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

NARAYANAN ILLATH VALAPPIL

THESIS

submitted in partial fulfilment of the
requirement for the degree

MASTER OF SCIENCE IN FORESTRY

KERALA AGRICULTURAL UNIVERSITY

Faculty of Agriculture

COLLEGE OF FORESTRY
Vellanikkara Trichur
1988

Dedicated to

My Parents

DECLARATION

I hereby declare that the thesis entitled Regeneration status of some important moist deciduous forest trees in the Trichur Forest Division is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other University or Society

Vellanikkara
15 12 1988

Narayanan Illath Valappil

CERTIFICATE

Certified that the thesis entitled Regeneration Study of Some Important Moist Deciduous Forest Trees in the Trichur Forest Division is a record of research work done independently by Shri Narayanan Illath Valappil, College of Forestry, Vellanikkara, under our guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

27/1/89

Dr B Mohan Kumar
Assistant Professor
College of Forestry
[Chairman, Advisory Committee]

Dr K Swarupanandan
Scientist
Kerala Forest Research Institute
[Co-Chairman, Advisory Committee]

Approved by

1 Dr B Mohan Kumar Chairman

2 Dr K Swarupanandan Co-Chairman

3 Dr K V Satheesan Member Satheesan

4 Sri N Sasidharan Member

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 Swarupanandan 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 cumber ome 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

CONTENTS

Contents (continued)

Contents (continued)

ABBREVIATIONS

ADNO	ADaptation Number
C	Celsius (° C)
CI	Continuum Index
cm	centimeter
D	Density
DBH	Diameter at Breast Height
DI	Distrubance Index
DPH	Density Per Hectare
d10	DBH > 1 cm and < 10 cm
d20	DBH > 10 cm and < 20 cm
d30	DBH > 20 cm and < 30 cm
d40	DBH > 30 cm and < 40 cm
d50	DBH > 40 cm and < 50 cm
d60	DBH > 50 cm and < 60 cm
dg60	DBH > 60 cm
GBH	Girth at Breast Height
ha	hectare
h50	height < 50 cm
h100	height > 50 cm and < 100 cm
hg100	height > 100 cm and DBH < 1 cm
ht	height
IVI	Importance Value Index
Kc	the locality Kalluchal
km,	kilometer
Kp	the locality Karadippara
Kt	the locality Kuthiran
Loc	Locality
MDF	Moist Deciduous Forest
Max	Maximum
Min,	Minimum
Mp	The locality Mundippadam
m	meter
mm	millimeter
No	Number
PC	Percentage Composition
Pk	the locality Pathrakkallu
RD	Relative Density
RDI	Relative Disturbance Index
RIVI	Relative Importance Value Index
SD	Standard Deviation
SE	Standard Error
Sp	Species
Spp	Species
Stat	Statistic
TFD	Trichur Forest Division
Vz1	the locality Vazhani-1
Vz2	the locality Vazhani 2
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 ecostystems 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 reaearch 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^2 of moist deciduous forests They are the habitats for our most valuable timber species like rose wood (*Dalbergia latifolia* Roxb *D sissoides* Grah et Wt et Arn) teak (*Tectona grandis* Linn f) irul (*Xylia xylocarpa* (Roxb) Taub) maruthi (*Terminalia crenulata* Roth *T paniculata* Roth) venteak (*Lagerstroemia microcarpa* Wt) chadachi (*Grewia tiliifolia* Vahl) vaga (*Albizia odoratissima* (Linn f) Benth) manjakkadambu (*Haldina cordifolia* (Roxb) Ridsd) etc Regeneration 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 stges 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 Divisionis situated on the western half of the horizontal arm of this T-shaped portion of the Western Ghats It is bordered by settlements and revenue lands all along the western eastern and northern boundaries and by the Chalakkudy and Nemmara Forest Divisions along the south and south east respecitively (Figure 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° 25 and 10° 45 N and longitudes 76° 05 and 76° 30 E As reconstituted in 1980 it comprises an area of approximately 328 km^2 of forests divided into four administrative blocks viz Wadakkanchery Machad Pattikkad and the Peechi Ranges (cf Figure 3) Of the above the Natural Forests the area of the present study constitutes approximately 204 km^2 spread oyer the Mukundapuram Trichur and Thalappilly Taluks (Menon and Balasubramanyan 1985)

Climate

The area shares a warm humid climate characteristic of the region

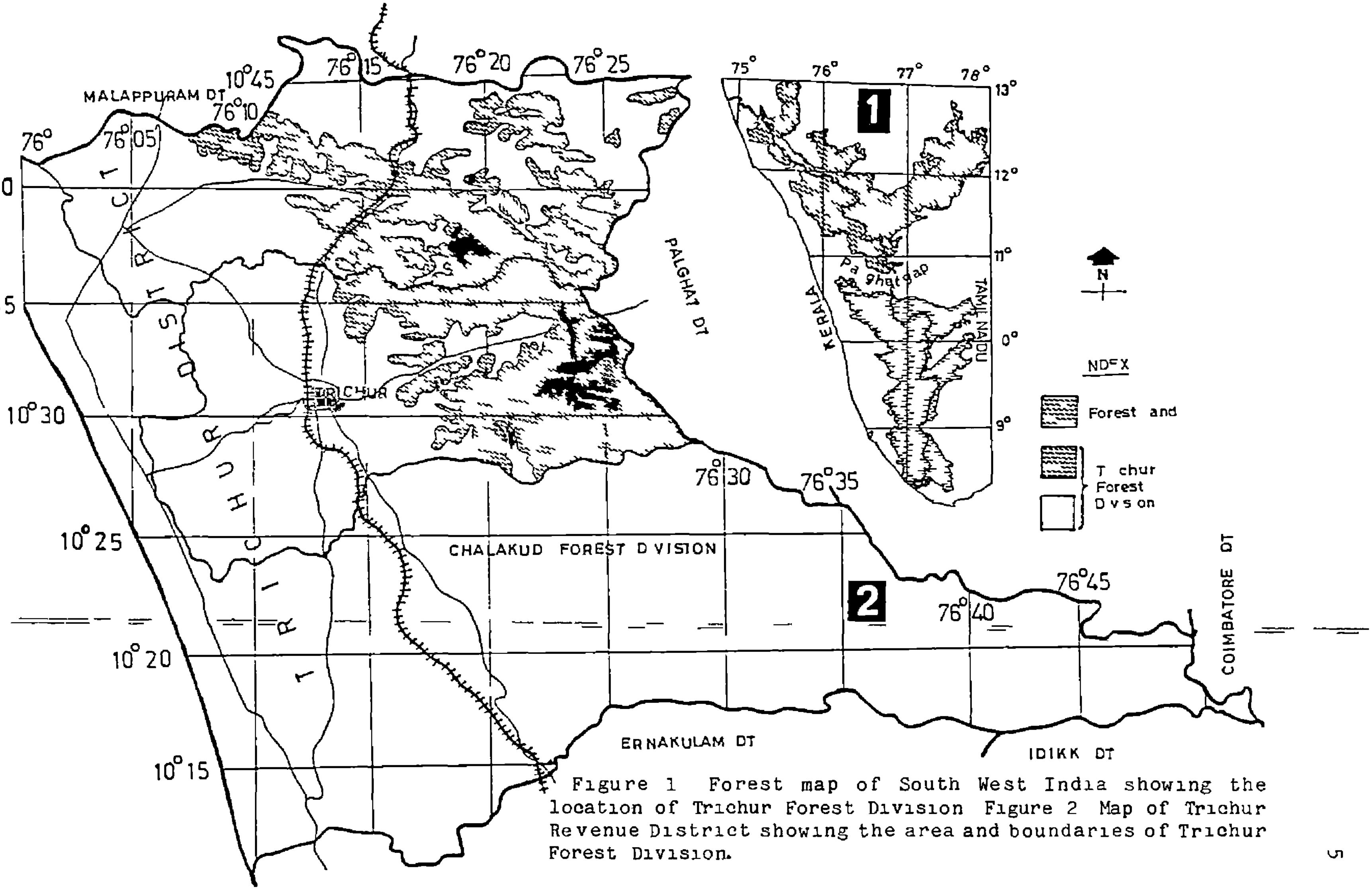


Figure 1 Forest map of South West India showing the location of Trichur Forest Division Figure 2 Map of Trichur Revenue District showing the area and boundaries of Trichur Forest Division.

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 is 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

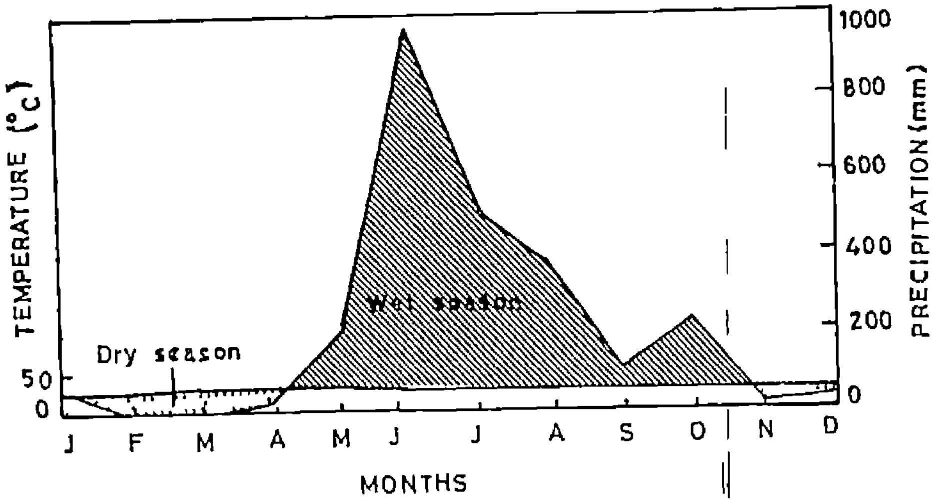
The trade winds during the two monsoons are south-west and north east respectively During the months December to February the forests on the eastern borders receive warm winds coming through the Palghat Gap A rare incident of cyclonic wind was also recorded for the Division during the year 1940

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 dur ng an ave age year (1985) at Peechi

Var	Stat	J	F	M	A	M	J	J	A	S	O	N	D
Temp (°C)	Max	33 3	36 1	37 2	37 8	38 3	31 1	31 7	31 1	32 8	32 8	33 3	34 4
	Min	18 9	19 4	22 2	22 2	20 6	21 1	20 6	21 1	21 7	21 7	20 0	20 0
	Mean	25 8	27 8	30 7	30 7	29 4	25 5	25 2	25 7	27 0	26 6	26 7	27 9
Ra n (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 hum d	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



F g 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 intrution 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 predominent 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
2 Wadakkanchery Vazhani Rd
3 Trichur-Mannamangalam Rd
4 Trichur-Ramavarmapuram Vazhani Rd
5 Trichur Shoranur Rd and
6 Pattikkad-Peechi Rd

People living immediately around the natural forests are highly dependent on the forests for agriculture firewood cattle grazing and smaller construction needs The Malayas the tribals at Velanganoor and 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 ±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 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 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 st) middle (II nd) and lower (III rd) strata

Table 2 List of tree species arranged according to their 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 sissoides 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 Aporusa lindleyana (Wt) Baill
23 Artocarpus hirsuta Lamk
24 Bauhinia racemosa Lamk
25 Bridelia squamosa Gerh
26 Carallia brachiata (Lour) Merr
27 Careya arborea Roxb
28 Cassia fistula L
29 Cleistanthus collinus Hook f
30 Cordia 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 Dcne
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 Schleichera oleosa (Lour) Oken
51 Spondias pinnata (L f) Kurz
52 Sterculia guttata Roxb
53 S urens Roxb
54 Streblus asper Lour
55 Strychnos nux vomica L
56 *Syzygium sp
57 Trema orientalis (L) Bl
58 Vitex altissima L f
59 Xeromphis spinosa (Thunb) Keay
60 X uliginosa (Retz) Mahesh

Lower stratum

61 Casearea sp
62 Holarrhena antidysenterica (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).

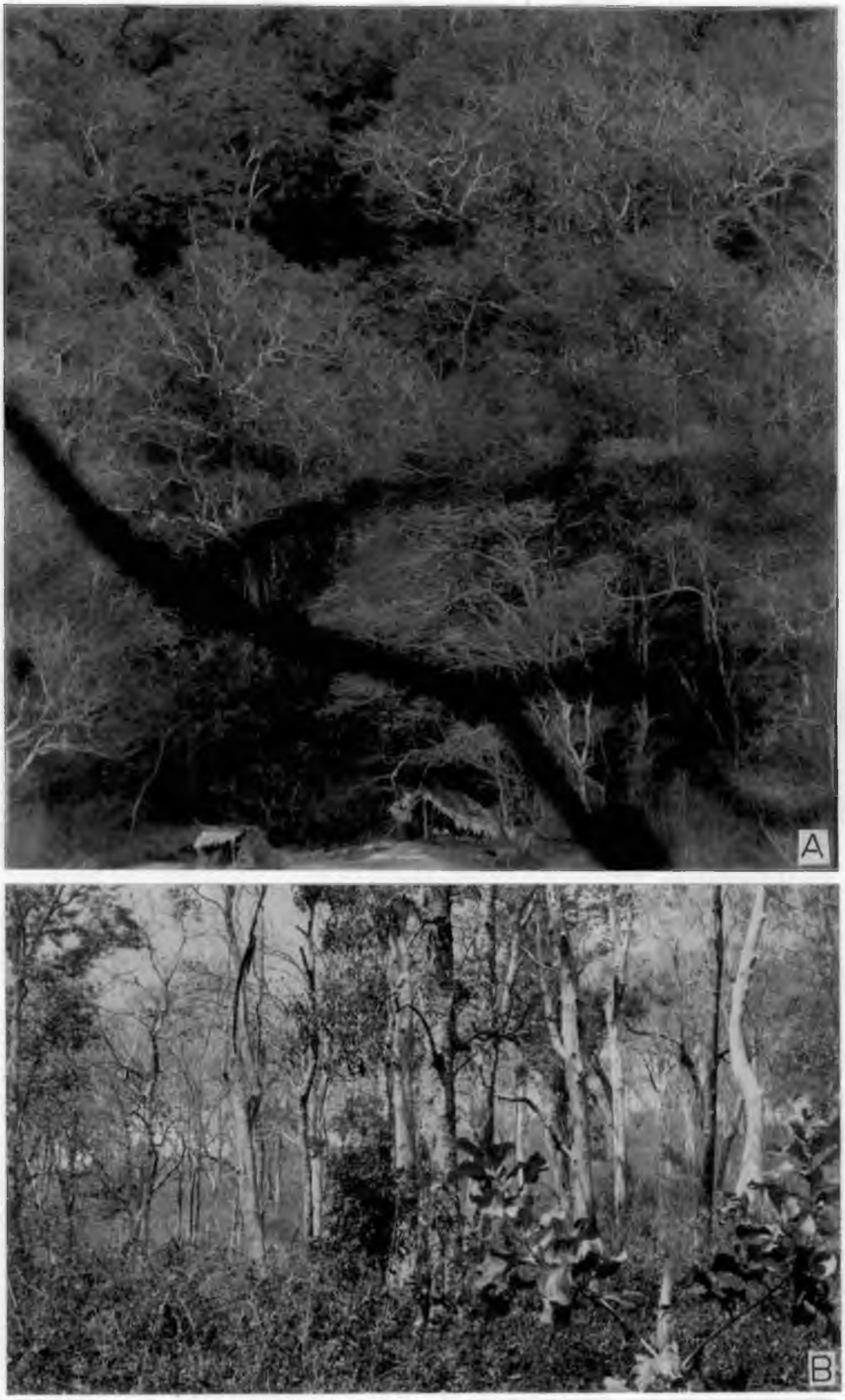


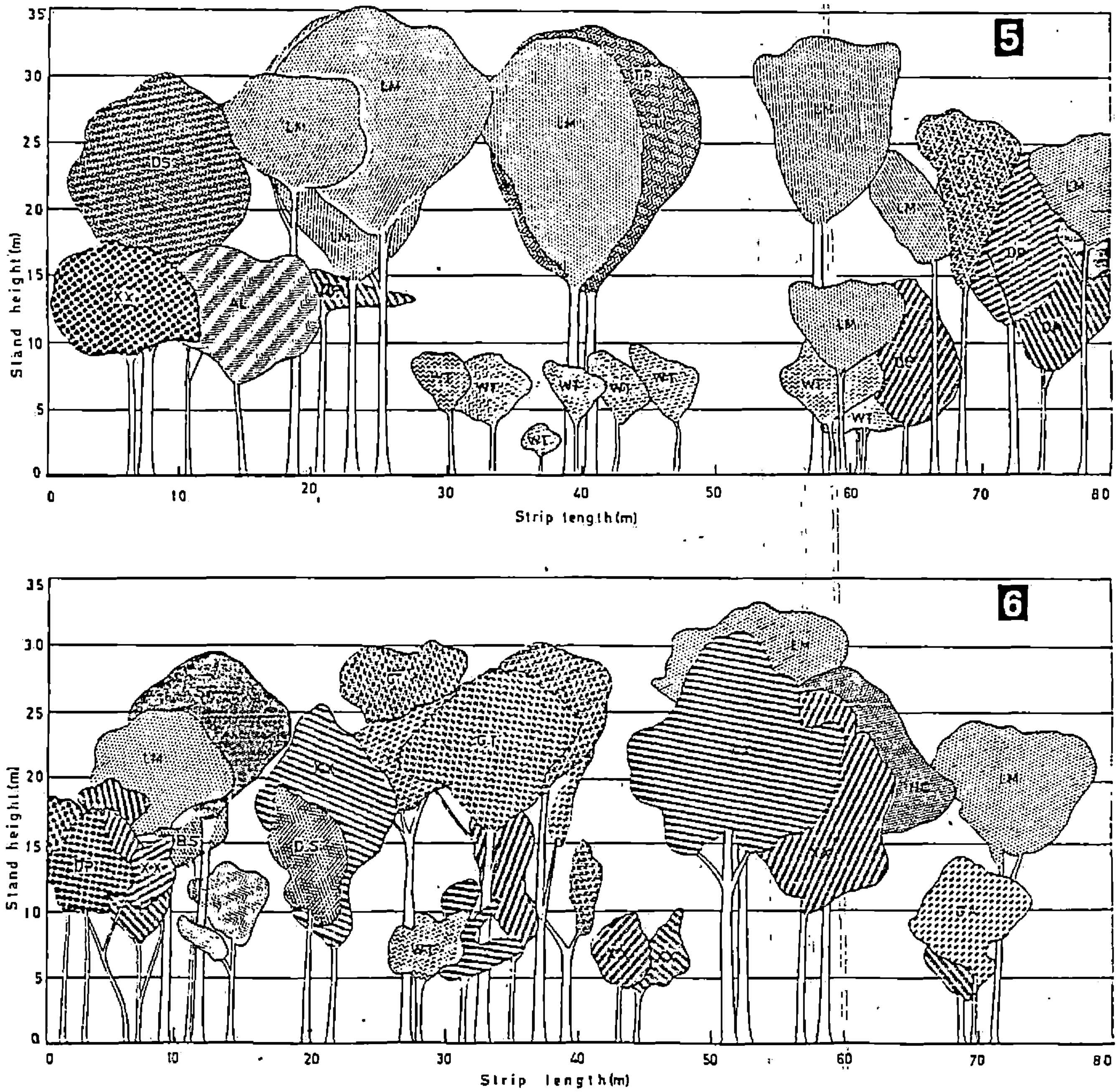
Plate III. Moist deciduous forests of Trichur Forest Division. A. A view from above (Chathupara, Peechi Forest Range, April 1988). B. A view of the stand from below (Vazhani, Machad Forest Range, April 1988).

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 preponderence of *Lagerstroemia microcarpa* is seen (Eg Karadippara - Plate V Figur 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 >= 10 cm DBH of tree species alone depicted).

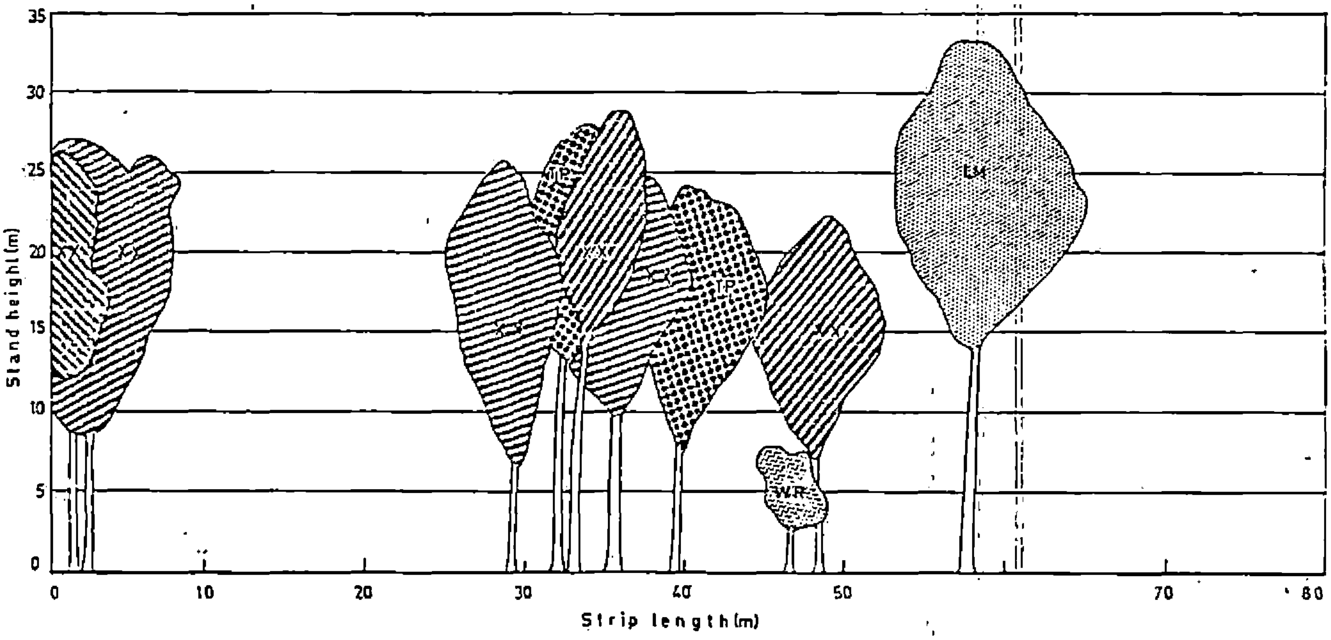


Figure 7. Vegetation profile of the locality Kuthiran (individuals >= 10 cm DBH of tree species alone depicted).

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 preponderence 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 Releve 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 m^2 Here they took 3 m as the lower threashold for consideration as a tree

However in the present study 30 cm GBH (≈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 specie 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 m^2 and at Kalluchal 60^2 m^2 (Figure 8) Accordingly

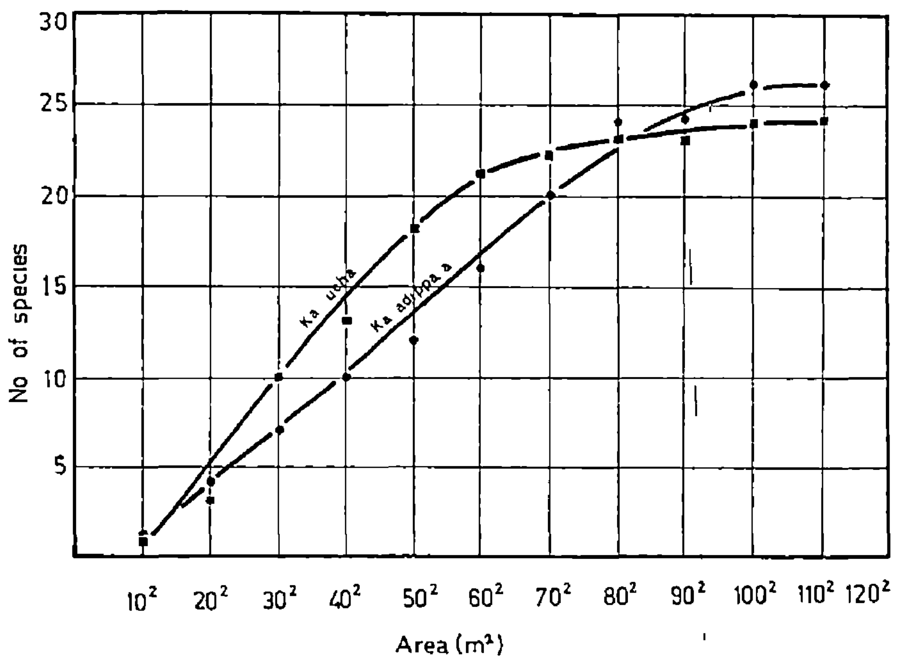


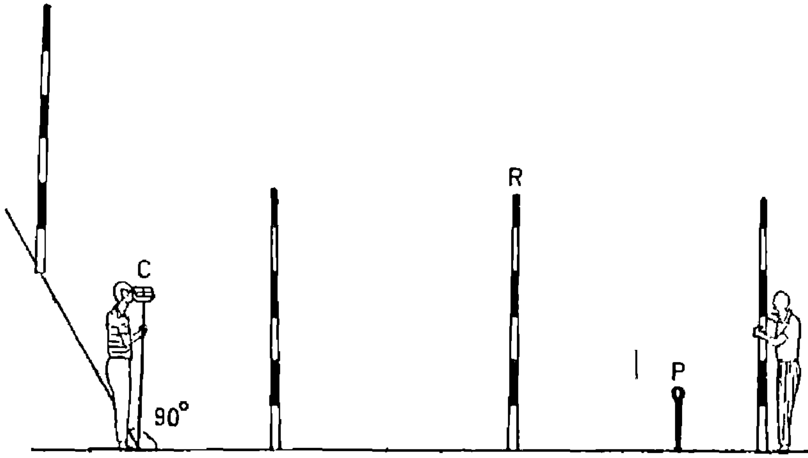
Figure 8 Species area curves and actual data points for two sample localities Regression equations for the localities are
1 Kalluchal y 26 9966 + 12 8745 log x
2 Karadippara y -30 5411 + 13 6009 log x R^2 0 919** where y is the number of species and x the area in m^2

releve of size 60^2 m^2 was studied for each locality except Karadippara

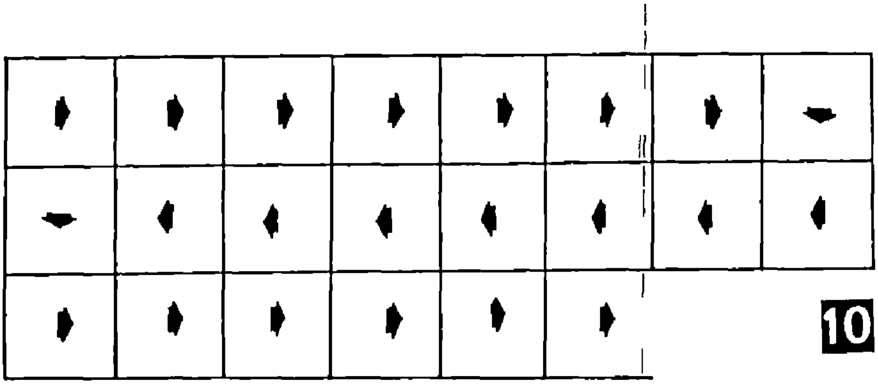
Sample Plots Once the size of the releve was determined three permanent plots were established at Karadippara Kalluchal and Kuthiran being representative samples for different canopy opening levels These plots were surveyed with the help of cross staff and ranging rods (Figure 9) The plots were divided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

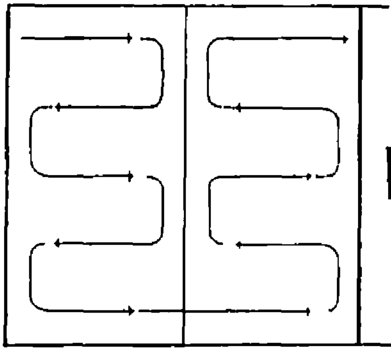
Releve Record Preparatory to regeneration enumeration based on general visual observations a releve record was obtained of the localities (cf Tables 3 10) Elevation aspect slope dominant species undergrowth soil and the kind of disturbances noted in the field



9



10



11

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 m^2) 11 Sequence of measurement of individuals in a quadrat

C cross staff P peg R ranging rod

Table 3 Releve 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 *Aporusa* *Strychnos* *Bauhinia* *Sterculia guttata* *Macaranga*
T3 *Holarrhena* *Wrightia*
C1 *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 cropsare practically absent fire usual during the summermonths grazing and browsing much less when compared to other localities

Table 4 Releve 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*
C1 *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 Releve record for locality Kuthiran(Kt)

Latitude $30^{o}34$ 12 Longitude $76^{o}23$ Altitude ±180 m

Administrative block Pattikkad Forest Range

Location About 1 5 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 Releve record for locality Mundippadam(Mp)

Latitude $10^{o}36$ Longitude $76^{o}23$ 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 regeneratawion of *Sterculia guttata* present

Table 7 Releve 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 Releve record for locality Vazhani 1(Vz1)

Latitude 10°38 53 Longitude 76$_{0}$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 $10^{o}38$ 52   Longitude $76_{o}18$ 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 $10_{o}38$ 52   Longitude $76^{o}18$ 45   Altitude +115 m

Administrative block Machad Forest Range

Location About 1 5 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 measuresments 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.

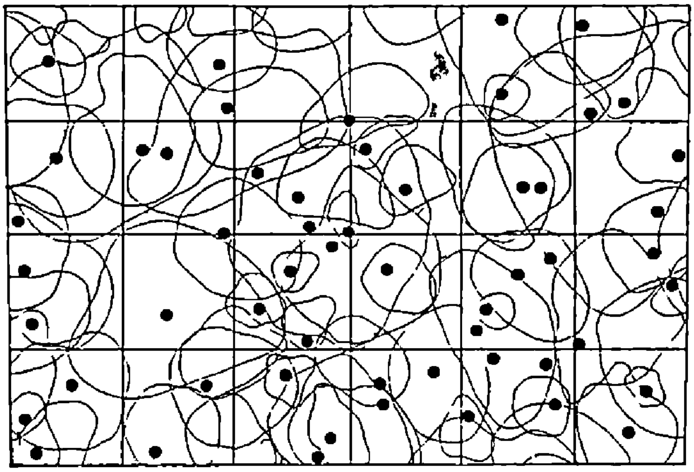
Plot No	Locality	Sample (m^2)	Gap (m^2)	Gap %
6	Kc	1600	19.36	1.21
3	Kp	2100	83.58	3.98
7	Kc	1700	184.79	10.87
5	Kc	2100	361.83	17.23
1	Kp	2300	421.59	18.33
8	Kt	2000	402.20	20.11
4	Kp	1200	261.72	21.81
9	Kt	2000	479.00	23.95
2	Kp	1500	394.95	26.33
10	Kt	2400	725.28	30.22

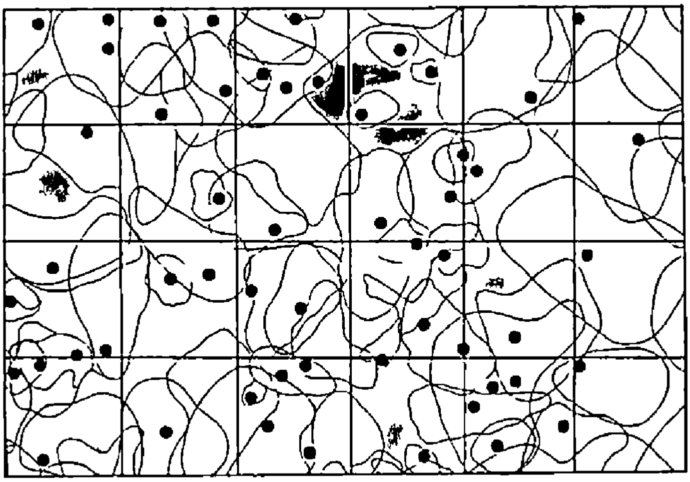
A size to scale map of the permanent plot was drafted on a graph paper. The position of the pegs were marked in the map. In each of the 10 m X 10 m quadrats, all the trees above 30 cm GBH were enumerated and numbered. Next the position of each of the trees in the quadrat was transcribed to binary numbers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

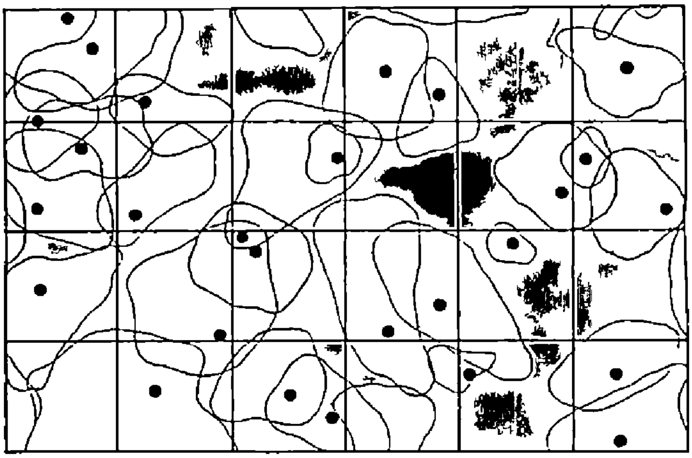
Plate VII. Measurements in the field. A. Measuring the GBH of a tree of Terminalia bellirica with large plank buttress. B & C. Measurement of the seedlings. B. A seedling of Sterculia guttata. C. A seedling of Dillenia pentagyna.

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 thespecies 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 cf 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 (Ayliffee 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 catagorical 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 Regneration 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 convertion 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 Hymmenaea courbanil (Fabaceae) although flowering takes place annually fruiting is abundant only once in five years Abortion of flowers and immature fruits ranging between 1 to 100 % 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 casualities 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 had 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 accoarding 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 Tamari 1973) while those of other species extend from two weeks to 3 years (de la Mensbrugi 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 dominent 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 tolerent 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 cf 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) clsses 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 strsucture of most tree species show strongly skewed L shaped graphs while others show an exponential model Some erratic species show normal distribution Semilogarathmic 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 overcrowing 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 modification 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 Fourty 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 Contribution 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 Mensbrugi (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 regenenration 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 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 ah 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 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 therfore 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	
Noof sp	Percentage	No of sp	Percentage	No ofsp	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 specie diversity and it 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+7 54 m^2/ha the actual range being 4 36 m^2 to 25 89 m^2/ha With respect to basal area too the MDFs of TFD are less productive compared to the 14 7 m^2/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+6 92 m^2 1 07+0 89 m^2 and 0 42+0 79 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 m^2 and 23 34 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

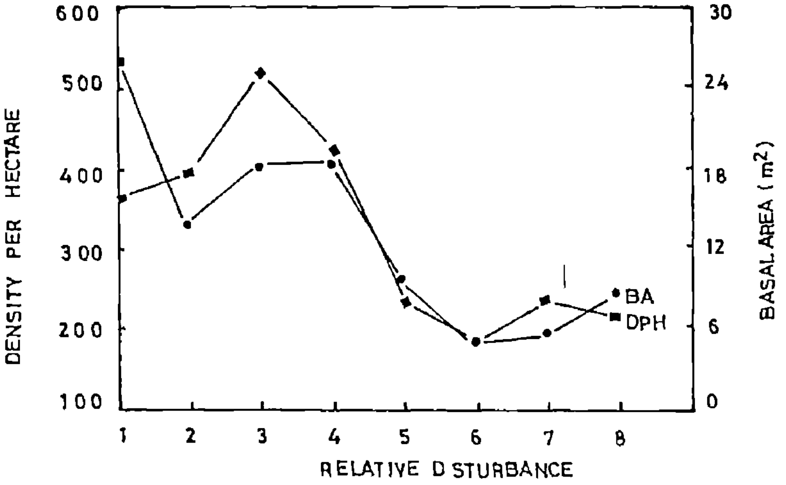


Fig 15 Disturbance and structural attributes

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

Loc	BA (m²/ha) All Trees	BA (m²/ha) Stratal number I	II	III	RBA Stratal number 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 (m²/ha) Max	Min	Mean	RBA 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 sissoides	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 analysi (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+6 55 8 59±5 9 and 1 99±2 77 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 m^2/ha and 4 0601 m^2/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 m^2/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_ alongwith the earlier listed five species

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

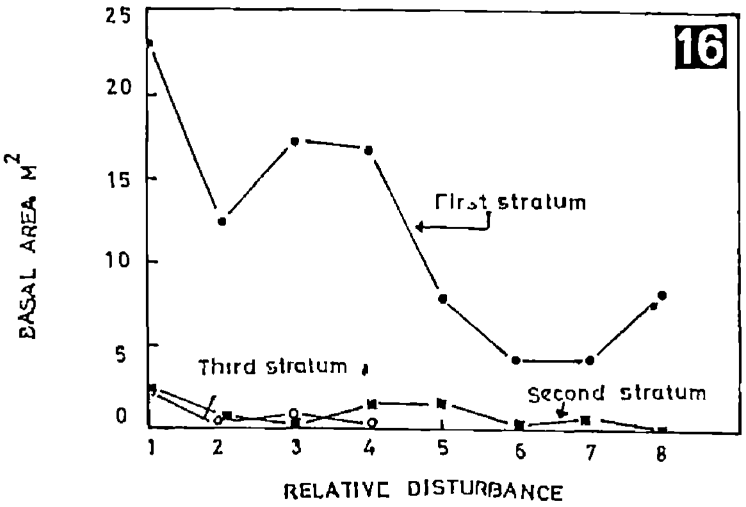
At Ecosystem Level The average per hectare growing stock of trees > 20 cm DBH per hectare was 149 79 the actual range being 120 and 182 84 trees Compared to the value of 167 trees/ha given by Seth and Kaul (1978) the average growing stock for the MDFs of TFD is less (Table 16) Coming to trees > 1 cm 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

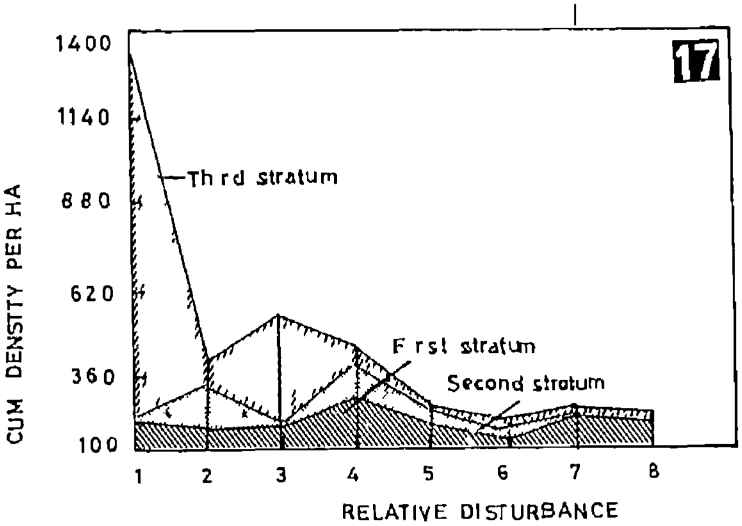
Table 16 Descriptive statistics of Density per Hectare (DPH) and Relative Density (RD)

Loc	Density Per Hectare (DPH) > 20 cm	Density Per Hectare (DPH) > 1 cm DBH				Relative Density (RD) > 1 cm DBH		
	All Trees	All Trees	Stratum number I	II	III	I	II	III
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





F gs 16 17 D sturbance and structural attr butes

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±38 76 52 65+43 12 and 218 11±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±19 51 14 32±9 97 and 23 86+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 DPH (> 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 insigne) 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 anlaysis 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 specieswere 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 insigne) 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)

Loc	Relative IVI			CI	DI
	Stratal number				
	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 sissoides	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 crenulata	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

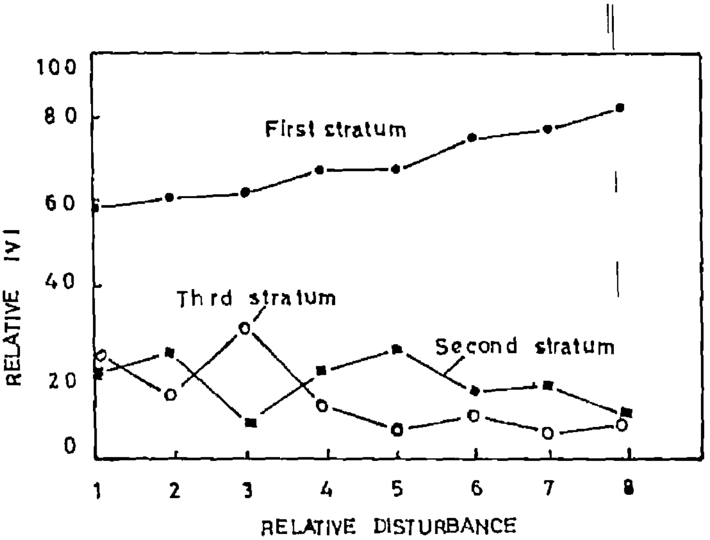


Fig 18 Relation between disturbance and IVI

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 where 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 allthough 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 extant 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 hectare 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 clas 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

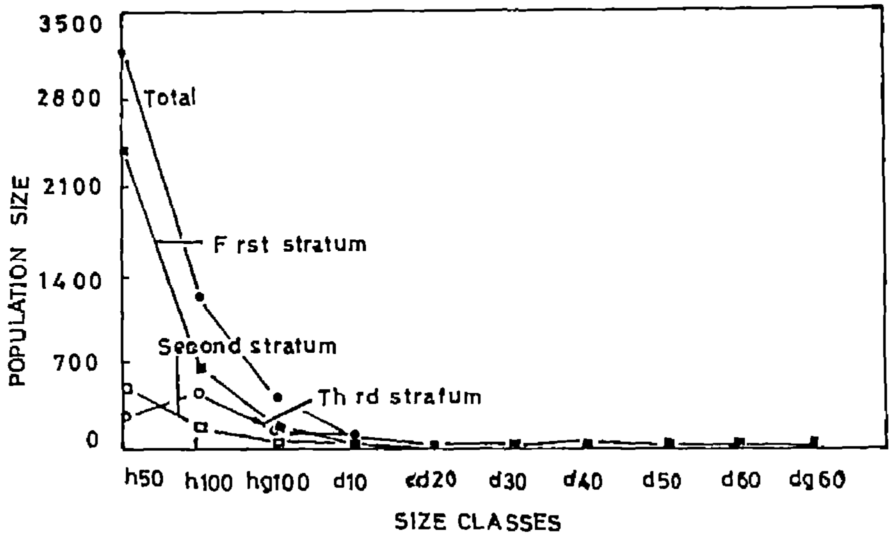


Fig 19 Population structure of different strata

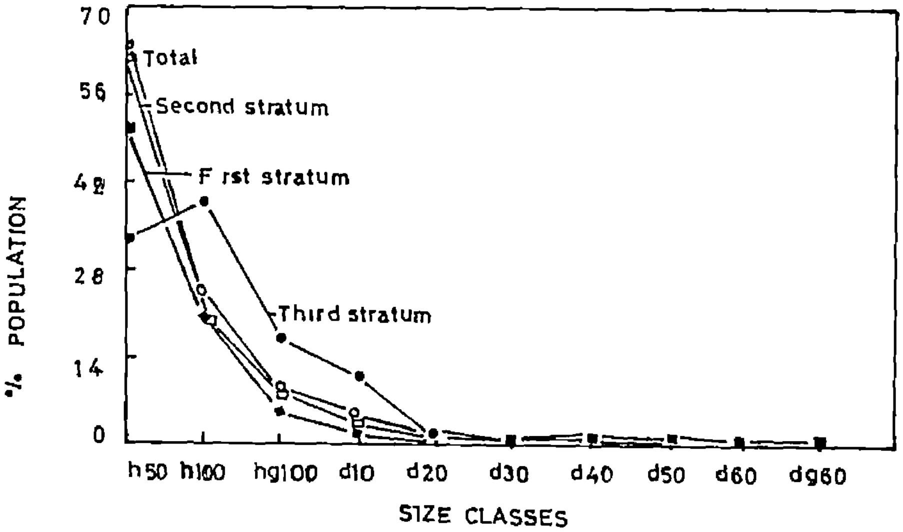


Fig 20 Percentage composition of size classes in each stratum

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 sharpely 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 <u>Shorea robusta</u> (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 conveneience 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 Nair s (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)

	Wet Evergreen Forests	Moist Deciduous Forests		
Regeneration classes	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+ 1091 60
Established seedlings (ht > 100 cm and DBH < 10 cm)	1000	577 86	525 58	238 77+ 88 55

Table 25 Observed frequencies in regeneration classes of different strata

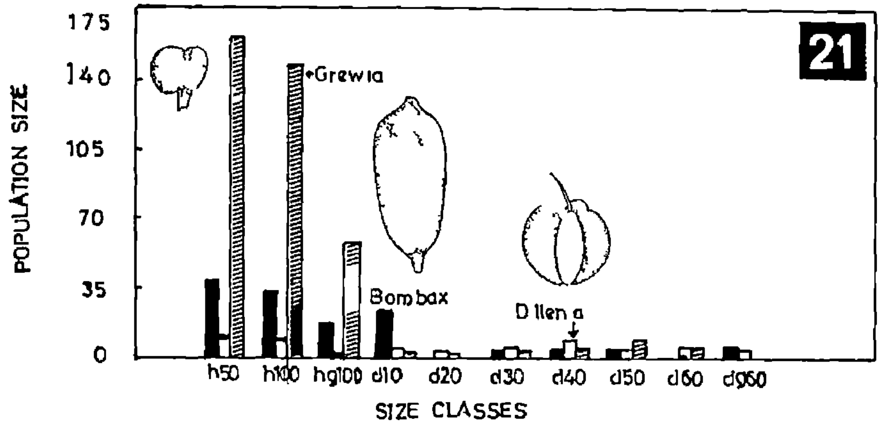
Regeneration class	Frequency in different strata		
	Stratal number		
	I	II	III
Unestablished seedlings (ht < 100 cm)	3042 85+ 1091 60	669 85+ 215 10	698 85+ 400 62
Established seedlings (ht > 100 cm and DBH < 10 cm)	238 77+ 88 55	115 44+ 59 38	231 34+ 124 95

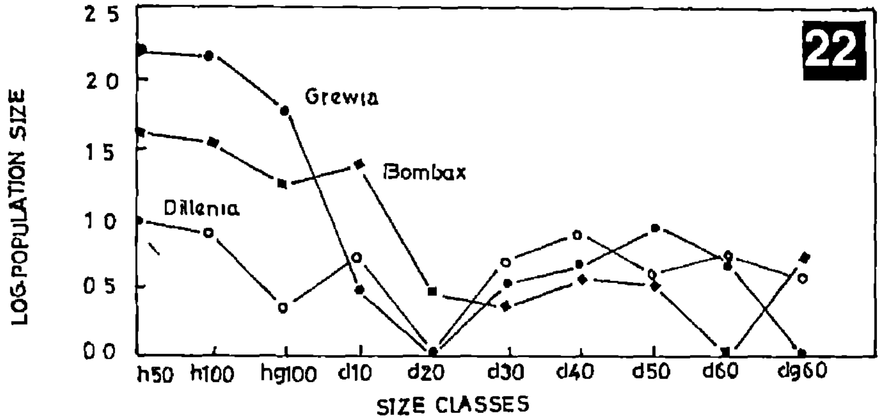
Observed frequencies in different regeneration classes of different strata are given in Table 25 the number of unestablished seedlings in each of the middle and lower strata is always less than that of the upper stratum Nevertheless together they accout to almost half of the population size of the upper 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 staratum 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 interms 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 tiliifolia* *Lagerstroemia microcarapa* *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*

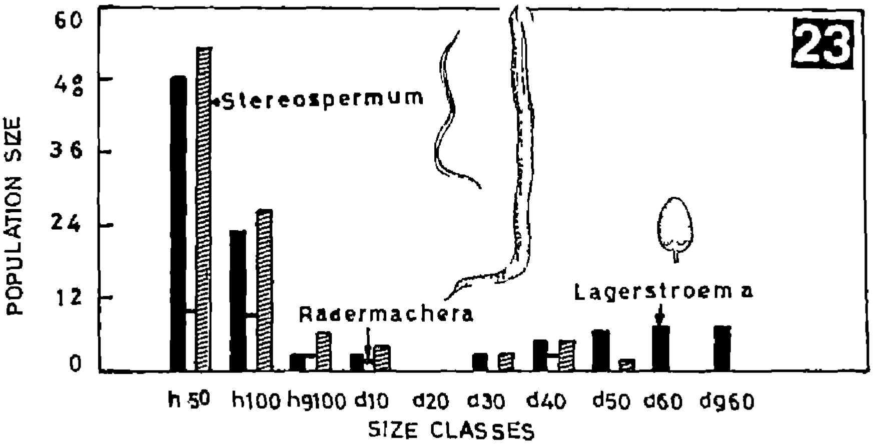
Table 26 Average size class frequencies given as percentage of total population of selected species

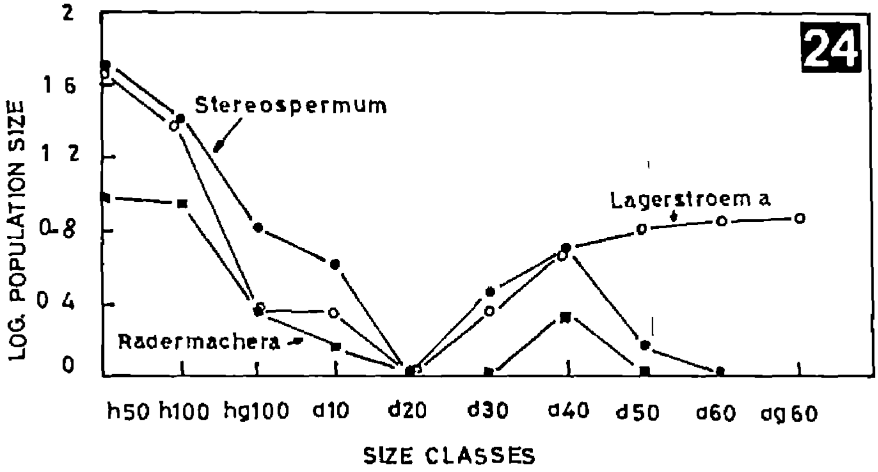
Species	Size classes									
	h50	h100	hg100	d10	d20	d30	d40	d50	d60	dg60
Albizia	96 04	2 75	0 10	0 04	0 00	0 00	0 06	0 11	0 00	0 00
Alstonia	17 72	37 43	20 08	20 46	4 30	0 00	0 00	0 00	0 00	0 00
Bombax spp	45 98	33 44	8 61	7 56	0 47	0 37	1 19	1 56	0 00	0 83
D sissoides	77 81	11 81	4 40	1 02	0 00	0 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





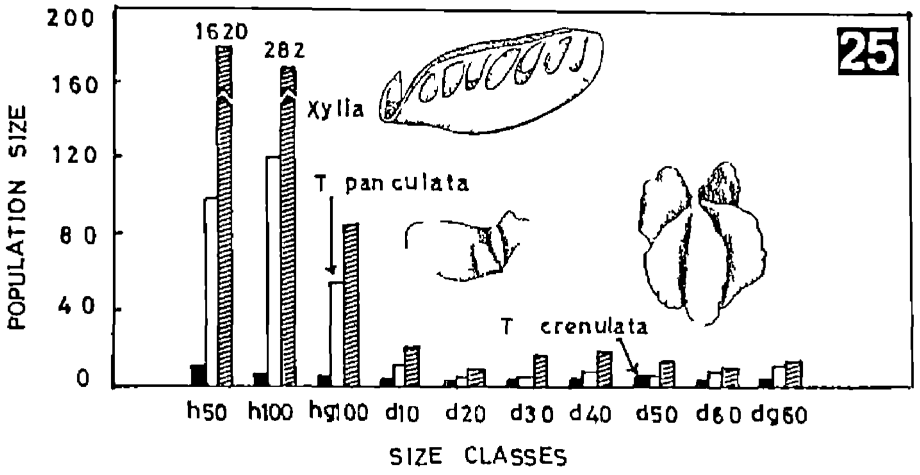
Figs 21 22 Population structure of selected species.

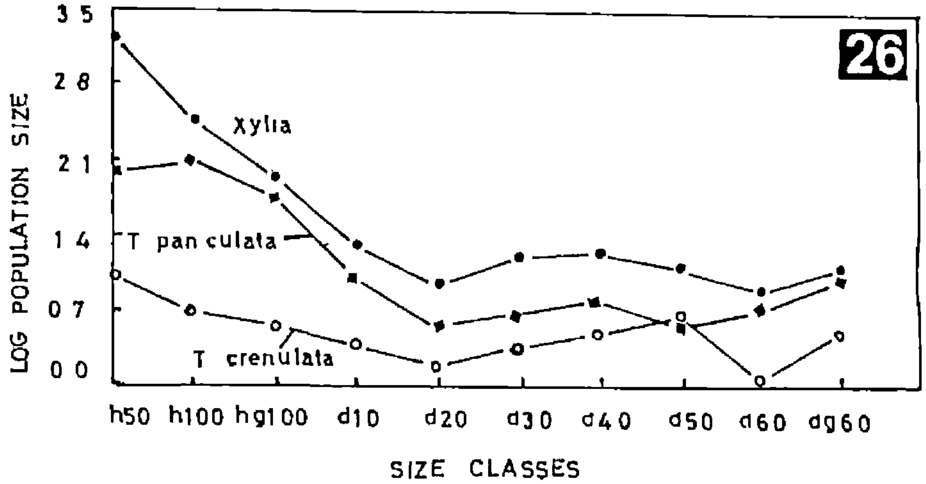




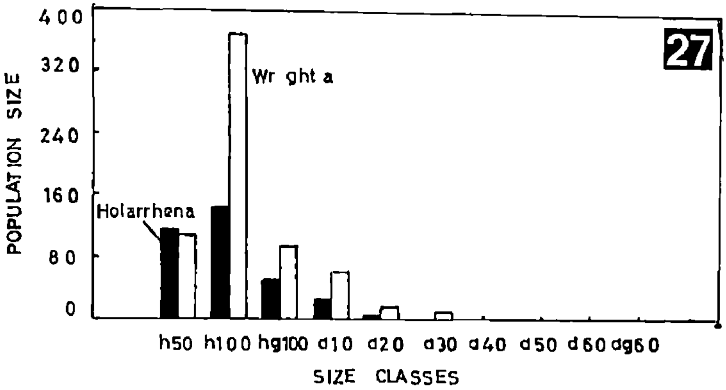
Figs 23 24 Population structure of selected species *antidysenterica* and *Wrightia tinctoria* are very much abundant in the stands and therefore are also included in the discussions

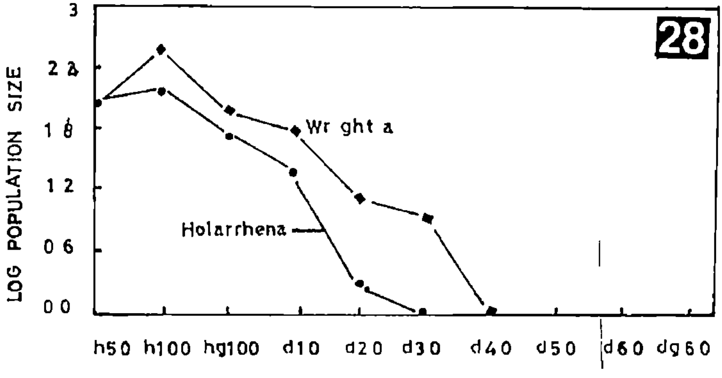
Population structure of the dominant species together with that of a few co dominant species are depicted in Figures 21 28 Size class representation in terms of percentage of the total population of each species is given in Table 26 Distribution of size in terms of semi logarithmic graphs has been proved 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 casualities 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

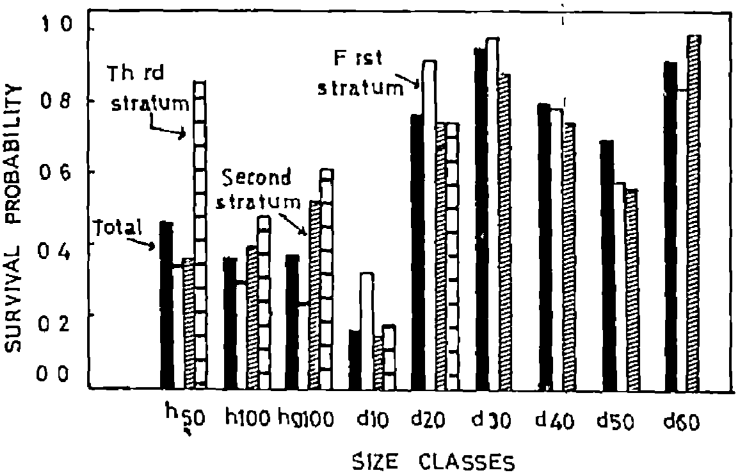
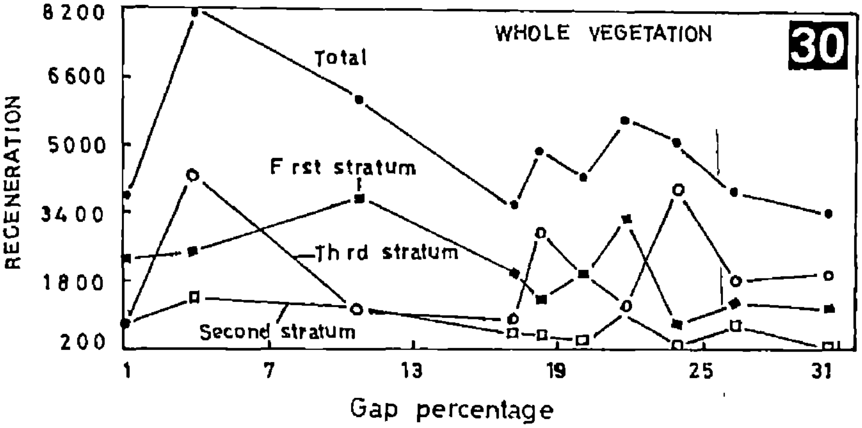
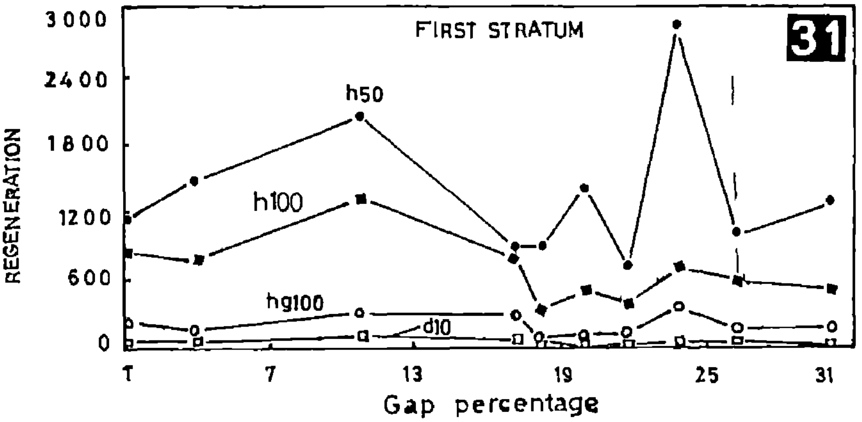


Fig 29 Distribution of survival probability

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

	Stratal number					
Stat	I		II		III	
	Mean	SE	Mean	SE	Mean	SE
Max	1 000	0 419	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	



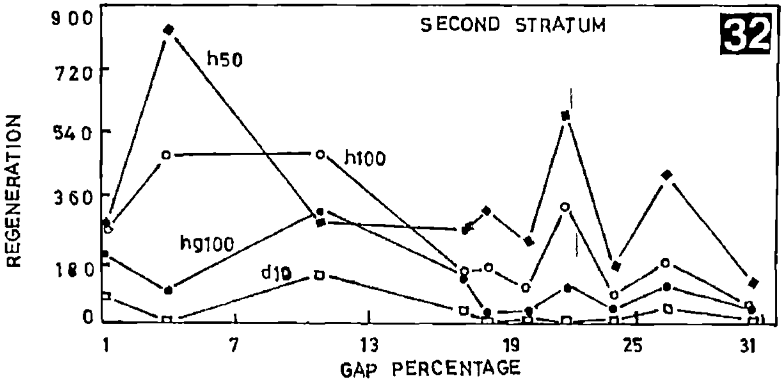


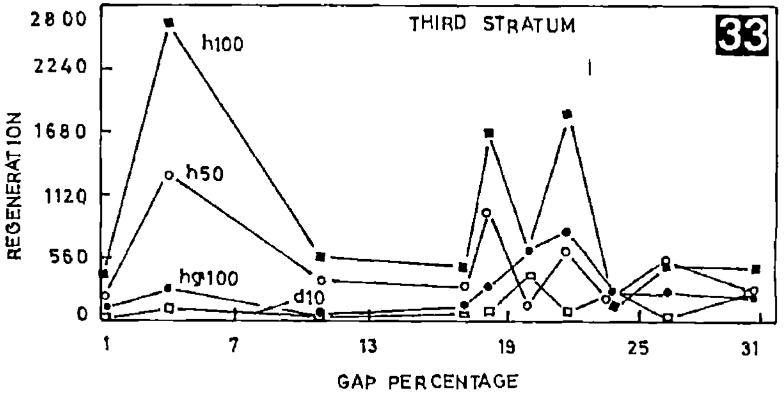
Figs 30 31 Relation between regeneration and gap percentages

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±SE 0 272) and lower stratum (0 220±SE 0 109) registered the highest and lowest values and the upper stratum was intermediate (0 325±SE o 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
Dillenia pentagyna	1 000	0 053	0 947	0 864
Grewia tiliifolia	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
Xylia xylocarpa	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 discusssion on this aspect is excluded]

Constraints of Natural Regeneration

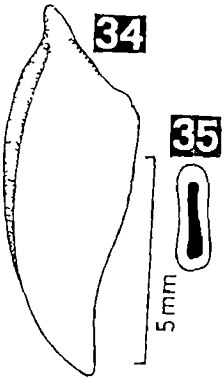
In examining the population structure at different levels a low survival probability is observed for saplings leading to poor representation in the pole crops Secondly taking account of the high mortality rates in the lower size classes in all the dominant commercially important species the number of 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 poulations or species themselves Phenological behaviour reflects intrinsic constraints of some species Our preliminary observations indicate that trees of Dalbergia sissoides 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 rea on 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 tiliifolia too Here even during the rainy season small seedlings with cotyledons are very rarely observed In Melia dubia regeneration dynamics is l ttle 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 this 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^2 of forest land was encroached that is approximately at the rate of 1 km^2/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 ecnroached 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 andfruits like soap nut etc burn the forest so that undergrwoth is removed and walking is made easy Once fire infests an area seedling populations are highly affected (Plate VIII) Enormous number of seedlings die rest loose 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 <u>Xylia</u> (Vazhani, Machad Forest Range, April 1988).

Grazing: 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).

Browsing: 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.

Illicit Extraction of Saplings and Poles: 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

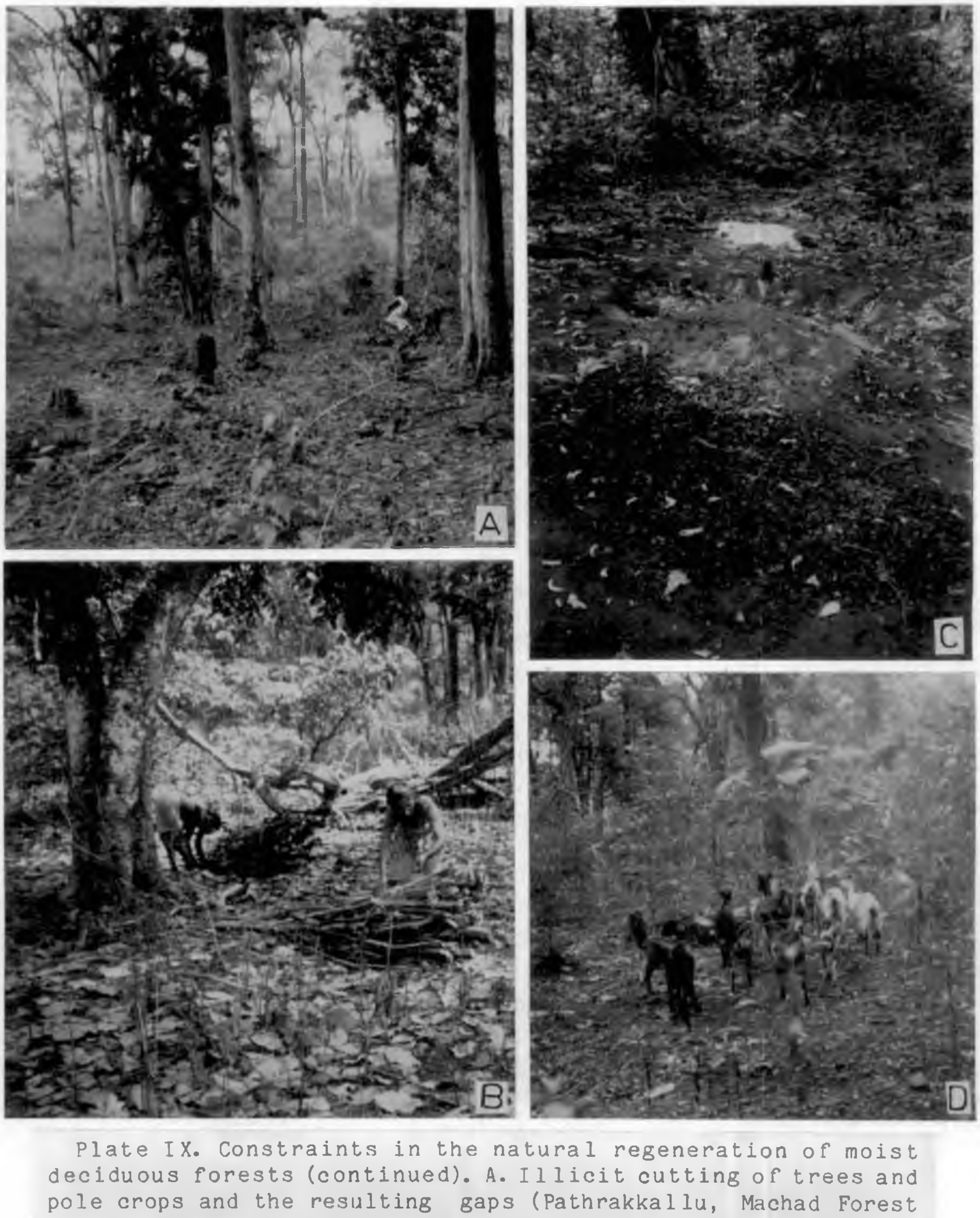


Plate IX. Constraints in the natural regeneration of moist deciduous forests (continued). A. Illicit cutting of trees and pole crops and the resulting gaps (Pathrakkallu, Machad Forest Range, 1988). B. Illicit charcoal making inside the forest (Mundippadam, Pattikkad Forest Range, 1988). C. Fire-wood 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 th century TFD was under the possession of the Raja of Cochin Early Portuguese and Duch 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 th 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 sissoides* *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 straum

2 While basal area and tree density (of trees > 20 cm DBH) contributed maximum by useful species The third stratum doe 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 has 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 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 m^2 and in other sites 60^2 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

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 m^2/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 m^2/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 speci viz *Dillenia pentagyna* *Grewia tiliifolia* *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 decreases 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 Howerver 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 casualities 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 lianas Some species have inherent intrinsic constraints This is best exemplified by

Lagerstroemia microcarpa where the millions 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

References Cited

7 REFERENCES CITED

Anderson J A R 1961 *The ecology and forest types of the peat swamp forests of Sarawak and Brunei in relation to their silviculture* Ph D Thesis Univ Edinburgh

Arora R K 1960 Ecology of *Xylia xylocarpa* *Indian For* 86 306-313

Ayliffee R S 1952 The natural regeneration of Trinidad forests *Proc Sixth Brit Com Conf Canada*

Baker H G Bawa K S Frankie G W and Opler P A 1983 Reproductive biology of plants in tropical forests Pages 183 215 In Golley F G and Lieth H (Eds) *Tropical rain forest ecosystems* Elsevier Scientific Publ

Baker H G and Harris B J 1957 The pollination of *arkia by* bats and its attendant evolutionary problems *Evolution* 11 449 460

Balasundaram A George M and Prasad K M 1979 A survey note on the regeneration of rose wood (*Dalbergia latifolia* Roxb) in Gudalure Wynad forest tract (Nilgiris) *Indian For* 105 727 732

Barnard R C 1955 Silviculture in the tropical rain forest of Western Nigeria compared with Malayan methods *Malay For* 18 173 190

Barnard R C 1956 Recruitment survival and growth of timber tree seedlings in tropical rain forest *Malay For* 19 (3)

Bawa K S 1974 Breeding systems of tropical tree species of a lowland tropical community *Evolution* 28 85 92

Bawa K S 1979 Breeding systems of trees in a tropical low land wet forest *New Zealand J Bot Spl Iss* 17 521 524

Bawa K S 1983 Patterns of flowering in tropical plants Pages 394 410 In Jones C E and Little R J (Eds) *Handbook of experimental pollination biology* Van Nostrand Reinhold New York

Bawa K S Bullock S H Perry D R Coville R E and Grayum M H 1985 a Reproductive biology of tropical lowland rainforest trees II Pollination systems *Am J Bot* 72 (3) 346 356

Bawa K S and Krugman S L 1986 Reproductive biology and genetics of tropical forest trees *Biol Internat Spl Iss* 18 22 25

Bawa K S Perry D R and Beach J H 1985 b Reproductive biology of tropical lowland rain forest trees I Sexual systems and incompatibility mechanisms *Am J Bot* 72 331-345

Bazzaz F A and Harper J L 1976 Relationship between plant weight and numbers in mixed populations of *Sinapis alba* (L) Rabenh and *Lepidium sativum* L *J Appl Ecol* 13 211 216

Beard J S 1946 The natural regeneration of Trinidad forests *Oxford Forestry Mem* no 20

Bernier P Y 1987 Regeneration and growth of lodgepole pine in small openings in the Alberta foot hills *Can J For Res* 17 758 759

Bharucha F R and de Leeuw W C 1957 A *practical guide to plant sociology* Bombay

Bhatnagar H P 1961 Basic information on sal (*Shorea robusta*) forest of Uttar Pradesh deficient in natural regeneration *J Indian Bot Soc* 40 47 489

Bhoojh R and Ramakrishnan P S 1981 Phenology of trees in a subtropical evergreen montane forest in north-east India *Geo Eco Trop* 5 189-209

Bor N L 1930 Sal regeneration *Indian For* 56 136 137

Borchert R Phenology and control of flowering in tropical trees *Biotropica* 15 81 89

Braun E L 1950 *Deciduous forests of eastern North America* Blackiston Philadelphia

Brooks R L 1941 The regeneration of mixed forests in Trinidad *Carribbean For* 2 164 172

Buell J H 1945 The prediction of growth in uneven-aged timber stands on the basis of diameter distribution *Duke Univ Sch For Bull* no 11

Burschel P Kateb H E Huss J and Mosandl R 1985 Regeneration in a mixed mountain forest *Forstwissenschaftlichas Centralblatt* 104 65-100

Cavers P B 1983 Seed demography *Can J Bot* 61 3578 3590

Chaconsotelo J M 1983 Regeneration through parent trees of Pinus arizoniana *Ciencia Forestal* 8 3 20

Chakravarthi R 1948 Natural and artificial regeneration of dry peninsular sal *Indian For* 74 56-57

Champion H G 1933 Regeneration and management of sal (*Shorea robusta*) *Indian For Rec Silvic* 19 (3)

Champion H G and Seth S K 1968 a *A revised survey of the forest types of India* Manager of publications Delhi

Champion H G and Seth S K 1968 b *General silviculture for India* Manager of Publications New Delhi

Chan H T 1981 Reproductive biology of some Malaysian Dipterocarps III Breeding systems *Malays For* 44 28 34

Chandrasekharan C 1962 Forest types of Kerala State Pt 2 *Indian For* 88 837 847

Chaturvedi M D 1931 Regeneration of sal in the United Provinces *Indian For* 57 157 166

Chaudari K N 1958 Regeneration of the dry peninsular sal forests of West Bengal *Indian For* 84 4 19

Chaudhuri D C 1960 Natural regeneration of sal in Tripura *Proc 19 th Silvic Conf Dehra Dun 1957* 1 118-120

Chengappa B S 1937 Reproduction of the Andaman forests *Indian For* 63 16-29

Chengappa B S 1944 Andaman forests and their regeneraion Pt 2 *Indian For* 70 339 351

Cockburn P F 1975 Phenology of Dipterocarps in Sabah *Malay For* 38 160-170

Cremer K W 1965 Dissemination of seed from *Eucalyptus regnans* *Aust For* 33-37

Curtis J T and McIntosh R 1951 Upland forest communities in the pairie forest border region of Wisconsin *Ecology* 32 476 496

Daly C and Shankman D 1985 Seedling establishment by conifers above tree limit on Niwot Ridge Front Range Colorado USA *Arctic Alpine Res* 17 389 400

Dansereau P 1957 *Biogeography an ecological perspective* Ronald Press New York

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

Dawkins H C 1958 The management of natural tropical high forest with special reference to Uganda *Imperial Forestry Inst Oxford Pap* no 34

Deshmukh D K 1985 Regeneration of rosewood (*Dalbergia latifolia* Roxb) *Myforest* 11 87 93

Dhamanijayakul P 1981 The phenology of trees in dry evergreen forest and its application to timing for logging operation *For Res Bull Fac For Ksasetsort Univ* no 64

Dimitrov D 1984 Natural regeneraion of *Quercus hartwissiana* in the Strandzha region of Bulgaria *Gorsko Stopanstvo* 40 22 25

Drapier J 1985 Problems in the natural regeneration of silver fir in the Vosges an ecological study *Rev For Franc* 37 45 55

FAO 1955 *Tree seed notes* FAO Rome

Everard J E 1987 Natural regeneration of oak *Oxford For Inst Occasional pappers* no 34 23 28

Fox J E D 1976 Constraints on the natural regeneration of tropical moist forest *For Ecol Manage* 1 37 65

Frankie G W Baker H G and Opler P A 1974 a Comparative phenological studies of trees in tropical wet and dry forests in the lowlands of Costa Rica *J Ecol* 62 881 919

Frankie G W Baker H G and Opler P A 1974 b Tropical plant phenology applications for studies in community ecology Pages 287-296 In Lieth H (Ed) *Phenology and seasonality modeling* Springer Verlag Berlin

Gadgil M 1971 Dispersal population consequences and evolution *Ecology* 52 253 261

Garwood N C 1983 a Seasonal rhythm of seed germination in a semideciduous tropical forest Pages 173 185 In Leigh E G Jr Rand A S and Windor D M (Eds) *The ecology of a tropical forest seasonal rhythms and longterm changes* Smithsonian Inst Washington

Garwood N C 1983 Seed germination in a seasonal tropical forest in Panama a community study *Ecol Monogr* 53 159 181

Gentry A H 1988 Changes in plant community diversity and floristic composition on environmental and geographical gradients *Ann Miss Bot Gard* 75 1 34

George M P 1963 *Working plan for the Trichur Forest Division 1955 56 to 1969-70* Govt Press Ernakulam

Gilbert G 1938 Observations preliminaires sur la morphologie des plantules forestieres au Congo belge *Publ INEAC Ser Sci* 17

Goff F G and West D 1975 Canopy understorey interaction effects on forest population structure *For Sci* 21 98 108

Gomez Pompa A Vazquez-Yanes C and Guevara S 1972 The tropical rain forest a non renewable resource *Science* 177 762 765

Gong W K 1981 Studies on the natural regeneration of a hill Dipterocarp species *Hopea pedicellata* *Malay For* 44 357-369

Grime J P 1979 Regenerative strategies Pages 79-122 In Grime J P (Ed) *Plant strategies and vegetation process* John Wiley and Sons New York

Hall J B and Swaine M D 1980 Seed stocks in Ghanian forest soils *Biotropica* 12 256 263

Halle F Oldeman R A A and Tomlinson P B 1978 *Tropical trees and forests an architectural analysis* Springer Verlag Berlin

Harper J L 1977 *Population biology of plants* Academic Press London

Harper J L and White J 1974 The demography of plants *Ann Rev Ecol Syst* 5 419 463

Heuveldop J and Neumann M 1983 Structure and functions of a rainforest in the International Amazon Ecosystem Project Preliminary data on growth rates and natural regeneration from a pilot study *Turrialba* 33 25-38

Hoi L V 1972 Forest calendar and forestry seed saigon *Inst Rech For* pp 1-100

Holmes C H 1942 Flowering and fruiting of forest trees in Ceylon Pt 1 *Indian For* 68 411 420

Holmes C H 1942 Flowering and fruiting of forest trees in Ceylon Pt 2 *Indian For* 68 488 501

Holmes C H 1956 The natural regeneration of the wet and dry evergreen forests of Ceylon *Ceylon For* 2 (4)

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

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

Hubbell S P 1979 Tree dispersion abundance and diversity in a tropical dry forest *Science* 203 1299 1309

Hubbell S P and Foster R B 1983 Diversity of canopy trees in a neotropical forest and implication for conservation In Sutton S L Whitmore T C and Chadwik S C (Eds) *Tropical rainforest ecology and management* Blackwell Scientific Publ Oxford

Janzen D H Seed predation by animals *Ann Rev Ecol Syst* 2 465-492

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

Janzen D H 1974 The role of seed predator guild in a tropical deciduous forest with some reflections on tropical biological control Pages 3-14 In Jones D P and Solomon M E (Eds) *Biology in pest and disease control* Blackwell Scientific Publ Oxford

Janzen D H 1978 Seeding patterns of tropical trees Pages 83 128 In Tomlinson P B and Zimmerman M H (Eds) *Tropical trees as living systems* Cambridge Univ Press Cambridge

Johnson E A 1975 Buried seed populations in the subarctic forest east of Great Slave Lake Northwest Territories *Can J Bot* 53 2933-2941

Jones E W 1950 Some aspects of natural regeneration in the Benin rain forests *Empire For Rev* 29 108 124

Jones E W 1955 Ecological studies in the rainforest of Southern Nigeria IV Part 1 *J Ecol* 43 564-594

Jones E W 1956 Ecological studies in the rainforest of Southern Nigeria IV Part 2 *J Ecol* 44 83 117

Kadambi K 1954 *Dipterocarpus* indicus Bedd (Syn *D turbinatus* Gaertn f) its silviculture and management *Indian For* 80

Kadambi K 1957 The silviculture of gregarious types - natural reproduction of teak *Trop Silvic* 2 187 192

Kahn F 1982 Regeneration of tropical rain forest in the southwestern Ivory Coast *Mem Orsotom* no 97

Karpov V G 1960 On the species composition of the viable seed supply in the soil of spruce *Vaccinium myrtillus* vegetation *Trudy Mask Obshch Ispyt Prir* 3 131 140

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

Keay R W J 1960 Seeds in forest soil *Nigeria For Dept Inform Bull N S* 4 1 12

Kellman M C 1970 The viable seed content of some forest soil in British Columbia *Can J Bot* 48 1383 1385

Khoon G W 1981 Studies on the natural regeneration of a hill Dipterocarp species *Hopea pedicellata* *Malays For* 44 357 369

Khosla P K Saamet G S and Sehgal R N 1982 Phenology and breeding systems of *Bombax ceiba* Linn

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

Krebs C J 1972 *Ecology the experimental analysis of distribution and abundance* Harper and Row new York

Krishnaswamy V S and Mathauda G S 1960 Phenological behaviour of a few forest species at New Forest Dehra Dun *Indian For Rec N S* 9 (2)

Lancaster 1952 Natural regeneration Tropical Nigeria *Sixth Brit Com For Conf Canada*

Landon F H and Settan G G K 1957 Forest and forest research in the Federation of Malaya *Unasylva* 11 165 171

Lee Y N 1971 Patterns of flowering periods in selected floras of the world *J Korean Res Inst Better Living* 6 41 51

Leih E G Jr Rand A B and Windsor D M 1982 *The ecology of tropical forest seasonal rhythms and long term changes* Smithsonian Institution Press Washington

Libby W J 1973 Domestication strategies for forest trees *Can J For Res* 3 265 276

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

Linhart U B and Whelan R J 1980 Woodland regeneration in relation to grazing and fencing in loed Gorswen North Wales *J Appl Ecol* 17 827 840

Medway L 1972 Phenology of a tropical rain forest in Malaya *Biol J Linn Soc* 4 117-146

Meher Homji V M 1979 The climate vegetation stability case studies from the Indian Subcontinent *Int J Ecol Environ Sci* 5 75 93

Melnik V I 1985 Natural regeneration of *Picea abies* in the polish region of the Ukraine *Lesnoe Khozyaistro* 6 34 35

Menon A R R 1986 Forest denudation in Kerala a case study of Trichur Forest Division Proc Seminar on Ecodevelopment of Western Ghats Peechi 1981 Kerala Forest Research Institute Peechi

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

Mensbruge C de la 1966 La germination et les plantules des essences arborees de la foret dense humide de la cote d ivoire Nogentsur-Marne Centre Technique Forestier Tropical (CTFT) Publ no 389

Meyer H A 1952 Structure growth and gain in balanced uneven aged forests J For 50 85 92

Mooney J W C 1961 Classification of the vegetation of the high forest zone of Ghana Page 85 86 In Unesco Trocpical soils and Vegetaion Unesco Paris

Morin H 1986 Regeneration of white spruce in the montane suabpine and alpine zones of Mout Jacques Cortier Quebec Natur Canad 113 347 354

Mueller Dombois D and Ellenberg H 1974 Aims and methods of vegetation ecology John Wiley and Sons New York

Murphy P G and Lugo A E 1986 Ecology of tropical dry forest Ann Rev Ecol Syst 17 67 88

Murray M 1981 Forest regeneration at high latitudes Experiences from northern Sweden USDA Forest Service General Technical Report no 132

Nair C T S 1986 Management of the tropical wet evergreen forests in India a comparative account of the silvicultural practises in Kerala Andaman Islands and Assam Paper read at the Symposium on Rain Forest Regeneration and Management Guri Venezuela 1986

Nair P N 1961 Regeneration of moist tropical forests with special reference to Kerala DAIFC Dissertation Indian For Coll Dehra Dun

Newbold A J Goldsmith F B and Hardinu J S 1981 The regeneration of oak beech and birch a literature review Discussion papers in conservation Univ College London no 33

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

Ng F S P 1977 Gregarious flowering of Dipterocarps in Kepong 1976 *Malays For* 40 126 137

Ng F S P 1981 Vegetative and reproductive phenology of Dipterocarps *Malays For* 44 197 221

Nicholson D I 1958 Natural regeneration of logged tropical rain forest North Borneo *Malay For* 21 (2)

Nicholson D I 1965 A study of virgin forest near Sandakan North Borneo Pages 67 87 In Unesco *Proc Symposium on ecological research in humid tropics vegetaion, Kuching 1963* Unesco

Odum E P 1971 *Fundamentals of Ecology* W B Saunders Philadelphia

Pnde P K and Bisht A P S 1988 Regeneration behaviour of some tree species of some forested ecosystems *J Trop For* 4 78 84

Pierlot R 1966 a Structure et composition des forets denses d Afrique Centrale specialement celles du Kiru *Bruxelles Mem Acad Roy Sci Outre Mer N S* 16 (4)

Pinto A E 1970 Phenological studies of trees at El Verde Pages D 237 269 In Odum H T (Ed) A tropical rain forest US Atomic Energy Commission

Prasad N S and Hegde M 1986 Phenology and seasonality in the troopical deciduous forest of Bandipur South India *Proc Indian Acad Sci (Pl Sci)* 96 121-134

Prasad R 1985 Effect of grazing Closure on the re habilitation of flowered bamboo areas in Mandla forest of Madhya Pradesh *J Trop For* 1 145 151

Primack R B 1985 Longevity of individual flowers *Ann Rev Ecol Syst* 16 15-37

Ralhan P K Khanna R K Singh S P and Singh J S 1985 Phenological characteristics of the tree layer of Kumaun Himalayan forests *Vegetatio* 60 113 120

Ramachandran K K 1988 Ecology and behaviour of Malabar Giant Squirrel *Ratufa indica maxima* *KFRI Res Report no* 55 Kerala Forest Research Institute Peechi

Rathcke B and Lacey E P 1985 Phenological patterns of terrestrial plants *Ann Rev Ecol Syst* 16 179 214

Richards P W 1952 *The tropical rain forest* Reprint 1979 Cambridge Univ Press Cambridge

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

Roberts H A 1981 Seed banks in soils *Adv Appl Biol* 6 1 55

Roe A L 1967 Seed dispersal in a bumper spruce seed year *U S Forest Service Res Pap* 39 1 10

Rollet B 1952 *Etudes sur les Forets claires* du *sud indochinois* Recherches Forestieres Saigon

Rollet B 1962 Inventaire forestier de L est Mekong *FAO Report no 1500* FAO

Rollet B 1974 *L architecture des forets dense humide sempervirente de plaine* Centre Technique Forestier Tropicale Nogent sur Marne

Rosayro R A 1954 A reconnaissance of Sinharaja rain forest *Ceylon For N S* 1 68-74

Saxena A K and Singh J S 1984 Tree population structure of certain Himalayan forest association and implications concerning their future composition *Vegetatio* 58 61-69

Seth S K and Kaul O N 1978 Tropical forest ecosystems of India the teak forest Pages 628 640 In Unesco UNEP and FAO *Tropical forest Ecostystems* Unesco UNEP France

Seymour R S Hannah P R Grace J R and Marquis D A 1986 Silviculture the next 30 years the past 30 years J *For* 184 31 38

Sharma J S Darbal B G and Sing K 1985 Edaphic and microclimatological studies with reference to regeneration of sal (Shorea robusta) *Indian For* 11 396 409

Sharma S K George M and Prasad K G 1983 Forest vegetation survey and classification with special reference to South India *Indian For* 109 384 393

Singh G 1983 Status of natural regeneration of fir forest in Jammu and Kashmir State *Indian J For* 6 132 136

Singh R P 1985 A note on the effect of grazing on regeneration of *Cedrus deodara* *Indian For* 111 767 768

Shrivastava R K 1982 A note on phenological observations on *Aegle marmelos* Correa *Indian For* 108 593 595

Shukla R P and Ramakrishnan P S 1982 Phenology of trees in a tropical humid forest in north eastern India *Vegetatio* 49 103 109

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

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

Sutton S L Whitmore T C and Chadwik S C (Eds) 1983 *Tropical rain forest ecology and management* Blackwell Scientific Publ Oxford

Symington C F 1933 The study of secondary growth on rain forest sites in Malaya *Malay For* 12 107 117

Synnott T J 1973 Seed problems In *IUFRO Int Symp on Seed Processing* Bergen

Szappanos A 1986 Natural regeneration of oak stands in the eighties *Ecos* 35 106-110

Tang H T and Tamari C 1973 Seed description and storage tests of some Dipterocarps *Malay For* 36 38 53

Thangam E S 1982 Regeneration methods of *Dipterocarpus* species in India *Indian For* 108 637 647

Thompson K and Grime J P 1979 Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats *J Ecol* 67 893-921

Troup R S 1921 *The silviculture of Indian Trees 3 vols* Oxford Univ Press Oxford

Unesco 1975 Regional meeting on integrated ecological research and training needs in tropical deciduous and semideciduous forest ecosystems of South Asia Final Report *MAB Report ser no 35* Hamburg Reinbek

Unesco 1978 a *Tropical forest ecosystems* Chapter 5 Organization (pp 112 142) Unesco-UNEP France

Unesco 1978 b *Tropical forest ecosystems* Chapter 8 The natural forest plant bilogy regeneration and tree growth (Pages 180 215) Unesco-UNEP France

Pijl van der 1969 *Principles of dispersal in higher plants* Springer Verlag Berlin.

Venning J 1985 Natural regeneration a south Australian perspective *Trs Nat Resourc* 27 9 11

Walton A B 1955 Forests and forestry in North Borneo *Malay For* 18 20 23

Walton A B Barnard R C and Wyatt Smith J 1952 Silviculture of lowland Dipterocarp forest in Malaya Malay For 15 1 181

Watt A S 1919 On the causes of failure of natural regeneration in British oak woods J Ecol 7 173 203

Watt A S 1923 On the ecology of British beech woods with special reference to their regeneration Part I The causes of failure of natural regeneration of the beech J Ecol 11 1 48

Webb L J Tracey J G and Williams W t 1972 Regeneration and pattern in the subtropical rain forest J Ecol 60 675 695

West D C Shugart H H Jr and Ranney J W 1981 Population structure of forests over a large area For Sci 27 701 710

Westoby M 1984 The self-thinning rule Pages 167 225 In MacFadyen A and Ford E D (eds) Advances in ecological research vol 14 Academic Press New York

White J 1974 Dynamics of forest tree populations (Abstr) Bull Can Bot Assoc 7 10 11

White J 1975 Patterns of thinning of plant populations 12th Int Bot Congr 1975

White J 1980 Demographic factors in population of plants Pages 21 48 In Solbrig T O (ed) Demography and evolution in plant populations Blackwell Oxford

White J 1981 The allometric interpretation of the self thinning rule J Theor Biol 89 475-500

Whitmore T C 1983 Secondary succession of seed in tropical rain forests For Abstr 44 769-779

Witter J A and Ragenovich I R 1986 Regeneration of fraser fir at Mt Mitchell North Carolina after depredationns by the balsam woolly adelgid For Sci 32 585 594

Wyatt-Smith J 1963 Manual of Malayan silviculture for inland forests Malay For Rec no 23

Yocom H A 1968 Short leaf pine seed dispersal J For 66 422

Yoda K Kira T Ogawa H and Hozumi H 1963 Self thinning in overcrowded pure stands under cultivated and natural conditions J Biol Osaka Cy Univ 14 107 129

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

by

NARAYANAN ILLATH VALAPPIL

ABSTRACT OF A THESIS

submitted in partial fulfilment 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 sylvigenesis 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