holarrhena pubescens* and *Wrightia tinctoria* also showed RIVI > 3.

Factors Affecting the Vegetation

. The vegetation is under heavy biotic pressure. This has resulted in the paucity of sapling and pole crops, low stocking, excessive opening of canopy and establishment of exotic weed like *Eupatorium.* Most of the forests are degraded and in the past and several enrichment plantings were done with commercially important tree species.

The biotic pressures are largely of anthropogenic origin. People living in the nearby settlements depend on the *Moist Deciduous Forests* for small timber, fire wood and green manure. Illicit charcoal making is also prevalent. These activities often result in burning the area.

Farmers often burn the forests so that their agricultural lands get enriched by ash brought down by rain water. In the absence of pasture lands people also drive their cattle and goats into the forests for grazing and browsing. Fire helps new grass growth and this facilitates grazing.

Tribals living inside the forests and the local people living in the adjoining villages collect minor forest produce such as *Acacia* fruits, soap nut, honey, *etc*. They burn the undergrowth to facilitatate easy collection. The fire spreads and causes havocs.

Ground fire is the prevalent form in the *Moist Deciduous Forests;* the dry litter carpet on the ground gets burnt during summer along with the young regeneration.

Permanent Sample Plots

Most of the phenological and demographic studies were conducted in two permanent plots established at Karadippara (Figure 4.7) and Kalluchal (Peechi Range). Both the plots were made into grids of 10 m x 10 m. The qaudrats were marked by chemically treated numbered wooden pegs. Species composition of the two plots is given in Table 4.2.

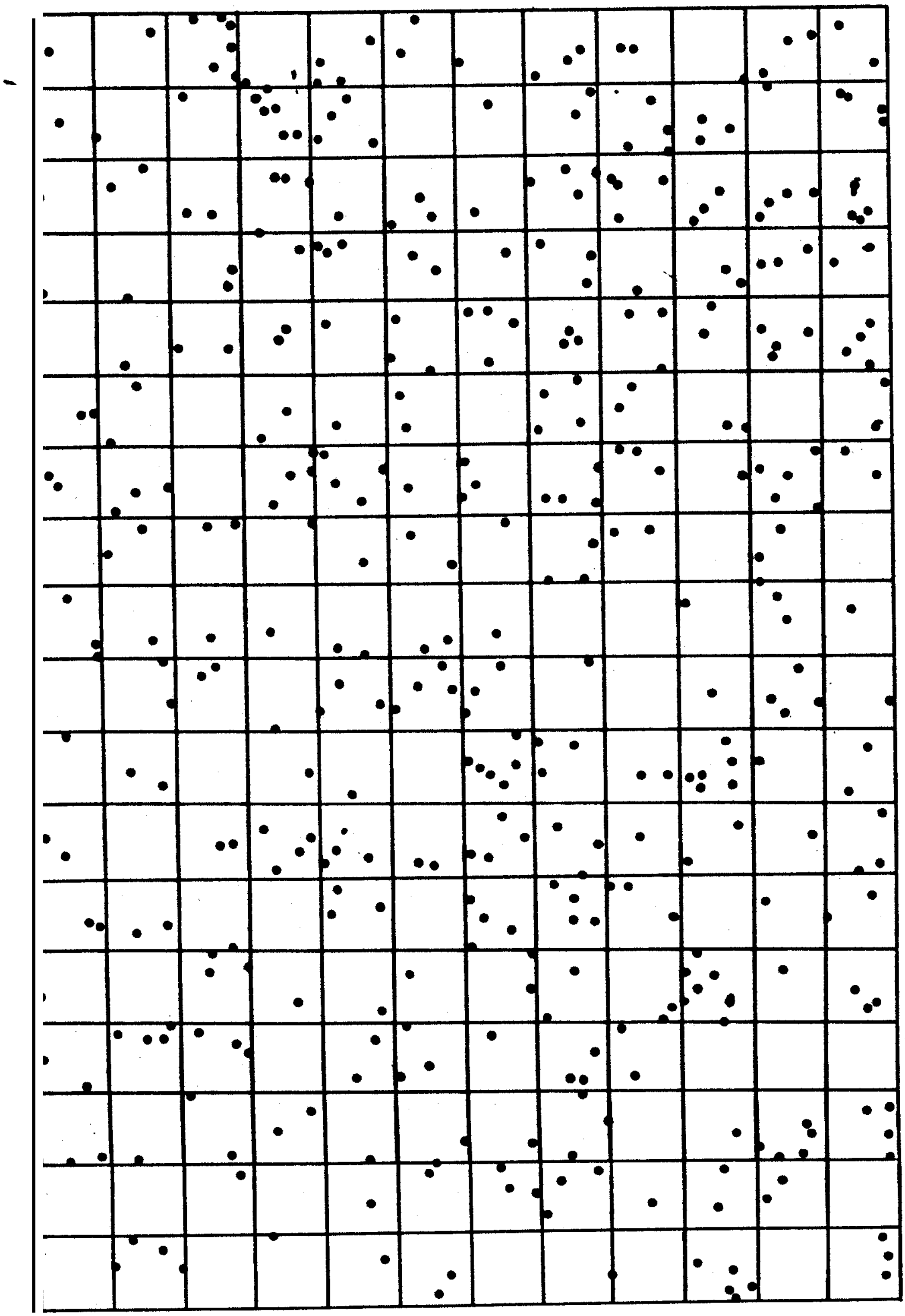


Figure 4.7 A size to scale map of the permanent plot at Karadippara (Kp), Peechi Range, Trichur Forest Division, established for the study. Each square is 100 m^2 (10 m x 10 m) in size. The dots indicate position of trees cm dbh.

Table 4.2 Percentage composition of stands of the two permanent plots established for demographic studies of regeneration.

Kalluchal			Karadippara		
No	Species	Percentage composition*	No	Species	Percentage composition4
1	*xylia xylocarpa*	31.12	1	*Wrightia tinctoria*	29.78
2	*Grewia tiliifolia*	10.48	2	*Lagerstroemia microcarpa*	19.35
3	*Cleistanthua collinus*	10.02	3	*Xylia xylocarpa*	14.57
4	*Dillenia pentagyna*	8.43	4	*Dillenia pentagyna*	14.13
5	*Terminalia crenulata*	6.83	5	*Aporusa lindleyana*	4.57
6	*Teminalia paniculata*	5.69	6	*Teminalia paniculata*	3.91
7	*Lagerstroemia microcarpa*	4.10	7	*Grewia tiliifolia*	1.52
8	*Tectona grandis*	3.64	8	*Dalbergia sissoides*	1.09
9	*Wrightia tinctoria*	2.96	9	*Emblica officinalis*	1.09
10	*Lannea coromandslica*	2.05	10	*Albizia odoratissima*	0.87
11	*Bridelia squamosa*	1.82	11	*Bridelia squamosa*	0.87
12	*Dalbergia lanceolaria*	1.59	12	*Strychnos nux-vomica*	0.87
13	*Haldina cordifolia*	1.59	13	*Bauhinia racemosa*	0.65
14	*Hymenodictyon orixense*	1.37	14	*Cassia fistula*	0.65
15	*Stereospermun colais*	1.37	15	*Holarrhena pubescens*	0.65
16	*Dalbergia sissoides*	0.91	16	*Careya arborea*	0.43
17	*Baubinia racemosa*	0.68	17	*Litsea sp.*	0.43
18	*Bombax insignis*	0.68	18	*Spondias pinnata*	0.43
19	*Macaranga peltata*	0.68	19	*Terminalia bellirica*	0.43
20	*Cassia fistula*	0.46	20	*Terminalia crenulata*	0.43
21	*Emblica officinalis*	0.46	21	*Tectona grandis*	0.43
22	*Pterocarpus marsupium*	0.46	22	*Bombax insignis*	0.22
23	*Terminalia bellirica*	0.46	23	*Bischofia a Javanica*	0.22
24	*Bridelia squamova*	0.23	24	*Ficus sp.*	0.22
25	*Careya arborea*	0.23	25	*Garuga floribunda*	0.22
26	*Cleistanthus collinus*	0.23	26	*Haldina cordifolia*	0.22
27	*Gmeline arborea*	0.23	27	*Macaranga peltata*	0.22
28	*Naringi crenulata*	0.23	28	*Melia dubia*	0.22
29	*Schleicher oleosa*	0.23	29	*Olea dioica*	0.22
			30	*Pterocarpus marsupium*	0.22
			31	*Randia* sp.	
			32	*Schleicher olsosa*	0.22
			33	*Sterculia guttata*	0.22
			34	*Tetrameles nudiflora*	0.22
	Total	100.00		Total	100.00

Chapter 6

Methods Followed

Contents **Page**

Introduction

The term 'regeneration' covers all life stages starting from flowering to the mature trees. Thus, in searching the causes of paucity of regeneration, the studies should cover all the life stages. In this context, the following questions arise.

Is the flowering behaviour of the trees in the *Moist Deciduous* Forests regular? Or, are they widely spaced as in the case of South East Asian dipterocarps with mast–flowering/ mast seeding? What is the extent of variability in the flowering behaviour at different organizational levels, such as all–trees, stratal and species levels? What quantity of flowers, fruits and seeds of commercially important tree species is produced? Is the quantity of seeds produced sufficient to meet the regeneration requirements of the stands? What is the strength of the population of existing seedling bank? What rates of natality, mortality, survival and rate of natural increase the seedling populations of different categories exhibit? What is the rate of survival of the mother trees that serve as the seed source for regeneration? Can these dynamic parameters be estimated so that prediction of the future of regeneration will be possible?

In attempting to answer the questions posed in the previous paragraph, conventional phenological, plant demographic and phytosociological methods were followed. They are described below.

Dynamics of the Reproductory Phase

Qualitative Phenology

Altogether, 22 species belonging to upper and middle tree strata were studied. One hundred and seventy two trees were paint marked in the two permanent plots at Kalluchal and Karadippara, for phenological observations (Table 5.1). Monthly phenological observations of these trees were made with the help of a 10 x 40 Leitz Trinovid binocular. At the beginning, each individual tree was screened for 10 phenological states by a visual rating from 0 -100 percent depending upon the intensity of the phenostate. Ratings during subsequent observations were made in comparison with the previous ratings. The phenostates observed were, flush, semimature leaves, mature leaves, old leaves, flower bud, mature flower, young fruit, semimature fruit and old fruit. The data were entered in data sheets. A thirty six month data have been collected during the three years. The dates of phenological observations are given in Table 5.2.

Data Analysis: The numerical data collected on individual species were entered into the computer and stored as computer files. The DBASE III PLUS software was used for entering the data. Three individual DBASE programs were written to calculate phenostate averages. Phenostate averages at 10 day intervals were calculated for 12 months. This was done at three organizational levels, viz. 1) species level, (2) stratum level and (3) all–trees level.

At species level, all percentages of the particular phenostate of all the trees belonging to tree species between each 10 day interval for each month were added up and divided by the number of observations to get the average. At stratum level, the phenostate values of all species belonging to that stratum were added up and phenostate averages calculated. At all–trees level, phenostate values of all trees of all species belonging to both the tree strata studied were added up and average calculated. The phenostate 'averages so obtained were then graphically represented (in phenograms) for each species, stratum and all–trees and for each phenostate separately (*of* Chapter 6, Figures 6.1-6.6).

Table 5.1 Trees used for monthly phenological observations

No	Species	Karadi-ppara	Kallu-chal	Total
	Stratum 1 Species			
1	*Albizia odoratissima*	2	-	2
2	*Alstonia scholaris*	a	-	2
3	*Bombax ceiba*	-	1	1
4	*Bombax insigne*	1	2	3
5	*Dillenia pentagyna*	12	8	20
6	*Dalbergia sissoides*	9	1	10
7	*Gmelina arborea*	1	3	4
8	*Grewia tiliifolia*	6	9	15
9	*Haldina cordifolia*	1	6	7
10	*Lagerstroemia microcarpa*	11	7	18
11	*Melia dubia*	-	2	2
12	*Terminalia bellirica*	5	1	6
13	*Terminalia paniculata*	13	6	19
14	*Tectona grandis*	6	10	16
15	Tetrameles nudiflora	1	1	1
16	*Xylia xylocarpa*	9	10	19
	Stratum 2 species			
17	*Bridelia squamosa*		3	3
18	*Cleistanthus collinus*	-	1	1
19	*Spondias pinnata*	1	-	1
20	*Strychnos nux-vomica*	3	-	3
21	*Lannea coromandelica*	-	5	5
22	*Macaranga peltata*	-	1	1
	Total	84	88	172

Table 5.2 Dates of qualitative phenological observations of marked trees in the localities Kalluchal and Karadippara.

Mth	Karadippara				Kalluchal			
	1988	1989	1990	1991	1988	1989	1990	1991
Jan		18	22	3		19	23	3
Peb		21	22	4		28	27	24
Mar	19	20	23	11	10	28	27	13
Apr	28	21	17	5	8	21	30	2
May	21	24	25		21		19	
Jne	15	27	27		18	21	18	
Jly		17	23		27		24	
Aug	2	2	27			2	28	
Sept	5	28	24		6	28	25	
Oct	3	25	6		3	26		
Nov	16	16	28		14		8	
Dec		16			19	19	30	

Quantitative Phenology

Quantitative phenological studies were conducted in the Karadippara permanent plot. Seventy five 1 m^2 wooden litter traps were made by affixing nylon meshes of 0.2 mm size. Litter traps were installed on 1 m wooden pegs, in groups of 26, in three subplots. The inter–trap distance was maintained as 6 m. The traps were numbered. At fortnight intervals, litter collected in the traps were transferred into polybags and transported to the laboratory. The polybags were numbered with the trap number. The contents of the polybags were separated specieswise and the number of flower buds, flowers, fruits, seeds *etc*. recorded in data sheets.

Data Analysis The bulk of numerical data were fed into a computer and stored in files using the DBASE III PLUS software. The data was processed using a DBASE program written for the purpose. For each species total number of flower buds, mature flowers, young fruits, semimature fruits mature fruits and old fruits, etc. were totalled individually. From these observed figures actual figures in each category was calculated as given in Table 6.3. The actual number obtained were then converted to per hectare values.

Table 5.3. Calculation of population structure of the reproductive phase.

Actual number of mature fruits produced	=	Observed number of fruits	+	Observed number of mature fruits
Actual number of semi-mature frui produced	=	Actual number of mature fruits	+	Observed number of semimature fruits
Actual number of young fruits produced	=	Actual number of semimature fruits	+	Observed number of young fruits
Actual number of mature flowers produced	=	Actual number of young fruits produced	+	Observed number number of mature flowers
Actual number of flower buds produced	=	Actual number of mature flowers	+	Observed number of flower buds

Dynamics of the Seedling Phase

Estimation of Seedling Bank

Life tables and survivorship curves provide the best method of knowing the structure of populations. It helps to pin point the locations (life stages) at which mortality (casualty) becomes a crucial factor. Thus, it gives clues about the constraints operating on the rate of natural increase.

The preparation of life tables involve demographic censusing of all life stages of organisms under study. The same methodology has been used in the present study and static life tables prepared. The methods followed are detailed out below.

Sample Selection: In estimating the regeneration status conventional phytosociological methods were followed. Initially many *Moist Deciduous Forest* localities in the Trichur Forest Division (Akamala, Elnadu, Pathrakkalu, Mundippadam and Vazhani from Machad Range, Kuthiran and Paravattani Hills from Pattikkadu Range, and Karadippara, Pannikkuzhi, Vaniyampara, Moodal Mala, Vengappara, Kalluchal, Kallala, and the far side of Vellakkarithadam area from the Peechi Range) were visited. Based on the vegetation map prepared by Menon and Balasubramanyan (1985) and the visual observations on stand composition, density and variability of stands eight localities were selected for sampling: Karadippara (Kp), Kalluchal (Kc), Kuthiran (Kt), Mundippadam (Mp), Pathrakkallu (Pk), Vazhani–1(Vz1), Vazhani-2(Vz2) and Vazhani–3 (Vz3).

Size of Releve: Since most parts of the *MDFs* were highly disturbed, species–area relation was worked out for a least disturbed near–natural site (Karadippara) and a more or less disturbed site (Kalluchal). The experiment was conducted using the expanding quadrat method (Bharucha and de Leeuw, 1957).

Thirty centimeter gbh(10 cm dbh) was taken as the lower limit for Consideration as a tree because regeneration is largely seed based and trees flower and fruit only after acquiring a certain age. From the graph obtained, the size of releve was determined as 90 m2 for Karadippara and 60 m^2 for Kalluchal, whereafter, a 10 % increase in area scarcely led to 10 % increase in species (Figure 5.1).

At Karadippara and Kalluchal, regeneration enumeration was done in the permanent plots. In other localities, temporary plots were laid out.

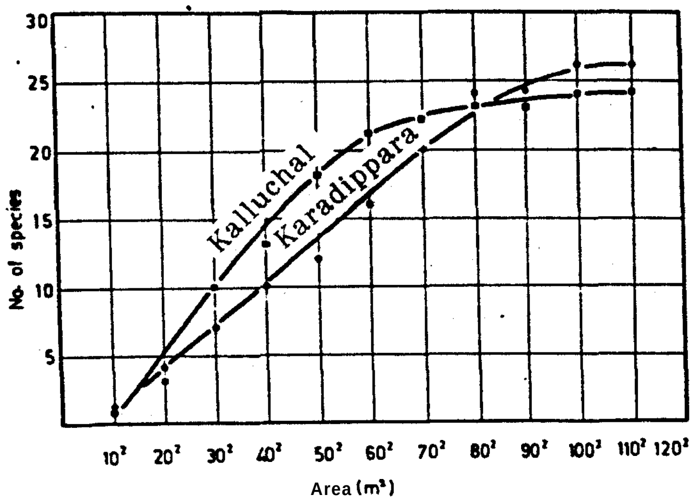


Figure 5.1 Species-area curves for the localitiesKalluchal (KC) and Karadippara (kp), Peechi Range, Trichur FD. The curves represent the richness of tree (>= 10 cm dbh) species only.

Releve Record: Preparatory to regeneration enumeration, based on general visual observations, a releve record of the localities was prepared (Table 5.4). Elevation, aspect, slope, dominant species, undergrowth and other details were noted in the field book.

The Sample Plots: In localities where permanent plots were not laid out studies were conducted in temporary plots. In demarcating the temporary plots the following methods were adopted. A right angled triangle of sides 3 m, 4 m and 6 m, was laid out on the ground with the help of a rope. The triangle was marked on the ground with three iron pegs along the corners. Next, by extending the vertical and horizontal sides of the triangle a 10 m x 10 m quadrat was laid out. The quadrat was marked with iron pegs on the ground and outlined by tying coloured nylon ropes to the pegs. Subsequent quadrats were laid out by extending the sides of the first quadrat using 10 m long nylon ropes. The sequence of quadrat making is shown in Figures 5.2 to 6.4.

Table 5.4 Releve record of the atudy plots.

Karadipara (Kp) : Peechi Range, 12 km South East of KPRI on the far aide of Peechi reservoir: $10^0$15' N, $76^0$24' I, ± 230 m > MSL. Aspect SE, slope gentle, rock formations close to the sample plot. Tl: *Xylia, D. sissoides, Grewia, Lagerstroemia, Tectona, Dillenia* T2: *Aporusa, Strychnos, Bauhinia, s. guttata, Macaranga.* C1: *Acacia intsia, Calycopteris, Spatholobus* S: *Bupatorium, Clerodendrum, Helicteres* . Canopy closed, pole Crops practically absent, fire usual. grazing and browsing much less KalluchalKc): Peechi Range: ca. 8 km south east from Kerala Forest Research Inst., 1.5 .km east of Thamaravellachal. 10^0 30' 57' N, $76^0$22'38' E, ±180 m > MSL. Aspect SE, slope gentle, rock formations close to sample plot, soil blackish loam. T1: *Xylia, Terminalia belliri ca, T. paniculata, Grewia, Lagerstroemia.* T2 : *Bridelia, Cleistanthus, Schleichera, Dalbergia lanceolaria.* T3 : *Casearia, Wrightia.* c1: *Acacia intsia, Zizyphus rugosa.* S : *Eupatorium, He1icteres.* Canopy almost closed, fire recurrent, grazing common, cut stumps of poles occasional	Kuthiran (Kt): Pattikkad Range, ca. 1.5 km away from NH 47 on the crest of the Kuthiran hill and about 1 km away from the Vana Vigyan Kendra: $30^0$34'12' N, $76^0$23'E, ±180 m > MSL. Aspect E, elope almost flat, T1: *Xylia, Terminalia belliri ca, T. paniculata, Grewia, Lagerstroemia; Tectona and Dillenia absent.* T2: *Trees of this layer prac tically absent.* T3: *Holarrhena, Wrightia.* C1: *Zizyphus rugosa.* S: *Bupatoriun, Helicteres.* Canopy opened up, large trees still frequent, fire recurring, browsing and grazing very common Mundippadam(Mp): Uachad Range, ca. 1 km away from the Mundippadam settlements: $10^0$36'N. $76^0$23'1' E, ±180 m > MSL. Aspect NW slope ca. 10 percent, T1: *Xylia, Grewia, Terminalia be1lirica, Dalbergia.* s : *He1icteres, Eupatorium.* Stand density poor, canopy opened up, illicit charcoal making active, regeneration of Sterculia guttata frequent [Secondary Mixed SIMDFs]. pathrakkallu (Pk): Machad Range, ca. 1 km away from the *Eucalyptus* coppice plantation: $10^0$36'80 N, $76^0$23'46' E, ±120 m > MSL.

Table 5.4 Releve Record of the study plots (continued).

Aspect S, slope almost flat: ground bouldry,

T1: *Xylia. Grewia, Terminalia paniculata, Lagerstroemia.*
S: *Helicteres. Eupatorium.*

Stand density poor, grazing and fire heavy, regeneration of *Xylia* some what satisfactory.

Vazhani-1(Vz1): Machad Range. ca. 1.5 km north east of the Vazhani dam, situated in the catchment: 10°38'53"N. 76°18'-44" E, ±180 m > MSL.

Aspect SW, slope 13 percent,

T1: *Xylia, Tetrameles, T. paniculata, Grewia, Pterocarpus, Dillenia.*
T2: *Bridelia.*
C1: *Spatholobus.*
S: *Eupatorium, Helicteres.*

Stand moderately disturbed, fire recurrent, root-sucker regeneration of *Xylia* profuse.

Vazhani-2 (Vz2): Machad Range, about 2 km north east of the Vazhani dam, situated in the catchment:10°38'52"S, 76°18'-42' E, ±125 m > MSL.

Aspect SW, slope 1 percent,

Tl: *Xylia, Grewia, Bombax, Albizia, Terminalia paniculata, Dillenia.*
c1: *Spatholobus.*
S: Mainly *Bupatorium.*

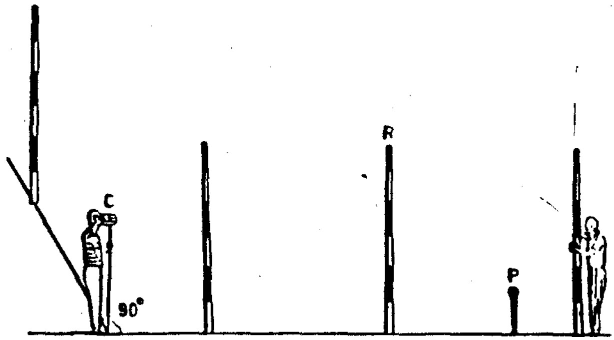
Stocking poor, grazing heavy, root sucker regeneration of *Xylia* profuse

Vazhani-3(Vz3): Machad Range, *ca.* 1.5 km eastward of the Vazhani dam: 10°38'52" S. 76°18'-45" E, 2115 m > MSL.

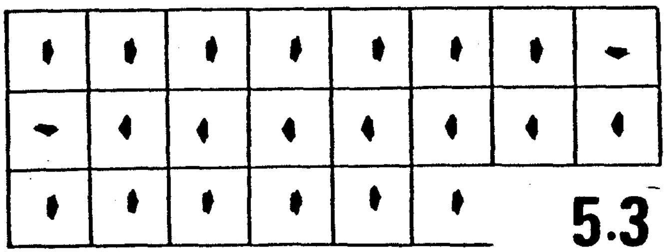
Aspect S, slope 13 percent,

T1: *Xylia, Grewia, Dillenia, paniculata.*
Cl: *Spathoiobus.*
S: *Helicteres, Bupatorium.*

Stand density poor



5.2



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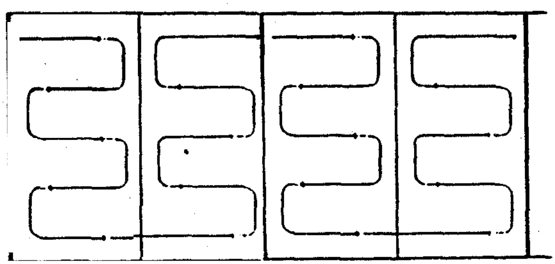

5.4

Figures 5.2 - 5.4 Methods used in regeneration survey. 5.2 Survey of permanent sample plots with the help of a cross staff and ranging rods. 5.3 Sequence of quadrat (=l00 ^{2} laying in temporary sample plots. 5.4 Sequence of enumeration in quadrats.

C - Cross staff; P - Peg; R - Ranging rod.

Enumeration and Measurements: Enumeration was done in the permanent plots at Karadippara, Kalluchal and temporary plots laid out at Kuthiran, Mundippadam, Pathrakkallu, Vazhani–1, Vazhani–2 and Vazhani–3.

Quadrats for regeneration enumeration were outlined by tying coloured nylon ropes on the pegs. All individuals belonging to all tree species were measured and recorded in data sheets.

The size measurements were done under the following categories: (1). height of all tree seedlings < 3 cm gbh, and (2). girth of all individuals >= 3 cm gbh. Once the size of all trees above 30 cm gbh was measured in a 10 m x 10 m quadrat, the quadrat was divided into two 5 m x 10 m quadrats by means of a rope. Then, the size dimensions of the lower size classes were recorded following a path as illustrated in Figure 6.4.

Data Analysis: The numerical data obtained were fed into a personal computer using the software DBASE III PLUS. The data were pooled at various size class levels. Of the larger size classes although measurements were taken in terms of gbh, the measurements were converted to dbh values using the geometric area–diameter relation and used in the analysis. The size classes recognized are given in Table 5.5. Further, the data were categorized at various magnitudes and taxonomic levels, viz. all–trees, stratal and species levels. Life tables were prepared at these' levels (Tables 7.1, 7.2, 7.3, 7.4) and percentage representation in each class worked out (Table 7.7). Semilogarithmic graphs were prepared for the dominant tree species (Figure 7.3).

Table 5.5 Size classes recognized.

No	Name	Size range
1	h50	ht <= 50 cm
2	h100	ht > 50 cm and <= 100 cm
3	hglOO	ht > 100 cm and dbh < 1 cm
4	d10	dbh >= 1 cm and <= 10 cm
5	d20	dbh > 10 cm and <= 20 cm
6	d30	dbh > 20 cm and <= 30 cm
7	d40	dbh > 30 cm and <= 40 cm
8	d50	dbh > 40 cm and <= 50 cm
9	d60	dbh > 50 cm and <= 60 cm
10	dg60	dbh > 60 cm

ht - height; *dbh* - diameter at breast height

Population Dynamics

Seedlings increase in number by seed germination, decrease by death of individuals or survive over a period of time. A surviving seedling has three options: (1) to grow and increase in size when conditions are favourable, (2) to remain dormant when conditions are adverse, or (3) to retard and go back to a lower phase of sylvigenesis when conditions are not favorable. Three separate experiments/ surveys were conducted for the purpose. Studies to quantify and describe the above population dynamic parameters were done mainly by monitoring populations in permanent plots at Kalluchal and Karadippara.

Of the 200 quadrats in each permanent plot, 50 quadrats were selected in a systematic way with a random start. All tree regeneration in these quadrats were tagged with numbered aluminium tags and measurements taken prior to the onset of monsoon, *ie,* before the start of growing season.

Two subsequent enumerations and measurements were made (as given in Table 5.6) such that there was a gap of one full growing season (one full wet season) between any two subsequent measurements.

Both the plots burnt completely during February 1989 (summer), owing to a wide spread fire that originated from the nearby forest dwelling. However, after a few monsoon showers surviving seedlings could be identified by the metallic tags hanging on their dead stumps or surviving shoot. Consequently, the tags on the dead stumps were transferred to their sprouted new shoots and subsequent measurements were made after the lapse of a full growing season. Because of the very cumbersome and time consuming procedure involved in tracing the seedlings, the number of samples were subsequently reduced to twenty five $10m^2$ quadrats per plot, instead of the 60 quadrat6 initially selected. The sample size, in terms of the number of individuals in the different size classes and strata of the Kalluchal plot is given in Table 5.7.

As fire was not anticipated, the combustible materials and intensity of fire could not be estimated. Nevertheless, to get a general idea of the intensity of fire, in the subsequent year the combustible materials on the ground in the plots were estimated. The mean weight of combustible materials burnt in the plots was found to be_7.9 $t\ ha^{-1}$

Table 5.6 Events and timings of regeneration enumeration and measurement in the two permanent plots for estimation of parameters of population dynamics.

permanent plots	First enumeration	Events between 1st and 2nd measurements	second Enumeration	Events between 2nd and 3rd	Third
Kalluchal	May1988	one growing season without fire	Nov. 1988	Fire burnt in Feb. 1989; one growing season after 2nd enumeration and fire	Sept. 1989.
Karadippara	Dec. 1988	Fire burnt in Feb. 1989; one growing season 1st enumeration and fire	Nov. 1989	One growing season without	Dec. 1990.

Table 5.7 **Samples used (number of seedlings observed) for studying the effect of fire protection (FP) and fire (F) on regeneration dynamics in the Kalluchal plot.**

Strata	h50		h100 .		hg100		d10		Total	
	FP	F	FP	F	FP	F	FP	F	FP	F
Strat 1	482	644	291	364	119	166	26	37	918	1211
Strat 2	338	368	140	129	106	120	22	38	606	655
Strat 3	95	123	172	183	75	84	10	13	352	403
Total	915	1135	603	676	300	370	58	88	1876	2269

In addition to the above mentioned experiment, supplementary experiments were conducted to quantify the natality.and to know the role of summer soil moisture depletion on seedling mortality.

Experiment to Determine Natality

The study was conducted in the two permanent plots at Kalluchal and Karadippara. A series of ninety 4 m^2 quadrats were laid out, 46 at the Karadippara and 45 at Kalluchal. The 46 quadrats were distributed in **3** groups of 15 each. The quadrats were marked with painted pegs and GI wire tied along the perimeter. The quadrats were cleared of shrubs so as to observe the emerging seedlings. Observations were taken for a full one year at fortnight intervals during 1990-1991. The observed data were summarized month–wise in species, stratum and all–trees levels.

Effect of Soil Moisture Depletion on Seedling Population

Soil moisture is an important parameter determining the survival of seedling bank. The seasonal deciduous phenology of *SIMDFs* allow the hot rays of the summer sun to reach the ground and deplete the soil moisture. The study was conducted in the Karadippara permanent plot to know whether the summer moisture depletion contributes to depletion of the seedling bank seriously. Considering the minor variations in terrain and the probable consequent soil moisture differences, a stratified random sampling scheme was followed. Three terrain strata of approximately 1 m elevational difference were selected. Ten replicate quadrats were selected in each stratum. Each quadrat was a strip of size 20 m^2 (= 10 m x 2 m).

The sample strips were demarcated with painted numbered wooden pegs and by tying GI wire along the perimeter. Tree seedlings (> 5 cm height and < 30 cm gbh) were enumerated in the sample strips and soi1 moisture estimated during February, March and April 1991 when soil moisture depletion reached its peak. The monitoring was stopped in May when, owing to copious pre–monsoon showers, the soil moisture had gone up.

The initial seedling enumeration was conducted in February. All tree seedlings were tagged with numbered aluminium tags, height/ gbh measured and data recorded in data sheets. In subsequent enumerations survival alone was noted.

Soil moisture in the samples was determined by gravimetric means (of. Gardner, 1965). Approximately 80 gm of soil from 10 cm depth of the ground was collected from freshly dug pits near the strips and kept in pre–weighed small steel vessels and closed. The samples were transported at the earliest to the laboratory and fresh weight determined. The samples along with the pots were oven dried at 105^0C until constant weight. The data were recorded in data sheets and moisture percentage worked out as (weight loss of soil sample X 100/ dry weight of soil sample). Moisture holding capacity of the soil at the study site was also estimated by gravimetric means, by drying of saturated soil samples (Jackson, 1958).

As the soil moisture percentage between the three elevational strata did not vary significantly at any given time of sampling (and enumeration), both soil moisture results (and enumeration results) of the different strata were pooled together for analysis.

Data Analysis

The data were analysed for various parameters of population dynamics, such as mortality, natality and survival. Survival was either by whole plants (ie, retaining the shoot) or by producing new shoots from the surviving root stocks in the succeeding favorable season. Growth of seedlings in the post–fire growing season could be negligible if the damage caused was high. In other instances growth could be significant if damage to the seedling was low and the addition of organic matter to the soil owing to fire was substantial. Thus, based on the extent of growth in the succeeding favorable season, the seedlings of the latter category were of 3 types:

1. Those that could grow only to a size class lower than the one to which they belonged prior to fire,

2. Those that could grow to the size class to which they belonged prior to fire, and

3. Those that could grow to a size class higher than the one to which they belonged prior to fire.

Under each of the population parameters mentioned above, the data were analysed at all-trees, stratal and species levels. In addition, impact on survival had been analysed at size class (szcl) level too. Thus the data were analysed in the following hierarchic order as given in Figure 6.5.

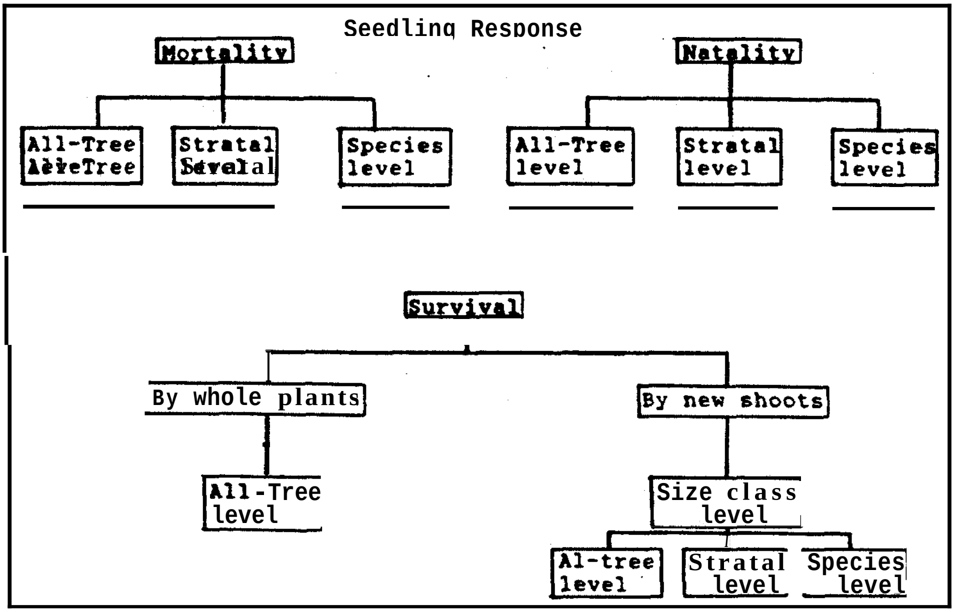

Figure 5.5 Analysis of seedling response data

Dynamics of the Mature Tree Phase

The fate of survival of 900 trees was studied in two permanent plots, Kallucahal and Karadippara. All these trees were numbered, the X and Y co-ordinate distances within the 10 m x 10 m quadrats measured, species identified, gbh measured and recorded in data sheets during February 1988. Survival of trees were monitored annually up to 1991, and the rates worked out.

Simulation Studies

Models provide windows to view the system's future, under the limitations offered by the assumptions (*cf* Pellew, 1983). Simulation is the technique of predicting future using models. Succession has been conceived as a stationary Markov process (Horn, 1975 a, 1975 b, 1976). The reliability of the concept has been questioned recently (Binkley, 1980). Thus simulation techniques are not true spectacles of the future of the system. However, simulation still is a useful technique in prospecting the future of systems with reasonable degrees of accuracy (*cf* Shugart, 1984).

A matrix of probabilities of transition under fire protection and Under fire for various size classes in the different strata were also worked out using a PASCAL program. These probabilities were extrapolated and pictorial models of population flux in different size classes of various strata under fire protection and under fire were also constructed. Employing matrix model and matrix multiplication, population flux in various size classes under different fire frequency intervals was studied.

Chapter 6

Results and Discussion I: The Reproductory Phase

Contents Page

Qualitative Phenology

Flowering and Fruiting Periodicity

Of the 16 commercially important tree species studied, all the individuals belonging to 10 species flowered and fruited in all the 3 years under observation. The species are given in Table 6.1.

inter-annual Variations: In other species interannual variations existed. In *Alstonia scholaris*, both the trees, although large sized, did not flower and fruit during 1988 and 1989 but flowered during 1990. In other locations along the plains, the same species was found to flower and fruit every year.

Intra-population Variations: In some species, although flowering was regularly circannual, all the trees did not produce mature fruits every year. Typical example is *Xylia xylocarpa* where fruit set was seen only in some individuals. In *Tectona grandis* in the Kalluchal plot 3 individuals in 1988, 9 individuals in 1989 and 3 individuals in 1990 did not flower and fruit. Likewise in *Terminalia bellirica*, out of the six trees under observation, one tree belonging to the large diameter class did not flower and fruit in 1989. In *T crenulata* out of the 11 trees under observation, 3 in 1988, 4 in 1989 and one in 1990 did not flower and fruit.

Due to Disease: In *Terminalia paniculata*, out of the 19 trees under, observation one tree did not flower and fruit in 1988 and 1989 as it had some disease, as was evident from the smaller crumbled leaves.

Due to Mammalian Predators: Mammalian predators were found to affect the intensity of mature fruit production in *Xylia xylocarpa*. In the Karadippara permanent plot, an isolated tree of the species could be located. In the year 1991 fruits fallen underneath the tree were counted. The statistics are given in Table 6.2. Production of mature fruits in many trees of the species is affected by heavy predation of Malabar giant squirrels *(Ratufa maxima*).

Despite the small percentage of occasional inter–annual andintra-populational irregularities in flowering and fruiting, at species level none of the commercially important species had shown irregular periodicity. Neither any species showed the incidence of gregarious flowering and mast seeding (for the terms *cf* Janzen, 1974; Appanah, 1985) nor they remained without flowering/ fruiting.

Temporal distribution of phenological behaviours at all–trees, stratal and species levels were worked out from the qualitative data. Phenograms of selected phenophases, strata and the dominant tree species are given in Figures 6.1 to 6.6. Nevertheless, no description is provided detailing the temporal and density distributions of phenostates, as they are graphically depicted.

Table 6.1 List of Stratum 1 species in which all the individuals under observation flowered and set fruit every year.

Albizia odoratissima	*Grewia tiliifolia*
Bombax ceiba	*Haldina cordifolia*
B. insigne	*Lagerstroemia microcarpa*
Dillenia pentagyna	*Melia dubia*
Gmelina arborea .	*Tetrameles nudif1ora*

Table 6.2 Effect of mammalian predation on fruit production of an isolated tree of Xylia xylocarpa during 1991.

categories of fruits collected	Jan	Feb	Mar	Total
Young fruits not eaten by *Ratufa*	-	7	-	7
Subaature fruits eaten by Ratufa	742	57	37	836
nature fruit. eaten by *Ratufa*	64	30	37	131
Total	806	94	74	974
Percentage	83	10	7	100

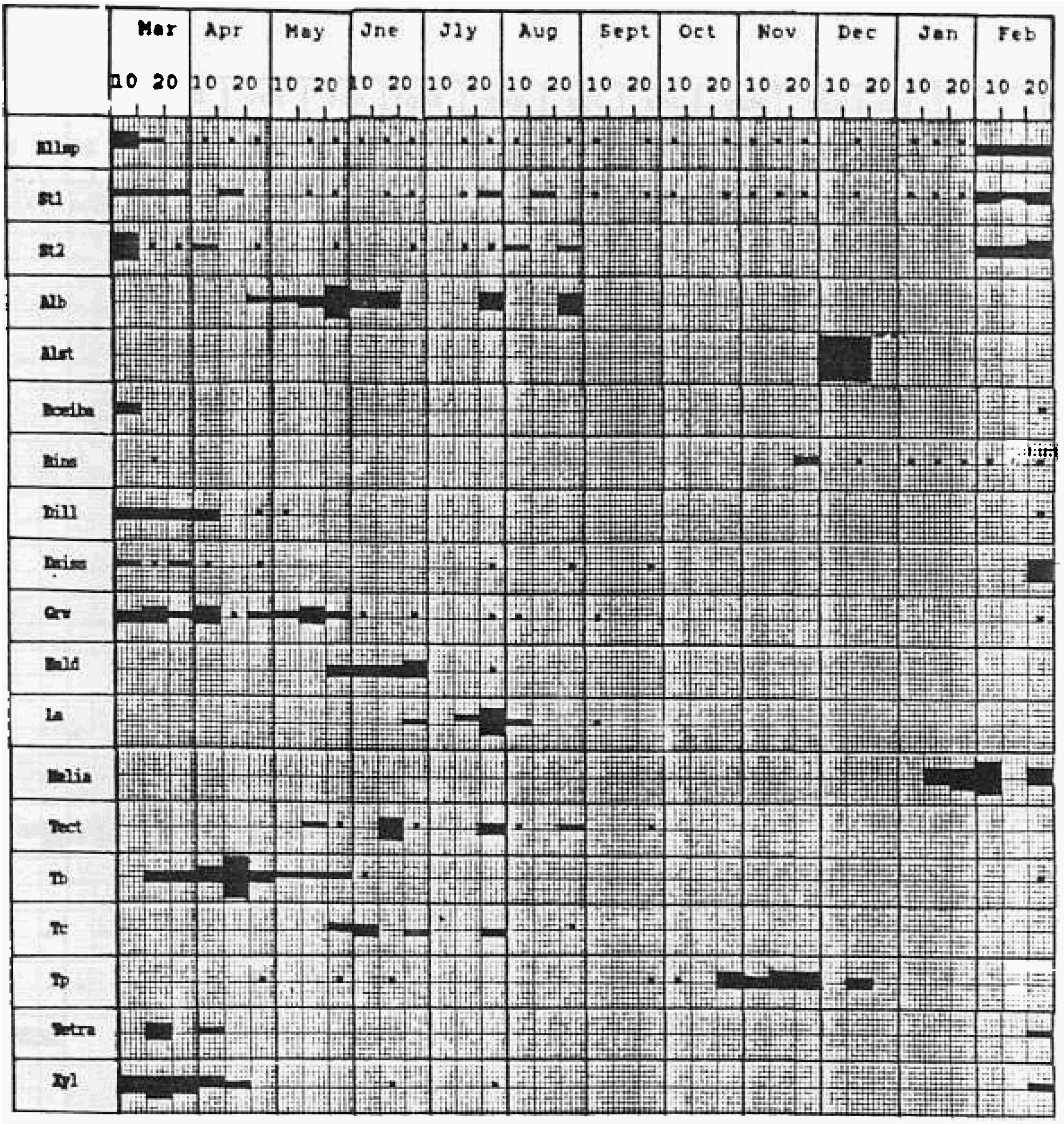

Figure 6.1 Phenogram of mature flower in the *MDFs* of Trichur Forest Division. Each dot represents intensity of expression in less than five percent. Each millimeter width of the bars represents 10 percent intensity of expression. The phenogram represents phenophase averages of 3-year monthly observations. (For further details please refer Chapter 5. Methods followed).

Alb - *Albizia odoratissima*
Allsp - All-Trees;
Alst. - *Alstonia scholaris*;
Bceiba - *Bombax ceiba*;
Bins - *Bombax insignis*;
Dill - *Dillenia pentagyna*;
Dsiss - *Dalbergia sissoides*;
Grw - *Grewia tiliifolia*;
Hald - *Haldina cordifolia*;
La - *Lagerstroemia microcarpa*.
Melia - *Melia dubia*;
St1 - Stratum 1;
St2 - Stratum 2;
Tect - *Tectona grandis*;
Tb - *Terminalia bellirica*;
Tc - *Terminalia crenulata*;
Tp - *Terminalia paniculata*;
Tetra - *Tetrameles nudiflora*;
Xyl - *Xylia xylocarpa*.

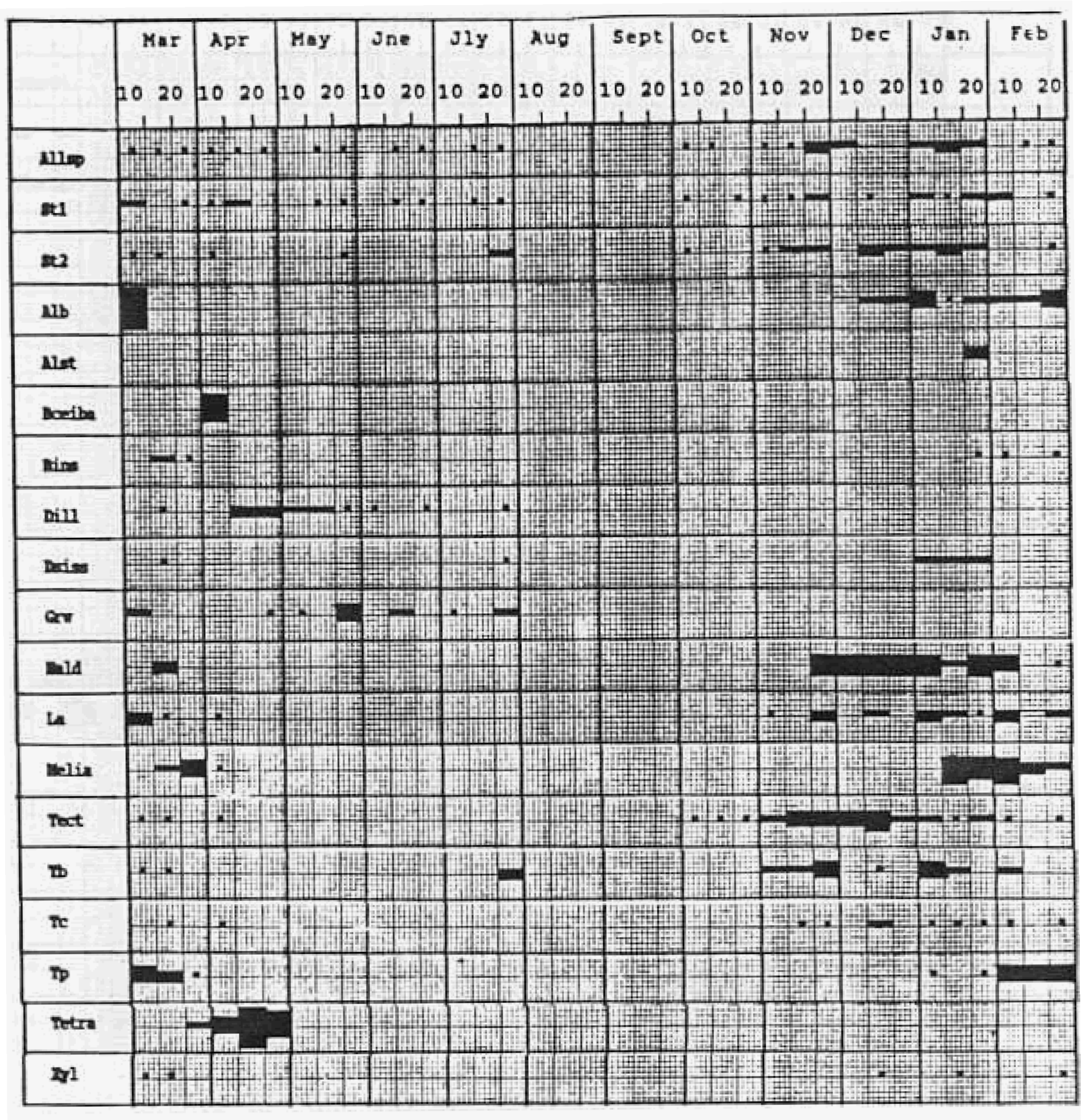

Figure 6.2 Phenogram of mature fruit in the *MDFs* of Trichur Forest Division. Each dot represents intensity of expression in less than five percent. Each millimeter width of the bars represents 10 percent intensity of expression. The phenogram represents phenophase averages of 3–year monthly observations. (For further details please refer Chapter 5. Methods followed).

- Alb - *Albizia odoratissima.*
- Allsp - All-Trees;
- Alst. - *Alstonia scholaris;*
- Bceiba - *Bombax ceiba;*
- Bins - *Bombax insignis;*
- Dill - *Dillenia pentagyna;*
- Dsiss - *Dalbergia sissoides;*
- Grw - *Grewia tiliifolia;*
- Hald - *Haldina cordifolia;*
- La - *Lagerstroemia microcarpa;*
- Melia - *Melia dubia;*
- Stl - Stratum 1;
- St2 - Stratum 2;
- Tect - *Tectona grandi*
- Tb - *Terminalia bellirica;*
- Tc - *Terminalia crenulata;*
- Tp - *Terminalia paniculata;*
- Tetra - *Tetrameles nudiflora;*
- Xyl - *Xylia xylocarpa.*

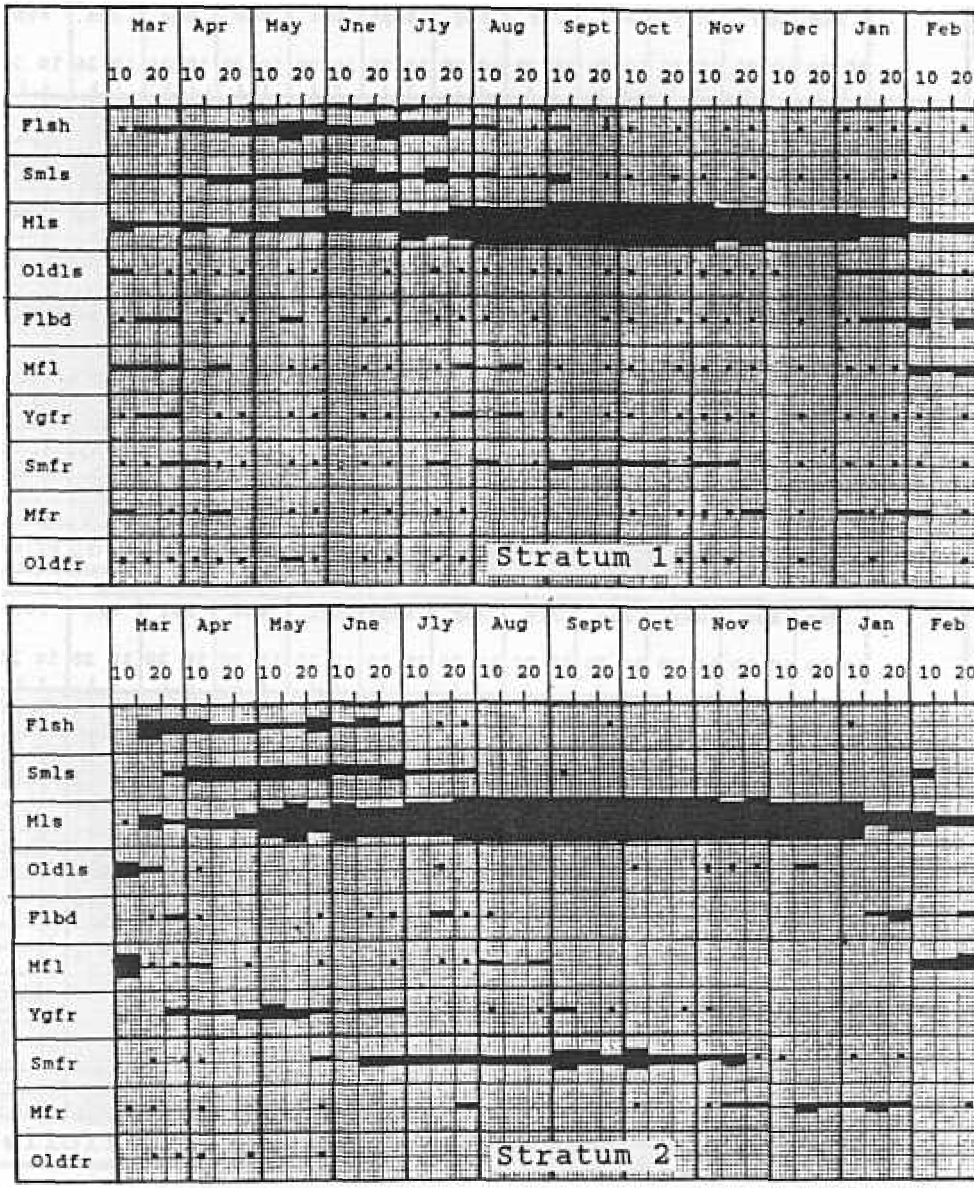

Figure 6.3 Phenogram of stratum 1 and stratum 2 in the *MDFs of* Trichur Forest Division. Each dot represents intensity of expression in less than five percent. Each millimeter width of the bars represents 10 percent intensity of expression. The phenogram represents phenophase averages of 3-year monthly observations. (For further details please refer Chapter 5. Methods followed).

Flbd - Flower bud;
Flsh - Flush;
Mfl - Mature flower;
Mfr - Mature fruit;
Mls - Mature leaves;
Oldfr - Old fruit;
Oldls - Old leaves:
Smfr - Semimature fruit:
Smls - Semimature leaves;
 - Young fruit.

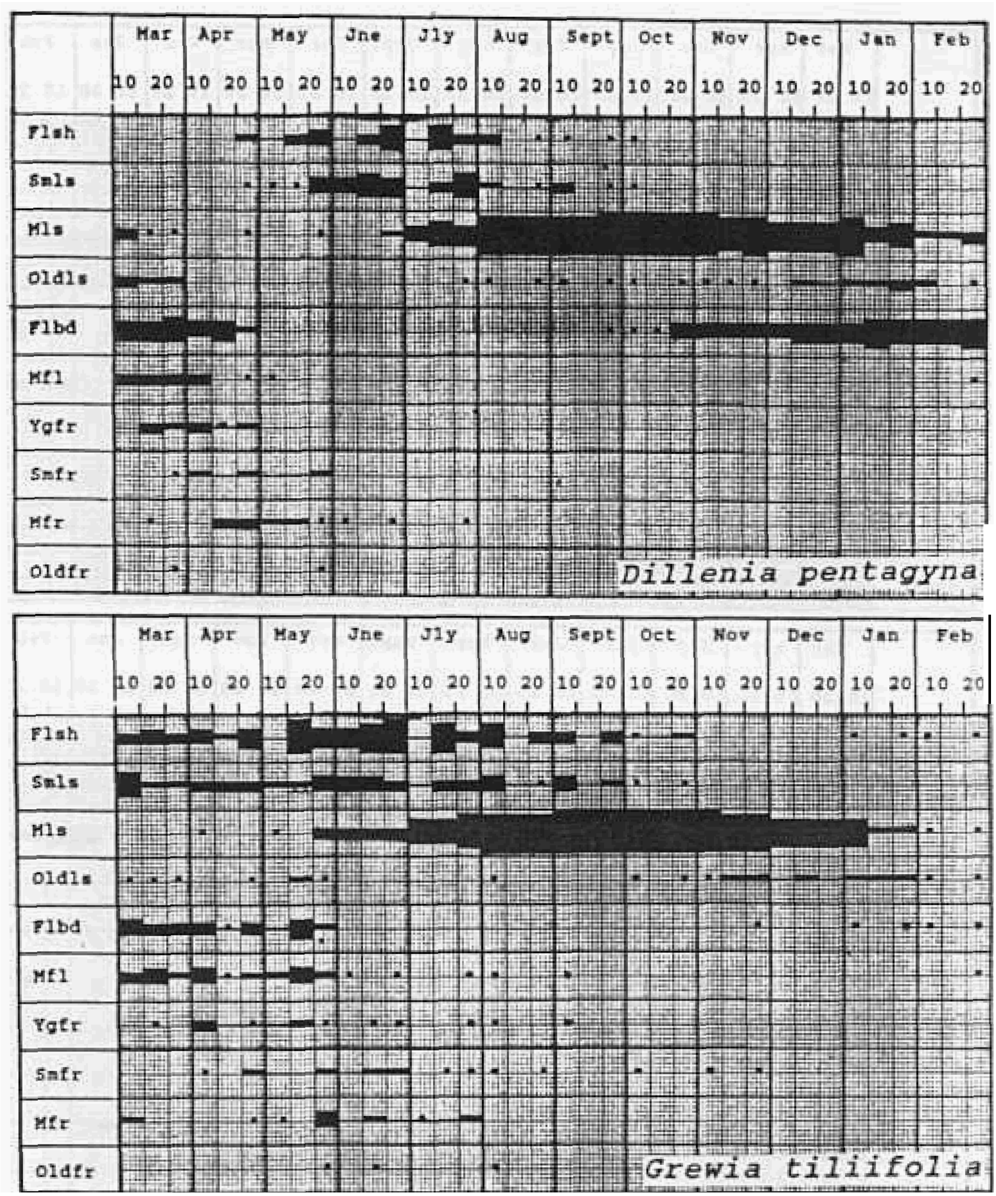

Figure 6.4 Phenqgram of dominant tree species in the *MDFs* of Trichur Forest Division. Each dot represents intensity of expression in less than five percent. Each millimeter width of the bars represents 10 percent intensity of expression. The phenogram represents phenophase averages of 3–year monthly observations. (For further details please refer Chapter 5. Methods followed).

Flbd - Flower bud;
Flsh - Flush;
Mfl - nature flower;
Mfr - nature fruit;
Mls - nature leaves;
Oldfr - Old fruit;
Oldls - Old leaves;
- Semimature fruit;
Smls - Semimature leaves;
Ygfr - Young fruit.

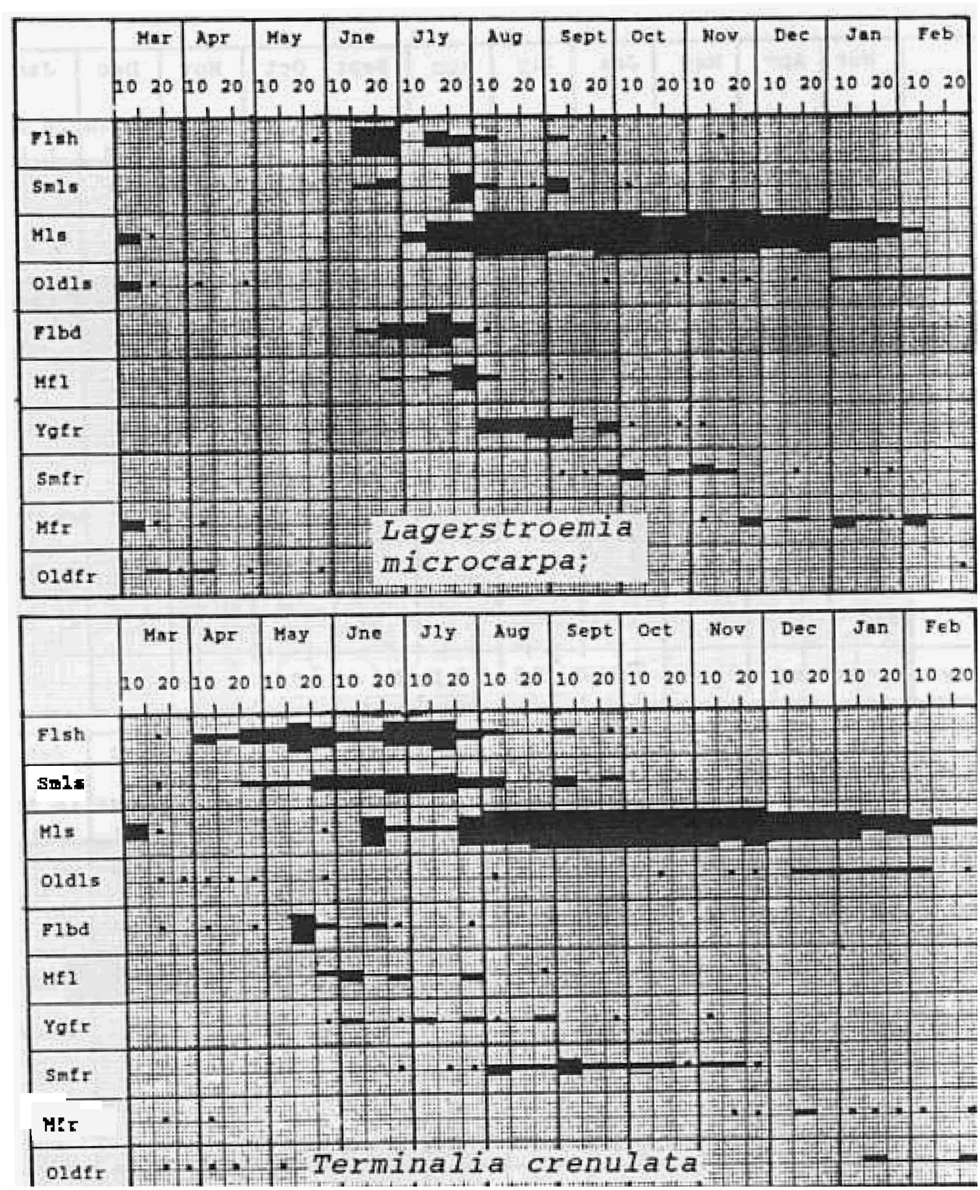

Figure 6.5 Phenogram of dominant tree species in the *MDFs* of Trichur Forest Division. Each dot represents intensity of expression in less than five percent. Each millimeter width of the bars represents 10 percent intensity of expression. The phenogram represents phenophase averages of 3–year monthly observations. (For further details please refer Chapter 5. Methods followed).

Flbd - Flower bud;
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- Young fruit..

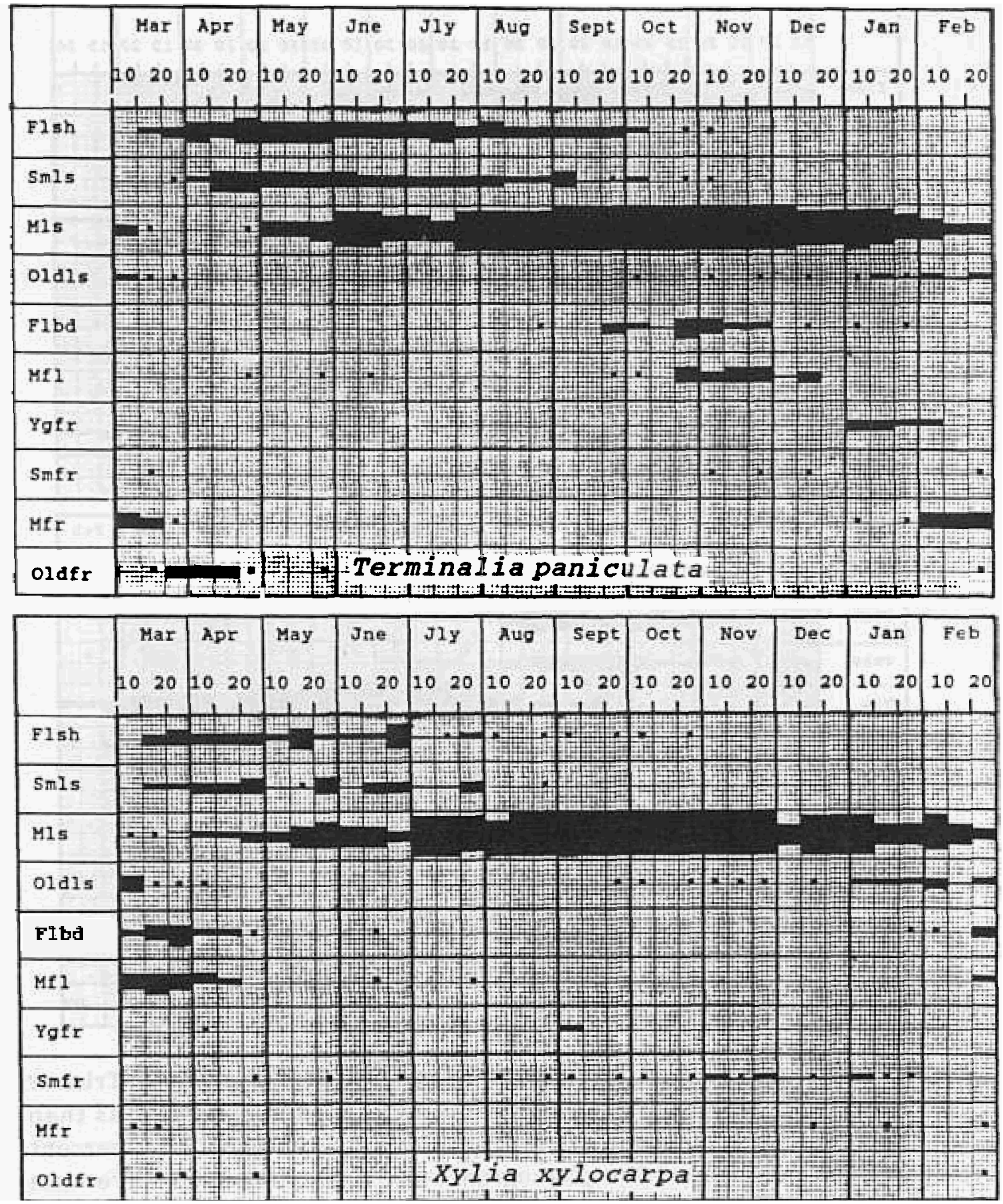


Figure 6.6 Phenogram of dominant tree species in the *MDFs* of Trichur Forest Division. Each dot represents intensity of expression In less than five percent. Each millimeter width of the bars represents 10 percent intensity of expression. The phenogram represents phenophase averages of 3-year monthly observations. (For further details please refer Chapter 5. Methods followed).

Flbd	- Flower bud;	Oldfr	- Old fruit;
Flsh	- Flush;	Oldls	- Old leaves;
Mfl	- Mature Flower;	Smfr	- Semimature Sruit;
Mfr	- Mature Sruit;		- Semimature loaves
Mls	- Mature leaves;	Ygfr	- Young Fruit.

Quantitative Phenology

Table 6.3 gives the population structure of individual tree strata and species starting from flower to fruit. At stratal level, the production of flowers of the upper stratum species was_ 124 million ha^{-1} yr^{-1}. Of this, _56 million matured to fruits bearing a seed population of _1156 million ha^{-1} yr^{-1}. Even after ignoring the seeds of *Lagerstroemia microcarpa* and *Tetrameles nudiflora*, which show very small percentages of germination, there were 2.85 million seeds. At any rate, this is a very large number especially when compared to the number of mature trees is less than 250 at the end of sylvigenesis, that too over a period of 50 or 60 years.

Seed production of individual tree species was also in no way low. However, inter–species variations in the number of seeds as evident from Table 6.3 is in not comparable as the reproductive potential of the species differ, depending upon tree size, density, inherent mortality rates at each reproductory stage.

Table 6.3 Estimated population size in different phenophases*.

Taxa	Flbd	Mfl	Ygfr	Smfr	Mfr	sd
Stratum 1	13,82,60	12,36,03	5,78,76	5,64,77	5,61,53	1,15,63,54
Stratum 2	56,40	56,39	2,63	1,33	1,22	1,24
Stratum 1 species						
Albizia odoratissima	8,48	8,48	6	6	6	20
Dillenia pentagyna	41,02	34,07	1,87	1,85	1,73	5,22
Dalbergia sissoides	34,00	34,00	1,45	1,26	84	1,27
Grewia tiliifolia	43,46	13,43	4,18	3,97	3,97	5,45
Lagerstroemia microcarpa	2,72,98	2,45,77	26,20	13,06	12,55	5,90
Terminalia bellirica	38,88	36,49	98	98	98	1,12
Tetrameles nudiflora	5,35,17	5,35,17	5,34,84	5,34,84	5,32,65	11,46,43
Terminalia paniculata	8,66	8,66	8,62	8,62	8,62	8,62
Xylia Xylocarpa	4,00,32	3,19,97	54	12	10	70

Flbd- Flower bud; *Mfl*- Mature flower; *Mfr*- Mature fruit; *sd*- Seeds; *Smfr* - Semimature fruit.

* All figures x 103

Table 6.4 gives survival rates of different generative stages of the two tree–strata and the various upper stratum species. There exist significant differences among different species and among different life stages. The survival rate from flower bud to mature flower is almost 100 percent in *Albizia odoratissima*, *Tetrameles nudiflora* and *Terminalia paniculata*, while it is just 31 percent in *Grewia tiliifolia*. Likewise, transition rate from mature flower to mature fruit is almost cent percent in *Tetrameles* and *Terminalia paniculata* while it is less than 10 percent in most other species, and lower than 0.1 percent in *Xylia xylocarpa*.

Table 6.4 Percentage of survival in different phenophases.+

Taxa	Flbd	Mfl	Ygfr	Smfr
Stratum 1	89	42	41	41
Stratum 2	100	5	2	2
Stratum 1 species				
Albizia odoratissima	100	*	*	*
Dillenia pentagyna	83	5	5	4
Dalbergia sissoides	100	4	4	3
Grewia tiliifolia	31	10	9	9
Lagerstroemia microcarpa	90	10	5	5
Terminalia bellirica	94	3	3	3
Tetrameles nudiflora	100	100	100	100
Terminalia paniculata	100	100	100	100
Xylia xylocarpa	80	*		*

Flbd - Flower bud; *Mfl* - Mature flower; *Smfr* - Semimature fruit; *Ygfr* - Young fruit.

* Less than 1 ; + Figures ruounded off to whole number.

Chapter 7
Results and Discussion II: The Seedling Phase (Regeneration)

Contents **Page**

Introduction

The term 'seedling' has several meanings. In a very restricted sense it refers to plants of seed origin. still retaining the cotyledonary leaves. In the wider sense it refers to plants of vegetative origin (ramets) (Grime. 1979). In general. it refers to smaller plants as opposed to adult (mature) plants of the same species.

In forestry. the term 'regeneration' encompasses the wider sense of the term seedling. Foresters generally recognize two categories under seedlings. Unestablished seedlings (< 100 cm height) and established seedlings (height > 100 cm and dhh <= 10 cm; includes saplings). In addition, pole stages (10- 20 cm dbh; *cf:* Ford–Robertson, 1971) also would come under the purview of the term 'regeneration' in a wider sense. The objectives of this chapter is to describe the population structure and dynamics of the various seedling *(s. 1.)* phases described above, at varioiis organizational/ population levels such as, all–trees, stratal and species levels.

Size Class Distribution

At All–Trees Level: The per hectare size class distribution of all–trees in the stand is given in Table 7.1 and depicted in Figure 7.1. The curve shows characteristic concave shape indicating negative exponential relation between the size classes. It also indicates that the rate of natural increase *(cf* Krebs, 1972; Harper and White, 1974) in the lower size classes is very high, from where it decreases exponentially. In other words, mortality rates decrease exponentially from lower size class upwards. Nevertheless, the horizontal more or less straight arm of the curve from d20 (dbh 10–20 cm dbh) onwards implies that trees in natural ecosystems when they cross the sapling and pole stages, mortality rate is low.

At Stratal Level: Frequency distribution in different size classes of different strata is given in Tables 7.2 to 7.4. They are also represented in Figure 7.1. Percentage population representation in different size classes is depicted in Figure 7.2. Both the diagrams, following the DeLiocourt's law (cf. Goff and West, 1975) show strongly skewed L–shaped distribution patterns for all the strata. From Tables 7.3 and 7.4 it can be seen that both the middle and lower strata decrease sharply from 10 cm dbh (d20) onwards. In the case of lower stratum, representation of trees over 30 cm dbh (d40) is totally lacking. This is basically because of the built–in limitation of growing ability of the species in this stratum. Species like *Wrightia tinctoria* and *Holarrhena pubescens etc.,* which are the main components of the lower stratum, practically do not grow beyond 30 cm dbh. In the middle stratum, absence of individuals in some of the size classes indicates that population in these classes are under some sort of stress (Table 7.3).

Table 7.1 Per hectare size class representation of All-trees in the stand*.

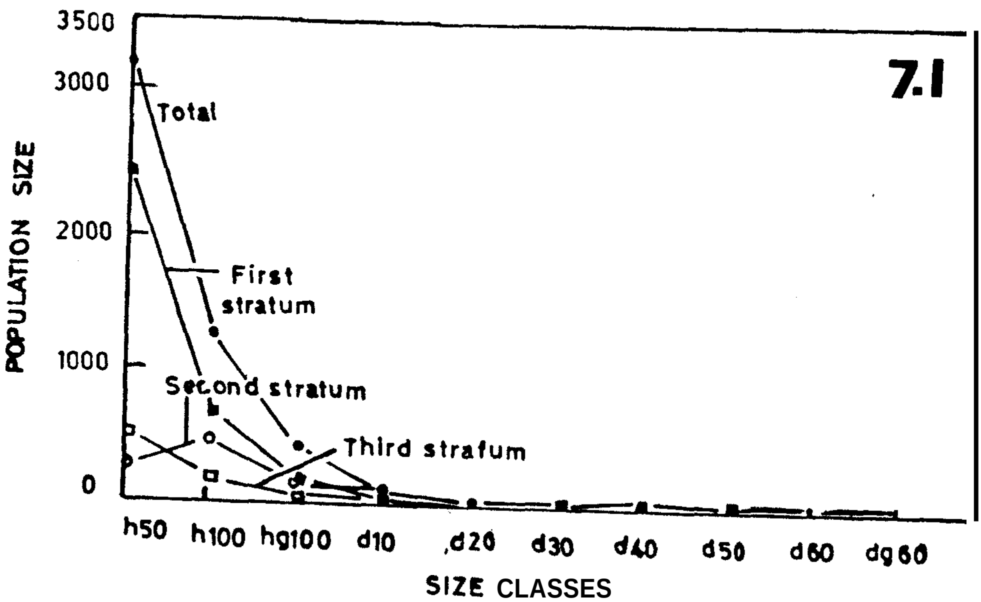
Loc	Size classes									
	h50	h100	hg100	d10	d20	d30	d40	d50	d60	dg60
KP	2270	2660	620	160	37	48	40	27	22	28
Kc	2520	1990	690	220	29	49	56	40	24	14
Kt	2140	1050	600	370	13	13	42	39	19	26
MP	3600	490	150	67	22	44	40	27	18	18
Pk	2410	860	500	250	14	9	31	31	20	40
Vzl	2860	1990	530	90	10	5	45	40	25	20
vz2	6960	370	140	60	15	5	35	45	15	20
vz3	2610	525	120	30		15	55	30	10	70
Max	6960	2660	690	370	37	49	56	45	25	70
Min	2140	370	120	30	10	5	31	27	10	14
Mean	3170	1240	420	160	20	23	43	35	19	29
SD	1600	860	240	120	10	20	9	7	5	18

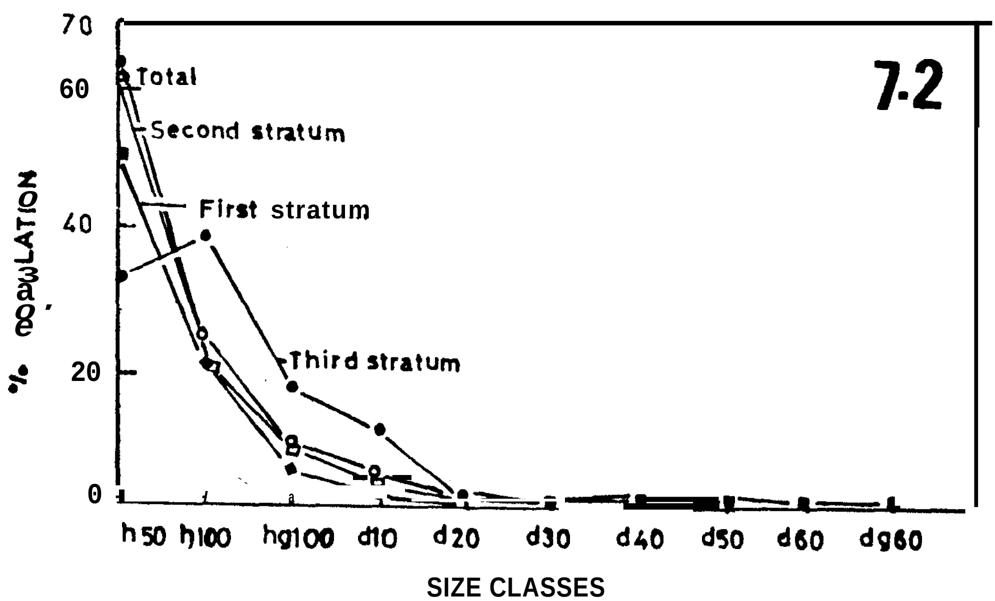
• Figures > 100 rounded off to tens: Loc- Loclaity.

Table 7.2 Per hectare size class representation in Stratum 1*.

Loc	Size classes									
	h50	h100	hg100	d10	d20	d30	d40	d50	d60	g60
KP	1030	560	150	60	6	24	31	23	20	24
Kc	1660	1080	340	81	16	40	50	36	21	11
Kt	1800	570	225	30		13	42	39	19	26
MP	2290	260	71	31	18	38	36	24	18	11
Pk	1660	390	150	49	3	6	26	31	14	40
VZl	2300	1640	490	70	5	5	45	30	25	15
vz2	6500	270	65	10	10	5	35	40	15	20
vz3	1970	400	80	5		15	55	30	10	70
Max	2300	1640	485	81	18	40	55	40	25	70
Min	1030	270	71	5	3	5	26	23	10	11
Mean	2400	640	200	42	10	19	40	32	18	27
SD	1700	480	150	28	6	14	10	7	5	20

* Figures > 100 rounded off to tens; Lof - Locality.





Figures 7.1 and 7.2 Per hectare population structure of different tree strata' in the Moist Deciduous forests of Trichur Forest Division. 7.1 Actual population structure. *7.2* Percentage population structure.

h50 - ht <=50 cm;
h100 - ht >50 and <=100 cm;
hg100 - ht >100 cm and dbh <1 cm.
d10 - dbh 1-10 a:
d20 - dbh>10 and <=20 cm;
d30 - dbh>20 and <=30 cm;
d40 - dbh>30 and <=40 cm;
d50 - dbh<40 and <=50 cm;
d60 - dbh>50 and <=60 cm;
dg60 - dbh>60 and <=60 cm;

Table 7.3 Per hectare size class representation in Stratum 2*.

Loc	Size classes									
	h50	h100	hg100	d10	d20	d30	d40	d50	d60	dg60
KP	520	290	81	19			6	22	1	3
Kc	480	340	230	74	7	9	6	4	3	
Kt	160	72	33	13						
Mp	1190	89	18	18	4	4	4	2		7
Pk	610	210	160	100	11	3	6		6	
Vzl	220	100	30		5			10		5
Vz2	340	95	35	20				5		
Vz3	610	50	5							
Max	1190	340	230	100	11	9	6	22	6	7
Min	160	50	5	13	4	3	4	2	1	3
Mean	520	150	74	41	7	5	5	9	3	5
SD	320	110	81	38	3	3	1	8	2	2

* Figures > 100 rounded off to tens.

Loc	Size classes				
	h50	h100	hg100	d10	d20
KP	720	1810	390	80	31
Kc	380	570	120	60	6
Kt	180	410	340	330	13
MP	120	140	60	18	
Pk	150	260	190	100	
Vzl	340	260	15	20	
vz2	120	10	40	30	5
vz3	35	80	35	25	
Max	720	1810	390	330	31
Min	35	10	15	20	5
Mean	260	440	150	80	14
SD	220	580	150	100	13

* figures > 100 rounded off to tens.

In the case of upper stratum, although population size reduces considerably with size classes up and up, there are no size classes without representation except in one or two instances. However, paucity of individuals in the size classes d20 (> 10 cm and <=20 cm dbh; pole stage) and d30 (> 20 cm and <=30 cm dbh), is very much obvious as the number of individuals in size classes both above and below these size classes are high.

For the *Wet Evergreen Forests* P. N. Nair (1961) has given some approximations for considering the regeneration status of desirable trees satisfactory. For the *Moist Deciduous Forests* these figures are not available. Nevertheless, comparable figures can be derived by proportionate calculations.

P. N. Nair (1961) classified regeneration into two classes: 1. Unestablished Seedlings with the size range of height <= 120 cm; 2. Established Seedlings with the size range of height > 120 cm and dhh <= 10 cm. According to his weighted estimates, *Wet Evergreen Forests* are fully stocked when six unestablished or one established seedling(s) per milliacre exist. He considerd regeneration as satisfactory when there is adequate stocking in at least 40 percent of the area. The per hectare values for the *Wet Evergreen Forests* as calculated from his figures are given in Table 7.5.

Table 7.5 Estimates of regeneration of desirable species (Upper

Derivation of data	Unesta-blished	Establ-ished
Figures for *Wet Evergreen Forests* Calculated from Nair (1961)	6,000	1,000
Proportionate calculations for *MDFs* using figures in Nair (1961) and Seth and Kaul (1978; stocking = 167 trees ha-1)	3,740	580
Calculated from observed stocking (150) and observed mean survival probability	1,620	530
Observed frequencies in *MDFs* of TFD	3,040± 1,090	240± 90

Seth and Kaul (1978) give average stocking of trees (> 20 cm dhh; given in square brackets) for *WetEvergreen Forests* [289], *Moist Deciduous Forests* [167]and even aged plantations of deciduous species like *Shorea robusta* [138]and teak 11111. From these figures, proportionate figures for unestablished and established seedlings of commercially important tree species for natural *Moist Deciduous Forests* are calculated and given in Table 7.5. (For the sake of convenience, here the size range of unestablished seedlings were taken as height <= 100 cm). Comparable figures for unestablished and established seedlings of the upper stratum were also calculated from observed mean survival probability (in TFD) and stocking (>=20 cm dbh). These figures are also given in Table 7.5. The observed frequencies in the regeneration classes from TFD are also given in Table 7.5.

From Table 7.5, it can be seen that the observed frequency of unestablished seedlings (3,040 ± SD 1090) comes more or less closer to the value estimated from P. N. Nair's (1961) weighing (3,740) and is far higher than the value estimated from mean survival probability (1,620). That is, at this stage, regeneration status is more or less satisfactory. On the other hand, the observed frequency of established seedlings (including saplings and poles; 240 ± SD 90) roughly accounts only to half of the estimated values (580 and 530). That is, regeneration at the sapling, and pole stage is highly unsatisfactory.

Observed frequencies in different regeneration classes of different, strata are given in Table 7.6. The number of unestablished seedlings in each of the middle and lower strata is always less than that of the upper stratum. Nevertheless, together they account to almost half of the population size of the upper stratum. The number of established seedlings of each of the middle and lower strata on the other hand, accounts to approximately half of the population size of the upper stratum. Together, they outnumber the population size of established seedlings of the upper stratum. Therefore, more than the unestablished seedlings, the established seedlings (saplings and poles) of the middle and lower strata must be offering significant stress in terms of competition for those of the upper stratum.

<u>At Species Level:</u> This section deals with the population structure of the more commercially important tree species only. Of the 21 commercially important species, *Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa* showed higher values of Basal Area (BA),Relative Basal Area (RBA), Density (D), Relative

Table 7.6. Observed frequencies in regeneration classes of different strata*.

Regeneration class	Frequency in Strata Stratal number		
	1	2	3
Unestablished Seedlings (ht <= 100 cm)	3040 ± 1090	670 ± 220	670± 400
Established Seedlings (ht > 100 cm and dbh <=lOcm)	240 ± 90	120 ± 60	230± 120

Density (RD)and Relative Importance Value Index (RIVI). In addition, two species of the lower stratum, *viz., Holarrhena pubescens* and *Wrightia tinctoria* are very much abundant in the stands and therefore are also included in the discussions.

Population structure of the important species together with that of a few co–dominant species is depicted in Figure 7.3. Size class representation in terms of percentage of the total population of each species is given in Table 7.7. In many tree species, distribution of size in terms of semilogarithmic graphs proved to be negatively exponential with a less prominent rotated sigmoid curve at the mid–size ranges (West et al., 1981; Saxena and Singh, 1984; Pande and Bisht, 1988). *Xylia xylocarpa* and *Terminalia paniculata* showed similar graphs (Figure 7.3). On the other hand many other species showed a strongly bimodal distribution pattern with a strong depression in the size class d20 (> 10 cm and <= 20 cm dbh). This depression in size class d20 indicates poor representation of pole crops. This means a poor survival probability for saplings (1-10 cm dbh). For species like *Dillenia pentagyna, Grewia tiliifolia* and *Lagerstroemia microcarpa* pole crops are totally wanting, while in others like *Terminalia crenulata, T. paniculata* and *Xylia xylocarpa* poor representation of pole crops is evident. In all the species there are more large sized trees than poles (d20). A slight depression, similar to the one noticed in the size class d20 (10–20 cm dbh), is noticeable in the size class hgl00 (> 100 cm height and < 1 cm dbh) indicating higher mortality rates during conversion to saplings. In *Bombax* spp., *Dillenia pentagyna, Terminalia crenulata, T. paniculata and Xylia xylocarpa* population size in the lower size classes (below d20 = 10-20 cm dbh) decreases more slowly, while in *Grewia tiliifolia* this is more quick (*cf* .Figure 7.3) .

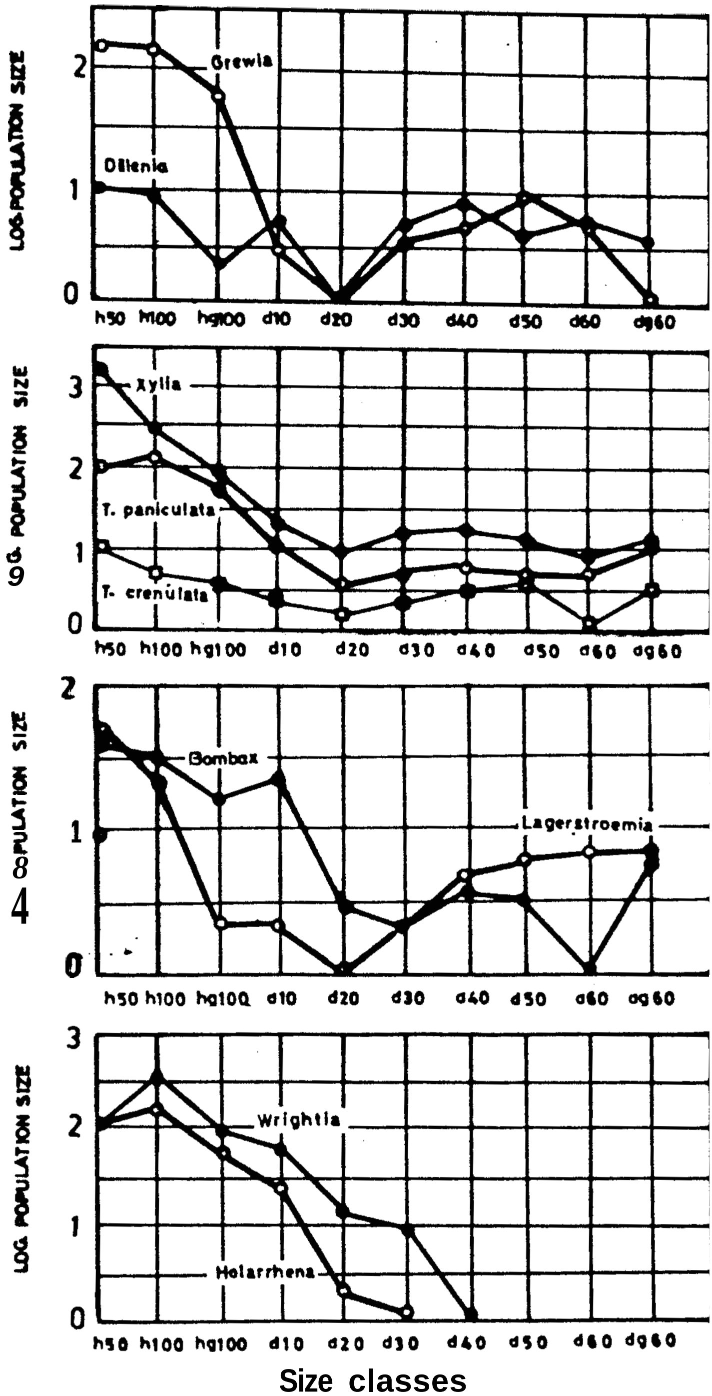


Figure 7.3 Semilogarithmic graphs of population structure of dominant Stratum 1- and Stratum 3-species.

h50	- ht <= 50 cm;	d30	- dbh > 20 and <= 30 cm;
h100	- ht > 50 and <= 100 cm;	d40	- dbh > 30 and <= 40 cm;
hg100	- ht > 100 cm and dbh < 1 cm.	d50	- dbh > 40 and <= 50 cm;
d10	- dbh 1-10 cm;	d60	- dbh > 50 and <= 60 cm;
d20	- dbh > 10 and <= 20 cm;	dg60	- dbh > 60 and <= 60 cm;

The process of regeneration is more or less satisfactory in *Xylia xylocarpa*. This maybe due to good germination, high fire resistance, root sucker formation and high coppicing ability. The species is found to regenerate even in disturbed sites. In other species, the number of seedlings is not that high compared to the number of large sized trees.

Table 7.7 Size class representation given as percentage of total population of selected species.

Species	Size classes									
	h50	h100	hg100	d10	d20	d30	d40	d50	d60	dg60
Stratum I species										
Albizia odoratissima	96	3	*	*			*	*		
Alstonia scholaris	18	37	20	21	4					
Bombax spp.	46	33	9	a	1	*	1	2		1
Dalbergia sissoides	78	12	4	1		1	1		3	1
Dillenia pentagyna	37	8	1	5	1	12	19	10	3	5
Grewia tiliifolia	45	38	10	*		*	1	2	1	
Haldina cordifolia	29	58	3	4	2		1		1	
		12	2	1		1	8	12	6	8
Lannea coromandelica	71	19	1	6	1	2			1	
Melia dubia	69	12			4					16
Pterocarpus marsupium	51	9	2		3	9	12	10	4	
Radermachera xylocarpa	59	32	8	3			4			
Stereospermum colais	67	24	6	2		1	1	*		
Terminalia bellirica	67	21	6	3		1				3
Terminalia crenulata	17	32	12	4	2	4	15	7	2	5
Terminalia paniculata	33	40	18	3	1	1	2	1	1	2
Tectona grandis	34	31	22	11			2		2	8
Tetrameles nudiflora	11	16	23	8						43
Xylia Xylocarpa	79	14	4	1	*	1′	1	1		1
Stratum 3 species										
Holarrhena pubescens	34	43	15	7						
Wrightia tinctoria	20	51	17	10	1					

* less than 0.5 percent.

Population Dynamics

Natality (N)

From Natality Experimental Plots

Estimates of total number of tree seedlings emerged per hectare of the study area are given in the Table 7.8. At all–trees level, the mean number of seedlings emerged was 27,360 ha^{-1} yr^{-1}. This is approximately equal to 3 seedlings per m^2.

The highest contribution to seedling emergence however was by the commercially important species (9,700 seedlings ha^{-1} ; = 1 seedling per m^2) which amounted to 35 percent of the total. Nonetheless, it is less than the cumulative total (17,670 seedlings ha^{-1}; = 2 seedlings per ^{2} 65 percent of total) contributed by all the other strata.

Table 7.8 Distribution of tree emergence at various levels and their statistics*

Levels	Mean*	Per hectare	Percent* of total
All-trees	164	27,360'	100
Stratum 1	58	9,700	35
Stratum 2	23	3,890	14
Stratum 3	42	7,000	26
Evergreen immigrants	41	6,780	25

Seasonal Variations: Distribution of percentage of seedling emergence according to seasons is given in Table 7.9.

The peak season of seedling emergence of all–trees, upper stratum, middle stratum and the evergreen immigrants was during the first two months of SW monsoon. Nevertheless, 75 percent of the seedlings of lower stratum emerged during the pre–monsoon showers during April itself, while the evergreen immigrants did not emerge during the pre–monsoon showers at al. During late monsoon (August - Setptember) the seedling emergence uniformly maintained a low rate (<=5 percent), at all–trees and stratal levels.

Species level: Although seedling emergence at all–trees and stratal levels showed higher values during June–July, some species of the upper stratum showed highest germination during April, after the pre–monsoon showers (Table 7.10).

Species like *Dillenia pentagyna, Lannea coromandelica, Melia dubia, Pterocarpus marsupium, Tectona grandis and Terminalia panicuiata* showed seedling emergence only during July–August. But, in all these cases, the number of observations (number of seedlings) were less than 10 and therefore needs further studies to confirm this.

In some experimental plots, a few evergreen/ semievergreen immigrants were found to germinate. The species were: *Aporusa lindeyana, Antiaris toxicaria* and *Cinnamomum malbathrum* . None of these species were found to germinate during April, but did so only from June onwards indicating that they require higher soil moisture conditions to germinate.

From Other General Experimental Plots

Natality denotes the number of births in a population leading to new individuals. In the present study there had been no efforts to determine the actual number of seeds germinated. Instead, the effective number of new recruits alone were determined, ie, number of births minus number of deaths of the new recruits. Distribution of effective natality percentages at different levels, under fire protection (UFP) and under fire (UF) are glven in Table 7.11 and represented in Figure 7.4.

At All–Trees Level: From the data obtained, it appears that has not increased the natality percentage at all–trees level. The natality

Table 7.9 Distribution of percentage of seedling emergence according to seasons.

Taxa	April	Jne + July	Aug + Sept	n*
All-trees	30	66	4	985
Stratum 1	30	68	2	349
Stratum 2	5	90	5	140
Stratum 3	75	20	5	252
Evergreen immigrants	-	97	3	244

* n = Total number of observations (seedling emergences)

Table 7.10 Distribution of seedling emergence according to species and seasons.

Strata	Taxa	April	Jne + July	Aug + Sept	n*
1	*Alstonia scholaris*	77	20	3	30
1	*Xylia xylocarpa*	60	40		119
3	*Wrightia tinctoria*	69	31		162

* n = Total number of observations (seedling emergences)

Table 7.11 Percentage of effective natallty (PN; at the end of the favourable season) under fire protection (UFP) and Under Fire (UF)

Level	UFP *	UF *	UF/UFP
All- trees	16	20	1.21
Stratum level			
Stratum 1	26	19	0.71
Stratum 2	5	23	4.47
Stratum 3	10	18	1.84
Species level +			
Grewia tiliifolia	21	24	1.13
Lagerstroemfa microcarpa	23	31	1.37
Terminalia crenulata	91	34	0.37
Terminalia paniculata	27	9	0.33
Xylia xylocarpa	21	13	0.62
Minimum	2	9	0.33
Maximum	91	34	15.20

* Figures rounded off to whole number.
\+ Values for only the dominant commercially important species are given, while the minima and maxima given are from the whole lot of species represented.

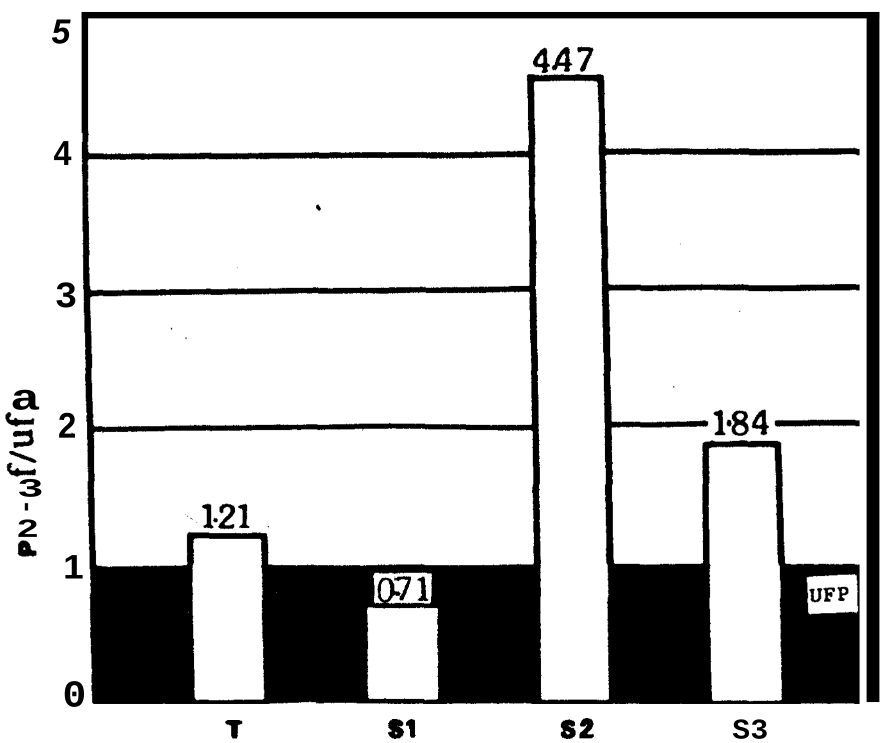


Figure 7.4 Comparison of Percentages of Natality (PN) In different Strata Under Fire Protection (UFP) and under Fire (UF).

PN - percentage of natality; S1 - Stratum 1; S2 - Stratum 2; S3 - Stratum 3; T - (Total) uf - under fire; ufp - under fire protection.

percentage under fire protection and under fire were respectively 16 and 20, the ratio being 1 to 1.2.

At Stratal Level : Natality percentage of stratum 1 under fire (19 %) was significantly less than that under fire protection (26 %). On the other hand, there was significant increase in natality percentage of strata 2 and 3, under fire. An approximately five fold increase is observed for stratum 2.

At Species Level: Under fire protection, at species level, natality percentages oscillated between 2 and 91 among the dominant species of the three strata. Under fire, this range changed to 9 and 34. The ratio between natality percentage under fire and under fire protection ranged between 0.2 and 15.

The non–uniform response to effective natality at stratal and species levels is very much obvious. Fire is a source of high temperature which in turn acts on seeds of different species differently (Floyd, 1966). In some species, it burns the seeds and reduces the population of viable seeds. It is a well established fact that in forested ecosystems viable seeds of the canopy trees are poorly represented in the seed bank in comparison to the pioneer species (*cf* Roberts, 1981). This precisely is the case with *Terminalia crenulata, T. paniculata and Xylia xylocarpa.* Their diaspores (dispersal unit; fruit/ seed, as the case may be) are large and therefore fail to enter the seed bank and get severely burned in ground fires.

Mortality (M)

Mortality denotes death of individuals. As in the case of natality, here also efforts were made only to estimate effective mortality, ie., mortality as recorded at the end of the favorable season. The data therefore excludes death of the new recruits of the year. The percentage of mortality under fire protection and under fire are given in Table 7.12 and represented in Figure 7.5.

Under fire protection, the mortality percentage at the all-trees level was only 11 percent. At stratum level it ranged between 9 % (stratum 1) and 14 % (stratum 2), while among the dominant species of all the strata it ranged between 6 % *(Cleistanthus collinus)* and 32 % *(Lagersroemia microcarpa).*

Table 7.12 Percentage of mortality (PM) under fire protection (UFP) and Under Fire (UF)

Level	UFP*	UF*	UF/UFP
All-trees	11	33	3.10
Stratum level			
Stratum 1	9	35	3.90
Stratum 2	14	27	1.92
Stratum 3	9	27	3.03
Species level+			
Grewia tiliifolia	12	41	3.53
Lagerstroemia microcarpa	32	55	1.70
Terminalfa crenulata	7	55	8.21
Terminalia paniculata	6	40	6.89
Xylia xylocarpa	6	27	4.78
Minimum	6	17	1.70
Maximum	32	55	8.24

* Figures rounded off to whole number.
\+ Values for only the dominant commercially important species are given, while the minima and maxima given are from the whole lot of species represented.

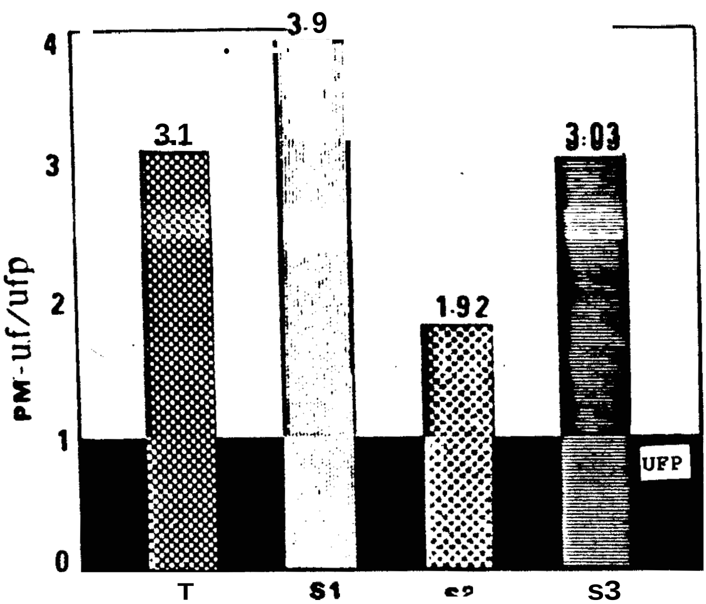


Figure 7.5 Comparison of Percentages of Mortality (PM) in different Strata Under Fire Protection (UFP) and Under Fire (UP).

PM - percentage of mortality; S1 - Stratum 1; S2 - Stratum 2; s3 - Stratum 3; T - (Total) All-Trees; uf under fire; ufp - under fire protection.

Under fire, mortality increased at all levels; the all-trees level average increased to 33 %, that is 3 fold; that, of strata ranged between **27** (stratum 2) and 35 (stratum 1) and of the individual species between 17 and 55 percent. The rate of increase in percentage was in the range of about 2–3 times in the different strata and 2 to 8 times in individual species.

Among the species, *Terminalia crenulata* and *Lagerstroemia microcarpa* were the most affected, mortality being greater than 50 % in the latter species. The ratio between mortality percentages under fire and under fire protection was highest for *Terminalia crenulata* and *T. panirulata,* the increase being 8 and 7 times respectively.

Summer Soil Moisture Depletion on Seedling Mortality

At All–Trees Level: The moisture holding capacity of the soil at the study site (fire protected) was found to be 35.3 $\pm$ SD 2.8 percent,. The summer soil moisture fluctuations and the variations in seedling survival are given in Table 7.13. .

Out of a total of 816 seedlings marked in February, 2.3 percent died off between February and March. The percentage of mortality increased to 7.1 percent by April end. The two values are statistically significantly different ($P = 0.05$). At the same time, when the seedling bank in *MDFs* (= 4,990 ha^{-1}; as estimated from regeneration survey) and the new recruits (9,700 ha^{-1} yr^{-1}; unestablished seedlings) are considered, seedling mortality purely due to moisture depletion during summer is quite insignificant.

At Stratum Level: Seedling mortality rates during the summer months for the different strata are given in Table 7.14. Mortality rates for strata 1 and 2 did not increase significantly with increasing soil moisture depletion, while for straturn 3 it increased more than thrice to the original value. Still the mortality rate remained less than ten percent.

At Species level. There were 28 tree species in the experimental samples Of these, only 4 species had a population greater than or around 50 in each. Distribution of mortality of these species is giv en in Table 7. I5

The net mortality percentage in all the four species were under 10 percent of the initial population. Nevertheless, a general doubling of mortality percentage from March to April is evident.

Table 7.13 Seedling mortality of All-Trees during summer soil moisture depletion in the study plot.

Month & Date	Soil moisture	Seedlings							
		Sample 1		Sample 2		Sample 3		Total	
		n	m%	n	m%	n	m%	n	mm%
Feb 16 (initial)	14 ± 0.7	234	-	266	-	316	-	816	-
Mar 15	13.2 ± 0.6	229	2.1	261	1.9	307	2.9	797	2.3± .4
April 25*	21 ± 0.9	219	6.4	250	6	288	9	757	7.1± 1.3

n = Number of seedlings observed : m % = Mortality percent; mm % = Mean mortality percent.

* The higher percent of moisture during April was due to a pre-monsoon shower 2 days before soil sampling. In fact the moisture content for the month should have been lesser than that of March.

Strata	Percentage of Mortality		'n' as on Feb. 16
	March 16	April 25	
Stratum 1	3.0	3.3	299
Stratum 2	2.1	3.2	94
Stratum 3	2.4	8.4	381

* Evergreen Immigrants not included: n = of seedlings observed.

Table 7.15 Distribution of seedling mortality in different species.

Stratum and species	Percentage of Mortality		'n' as on Feb. 16
	March 16	April 25	
Stratum 1 species			
Grewia tiliifolia	1.2	2.4	84
Xylia xylocarpa	4.8	7.7	168
Holarrhena pubescens	2.3	6.8	44
Wrightia tinctoria	2.4	8.7	335

n - Number of observations.

At Size Class Level: Distribution of summer mortality in different size classes is given in Table 7.16. At the all-trees level, mortality is seen in all regeneration size classes except d10 (1 - 10 cm dbh). In the size class h50 (height <=50 cm) mortality percentage was highest in March (4.9) and maintained almost the same (3.7) in April. On the other hand, in the size classes hl00 (height 50-100 cm) hgl00 (height > 100 cm and dhh < 1 cm), the mortality percentage was low in March (_ 1) which increased in April. This definitely shows that the upper size classes are able to resist low summer soil moisture than the lowest size class signifying the role of size in summer mortality due to soil moisture depletion.

Survival

Survival by Whole Plants (SWP)

The simplest destruction that fire can bring about. to the regeneration is the burning of above ground shoots. Of the total 2,269 marked seedlings only 107 seedlings survived fire by their old shoots. The data is not sufficient enough to analyze the percentage of survival of old shoots under fire, at stratal and species levels. However, disregarding species and strata, percentage of survival in different size classes at all-trees level seems to convey some indications. Percentage of survival by whole plants (ie., including the old shoot) under fire protection and under fire are given in Table 7.17 and represented in Figure 7.6.

Table 7.16 Distribution of sunnner mortality at size class level*.

Strata'	Mortality percentage in size classes							
	h50		h100		hg100		dl0	
	Mar 16	April 25	Mar 16	April 25	Mar 16	April 25	Mar 16	April 25
All-Trees	4.9 [328]	3.7 [328]	0.8 [265]	5.7 [265]	1.1 [187]	4.3 [187]	- [11]	- [11]
Stratum 1	5.8 [156]	4.5 [156]	- 1841	1.2 [84]	- [59]	.4 [59]	- [6]	- [6]
Stratum 2	4.4 [46]	- [46]	- [25]	- [25]	- [23]	4.4 [23]	- [3]	- [3]
Stratum 3	4.1 [123]	3.3 [l231	1.3 [155]	9.0 [155]	1.9 [l03]	4.9 [l03]	- [2]	- [2]

* Evergreen immigrants not included.
* Figures in parentheses indicate sample size in terms of number of seedlings observed.

Under fire protection, the survival percentage was greater than 85 in all size classes. There is a trend of gradual increase of the survival percentage with higher and higher size classes. Following fire, the percentage was seen much affected. However, similar to that under fire protection, a gradual increase in the survival percentage with higher size classes was observed. The percentage of survival was around 3 in both the size classes h50 and hl00 and it doubled in the size class hgl00(_7). A sudden increase was observed in the size class d10 (_46) which is: 13 times that observed in the size class h50. Frequency of survival of regeneration of different strata and species by whole plants is given in Tables 7.18 and 7.19.

Survival by New Shoots (SNS)

Great majority of the regeneration which survived by producing new shoots in the succeeding favorable season following fire did not acquire their original size which they had before the occurrence of fire. A small percentage reached the same size classes as they were before fire. A still smaller percentage had grown to higher size classes than the pre-fire size classes.

Table 7.17 Fire survival of seedling shoots under fire protection (UFP) and Under Fire (UF)-

No	Size class	UFP	UF	UF/UFP
1	h50 (ht >=5 <=50 cm)	85	3	0.039
2	hl00 (ht >50 <=l00 cm)	91	3	0.031
3	hgl00 (ht >l00 cm dbh <=1 cm)	97	7	0.069
4	d10 (dbh > = 1 cm <=10 cm)	98	46	0.468

***dbh* - diameter at breast height; *hg* - helght greater than; *ht* - height.**

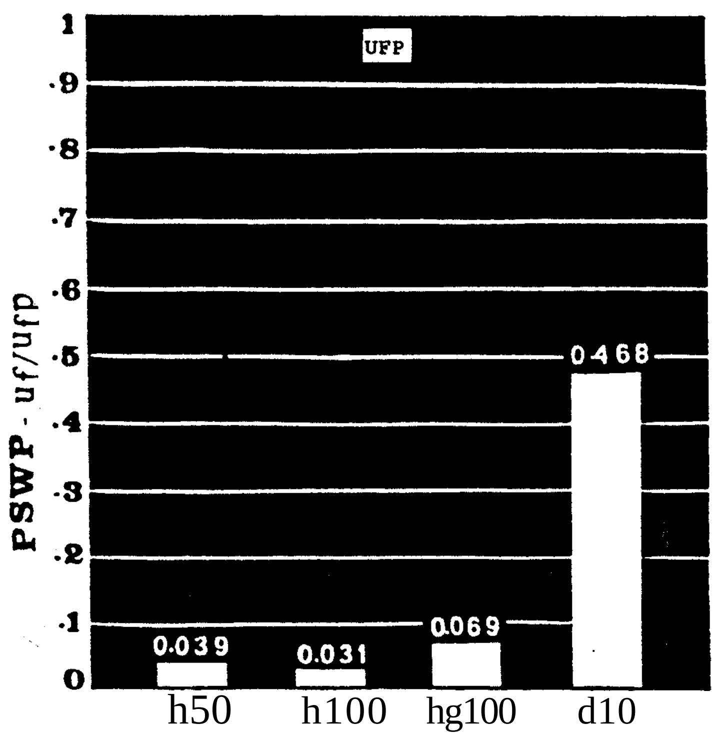


Figure 7.6 Comparison of Survival by Whole Plants (including shoots; PSWP) in different strata under fire protection (UFP) and Under Fire (UF).

PSWP - Percentage of Survival by Whole Plants; S1 - Stratum 1; S2 - Stratum 2; S3 - Stratum 3; T - (Total) All-Trees; uf - under fire; ufp - under fire protection.

Table 7.18 Survival of old shoots after fire at stratal and all trees level.

Strata	4-5	5.1-10	10.1-20	20.1-30	Total	Sample
Strat 1	6	8	3	2	19	37
Strat 2	3	9	5	-	17	38
Strat 3	4	6	3	-	49	13
All-Trees	13	23	11	2	49	88

Table 7.19 Survival of old shoots after fire in different species.

Stratum	Species	Diameter classes (cm) 4-5 cm	5.1-10 cm	10.1-20 cm	20.1-30 cm	Total
1	*Dillenia pentagyna*	-	1	-	-	1
1	*Haldina cordifolia*	-	-	2	1	3
1	*Tectona grandis*	1	2	-	-	3
	Xylia xylocarpa	5	5	1	1	12
2	*Cleistanthus collinus*	3	9	5	-	17
	Casearea sp.	1	1	-	-	1
	Holarrhena pubescens	1	1	-	-	2
	Total	13	23	11	2	49

Retention in the Same Size Classes (RSSC)

Population retained in the same size classes (as they were during the enumeration before fire) does not convey details of positive or negative growth. This attribute includes elements of both growth and reduction in size due to fire. If there is a strong reduction in the population, it can be either due to conversion to higher or lower classes. Descriptive statistics of the variable are given in Table 7.20 and illustrated in Figure 7.7.

At all–trees level, under fire protection, the percentage of population retained in the same size classes was ≃ 73 %; under fire the figure reduced to ≃ 45 percent..

At stratal level under fire protection, all the three strata had high percentage of retention in the same size classes, the range being between ≃ 71 and ca.76 percent. Under fire, significant reduction was the trend, the range limits having changed to: 42 and ≃ 52. The times by which the percentage of retention reduced was between 0.56 and 0.73, the highest retention under fire being in stratum 2.

At species level, under fire protection, the percentage of retention ranged between ≃ 55 *(Lagerstroemia microcarpa)* and ≃ 82 *(Xylia xylocarpa)*. Under fire it invariably decreased, the range being between ≃ 30 percent *(Terminalia crenulata)* and ≃ 60 percent *(Hymenodictyon orixense)*.The reduction, in terms of number of times of the values under fire protection ranged between 0.47 *(T.crenulata)* and 0.81 *(Cleistanthus Collinus)*.

Conversion to Higher Size Classes (CHSC)

Conversion to higher size classes indicates the extent of growth in terms of size. The statistics are given in Table 7.21 and represented in Figure 7.8.

The average rate of conversion to higher size classes at. all–trees level under fire protection was: 13 % which was subsequently reduced to: 7 %, under fire.

At stratal level, under fire protection the percentage was highest for stratum 1 (≃ 15 %) and least for stratum 3 (≃ 10 %) Under fire, the percentage values decreased for both strata 1 and 2, while that of stratum 3 was not much affected. In fact the latter showed a slight increase, although not very significant.

Table 7.20 Percentage of population retalned In the same size classes (PPRSC) under fire protection (UFP) and Under Fire (UF).

Level	UPP *	UF*	UF/UFP
All- trees	73	45	0.63
Stratus level			
Stratum 1	73	43	0.59
Stratum 2	71	52	0.73
Stratum 3	76	42	0.56
Species level+			
Grewia tiliifolia	59	52	0.89
Lagerstroemia microcarpa	55	61	1.11
Terminalia crenula	65	30	0.47
Terminalia panicula	66	36	0.55
Xylia xylocarpa	82	53 .	0.65
Minimum	55	30	0.47
Maximum	82	61	1.11

* Figures rounded off to whole number
\+ Values €or only the dominant commercially important species are given, while the minima and maxima given are from the whole lot of species represented.

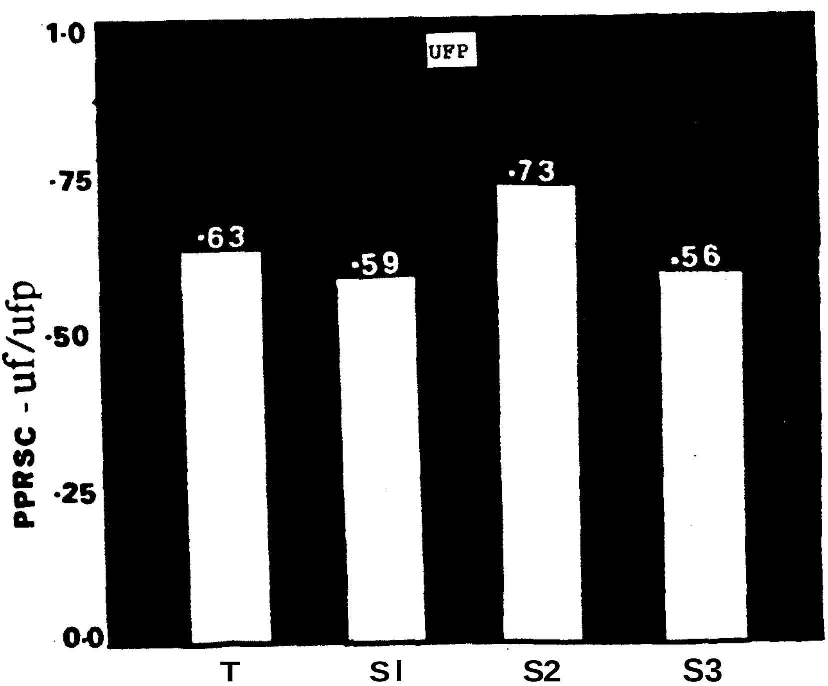


Figure 7.7 Comparison of Percentage of Population Retaintion in the Same Size Classes (PPRSC) in different Strata Under Fire Protection (UFP) and Under Fire (UF).

PRSC - Percentage *of* Retention in the Same Size Classes; S1 - Stratum 1; S2 - Stratum 2; S3 - Stratum 3; T - (Total) All-Trees; uf - under fire; ufp - under protection.

Table 7.21 Percentage of conversion, to higher size classes (PCHC) under fire protection (UFP)and Under Fire (UF) -

Level	UFP*	UF*	UF/UFP
All-trees	13	7	0.54
Stratum level			
Stratum 1	15	6	0.41
Stratum 2	11	5	0.43
Stratum 3	10	12	1.23
Species level +			
Grewia tiliifolia	18	11	0.62
Lagerstroemia microcarpa	13	6	0.40
Terminalia crenulata	28	6	0.19
Terminalfa paniculata	23	6	0.27
Xylia xylocarpa	10	6	0.61
Minimum	1	3	0.26
Maximum	28	14	1.93

* Figures rounded off to whole number.
\+ Values for only the dominant commercially important species are given, while the minima and maxima given are from the whole lot of species represented.

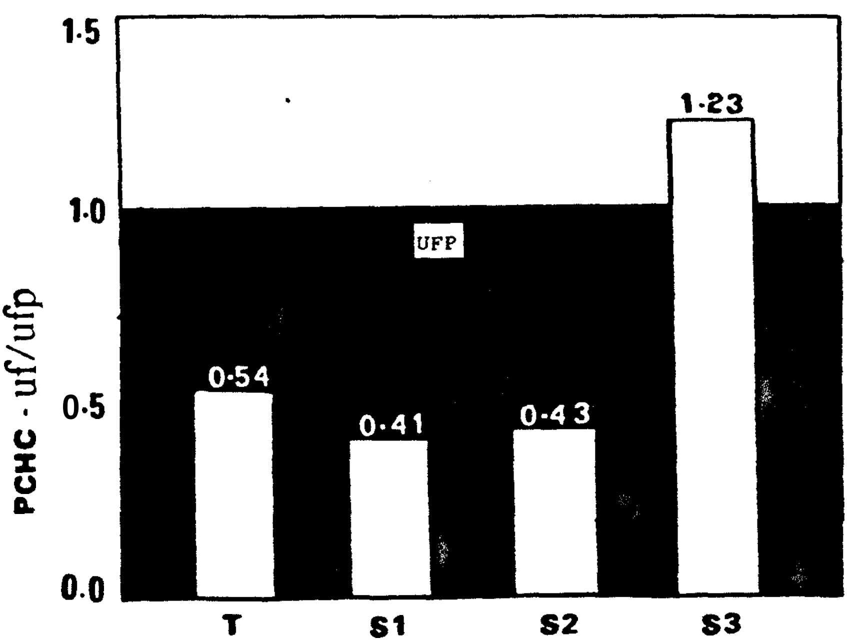


Figure 7.8 Comparison of percentage of conversion to higher size classes (PCHC) in different strata under fire protection (ufp) and Under Fire (UF).

PCHC - Percentage of Conversion to Higher Size Classes; S1 - Stratum 1; S2 - Stratum 2; S3 - Stratum 3; T - (Total) All-Trees; uf - under fire; ufp- under fire protection.

At species level, under fire protection, the conversion ranged between ≃ 1 and ≃ 28 percent among the dominant species of the three strata. Under fire the range condensed between: 3 and: 14 percent. In most species, there is a reduction in the value of the attribute while in some species of strata 2 and 3 it increased a little. The percentage of conversion to higher size classes at various levels decreased from 0.26 times to 0.41 times, while that of *Wrightia tinctoria* (stratum 3 species) and *Hymenodictyon orixense* (stratum 2 species) increased one to two fold. This would imply that fire would enhance the growth of regeneration of less commercially useful species in the favorable season following fire. The reason perhaps may be the accumulation of organic matter in the soil owing to fire and the ability of the staratum 3 species to take advantage of the situation better than species of other strata.

Conversion to Lower Size Classes (CLSC)

Conversion to lower size classes speaks of reduction in the size of seedlings. The figures for the attribute are given in Table 7.22 and the dynamics represented in Figure 7.9.

At all–trees level the rate of conversion to lower size classes under fire protection was only: 4 % while under fire this had increased: 4 times (≃ 15 %).

At stratal level figures under fire protection ranged between ≃ 36 % (stratum 1) and ≃ 5 % (stratum 3). In all the three strata, under fire the values increased, the rate of increase being ≃ 3 times (stratum 3) to: 5 times (stratum 1).

At species level, under fire protection, the percentages ranged between 0 to ≃ 14 % while under fire, the range increased from: 5 to ≃ 39 percent. The percentage of retardation invariably increased and ranged between ≃1 to ≃39 times the values under fire protection. Perhaps this might explain the absence of saplings and poles in many of the commercially important tree species.

Intrinsic Rate of Natural Increase *(rN)*

Every population has a tendency to increase over a period of time. The rate at which populations increase is denoted by the term 'intrinsic rate of natural increase' and is generally denoted by *rN* (Harper and White, 1974). Invasive (increasing) populations assume positive values of *rN*

Table 7.22 Percentage of conversion to lower size classes (PCLC) under fire protection (UFP) and Under Fire (UF).

Level	UFP *	UF *	UF/UFP
All-trees	4	15	3.95
Stratum level			
Stratum 1	3	14	4.65
Stratum 2	4	12	3.06
Stratum 3	5	17	3.22
Species level +			
Grewia tiliifolia	14	15	1.05
Lagerstroemia microcarpa	0	11	10.90
Terminalia crenulatfa	0	8	8.42
Terminalia paniculata	6	18	3.09
Xylia xylocarpa	2	15	6.65
Minimum	0	5	1.05
Maximum	14	39	38.54

• Figures rounded off to whole number.
\+ Values for only the dominant commercially important species are given, while the minima and maxima given are from the whole lot of species represented.

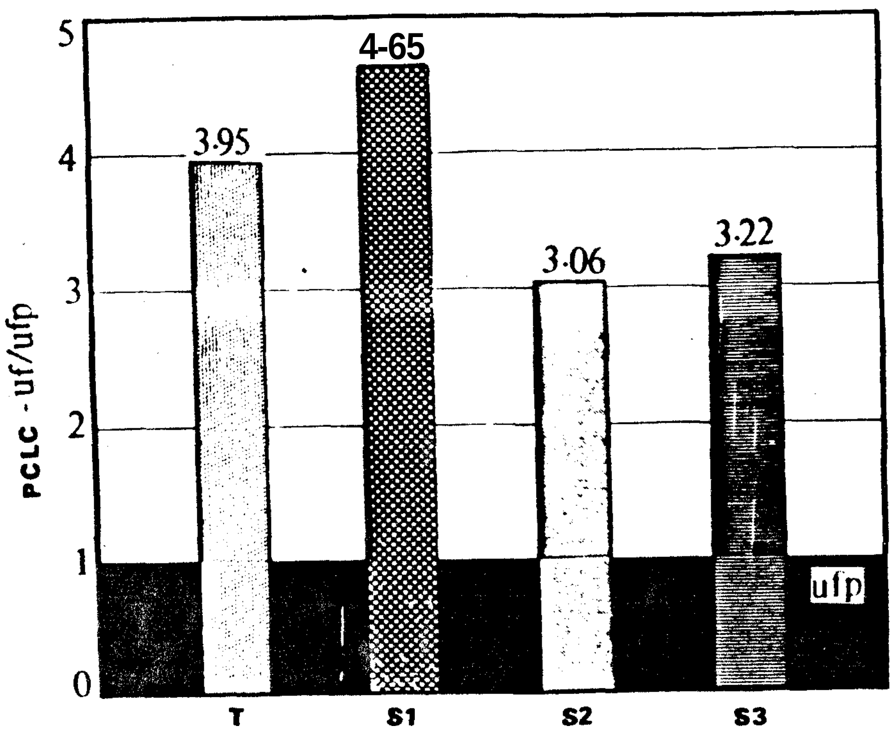


Figure 7.9 Comparison of percentage of conversion to higher size classes (PCHC) in different strata under fire protection (ufp) and Under **Fire (UF)**.

PCLC - percentage **of** conversion to Lower Size Classes; **S1** - stratum **1**; S2 - stratum 2; S3 - Stratum 3; **T** - (Total)**All-Trees;** uf - under fire; ufp - under fire protec while regressive (shrinking) populations assume negative values. Statistics of *rN* values are given in Table 7.23 and the dynamics illustrated in Figure 7.10.

While intrinsic rate of natural increase tells us about the dynamics in each population of the concerned level, it does not reflect the relative picture, ie, with respect to the all–trees regeneration population. To get some idea about this, importance value indices (IVI), under fire protection and under fire were calculated at all levels, based on their density (Table 7.24).

The average percentage of natural increase for all–trees was positive under fire protection, the value being 5.8 % or 1.058 times a year. Under fire, the value increased but in the regressive direction. This indicates that, under fire, instead of growth, the population shrunk more than twice by which it increased under fire protection. In other words, this would imply that after a fire, the population would require at least two years of fire protection to come to the original status.

Under fire, all the strata showed negative values of *rN*, the fold of shrinkage in population being distributed between $\simeq 1$ and $\simeq 5$ times. The percentage values of natural increase within the regeneration population of stratum 1 under fire protection and under fire mutually nullified, their signs being opposite. Thus, alternate years of fire (once in two years) might not affect the regeneration status of stratum 1 significantly. The post–fire importance value of the population was $\simeq 52$ %, which again was more or less equal to the pre–fire importance value ($\simeq 54$ %), but with a slight loss ($\simeq 2$ %) This loss on the other hand was complemented by increase in the importance value of strata 2 and 3.

Although the under fire importance value of stratum 2 shows slight increase (1.25 %), the percentage values of natural increase for this stratum showed negative values both under fire protection and under fire. This indicates that, regardless of fire or fire protection this population is regressive; perhaps the succession process favours further thinning in this stratum. Under fire, its importance value increased, owing to a reduction in the population of stratum 1.

Stratum 3 showed positive value (+2.00) of *rN* under fire protection while under fire it increased 5 folds in the regressive direction. Its importance value increased slightly (+ 0.81 %) under fire, as already mentioned.

Table 7.13 Percentage of natural Increase (rN) under fire protection (UFP) and Under Fire (UF)-

Level	UFP*	UF *	UF/UFP
All-trees	6	-13	-2.26
Stratum level			
Stratum 1	17	-16	-0.94
Straturn 2	-9	-9	-1.05
Stratum 3	2	-10	-6.20
Species level +			
Grewia tiliifolia	13	-22	-1.78
Lagerstroemia microcarpa	-10	-25	2.64
Terminalia crenulata	84	20	-0.24
Terminalia paniculata	22	-31	-1.41
Xylia xyiocarpa	15	-14	-0.90
Minimum	-16	-2	-0.09
Maximum	84	-31	-5.06

Figures rounded off to who number.
\+ Values for only the dominant commercially important species are given, while the minima and maxima given are from the whole lot of species represented.

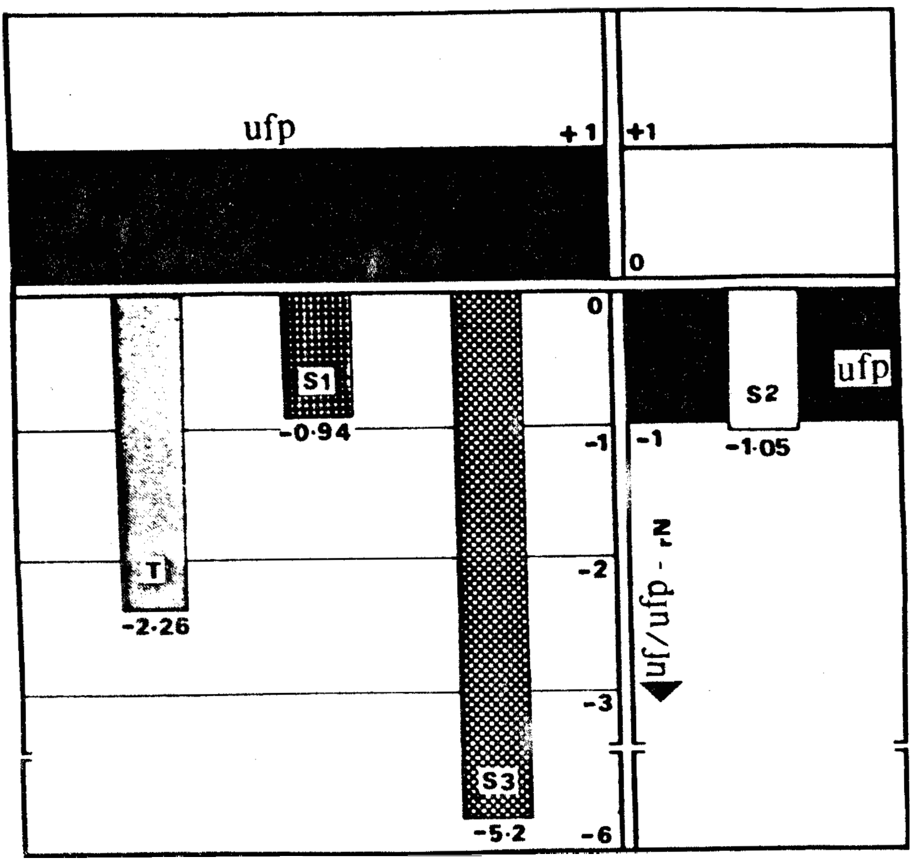


Figure 7.10 Comparison **of** Rateo of Natural Increase *(rN)* in different Strata Under Fire Protection (UFP) and Under Fire **(UF)**.

rN **- Rates** of Natural Increase; **S1** - Stratum **1;** s2 - Stratum 2; **S3** - Stratum 3; T - (Total) All-Trees; uf - under fire: ufp - under fire protection.

At species level, most species showed positive values of *rN* under fire protection except *Lagerstroemia microcarpa* (stratum 1 species), *Cleistanthus collinus* (stratum 2 species) and *Hymenodictyon orixense* (stratum 3 species). Under fire, however, all species have shown negative values, the values being one to two fold the values obtained under fire protection. Likewise, under fire importance value of most commercially important species reduced slightly. A few species of strata 2 and 3 such as *Cleistanthus collinus* and *Holarrhena pubescens* also showed an increase of rN (not given in Table).

Shrinkage of population of *Lagerstroemia microcarpa* both under fire protection and under fire is very much evident from the *rN* values. This species is found to produce millions of seeds but characteristically lacks a viable embryo in the seeds except rarely. This could be the reason for the negative rNvalues. In the tree populations of the species, medium to large sized individuals are plenty, while saplings and poles are practically lacking.

From the values of intrinsic rate of natural increase (*rN*) and importance value index (IVI) (Table 7.24) fire does not seem to affect species composition and relative importance of species in the regeneration population significantly. Nevertheless, repeated fires can accumulate the differences in IVI and reduce the regeneration of stratum 1 significantly. However, the possibility of the strata 2 and 3 acquiring a higher strength than stratum 1 seems not likely, as long as the trees of stratum 1 are available as seed source.

Table 7.24 Importance Value Indices (IVI) of regeneration under protection (UFP) and Under Fire (UF).

Level	UFP	UF	UF/UFP
All-trees	100	100	na'
Stratum level			
Stratum 1	54.4	62.4	0.96
Stratum 2	28.0	29.2	1.04
Stratum 3	17.7	18.5	1.05
Species level +			
Grewia tiliifolia	4.2	3.0	0.72
Lagerstroemia microcarpa	1 9	1.6	. 0.86
Terminalia crenulata	8.6	7.8	0.90
Termlnalia panicula ta	7.7	6.1	0.80
Xylia xylocarpa	21.6	21.4	0.99

na* not applicable,
+ for only the dominant commercially important species given.

Chapter 8
Results and Discussion III: The Tree Phase

Contents Page

Introduction

Trees provide the propagules (the seeds), the source materials needed for the regeneration process to initiate, Thus, their population structure too has a bearing on regeneration.

Survival of Trees

Of the population of 900 trees monitored, 45 trees died off within a period of three years due to various reasons (Table 8.1). This is roughly equivalent, to 3.7 trees ha^{-1} yr^{-1}. The break up of mortality at various levels of organization is given in Table 8.2. At the all-trees level, the annual mortality rate was 1.7 percent. Among the three tree strata, stratum 2 showed the highest rate (2.8 %) and stratum 1 the least (1.5 %). Among the dominant commercially important species, *Grewia tiliifolia* and *Xylia xylocarpa* showed highest rates, 2.5 and 2.2 percent respectively.

Table 8.3 gives the distribution of mortality in different size classes of the tree phase. Apparently, there is a reduction in the mortality percentage with increase in size classes. The vailable data is insufficient to study the distribution of mortality in different size classes at stratal and species levels and hence not attempted.

Other Damages to Trees

Although the tree phase mortality is just 1.7 percent per year (= 3.7 trees ha^{-1} yr^{-1}), a very high percentage of trees is found to be damaged. Twenty nine percent had burn blisters/ decay holes on the trunk/collar region.

Table 8.1 Percentage mortality of the tree phase at All-Trees level in the three year period of study.

Number	Causes of death	Number of deaths
1	Due to fungal infection (wood decaying fungi)	2
2	Due to wind fall	5
3	Due to fire	2
4	Due to illicit cutting	2
5	Due to other unknown reasons	34

Sample size 900 trees.

Table 9.2 Percentage mortality in mature trees at different levels.

Taxa	Mortality % yr^{-1}	Number of trees observed
All-Trees	1.7	900
Stratum 1	1.5	614
Stratum 2	2.8	97
Stratum 3	2.0	164
Dillenia pentagyna	0.7	103
Grewia tiliifolia	2.5	53
Lagerstroemia microcarpa	1.3	107
Terminalia crenulata	1.0	32
Terminalia paniculata	0.8	43
Xylia xylocarpa	2.2	208
Dominant Stratum 3 species		
Wrightia tinctoria	2.2	150

8.3 Distribution of percentage mortality in different size size classes of tree phase during the three year period of study*.

Taxa	Size classes						
	d10	d20	d30	d40	d50	d60	dg60
All-Trees	17.7 [17	5.7 176	4.5 202	6.7 178	4.6 151	4.8 84	0.0 92]
Stratum 1	50 [4	10 60	1.7 117	7 143	3.1 130	4.1 74	0.0 86]

* Figures in parentheses indicate sample size.

Decay holes on the trunk of trees, especially on the lower portion of the trunk are largely due to fire. Frequency distribution of such decay holes is given in Tables 8.4 and 8.5. Cent percent of the evergreen tree elements had decay holes on the trunk while stratum 1 showed only 17 percent. Among the spectrum of tree species represented, the dominant stratum 1 species, *Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia paniculata* and *Xylia xylocarpa* showed low percentages of trees with decay holes (ranging between 7.5 and 18.5 percent). At the species level, the stratum 3 species *Wrightia tinctoria* showed the highest percentage (58%) with decay holes.

The fact is that fires burn the base of the tree trunks, which gradually gets killed and infected by wood decaying fungi. The extent of decay increases on repeated fires and over years the trees topple down during the rainy season winds. Thus, fire reduces the seed source at one end while it increases the gaps in the canopy at the other end.

Table 8.4 Percentage frequency distribution of decay holes on trunk in tree populations.

Taxa	Percentage of trees with decay holes	No. of trees observed
All-Trees	29.2	900
Strata		
Stratum 1	17.1	614
Stratum 2	40.2	97
Stratum 3	57.3	164
Evergreen Trees	100	25
Dominant Stratum 1 Species		
Dillenia pentagyna	18.5	103
Grewia tiliifolia	11.3	53
Lagerstroemia microcarpa	7.5	107
Terminalia crenulata	3.1	32
Terminalia paniculata	16.3	43
Xylia xylocarpa	17.3	208
Dominant Stratum 3 Species		
Wrightia tinctoria	58.0	150

Table 8.5 Percentage distribution of decay hole on tree trunk in different size classes.

Taxa	size classes						
	d10	d20	d30	d40	d50	d60	dg60
All-Trees	64.7 [17	44.9 176	28.7 202	15.2 178	27.2 151	16.7 84	37.9 92]
Stratum 1	0.0 [4	13.3 60	13.7 117	8.4 143	22.3 130	14.9 74	33.7 86]

* Figures parentheses indicate sample size.

Chapter 9

Results and Discussion IV: Future of Regeneration in the South Indian Moist Deciduous Forests

The probabilities of transition of the three tree strata under fire protection and under fire are given in Tables 9.1 and 9.2. Pictorial models of population flux as represented in these matrices are illustrated in Figures 9.1–9.4. Population structure of individual strata for 15 years was simulated for various frequencies of fire using the population structure of the stand as on September 1989 as the initial population. The results for stratum 1, which comprises all the commercially important species, are plotted in a graph (Figure 9.5).

The decay rates of vegetations are generally accounted as half life periods (*cf* Harper, 1977). The half life periods for the three strata, under different fire frequencies, as derived from simulated data are given in Table 9.3.

When the frequency of fire was at 1–year interval, regeneration population of all the strata decreased rapidly. The populations became half in every sixth year (Table 9.3).

When the frequency of fire was lowered to a 2–year interval, the half life period of the strata ranged between 13 to 15 years. Still the curve sloped down as years increased.

At a 3–year fire frequency interval, the graph approached a more or less horizontal position and conformed to almost a straight line–saw tooth. Population decay was very low as indicated by the half life periods (63 to 83 years).

For every increase in fire frequency interval beyond 3 years, over years population strength of regeneration would never diminish (see Figure 9.5), unless and until other factors such as self thinning (*cf* Westoby, 1984), overgrazing, severe drought or other critical phenomena interfere.

Figure 9.6 shows graphs of the population flux of established seedlings 50 cm ht and <= 10 cm dbh) under varying fire frequency intervals. The graphs show that even alternate–year (two year) frequency would enhance the established seedling population.

Table 9.1 Probabilities of transition in various size classss under fire protection.*

Stra	Szcl	Zero,	h50(1)	h100(2)	hgl00(3)	d10(4)	d20(5)
1	0		0.78720	0.14865	0.10675		
	1	0.12956	0.72242	0.13805	0.00997		
	2	0.04505	0.03801	0.74497	0.16835	0.00362	
	3	0.02609	0.03382	0.14044	0.72870	0.07095	
	4	0.07143				0.92857	
	5						
2	0		0.31589	0.13434	0.08279		
	1	0.15950	0.76287	0.07269	0.00494		
	2	0.17941	0.13311	0.46922	0.21826		
	3		0.00397	0.05113	0.73452	0.21039	
	4					1.00000	
	5						
3	0		0.65887	0.67446	0.13680		
	1	0.14110	0.72764	0.07246	0.05880		
	2	0.06841	0.07490	0.76254	0.09425		
	3	0.04080	0.01667	0.11764	0.77988	0.04502	
	4					0.87500	0.12500
	5						

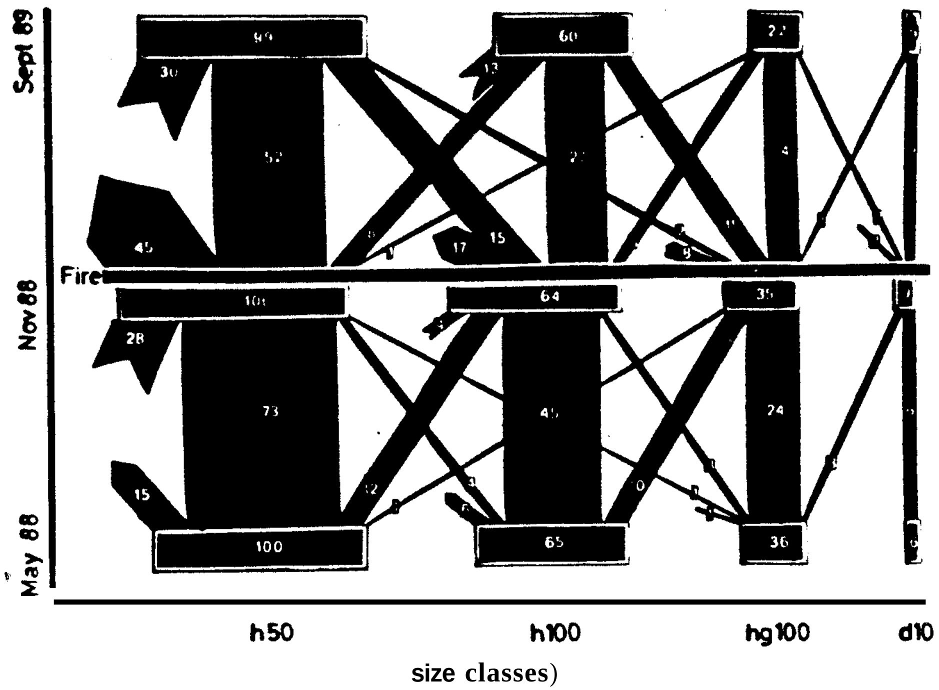
Table 9.2 Probabilities of transition in various size classes under fire.

Stra	Szcl	Zero	h50 (1)	h100 (2)	hg100 (3)	d10 (4)	d20 (5)
1	0		0.19989				
	1	0.42727	0.49732	0.06984	0.00556		
	2	0.21708	0.22018	0.50956	0.05319		
	3	0.19335	0.08270	0.32805	0.36004	0.03586	
	4	0.04762	0.01786	0.07143	0.19048	0.67262	
	5						
2	0		0.16414				
	1	0.25749	0.63456	0.08077	0.02717		
	2	0.34439	0.16961	0.42653	0.05947		
	3	0.33102	0.03631	0.19255	0.43834	0.00179	
	4	0.22279	0.01020	0.05159	0.33163	0.38379	
	5						
3	0		0.41979				
	1	0.14110	0.54110	0.11599	0.01449		
	2	0.19944	0.16340	0.52108	0.11607		
	3	0.22587	0.05863	0.36015	0.34416	0.01120	
	4	0.08333		0.10000		0.81667	
	5						1.00000

Stra - Strata: h50, h100, hg100, dl0, d20: Size classes.

Figures 9.1 and 9.2 Flow charts showing the population flux in the various size classes of all– trees (Fig. 9.1) and stratum 1 (Fig. 9.2) under fire protection and after fire. Time is given in the vertical axis, indicating the direction of flow. Fire incidence is shown by a narrow bar traversing the entire flow chart in the middle. The portion above the fire incidence line pertains to population flux after fire and that beneath the line pertains to that under fire protection. The horizontal boxes at the bottom, middle and top depict the population strength at the different time points of sampling. The vertica1 arid inclined bars represent the population flow between the successive samplings. Bars with arrow head at the bottom and middle, emerging from the horizontal boxes, indicate seedling mortality. Bars with a sagitate base and joining the horizontal hoxes at the middle and top depict new recruits. Relative figures arid proportionate width of population flux alone are depicted.

d10 - dbh 1–10 cm; *h50* - ht <= 50 cm; *h100* - ht > 50 and <= 100 cm; *hg100* - ht > 100 cm and dbh < 1


Sept 89
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May 88
Fire
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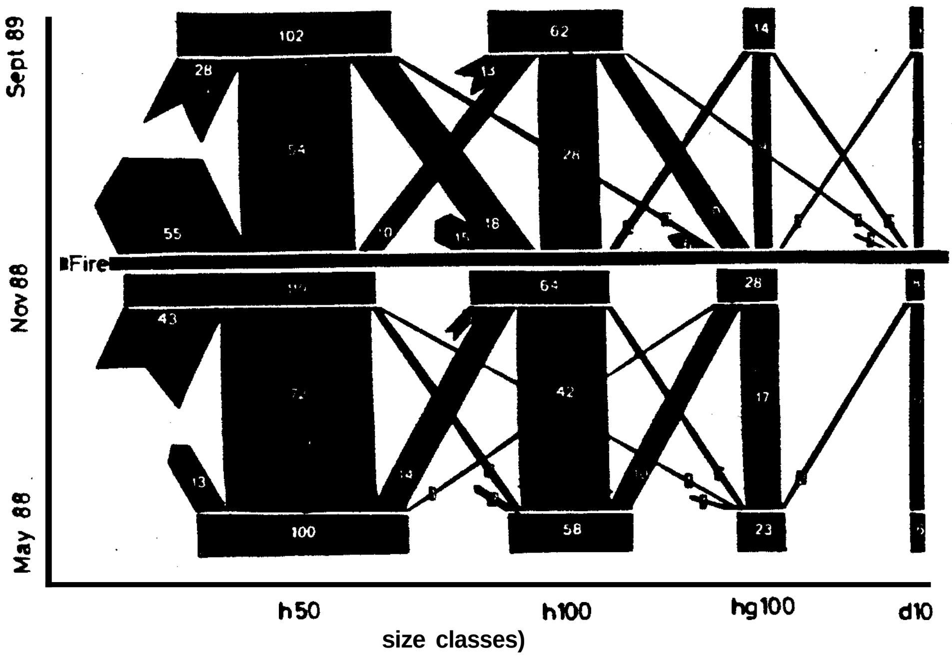
d10
size classes)

9·1


Sept 89
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May 88
Fire
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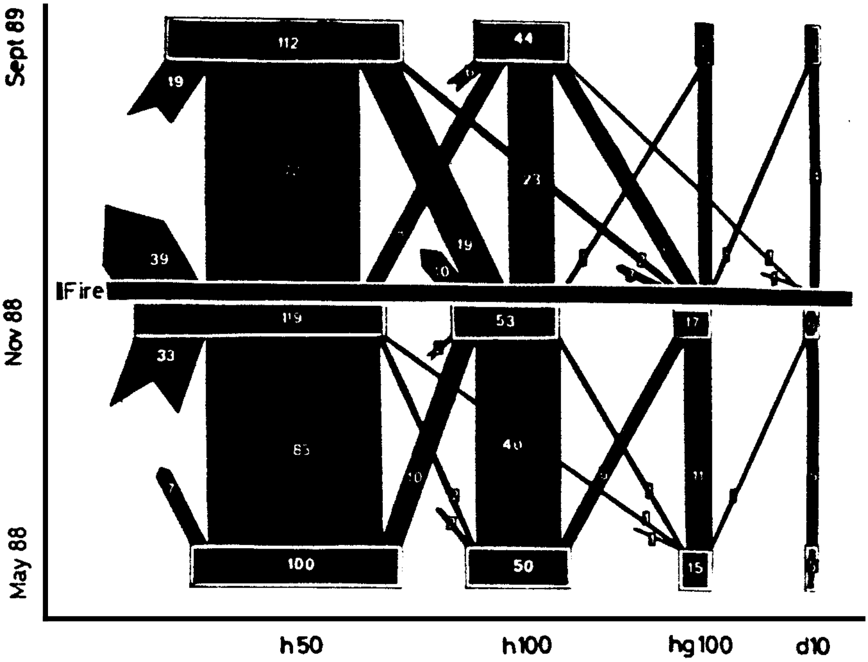
23
h50
h100
hg100
d10
size classes)

9·2

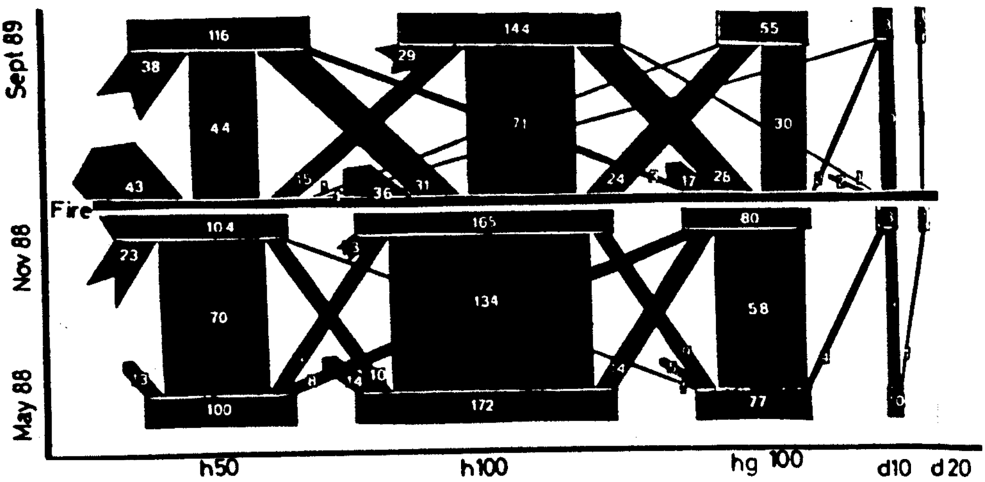
Figures 9.3 and 9.4 Flow charts showing the population flux in the various size classes of stratum 2 (Fig. *9.3)* and stratum 3 (Fig. 9.4) under fire protection and after fire. Time is given in the vertical axis, indicating the direction of flow. Fire incidence is shown by a narrow bar traversing the entire flow chart in the middle. The portion above the fire incidence line pertains to population flux after fire and that beneath the line pertains to that under fire protection. The horizontal boxes at the bottom, middle and top depict the population strength at the different time points of sampling. The vertical and inclined bars represent the population flow between the successive samplings. Bars with arrow head at the bottom and middle, emerging from the horizontal boxes, indicate seedling mortality. Bars with a sagitate base and joining the horizontal boxes at the middle and top depict new recruits. Relative figures and proportionate width of population flux alone are depicted.

d10 - dbh 1–10 cm; *h50* - ht <= 50 cm; *h100* - ht > 50 and <= 100 cm; *hg100* - ht 100 cm and dbh < 1 cm.

93



9.4



size classes)

Table 9.3 Computed values of half life periods (years) under different fire frequencies (simulated data used).

Strata	I Yr	II Yr	III Yr
Stratum 1	6	14-15	63-76(-80)
Stratum 2	6	13-14	72-76(-83)
Stratum 3	6	13-14	72-76(-83)

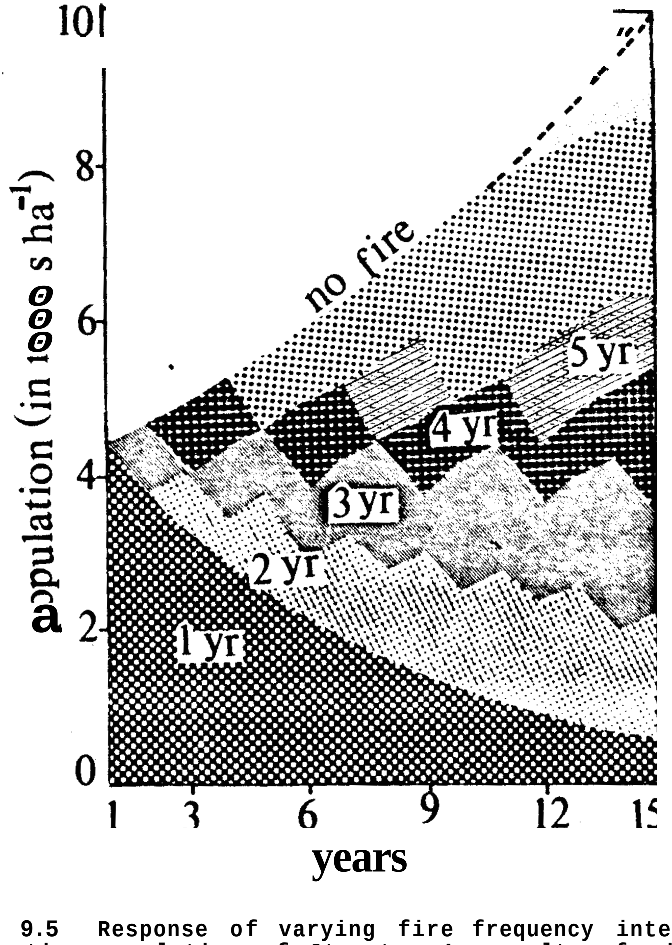


Figure 9.5 Response of varying fire frequency intervals on regeneration population of Staratum 1: results of simulation studdies using matrix model and exponential interpolation of transition probabilities.

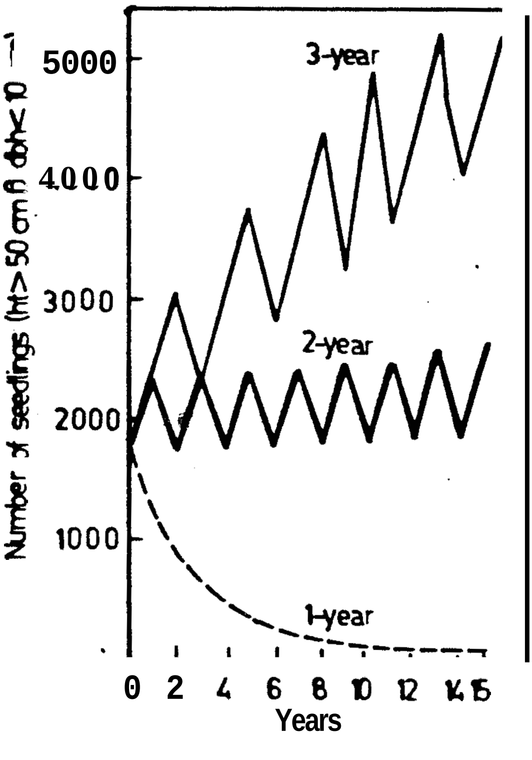


Figure 9.6 Response of varying fire frequency intervals on the population of established seedlings (ht > 50 cm and dbh < 10 cm) of Stratum 1; result of simulation studies using matrix model and exponential interpolation of transition probabilities.

Chapter 10

Synthesis

Contents **Page**

A summary of ohservatinns carried out and the results obtained from the study is given in Table 10.1.

The Reproductory Phase

Studies on the population dynamics of the reproductive life stages of the commercially important tree species of the *Moist Deciduous Forests* showed no abnormalities. The flowering and fruiting periodicities were regularly circannual, in all the species. No gregarious flowering/ mast seeding was evident from the studies. Therefore, there are no significant temporal gaps in the seed source. Litter trap studies showed that there were more than 124 x 106 flowers ha^{-1} yr^{-1} which were capable of producing more than 56 x 106 mature fruits and containing a resource of of 1156 x 106 seeds ha^{-1} yr^{-1}. Such large quantities of flower, fruit and seed overrule the existence of any constraints in the reproductory phase of the commercially important tree species.

At species Level, some commercially important species are known to have constraints of intrinsic and environmental origin. *Lagerstroemia microcarpa* produced millions of seeds of which over 90 percent were without a viable embryo. Perhaps owing to this reason, the species is poorly represented in all stages of regeneration while mature tree phase is fairly well represented. The reason for this state of affairs requires further studies. Investigations into the causes of the production of such large number of sterile seeds and search for alternate methods of multiplication are desirable.

In areas where Malabar giant squirrel inhabits, seeds of *Xylia xylocarpa* are heavily predated (also *cf.* Ramachandran, 1988). Nevertheless, regeneration of the species is more or less satisfactory, presumably because of vegetative reproduction through offsets from roots and root suckers.

Table 10.1. summary of observations and results of the study on commercially Important Trees of SIMDFs of TFD.

s1- No	parameters studied	Observations	Status	
	The Reproductory Phase			
1	Flowering and fruiting periodicities	circannual, regular	OK OK	
2	Flower production	124 mill. ha^{-1} yr^{-1}	OK	
3	Fruit production	56 mill. ha^{-1} yr^{-1}	OK	
4	Seed production	1156 mill. ha^{-1} yr^{-1}	OK	
	The Seedling Phase			
5	Emerging new recruits	10,000 ha^{-1} yr^{-1}	OK	
6	Unestablished Seedlings	3,000 ha^{-1}	OK	1. Forest fire
7	Established seedlings	240 ha^{-1}	UNS	2. Over-grazing
8	Poles	10 ha^{-1}	UNS	3. Illicit cutting
	Mature Tree Phase			
9	stocking	145 ha^{-1}	OK	
10	Mortality rates	1.5% yr^{-1}	?	
11	Unhealthy trees	29%	?	

UNS - Unsatisfactory.

The Seedling Phase

A preliminary survey of the seedling bank had shown an average of more than 3,000 unestablished seedlings of commercially important tree species per hectare. Studies on seedling emergence have shown that every year a population of about 10,000 new recruits enrich the existing seedling bank. Despite such large seedling banks and annual enrichments, the presence of established seedlings (240 ha^{-1}) and poles (10 ha^{-1}) is extremely low.

Semilogarithmic graphs of population structure of several species like *Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa* have shown strong bimodal distributions while in other species like *Terminalia crenulata, T. paniculata* and *Xylia xylocarpa* there are strong depressions in the graphs indicating the paucity of saplings and poles. All these show that the continuity of the process of sylvigenesis is interrupted, especially during conversion from seedling to sapling and sapling to pole stages.

Experimental studies in fire protected samples have brought out that mortality of tree seedlings is less than 10 percent during summer months. This indicates that summer soil moisture depletion in itself is not a serious constraint for sylvigenesis.

By following the life of over 4,000 individual seedlings for a period of two years, it is clear that fire is the single largest factor that acts as a degrading factor in tree regeneration in *MDFs*. Fire apparently is capable of retarding the seedling emergence rates of commercially important tree species, The diaspores (seeds/ fruits) of most commercially important tree species are large enough to be trapped in the thick litter layer available on the ground and as the litter burns seeds also get burnt. Fire is capable of accelerating the rate of mortality to several fold comparaed to that of natality. Enormous number of seedlings die, many loose their above ground portions. As a result, fire retards the rate of natural increase at all levels, thus leading to regression in the populations.

Regeneration is the starting population which in due course undergoes the process of sylvigenesis and builds up the stand. The amount of regeneration (excluding saplings and poles) encountered in natural *Moist Deciduous Forests* gives the impression that they are not. that poor in regeneration. In fact, the situation is very different. The lion's share of the regeneration population in fire infested *Moist Deciduous Forests* has only temporary existence. Being swallowed by fire every year, the regeneration is not available for the process of sylvigenesis (tree building) to advance.

In addition to the deleterious effect on the population, fire also accelerates the conversion of individuals to lower size classes. Side by side with this, it can also cause significant reduction in the conversion of individuals to higher classes. Thus, the process of sylvigenesis slows down considerably leading to degradation of *Moist Deciduous Forests.*

The rate of natural increase of certain commercially important tree species such as *Haldina cordifolia* and *Lagerstroemia microcarpa* is affected very adversely by fire. If annual fire is very regular there is every chance that some of these species get eliminated from the ecosystem altogether, once their adult trees die off.

Simulation studies using the observed probabilities of transition have shown that a low fire incidence frequency such as 3–year frequency would be able to shift the regeneration population from regressive to a stable structure. This would enhance the establishment of advance growth (saplings and poles) to a satisfactory level.

In the study plots, simply by taking fire protection measures alone, more than 85 percent of regeneration could survive. Regeneration loss due to other reasons amounts to just 15 percent. Thus, fire is by far the single largest factor causing heavy damage to the regeneration in *Moist Deciduous Forests.*

Forest fire is invariably of human origin (Fox, 1976). *Moist Deciduous Forests* are burnt by people for various reasons (for a full list please see Basha, 1990). The agricultural lands are on the valleys of these *Moist Deciduous Forests*. Therefore, farmers burn the forest so that the fields are enriched by ash brought through rain water. Fire also helps new grass growth for cattle grazing. The tribals who live inside the forest and the local people who collect minor forest produce such as honey, bark of *Acacia*, and fruits like soap nut *etc*. burn the forest so that undergrowth is removed and walking and collections made easy.

Instances abound from other parts of the world, where uncontrolled grazing and browsing have been proved to be inimical to the regeneration of forest trees (Linhart and Whelan, 1980; G. Singh, 1983; Prasad, 1985; R. P. Sing, 1985). People living close to the forest areas, in the absence of pasture lands, depend the forest for their cattle and goats to graze and

browse. Many people leave the cattle inside the forest and only during times of agricultural field work they bring their cattle back. Likewise, cows are brought back only when they milch. Slaughter house owners also leave their cattle to graze and breed inside the forest. With
the result, at any given time forests are always with a certain cattle population.

The destruction done to the regeneration by sheep herds is murh more destructive. Though Kerala State as such does not have any sheep farming, sheep herds from Tamilnadu, Andhra Pradesh and Karnataka find their feed in many areas of the forests of Kerala. A few months stay of the sheep herds inside the forest devastates all green herbage, including regeneration of tree species. However, no efforts were made to quantify destruction of tree regeneration due to these agents.

Sapling and Pole Stages: The paucity of saplings especially within the size range of 5–10 cm dbh is partly due to illicit cuttings. During the past few years, especially when paddy cultivation has turned out to be uneconomical, the paddy fields in the plains are being put under banana cultivation. In order to protect the plantations from wind damage, support is given for each banana plant. Saplings are regularly extracted from the forests for this purpose. Cutting of poles for the construction of huts, cattle sheds, *etc,* is also quite common. A quantification of this aspect is beyond the scope of this study. But this is also one of the factors leading to the degradation of *Moist Deciduous Foresets.*

The Mature Tree Phase

The mature tree populations, although do not pose serious constraints for the seed source, the amount of fire damage to trees is considerable. Approximately 29 percent of the trees in the study plots were found to have rotten/ decayed holes originating largely from fire damage. These trees on subsequent action by wood decaying fungi get deteriorated and topple down in the strong winds associated with the monsoon rains. Thus the seed source is getting, reduced although not much significant at smaller time scales.

Conclusions

Among the causes of poor natural regeneration of commercially important tree species in the *Moist Deciduous Forests,* fire is the most important factor. Other causes are over–grazing and browzing, illicit cutting of saplings and poles, charcoal making and so on. All these proximate causes for poor natural regeneration are of anthropogenic/ sociological origin.

Recommendations

1. Fire protection is the most important measure to be adopted for augmenting the natural regeneration in the *Moist Deciduous Forests.* This will not only help to improve the regeneration status, but also improve the standing crop and the whole ecosystem. Along with this, cattle grazing, goat/sheep browsing, illicit cutting and charcoal making also need to be controlled for obtaining satisfactory regeneration and sylvigenesis.

2. In the already degraded forests, enrichment plantings with seedlings of native species having commercial value are to be carried out ensuring fire protection, lest the efforts should go wasted.

3. The studies show that the size class 1–10 cm dbh has a 50 percent survival probability under fire and hence standardisation of planting stock and technology of the lower half of the this size class would be a better option in places where full fire protection measures cannot be enforced.

4. The causes of forest degradation being fully anthropogenic creating awareness among the user community involving them in participatory management is to be seriously considered as the adjoining villagers cannot be completely kept away from using the forests for their bona fide purposes.

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