

**Regeneration Status of Some Important Moist Deciduous Forest Trees  
in the Trichur Forest Division**

Regeneration Status of  
Some Important Moist Deciduous Forest Trees  
in the Trichur Forest Division

by

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**THESIS**

submitted in partial fulfillment of the  
requirement for the degree

**MASTER OF SCIENCE IN FORESTRY**

KERALA AGRICULTURAL UNIVERSITY

Faculty of Agriculture

**COLLEGE OF FORESTRY**

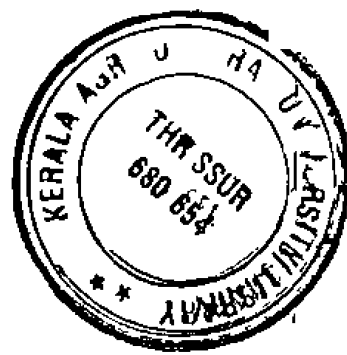
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**Dedicated to**

**My Parents**

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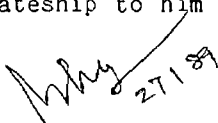


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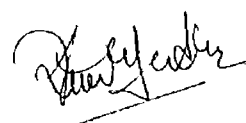
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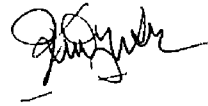
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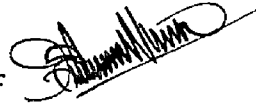
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## ACKNOWLEDGEMENTS

I am happy to place on record my deep sense of gratitude and indebtedness to Dr B Mohan Kumar Assistant Professor College of Forestry and Chairman of the Advisory Committee for his valuable advice and encouragements during the period of this study

I am deeply indebted to Dr K Swarupananadan Scientist Kerala Forest Research Institute Peechi Co Chairman of the Advisory Committee for suggesting this problem for study and for his very valuable guidance and constant encouragements

Sri V R Krishnan Nair Special Officer |College of Forestry was very much helpful and gave propitious support for the successful implementation of this research work

Dr C T S Nair Former Director Kerala Forest Research Institute was very kind enough to permit me to conduct the studies partly in KFRI and also to utilise the Institute Library My heart felt thanks are acknowledged with due respect

Shri N Sasidharan Scientist Kerala Forest Research Institute Peechi and Member Advisory Committee to whom I owe my sincere thanks for his constructive suggestions and help rendered during my field trips

Dr K V Satheesan Assistant Professor College of Forestry Member of the Advisory Committee to whom I am grateful for his whole hearted co operation during this study

Many staff members of the Kerala Forest Research Institute helped me in various ways Foremost among them is Dr P Vijayakumaran Nair Scientist in Charge Wild Life Division who prepared an efficient computer programme solely for the analysis of the data of my study He was very kindful to allow me to use a computer programme developed by him for plotting graphs without which it would have been much cumbersome I hereby place on record my deep sense of obligations and thanks to him

Dr A R R Menon was very helpful by providing some statistics of Trichur Forest Division Dr K V Sankaran Sri M Balasundarn Smt E J Maria Florence were very helpful in various ways Smt P Rugmini kindly provided some statistical assistance

Constant encouragements and other helps offered by Shri T Surendran is acknowledged with due gratitude

The timely help and assistance rendered by my friends Mr T P Gopalakrishnan Mr Azad Mr Santhosh Mr E V Anoop Mr V Syam Mr Mohan Varghese Mr K Venugopalan Mr P Ali and others during field work are gratefully remembered

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# ABBREVIATIONS

|       |                                |      |                                 |
|-------|--------------------------------|------|---------------------------------|
| ADNO  | Adaptation Number              | Kp   | the locality Karadippara        |
| C     | Celsius ( $^{\circ}$ C)        | Kt   | the locality Kuthiran           |
| CI    | Continuum Index                | Loc  | Locality                        |
| cm    | centimeter                     | MDF  | Moist Deciduous Forest          |
| D     | Density                        | Max  | Maximum                         |
| DBH   | Diameter at Breast Height      | Min, | Minimum                         |
| DI    | Disturbance Index              | Mp   | The locality Mundippadam        |
| DPH   | Density Per Hectare            | m    | meter                           |
| d10   | DBH > 1 cm and < 10 cm         | mm   | millimeter                      |
| d20   | DBH > 10 cm and < 20 cm        | No   | Number                          |
| d30   | DBH > 20 cm and < 30 cm        | PC   | Percentage Composition          |
| d40   | DBH > 30 cm and < 40 cm        | Pk   | the locality Pathrakkallu       |
| d50   | DBH > 40 cm and < 50 cm        | RD   | Relative Density                |
| d60   | DBH > 50 cm and < 60 cm        | RDI  | Relative Disturbance Index      |
| dg60  | DBH > 60 cm                    | RIVI | Relative Importance Value Index |
| GBH   | Girth at Breast Height         | SD   | Standard Deviation              |
| ha    | hectare                        | SE   | Standard Error                  |
| h50   | height < 50 cm                 | Sp   | Species                         |
| h100  | height > 50 cm and < 100 cm    | Spp  | Species                         |
| hg100 | height > 100 cm and DBH < 1 cm | Stat | Statistic                       |
| ht    | height                         | TFD  | Trichur Forest Division         |
| IVI   | Importance Value Index         | Vz1  | the locality Vazhani-1          |
| Ke    | the locality Kalluchal         | Vz2  | the locality Vazhani 2          |
| km,   | kilometer                      | Vz3  | the locality Vazhani 3          |

## Introduction

## 1 INTRODUCTION

The science of forest management remained stagnant for approximately half a century because of its strong bias for monoculture plantations. However, having experienced with the demerits of the homogenous 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 are a sine qua non in developing practical methods for sustainable management. Thus, research with the aim of acquiring basic information on ecosystem dynamics are in progress in various parts of the world (Bawa 1974, 1979, 1983, Bawa et al 1985, Chan 1981, Frankie et al 1974, Janzen 1978, Leigh et al 1982, Sutton et al 1983).

Regeneration is the process of sylvigenesis (forest building cf. Halle and Oldeman 1978) by which trees and forests survive over time. Unlike homogeneous plantations, management of mixed resources rely largely on natural regeneration. Successful management therefore depends on good natural regeneration of valuable species. Regeneration dynamics is one of the thrust areas of scope for intensive research. The final goal of these research programmes should be to evolve methods to harmonise the rates of exploitation and regeneration by being able to manipulate the patterns of regeneration to desired quantities and qualities.

Because of the fragile nature round the globe evergreen forests receive much attention on the above lines. On the other hand the mixed deciduous forests did not receive much attention. The moist deciduous forests are commercially much more important and human dependence on this forest type is greater than on evergreens. In fact the problem of the moist deciduous forests are much more acute than that of the evergreens the situation being complicated with a high degree of anthropogenic constraints.

Kerala has approximately 3 140 km<sup>2</sup> of moist deciduous forests. They are the habitats for our most valuable timber species like rose wood (Dalbergia latifolia Roxb. D. sissooides Grah et Wt et Arn) teak (Tectona grandis Linn f) irul (Xylia xylocarpa (Roxb) Taub) maruthi (Terminalia crenulata Roth T. paniculata Roth) ventek (Lagerstroemia microcarpa Wt) chadachi (Grewia tiliifolia Vahl) vaga (Albizia odoratissima (Linn f) Benth) manjakkadambu (Haldina cordifolia (Roxb) Ridsd) etc. Regeneration is very poor in many areas of these moist deciduous forests and very unsatisfactory for many of the economically 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 topic for the present study was undertaken so as to have a general idea of the demographic

status of the moist deciduous forests The Trichur Forest Division has a preponderance of moist deciduous forests and therefore this area has been selected accordingly for the study

In Forestry generally 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 adult trees passing through fruits seeds seedlings saplings and poles Thus in a wider sense the term applies to all life stages of the plant Regeneration assessment to be helpful in identifying the constraints must therefore embrace all the life stages This is a strenuous piece of study requiring a longer span of time However because of the time limitations the present study is restricted to the demographic details of size classes starting from seedlings The study was undertaken with the following objectives

- 1 To have a preliminary idea whether the forests have ample regeneration
- 2 To get a general idea of regeneration dynamics and its constraints in the forests
- 3 To identify the constraints of regeneration specific to selected commercially important species by demographic means and
- 4 To know the role of gaps in the regeneration dynamics of commercially important species

## Study Area

## 2. STUDY AREA

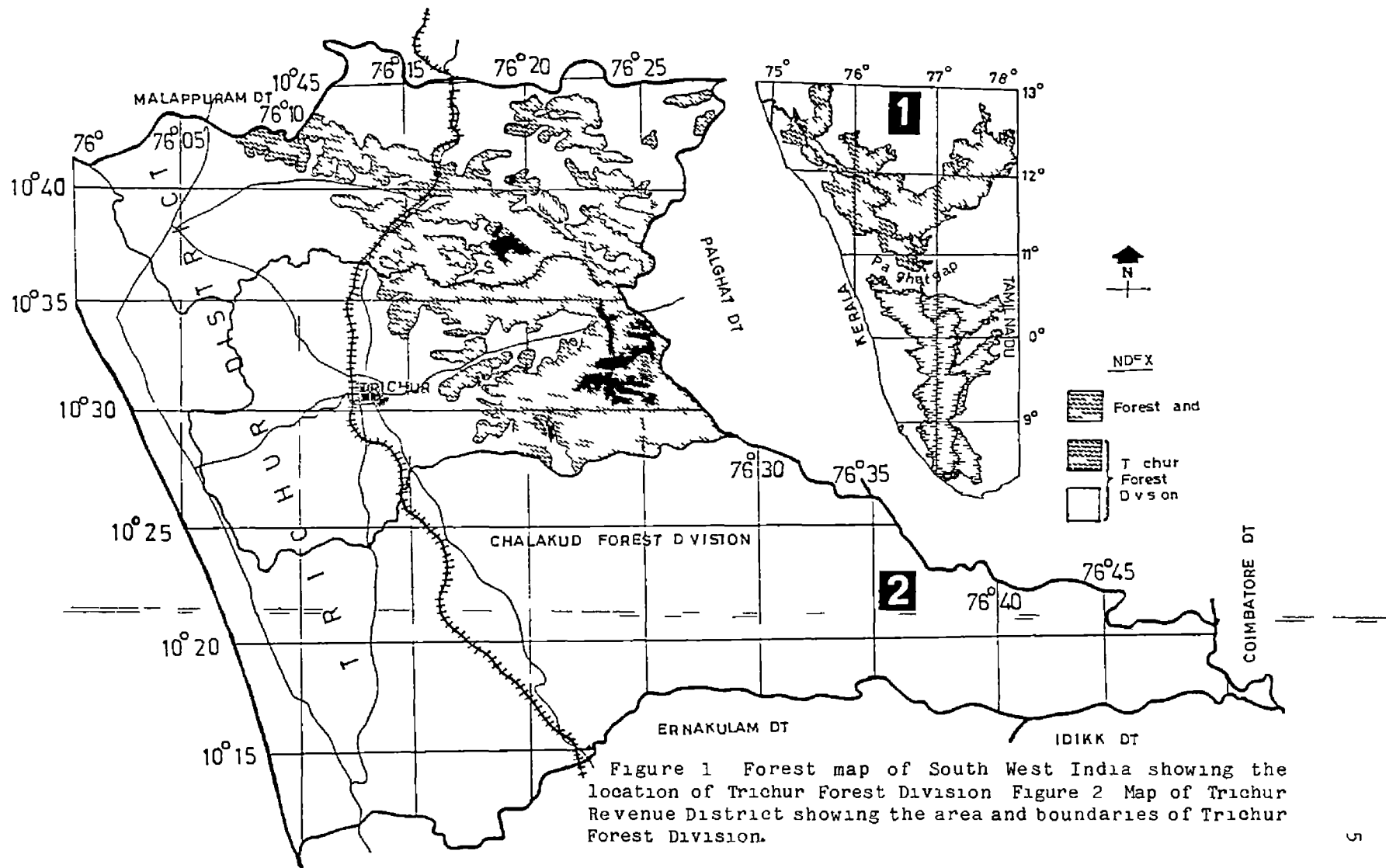
### Location and Area

The biogeographic region 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 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 respectively (Figure 2 George 1963).

The Division falls wholly within the limits of the Trichur Revenue District of the Kerala State and lies between the latitudes  $10^{\circ} 25'$  and  $10^{\circ} 45'$  N and longitudes  $76^{\circ} 05'$  and  $76^{\circ} 30'$  E. As reconstituted in 1980 it comprises an area of approximately  $328 \text{ km}^2$  of forests divided into four administrative blocks viz Wadakkanchery, Machad, Pattikkad and the Peechi Ranges (cf Figure 3). Of the above the Natural Forests the area of the present study constitutes approximately  $204 \text{ km}^2$  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 monsoon which showers between June to September especially during June and July. The north east monsoon showers during the later part of year between October to November. The annual total for the last 10 years (1978-1987) ranges between 2793.08 and 3599.4 mm with the mean value being 2793.08 mm. The details of distribution of precipitation for an average year (for the term refer Meher Homji 1979) 1985 for Peechi (Trichur Forest Division) are given in Table 1.

The temperature extremes recorded for the past few years for Peechi are 18.9° C and 39.4°C. The details of temperature fluctuations during 1985 are given in Table 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° 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 borders 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 statistic for 1985 for Peechi are given in Table 1.

Figure 4 is an ombrothermic graph for 1985 for Peechi. Generally May to October are wet months and November to April are dry.

Table 1 Statistic of climatic variables during an average year (1985) at Peechi

| Var Stat     |       | Months |      |      |      |       |       |       |       |      |       |      |      |
|--------------|-------|--------|------|------|------|-------|-------|-------|-------|------|-------|------|------|
|              |       | J      | F    | M    | A    | M     | J     | J     | A     | S    | O     | N    | D    |
| Temp<br>(°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<br>(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<br>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 |

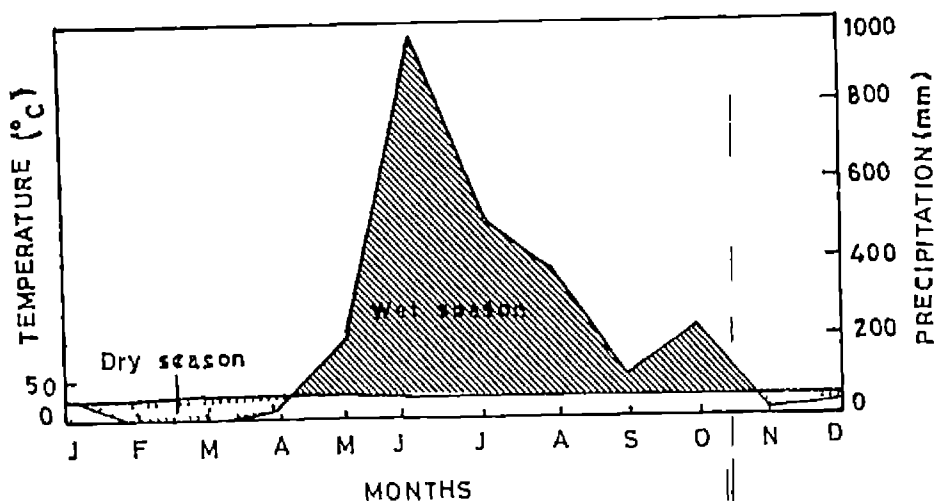


Fig 4 Omb otherm for Peech

## 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 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
- 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 200 m 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
- 5 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 Dams irrigating the agricultural lands along the west

### Geology Rock and Soil

The predominant parent material seen is of metamorphic rocks of the gneiss series weathering in large sheets especially on the upper elevations. However on the lower slopes the rocks tend to become lateritic. Occasionally on the higher ups exposed banks show the occurrence of lateritic parent materials. Owing to active weathering the ground is very much bouldry especially in the moist deciduous forests. The soil is blackish or reddish and loamy.

### Vegetation

The forest land is recognizable into three kinds open blanks plantations and natural forests. Of these the natural forests comprise moist deciduous semievergreen and evergreen forest types.

The dominant species in the evergreen forests are Dipterocarpus indicus Bedd Calophyllum apetalum Willd Mesua ferrea Linn Palaquium ellipticum (Dalz ) Baillon Syzygium chavaran (Bourd ) Gamb S. gardneri Thw etc

The dominant species of the semievergreens are Polyalthia fragrans (Dalz ) Bedd Diospyros crumenata Thw Hopea parviflora Bedd Diospyros buxifolia (Bl ) Hiern etc

The details of the moist deciduous forests being the subject of the present study are given in detail in subsequent Sections

### Settlements

On all 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 NH 47 bisects it into two north-south halves Some of the other important roads are

- 1 Chelakkara Elanad Rd    4 Trichur-Ramavarmapuram Vazhani Rd
- 2 Wadakkanchery Vazhani Rd    5 Trichur Shoranur Rd    and
- 3 Trichur-Mannamangalam Rd    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 Ollukkara are by tradition dependent on the forests for their livelihood

## Materials and Methods

### 3 MATERIALS AND METHODS

#### The Moist Deciduous Forests

The Moist Deciduous Forest (MDF) ecosystem of the Trichur Forest Division (TFD) distributed between  $\pm 25$  m and 928 m (Ponmudi) is a complex association of different kinds of habitats like reservoirs man made forests and natural forests. Along the upper reaches of elevation it forms part of the insulation belt around the wet evergreen forest formations of the Western Ghats (Figure 1). On the lower reaches they are surrounded by settlements and agricultural lands (Plate I).

The Division at present holds a total of  $162 \text{ Km}^2$  of natural moist deciduous forests covering 80 % of the whole natural forests. In the past a good percentage of the moist deciduous forests were converted into Bombax and teak plantations (Figure 3). The area occupied by the two reservoirs were also moist deciduous forests. Once probably the open lands were also moist deciduous forests that gradually degraded due to overexploitation. Thus a total of  $159 \text{ km}^2$  of moist deciduous forests were devastated from the Division in the past. At present natural moist deciduous forests are restricted to the Peechi Pattikkad and the Machad Ranges. The natural moist deciduous forests of Wadakkanchery Range have been completely converted to plantations (Figure 3).

Undisturbed natural moist deciduous forests are totally absent in the Division. Some less disturbed areas are met at Karadippara (Peechi Range).



Plate I. 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).

During the wet season because of the thick foliage the moist deciduous forest do not permit light to reach the ground and thereby mimics the evergreen forest type. During this season their surface morphology is very much like that of the evergreen and therefore the two types of forests are scarcely distinguishable (Plate II Figure 1). However during the dry season the MDFs reveal their identity as the trees dehisce their foliage and leaves the vertical structure of the stands pellucid to light rays (Plate II Figure 2 Plate III Figure 1 & 2).

Champion and Seth (1968 a) classified the MDFs of India into three regional types viz South Indian North Indian and the Andaman Nicobarican. Of the South Indian type they further recognized three subtypes the moist teak bearing forests dry teak bearing forests and the moist mixed deciduous forests. Majority of the MDFs of Kerala fall under the last category. MDFs of TFD comes closer to the Sungam regional type of moist mixed deciduous forest recognized by Chandrasekharan (1962).

#### Species Composition

A list of the common tree species encountered in this forest is given in Table 2 and some important species are photographed in Plate IV.

#### Vertical Structure

Standard profile diagrams of three strips representing varying levels of disturbance are given in Figures 5-7. The trees are stratified into three viz upper (I<sup>st</sup>) middle (II<sup>nd</sup>) and lower (III<sup>rd</sup>) strata.

Table 2 List of tree species arranged according to the r strata

Upper stratum

- 1 Albizia odoratissima (L f ) Benth
- 2 Alstonia scholaris (L ) R Br
- 3 Bombax ceiba L
- 4 B insigne Wall
- 5 Dalbergia sissooides Wt et Arn
- 6 Dillenia pentagyna Roxb
- 7 Gmelina arborea Roxb
- 8 Grewia 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

- 22 Aporosa 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 f stula L
- 29 Cleistanthus coll nus Hook f
- 30 Cordia wallichi G Don
- 31 Dalbergia lanceolaria L f

- 32 Diospyros montana Roxb
- 33 Emblica officinalis Gaert
- 34 Ervatamia heyneana (Wall ) Cooke
- 35 Ficus exasperata Vahl
- 36 F mysorensis Heyne ex Roth
- 37 Garuga floribunda Dene
- 38 Hymenodictyon orixense (Roxb ) Mabb
- 39 Litsea sp
- 40 Mitragyna parvifolia (Roxb ) Kunth
- 41 M tubulosa (Arn ) Havil
- 42 Macaranga peltata (Roxb ) Muell Arg
- 43 Mallotus 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 Schleicheria 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 ) Bl
- 58 Vitex altissima L f
- 59 Xeromphis sp nosa (Thunb ) Keay
- 60 X uliginosa (Retz ) Mahesh

Lower stratum

- 61 Casearea sp
- 62 Holarrhena ant dysenterica (Roth)DC
- 63 Naringi crenulata (Roxb ) Nicols
- 64 Wrightia tinctoria (Roxb ) R Br

\* Exotic or semievergreen immigrants seen only as seedlings



Plate II. Physiognomy of the moist deciduous forest during wet and dry seasons. A. Wet season (September). B. Dry season (April) - (Chathupara, Peechi Forest Range, 1988).



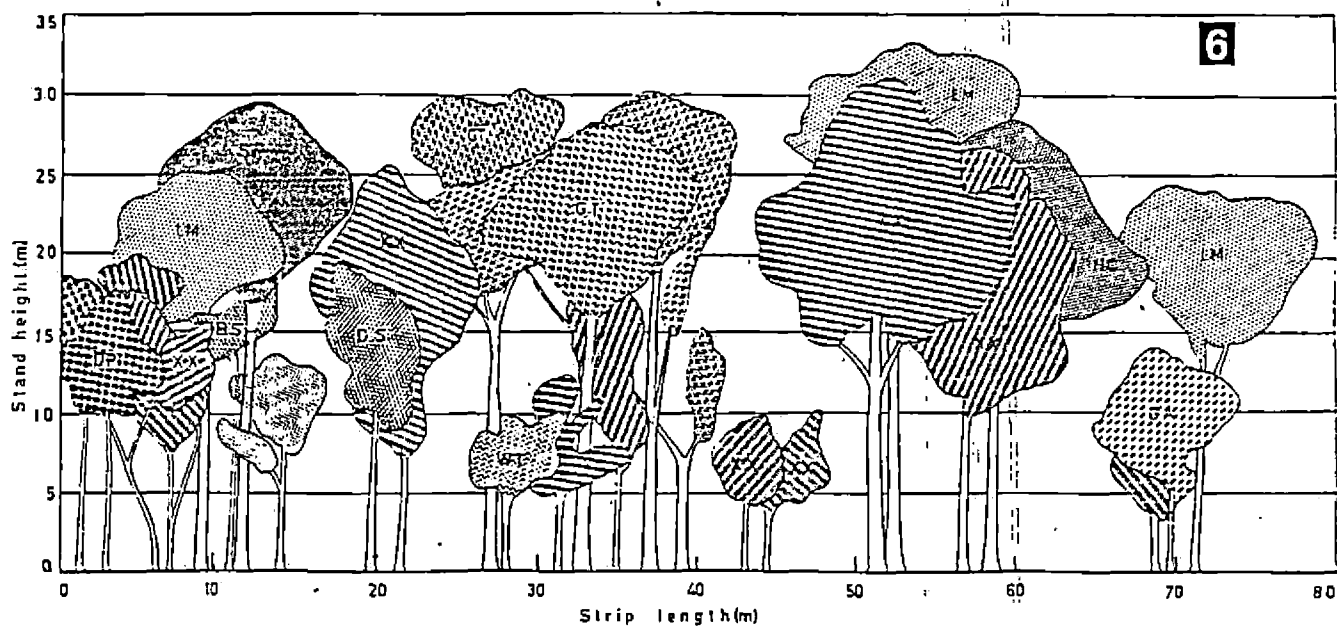
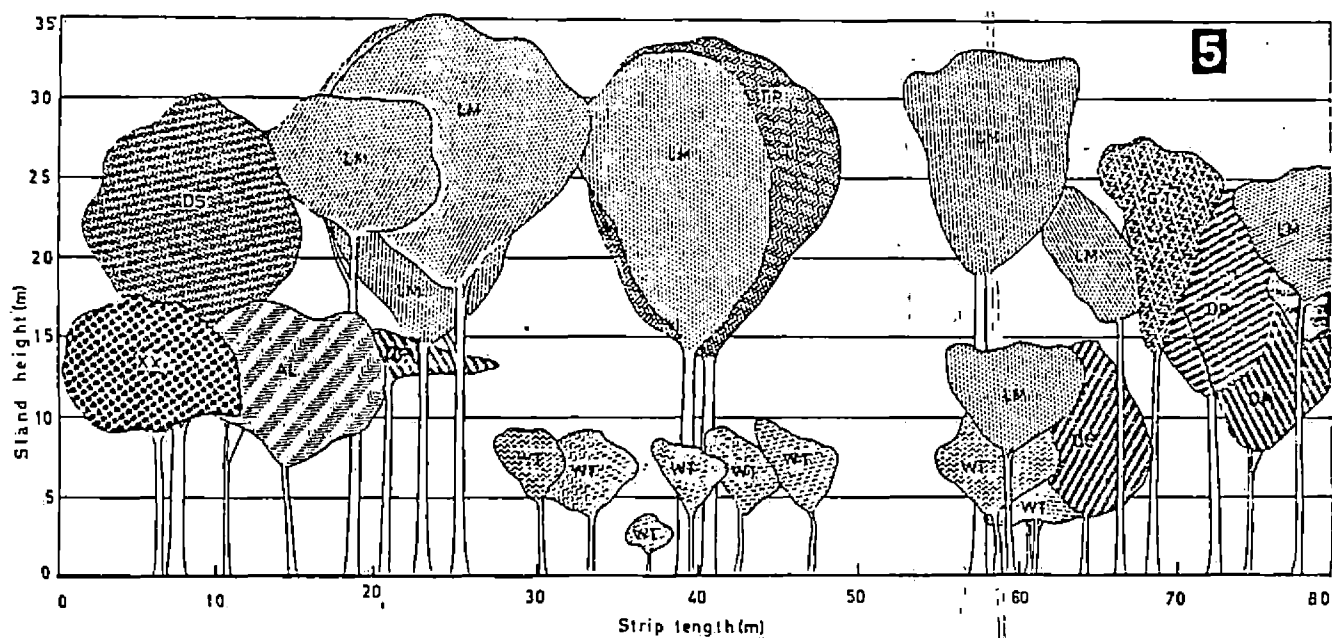
Plate III. Moist deciduous forests of Trichur Forest Division. A. A view from above (Chathupara, Peechi Forest Range, April 1988). B. A view of the stand from below (Vazhani, Machad Forest Range, April 1988).

The upper stratum is 25-35 m in height. Some 20 species are recorded in this stratum (Table 2). The middle stratum ranges between 18 to 25 m in height. About 40 species are known from this stratum (Table 2). The lower stratum grows up to 10 m height. Only 4 species are known from this stratum (Table 2). The shrub layer mainly consists of Helecteris isora, Eupatorium odoratum and to a lesser extent Lantana camera.

#### Horizontal Structure

The area does not show any character species association (Menon and Balasubramanyan 1985). Dominant sylvan community of the medium ranked association is composed of species like Xylia xylocarpa, Dillenia pentagyna, Tectona grandis, Grewia tiliifolia, Terminalia paniculata, T. crenulata and Lagerstroemia microcarpa (Plate V Figure A). In better moisture regimes and less disturbed areas a preponderance of Lagerstroemia microcarpa is seen (Eg. Karadippara - Plate V Figure B). In drier regimes especially with underlying rock formations Anogeissus latifolia (a representative of the dry deciduous forest) appears in association with Pterocarpus marsupium (Eg. Pathrakkallu Machad Range) or with T. crenulata (Eg. Vazhani - Plate V Figure C). However, the extent of these specialised communities are 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.

The sylvan communities are also well represented with lianous species like Acacia sp., Butea parviflora Roxb. (Plate IV



Figures 5-6. Vegetation profiles of selected sample localities. 5. Karadippara. 6. Kalluchal (individuals  $\geq 10$  cm DBH of tree species alone depicted).

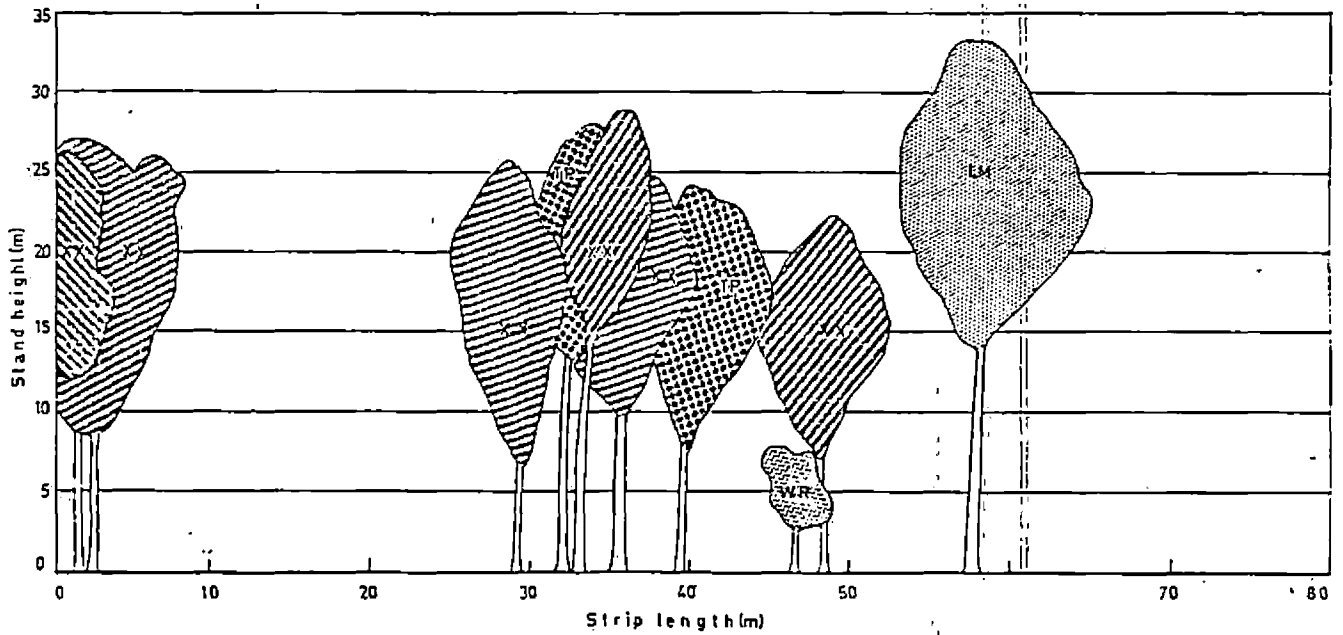


Figure 7. Vegetation profile of the locality Kuthiran  
(individuals  $\geq 10$  cm DBH of tree species alone depicted). ||



Plate IV. Species composition in the moist deciduous forests of Trichur Division. A. Terminalia paniculata (in fruit). B. Dillenia pentagyna (in flower). C. Terminalia crenulata. D. Tetrameles nudiflora (in flower). E. The lianous climber Butea parviflora.



Plate V. 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 - Terminalia crenulata community (Vazhani, Machad Forest Range, April 1988).

Figure E) Calycopteris floribunda Lamk Dalbergia volubilis Roxb and Zizyphus rugosa Lamk (not represented in the profile diagrams)

### Methodology

**Sample Selection** In estimating the regeneration status conventional phytosociological methods were followed Initially many moist deciduous forest localities of the Trichur Forest Division were visited The areas visited during this reconnaissance study were 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 Based on the forest type map prepared by Menon and Balasubramanyan (1985) and the visual observation on stand composition density and degree of variability of stands eight localities were selected for sampling The localities are Karadippara Kalluchal Kuthiran Mundippadam Pathrakkallu Vazhani-1 Vazhani 2 and Vazhani 3

**Size of Relve** Since most parts of the MDFs are highly disturbed species area relation were worked out for a least disturbed near natural site (Karadippara) and a more or less disturbed site (Kalluchal) The experiment was conducted in permanent two hectare plots gridded at 10 m espacement

Using the species area guide line and the nested plot technique Sharma et al (1983) had standardised the releve size

for South Indian MDFs as  $20 \text{ m}^2$ . Here they took 3 m as the lower threshold for consideration as a tree.

However, in the present study 30 cm GBH ( $\approx 10$  cm DBH) was taken as the lower limit for consideration as a tree. This change in the criterion was due to two reasons. First, that in most forested habitats regeneration is largely seed based. Most of the commercially important trees flower and fruit only after acquiring a certain age. The age and size at first flowering of our trees are not known. However, 30 cm GBH was taken as the criterion for consideration as a mother tree. Therefore, releve must be the sample size in which the fluctuation of number of species in terms of mother trees is minimum. Secondly, in recent years a general discontent in smaller sample sizes are obvious in forest ecological studies. In many structural studies involving international comparison, 1 ha sample size has been used (cf Gentry 1988). In other long term studies 20 to 50 ha sample sizes are being used (cf Hubbell and Foster 1983).

Considering the above points, in order to get a justified releve size, 30 cm GBH and above were taken as trees and species-area relation were worked out using the expanding quadrat method (Bharucha and de Leeuw 1957). The results are given in Figure 8. From the graph obtained, the size of releve was determined, whereafter a 10 % increase in area scarcely leads to 10 % increase in species. Thus at Karadippara, releve size turned out to be  $90^2 \text{ m}^2$  and at Kalluchal  $60^2 \text{ m}^2$  (Figure 8). Accordingly

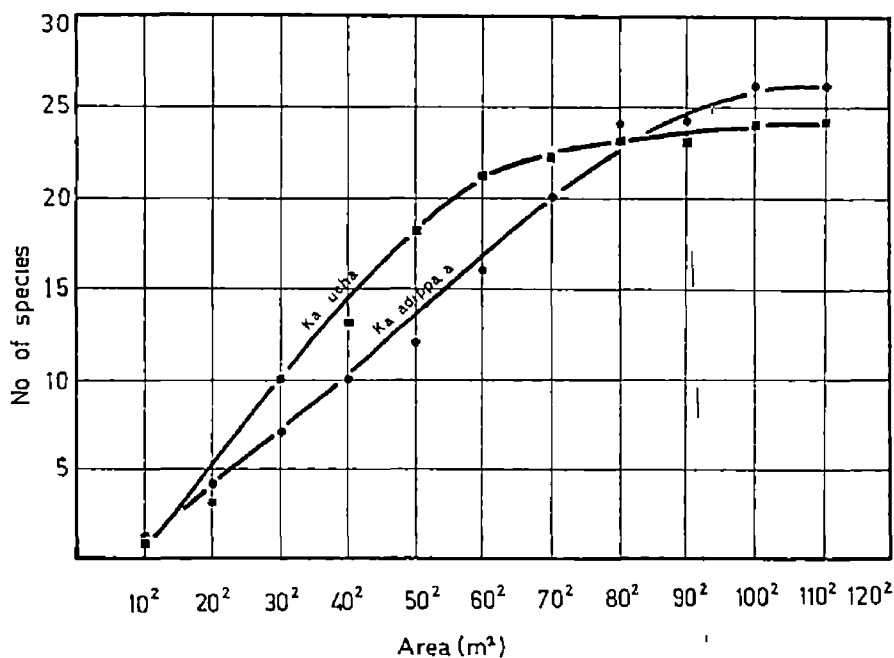


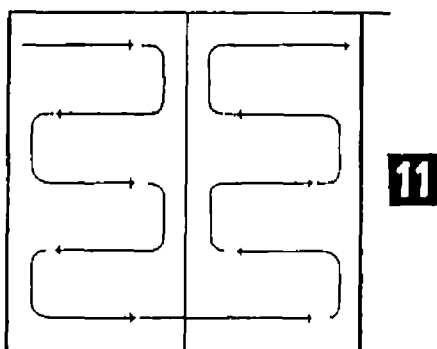
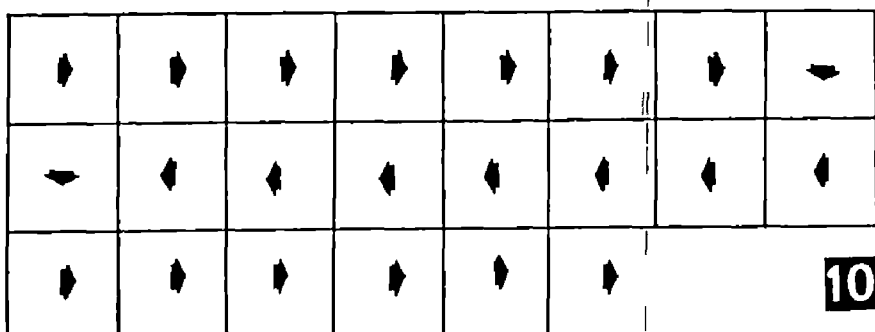
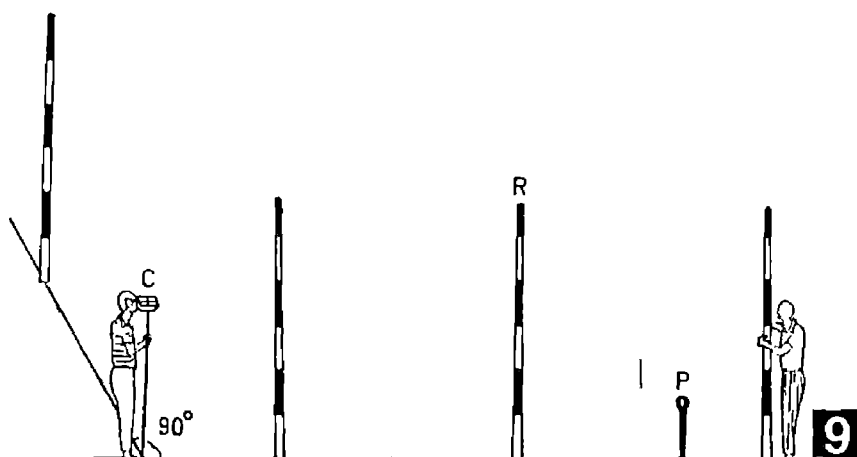
Figure 8 Species area curves and actual data points for two sample localities  
 Regression equations for the localities are  
 1 Kalluchal  $y = 26.9966 + 12.8745 \log x$   
 2 Karadippara  $y = -30.5411 + 13.6009 \log x$   
 $R^2 = 0.919^{**}$  where  $y$  is the number of species and  $x$  the area in  $m^2$

releve of size  $60^2 \text{ m}^2$  was studied for each locality except Karadippara

**Sample Plots** Once the size of the releve was determined three permanent plots were established at Karadippara Kalluchal and Kuthiran being representative samples for different canopy opening levels These plots were surveyed with the help of cross staff and ranging rods (Figure 9) The plots were divided into 10 m X 10 m grid and the quadrats were marked with painted pegs

In localities where permanent plots were not marked studies were conducted in temporary plots In demarkating the temporary plots the following methods were adopted A right angled triangle of sides 3 m 4 m and 5 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 Figure 10

**Releve Record** Preparatory to regeneration enumeration based on general visual observations a releve record was obtained of the localities (cf Tables 3 10) Elevation aspect slope dominant species undergrowth soil and the kind of disturbances noted in the field



Figures 9-11 Methods used in the regeneration survey  
 9 Survey of permanent sample plots with the help of cross staff and ranging rods  
 10 Sequence of quadrat laying (quadrat size  $100 \text{ m}^2$ )  
 11 Sequence of measurement of individuals in a quadrat

C cross staff P peg R ranging rod

Table 3 Relieve record for locality Karadippara(Kp)

Latitude 10° 15 Longitude 76° 24 Altitude +230 m

Administrative block Peechi Forest Range

Location About 2 km south east of Peechi Reservoir on the peak  
of Karadippara hillocks

Aspect South east Slope Gentle

Ground Occasionally bouldry rock formations close  
to the sample plot Soil Deep blackish loam

Profile T1 Xylia Dalbergia sissoides Grewia Lagerstroemia  
Tectona Dillenia  
T2 Aporosa Strychnos Bauhinia Sterculia guttata  
Macaranga  
T3 Holarrhena Wrightia  
Cl Acacia intsia Calycopteris Spatholobus  
S Eupatorium Clerodendron Helicteres

Remarks The locality is heavily exploited for the extraction of  
MFP by the hill men canopy is almost closed pole  
crops are practically absent fire usual during the  
summer months grazing and browsing much less when  
compared to other localities

Table 4 Relieve record for locality Kalluchal(Kc)

Latitude 10° 30 57 Longitude 76° 22 38 Altitude +180 m

Administrative block Peechi Forest Range

Location About 8 km south east from Kerala Forest Research Inst  
1.5 km east of Thamaravellachal

Aspect South west Slope very gentle

Ground Rock formations close to sample plot Soil Blackish loam

Profile T1 Xylia Terminalia bellirica T. paniculata Grewia  
Lagerstroemia  
T2 Bridelia Cleistanthus Schleichera Dalbergia  
lanceolaria  
T3 Casearea Wrightia  
Cl Acacia intsia Zizyphus rugosa  
S Eupatorium Helicteres

Remarks Stand somewhat disturbed but still with almost closed canopy  
fire recurrent grazing common cut stumps of poles are  
occasional being cut by local people

Table 5 Relieve record for locality Kuthiran(Kt)

Latitude 30°34 12 Longitude 76°23 Altitude +180 m

Administrative block Pattikkad Forest Range

Location About 15 km away from NH 47 on the crest of the Kuthiran hill and about 1 km away from the Vana Vigyan Kendra

Aspect Easterly Slope Almost flat

Soil Blackish loam

Profile T1 Xylia Terminalia bellirica T paniculata  
Grewia Lagerstroemia Tectona and Dillenia absent  
 T2 Trees of this layer practically absent  
 T3 Holarrhena Wrightia  
 C1 Zizyphus rugosa  
 S Eupatorium Helicteres

Remarks Intermittent fire common shrub layer dominated by the regeneration of Wrightia browsing and grazing very common.

Table 6 Relieve record for locality Mundippadam(Mp)

Latitude 10°36 Longitude 76°23 1 Altitude +180 m

Administrative block Machad Forest Range

Location About 1 km away from the Mundippadam settlements

Aspect North west Slope 9 per cent

Soil Blackish loamy

Profile T1 Xylia Grewia Terminalia bellirica Dalbergia  
 S Helicteres Eupatorium

Remarks Stand density poor charcoal making active in these forests regenerataion of Sterculia guttata present

Table 7 Relve record for locality Pathrakkallu(Pk)

Latitude 10°36 8 Longitude 76°23 46 Altitude +120 m  
 Administrative block Machad Forest Range  
 Location About 1 km away from the Eucalyptus coppice plantation  
 Aspect Southerly Slope 1 per cent almost flat  
 Ground bouldry Soil Blackish loamy  
 Profile T1 Xylia Grewia Terminalia paniculata Lagerstroemia  
 S Helicteres Eupatorium  
 Remarks Stand density poor grazing and fire heavy | regeneration  
 of Xylia some what satisfactory

Table 8 Relve record for locality Vazhani 1(Vz1)

Latitude 10°38 53 Longitude 76°18 44 Altitude +180 m  
 Administrative block Machad Forest Range  
 Location About 1.5 km north east of the Vazhani dam situated in the  
 catchment  
 Aspect South west Slope 13 percent  
 Soil Blackish  
 Profile T1 Xylia Tetrameles T paniculata Grewia Pterocarpus  
Dillenia  
 T2 Bridelia  
 C1 Spatholobus  
 S Eupatorium Helicteres  
 Remarks Stand moderately disturbed fire recurrent vigorous  
 growth of Xylia root suckers met with

Table 9 Releve record for locality Vazhani-2(Vz2)

Latitude 10°38 52 Longitude 76°18 42 Altitude, ±125 m

Administrative block Machad Forest Range

Location About 2 km north east of the Vazhani dam situated  
in the catchment

Aspect South west Slope 1 per cent

Soil Blackish

Profile T1 Xylia Grewia Bombax Albizia Terminalia paniculata  
          Dillenia  
          C1 Spatholobus  
          S Mainly Eupatorium

Remarks Stand density poor regeneration of Xylia from root suckers  
abundant grazing very much

Table 10 Releve record for locality Vazhani 3(Vz3)

Latitude 10°38 52 Longitude 76°18 45 Altitude ±115 m

Administrative block Machad Forest Range

Location About 15 km eastward of the Vazhani dam

Aspect Southerly Slope 12 64 percent

Soil Reddish

Profile T1 Xylia Grewia Dillenia Terminalia paniculata  
          C1 Spatholobus  
          S Helicteres Eupatorium

Remarks Stand density poor

**Profile Diagram** A mimic of the physiognomy of the stands in the permanent plots at Karadippara Kalluchal and Kuthiran were depicted in the form of a profile diagram. The profile diagram is a physical size to scale pictorial transectional representation of a representative segment of the forest stand. These diagrams were prepared using the methodology described by Richards (1952). A strip of 10 m X 80 m stand was demarkated in a gridded plot. A linear representation of this strip is made in a size to scale graph ignoring the width of the strip. The position of each tree was marked on the line. GBH, total height, height to first branch etc. were recorded using a multimeter. Crown diameter was measured by tracing it on the ground with the help of two long rods. The vertical projection of crown shape of each tree was drawn by hand in the field. From these pictorial and quantitative data obtained, the profile diagram was synthesised keeping the measurements to scale (cf. Figures 5-7).

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

Quadrats for regeneration enumeration were outlined by tying coloured nylon ropes on the pegs (Plate VI, Figure C). 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 up to 1 m height; 2. girth of all individuals > 1 cm GBH (Plate VII, Figure A); 3.



Plate VI. Method of field work. A. Camp shed at Karadippara. B. Team work in the field. C. Quadrat laying.

the size class between  $> 1$  m height and  $< 1$  cm GBH were not measured but merely counted and recorded. Measurement of various size classes mentioned above were done in the following sequence. Once the size of all trees above 30 cm GBH was measured in a 10 m X 10 m plot, 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 (Plate VII, Figure B & C) following a path as illustrated in Figure 11.

**Regeneration in Gaps:** This experiment was conducted in the three permanent plots. Ten samples of varying gap percentages were identified (Table 11).

Table 11. Samples studied for estimation of cover gap.

| Plot No | Locality | Sample (m <sup>2</sup> ) | Gap (m <sup>2</sup> ) | Gap % |
|---------|----------|--------------------------|-----------------------|-------|
| 6       | Kc       | 1600                     | 19.36                 | 1.21  |
| 3       | Kp       | 2100                     | 83.58                 | 3.98  |
| 7       | Kc       | 1700                     | 184.79                | 10.87 |
| 5       | Kc       | 2100                     | 361.83                | 17.23 |
| 1       | Kp       | 2300                     | 421.59                | 18.33 |
| 8       | Kt       | 2000                     | 402.20                | 20.11 |
| 4       | Kp       | 1200                     | 261.72                | 21.81 |
| 9       | Kt       | 2000                     | 479.00                | 23.95 |
| 2       | Kp       | 1500                     | 394.95                | 26.33 |
| 10      | Kt       | 2400                     | 725.28                | 30.22 |

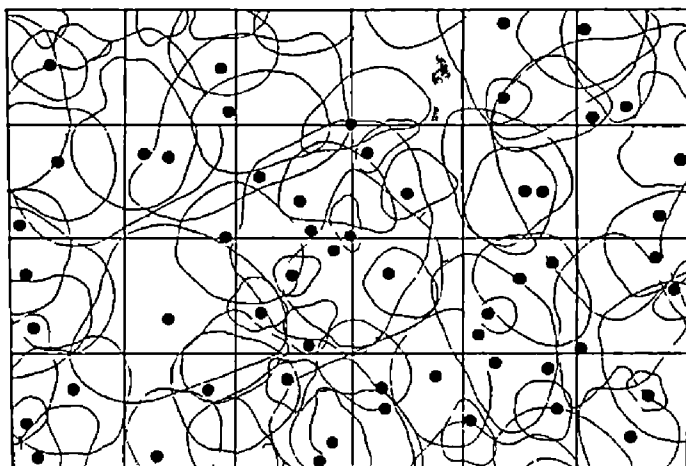
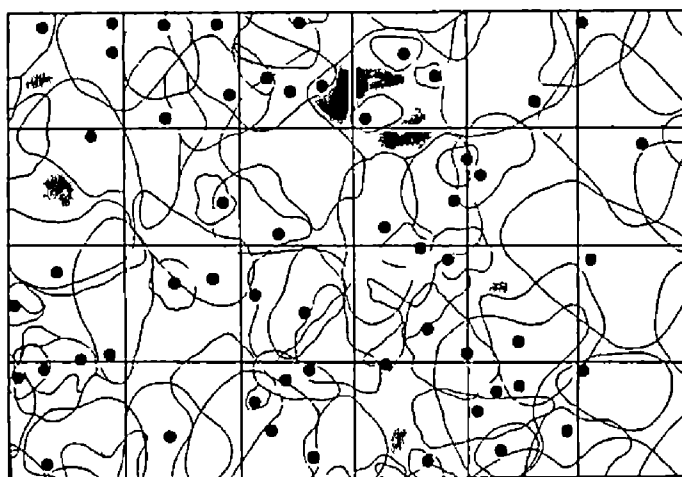
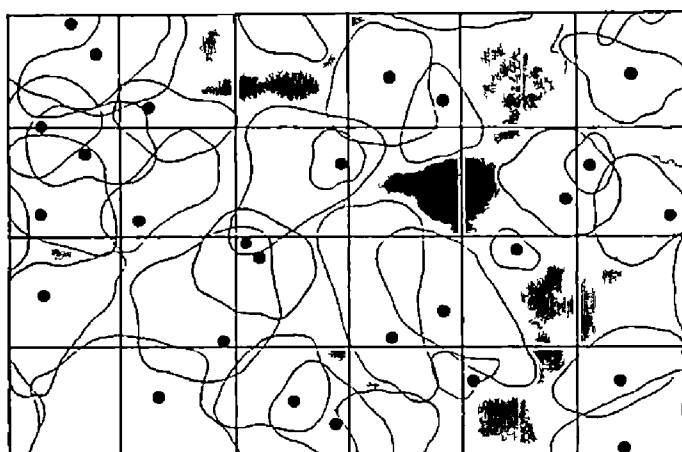
A size to scale map of the permanent plot was drafted on a graph paper. The position of the pegs were marked in the map. In each of the 10 m X 10 m quadrats, all the trees above 30 cm GBH were enumerated and numbered. Next the position of each of the trees in the quadrat was transcribed to binary numbers by



Plate VII. Measurements in the field. A. Measuring the GBH of a tree of Terminalia bellirica with large plank buttress. B & C. Measurement of the seedlings. B. A seedling of Sterculia guttata. C. A seedling of Dillenia pentagyna.

measuring the distance from  $x$  and  $y$  co ordinates of the quadrat to the tree. Later the binary numbers were translated to graphic points to mark the position of trees in the map (Figure 12.14). In the map of the plot where the position of the trees were marked, the crown of the trees were also mapped. Perimeter of the tree crown were traced with the help of a ranging rod. The traced perimeter was marked on the ground with painted iron pegs. From the outline of the crown so obtained an approximately proportionate mapping was done on the graph sheet (Figure 12.14). From this graph portions not covered by crown (gaps in the canopy) were cut and the area determined with the help of a leaf area meter (cf. Table 11). The regeneration enumeration data were compared with the percentage of gap in canopy. Analysis was done for individual species separately and for all tree species cumulatively and the trends analysed.

**Phytosociological Analysis** The bulk of numerical data obtained from field studies were fed to a personal computer using the software DBASE III. Preliminary phytosociological analyses were done by running a computer programme in PASCAL. Data were analysed to find out Density (D), Abundance (AB), Relative Density (RD), Percentage Frequency (% F), Relative Frequency (RF), Basal Area (BA) and Relative Basal Area (RBA) for each species and for each locality. Based on the results Importance Value Index (IVI) and Relative Importance Value Index (RIVI) was calculated for individual localities.

**12****13****14**

Figures 12 14 Crown cover maps for three selected sample plots used in the analysis of crown regeneration relationship 12 Sample no 3 from Karadippara (gap % 3 98) 13 Sample no 5 from Kalluchal (gap % 17 23) 14 Sample no 10 from Kuthiran (gap % 30 22)

○ gap in canopy

The values of the parameters were arrived at using the following formulae

- 1 Density    No of trees /area
- 2 Relative density    No of individuals of the species X  
100/No of individuals of all species
- 3 Abundance    Total no of individuals/No of quadrats of occurrence
- 4 Percentage frequency    No of quadrats of occurrence X  
100/Total no of quadrats studied
- 5 Relative frequency    No of quadrats of occurrence X  
100/Sum percentage frequency of all species
- 6 Basal area     $GBH^2/4 \pi$
- 7 Relative basal area    Basal area for the species X  
100/Basal area of all species
- 8 Importance value index    Relative density + Relative frequency + Relative basal area
- 9 Relative importance value index    Importance value index/3

In addition a Relative Disturbance Index (RDI) was also worked out for each locality. The method followed is described below. The IVI for the different strata of trees were obtained by summing up the IVI for the component species in each stratum. Adaptation Index (AI) for the strata was derived by dividing the range of RIVI values into 10 equal classes. The product of RIVI and the corresponding AI values were worked out. The sum of these values for all the strata in each locality is the Continuum index (CI of Curtis and McIntosh 1951). The CI values as they denote the role of environment also indicate the extent of

disturbance. Thus the CI values for the studied localities were arranged according to their magnitude and Relative Disturbance Index (RDI) was assigned to each locality with 1 for the least and 8 for the maximum without any consideration to the exact magnitude of difference between the values

Life tables were worked out by classifying the recorded individuals into different size classes. There are many different size class scales followed by various workers (cf Unesco 1978 a). However in order to make the data more readily comparable the size classes given in Table 12 were used

Table 12 List of size classes recognized

| No | Name  | Size range                     |
|----|-------|--------------------------------|
| 1  | h50   | height < 50 cm                 |
| 2  | h100  | height > 50 cm and < 100       |
| 3  | hg100 | height > 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                    |

Of the larger size classes although measurements were taken in terms of gbh these measurements were converted to DBH values using the geometric area diameter relation and used in the analysis. Interpretations are largely based on population structure at three levels of organization viz at ecosystem level stratal level and species level

## Review of Literature

#### 4 REVIEW OF LITERATURE

##### History of Regeneration Studies

In India the very birth of the science of forestry was as regeneration studies. The colonial powers in India were very much in need of teak timber for ship building. Shortage of teak and the need for its continuous supply led to the 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 had the demerits of monocultures. Epidemic diseases and outbreak of pests are always associated with it. Moreover plantations modify the natural vegetation completely. Perhaps it was this dilemma that led to the concept of managing the natural forests keeping their original structure and diversity that will augment the regeneration potential of stands. Researches with the above objective gradually gave birth to a second method of forest regeneration namely natural regeneration. The practice of natural regeneration over many decades had contributed a vast store of knowhows of silvicultural practices in forest management (Nair 1961 1986).

While the method of natural regeneration of forests was getting established conservation movement was yet to develop. As the concept of conservation was well established forest management science conceived the concept of sustained yield. Today many international forums are finding their efforts to develop suitable methods for practising the concept of sustained yield in forestry (Unesco 1975). Therefore today the subject of natural regeneration has better prospects than ever before.

To take a brief retrospect of the history of forestry artificial regeneration (plantation forestry), natural regeneration and the sustained yield concept are three phases of development in forestry. Of these plantation forestry does not come under the purview of the present work and studies on this are not reviewed here. Of the other two the sustained yield concept in the management of natural forests was only a later development of the natural regeneration trend. In fact both the approaches have the same ultimate objective. As such a brief review of the pertinent literature is given below.

**Natural Regeneration.** Foresters, silviculturalists and ecologists have contributed to the knowledge of regeneration dynamics of natural forests. Regeneration dynamics has been studied in both unmodified and modified forests of different latitudinal, longitudinal and altitudinal and typological specification (Ayliff 1952, Brooks 1941, Burschel et al. 1985, Holmes 1956, Heuveldop and Neumann 1983, Kahn 1982, Murray 1981, Venning 1985, Webb et al. 1972 and many others). Temperate

forests and wet evergreen forests of the tropics are the best studied. Regeneration studies on selected species specific categories of taxa are also numerous (Barnard 1956, Bernier 1987, Chaconsotelo 1987, Daly and Shankman 1985, Dimitrov 1984, Drapier 1985, Everard 1987, Khoon 1981, Melnik 1985, Morin 1986, Newbold et al. 1981, Szappanos 1987, Watt 1919, 1923).

Nair (1961) has given a detailed review of the literature concerning the various aspects of natural regeneration. Nair (1986) has given a concise account of the silvicultural systems associated with natural regeneration. Fox (1976) has given a categorical review of constraints of natural regeneration. The vast store of literature on natural regeneration differ markedly in their content as the forest types themselves and the factors and processes involved in regeneration differ. Important aspects are reviewed hereunder followed by synoptic review of pertinent studies on the deciduous forests.

#### Studies on the Processes and Phases of Natural Regeneration

A number of reviews on this subject are already available. Nair (1961) has given a review of the subject on tropical evergreen forests. Unesco (1978 a, 1978 b) covers the subject again for tropical forests with separate chapters on wet and dry forests (Unesco 1978 b).

All populations are under the flux of two vital but opposite processes viz growth and death. Regeneration denotes

the process of intrinsic natural increase or 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 (i.e. by means of genets) although some species also show a certain degree of vegetative regeneration (i.e. by ramets)

Adequate seed supply effective dispersal good viability and longevity of seeds successful establishment of seedlings and good conversion to mature trees all are unavoidable for a sustainable forest management Therefore the population structure at each of these life stages viz flowering fruiting seed dispersal germination establishment conversion to adult trees etc determine the structure of mature tree populations The characteristic regeneration pattern of individual species and forest types are therefore compromises between the real regeneration potential and the pressure offered by the constraints (Fox 1976) Silviculturists ecologists and population biologists have contributed to the understanding of regeneration dynamics (Harper 1977)

**Flowering** Flowering and fruiting are subjects of a branch of ecology namely phenology In the tropics flowering and fruiting of forest trees are quite often not regular These irregularities affect regeneration For this reason felling operations are to be based on the flowering and fruiting behaviour of the more important trees (Dhamanijayakul 1981 Nair 1961) In fact such

phenological observations 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 had been studied in the tropics (Cockburn 1975 Holmes 1942a 1942 b Holttum 1931 Koelmeyer 1959 Medway 1972 Ng 1977 1981 Ng and Loh 1974 Pinto 1970) Flowering phenology of a few ecosystems in toto had also been studied (Frankie et al 1974)

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 like floral biology pollination and dispersal 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 1974) 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 of breeding systems (Baker et al. 1983, Frankie et al. 1974 b) of individual species including anthecology (pollination ecology, Bawa et al. 1985 a) and incompatibility mechanisms (Bawa et al. 1985 b) are only being understood.

**Fruiting (Seeding)** Fruiting (seeding) includes fruit initiation, growth, ripening and fall of fruit and the presentation of fruit (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 too. A tree may flower profusely but need not fruit. Size of the seed crops of any given individual for any two years need not be the same. For example, in Hymenaea 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 % have been recorded (Bawa et al. 1985 b). In the West African Parkia capertoniana, out of approximately 2000 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, 1978) 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 although a few studies are available (Boojh and Ramakrishnan 1981 Kaul and Raina 1980 Khosla et al 1982 Krishnaswamy and Mathauda 1960 Prasad and Hegde 1986 Shukla and Ramakrishnan 1982 Shrivasthava 1982 Ralhan et al 1985)

**Dispersal** The place of production of seeds do 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 van der Pijl 1969) In wet forests seeds of more than 50 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 losing viability (Fielding 1965) 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 densest 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 have been recorded (Unesco 1978) 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 (Nair 1961 Grime 1979)

**Dormancy** Dispersed seeds generally show a period of rest termed dormancy (cf Harper 1977) Seeds of trees of mature phase in wet forests are generally not dormant (Tang and Tamarı 1973) while those of other species extend from two weeks to 3 years (de la Mensbrugı 1966) Most species of semievergreen forests lack seed dormancy (Hoi 1972)

**Seed Banks** Not all the dispersed seeds germinate as soon as they are dispersed A good percentage move into the soil a few centimeters down These form a seed bank contributing viable plants on germination 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 (Hall and Swaine

1980 Symington 1933 Liew 1973) and of higher latitudes (Johnson 1975 Kellman 1970)

Most studies indicate that seeds of dominant trees of the communities 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 lianes and the pioneer species germinated show a unimodal pattern of germination On the contrary that of understorey and shade tolerant species germination was throughout the rainy season without a peak in any of the months (Garwood 1983 b) Seedling emergence in light gaps peaked 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 specialised (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 1978 b)

**Conversion to Upper Size Classes** Trees are perennials with long life spans extending over hundreds of years Therefore studies on the conversion of size classes to higher up by following the life history of individuals in a given population of any given species or forest type 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 cf Harper 1977)

Distribution of size (diameter) classes is the most studied parameter Nevertheless comparison of data is very much difficult owing to differences in the lower DBH limit the class intervals and units of measurement (Unesco 1978 a) or because of limiting measurements to certain classes Size class distributions were studied of most forest types viz low land and montane evergreen forests semideciduous forests dry deciduous forests mangrove and swamp forests (Anderson 1961 Beard 1946 Dawkins 1958 Rollet 1952 1962 1974 etc of Unesco 1978 a)

Each forest type shows wide variability in stand structure Some forest types are richer in large stems (> 60 cm DBH) than others (Pierlot 1966 Rollet 1962 Nicholson 1965) 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  $1/2$  the conversion from one class to another increases (Wyatt Smith 1963) Meyer (1952) theorises 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 show strongly skewed L shaped graphs while others show an exponential model Some erratic species show normal distribution Semilogarithmic graphs show upward or downward concavity indicating sharp decrease in the survival probability of lowermost or uppermost classes (Krebs 1972 Unesco 1978 a)

Yoda et al (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 i e due to overcrowding and tied up biomass (Westoby 1984) Harper's (1970) and 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 Nair (1961) and 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 and to give rise to a new generation of trees This system is known from Malaya (Barnard 1955 Landon and Settan 1957 Walton et al 1952) and North Borneo (Nicholson 1958 Walton 1955)

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 (Barnard 1955 Lancaster 1952) India (Chengappa 1944 Kadambi 1954 Nair 1986) areas of East Pakistan and Sri Lanka (Rosayro 1954)

The selection system involves reducing part of the growing stock especially of the undesirable species by which growth and regeneration of the desirable species can be increased. This system has also many modifications and are practiced in West Africa, Sri Lanka, India (Kadambi 1954), Pakistan, Burma, Philippines and Australia (Nair 1961).

### Studies on Deciduous Forests

Broadly speaking, forested ecosystems can be recognized into two viz. the wet and the dry types. Forty-two percent of the total tropical and subtropical forest are composed of dry forests (Murphy and Lugo 1988). The dry forests comprise seasonal forests like semievergreen, semideciduous and dry evergreen. Compared to the wet types, the dry types are poorly studied. Consequently, literature on the regeneration dynamics of these forest types are also but a few. Contributions of Rollet (1952, 1962), Mooney (1961) and Lamprecht (1961, 1962) on stand structure, FAO (1955) on phenology, Gilbert (1938), Jones (1950, 1956) and de la Mensbrug (1966) 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)

Regeneration of rosewood (Dalbergia latifolia Balasundaram  
et al 1979) Dipterocarpus spp (Thangam 1982) sal (Shorea  
robusta Bhatnagar 1961 Bor 1930 Chakravarthi 1948  
 Champion 1933 [Chaudari 1958 Chaudhuri 1960 Chaturvedi  
 1931) teak (Tectona grandis Kadambi 1957) irul (Xylia  
xylocarpa Arora 1960) 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

## Results and Discussion

## 5 RESULTS AND DISCUSSION

Forests are biocoenotic organizations organizations of greater magnitude scale (Odum 1971) These colossal organizations also do have characteristic structure At the same time they are not static They are also under constant stress and strain due to factors of the environment (Braun 1950) both of external and internal With the result they have a dynamic aspect too Regeneration the process of sylvigenesis (Halle et al 1978) is one of the important dynamic aspect of forests The features of this dynamic property can be visualised in terms of structure

Structure is a spatial property (Dansereau 1957) Vegetation ecology recognizes different levels of structure like floristic structure stand structure etc (cf Mueller Dombois and Ellenberg 1974) In order to meet the objective of the present discussions the sections of this chapter are treated in compliance with the parameters mentioned above and the subsections are arranged in compliance with the different levels of organizations viz ecosystem level stratal level and species level Discussions on species level are restricted to the more abundant commercially important species Occasionally a few abundant lower stratum species are also included in discussions The section Constraints of Natural Regeneration does not follow this sequence

### Genetic Diversity

Genetic diversity is best known at specific level viz species diversity. It is also termed as alpha diversity (Mueller-Dombois and Ellenberg 1974). Alpha tree diversity has been worked out for different forest types (Unesco 1978 b). However there is much difficulty in comparing available data because of the difference in the magnitude of samples and the size of the trees considered. Murphy and Lugo (1987) have made extensive literature survey and compared the per hectare tree species diversity of the wet and dry forests. Compared to the wet forests diversity is less in the dry forests. In the wet forest species > 10 cm DBH range between 50 and 200 while in the dry forests it ranges between 35 and 90.

**At Ecosystem Level** In the MDFs of TFD in the ca 5 ha of sampled area distributed over an area of  $162 \text{ km}^2$  a total of 64 tree species > 10 cm DBH have been encountered. This number would scarcely increase to a 10 % if further intensive sampling is done. Of the 64 two were seen only as seedlings one being an immigrant from adjacent wet forests and the other of an introduced tree. Of the rest six species were common to the MDFs and semievergreen/evergreen forests. Species area relation in two localities in MDFs of TFD reveals that the diversity of species > 10 cm DBH (> 30 cm GBH) ranging between 24 and 26 per hectare. Compared to the 87 tree species recorded in Costa Rica (Hubbell 1979) this is a very low value but comes closer to the 30-35 species range recorded in Puerto Rico (Murphy and Lugo 1986 b). In the present study the low diversity<sup>1</sup> in the disturbed

site indicates that disturbance can also reduce species richness in MDFs

Menon and Balasubramanyan (1985) have analysed the pattern of species association in the MDFs of TFD. They note that the species Xylia xylocarpa and Grewia tiliifolia although form dominant communities their detailed survey indicates negative relations owing to selective removal of the species. Their finding therefore is congruous with the present observation that disturbance can reduce species diversity.

At Stratal Level Richness of tree species > 10 cm DBH (30 cm GBH) of individual strata and their percentages for the whole community in TFD are given in Table 13

Table 13 Species richness in different strata

| I Stratum |            | II Stratum |            | III Stratum |            |
|-----------|------------|------------|------------|-------------|------------|
| No of sp  | Percentage | No of sp   | Percentage | No of sp    | Percentage |
| 21        | 33.87      | 39         | 61.29      | 4           | 6.45       |

The data shows significant differences between individual strata. Diversity is least in the lower stratum (6.45 %) highest in the middle stratum (61.29 %) while that of the upper stratum is intermediate but sufficiently high (33.87 %). The list of trees given in Table 2 shows that all species of the upper stratum are commercially very important. This indicates that they must invariably be high light demanders at least after they have crossed the pole stage. Likewise most of the species in the middle and lower stratum are commercially useless. Therefore

stratawise species diversity and its changes may be useful in application oriented impact assessment studies although such attempts are stray in literature

**At Species Level** Diversity within individual species denotes infraspecific genetic variabilities. This aspect was not attempted in the present study for want of data

#### Basal Area (BA) and Relative Basal Area (RBA)

**At Ecosystem Level** Basal area for the stands and the different strata are given in Table 14. The value for the whole area is  $12.83 \pm 7.54 \text{ m}^2/\text{ha}$  the actual range being  $4.36 \text{ m}^2$  to  $25.89 \text{ m}^2/\text{ha}$ . With respect to basal area too the MDFs of TFD are less productive compared to the  $14.7 \text{ m}^2/\text{ha}$  cited by Seth and Kaul (1978). Of the eight localities sampled four have values greater than the mean and four lesser.

**At Stratal Level** The average values of basal area for the three strata are  $11.75 \pm 6.92 \text{ m}^2$ ,  $1.07 \pm 0.89 \text{ m}^2$  and  $0.42 \pm 0.79 \text{ m}^2$  respectively for upper, middle and lower strata. The basal area of the upper stratum has high value but shows high degree of variability. In the samples studied it ranges between  $4.13 \text{ m}^2$  and  $23.34 \text{ m}^2$ . The change in basal area against increasing disturbance is shown in Figures 15 and 16. The basal area for the stand is chiefly constituted by that of the upper stratum and therefore it follows the sequence of the latter. That is there is a high degree of relation between disturbance and basal area. Basal area of the second and third strata do decrease with

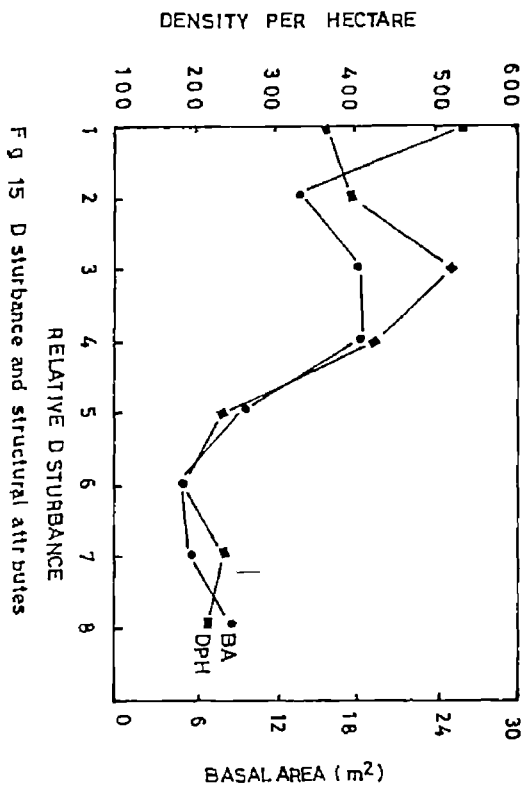


Fig. 15. Disturbance and structural attributes

Table 14 Descriptive statistics of Basal Area (BA) and Relative Basal Area (RBA)

| Loc  | BA ( $m^2/ha$ ) |       |      |                |       |       | RBA  |    |     |   |    |     |
|------|-----------------|-------|------|----------------|-------|-------|------|----|-----|---|----|-----|
|      | All Trees       |       |      | Stratal number |       |       |      |    |     |   |    |     |
|      | I               | II    | III  | I              | II    | III   | I    | II | III | I | II | III |
| Kp   | 25 89           | 23 34 | 2 53 | 2 29           | 82 81 | 9 00  | 8 12 |    |     |   |    |     |
| Kc   | 18 48           | 16 82 | 1 54 | 0 12           | 90 53 | 8 26  | 1 20 |    |     |   |    |     |
| Kt   | 18 04           | 17 27 | 0 03 | 0 74           | 95 74 | 0 18  | 4 08 |    |     |   |    |     |
| Mp   | 9 61            | 7 86  | 1 70 | 0 06           | 81 71 | 17 64 | 0 64 |    |     |   |    |     |
| Pk   | 13 26           | 12 37 | 0 82 | 0 08           | 93 16 | 6 15  | 0 68 |    |     |   |    |     |
| Vz1  | 4 86            | 4 15  | 0 70 | 0 01           | 85 41 | 14 37 | 0 22 |    |     |   |    |     |
| Vz2  | 4 36            | 4 13  | 0 20 | 0 04           | 94 59 | 4 56  | 0 82 |    |     |   |    |     |
| Vz3  | 8 10            | 8 10  |      | 0 01           | 99 82 |       | 0 18 |    |     |   |    |     |
| Max  | 25 89           | 23 34 | 2 53 | 2 29           | 99 82 | 17 64 | 8 12 |    |     |   |    |     |
| Min  | 4 36            | 4 13  | 0 03 | 0 01           | 81 71 | 0 18  | 0 18 |    |     |   |    |     |
| Mean | 12 83           | 11 75 | 1 07 | 0 42           | 90 47 | 8 59  | 1 99 |    |     |   |    |     |
| SD   | 7 54            | 6 92  | 0 89 | 0 79           | 6 55  | 5 90  | 2 77 |    |     |   |    |     |

Table 15 Descriptive statistics of Basal Area (BA) and Relative Basal Area (RBA) of selected species

| Species       | BA ( $m^2/ha$ ) |        |        | RBA   |       |       |
|---------------|-----------------|--------|--------|-------|-------|-------|
|               | Max             | Min    | Mean   | Max   | Min   | Mean  |
| Albizia       | 0 1449          | 0 0016 | 0 0765 | 1 09  | 0 01  | 0 58  |
| Alstonia      | 0 0704          | 0 0012 | 0 0252 | 0 57  | 0 01  | 0 34  |
| Bombax spp    | 0 3692          | 0 0129 | 0 1641 | 5 52  | 0 72  | 2 22  |
| D. siissoides | 1 3279          | 0 0005 | 0 3062 | 6 24  | 0 01  | 2 68  |
| Dillenia      | 3 0855          | 0 0688 | 0 8116 | 18 66 | 0 38  | 6 46  |
| Grewia        | 2 6513          | 0 3531 | 1 0495 | 14 27 | 1 57  | 9 19  |
| Haldina       | 0 3980          | 0 0018 | 0 1999 | 2 14  | 0 01  | 1 08  |
| Lagerstroemia | 9 0979          | 0 1672 | 1 7275 | 32 30 | 1 74  | 9 56  |
| Lannea        | 0 3110          | 0 0039 | 0 1329 | 1 67  | 0 03  | 0 86  |
| Melia         | 0 3309          | 0 0298 | 2 3050 | 7 59  | 0 11  | 5 10  |
| Pterocarpus   | 0 3415          | 0 0002 | 0 1309 | 3 56  | 0 76  | 1 53  |
| Radermachera  | 0 1126          | 0 0002 | 0 0286 | 1 17  | 0 01  | 0 59  |
| Stereospermum | 0 2420          | 0 0004 | 0 0582 | 2 09  | 0 03  | 0 86  |
| T. bellerica  | 1 2062          | 0 0086 | 0 4301 | 6 68  | 0 03  | 2 03  |
| T. crenulata  | 0 7609          | 0 0498 | 0 2853 | 4 22  | 0 52  | 2 01  |
| T. paniculata | 6 4349          | 0 9911 | 2 0072 | 48 47 | 6 77  | 17 67 |
| Tectona       | 1 0782          | 0 0013 | 0 6712 | 5 80  | 0 01  | 3 04  |
| Tetrameles    | 1 1510          | 0 337  | 0 7442 | 6 95  | 1 09  | 5 52  |
| Xylia         | 8 0551          | 1 4129 | 4 0601 | 48 93 | 17 86 | 33 61 |
| Holarrhena    | 0 1212          | 0 0037 | 0 0376 | 0 67  | 0 08  | 0 25  |
| Wrightia      | 1 1754          | 0 0070 | 0 2588 | 4 17  | 0 14  | 1 31  |

disturbance but gradually Correlation analysis (CORMAT) shows positive linear correlation between basal area of upper and lower strata the value being (0.7959) significant at 5 % level. The values of Relative Basal Area (RBA) are  $90.655 \pm 18.59$  and  $199.277$  respectively for upper, middle and lower strata (Table 14).

**At Species Level** The highest values of maximum and mean basal area shared by any single species in the area were  $8.055 \text{ m}^2/\text{ha}$  and  $4.0601 \text{ m}^2/\text{ha}$  respectively (cf. Table 15) for Xylia xylocarpa. The highest values of maximum and mean relative basal area shared by any single species were 48.93 and 33.61 respectively again for Xylia xylocarpa. Of the 21 commercially important species in the area, five species have mean basal area  $> 1 \text{ m}^2/\text{ha}$ . The species are Grewia tiliifolia, Lagerstroemia microcarpa, Melia dubia, Terminalia paniculata and Xylia xylocarpa. Seven species have RBA  $> 5$ . They include Dillenia pentagyna and Tetrameles nudiflora along with the earlier listed five species.

#### Density Per Hectare (DPH) and Relative Density (RD)

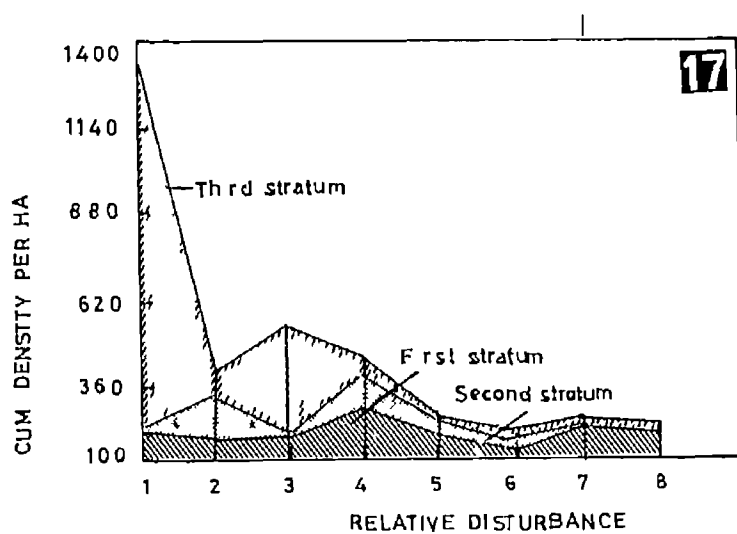
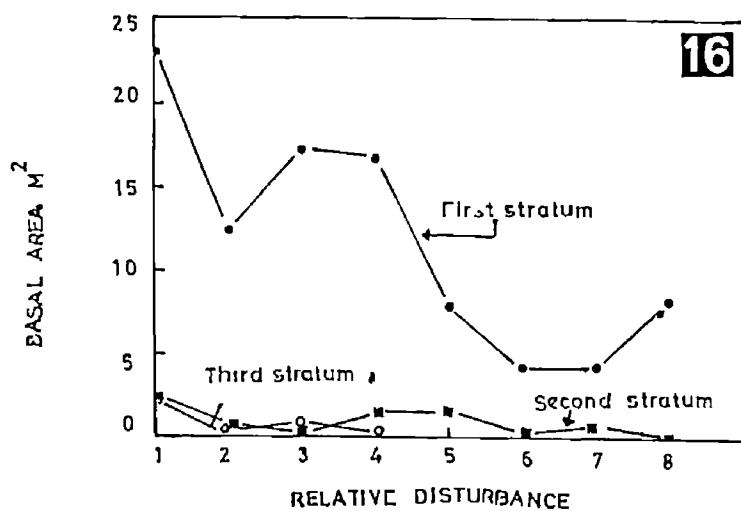
**At Ecosystem Level** The average per hectare growing stock of trees  $> 20 \text{ cm DBH}$  per hectare was 149.79, the actual range being 120 and 182.84 trees. Compared to the value of 167 trees/ha given by Seth and Kaul (1978), the average growing stock for the MDFs of TFD is less (Table 16). Coming to trees  $> 1 \text{ cm DBH}$ , the Division has an average of 322.75 trees/ha, the extremes being 185 and 522.42 respectively (Table 16). Unfortunately, at this size class level, there are no data for comparison.

Table 16 Descriptive statistics of Density per Hectare (DPH) and Relative Density (RD)

| Loc  | Density Per Hectare (DPH) |        |        |            |                |       | Relative Density (RD) |       |    |    |
|------|---------------------------|--------|--------|------------|----------------|-------|-----------------------|-------|----|----|
|      | > 20 cm                   |        |        | > 1 cm DBH |                |       | > 1 cm DBH            |       |    |    |
|      | All                       |        | All    |            | Stratum number |       | I                     |       | II |    |
|      | Trees                     | Trees  | I      | II         | III            | I     | II                    | III   | I  | II |
| Kp   | 161 41                    | 363 32 | 192 27 | 31 05      | 1140 00        | 52 91 | 8 70                  | 38 54 |    |    |
| Kc   | 182 84                    | 426 37 | 263 48 | 97 17      | 65 72          | 59 87 | 22 63                 | 15 38 |    |    |
| Kt   | 138 06                    | 522 42 | 168 75 | 11 51      | 339 16         | 32 45 | 0 25                  | 65 16 |    |    |
| Mp   | 146 61                    | 237 75 | 175 54 | 42 22      | 19 99          | 73 80 | 17 74                 | 8 41  |    |    |
| Pk   | 131 47                    | 397 14 | 168 57 | 128 57     | 100 00         | 42 12 | 29 98                 | 25 00 |    |    |
| Vz1  | 135 00                    | 235 00 | 195 00 | 20 00      | 20 00          | 82 98 | 8 15                  | 8 51  |    |    |
| Vz2  | 120 00                    | 185 00 | 125 00 | 35 00      | 35 00          | 69 22 | 12 81                 | 17 94 |    |    |
| Vz3  | 180 00                    | 215 00 | 185 00 |            | 25 00          | 88 10 |                       | 11 90 |    |    |
| Max  | 182 84                    | 522 42 | 263 48 | 128 57     | 1140 00        | 88 10 | 29 98                 | 65 16 |    |    |
| Min  | 120 00                    | 185 00 | 125 00 | 20 00      | 20 00          | 32 45 | 0 25                  | 8 41  |    |    |
| Mean | 149 79                    | 322 75 | 184 20 | 52 65      | 218 11         | 62 68 | 14 32                 | 23 86 |    |    |
| SD   |                           | 121 48 | 38 76  | 43 12      | 387 49         | 19 51 | 9 97                  | 19 45 |    |    |

Table 17 Descriptive statistics of Density Per Hectare (DPH) and Relative Density (RD) of selected species

| Species       | DPH (> 1 cm DBH) |       |       | RD    |      |       |
|---------------|------------------|-------|-------|-------|------|-------|
|               | Max              | Min   | Mean  | Max   | Min  | Mean  |
| Albizia       | 2 86             | 1 11  | 1 84  | 0 71  | 0 30 | 0 44  |
| Alstonia      | 20 00            | 1 56  | 6 76  | 5 00  | 0 30 | 2 27  |
| Bombax spp    | 40 00            | 1 56  | 11 06 | 17 02 | 0 30 | 4 61  |
| D. sissoides  | 5 00             | 1 56  | 3 10  | 2 56  | 0 30 | 1 19  |
| Dillenia      | 32 22            | 1 56  | 12 89 | 10 64 | 0 30 | 4 30  |
| Grewia        | 28 57            | 5 56  | 16 99 | 7 69  | 1 53 | 5 75  |
| Haldina       | 10 00            | 1 11  | 5 56  | 2 34  | 0 31 | 1 33  |
| Lagerstroemia | 42 22            | 2 22  | 13 67 | 11 62 | 0 93 | 4 46  |
| Lannea        | 6 67             | 5 71  | 6 03  | 2 80  | 1 34 | 1 86  |
| Melia         | 5 00             | 1 11  | 3 70  | 2 56  | 0 31 | 1 81  |
| Pterocarpus   | 5 00             | 2 80  | 3 79  | 2 13  | 0 67 | 1 35  |
| Radermachera  | 2 22             | 1 43  | 1 83  | 0 93  | 0 33 | 0 63  |
| Stereospermum | 11 43            | 2 22  | 5 38  | 2 68  | 0 71 | 1 61  |
| T. bellirica  | 5 56             | 1 43  | 3 09  | 1 53  | 0 33 | 0 85  |
| T. crenulata  | 7 14             | 1 11  | 4 62  | 1 87  | 0 31 | 1 24  |
| T. paniculata | 5 00             | 14 44 | 30 22 | 23 08 | 3 68 | 11 24 |
| Tectona       | 8 57             | 1 56  | 4 86  | 2 01  | 0 30 | 1 18  |
| Tetrameles    | 5 00             | 2 22  | 3 61  | 2 13  | 0 61 | 1 37  |
| Xylia         | 148 57           | 35 00 | 72 41 | 42 06 | 9 29 | 24 09 |
| Holarrhena    | 68 75            | 5 00  | 25 85 | 15 38 | 2 13 | 8 34  |
| Wrightia      | 262 50           | 4 44  | 61 08 | 50 45 | 1 87 | 14 36 |



Figs 16 17 Disturbance and structural attributes

DPH values for the size class  $> 1$  cm DBH are plotted against increasing disturbance values. The graph (Figure 15) shows a more or less inverse relation, the DPH decreasing with increasing disturbance.

**At Stratal Level** The DPH values of trees  $> 1$  cm DBH for the different strata are given in Table 16. The average values for the upper, middle and lower strata are  $184.2 \pm 38.76$ ,  $52.65 \pm 43.12$  and  $218.11 \pm 387.49$  respectively (Table 16). The greater percentage of growing stock ( $> 1$  cm DBH) is contributed by the lower stratum. However, the standard deviation of the actual values is greater than that of the mean, indicating that growing stock in the third stratum varies considerably. From Figure 17 it can be seen that the growing stock of the middle and lower strata decreases exponentially with increasing disturbance. The upper stratum, on the other hand, is not very much affected by increasing disturbance. In fact, with slight disturbance it increases a little.

Relative Density (RD, Table 16) for the different strata are  $62.68 \pm 19.51$ ,  $14.32 \pm 9.97$  and  $23.86 \pm 19.45$  respectively for upper, middle and lower strata. Average RD of the lower stratum is higher than that of the middle stratum.

**At Species Level** The highest values of maximum and mean  $DP_i$  ( $> 1$  cm DBH) shared by any single species are 148.57 trees/ha and 72.41 trees/ha respectively. Xylia xylocarpa has the highest maximum and mean values of Relative Density (RD). The values

being 42.06 and 21.09 respectively. Six species have mean DPI > 10 trees/ha and RD > 4. The species are Bombax spp. (cumulative value for two species B. ceiba and B. insignis), Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa (Table 17).

#### Relative Importance Value Index (RIVI), Continuum Index (CI) and Disturbance Index (DI)

**At Stratal Level** Relative importance values of the different strata are given in Table 18. The value is maximum for upper stratum (68.63 ± 8.5), minimum for third stratum (13.96 ± 8.48) and intermediate for middle stratum (25.62 ± 8.07). The values are plotted against increasing disturbance in Figure 18. The graph shows a positive linear correlation between the RIVI of the upper stratum and disturbance. On the other hand, RIVI of lower stratum slightly increases with slight disturbance and then decreases with increasing disturbance. RIVI of the middle and lower strata are interesting. Correlation analysis of RIVI of the upper stratum and third stratum shows negative linear correlation; the value (0.7259) being significant at 5% level. Where RIVI of the former increases, that of the latter decreases and vice versa.

**At Species Level** The highest values of maximum and mean Relative Importance Value Index (RIVI) shown by any single species were 32.68 and 22.47 respectively for Xylia xylocarpa. Six species have RIVI > 3. The species are Bombax spp. (cumulative values of two species B. ceiba and B. insignis), Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa. In addition, the third stratum species

Table 18 Statistic of Relative IVI  
(RIVI) Continuum Index (CI)  
and Disturbance Index (DI)

|      | Relative IVI   |       |       |  |        |    |
|------|----------------|-------|-------|--|--------|----|
| Loc  | Stratal number |       |       |  | CI     | DI |
|      | I              | II    | III   |  |        |    |
| Kp   | 57 78          | 19 09 | 23 13 |  | 512 03 | 1  |
| Kc   | 67 65          | 19 80 | 12 54 |  | 660 79 | 4  |
| Kt   | 62 03          | 8 07  | 29 90 |  | 623 67 | 3  |
| Mp   | 67 41          | 25 62 | 6 96  |  | 690 51 | 5  |
| Pk   | 60 64          | 24 85 | 14 51 |  | 588 69 | 2  |
| Vz1  | 76 96          | 16 80 | 6 03  |  | 809 23 | 7  |
| Vz2  | 74 85          | 15 31 | 9 83  |  | 788 95 | 6  |
| Vz3  | 81 69          | 10 14 | 8 17  |  | 835 21 | 8  |
| Max  | 81 69          | 25 62 | 29 90 |  | 835 21 |    |
| Min  | 57 78          | 8 07  | 6 03  |  | 512 03 |    |
| Mean | 68 63          | 17 46 | 13 96 |  | 688 64 |    |
| SD   | 8 50           | 6 28  | 8 48  |  | 114 81 |    |

Table 19 Statistic of Percentage Composition (PC)  
and Relative Importance Value Index (RIVI)  
of selected species

| Species       | PC (> 10 cm DBH) |      |       | Relative IVI |       |       |
|---------------|------------------|------|-------|--------------|-------|-------|
|               | Max              | Min  | Mean  | Max          | Min   | Mean  |
| Albizia       | 0 71             | 0 30 | 0 44  | 3 81         | 0 09  | 2 14  |
| Alstonia      | 2 56             | 0 30 | 1 08  | 2 51         | 0 08  | 1 08  |
| Bombax spp    | 17 02            | 0 30 | 4 52  | 9 04         | 0 04  | 3 26  |
| D. siissoides | 2 56             | 0 30 | 0 97  | 3 41         | 0 37  | 1 85  |
| Dillenia      | 11 91            | 0 30 | 5 63  | 10 86        | 0 38  | 3 83  |
| Grewia        | 7 69             | 1 53 | 5 09  | 9 18         | 3 81  | 7 70  |
| Haldina       | 2 34             | 0 31 | 1 33  | 2 14         | 0 09  | 0 50  |
| Lagerstroemia | 14 29            | 0 94 | 5 61  | 15 78        | 1 17  | 5 44  |
| Lannea        | 2 80             | 1 34 | 1 86  | 1 26         | 0 24  | 0 94  |
| Melia         | 2 56             | 0 31 | 1 44  | 3 86         | 0 21  | 1 43  |
| Pterocarpus   | 2 38             | 0 67 | 1 76  | 2 28         | 0 08  | 0 66  |
| Radermachera  | 0 94             | 0 33 | 0 64  | 0 80         | 0 18  | 0 36  |
| Stereospermum | 2 68             | 0 71 | 1 62  | 3 78         | 0 38  | 1 65  |
| T. bellirica  | 1 53             | 0 33 | 0 85  | 2 97         | 0 18  | 1 38  |
| T. crēnulata  | 1 87             | 0 31 | 1 24  | 2 22         | 0 61  | 1 23  |
| T. paniculata | 23 08            | 3 68 | 10 14 | 19 56        | 5 29  | 12 43 |
| Tectona       | 2 01             | 0 30 | 1 18  | 3 42         | 0 27  | 1 87  |
| Tetrameles    | 2 13             | 0 67 | 1 37  | 3 21         | 0 05  | 1 65  |
| Xylia         | 42 06            | 9 27 | 26 15 | 32 68        | 11 48 | 22 47 |
| Holarrhena    | 15 37            | 2 13 | 7 01  | 7 28         | 2 37  | 4 98  |
| Wrightia      | 50 45            | 1 87 | 14 93 | 14 57        | 1 72  | 7 15  |

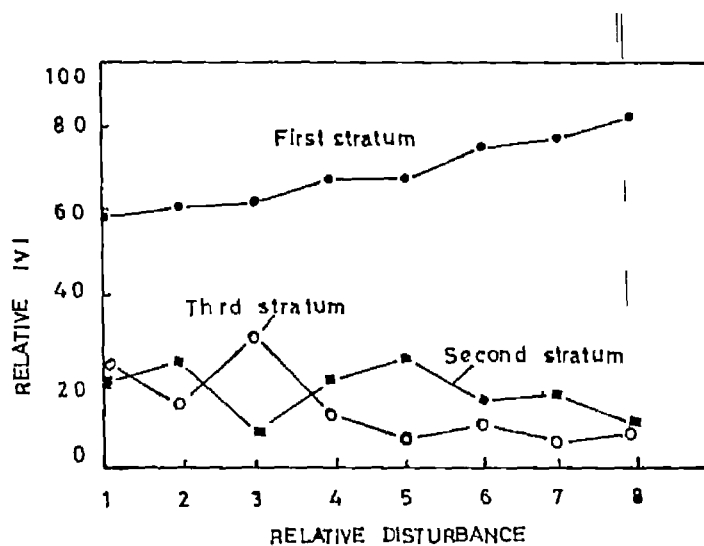


Fig 18 Relation between disturbance and IVI

Holarrhena antidysenterica and Wrightia tinctoria also show RIVI  
> 3 (Table 19)

#### Size Class Distribution

At Ecosystem Level The per hectare size class distribution of all-trees in the stand is given in Table 20 and depicted in Figure 20. The curve shows characteristic concave shape indicating negative exponential relation between the size classes. It also indicates that the rate of natural increase (Krebs 1972; Harper and White 1974) in the lower size classes is very high. From there upwards it decreases exponentially. In other words, mortality rates decrease exponentially from lower size class upwards. The horizontal, more or less straight arm of the curve from d20 (DBH > 10 cm) onwards imply that trees in natural ecosystems when they cross the sapling and pole stage although the rate of intrinsic natural increase is low, mortality rate is also low.

The high mortality of individuals in the lower size classes may in part be due to self thinning. The size of individuals relative to its neighbours is very important in survival (Harper 1977). Even in mixed populations smaller individuals get eliminated (Bazzaz and Harper 1976) due to self thinning (Westoby 1984; Yoda et al 1963). However, the extent of mortality caused by self thinning remains to be studied further as other extrinsic factors like fire, grazing, browsing, anthropogenic constraints etc. interplay.

Table 20 Per hectare size class representation of all trees in the stand

| Loc  | h50     | h100    | hg100  | d10    | d20   | d30   | d40   | d50   | d60   | dg60  |
|------|---------|---------|--------|--------|-------|-------|-------|-------|-------|-------|
| Kp   | 2272 20 | 2656 64 | 623 40 | 159 98 | 36 66 | 47 77 | 39 99 | 26 66 | 22 22 | 27 77 |
| Kc   | 2520 00 | 1985 73 | 692 88 | 215 75 | 28 58 | 48 59 | 55 72 | 40 02 | 24 30 | 14 21 |
| Kt   | 2142 21 | 1053 14 | 601 57 | 368 75 | 12 50 | 12 50 | 42 18 | 39 06 | 18 75 | 25 57 |
| Mp   | 3604 45 | 486 65  | 148 86 | 66 66  | 22 21 | 44 43 | 39 98 | 26 66 | 17 77 | 17 77 |
| Pk   | 2414 28 | 857 17  | 502 02 | 251 42 | 14 30 | 8 58  | 31 43 | 31 44 | 20 00 | 40 02 |
| Vz1  | 2855 00 | 1990 00 | 530 00 | 90 00  | 10 00 | 5 00  | 45 00 | 40 00 | 25 00 | 20 00 |
| Vz2  | 6955 00 | 370 00  | 140 00 | 60 00  | 15 00 | 5 00  | 35 00 | 45 00 | 15 00 | 20 00 |
| Vz3  | 2605 00 | 525 00  | 120 00 | 30 00  |       | 15 00 | 55 00 | 30 00 | 10 00 | 70 00 |
| Max  | 6955 00 | 2656 64 | 692 88 | 368 75 | 36 66 | 48 59 | 55 72 | 45 00 | 25 00 | 70 00 |
| Min  | 2142 21 | 370 00  | 120 00 | 30 00  | 10 00 | 5 00  | 31 43 | 26 66 | 10 00 | 14 21 |
| Mean | 3171 01 | 1240 54 | 419 84 | 155 32 | 19 90 | 23 36 | 43 04 | 34 86 | 19 13 | 29 42 |
| SD   | 1594 16 | 857 12  | 241 88 | 116 73 | 9 74  | 19 85 | 8 67  | 7 00  | 4 98  | 18 21 |

Table 21 Per hectare size class representation in the upper stratum

| Loc  | h50     | h100    | hg100  | d10   | d20   | d30   | d40   | d50   | d60   | dg60  |
|------|---------|---------|--------|-------|-------|-------|-------|-------|-------|-------|
| Kp   | 1027 77 | 563 33  | 149 98 | 61 11 | 5 55  | 24 43 | 31 11 | 23 33 | 20 00 | 24 44 |
| Kc   | 1661 41 | 1081 42 | 342 88 | 81 44 | 15 72 | 40 01 | 50 00 | 35 73 | 21 44 | 11 21 |
| Kt   | 1801 59 | 567 20  | 225 01 | 29 68 |       | 12 50 | 42 18 | 39 06 | 18 75 | 25 57 |
| Mp   | 2286 67 | 255 55  | 71 10  | 31 11 | 17 77 | 37 77 | 35 54 | 24 44 | 17 77 | 11 10 |
| Pk   | 1657 15 | 385 72  | 151 30 | 48 56 | 2 86  | 5 72  | 25 71 | 31 44 | 14 28 | 40 02 |
| Vz1  | 2300 00 | 1635 00 | 485 00 | 70 00 | 5 00  | 5 00  | 45 00 | 30 00 | 25 00 | 15 00 |
| Vz2  | 6495 00 | 265 00  | 65 00  | 10 00 | 10 00 | 5 00  | 35 00 | 40 00 | 15 00 | 20 00 |
| Vz3  | 1965 00 | 395 00  | 80 00  | 5 00  |       | 15 00 | 55 00 | 30 00 | 10 00 | 70 00 |
| Max  | 2300 00 | 1635 00 | 485 00 | 81 44 | 17 77 | 40 01 | 55 00 | 40 00 | 25 00 | 70 00 |
| Min  | 1027 77 | 265 00  | 71 10  | 5 00  | 2 86  | 5 00  | 25 71 | 23 33 | 10 00 | 11 10 |
| Mean | 2399 32 | 643 53  | 196 66 | 42 11 | 9 48  | 18 19 | 39 94 | 31 75 | 17 78 | 27 17 |
| SD   | 1703 76 | 479 44  | 149 29 | 27 80 | 6 12  | 14 36 | 9 89  | 6 19  | 4 65  | 19 72 |

Table 22 Per hectre size class representation in the middle stratum

| Loc  | h50     | h100   | hg100  | d10    | d20   | d30  | d40  | d50   | d60  | dg60 |
|------|---------|--------|--------|--------|-------|------|------|-------|------|------|
| Kp   | 519 99  | 287 76 | 81 09  | 18 87  |       |      | 5 55 | 22 22 | 1 11 | 3 33 |
| Kc   | 477 16  | 335 74 | 231 43 | 74 30  | 7 15  | 8 58 | 5 72 | 4 29  | 2 86 |      |
| Kt   | 164 05  | 71 87  | 32 81  | 12 51  |       |      |      |       |      |      |
| Mp   | 1193 34 | 88 89  | 17 76  | 17 77  | 4 44  | 4 44 | 4 44 | 2 22  |      | 6 67 |
| Pk   | 605 71  | 214 29 | 162 01 | 102 86 | 11 44 | 2 86 | 5 72 |       | 5 72 |      |
| Vz1  | 215 00  | 95 00  | 30 00  |        | 5 00  |      |      | 10 00 |      | 5 00 |
| Vz2  | 340 00  | 95 00  | 35 00  | 20 00  |       |      |      | 5 00  |      |      |
| Vz3  | 605 00  | 50 00  | 5 00   |        |       |      |      |       |      |      |
| Max  | 1193 34 | 335 74 | 231 43 | 102 86 | 11 44 | 8 58 | 5 72 | 22 22 | 5 72 | 6 67 |
| Min  | 164 05  | 50 00  | 5 00   | 12 51  | 4 44  | 2 86 | 4 44 | 2 22  | 1 11 | 3 33 |
| Mean | 515 03  | 154 82 | 74 39  | 41 05  | 7 01  | 5 29 | 5 36 | 8 75  | 3 23 | 5 00 |
| SD   | 321 10  | 109 10 | 80 76  | 38 00  | 3 18  | 2 95 | 0 62 | 8 06  | 2 33 | 1 67 |

Table 23 Per hectare size class representation in the lower stratum

| Loc  | h50    | h100    | hg100  | d10    | d20   |
|------|--------|---------|--------|--------|-------|
| -    |        |         |        |        |       |
| Kp   | 724 44 | 1805 55 | 393 33 | 80 00  | 31 11 |
| Kc   | 381 43 | 568 57  | 118 57 | 60 01  | 5 71  |
| Kt   | 176 57 | 414 07  | 343 75 | 326 56 | 12 50 |
| Mp   | 124 44 | 142 22  | 60 00  | 17 77  |       |
| Pk   | 151 42 | 257 14  | 185 71 | 100 00 |       |
| Vz1  | 340 00 | 260 00  | 15 00  | 20 00  |       |
| Vz2  | 120 00 | 10 00   | 40 00  | 30 00  | 5 00  |
| Vz3  | 35 00  | 80 00   | 35 00  | 25 00  |       |
| Max  | 724 44 | 1805 55 | 393 33 | 326 56 | 31 11 |
| Min  | 35 00  | 10 00   | 15 00  | 20 00  | 5 00  |
| Mean | 256 66 | 442 19  | 148 92 | 82 42  | 13 58 |
| SD   | 221 72 | 579 52  | 146 70 | 103 20 | 12 17 |

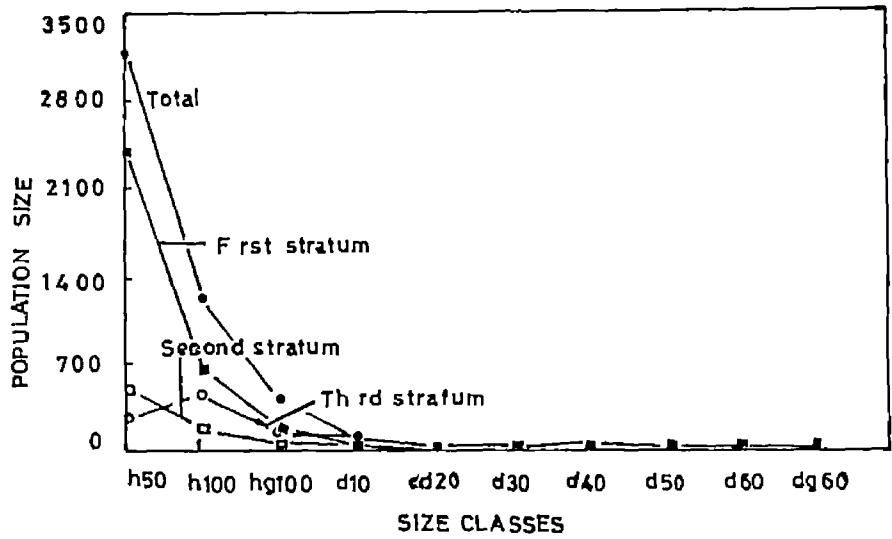


Fig 19 Population structure of different strata

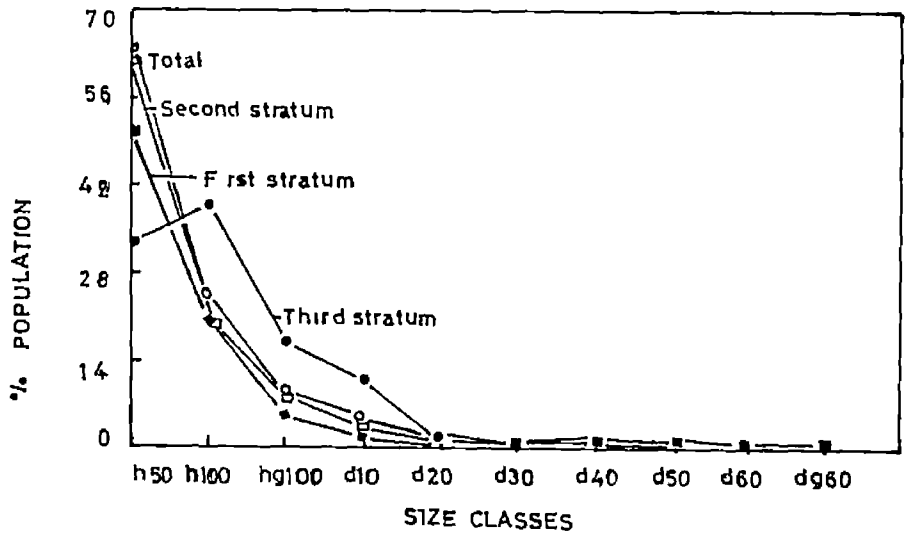


Fig 20 Percentage composition of size classes in each stratum

At Stratal Level Frequency distribution in different size classes of different strata are given in Tables 21-23. They are also represented in Figure 19. Percentage population representation in different size classes is depicted in Figure 20. Both the diagrams following the DeLiocourt's law (cf Goff and West 1975) show strongly skewed L shaped distribution patterns for all the strata but the lower stratum shows a peak in the height class 50-100 cm. From Tables 22 and 23 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 > 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 antidysenterica etc. 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 22). 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. Also from 10 cm DBH (d20) onwards there is not much fluctuation of frequency in the upper size classes. However a general reduction of individuals in the size classes d20 (> 10 cm and < 20 cm DBH i.e. pole stage) is very much obvious. This reduction is also observed in the size class d30 (> 20 cm and < 30 cm DBH) but to a lesser extent.

For the wet forests Nair (1961) has given some approximations for considering the regeneration status of desirable trees satisfactory For the dry forests these figures are not available The wet and dry forests differ significantly in both structure and dynamics (Murphy and Lugo 1986 Seth and Kaul 1978 Unesco 1978 b) Although weighted estimates for the dry forests are not available comparable figure can be derived by proportionate calculations

Nair (1961) classifies 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 DBH < 10 cm According to his weighted estimates wet forests are fully stocked when six unestablished or one established seedling(s) per milliacre exist He considers a 40 % stocking with desirable species as satisfactory regeneration. The per hectare values calculated from his figures are given in Table 24

Seth and Kaul (1978) gives average stocking densities of trees (> 20 cm DBH) for wet evergreen (289) moist deciduous (167) and even aged plantations of deciduous specie like Shorea robusta (138) and teak (111) from these figures proportionate figures for unestablished and established seedlings for natural moist deciduous forests are calculated and given in Table 24 [For the sake of convenience here the size range of unestablished seedlings were taken as height < 100 cm] Comparable figure for unestablished and established seedlings of the upper stratum were also calculated from observed mean

survival probability (in TFD) and stocking density ( $> 20$  cm DBH) These figures are also given in Table 24 The observed frequencies in the regeneration classes from TFD are also given in Table 24

From Table 24 it can be seen that the observed frequency of unestablished seedlings (3042.85+1091.60) comes more or less closer to the value estimated from Nairs (1961) weighting (3467.13) and is far higher than the value estimated from mean survival probability (1617.17) 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 238.77+88.55) roughly accounts only to half of the estimated values (577.86 and 525.88) That is regeneration at the sapling and pole stage is highly unsatisfactory

Table 24 Estimates of regeneration of desirable species (Upper stratum)

| Regeneration classes                                | Wet Evergreen Forests       | Moist Deciduous Forests                                                                                 |                                                                                           |                                     |
|-----------------------------------------------------|-----------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------|
|                                                     | Calculated from Nair (1961) | Proportionate calculations using figures in Nair (1961) and Seth and Kaul (1978) (stocking density 167) | Calculated from observed stocking density (149 78) and observed mean survival probability | Observed frequencies in MDFs of TFD |
| Unestablished seedlings (ht < 100 cm)               | 6000                        | 3467 13                                                                                                 | 1617 17                                                                                   | 3042 85+<br>1091 60                 |
| Established seedlings (ht > 100 cm and DBH < 10 cm) | 1000                        | 577 86                                                                                                  | 525 58                                                                                    | 238 77+<br>88 55                    |

Table 25 Observed frequencies in regeneration classes of different strata

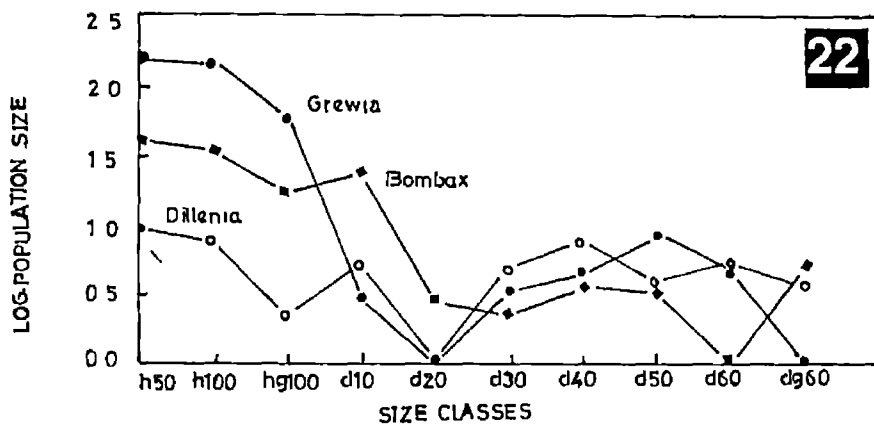
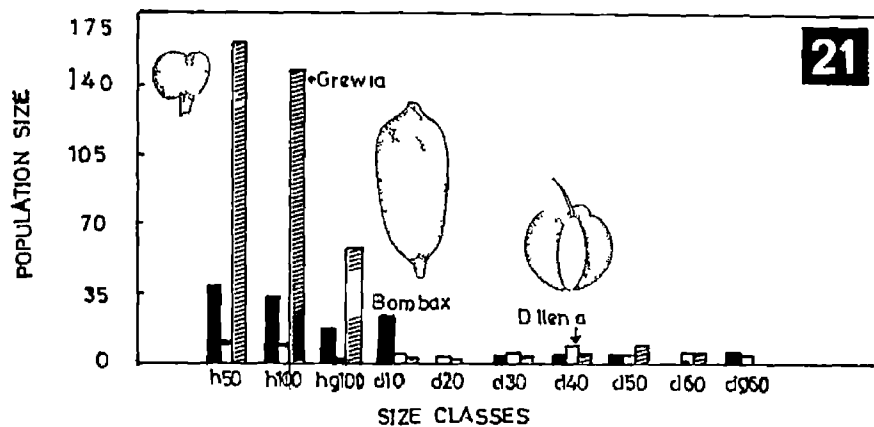
| Regeneration class                                  | Frequency in different strata |                   |                   |
|-----------------------------------------------------|-------------------------------|-------------------|-------------------|
|                                                     | Stratal number                |                   |                   |
|                                                     | I                             | II                | III               |
| Unestablished seedlings (ht < 100 cm)               | 3042 85+<br>1091 60           | 669 85+<br>215 10 | 698 85+<br>400 62 |
| Established seedlings (ht > 100 cm and DBH < 10 cm) | 238 77+<br>88 55              | 115 44+<br>59 38  | 231 34+<br>124 95 |

Observed frequencies in different regeneration classes of different strata are given in Table 25. 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 and therefore might be offering strong competition. 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 third strata must be offering significant stress in terms of competition for those of the upper stratum.

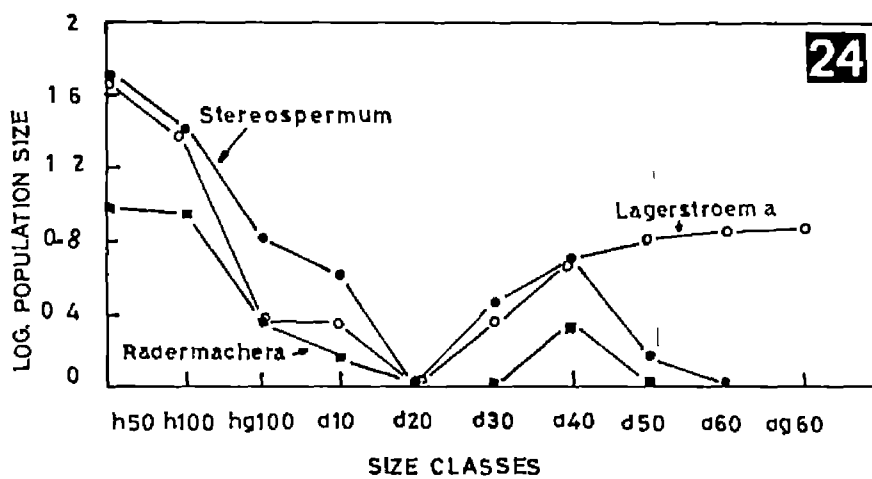
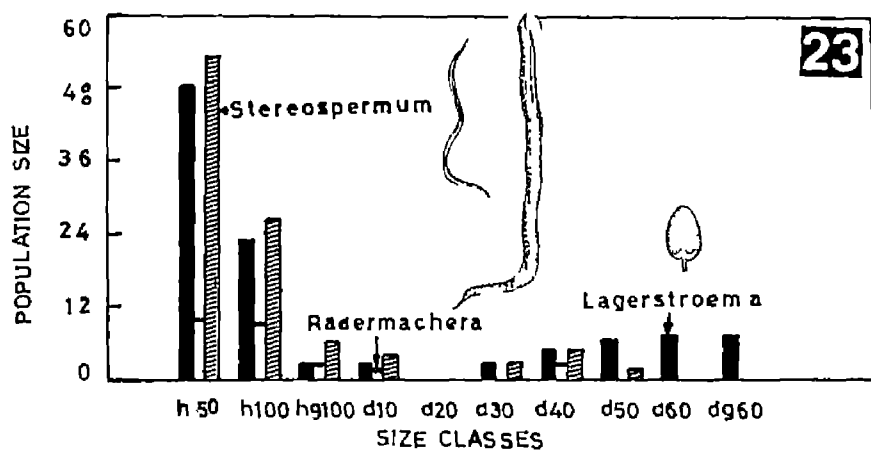
**At Species Level** This section deals with sociodynamics and population structure of the more commercially important species only. A total of 21 commercially important species have been encountered in the MDFs of TFD (Table 2). Of these five species have mean Percentage Composition (PC) > 5 (Table 19). The species are Dillenia pentagyna, Grewia tiliaefolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa. These are the dominant species that are commercially important. These species also show higher values of BA, RBA, DPH, RD and RIVI. A few co-dominant species such as Radermachera xylocarpa and Stereospermum colais are also included in the discussions. In addition two species of the lower stratum viz Holarrhena

Table 26 Average size class frequencies given as percentage of total population of selected species

| Species       | Size classes |       |       |       |      |       |       |       |      |       |
|---------------|--------------|-------|-------|-------|------|-------|-------|-------|------|-------|
|               | h50          | h100  | hg100 | d10   | d20  | d30   | d40   | d50   | d60  | dg60  |
| Albizia       | 96 04        | 2 75  | 0 10  | 0 04  | 0 00 | 0 00  | 0 06  | 0 11  | 0 00 | 0 00  |
| Alstonia      | 17 72        | 37 43 | 20 08 | 20 46 | 4 30 | 0 00  | 0 00  | 0 00  | 0 00 | 0 00  |
| Bombax spp    | 45 98        | 33 44 | 8 61  | 7 56  | 0 47 | 0 37  | 1 19  | 1 56  | 0 00 | 0 83  |
| D. sissoides  | 77 81        | 11 81 | 4 40  | 1 02  | 0 00 | 0 51  | 0 51  | 0 00  | 3 14 | 0 79  |
| Dillenia      | 36 75        | 7 69  | 1 10  | 5 10  | 0 55 | 12 14 | 18 87 | 9 96  | 2 47 | 5 37  |
| Grewia        | 44 60        | 37 52 | 10 20 | 0 30  | 0 00 | 0 34  | 1 08  | 1 72  | 0 94 | 0 00  |
| Haldina       | 29 40        | 58 43 | 3 39  | 4 26  | 2 26 | 0 00  | 1 13  | 0 00  | 1 13 | 0 00  |
| Lagerstroemia | 52 74        | 11 83 | 1 73  | 0 58  | 0 00 | 0 58  | 7 78  | 11 53 | 5 56 | 7 69  |
| Lannea        | 71 11        | 18 48 | 1 14  | 5 53  | 1 14 | 1 87  | 0 00  | 0 00  | 0 73 | 0 00  |
| Melia         | 69 21        | 11 77 | 0 00  | 0 00  | 3 46 | 0 00  | 0 00  | 0 00  | 0 00 | 15 57 |
| Pterocarpus   | 50 91        | 8 98  | 2 09  | 0 00  | 2 70 | 9 43  | 12 13 | 9 58  | 4 19 | 0 00  |
| Radermachera  | 59 09        | 32 28 | 8 01  | 2 59  | 0 00 | 0 00  | 4 02  | 0 00  | 0 00 | 0 00  |
| Stereospermum | 66 78        | 23 57 | 5 79  | 2 20  | 0 00 | 0 51  | 0 90  | 0 26  | 0 00 | 0 00  |
| T. bellirica  | 66 98        | 20 98 | 5 66  | 2 87  | 0 00 | 0 74  | 0 00  | 0 00  | 0 00 | 2 76  |
| T. crenulata  | 16 92        | 31 64 | 12 35 | 3 76  | 2 42 | 3 76  | 14 72 | 7 26  | 1 88 | 5 30  |
| T. paniculata | 32 58        | 40 06 | 17 87 | 2 45  | 0 56 | 0 63  | 1 55  | 1 00  | 0 60 | 2 29  |
| Tectona       | 33 45        | 30 57 | 21 79 | 11 02 | 0 00 | 0 00  | 2 37  | 0 00  | 2 37 | 8 43  |
| Tetrameles    | 10 88        | 15 48 | 23 22 | 7 75  | 0 00 | 0 00  | 0 00  | 0 00  | 0 00 | 42 61 |
| Xylia         | 78 48        | 13 67 | 4 08  | 0 85  | 0 15 | 0 46  | 0 84  | 0 57  | 0 36 | 0 59  |
| Holarrhena    | 34 43        | 43 19 | 15 40 | 6 84  | 0 14 | 0 00  | 0 00  | 0 00  | 0 00 | 0 00  |
| Wrightia      | 19 94        | 51 25 | 17 23 | 10 13 | 1 05 | 0 41  | 0 00  | 0 00  | 0 00 | 0 00  |



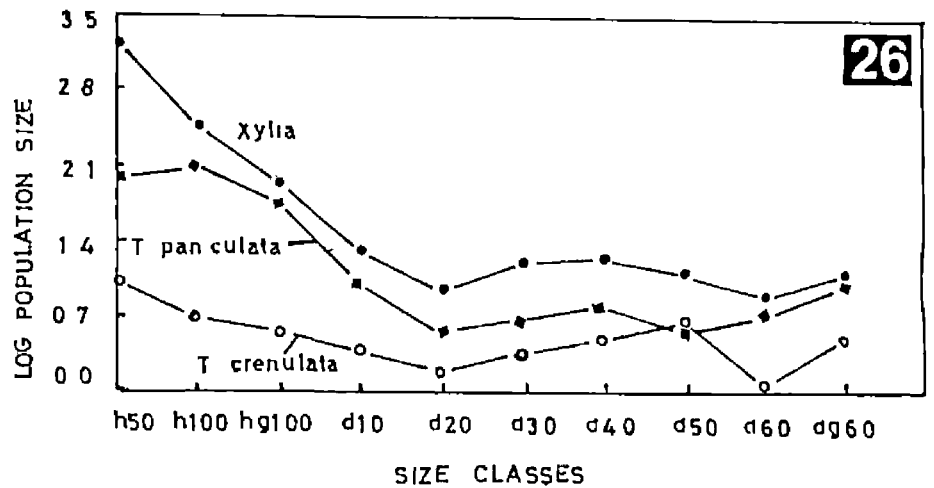
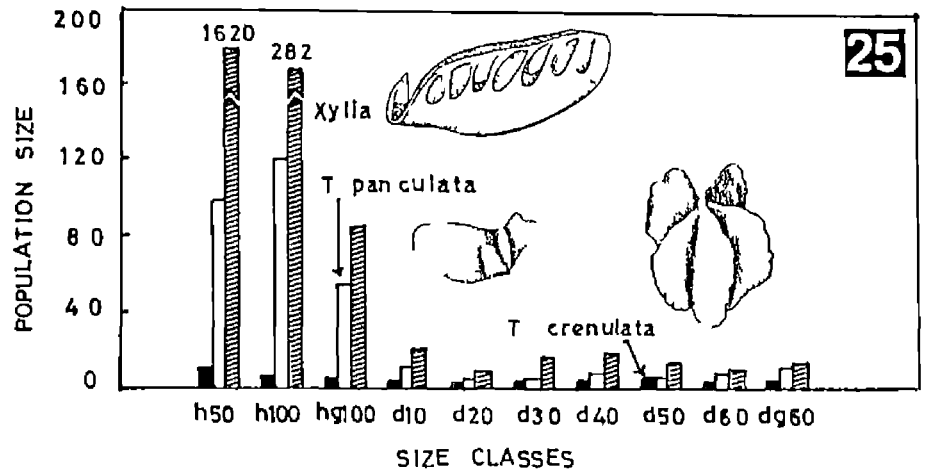
Figs 21 22 Population structure of selected species.



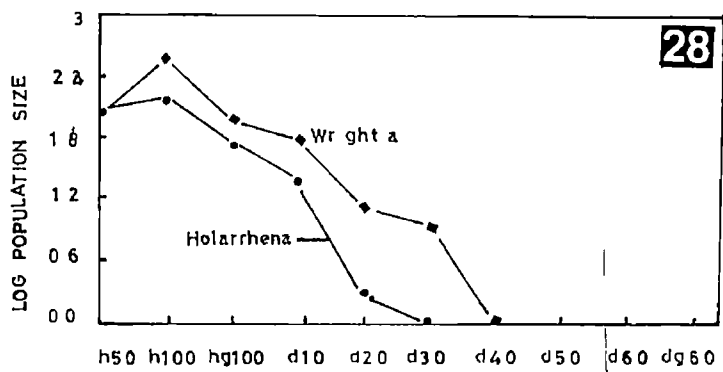
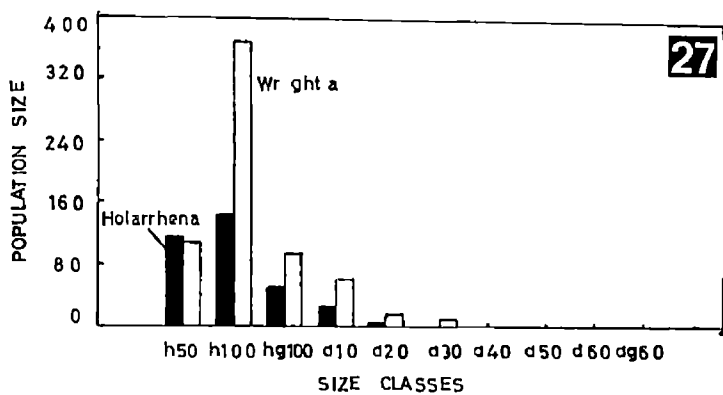
Figs 23-24 Population structure of selected species

antidysenterica and Wrightia tinctoria are very much abundant in the stands and therefore are also included in the discussions

Population structure of the dominant species together with that of a few co dominant species are depicted in Figures 21-28. Size class representation in terms of percentage of the total population of each species is given in Table 26. Distribution of size in terms of semilogarithmic graphs has been proved to be negatively exponential with a less prominent rotated sigmoid curve at the mid size ranges (Pande and Bisht 1988, Saxena and Singh 1984, West et al 1981). Xylia xylocarpa and Terminalia paniculata do show similar graphs (Figure 26). On the other hand most other species show a strongly bimodal distribution pattern with a strong depression in the size class d20 (> 10 cm and < 20 cm DBH). This depression at size class d20 indicates poor representation of pole crops. This means a poor survival probability for saplings (size class 1-10 cm DBH). For species like Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Radermachera xylocarpa and Stereospermum colais pole crops are totally wanting while in others like Terminalia crenulata, T. paniculata and Xylia xylocarpa poor representation of pole crops is met with. In all the species there are more larger sized trees than poles (d20). A slight depression similar to the one noticed in the class 10-20 cm DBH (d20) is noticeable in the size class hg100 (> 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



Figs 25 26 Population structure of selected species



Figs 27-28 Population structure of selected species

classes (below d20 10 20 cm DBH) decreases more slowly while in Grewia tiliifolia this is more quick (cf Figure 22)

The process of regeneration is more or less satisfactory in Xylia xylocarpa. This may be due to the large seed source good germination high fire resistance root sucker formation and high coppicing capacity. For these abilities this species is found to regenerate even in disturbed sites. In other species taking account of the extent of casualties the number of seedlings is not that high compared to the number of large sized trees especially in Terminalia crenulata.

#### Survival Probability

**At Ecosystem and Stratal Levels** The distribution of average survival probabilities (no of individuals in size class/no of individuals in the preceeding size class) for the various size classes in each strata and the whole stand are given in Figure 29. The general trend of the graphs is indicative of the fact that the probability of survival is higher from 1 10 cm DBH class upwards for the whole stand and the upper and middle strata. For the lower stratum probability is highest in h50 (height < 50 cm i.e seedlings) and as size increases probability decreases. Invariably all the strata show a sharp decrease of probability in size class d10 (> 1 cm and < 10 cm DBH i.e saplings). This implies that percentage of mortality is maximum during the conversion from saplings to poles.

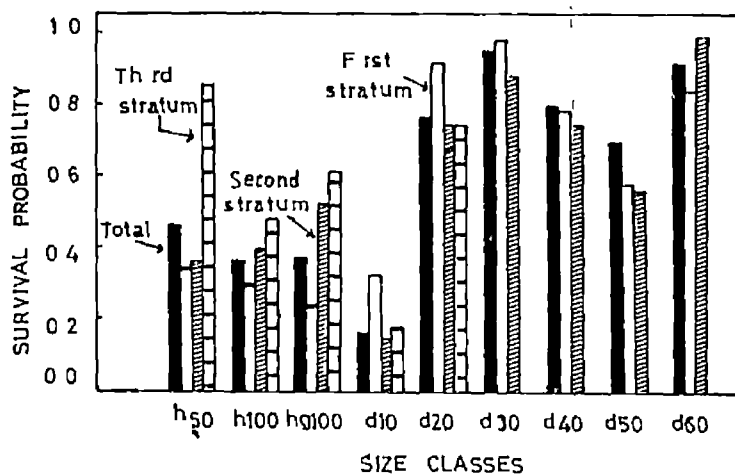
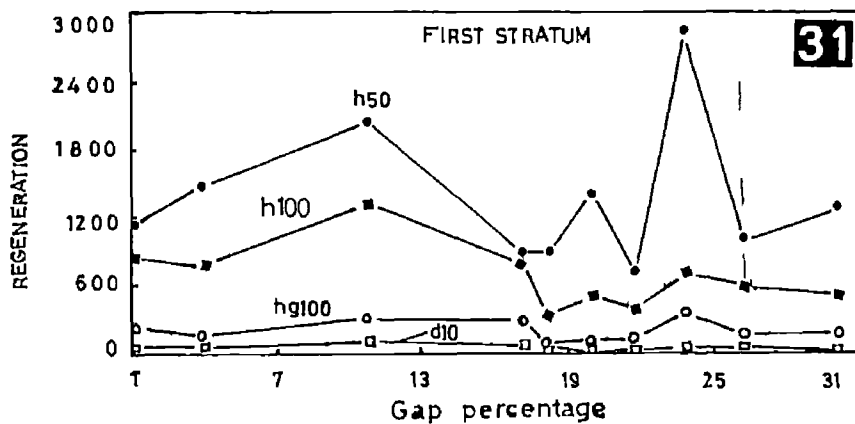
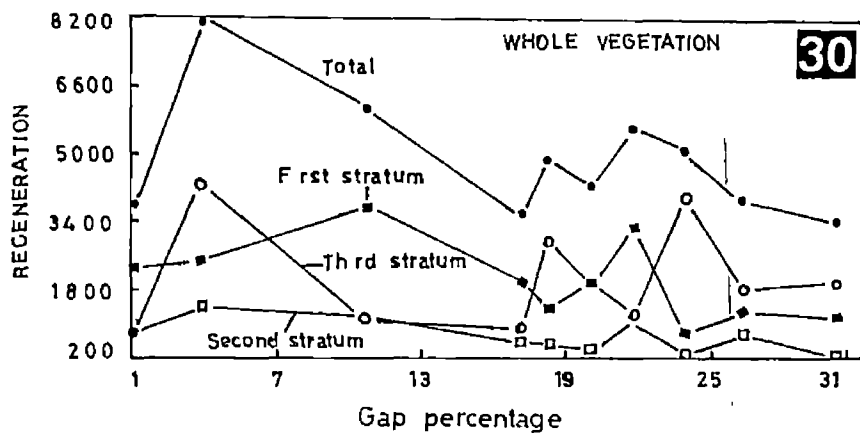


Fig 29 Distribution of survival probability

Table 27 Distribution of survival probability of regeneration < 1 cm DBH getting converted to the size class > 1 cm dbh of different strata

| Stat | Stratal number |       |       |       |       |       |
|------|----------------|-------|-------|-------|-------|-------|
|      | I              |       | II    |       | III   |       |
|      | Mean           | SE    | Mean  | SE    | Mean  | SE    |
| Max  | 1.000          | 0.119 | 1.000 | 0.359 | 0.320 | 0.182 |
| Min  | 0.011          | 0.004 | 0.051 | 0.101 | 0.161 | 0.182 |
| Mean | 0.325          | 0.105 | 0.358 | 0.272 | 0.220 | 0.109 |
| SD   | 0.341          |       | 0.348 |       | 0.087 |       |

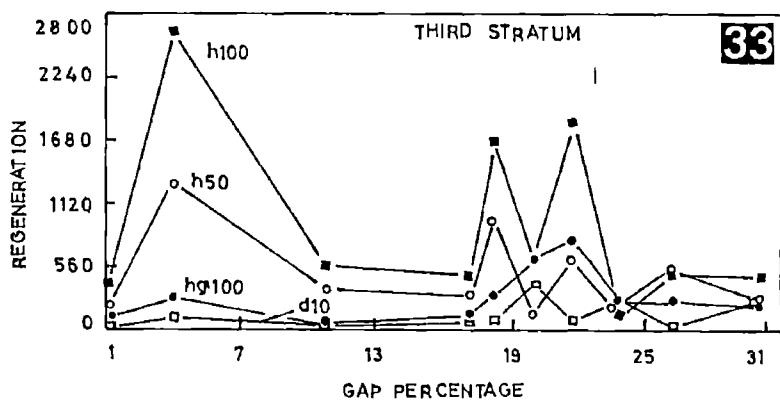
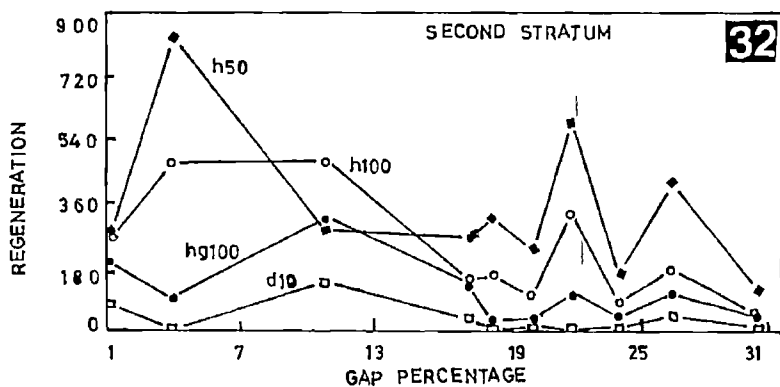


Figs 30-31 Relation between regeneration and gap percentages

The survival probability of regeneration < 1 cm DBH getting converted to the size class > 1 cm DBH were computed for the three strata (Table 27). The middle stratum ( $0.358 \pm SE 0.272$ ) and lower stratum ( $0.220 \pm SE 0.109$ ) registered the highest and lowest values and the upper stratum was intermediate ( $0.325 \pm SE 0.105$ ). The low survival probability of third stratum is expected due to the growth habits of the species. On the other hand, the higher value of the middle stratum higher than that of the upper stratum is not desirable. However, this value shows SE greater than that shown by the value for the upper stratum.

**At Species Level** The five dominant species (Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa) show the same pattern of distribution of survival probability as that of the upper stratum. That is, survival probability is higher from 1-10 cm DBH class upwards compared to that of the lower size classes.

The probability of survival of regeneration of the dominant species < 1 cm DBH getting converted to the size class > 1 cm DBH shows different values in different sample localities. Important statistics of these variations are given in Table 28.



Figs 32 33 Regeneration to gap percentages

Table 28 Descriptive statistics of probability of regeneration of the five dominant species < 1 cm DBH getting converted to the size class > 1 cm DBH

| Species                   | Maximum | Minimum | Range | Mean  |
|---------------------------|---------|---------|-------|-------|
| <u>Dillenia pentagyna</u> | 1 000   | 0 053   | 0 947 | 0 864 |
| <u>Grewia tiliifolia</u>  | 0 278   | 0 012   | 0 266 | 0 119 |
| Lagerstroemia microcarpa  | 0 429   | 0 079   | 0 350 | 0 284 |
| Terminalia paniculata     | 0 414   | 0 049   | 0 365 | 0 146 |
| <u>Xylia xylocarpa</u>    | 0 077   | 0 006   | 0 071 | 0 049 |

The highest maximum-survival probability is shown by Dillenia pentagyna. On the other hand the same species shows the largest range of probability (0 947) indicating that survival of the regeneration of the species is very much affected by changes in the environment. Likewise the lowest minimum survival probability and the smallest range (0 071) are exhibited by a single species Xylia xylocarpa indicating that the regeneration of the species are well adapted to wide range of environs.

#### Regeneration in Gaps

Figure 30 is a graphic presentation of the dynamics of regeneration (< 10 cm DBH) of the different strata in relation to the percentage of gap the stand contains. Regeneration of trees for the whole stand of the middle and lower strata increases with initial small scale openings in the canopy. It reaches maximum at about 5 % gap and then decreases considerably with increasing gap percentages. While regeneration of the upper stratum increases and reaches the peak at ca 10-11 % of gap.

This indicates that a 10-11 % gap in natural moist deciduous forests is ideal for regeneration. In all gap percentages regeneration of upper stratum is high in comparison to that of the lower stratum.

The response of different regeneration classes of the upper stratum are presented in Figure 31. All the size classes (h50, h100, hg100 and d10) show maximum representation at about 10 % gap. The behaviour of different regeneration classes of the middle stratum are plotted in Figure 32. The size class h50 (< 50 cm height) shows maximum representation at 5 % gap, while the size classes h100 (height > 50 cm and < 100 cm), hg100 (> 100 cm height and < 1 cm DBH) and d10 (> 1 cm and < 10 cm DBH) show maximum representation at about 10 % gaps. That is, size class conversion of regeneration of this stratum has the same dynamics as that of the upper stratum with respect to gap percentages. Quantitative changes in the different size classes of the lower stratum are given in Figure 33. Invariably, all the size classes show maximum representation at ca. 5 % gap. To sum up, a 10 % gap is ideal for increasing the regeneration of commercially important species at which the representation of regeneration of the third stratum decreases considerably.

[In all the graphs 30-33 a second peak is observed towards the distal half of the gap axis. From data we find that this may be due to locality factor, i.e. differences in the stand structure in different localities and therefore discussion on this aspect is excluded.]

### Constraints of Natural Regeneration

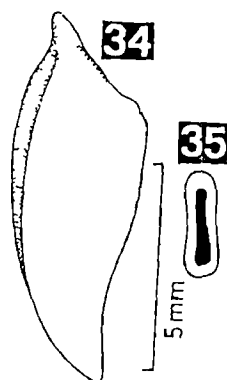
In examining the population structure at different levels a low survival probability is observed for saplings leading to poor representation in the pole crops. Secondly taking account of the high mortality rates in the lower size classes in all the dominant commercially important species the number of regeneration (< 10 cm DBH) is not that high compared to the number of large sized trees especially in T. crenulata. Both these observations suggest the existence of constraints in the conversion of smaller size classes (regeneration) to adult trees.

Fox (1976) has discussed in detail the different kinds of constraints hindering the natural regeneration of tropical forests. For the sake of convenience constraints observed in the MDFs of TFD are discussed below under categories as recognized by Fox (1976).

**Environmental Constraints** Comparison of population size of regeneration in areas with different gap percentages indicate that gaps up to 10 % increase the regeneration potential of the upper stratum comprising most of the commercially important species. This indicates that closed canopy offers constraints to regeneration. A similar situation has been documented in the wet evergreen forests where the closed canopy and consequent reduction in light below the inversion surface (Halle et al 1978) leading to mortality of saplings and poles (Nair 1961). However gaps in most parts of the MDFs of TFD are more than 10 %.

**Intrinsic Constraints** Intrinsic constraints are those due to the biological peculiarities of stands populations or species themselves Phenological behaviour reflects intrinsic constraints of some species Our preliminary observations indicate that trees of Dalbergia sissooides in natural forest stand do not bear fruits every year In Lagerstroemia microcarpa each tree produces thousands of seeds every year However of this rich seed source more than 90 % or even more are without a viable embryo Seeds show hollow seed cavity (Figures 34 35) This may be the reason why the lower size classes compared to the population of large size classes are very poor in this species The exact reasons for the sterile seeds are yet to be investigated

A similar situation perhaps exists in Grewia tiliaefolia too Here even during the rainy season small seedlings with cotyledons are very rarely observed In Melia dubia regeneration dynamics is little known Adult individuals of this species are very few and widely spaced Nevertheless each tree produces thousands of fruits every year Eventhough the fruit population is very high near the mother trees population size of regeneration is extremely small This disharmony between the two life stages of the species is interesting Germination trials indicate that germination extends over a period of two to three years (Chacko 1988 Personal communication) Perhaps the species is adapted to fire prone habitats where fire burns the woody pericarp to expose the seeds for germination.



Figures 34 35 Lagerstroemia  
microcarpa 34 A seed 35  
 Transection of the seed area  
 showing the empty seed cavity

**Natural Biotic Factors Wild Plants** The MDFs have a thick shrubby stratum composed of weedy perennial shrubs like Eupatorium odoratum Helecteris isora Lantana camera together with copious seedlings of lower stratum trees like Wrightia tinctoria. Seeds begin to germinate with the onset of monsoon rains. By the time seedlings of tree species emerge from the seeds, the shrubby species (especially of Eupatorium odoratum) might have built a thick ground cover. When this shrub growth is entangled with twiners and climbers, tree seedlings are trapped being suppressed from growing up. Even in established seedlings, growth is considerably hindered with twiner entanglement.

**Wild Animals** Wild animals in the MDFs of TFD are giant malabar squirrel, porcupine, wild boar, spotted deer, sambar deer and bear. During the rainy season, elephant population from the adjacent evergreen forests also occasionally migrate to some portions of the MDFs. Of these, malabar squirrel is known to eat the seeds of Xylia xylocarpa, T. crenulata, Dillenia pentagyna and Tectona grandis (Ramachandran 1988). Nevertheless, regeneration of Xylia xylocarpa is more or less satisfactory in the area, as already discussed in previous sections. Whether the squirrel attains the predator status in these forests is yet to be studied.

**Constraints of Human Origin Encroachment** Within the Peechi Forest Range between the period 1950 to 1980, about 30 km<sup>2</sup> of forest land was encroached, that is, approximately at the rate of 1 km<sup>2</sup>/year (Menon 1988, Personal communication). With the

increase in population the perimeters of settlements have encroached in to the forest land Encroachments could not be evicted due to population pressure and partly due to political reasons The encroached areas in turn were converted to settlements and the natural habitats for natural forest regeneration shrinks

**Excessive Canopy Opening** Illicit cutting of trees for furniture construction fire wood (Plate IX Figure A & B) and charcoal making (Plate IX Figure C) are very much in vogue throughout the MDFs of TFD This has resulted in excessive opening and consequent paucity of regeneration in many areas Effective forest protection is very much lacking in the area

**Forest Fire** In the tropics forest fire is invariably of human origin (Fox 1976) MDFs are burnt by people for various reasons 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 feeding The hillmen who live inside the forest and the local people who depend on the forest for minor forest produce such as honey Acacia bark and fruits like soap nut etc burn the forest so that undergrowth is removed and walking is made easy Once fire infests an area seedling populations are highly affected (Plate VIII) Enormous number of seedlings die lest lose their above ground portions In areas with recurring fire seedlings of fire resistant species alone can survive



Plate VIII. Constraints in the natural regeneration of moist deciduous forests. A. Forest fire (Kuthiran, Pattikkad Range, April 1988). B. The result of fire in a rich population of natural regeneration of Xylia (Vazhani, Machad Forest Range, April 1988).

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**G r a z i n g:** People living close to the forest areas, in the absence of pasture lands depend on the forest for their cattle and goats to graze and browse. Many people allow their cattle to shelter inside the forest. Only during times of agricultural field work they bring their cattle back for ploughing. Likewise, cows are brought back only when they are milchy. 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 given population of cattle that affect regeneration. Instances abound from other parts of the world, where uncontrolled grazing has been proved to be inimical to the regeneration of forest trees (Linhart and Whelan, 1980; Prasad, 1985; Singh, 1983, 1985).

**B r o w s i n g:** Browsing by goats from the adjacent habitations are usual (Plate VIII, Figure D). But more destructive is the browsing by sheep herds. Kerala State as such does not have any sheep farming. With the consent of the Department, during the summer months sheep herds from Tamilnadu, Andhra Pradesh and Karnataka find their feed inside the Reserved Forests. A few months stay of the sheep herds inside the forest devastates all green herbage, including regeneration of tree species.

**I l l i c i t      E x t r a c t i o n      o f      S a p l i n g s  
a n d      P o l e s:** In recent years, especially when paddy cultivation has turned out to be uneconomical, throughout the plains paddy fields are used for banana cultivation. In order to protect the plantations from wind damage, support is given for each banana plant. Saplings and pole stage regeneration of trees

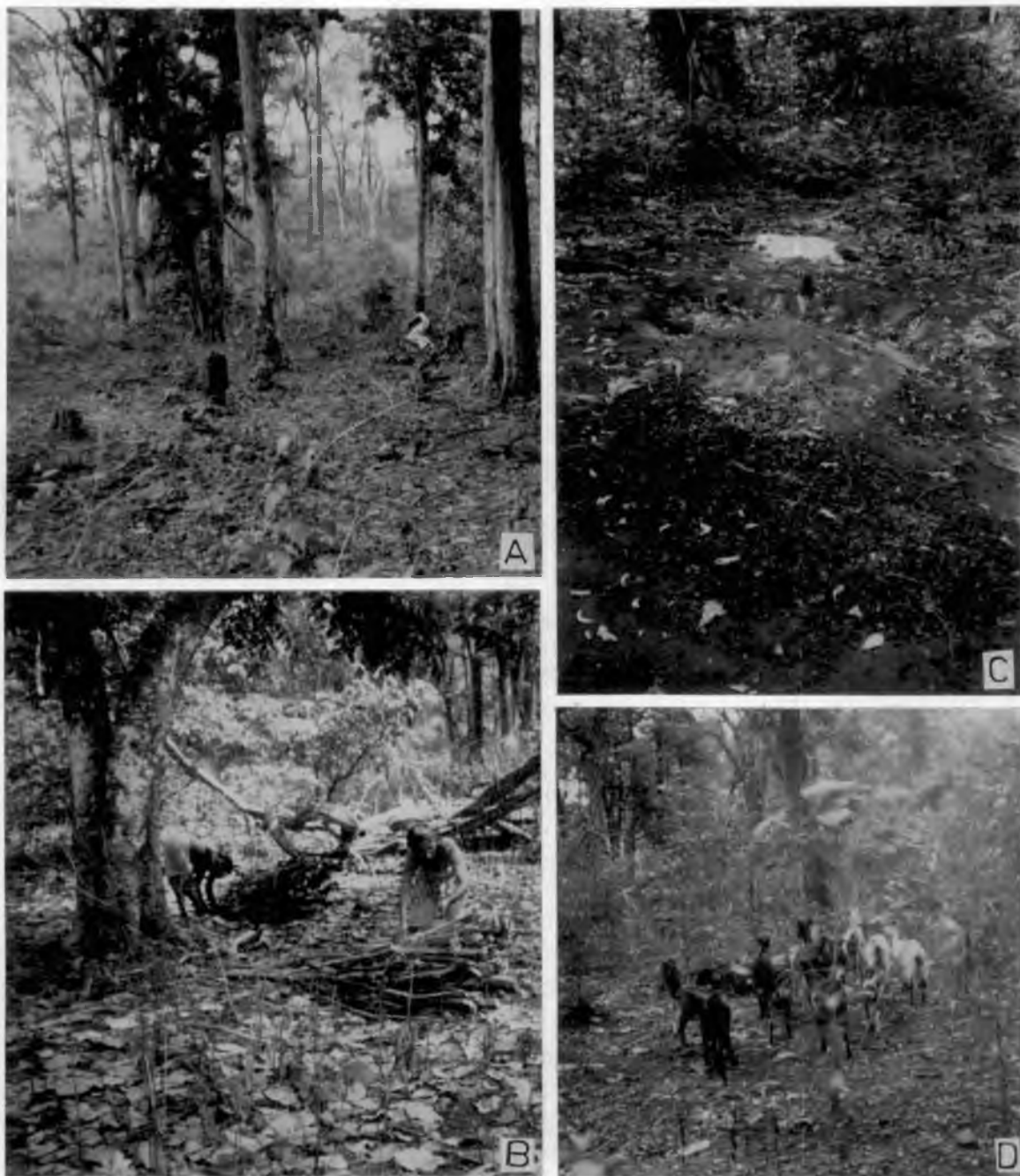


Plate IX. Constraints in the natural regeneration of moist deciduous forests (continued). A. Illicit cutting of trees and pole crops and the resulting gaps (Pathrakkallu, Machad Forest Range, 1988). B. Illicit charcoal making inside the forest (Mundippadam, Pattikkad Forest Range, 1988). C. Fire-wood collection. D. Browsing (Kuthiran, Pattikkad Forest Range, 1988).

are extracted from the forest for this purpose. In a similar way pole crops are also cut by local people for local small scale construction. These also contribute to the paucity of these life stages in the stands.

**Management Constraints** Before 19<sup>th</sup> century TFD was under the possession of the Raja of Cochin. Early Portuguese and Dutch extracted teak timber unscrupulously from the forests. Leasing to forest contractors after 1800 also resulted in over exploitation. Some measures to ensure regeneration were done during the 19<sup>th</sup> century by dibbling teak seedlings and by preventing unregulated cuttings. Scientific forest management in the Division started only during the 1900s. In 1908 Dewan Banerji closed Machad Range for extraction of valuable species. An area of ca. 520 ha distributed in the Machad and Pattikkad Ranges were successfully regenerated through a series of regeneration felling between 1931 and 1945. Selection felling for valuable species like Tectona grandis, Dalbergia sissooides, Xylia xylocarpa, Grewia tiliifolia, Terminalia crenulata, T. paniculata, Bombax spp, Tetrameles nudiflora and Alstonia scholaris were done during the period 1955 to 1970 (George 1963). However effective measures for assessment of regeneration status and implementing augmentation are lacking at present. Effective fire protection measures are also not being taken for the natural forests.

### Conclusions

The following conclusions are evident from the study

- 1 The MDFs of TFD show a three stratal vertical structure  
Species richness is highest in the middle stratum while least in the third stratum and intermediate in the upper stratum
- 2 While basal area and tree density (of trees > 20 cm DBH) contributed maximum by useful species The third stratum does not contribute significantly to stocking and biomass in terms of basal area
- 3 Frequency distribution in different size classes of the upper stratum and the dominant more abundant species of this stratum shows a negatively exponential curve with a less obvious rotated sigmoid curve at higher size classes  
Regeneration in terms of unestablished seedlings is not that deficient in the forests On the other hand saplings show low survival probability and conversion to pole stage crops is too little
- 4 The MDFs of TFD have good regeneration potential in terms of seed and seedling output Constraints operating on these regenerative sources are so many The exact cause of the acute deficiency of pole crops is yet to be ascertained  
Anthropogenic disturbances can be one among the dominant factors causing this anomaly Forest protection measures are not very effective owing to the involvement of human elements

- 5 Although mean values show good regenerative potential to the forests there are many degraded areas where this potential is low Here proper cultural and augmentation measures have to be undertaken so as to ensure good regeneration

## Summary

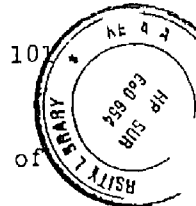
## 6 SUMMARY

Forest resources are renewable only because they do regenerate. Regeneration dynamics is one of the thrust areas of study in natural forest management. In the present study regeneration dynamics of commercially important species of the Moist Deciduous Forests of Trichur Forest Division are examined. Conventional demographic methods were followed so as to identify the nature of constraints and the life stages affected.

Enumeration and measurement of all trees and their regeneration were carried out in eight localities of varying disturbance. The size of releve studied in the least disturbed near natural site was  $90^2 \text{ m}^2$  and in other sites  $60^2 \text{ m}^2$ . Regeneration dynamics at population level in different cover percentages were also studied in three permanent plots.

The data were processed at three levels of organization viz. ecosystem (stand), stratum and species levels. The data were analysed to understand the behaviour of various parameters like genetic diversity, growing stock, basal area, importance value index, population structure, survival probability and regeneration status. Important findings are outlined in subsequent paragraphs.

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In the ca 5 ha area sampled (total of 8 samples) a total of 64 tree species have been encountered. The forests have a 3 stratum structure. Species diversity is least in the lower stratum (6.46 %) highest in middle stratum (61.29 %) and intermediate (33.87 %) in the upper stratum. All the 21 species occupying the upper stratum are commercially important and therefore high light demanders than the 43 species occupying the middle and lower strata.

Compared to the  $14.7 \text{ m}^2/\text{ha}$  of basal area cited by Seth and Kaul for the forest type, the Moist Deciduous Forests of Trichur Forest Division are less productive, the value being  $12.83 + 7.54 \text{ m}^2/\text{ha}$ . Basal area of the upper stratum is the largest and it decreases sharply with increasing disturbance. Whereas that of the middle and lower strata also decrease but gradually. Again compared to the growing stock of 167 trees/ha > 20 cm DBH cited by Seth and Kaul, the value obtained for Trichur Forest Division (149.79 trees/ha) is much less. Coming to individuals > 1 cm DBH, Trichur Forest Division has a mean value of 322.75 trees/ha. The growing stock of the middle and lower strata decrease exponentially with increasing disturbance. Nevertheless, that of the upper stratum is not very much affected by increasing disturbance.

Relative importance value index is maximum for the upper stratum, whereas it is minimum for the lower stratum. There exists a positive linear correlation between the relative importance value index of the upper stratum and disturbance. Analysis of the relative important value indices of the upper and

lower strata shows negative linear correlation the coefficient (-0.7259) being significant at 5 % level. Out of the 21 commercially important species five species viz Dillenia pentagyna, Grewia tillofolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa show higher value of basal area, relative basal area, density per hectare, relative density and relative importance value index and therefore are the dominant trees.

Population structure viz the pattern of frequency distribution in the different size classes shows a strongly skewed L shaped exponential curve for all the 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.

Weighted numerical estimates which qualify satisfactory regeneration status for the wet evergreen forests are already available. Comparable figures can be obtained for moist deciduous forests by taking account of the stocking level and observed survival probability of regeneration. Comparison of observed frequencies of unestablished (ht < 100 cm) seedlings to the weighted estimates indicates that their status is more or less satisfactory. On the other hand that of the established

seedlings (ht > 100 cm and < 10 cm DBH) is quite unsatisfactory. This denotes that actually the reproductive potential of the commercially important species is not low but is significantly mutilated by constraints operating during the conversion to established seedlings.

Semilogarithmic graphs of population structure of individual species generally mimics those of stands and therefore tends to be negatively exponential. Commercially important dominant species like Xylia xylocarpa and Terminalia paniculata do show similar graphs but with a depression in the size class d20 (> 10 and < 20 cm DBH pole stage). This depression is due to poor representation of pole crops. A deepening of this depression gives rise to a strongly bimodal graph in Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Radermachera xylocarpa, Stereospermum colais etc. owing to a total absence of pole crops. The low survival probability of saplings (1-10 cm DBH) leading to acute paucity of pole crops is the most serious constraint in the regeneration of commercially important species. Taking into account the casualties and mother tree populations, regeneration status is quite unsatisfactory for most commercially important species except perhaps in Xylia xylocarpa.

Constraints in the regeneration of the commercially important species are manifold. The regeneration population of the commercially useless species outnumber that of the useful species and offers strong competition to the latter. In addition to that offered by weedy shrubs, twiners and lianes. Some species have inherent intrinsic constraints. This is best exemplified by

Lagerstroemia microcarpa where the mill on of seeds produced each year are sterile in the absence of a viable embryo. More crucial are the constraints of human origin. Grazing and browsing (especially by sheep) reduce the population size considerably. Recurrent fire both intentional and unintentional nullifies the reproductive potential by devastating the cohorts. Illicit cutting of saplings, poles and trees creates gaps in stands and distorts the population structure of individual species. This in turn leads to poor regenerative potential.

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Regeneration Status of  
Some Important Moist Deciduous Forest Trees  
in the Trichur Forest Division

*by*

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**ABSTRACT OF A THESIS**

submitted in partial fulfillment of the  
requirement for the degree

**MASTER OF SCIENCE IN FORESTRY**

**KERALA AGRICULTURAL UNIVERSITY**

Faculty of Agriculture

**COLLEGE OF FORESTRY**

Vellanikkara Trichur

1988

## ABSTRACT

Sustained management of forests depends on their ability to regenerate. The pace at which the older trees are replaced by younger ones is very important in this respect. The details of sylvigensis is little known especially of the moist deciduous forests.

To get a general idea of the regeneration behaviour of the moist deciduous forests eight localities of varying levels of disturbance were sampled in the Trichur Forest Division. Enumeration of trees and their regeneration were done and data were analysed at three levels of organization viz ecosystem level, stratum level and species level.

Physiognomically the moist deciduous forests comprise three vertical strata namely upper, middle and the lower. The middle stratum is richest in species. Most of the species represented in the upper stratum are commercially important. Five species Dillenia pentagyna, Grewia tiliifolia, Lagerstroemia microcarpa, Terminalia paniculata and Xylia xylocarpa occupying the upper stratum possess higher values of basal area, relative basal area, density per hectare, relative density and importance value index and are the dominant ones.

The average growing stock of desirable commercially important species > 20 cm DBH per hectare is 149.79. This is slightly lower than the average of 167 trees/ha cited by Seth and Kaul. The growing stock of trees > 1 cm DBH of the middle and

lower strata decrease exponentially with increasing cover gaps. The upper stratum on the other hand is not much affected by disturbance. In fact, with slight disturbance it increases a little. Relative importance value index of the middle stratum increases where that of the lower stratum decreases and vice versa.

Frequency distribution statistic for stands and strata conform to the negatively exponential model. Mortality rates are maximum in the lower size classes. Comparison of observed frequencies of unestablished seedlings to the expected frequencies of the commercially important stratum indicates that the reproductive potential of stands is not poor. On the other hand, the growing stock of established seedlings (saplings + poles) is very low. Owing to very low survival probability in the sapling stage, acute paucity of poles of the upper stratum is observed. The five dominant species show the same pattern of population structure and distribution of survival probability as the stratum.

Regeneration of important species in the moist deciduous forests is under various stresses of which that of human origin is the most hazardous. Grazing, browsing, fire, and illicit cutting are the greatest constraints. Some species like Lagerstroemia microcarpa also show some intrinsic constraints.