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Fox, J. E. D.

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The Natural Vegetation of Sabah and Natural Regeneration of the Dipterocarp Forests

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J.E.D. Foxe

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Department of Forestry
and Wood Science
University College of
North Wales, Bangor.

Frontispiece

Interior of Yield Plot 7 In Kalabakan Forest Reserve Felled 1957. Photograph taken in 1967, ten years after felling.

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The Natural Vegetation of Sabah and Natural Regeneration of the Dipterocarp Forests

SUMMARY

The thesis has two objectives. The first is to describe the vegetation in the State of Sabah. To this end all available knowledge has been examined and a classification scheme outlined based on ecological considerations. A more detailed classification of the dipterocarp forests into Types based on the relative abundance of big tree species is presented.

The second objective is the development of management criteria to achieve satisfactory natural regeneration following logging in the dipterocarp forests and to enhance growth rates. An account is given of the dynamic processes in the natural forest which lead to the replenishment of the species and this is followed by an examination of silvicultural treatments designed to influence the success of natural regeneration. Climber cutting and tree marking prior to felling are suggested as being useful in restricting the amount of damage done to the forest, particularly to soil and seedlings. After felling selective removal of unwanted species where these are likely to interfere with the growth of regeneration is advocated and a further intervention is recommended at 10-15 years after felling.

Assessment techniques designed to measure desirability of treatment are discussed and preliminary results from yield plots are presented. Providing silvicultural treatments are undertaken it is estimated that second cuts in these forests may be taken at 60 years after felling. The stands will be essentially of the same species though refinement will have eliminated many of the

less desirable timbers, and growth rates suggest that trees of the genus *Shorea* (section Rubroshorea) will be of most importance in the second growth stands.

Conventions Followed in the Text

Botanical Nomenclature

Species names used in the text are based on those used in Botanical Bulletins Nos 1-11 prepared by W.Meijer during 1963-68. These form the basis of a manual on the non dipterocarp trees of Sabah being prepared by P.F. Cockburn. Species in the various plots referred to were named by matching collections with those held in the Sandakan Herbarium of the Forest Department. In many cases specimens from the plots may be examined in the permanent reference collection of the Herbarium.

Sabah Forest Record No. 7 is included in this submission. This text lists 632 species including the 160 species of Dipterocarpaceae known to occur in Sabah at the end of 1970. Some 170 species of those listed regularly exceed 6 feet girth (58 cm diameter), including 96 dipterocarps.

Sample Plots

Three main types of plot were established to obtain the information presented herein. Yield plots of 5 x 5 chains (100 x 100 m) square, i.e. 2.5 acres (approximately 1 ha) were established in regeneration areas. The same size of plot was used in some experimental comparative studies. The yield plot technique is described in Fox (1970a), included in this submission.

The second type of plot was the one acre (0.4 ha) circular plot used for broad ecological survey work. Both these and the yield plots were randomly located in large areas, unless otherwise stated. Thirdly a number of 10 acre (4 ha) plots of side 10 x 10 chain (200 x 200 m) were placed subjectively in undisturbed areas presumed representative of surrounding forest.

Earlier plots of various sizes, but all based on extensions of the 1 chain square (20 x 20m) are drawn on for growth and stocking data. Seedling assessment plots are 1 milliacre (one thousandth of an acre) generally 6.6 ft square (2 m x 2 m). Justification for the use of these plot sizes is based on a combination of tradition and simplicity. Statistical analysis of plot sets (e.g. Appendix 15) has generally shown that plots used in random sampling have adequately sampled the populations.

All plots (except yield plots) and experiments embracing plots are termed Research Plots (R.P.'s). A list of these is given in Annual Report of the Research Branch for 1969, which is included in this submission. Of these listed R.P.'s 200-350 were established by me during 1966-71.

Measurements

Measurements in permanent increment plots were made with a steel tape and bole sizes were recorded to the completed decimal inch of girth. Linen tapes were used in temporary plots where measurement was to the completed inch. All tabular material herein and statements referring to size classes include trees in classes from the size given. For example in Table 8 the 6 ft class includes trees from 72 ins girth to less than 84 ins.

Expressions of basal area (always true, not quarter girth) are based on measured trees over 12ins girth. This is the general lower limit of measurement except for yield plots, milliacre plots and linear sampling surveys. Volumes are given in hoppus cubic feet.

Abbreviations Used in Text

A.R.R.B. Annual Report of the Research Branch (Sabah Forest Dept.)

F.D.A.R. Forest Department Annual Report (Sabah).

Reg. Notes Regional Notes in the Malayan Forester

M.F. The Malayan Forester

R.P. Research Plot

F.R. Forest Reserve

C.A.I. Current annual increment (usually expressed as an average over several years, i.e. the periodic current annual increment).

M.A.I. Mean annual increment

Y.P. Yield Plot

L.S.M. Linear Sampling Milliacre

L.S.¼ Linear Sampling Quarter-chain

L.S.½ Linear Sampling Half-chain

B.a. Basal area

Preface

The process of natural regeneration in tropical rain forest is exceedingly complex because of the enormous wealth of species, and the complexity of the structure and of the floristic composition of the forest both in the vertical and in the horizontal plane.

J.P. Schulz (1960, p.216)

Being almost a virgin country and therefore without the restrictions imposed by a cultural landscape of long standing, such as often occurs in the more developed countries, the land use and settlement patterns of (Sabah) are fairly free to develop as future events may decide.

Y.L. Lee (1961 b)

Timber will be a problem. It is our greatest asset but it is also in a way our biggest political curse.

Dato Donald Stephens, June 15 1967
(in Sabah Times)

CONTENTS

Maps

1 Topography

2 Communication and Administration

3 Geology

Additional Submissions (Separate Folder)

Sabah Forest Record No. 7 "Preferred Check List of Sabah Trees" 1970.

Annual Report of Research Branch, Forest Department, Sabah, 1969.

Miscellaneous published papers.

Part 1 Introduction

CHAPTER 1

OBJECTIVES

This thesis is an investigation into the vegetation of the State of Sabah, in northern Borneo, and of the natural regeneration of its dipterocarp forests. The first, subsidiary, objective is the production of a suitable classification scheme of the vegetation in the State, distinguishing between forests of little or no present commercial value and those carrying valuable stands of Dipterocarpaceae. The second and principal objective is the derivation of desirable management criteria which aim at ensuring successful regeneration following felling, enhancing its growth, and defining suitable stocking and rotation for the second crop.

Present day management is based on the sustained yield principle with areas to be cut annually determined from the estimated rotation of 80 years for cut over areas to return to an exploitable condition. This is based on the following assumptions:

(1) Seedling regeneration can be relied on

(2) More or less clear felling of large trees can be allowed

(3) Heavy mechanical logging equipment can be used with no control

(4) Blanket girdling of unwanted trees after felling promotes seedling growth.

These are interrelated and my main purpose is to examine, as far as is possible, how present silvicultural practices may be used to (a) favour regeneration stocking at the time of felling, and (b) increase its subsequent growth. Desirable management objectives must be based on what responses can be obtained from the possible treatments. The second objective will be met, therefore, by considering the effects of treatments on growth.

The thesis is organised in three parts. In Part 1 a description of environmental factors influencing vegetation is presented as a background to Parts 2 and 3 (Chapter 2). This includes a brief account of the importance of forestry in Sabah in terms of the scale of present logging activity. Vegetation development is dependent on the physical environment, a combination of climatic, physiographic and parent material influences. In Part 2 these will be taken into consideration together with species content and general vegetation characteristics in an attempt to draw up an ecological scheme of classification embracing all forms of vegetation (Chapter 3). The dipterocarp forests are of most importance and it is considered desirable to attempt to distinguish between any distinctive forms which can be shown to exist. The question of the existence of different types within the dipterocarp forests will be dealt with in Chapter 4. The multitude of species presents a major difficulty and an attempt at simplification of this problem forms a major theme in both Parts 2 and 3. That is, for example, can certain species be taken as representative and are these of value in management?

In Part 3 the prospects for successful natural restocking of felled areas and for enhanced growth will be analysed with reference to experimental data. The distribution of species in the natural forest will be examined with respect to relative natural abundance and likely abundance following felling. Reproductive and growth patterns of the dipterocarps will be assessed in an attempt at defining the mechanics of reproduction of the main species in the natural condition and the dynamic characteristics of natural stands. Studies of natural forest seedling behaviour are examined to show the extent to which seedling regeneration can be relied on.

The results of experiments undertaken in stands prior to felling will be dealt with in Chapter 6 where the principal concern will be: Can silvicultural treatment prior to felling lead to increased regeneration? In Chapter 7 I shall be concerned with the effects of logging, particularly with respect to the stocking of residual trees following more or less clear felling; and damage done to seedlings and residual trees by logging.

Change in environmental conditions following logging leads to growth of dipterocarp seedlings and the invasion of seral species. Questions to be dealt with in Chapter 7 relate to what rates of growth can be expected for dipterocarp seedlings and seral species and the potential for dipterocarp restocking from seedbearers. Silvicultural treatment after logging is discussed in Chapter 8: can damaged areas be restocked? what alternatives to blanket girdling are available? Emphasis will be given to the effect of liberation treatments in older stands as this practise has received little attention hitherto. The main concern will be the definition of treatment, can blanket treatments work in older stands?

Assessment methods are of great importance in tropical natural forest silviculture as it is notoriously difficult to obtain a valid visual estimate of stocking.

Linear sampling survey methods designed to show the desirability of treatments will be described and preliminary results from the yield plot program presented. This latter seeks to predict second crop yields and the development of further methods will be suggested.

Desirable management objectives will be outlined in Chapter 10 in terms of what second growth crops can be expected provided sufficient silvicultural attention is given. Limitations to stocking imposed by crown size and possible bole area may be expected to set an upper limit to second growth stands and clearly with a biological resource of great variability average predictive parameters must be relied on to a considerable extent.

CHAPTER 2

THE PHYSICAL ENVIRONMENT

In this chapter a brief account of the main environmental factors assumed likely to influence vegetation is given. Three maps are included at the end of this work for reference. Map 1 illustrates topography, Map 2 gives communications, place names and general geography, and Map 3 deals with the main geological formations.

At the end of the chapter a short note outlines historical aspects, from a forest management viewpoint, of forestry activity with respect to prices, revenue and the extent of reserved forest.

Geography and Physiography

The State of Sabah is situated at the northern tip of the island of Borneo and occupies a land area of 29,388 square miles (76,000 sq. km). The northernmost point of the mainland is Cape Simpang Mengaiau in 7°1' North latitude and the most southerly is the watershed of the River Padas in 3°42' N. At this point the southern boundary forms a wedge between Sarawak and Kalimantan. The greatest length of the State is 285 miles (460 km) and greatest breadth is 270 miles (435 km) from Klias Point in 115°20' East longitude to Hog Point in 119°17' E.

The main offshore islands are Labuan in the west, Banggi in the north, and, in the east, Jambongan, Timbun Mata and Sebatik. The latter is bisected by the boundary with Kalimantan. To the west is the South China Sea, to the east the Sulu Sea and the Celebes Sea is off the southeast of the State. Sandakan is the principal port dealing with timber export; this is 1000 miles from Singapore, 1200 from Hong Kong and 600 miles from Manila (1600, 1900 and 1000 km respectively). The commercially important forest areas lie to the east of the State and other major export centres are off Jambongan Island in the north, Lahud Datu, Kunak and Bohiyan Island in Darvel Bay, and at Tawau and Wallace Bay in the south.

Sabah is a mountainous country and its physiography is dominated by the main mountain mass, the Crocker Range. This extends from the southern end of Marudu Bay in the north, and following the coastline at about 15 miles (24 km) inland, extends southwards, along the western part of the country, to the Sarawak border. Large rivers flow to the east from their origins in the main mass of mountains through valleys that spread into broad alluvial plains and mangrove deltas near the coast. Coastal plains occur in most areas with low hills rising from them, but the West Coast rivers are comparatively short and shallow, except the Padas River which rises far inland and drains much of the southwest. This river is not used for navigation, passing through rocky gorges beyond Beaufort.

The large rivers on the East Coast are all navigable and used for towing logs. The Kinabatangan River is the largest, of some 350 miles (560 km) in overall length, navigable for 200 miles (320 km) and by shallow draft launches for over 100 miles in a direct line from the coast. The Segama, Labuk and Sugut Rivers are navigable by small craft for considerable distances. These rivers terminate in mangrove deltas which are interlaced with strips of old beach sand terraces. In their middle reaches they meander through low-lying alluvial land backed and separated by gently undulating areas which in turn become hilly, and then mountainous further from the coast where the rivers are fast flowing. Much of the lowlying land is subject to flooding, and extensive flooding of vast areas is experienced every few years. The largest areas of lowland are those between the Segama and Kinabatangan Rivers and north to Sandakan Bay.

Narrow coastal plains along the West Coast are densely settled. In the southwest the Klias Peninsula, at the mouth of the Padas, and some coastal locations north and south of Beaufort have peat swamps on lowlying land. Inland between the Crocker Range and the mountainous central area are several level upland plains, notably at Keningau, Sook and Ranau.

Mount Kinabalu at 13,455 ft (4,100 m) is the highest mountain rising out of the Crocker Range where the main hills are 4-6,000 ft (12-1800 m). The sources of the Paitan, Sugut and Labuk Rivers are in the Kinabalu area.

The Witti and Maitland Ranges in the interior are not as well defined as the Crocker Range. The Witti Range runs from east of the inland plains more or less parallel to the Crocker, while the Maitland Range runs south-east to Kalimantan. Trus Madi mountain at 8000 ft (2440 m) is the highest point of these ranges which give rise to the Kinabatangan River.

The Brassey Range runs in a more or less north-east/southwest direction in the country behind Darvel Bay. Spurs from this form mountainous country south of the Kinabatangan, and give rise to Segama River and the rivers entering Darvel Bay. The Bagahak Range north of Darvel Bay is of less extent but has steep land rising to

2000 ft (610 m). Inland and north of Tawau a tangled mass of rugged volcanic mountains culminate in Mount Magdalena at 5000 ft (1520 m), this area is linked to the Brassey Range.

Climate

The climate of Sabah is warm and moist. Temperatures of lowland stations in the region average 26.3°C and decrease by 0.6°C for every 100 m rise in elevation to 2000 m and then by 0.5°C (van Steenis 1962). This lapse rate has been confirmed for Malayan mountains (Burgess 1968). Variation in temperature is diurnal rather than seasonal. Temperatures in the lowlands rise from about 23°C in the early morning to 31°C at midday, and on hot days to 34°C. Night temperatures are lower in upland areas, frost occurring rarely on the summit of Mt. Kinabalu where no purely tropical plant family is found above 3000 m at average temperatures in the range 10-18°C. Cool air descending at night from Kinabalu reduces temperatures in the vicinity. Inside the forest temperature ranges differ with height and are of some relevance to silviculture, as are changes in ground temperatures following felling.

Average annual rainfall varies from 68 to 173 ins (1730-5080 mm) and is subject to seasonal variation due to the monsoons. The West Monsoon (known as the northeast in Sabah due to the direction of prevailing winds) is experienced from October or November to February, and the East Monsoon (southeast in Sabah) from May to August or September.

Between the monsoons winds are indeterminate. Sabah lies south of the typhoon belt but severe rain and wind storms occur in association with typhoons over the

Philippine Islands to the north. Localised cyclonic winds which may cut swathes through low vegetation are uncommon. Mean wind speed is low but heavy gusts often precede rainstorms. Wind damage to forests on exposed coastal hills is not uncommon (Burgess 1961) though more or less even-aged stands following extensive wind damage of the form described by Cousens (1965) in Malaya are unknown. Landslips and flooding, associated with heavy rain, as are windfalls, are of more importance in Sabah.

Lightning frequently accompanies heavy rain storms and several cases of individual or group death of trees following lightning strike are known from Sepilok F.R. This form of damage is unpredictable (A.J. Vincent letters in M.F. 1963, p. 304; 1964, p. 279). Humidity is generally high, especially inside the forest, at 70-90 per cent R.H. rising to 100 per cent at night. Perhaps because of this fire is not known to occur in the natural dipterocarp forests though in open areas may follow lightning (Anderson 1966). Man made fires have damaged peat swamp forests (e.g. at Seria, Brunei) and heath forests (at Sook Plain, Sabah). Large areas of fire climax grassland occur, with occasional fire resistant trees, notably in Kudat and Kota Belud districts.

Rainfall

Lowest recorded mean annual rainfall at 68 ins (1730 mm) occurs at Melalap near Tenom; and highest, 173 ins (5080 mm), at Lumadan Estate near Beaufort in the Brunei Bay area. Rainfall records summarised to date (Anon 1961) give most coverage to coastal and riverside stations.

At present little is known of the interior areas of the upper Padas River, and the areas drained by the upper waters of the Rivers Kinabatangan, Kuamut and Segama. It is likely that many mountainous areas have higher rainfall than available records show (Meijer 1963b). The early records suggest that mean annual total rainfall can be considered on a regional basis as follows:

(a) The area bordering Brunei Bay, centred on Beaufort, including most of the Klias Peninsula. This area receives highest rainfall between 140 and 160 ins (3500-4100 mm).

(b) The north-east of the country, north of the Kinabatangan delta, receiving 120-140 ins (3000-3500 mm).

(c) Two areas of comparatively low rainfall, 60-80 ins (1500-2000 mm) one in the southwest extending northeast from the upper Padas River to Tambunan, lying east of the Crocker Range and west of the Witti Range. The other is in the south east of the country occupying an arc embracing Lahud Datu and Tawau where the rainfall is slightly higher at Semporna (87 ins, 2210 mm).

(d) The remainder of the State receiving between 80 and 120 ins (2000-3000 mm): segments in the northwest and southeast receiving 80-100 ins (2000-2500 mm) and the remainder 100-120 ins (2500-3000 mm).

Variations within these broad regions occur from place to place, e.g. rainfall is locally heavy in the Bagahak Range east of Lahud Datu, but oomparatively light on the islands in Darvel Bay. The broad regions are illustrated in Figure 1 with 19 histograms showing monthly distribution of average rainfall.

The West Monsoon brings heavy rain to the north-eastern part of the State in December and January. Heaviest rainfall in the Brunei Bay area occurs in October to November, also associated with the West Monsoon. However during the period May to July, when the East Monsoon is influencing the region, the Brunei Bay area also receives heavy rain, as does the southeastern part of Sabah. The interior plains have a more even distribution, as they lie in the rain shadows of both monsoons.

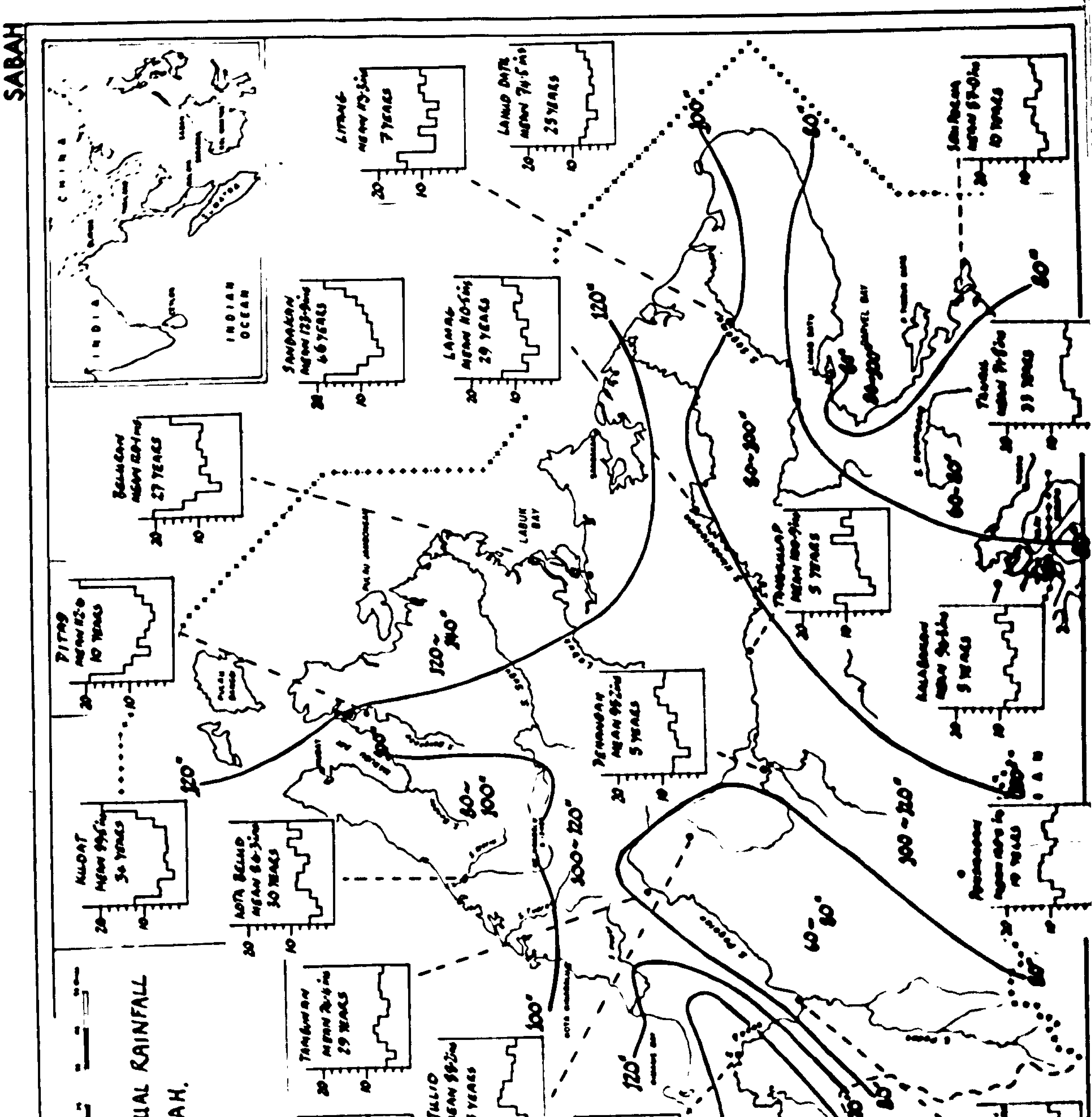


FIGURE 1 MEAN ANNUAL RAINFALL
SABAH

Total annual rainfall varies considerably from year to year. The following ranges for East Coast stations illustrate the extent of variation.

Station	Mean	Maximum	Minimum
	Rainfall in inches (Year in brackets)		
Kalabakan (5years)	96.3	104.4(1956)	87.4(1953)
Tawau (33years)	71.6	99.1(1952)	25.4(1907)
Lahud Datu(25years)	74.5	101.1(1932)	52.8(1951)
Sandakan (46years)	123.9	173.2(1938)	58.4(1914)
Lamag (29years)	110.5	168.7(1934)	71.9(1957)
Beluran (27years)	129.1	177.7(1928)	92.4(1931)

Much of the rainfall is heavy in intensity, and thoughout the year individual showers derived from passing convectional rainclouds may be released intermittently. At the height of the monsoon, several consecutive days may be wet and on average 50 per cent of days have rain in the Sandakan area. Dry spells are not uncommon and there is some evidence for a 9-11 year drought cycle, said to coincide with migratory locust swarming on the West Coast (F.D.A.R. 1947). The occurrence of flowering in relation to dry weather is discussed below.

Rainfall in the forest

A comparison of rainfall in the open and under a forest canopy some 200 m away was made during June 1970 to April 1971 inside Sepilok F.R. The open area was a cleared, grassy site and at the forest station the canopy was irregular with trees of all sizes and a moderately dense undergrowth. Conditions of rainfall interception were similar to what may be expected inside a natural dipterocarp forest. Three gauges 2-3 m apart were read daily inside the forest, and records compared with the gauge in the open. Rainfall at all three forest gauges was generally less than that in the open. Of the 132 rainy days rainfall in the forest gauges averaged less than, or equal to, that in the open on 94 days, while on 38 days the average recorded in the forest was higher. Rainfall in the forest tended to be higher with greater levels of rainfall:

Rainfall in Open (inches)	Number of Days	
	Open Higher	Forest Higher
less than 0.50	62	6
0.50-0.99	14	9
1.00-1.99	13	14
2.00-2.99	3	6
3.00+	2	3

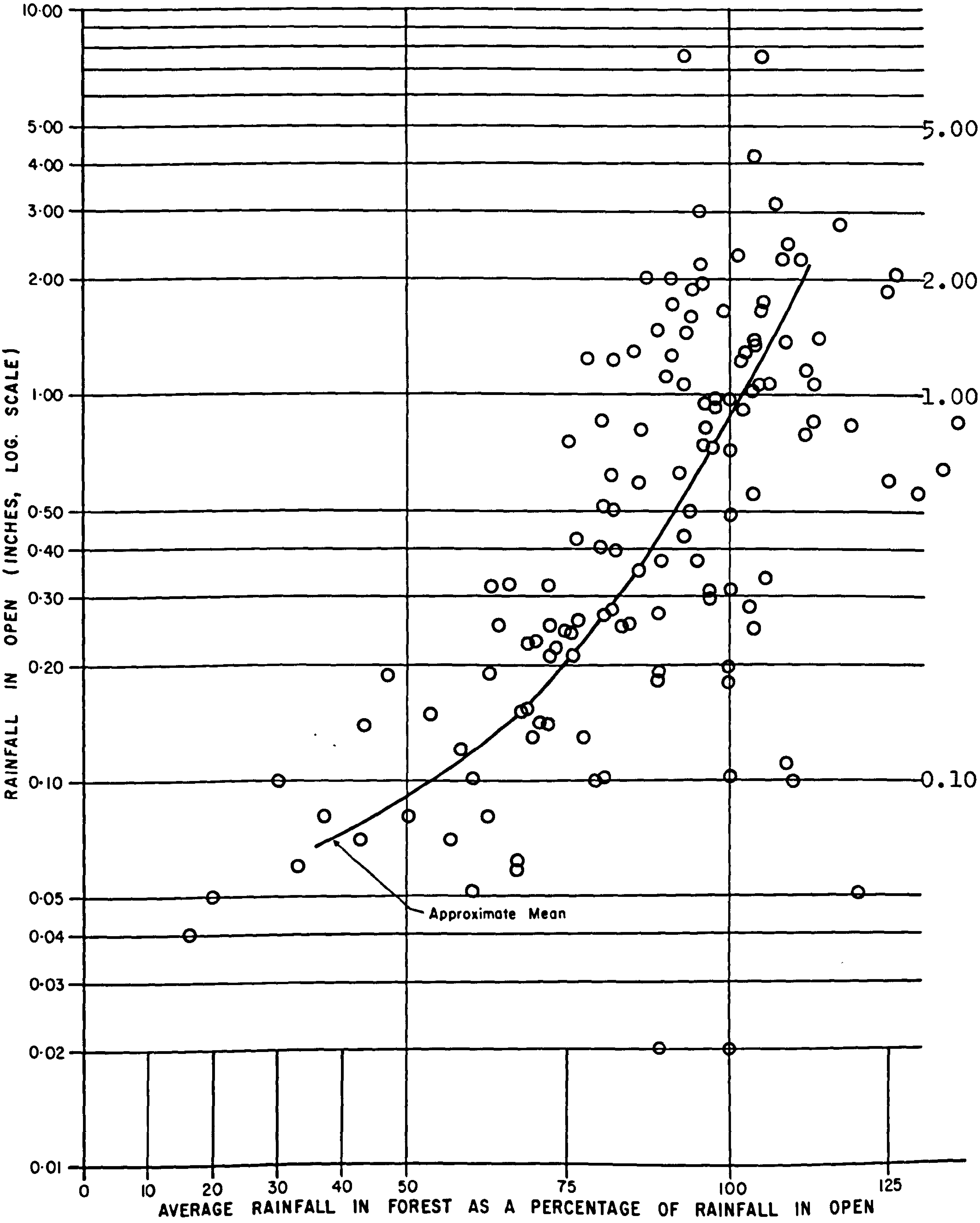
Interception tended to be greater the lighter the rainfall (Figure 2). With rainfall at the open site at less than 0.1 ins some 30-80 per cent did not reach the ground, while maximum interception for rainfall over 1.5 ins was 14 per cent.

Temperature

Records from Sandakan aerodrome and at Sepilok F.R. only are discussed here. These stations fairly represent forest areas on the East Coast, with the proviso that local temperatures are lowered by rainfall, more equable near the sea, and fall off with altitude. Table 1 summarises mean monthly temperatures, from Department of Civil Aviation records, for open conditions:-

FIGURE 2

RAINFALL AND INTERCEPTION



(Vertical scale is rainfall in open, inches log. scale)

Forest Department, Sabah. 1972.

Table 1. Temperatures at Sandakan Aerodrome

(Degrees Centigrade)

	Mean Daily (1966)	Mean Minimum (1951-1963)	Mean Maximum
January	26.5	23.1	29.2
February	27.0	23.0	29.4
March	27.3	23.1	30.3
April	27.8	23.1	31.2
May	27.2	23.2	32.0
June	26.7	22.9	32.0
July	27.0	22.5	31.7
August	27.0	22.6	31.8
September	27.3	22.8	31.7
October	26.5	22.8	31.5
November	26.8	22.9	30.5
December	26.8	22.9	29.9

Average daily temperatures show little variation through the year though minor peaks are evident for April and September, coinciding with the equinoxial periods. Maximum temperatures are lowest during the monsoon months of December to February and least variation is shown with mean minimum temperatures.

Temperature records in the forest at Sepilok F.R. (q.v. rainfall stations described above) at hourly intervals during daylight showed a substantial cooling effect inside the forest. Table 2 presents mean hourly readings for three 15 day periods. The June period experienced some 6 ins (150 mm) of rainfall; the October period a little over 2 ins (50 mm); and the February period was extremely wet with rainfall in excess of 22 ins (560 mm). During the hours of darkness it may be presumed that open sites tend to have lower temperatures but with smaller differences than for daylight hours. The February figures clearly illustrate the depressant effect of rainfall. There is a tendency for forest temperatures to lag behind the open and for changes due to cloud effect or rainfall to be lessened inside the forest. Individual daily records illustrate these differences dramatically.

Table 2. Mean Temperatures at 4 ft (1.2 m) above ground, Sepilok F.R.

	June 1-15 1970			October 1-15 1970 (Degrees Centigrade)			February 1-15 1971		
Hours	Open	Forest	Difference	Open	Forest	Difference	Open	Forest	Difference
0700	23.4	23.2	0.2	23.7	23.3	0.4	22.5	22.6	0.1
0800	24.8	24.1	0.7	24.3	23.4	0.9	23.4	22.8	0.6
0900	26.8	25.1	1.7	26.3	24.3	2.0	24.1	23.3	0.8
1000	29.0	25.9	3.1	27.0	24.7	2.3	25.1	23.8	1.3
1100	30.4	26.8	3.6	28.3	25.4	2.9	25.7	24.2	1.5
1200	31.1	27.6	3.5	29.2	26.1	3.1	26.1	24.4	1.7
1300	31.6	28.1	3.5	29.9	26.8	3.1	26.4	24.7	1.7
1400	31.4	28.3	3.1	30.0	27.1	2.9	25.9	24.6	1.3
1500	30.7	28.2	2.5	29.1	27.0	2.1	26.0	24.6	1.4
1600	29.7	27.9	1.8	28.6	27.0	1.6	25.4	24.4	1.0
1700	28.4	27.4	1.0	27.1	26.5	0.6	25.2	24.4	0.8
1800	27.4	26.2	1.2	25.9	26.0	0.1	24.8	24.2	0.6

Soil Temperature

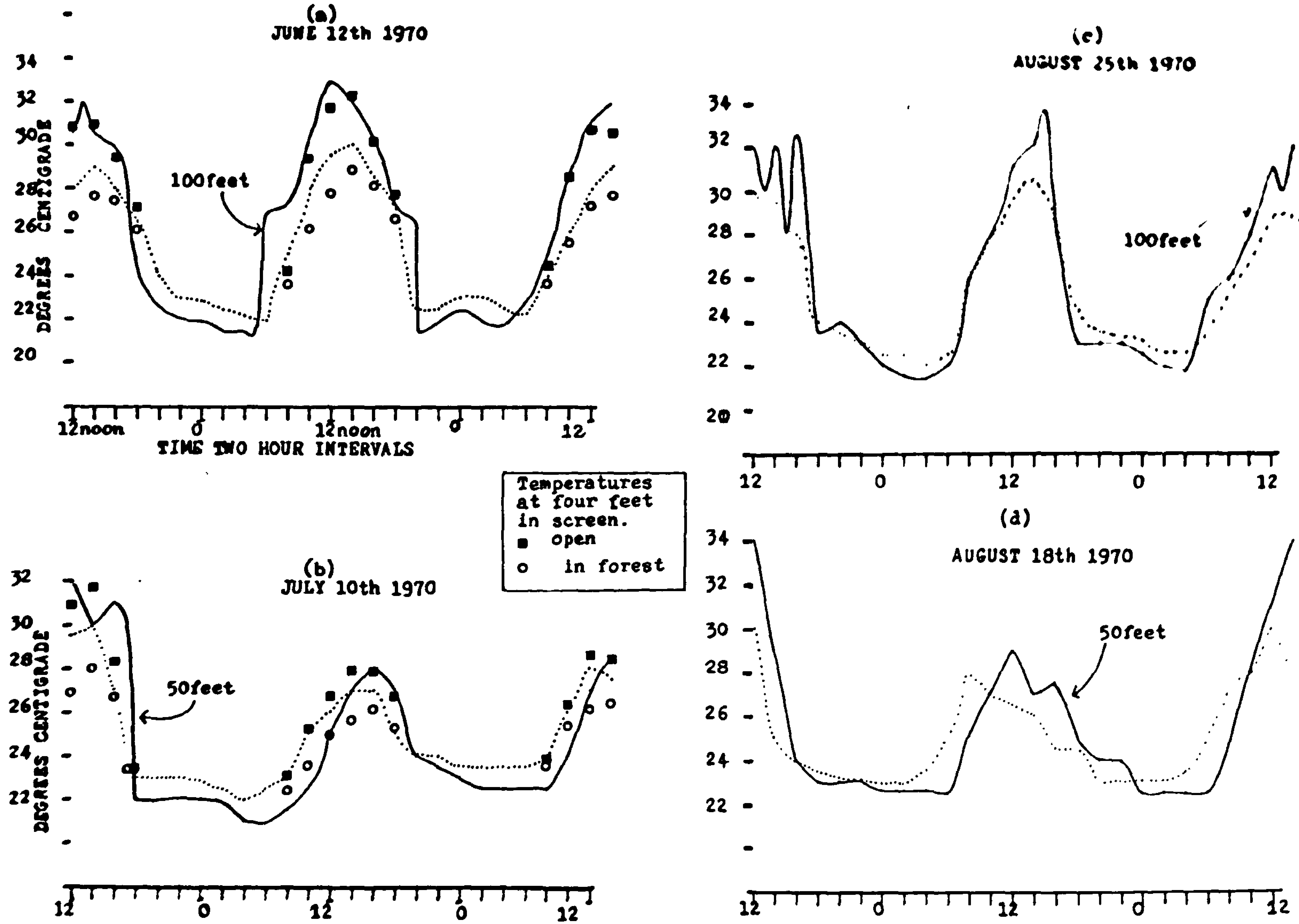
Soil temperatures are of some importance with respect to seedlings of the Dipterocarpaceae. Barnard (1951) showed that shaded soils took longer to warm up than those in the open, and that highest temperatures occurred after mid-day. Nicholson (1960) noted soil temperatures in open and shaded conditions were less variable with overcast skies than in sunny conditions, the various levels of shade having progressively depressant effects on soil temperature. Hill (1966) demonstrated that ranges of soil temperatures were greater under open conditions, and that soil temperatures at various depths were always lower under forest than in the open. Grass covered soils were intermediate between forest and bare soils. Soil temperatures at Sepilok during the periods given in Table 2 were lower inside the forest than in the open. At 1.2 m depth the difference was of the order of 1.5°C, with no noticeable daily variation. The differences were greater nearer the surface viz.: 2°C at 0.6 m, and 2.5°C at 0.3 m. Differences were much less for the February period, suggesting that water-logged soil under both conditions is similar. At 0.15 m depth in both June and October the soil tended to warm up after mid-day but more noticeably in the open than inside the forest. Overall soil temperatures were lowest in February, but similar for June and October.

Temperatures at Different Heights

During the period June to August 1970 recording thermographs were used to examine the daily march of temperatures above ground level. The instruments were placed at 6,15 and 30 metres from the ground. Four periods are illustrated in Figure 3 for the 6 m station (dotted line) and higher levels as labelled. The illustration shows temperatures plotted at two hourly intervals, but with extremes within these intervals also shown. The periods illustrated were mainly dry though some rain fell during July 9-11. The tallest trees in the vicinity were 45-52 m high, and it is assumed that the stations experienced similar temperature regimes to those of natural forest. The thermographs were sheltered from rain, and, incidentally, from direct sunlight. At 30 m temperatures of 32°C or more were reached at around midday falling to below 22°C at night. Temperature ranges at this height exceeded those at 1.2 m in the open but at other heights the ranges were more variable, often less than the range in the open. Generally the range increased

FIGURE 3 DAILY MARCH OF TEMPERATURE IN FOREST CANOPY

THERMOGRAPH DATA SEPILOK F.R.



with height inside the forest. More complete data from Sarawak (Palmer 1970) suggests a consistent mean difference between the upper canopy and near ground level temperatures of 2.8-3.9°C and also that there is considerable seasonal variation with the greatest ranges in the driest months.

Humidity and Sunshine

Humidity is highest at night, when the atmosphere is often saturated, and lowest at mid-day. The humidity inside the forest is higher than in cleared areas, and fluctuates less markedly. Palmer (1970) has shown seasonal variation in humidity at different heights in the forest. Diurnal ranges of 15 and 27 per cent at 0.8 and 32 m respectively were observed during the wetter weather and of 27 and 33 per cent in the drier weather; that is, in January and in June. Mean monthly values for Sandakan are given in Table 3.

Sunshine averages 5-7 hours daily (Table 3), though occasional days of 11 or more hours occur, and completely cloudy days are not unusual during December to February. Early morning mists are common in forest areas during wet weather, but these usually clear by 7 a.m. Sunshine is greater in drier areas. Whitmore and Wong (1959) have suggested that 1 per cent of daylight may be recorded inside the forest during cloudy weather and some 2 per cent of sunshine can reach the forest floor as sunflecks in sunshine.

Table 3. Humidity and Sunshine Data Recorded at Sandakan Aerodrome (Department of Civil Aviation Records).

	Relative Humidity Mean Percent 1954-1963			Sunshine Mean Hours 1953-1963
Time	0800	1400	2000	
January	93	78	87	4.8
February	92	75	85	5.6
March	92	73	84	7.1
April	91	71	85	8.1
May	91	70	88	7.6
June	92	68	89	6.9
July	93	67	88	7.1
August	92	67	88	6.7
September	92	68	89	6.6
October	92	70	89	6.6
November	93	74	89	5.6
December	93	77	88	5.1

(All values rounded off).

Geology

The geology of Sabah is well documented. The Geological Survey staff have produced a number of regional memoirs and bulletins dealing with particular problems. The map "Geological Map of Sabah, Brunei and Part of Sarawak" is included herein (Map 3). A larger map (Geological Survey 1967) gives more detail.

It is considered that the present distribution of forests owes much to the effects of geological history and some correlations exist between types of formation. These will be referred to in Chapter 4 in attempting to differentiate dipterocarp forests. Fossil material of *Dipterocarpus acutangulus* and other present day genera has been found in Quaternary basalt lava in the Tawau area (W. Meijer: Bot.Bull. 5, 1965). Symington (1943) stated that the family Dipterocarpaceae was well established within its present geographical limits towards the end of the Tertiary, and may have originated in the late Mesozoic or early Tertiary. The oldest rocks in Sabah are those of the Crystalline Basement Formation, high land to the west of Lahud Datu, probably of Jurassic, or earlier, origin (Geological Survey 1967). Kinabalu the highest land mass which dominates much of Sabah is of Upper Tertiary origin (Collenette 1966).

At the start of the Tertiary the north of Borneo probably resembled an archipelago (Keith 1935). Igneous intrusions and sedimentation gradually united the islands. The general result of historical processes gave harder, older sedimentary rocks to the north and west, with younger formations in the east. The country may be broadly divided into five regions (Wilford 1967 a). Firstly the western half, dominated by the Western Cordillera with inland plains and coastal lowlands. The formations are mainly hard sandstone mixed with other sedimentary rocks, the area dominated by the Crocker Formation, geosynclinal flysch deposits of sandstones and shales. The Sapulot Formation has mudstone predominant with some sandstone. The East Crocker Formation, in the higher parts of the Range is composed of sandstone and shale with marl and rare limestone breccia. This abuts on the Trus Madi Formation of shale and phyllite with siltstone and sandstone. The interior plains of Tambunan, Keningau, Tenom, Sook/Dalit and Nabawan lie between upfaulted areas where alluvial infilling occurred and have several levels of terrace features. High level bouldery alluvium terraces flank Kinabalu at 600-1800 m, the largest being Pinusok Plateau, possibly of morainic origin. Marine terraces in the Brunei Bay area occur at several levles, from late to mid-Pleistocene and of recent origin. These and similar terraces near Kudat and Kota Belud may have been formed at the height of the post-glacial rise of sea level.

The second region is the northeastern segment of the country south to the Segama River. The area is generally less than 300 m altitude but ultrabasic intrusions and basalt of volcanic origin form mountains in the Labuk and Karamuak valleys. Ultrabasic hills are steep sided with youthful drainage suggesting upward movement in Quaternary times (Wilford 1967 a) though their origin is probably earlier. This region is characterised by dissected peneplains that have been periodically uplifted. The Lokan Peneplain of the Kolapis Formation is predominantly red sandstone and shales; and terrace features, with sand or gravel, probably represent dissected marine platforms. Terrace deposits are also present in Sandakan Peninsula where concentric arcs of sandstone cliffs form the Sandakan Formation (Lee 1967). The Kapilit and Tanjong Formations have similar features. The Garinono Formation mainly of mudstone and slump breccia is east of the Lokan Peneplain and the Kudat Formation, of sandstone and shale with some limestone, is found in the north.

The third major region is the southeastern mountainous segment, excluding the Semporna Peninsula, but embracing the highlands of the Kuamut and Segama River sources. The area has undergone periodic uplift with rejuvenation of drainage. The Brantian and Umas Umas Rivers have rapid lower courses and wide alluvium filled upper reaches. Similar alluvial areas occur in the middle valleys of the Rivers Binuang, Tingkayu and in part of the upper Kalumpang. Terrace deposits occur in the lower

Serudong and Brantian valleys above alluvium. The igneous rocks of the Crystalline Basement include gabbro, diorite and granite. Numerous intrusions of ultrabasic and metamorphic rocks occur as belts through the Chert-Spilite Formation, which consists of a mixed assemblage of chert, spilite, greywacke, limestone (e.g. Mt. Madai) etc., with many small volcanic outcrops. Other, mainly sedimentary, formations are the Labang, Kalabakan, Kalumpang and Kapilit.

The fourth region is the Dent Peninsula and lower Segama valley to Lahud Datu in the west. Volcanic activity in the Tertiary gave rise to andesite and dacite in the Bakapit area. The rocks east of Lahud Datu are mixed volcanic and sedimentary: tuffaceous sandstones and conglomerate mixed with shales, mudstones and sandstones of the Ayer, Tabanak and Tungku Formations. Inner necritic to littoral deposits at the east of Dent Peninsula consist of mudstone, clay and coral limestone, with lignite, marl and conglomerate, of the Sabahat and Ganduman Formations.

Fifthly the Semporna Peninsula, east of Tawau where an involved process of intrusive and volcanic activity has worked on the landscape (Paton 1963). The area consists of erosion surfaces within 100 m of sea level, out of which rise hills of the more resistant rocks and upon which volcanic landforms have been superimposed. At the start of the Miocene much of this area was submerged and widespread volcanic activity of acid (rhyolite) and basic (andesite, basalt) types occurred during the Miocene, followed by three further periods of activity. The early Pliocene gave intrusive hornblende diorite (eastern Timbun Mata) associated with volcanic breccia (Gaya and Bohidulong Islands, and eastern Mt. Pock). Other features from this period are: volcanic agglomerate and breccia of Tinagat, Membalua and Tiku Hills; intrusive basic to intermediate dolerite on the flanks of Mts. Andrassey, Wullersdorf, and Lucia; microdiorite, small hills north of Tawau; and diorite at Sangster and Forbes Hills in the Kalumpang valley. In the late Pliocene andesitic lava and ash erupted from Magdalene-Lucia, Andrassey, Wullersdorf and Pock Mountains, products of these eruptions now forming the highest ground of the region. Rhyolite was later extruded from Wullersdorf, Andrassey and Glas Hill and at the end of the Pliocene dacite was erupted from Mt. Maria. The coastal platform was formed prior to the last, probably Quaternary, series of eruptions of basaltic lavas. Basalt flows following eruptions from hills in the Table-Tiger area, Quoin Hill and at Mostyn caused much disruption of drainage and account for the upper alluvial valleys mentioned in the third region.

Soils

Preliminary soil surveys since 1953 have covered much of Sabah. Thomas and Allen (1966) compiled all available data to 1965 in a soil map of the State. They used 23 mapping units from a combination of 18 basic soil groups of which the most important were:

(1) Lithosols, red/yellow latosols and podsolics: 41 percent.

(2) Red/yellow latosols and podsolics: 36 percent

(3) Active riverain alluvial and organic soils: 9 percent.

(4) Lithosols and red/brown ferrasols: 4 percent.
(Percentages refer to land area of the State)

The first group includes soils derived from sedimentary sandstones and shales (much of the Crocker Range under shifting cultivation and other steepland areas) and also soils on steeplands derived from volcanic ash and conglomerate (large areas north of Tawau and east of Lahud Datu). Important commercial dipterocarp forests in this group include much of Gunong Rara, Kalabakan and Silabukan F.R.'s.

The second group includes much of northeastern Sabah, the drainage of the Sugut, Paitan and Labuk Rivers, the Lokan Peneplain, Dent Peninsula, land between the Kinabatangan and Segama Rivers and patches in the lower valleys of the Kalabakan, Brantian and Umas Umas Rivers. Red/yellow podsolic soils, with distinct A and B horizons, are the most common soils of the dipterocarp forest areas. McCredie (1970) described all the soils of dry undulating, hill and steepland areas of the Sugut region as red/yellow podsolics on the Crocker and Bongaya Formations. Dipterocarp forests in the Kinabatangan/Segama area are found on ferric and orthic acrisols and luvisols (mainly equivalent to red/yellow podsolic soils) developed on low mudstone and sandstone hills in undulating areas; on gleyic acrisols and luvisols on mudstone or alluvium in lowlying areas; and on orthic acrisols, dystic cambisols tending to lithosols on sandstone hills (Acres and Folland, in press).

Red/yellow latosols, often intermingled with the podsolic soils, are distinguished by indistinct A and B horizons. These are found more frequently in drier areas and where the vegetation is grassy or sparse in trees. Red/brown latosols also have indistinct horizons and are deep soils developed on the andesite and dacite ash areas of Semporna Peninsula. Red/brown feralsols are deep soils of stable structure on the olivine basalts and ultrabasic rocks. Ultrabasic soils described by Acres and Folland (in press) include mainly orthic ferralsols on weathered colluvium e.g. Lawa Lawa Hill; while orthic luvisols (e.g. small hills in Segaliud-Lokan F.R.), eutric cambisols and lithosols are found on rock outcrops and stony colluvium. Soils of ultrabasic rocks are rich in iron, alumina, manganese, copper and lead (Fox and Tan 1971) and carry different kinds of forest from those on soils of other rock types.

Lithosols are skeletal soils developed on severe terrain covering the range of parent materials, with stony profiles of poor zonation. Kinabalu soils have been examined by Askew (1962). Humus is well developed with peat in the Oak/Coniferous zone and mull in *Lithocarpus havilandii* forest. These mountain soils are acidic with podsol tendencies and grouped as rankers by Thomas and Allen (1966). In lower areas podsol soils occur on sharp sandstone ridges subjected to severe leaching, e.g. Obar Ridge, Sugut (McCredie 1970); terrace features often have podsol profiles and carry low forests of few species. Barber (1966) mapped an area of Kubota soil at Merotai, Tawau, where a series of podsols lay superimposed. This soil type carries patches of *Tristania* Heath forest in the coastal plains of the Semporan Peninsula (Paton 1963). McCredie (1968) described similar areas on dissected terraces, near Ulu Dusun, Sandakan, as Manjang soils. He has also described podsols of the Baiayo Series in the Pelawan Valley where *Dacrydium* Heath forest occurs.

The more sandy soils tend to develop podsols and less sandy terrace features carry more normal forest (Barber and Thomas 1965). These soils are grouped by Thomas and Allen (1966) as grey podsols while they describe brown podsols as sandy soils occurring on old beach deposits in the coastal Crocker Plain. The term gleyic podsol is used by Acres and Folland (in press) for old sand terraces. Regosols are developed on active beach sands characterised by strand forest with *Casuarina equisetifolia*.

Limited areas of terra rossa soils are found in the vicinity of limestone outcrops, while rendzinas occur on limestone coralline remains in the east of Semporna and Dent Peninsulas. River deltas and estuaries carrying mangrove forests have soils classed as saline estuarine by Thomas and Allen (1966) and organic soils occur as deep peat in the Klias Peninsula, as high altitude shallow bogs on Kinabalu, in basins of the Kinabatangan River and in limited areas of impeded drainage elsewhere.

Alluvial and organic soils of the Kinabatangan and Segama areas are described in detail by Acres and Folland (in press). They distinguished four zones: meander belt, flood plain, backswamps and peat swamps. In the meander belt eutric fluvisols are developed on more recent deposits and cambisols are dominant on the older more weathered areas, with gley soils in poorly drained places. Gleyic luvisols and acrisols of the flood plain carry swamp forests or dipterocarp forest, apparently dependant on the periodicity of inundation. Humic and dystric gleysols of the back-swamps are developed where drainage is impeded by levee formation. These areas often carry sedge swamps with few trees. Kinabatangan peat swamps are at an early stage of development and the dystric histosol soils support more open swamp forests of lower density than those of the Klias Peninsula.

Other soil types described by Thomas and Allen (1966) are red podsolic soils derived from fine grained alluvium, only found in association with the volcanic areas of the Tawau highlands; ferruginous soils and vertisols. The latter are fairly deep soils developed from altered tuffaceous sediments of the Dent Peninsula and the Silabukan Basin. Ferruginous soils with indistinct profiles are of local occurrence where ironstone is present in basins infilled with colluvial ultrabasic rock, e.g. at Tavai Plateau (Wilford 1967 b).

Vegetation descriptions which follow rely heavily on sample plots made during soil surveys by myself 1966-71 and by Messrs Wood and Nicholson earlier, largely in association with Paton (1963). Both the latter and the Labuk Valley Project soil survey used geological formations as a basis for classification and soil series were described based on the age of rocks, composition of parent material and topographic position. All these are of considerable influence on the distribution of vegetation types. The more recent soil reports referred to above have devoted more attention to drainage characteristics, leaching and clay content and, latterly, overall landform units. The primary purpose of most of the soil survey work has been reconnaissance and the vegetation classification to be described must, of necessity, be considered as of a similar nature. Insufficient attention has been devoted to differences within small areas, though it is well known that minor variations in site, and particularly of soil, topography and drainage (Ashton 1964 a,b,c; Austin *et al* 1972; Poore 1968) are of considerable importance in the distribution of species. This will be discussed in Part 3 with reference to expected regeneration in dipterocarp forests.

Forestry in Sabah

Until the second world war the country was governed by a Chartered Company. Following the Japanese defeat a period of colonial status ended in 1963 with independance in the Federation of Malaysia and the former North Borneo became the State of Sabah. For administrative purposes the State is divided into 4 residencies: West Coast, Interior, Sandakan and Tawau (Map 2). These are subdivided into districts based on principal towns.

At 1960 the population was 454,000 of whom half lived in coastal port town districts (Lee 1968). The main concentration of 40 per cent was on the narrow west coast plains. Kota Kinabalu is the most densely populated district and had 168 persons per square mile in 1960. The proportions of town dwellers and settled rural communities have increased in recent years with the expansion of Government assisted settlement schemes.

State revenues from timber provide the main source of revenue. Other important earners are rubber, fisheries (prawns), palm oil, cocoa and copra. A number of semi-government corporations concerned with development, some of which may eventually become self supporting, are directly supported by the State. The 1st Sabah Foundation provides educational scholarships from income derived from the cutting over of several square miles of forest per annum for a period of 10 years. Latterly the 2nd Sabah Foundation has been formed to provide a direct source of income for the entire adult population. This organisation has an annual coupe of 30 square miles of forest in perpetuity.

Forest Revenues

After formation of the Chartered Company in 1882 export duty on jungle produce and timber was one of the earliest sources of revenue. The Company explored forest areas and administered limited exploitation firstly under the Treasurer General and later the Commissioner for Land. A Forest Department was organised in 1915 and a Conservator appointed. Later the British Borneo Timber Company (B.B.T.C.) was formed and awarded exclusive rights to the timber in the territory. Export of logs and local processing were undertaken but the total scale of activity remained comparatively small for many years. Principal requirements in the early years were for heavy durable timbers, e.g. *Eusideroxylon, Intsia* and selangan batu (Keith 1935).

By the early 1950's the timber trade had improved and the administration (F.D.A.R. 1947) foreseeing a rise in national aspirations, local enterprise increasing and apparent disadvantages of the monopoly, bought out the B.B.T.C. Forest Reserves were constituted on a large scale and areas were offered to interested parties to be cut on a sustained yield basis. Other areas, largely in unreserved forest, were also given out as "Special Licence" blocks with cutting scheduled for 10 year periods. The sustained areas were to be cut at 1 per cent of the total per annum, allowing a theoretical rotation of 80 years and a 20 per cent allowance for inaccessible or unstocked areas. These areas were known as "concessions" and ran for periods of 21 years, with renewable options at half-term. Options were no longer offered after 1970 when the Government formed the 2nd Sabah Foundation which was given the balance of much of the concession "back-up" area to fell over at the rate of 1 per cent.

Prices of heavy hardwoods remain higher than for the lighter woods, reflecting their more difficult extraction and handling, but demand has dropped. Early markets such as sleepers, have declined, rising use of preservatives has brought lighter woods into many markets but the main trend in post-war years has been the rise of veneer and plywood products. Most of the light/medium weight Dipterocarpaceae are satisfactory peelers. Approximately 20 per cent of log exports in recent years have been "white seraya" genus *Parashorea* the price of which may be taken as an index for Class B timbers (the bulk of production) generally. In 1950 the price FOB was $m1.09 and for 14 of the years to 1966 lay between $1.63 and $2.08. Prices gradually edged up from $2.11 in 1966 to $2.37 in 1969. Recent setbacks due to hardening markets in Japan may alter the upward trend.

Six distinct phases are evident in the period for which production and export figures are available. Firstly 1915-1926 a static period with overall production between 1½ and 3 million cubic feet/annum. Secondly 1927-37 a period of steady expansion, followed by a decline just prior to, and during, the second world war. Fourthly the period of reconstruction 1946-54 during which export finally reached the level attained in 1937, the best of the pre-war period. During the fifth phase 1955-65 production and export rose annually by substantial amounts as the concessions and special licence holders got under way. Production reached 100 million cubic feet in 1964, and exports that figure the following year. The sixth period 1965 to mid 1971 was one of steadily increasing production and export, but at a lower rate than the fifth phase.

Revenue has shown a similar increase. In no year has a surplus of revenue over expenditure failed to materialise. Prior to the war the surplus was of the order of 3-4 times expenditure. By 1959 the surplus was about twice the expenditure, by 1960 three times, by 1961 five times as large and in 1966 it was 6 times as large. The rise the next year, largely due to a doubling of royalty rates gave a surplus of revenue 13 times as great as expenditure.

The export value of timber was $2.7 million in 1948, $6.5 m in 1950, $61 m in 1959, $121 m in 1962, $257 m in 1966 and $375 m in 1969. In 1963 the labour force estimated at 12,500 produced a per capita export value of $12,000 (Labuk Valley Report 1963). The principal export market is Japan which has consistently taken in excess of 70 per cent of Sabah's exports since 1961. Korea and Taiwan are second and third in importance with Hong Kong, the principal market for poorer grade logs, fourth.

Extent of Forests

The present estimate of "Lowland Exploitable Dipterocarp forests" is 10,000 square miles (F.D.A.R. 1966). Forest Reserves total 11,000 square miles, but include much high land protection forest. At the end of 1966 there were 22 "production" reserves constituting the area of forest under sustained yield management and organised into 12 concession areas. These are shown in Table 4.

Table 4. Concession Forest Reserves

Forest Reserve	Area (Acres)	Concessionaire	Annual Coupe (Acres)
Kalabakan	920,581	Wallace Bay	6400
Kalumpang	206,906	Sabah Timber Co.)	
Binvang-Tengkayu	31,360	Sabah Timber Co.)	6400
Segaliud-lokan	401,600	Sabah Timber Co.)	
Silabukan	340,890	1)River Estates	
		Kennedy Bay)	6400
UluSegama	680,689	Kennedy Bay)	
		2)Yeng Ho Hong	
Ganduman	142,720	Shing Kee)	3200
Tenegang	198,400	Shing Kee)	
Lumerau	185,600	1)River Estates	1920
Kretam	186,880	North Borneo Timbers)	5760
Gunong Rara	668,800	North Borneo Timbers)	
Sungei Sapi	98,560	Kwong Borneo)	
Bonggaya	153,600	Kwong Borneo)	2752
Pin[illegible]	74,240	Kwong Borneo)	
Paitan	174,080	Ngui Ah Kui	1728
Sugut	108,160	Kwong Fui Loong	1280
Malua	85,120	2)Yeng Ho Hong)	2624
Lamag	41,600	Yeng Ho Hong)	
Kuamut	271,360	Chung Chao Loong	1920
Deramakot	128,640	United Timbers)	
Tangkulap	64,000	United Timbers)	6400
Sungei Penangah	576,000	United Timbers)	
Total area	5,730,886	= 8954.5 sq. miles (2,318,760 ha.)	

At the time of preparation of this table, only Silabukan F.R. had areas licenced under short term, unsustained agreements. This position changed rather dramatically during 1970-71 following the change of policy referred to earlier. Several other production reserves were worked under un-sustained agreements, and form part of the forest estate under management for production of regenerated stands, e.g. Sapagaya, Supu, Koyah but no information is given on them in this work.

At present a simple land capability classification is in progress. This categorises land intuitively by its estimated soil composition, steepness, liability to flooding, etc. Forest potential is given by its estimated carrying capacity based on aerial volume interpretation from photography taken prior to felling. This is very much a preliminary step in mappying of land resources, as is, with forests specifically, the mapping of forest volumes by the Forest Inventory Project (F.D.A.R. 1969).

Part 2 The Natural Vegetation of Sabah

CHAPTER 3

CLASSIFICATION OF VEGETATION IN SABAH

In this chapter literature describing aspects of the vegetation of Sabah is reviewed. This is complemented by discussion of vegetation classification in Malaya, Saravak and Brunei. A vegetation classification scheme for Sabah, based on species and general ecological principles is presented. A brief account of the vegetation types, excluding the dipterocarp forests, is then given supplemented by plot data and profile diagrams (cf Richards 1952).

Literature Review

The Vegetation of Sabah

Forest is the natural vegetation cover throughout the State, with the exception of bare rock at the summit of Mt. Kinabalu and some swamps. Many areas have been disturbed by man and the production of a vegetation map to show natural communities could only involve deduction for such areas (Wood 1955 a). The Canadian aid project "Forest Inventory of Sabah" will, no doubt, classify the vegetation in its present state in some detail in its final report (expected some time in 1972). However the view expressed by Wood:

> "If the composition of the primary vegetation is to be adequately recorded before it is irretrievably lost then there must be more botanists and ecologists on the ground with plenty of time for field studies"

still holds and the preliminary nature of the classification proposed herein must be stressed.

First attempts at classifying vegetation on an ecological basis were made by Keith (1935). The basic division was between littoral and inland forests and the latter were subdivided into fresh-water swamp, dipterocarp and hill forests. He described the dipterocarp forest as:

> "A lofty, evergreen, three storied forest formation. This forest not only represents a single formation but, except for the tension zone at its upper limits, it also belongs to a single well defined association."

He recognised variation with site, rarity and topography, and noted that large trees were scarce in ravines and narrow valleys. Later Keith went into more detail, following the terminology of Burtt-Davy (1936) and the outline of Symington (1943) to give the following classification (F.D.A.R. 1947):

Main (Climatic) Climax Formation

(a) Tropical Lowland Evergreen Rain Forest Formation (Lowland Dipterocarp Forest)
(b) Tropical Lowland Evergreen Rain Forest Formation (Hill Dipterocarp Forest)
(c) Tropical Lower-montane Evergreen Rain Forest Formation (Upper Dipterocarp Forest)
(d) Tropical Alpine Elfin-woodland Formation (Mossy Forest)

Edaphic Climax Formations

(e) Tropical Mangrove Woodland Formation
(f) Tropical Littoral Woodland Formation (Beach Forests)
(g) Peat Swamp Forests
(h) Tropical Riparian Woodland Formation (Riparian Fringe)
(i) Heath Forests

and, lastly, Forests of Uncertain Ecological Status. Of these he remarked that (a) was the main type but was practically non-existent on the West Coast. It had not been present for many years: "Certainly the untrodden jungle of fiction seems to be as non-existent in this country as the rain-forest of science" (Gibbs 1913). The Hill Dipterocarp Forest Keith characterised by the absence of *Eusideroxylon zwageri*, and scarcity of *Dryobalanops lanceolata*. His type (c) was a transition between lowland forests and the mossy forests present on the higher mountains at 750-1700 m with dipterocarps seldom found above 1000 m and conifers higher. This forest he described as generally two storied with moss and lichens abundant at the higher elevations. The mossy forest consisted of trees with short gnarled stems and bent branches overhung with moss, lichens, ferns and other epiphytes. Heath forests he thought were areas depopulated of dipterocarps, and characteristic of areas that were or had been, densely populated. Only in the latter do we now differ from his general classification.

Following the second world war increasing use of aerial photography became applied to map-making in general, and the estimation of forest resources in particular following the Fifth British Empire Forestry Conference (Brown 1948). By 1949 it was considered practicable to map the following categories (F.D.A.R. 1949): (1) Lowland Dipterocarp Forest with large trees, (2) As in (1) but recently exploited, (3) L.D.F. unclassified, (4) Forest of no commercial value, (5) Belukar (= secondary forest), (6) Mangrove, (7) Nipa, (8) Fresh-water swamp, (9) Herbaceous growth, (10) Rubber, (11) Miscellaneous cultivation. Brown completed work along these lines and published figures (F.D.A.R. 1953; M.F. 1953, p. 233) summarised in Table 5, together with later work by Francis and Wood (1955).

Table 5. Vegetation Classification of Sabah 1953.

Vegetation Type	Land Area (sq.miles)	Percent	Francis & Wood 1955
Commercial dipterocarp forest	7876	26.8	10,part 6
Inaccessible dipterocarp forest	8258	28.1	part 6,7
Dipterocarp forest of doubtful value	2145	7.3	part 7,11
Low stature (mainly montane) forest	1499	5.1	part 8
Miscellaneous: secondary swamps, etc.	2616	8.9	12,part 4,5,8
Commercial freshwater swamp	235	0.8	part 11
Beach	59	0.3	3,4,5
Nipa	676	2.3	2
Mangroves	1058	3.6	1
Cultivation (permanent)	970	3.3	13
Herbaceous	558	1.9	16,part 15
Cultivation (shifting) + secondary	3321	11.3	14,part 15

The value for shifting cultivation agreed closely with a random assessment made by C.S. Howroyd (Brown, in lit.) and a later estimate by a geographer of settled cultivation gave 4 per cent (Lee 1961 a).

This work was the beginning of the development of methods used to estimate volumes of commercial stands from aerial photographs pioneered by Howroyd (1954) and improved and standardised by Francis (1966). Brown's classification was expanded by Francis and Wood (1955) who included 16 kinds of vegetation which were illustrated on Forest Department Management Maps. Beach and mangroves were subdivided and inland forests classified on the basis of crown sizes. Area estimates used subsequently to summarise the pattern of vegetation in Sabah drew on their estimates (e.g. F.D.A.R. 1961; Fyfe 1964). In addition to the estimate of 10,000 square miles for productive dipterocarp forests given earlier (page 30) a further 8,000 were grouped as inaccessible (cf Table 5) dipterocarp forests.

These estimates can be misleading as forests change in content and type with altitude and rock type. Meijer (1963 a, 1964) drew attention to forest composition on distinctive land forms and Paton (1963) was able to correlate soil types with vegetation through consideration of land forms. Ecological studies have lagged behind timber volume mapping and much of the recent work has been concerned with exploitability.

Classification in Malaya and Sarawak

As we have seen Symington's (1943) classification of forests of the Malayan peninsula considerably influenced Keith's definitions. Symington's analysis illustrates how other vegetation forms differ from the Lowland Dipterocarp Forest. The Hill Dipterocarp Forests and other mountain forms, occur at higher altitudes, while mangroves, beach forests and so on are edaphically influenced, and secondary forms are biotically influenced. Obscure local climatic or edaphic variations may influence species distribution, but over considerable areas chance and opportunity are paramount.

Symington's differentiation of altitude forms was more precise than that of Keith; he recognised a Montane Oak zone above the Upper Dipterocarp Forest at 1050-1500 m and then a Montane Ericaceous zone from 1500 m, sometimes lower on isolated peaks. General physiographic pattern accounting for both this "mass-elevation" effect, and the local downward, ridge, extension of hill species to quite low altitudes on coastal hills, paraleled by upward extension of lowland species ascending valleys, render altitude limits of general value only. Symington suggested that the richest variety of species occurred at lower levels and where ridges descend into lowlands certainly more species may be expected. In so far as the Upper Dipterocarp Forest exists it is only on higher mountains 760-1250 m, and may be telescoped on isolated ranges to 600-900 m.

For silvicultural purposes a unit embracing exploitable areas, capable of subdivision for management is desirable. Landon (1955) defined Malayan "Tropical Rain Forest" as all forest from sea level to about 760 m, except for the edaphic forms. That is, embracing Symington's lowland and hill Dipterocarp forests and corresponding to Burtt-Davy's "Tropical Lowland Evergreen Rain-Forest" and Champion's "Evergreen Dipterocarp Forest". Wyatt-Smith (1961 b) elaborated on Symington's subdivision of Lowland Dipterocarp Forest, in order to clarify silvicultural work, and gave the following:

*L (1) *Shorea* (Rubroshorea)/*Dipterocarpus*
L (2) *Shorea* (Shorea)
L (3) *Dryobalanops aromatica*
L (4) *Shorea* (Anthoshorea)/*Parashorea lucida*
L (5) *Intsia palembanica/Cynometra elmeri*
L (6) *Balanocarpus heimii*
L (7) *Shorea pauciflora*
L (8) *Dipterocarpus*
L (9) *Shorea kunstleri*
L (10) Heaths - *S.materialis* or *S.glauca*

He recognised 5 types of Hill Dipterocarp Forests:

*H (1) *Shorea curtisii*
H (2) *Shorea laevis/S.multiflora*
H (3) *Shorea glauca*
H (4) *Shorea* (Shorea)/*Dipterocarpus*
H (5) *Swintonia spicifera*

* my notation

A further category was added later (Wyatt-Smith 1963) namely H (6) *Dipterocarpus/Vatica/Heritiera* and L (5) was raised to separate rank as seasonal forest. Robbins and Wyatt-Smith (1964) split "Heaths" into 2 categories of

"Heath Dipterocarp Forest" : L (11) *Shorea materialis* and L (12) *S.glaca*. Thus 12 associations comprise the optimum lowland sub-formations of the general Lowland Evergreen Rain-Forest Formation in Malaya. Within this occur tendencies to single dominance, correlated with environmental stress. It is suggested that dipterocarp forests may be an edaphic complex on a regional scale, and if the forests are examined for their structural content, all 3-layered communities should comprise the lowland formation.

Working in Brunei Ashton (1963) observed distributions related to environmental factors of soil and drainage, and suggested vegetation changes with environment, noticeably at soil and slope changes in hilly areas. Despite a lack of single dominance a practicable field definition could be based largely on a single indicative species. He suggested the following within the "Mixed Dipterocarp Forest":

1. *Shorea parvifolia* (silty clay soils on shales and clays)
    - 1.1 *Dipterocarpus verrucosus* (deep silty clay, well drained ridges)
    - 1.2 *Dryobalanops lanceolata* (clay-rich skeletal soils on steep hills and low clay hills)
2. *Cotylelobium malayanum* (skeletal, silty leached soils on shale ridges)
3. *Dryobalanops aromatica* (friable, yellow sandy soils on mixed material)
    - 3.1 *Anisoptera grossivenia* (deep soils, little leaching)
    - 3.2 *Shorea flemmichii* (leached sands, transitional to heath)

Later work suggested continuous variation, even when samples were confined to site types, but in any one area there was a tendency for areas of constant floristic composition to be connected to others by transitional bands of continuous variation. High constancy species could be used to characterise arbitrary sections of such a continuum (Ashton 1964 a). Recent re-examination of Ashton's data (Austin *et al*

1972) confirms the importance of soil factors, e.g. texture and leaching, as distinct from chance and opportunity in influencing variation in vegetation. Ashton (1965) commenting on the Types of Robbins and Wyatt-Smith suggested that *Dipterocarpus* L (9) was typical of more acid soils, *Dryobalanops aromatica* of quartzitic sand, and of the hill species *Shorea curtisii* favoured granite and *S. laevis* shale. In Sarawak L (1) could be expected on base rich clay soils over sedimentary or igneous rocks.

Undoubtedly such relationships occur, not only in Sarawak and Brunei, but elsewhere, and doubtless the conclusion demonstrated for small areas of Brunei (Ashton 1964 b) that associations may be recognised within the dipterocarp forest would hold for wider areas. Brünig (1969) could only classify the forest on the basis of physiography using aerial photographs and suggests that classification using species, or associations is difficult. Brünig's classification is particularly detailed with respect to Heath vegetation, his own special study, and to peat swamps, drawing on the work of Anderson (1961).

A discontinuous pattern of theoretical succession may be in operation which would obscure attempts at extrapolating Ashton's "floristic continua based on edaphic and physiographic differentials between species" (Cousens 1965). Cousen's example of *Shorea macroptera* colonising secondary forest may be compared with some species growing more rapidly than others in stands. He suggests that prospects for a "natural" classification based on climax associations is remote and the forester is basically interested in schemes of classification based on abundance and distribution of the faster growing trees capable of yielding valuable timber.

The increasing use of aerial photography has perhaps outstripped basic ecological knowledge. An exact knowledge of the components of natural forest is difficult to achieve (Gibbs 1913) and though forming one of the last great vegetation formations still available for study (Ashton 1969) data on distribution is scant. It is difficult to assess how far floristic differences between forest types are due to segregation from a uniform flora, influenced by habitat, and how far to differences in available species (Poore 1968). It is still notoriously difficult to separate types within the dipterocarp forests from the air (Mok 1966 a) and even low-level flying can only show up a few species, e.g. *Shorea albida, S. argentifolia, Dryobalanops* species (M.F. 1952 p.38), *Shorea curtissi, Koompassia excelsa* and large leaved *Dipterocarpus* species. Crown size and physiography remain the dominant criteria for classifying Dipterocarp forests (Mok 1966 b; Brünig 1969). These criteria are of economic significance as productivity classes, which are generally desired (Mok 1967; Murthy and Yong 1968), in terms of volume and basal area can be correlated with them.

Scheme for Adoption in Sabah

Classification schemes, as we have seen, may be of various forms. They may be based on productivity, using either basal area or volume; on air photography cover types; or based on the types of forest. The vegetation of the lowland and hill dipterocarp forests covers a greater land area than the others and will be described in detail in Chapter 4. The following modified version of Keith's (F.D.A.R. 1947) classification will be used here:

Scheme	Climax Formations
1.	Lowland and Hill Dipterocarp Forests 0 to 6-900 m
2.	Lower Montane Forests 2-canopy (c.f. Robbins 1969)
3.	Montane Forests 1-canopy (c,f. Robbins 1969)
	Sub-Formations
4.	Swamps
	4.1 Mangroves
	4.2 Peat Swamp
	4.3 Fresh Water Swamp
	4.4 Riparian
5.	Beach
6.	Limestone
7.	Heath (Kerangas of Brünig 1969)
	Secondary Formations
8.	Secondary Forest
9.	Grasslands (not dealt with)
10.	Plantations (not dealt with)

The remainder of this chapter is devoted to a descriptive account of Types 2 to 10 of this scheme.

2. Lower Montane Forest

(a) Upper Dipterocarp Forest

This type is not abundant, occupying a transitional position between lower level forests rich in dipterocarp species and higher levels dominated by conifers and Fagaceae. It is largely confined to the eastern slopes of Mount Kinabalu petering out at 1000-1500 m, though individuals or small stands occur on other mountains. The structure and composition of typical stands have not been discribed, and the full range of species is not known. Nicholson (1962 b) noted *Shorea nebulosa* at 1000 m in Oak forest on sandstone and shales, and *S.plätyclados* with some

S.faguetiana off ridges at 1200 m. Corner (1962 a) noted *S.monticola* in gregarious stands at 1200-1500 m, generally on peaks, while he observed *S.platyclados* at 1000 m. In Brunei Ashton (1964 c) recorded *S.monticola* in small groups on white sandy soil at 1750 m, but also on lower mountains at 900 m. Other observations from the Kinabalu area are of *Shorea monticola* at the summit of Mt. Hampuan, 1200 m. in a matrix of conifers, and with *S.nebulosa, S.platyclados, Vatica* spp., and *Hopea* spp. at 1500-1800 m. in the Kundasang/Tenompok area on the southern side of the mountain in a region of conifers and Fagaceae (Meijer 1963 b). Montane species of dipterocarps have been collected in the Crocker Range in the Tambunan/Sensuron area, on Mount Lumaku (Gunong Lumaku F.R.), in Mount Templar F.R., and on Mount Trus Madi. Several species occur from about 700 m in Gunong Rara F.R.

(b) *Agathis dammara* Forest

This species occurs in gregarious stands at 1600 m. near Park Headquarters to the south of Kinabalu, and is locally frequent on the eastern side at 1200-1700 m. A fine stand was seen northeast of Gunong Alab in the Crocker Range at about 1700 m. Stands occur in the Serudong Hills of Kalabakan F.R. and isolated clumps occur in the Tawau mountains, e.g. Mts. Andrassey and Wullersdorf (600-650 m). Tree sizes exceed 60 cm diameter and 24 m in height.

(c) Oak/Conifer Forest

This is the most extensive form of mountain forest and is present on all the higher parts of the Crocker Range above the zone of shifting cultivation, as well as on the flanks of Kinabalu. Meijer (1963 b) gives a map of Kinabalu based on aerial photography suggesting that this type extends from 900-1500 m on the eastern side and 1500-2100 on the south. It must be stressed that altitudinal limits, especially the lower, by no means strictly coincide with contour lines (van Steenis 1962) and the effects of "mass-elevation" (page 36) are everywhere evident. Shifting cultivation at present extends to 1200-1500 m on the south and west of Kinabalu though primary forest existed at Tenompok sixty years ago (Gibbs 1913). The areas south of Park Headquarters, Sosopodon, and north of Kundasang have been cleared off only in recent years. The best development of this type in the Crocker Range is from 1200 to 1800 m.

It is not possible to do justice here to the flora of Kinabalu whose wealth of forms and species is enormous: one collector is said to have obtained 200 species of the orchid genus *Bulbophyllum* (Corner 1962 b). Details of the flora may be found in Meijer (1963 b) and a preliminary account of Pinusok Plateau in Corner (1962 a). Of the conifers large trees of *Phyllocladus hypopyllus*, *Podocarpus imbricatus* and *Podocarpus neriifolius* occur in this type, together with smaller trees of *Dacrydium falciforme*, *Dacrydium beccari*. These are found with many species of *Lithocarpus* e.g. *L.clementianus*, *L. confertus*, *L.echinulatus*, *L.encleisacarpus*, *L.hallieri*, *L.lampadarius*, *L.luteus*, *L.papillifer*, *L.revolutus*, *L.woodii* some *Castanopsis* e.g. *C.acuminatissima*, *C.clemensii*. Other species of *Lithocarpus* which extend into higher altitudes are *L.bullatus*, *L.havilandii*, *L.nodosus* and *L.turbinatus*. The type may be described as a two layered forest in the sense of Robbins (1969) with a thin understorey consisting of species of the families Lauraceae, Theaceae, Clusiaceae, and of *Eugenia* species. In admixture with the oaks and conifers, sometimes reaching large sizes, are species of the lowland genera of Moraceae Meliaceae, Myristicaceae etc.

Physiognomy of the mountain forest varies with topography, exposure and soil. In gullies groves of larger trees extend to high elevations, while on exposed sites trees are smaller. In the Mamut valley the mossy forest descends to 1500 m due to the effect of low cloud and mist. Similarly hill tops at 1200 m+ sometimes have low coniferous-myrtaceous forest also found on higher ridges. In general heights are from 10-30 m, and bole sizes reach 60 cm diameter in better growth. Local stands of thin boled *Tristania/Eugenia* occur on white sandy soils throughout the type and Corner noted *Gymnostoma (Casuarina) sumatrana* at 1650 m and riveraine stands of *Tristania, Engelhardtia, Duabanga, Adinandra* etc. in the Mamut area at 1100-1350 m. The "trig oak" - *Trigobalanus verticillata* is locally abundant on steep slopes and ridges at 1200 - 1500 m.

3. Montane Forests

One layered forests occur generally above 1800 m on Kinabalu, and on exposed peaks elsewhere. It is general to term these forests "mossy" though some high altitude forms may not be as mossy as parts of the Oak/Conifer forest and other 2-layered forests with *Gymnostoma* locally emergent.

(a) Ericaceous Forest

This term is applied to the forests above the Oak/conifer forest from 1800 m. Between 1800 and 2400 m *Schima wallichii*, *Leptospermum flavescens*, *Dacrydium beccarii*, *Lithocarpus* spp. *Rhododendron* spp. , *Vaccinium* spp., *Eugenia* spp. and Lauraceae are abundant. Above 2400 m Fagaceae decrease and *Schima brevifolia*, with *Polyosma* sp., *Drimys piperata*, *Elaeocarpus congestifolius* occur with the Ericaceae and small conifers, e.g. *Podocarpus imbricatus* var. *kinabaluense*. Open glades of grasses and sedges occur in boggy places and *Rhododendron buxifolium*, *R. ericoides*, *Myrica javanica*, *Ilex*, and dwarf *Leptospermum recurvum* occur as small stunted plants above 3200 m in the summit zone. Ericaceous forest also occurs on Mt. Trus Madi, in the summit area 2400 m, and *Diplycosia*, *Rhododendron*, *Vaccinium* are present with *Adinandra*, *Eugenia*, *Dacrydium pectinatum*, and *Lithocarpus* spp.

(b) *Dacrydium gibbsiae* Forest

A unique low-statured forest of *Dacrydium gibbsiae* occurs at 2400-2700 m, on ultrabasic rocks along the classical route up Mount Kinabalu between Carson's Camp and Paka Cave. Also present in this type are *Leptospermum recurvum*, *Rhododendron ericoides*, and *Racemobambos gibbsiae*, a thin climbing bamboo also found in other ultrabasic forests. In open wet places the sedges *Schoenus curvulus* and *Machaerina micranthes* are found.

(c) *Lithocarpus havilandii* Forest

On Kinabalu above the general mossy forests low stands of *Lithocarpus havilandii* occur on granite outcrops.

Other shrubby trees present at these higher levels, include *Eugenia*, *Ilex*, *Eurya*, *Sýmplocos*, and *Polyosma*. These ascend to the limits of woody vegetation with Ericaceae. *Adinandra* has been observed as a secondary formation on scree (Corner 1962 a). In more sheltered gullies *Magnolia carsonii*, *Schima brevifolia*, *Photinia*, *Symplocos buxifolia*, *Podocarpus imbricatus*, *Phyllocladus hypophyllus* and *Leptospermum recurvum* reach 15 m in height in the 2700-3000 m zone.

(d) *Gymnostoma/Tristania* Mossy Forest

The summit areas of Mt. Wullersdorf and Glas Hill (730,610 m) with poor soils derived from rhyolite have mossy forests at their summits. *Gymnostoma (Casuarina) sumatrana* and *Tristania* sp.cf *elliptica* are typical for these. Mt. Silam (880 m), an ultrabasic peak, has a summit mossy forest of *Leptospermum flavescens*, Eugenia spp., *Schima*, *Dacrydium elatum*, *Buxus rolfei*, *Palaquium herveyi*, *Calophyllum* and *Anisophyllea*. *Tristania grandifolia* and *Gymnostoma sumatrana* occur locally from 760 m on exposed ridges of this mountain. This ultrabasic mossy forest is physiognomically similar to the high level forests on Kinabalu (Wood 1955 b) and reappears on ultrabasic peaks in the Labuk/Tavai area. Meijer (1963 b) described the forest of the ultrabasic Mt. Hampuan (1200 m), a subsidiary flank of the main Kinabalu massif, as mossy forest with conifers: *Dacrydium beccari*, *D.falciforme*, *Podocarpus neriifolius* and *Agathis*; the oaks , *Lithocarpus borneensis*, *L.cyrtoryncha*, and *L.sericobalanus*, with *Shorea monticola*, *Gymnostoma* and *Tristania* present.

The profile diagram (Figure 8) of ultrabasic forest in Segaliud-Lodan F.R. at 180 m illustrates a forest floristically similar to the higher, mossy peaks, but it is distinctly 2-layered and has little moss. The presence of *Gymnostoma* as a local emergent in the summit forests suggests that in Robbin's definition (1969) they should be classed as Lower Montane Forest (see Ashton 1958).

4. Swamp Forests

4.1. Mangrove Swamp Forests

Some 27 tree species indigenous to Sabah are tolerant of salt water and may be classed as mangroves. Of these eight are Rhizophoraceae. The following distinctions are made:

(a) *Rhizophora mucronata*

This species is found in gregarious stands at the outer parts of deltas, forming a seaward fringe. There is some admixture of *R.apiculata*

(b) *Rhizophora apiculata*

R.apiculata lines tidal river banks and estuarine delta areas. These are the main areas of mangrove forest and other species are *Ceriops tagal*, often in dense clumps; *Lumnitzera littorea* as large standards on drier sites; and *Xylocarpus granatum* lining river banks. Locally smaller stands are often dominated by *Ceriops tagal* (this species reaches 45 cm in diameter, but has been much exploited for its bark) with the shrub *Scyphiphora hydrophyllaceae*. *X.granatum* and *R.apiculata* are occasionally present as larger trees.

(c) *Nipa fruticans*

This palm is found in extensive pure stands in delta areas, and it also lines the banks of major rivers to the limit of tidal influence. It is important as a coloniser as its growth habit accentuates mound development (cf extensive area, Table 5).

(d) *Oncosperma tigillaria*

This is another palm occurring in smaller stands, generally on sandy mud heaps associated with crabs at the back of the woody mangroves, especially where the transition to dry land is relatively abrupt.

(e) *Bruguiera gymnorrhiza*

Dense pure stands of *B.gymnorrhiza* are often found behind the main zone where the duration of tidal influence is not as great. Stemless palms and the fern *Acrostichum aureum*, which invades (b) when cut, occur in open places on mounds. *Heritiera littoralis* is an associate at the limits of inundation with *Lumnitzera littoralis* and local patches of other *Bruguiera* species also occur behind the main zone. *Osbornia octodonta* is another species of the inner (or back) mangroves.

(f) *Avicennia alba*

The outer fringes of large rivers, especially exposed bends, often have more or less pure stands of the large pioneer species *Avicennia alba*. The habitat of *Sonneratia alba* is similar and both species may be found on sandy beaches where wave action is not severe.

(g) Miscellaneous Mangrove areas.

River banks with less developed forest may have representatives of *Excoecaria agallocha*, *Aegiceras corniculatum*, and *Cerbera odollam*. *Heritiera globosus* is often locally abundant on river banks at the limit of tidal influence, standing above *Nipa* and other shrubby species (see 4.4(a)).

Many areas of mixed mangrove forests occur which are at present insufficiently understood. In addition to the species already mentioned the following are found: *Lumnitzera racemosa* as a small shrub on the sandy beach of Kota Kinabalu, *Sonneratia caseolaris* is found in tidal creeks behind the *Rhizophora* species and on muddy shores: in the Labuk delta it is found with a *Pandanus*. Other sea-shore species are *Thespesia populnea*, *Hibiscus tiliaceus*, and *Brownlowia argentea*. *Bruguiera cylindrica* is locally gregarious on newly formed soils. Other species inland of the mangroves proper, but often classed with them in so-called transitional forest, are *Intsia bijuga* and *Kandelia candel*.

(h) Transition Forest.

This term covers vegetation forms transitional between mangroves and dry land forest - in most cases lowland dipterocarp forests. It is of varying width and often restricted to non-tidal stream areas or lowlying, but not tidal, flats. The following species may be present in addition to those given earlier for the back parts of the mangroves:

Amoora cucullata
Ardisia elliptica
Croton heterocarpus
Cynometra ramiflora
Diospyros euphlebia
Ficus microcarpa
Gluta velutina
Myrsine umbellulata
Nauclea coadunata
Pandanus alcinae
Parinari asperula
Pericopsis mooniana
Planchonella obovata
Quassia borneensis
Quassia indica
Sandoricum borneense
Stemonurus scorpioides
Symplocos celastrifolia
Tarenna bartlettii
Teijsmanniodendron hollrungii
Vitex negundo

The palm *Arega recroflorescens* and the dipterocarp *Vatica umbonata* are also found behind the mangroves.

4.2. Peat Swamp Forests

(a) *Dactylocladus stenostachys/Gonystylus bancanus*

In the Klias Peninsula some 650 sq.km. (250 sq. miles) of mixed forest (cf Anderson 1958) forming stands on deep peat, similar to Brünig's (1969) classification 3.1 to 3.5 formerly existed. All have now been logged off for the valuable species, of which the principal ones were *Dactylocladus stenostachys, Gonystylus bancanus,* and *Dryobalanops rappa.* An enumeration of the main, Klias area gave a commercial volume of 1125 cu.ft/acre (100 cu.m/ha) of which these three species accounted for 70 per cent. A similar forest at Marintaman-Mengalong carried a lower volume, and the three main species accounted for 54 per cent. Small areas at Kimanis also carried limited areas of this form of peat-swamp, but nowhere in Sabah had these swamps developed to the extent seen in Brunei, Sarawak and Kalimantan, and they are not dealt with in great detail here. In addition to the three valuable species, given above, the following are found in the Klias:

Aglaia argentea
Amoora rubiginosa
Aromadendron nutans
Baccaurea bracteata
Blumeodendron tokbrai
Calophyllum retusum
C.rhizophorum
C.sclerophyllum
Campnosperma coriacea
Carallia brachiata
Combretocarpus rotundatus
Cratoxylon arborescens
Ctenolophon parvifolius
Dillenia pulchella
Diospyros evena
Disepalum coronatum
Dyera polyphylla
Elaecarpus griffithii
E.marginatus
Eugenia christmannii
Ganua motleyana
Gardenia pterocalyx
Gonystylus maingayi
Horsfieldia crassifolia
Ilex cymosa
Jackia ornata
Kokoona ovatolanceolata
Koompassia malaccensis
Knema kunstleri
Lithocarpus dasystachyus
Litsea resinosa
L.crassifolia
Lophopetalum multinervium
L.rigidum

Melanorrhoea beccarii	*Pseudosindora palustris*
Notaphoebe obovata	*Prunus turfosa*
Palaquium pseudocuneatum	*Sandoricum emarginatum*
Parartocarpus venenosus	*Stemonsuros scorpioides*
Parastemon urophyllum	*Tarenna bartlettii*
Parishia sericea	*Tetramerista glabra*
P.polycarpa	*Xylopia corifolia*

and the dipterocarps *Shorea platycarpa, S.scabrida, S. teysmanniana.*

In common with other areas described (Anderson 1958, Kostermans 1958, Wyatt-Smith 1959) these forests vary somewhat and areas elsewhere of white sand, with or without peat, but in low-lying swampy areas often carry similar species. Because of the difficulty of access such areas in the East Coast riverain swamps have not been intensively studied as yet, though it may safely be stated that development is only at a relatively primitive stage. Many peaty areas on the East Coast may be inundated when the large rivers are in spate (4.3) Muller (1963) gave evidence that the peat swamp forests arose from the infilling of *Rhizophora* mangrove swamps, Type 4.2(a) on clay, and 4.2(b) on sand, though the latter is possibly of terrace origin (see discussion in Muller 1963). Areas of white sand terraces will be dealt with under Heath (7).

(b) *Dacrydium elatum/Gymnostoma nobile*

This type of forest was described by Browne (1952) from Lawas, Sarawak and occurs in a limited stand just behind the sandy sea beach at Marintaman-Mengalong F.R. south of Sipitang (R.P. 36). Browne suggested that the association was a precursor of peat swamp forest on sandy soil. In both areas the *Dacrydium* trees are dying, possibly due to water table changes, and seedling regeneration of this species is sparse. *Cyrtostachys lakka*, a thin red-stemmed palm, forms an under-storey to 15 m height. The largest trees are 30 m or so in height and the maximum diameter is of the order of 80 cm. The following summarises stocking data for R.P. 36:

Species	Numbers of Stems >1ft girth >10cms diam.	>4ft >39cms	>6ft >58cms
Dacrydium elatum	159	48	-
Gymnostoma nobile	38	5	1
Dactylocladus stenostachys	68	31	8
Combretocarpus rotundatus	33	24	2
Calophyllum retusum	18	6	-
Palaquium pseudocuneatum	6	1	-
11 other species	52	-	-

Total trees on plot 372
Basal area/acre 189 sq.ft (43sq.m/ha)

A similar association is present on high altitude peat at Tavai Plateau, though the trees are smaller and the species of *Gymnostoma* is uncertain.

(c) *Lophopetalum multinervium*

This form of peat swamp is found in the Sugut (McCredie 1970) and Labuk (Meijer 1964). Typical areas are variable in height and density across, with the more open areas where trees are stunted in the centre. The thorny grass *Thoracostachyum pandanophyllum* occurs in open areas, with some *Pandanus* sp., while trees occurring with *L.multinervium* include *Campnosperma coriaceae*, *Cratoxylon arborescens*, *Jackia ornata*, *Stemonuros* sp., *Fagraea* sp. and *Amoora rubiginosa*.

Also placed in this type are the variety of, often large, areas in the Kinabatangan and Segama flood plains mapped as peat swamps by Acres and Folland (in press). Dying or dead trees are often found at the centre, and *Mapania*, with large strap shaped, shiny leaves, is characteristic of many areas. In addition to the species given above the following have been recorded from Kinabatangan peat-swamps:

Ilex cymosa	*Eugenia sarawakensis*
Buchanania arborescens	*Baccaurea puberula*
Ficus sundaica	*Alstonia angustiloba*
Notaphoebe kingiana	*Pouteria malaccensis*
Diospyros elliptifolia	*Calophyllum globuliferum*

The forests of this type are transitional to freshwater swamp, are occasionally flooded, whereas (a) and (b) receive only rain water.

4.3. Fresh Water Swamp Forests

These forests all receive water from flooding or poor surface drainage. Small areas of swampy soil are common throughout the lowland forests, and are often characterised by the presence of Myristicaceae. Many swamps have few dominant species. Many of the West Coast vegetation forms of this group are secondary or have been considerably influenced by man.

(a) *Metroxylon rumphii*

Sago palm swamps are particularly abundant in the Klias peninsula bordering peat swamp areas, and are also found throughout the West Coast adjacent to rice fields.

(b) *Alstonia spatulata*

This species occurs in similar areas to (a) and is a secondary association dominant following destruction of the original forest. Thomas (1963) has described the Krah Swamp at Kota Belud in some detail; the wetter areas are devoid of trees and sedges and ferns, e.g. *Blechnum indicum*, *Nephrolepis biserrata*, and *Cyclosorus gongylodes* are common. *A. spatulata* swamps where this species often reaches a large size occur in low-lying areas near major East Coast rivers. Towards the end of the main monsoon individual trees in new, light green leaf can be seen from the air. The tree is easily recognised on the ground by its high, tapered buttresses and light cream to pink coloured bole.

(c) Sedge swamps

Sedge swamps which are apparently natural are not unknown (Wyatt-Smith 1961 b) and occur in Sabah at Balembangan Island and in East Coast river plains on mucky soils. The following species of sedge were recorded at Balembangan Island: *Triostularia undulata*, *Fimbristylis nutans*, *Machaerina* sp. and *Carex saturata*. McCredie (1970) described an open sedge swamp in the Sugut area with *Scirpodendron* sp. and the treelet *Samadera indica*.

(d) *Ficus* swamps

Large areas near Pandasan, Kota Belud have *Ficus* sp. with *Sapium indicum*. (See also 4.4 (c) below).

(e) *Corypha utan*

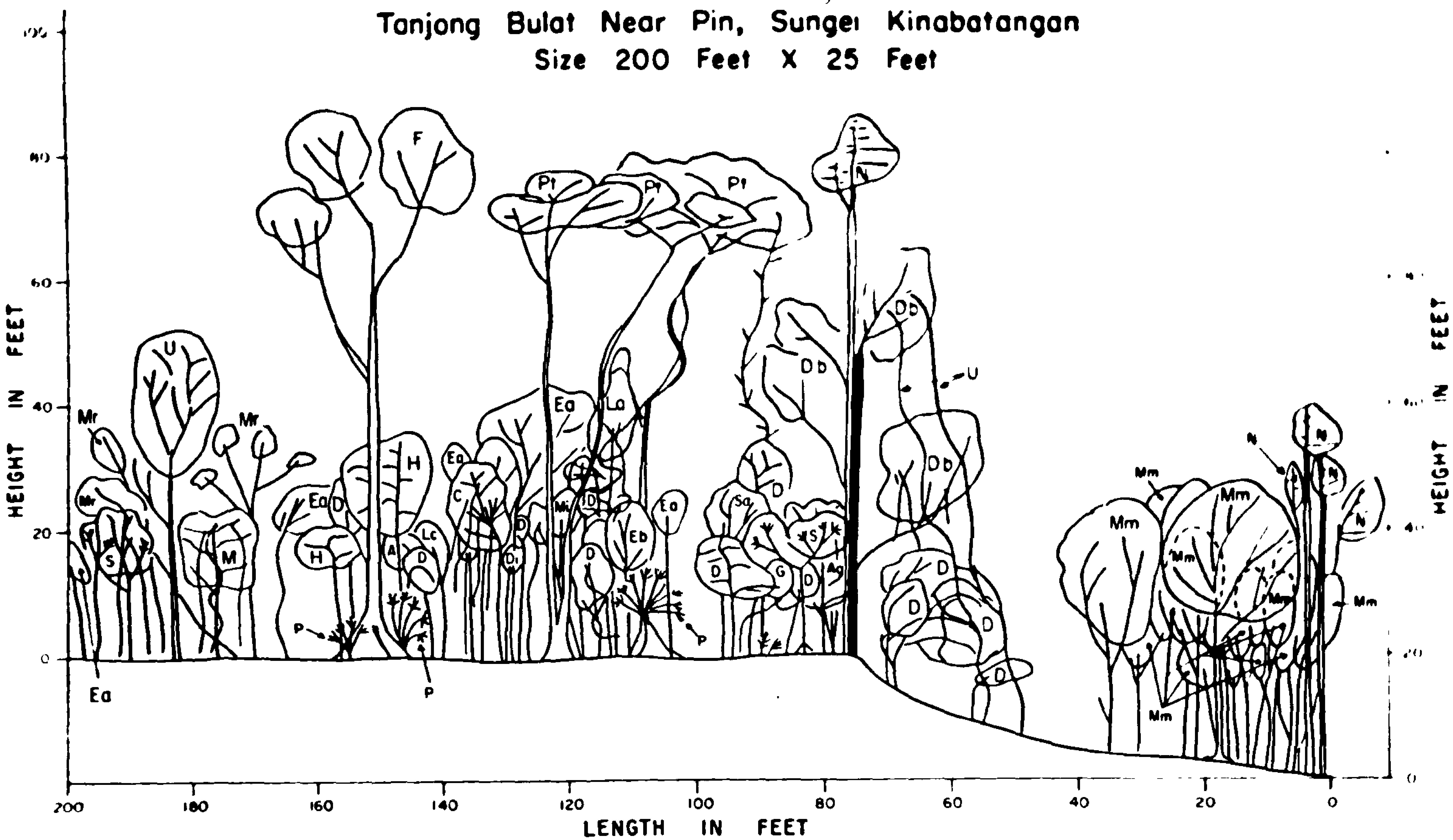
This palm grows on bunds in swamps south of Marudu Bay, but is also found on raised ground in Bengkoka Peninsula.

(f) *Nauclea* swamps

Several species of *Nauclea* grow in dense stands in the meander belt of the major rivers. The following have been recorded: an association of *N.maingayi*, *Ficus* sp., *Glochidion breynoides*, *Colona seratifolia* at Subak, Kinabatangan; also *N.subdita*, and *N.orientalis*. Figure 4 illustrates the latter species growing on gently sloping land at the edge of an ox-bow lake and as a larger tree on the raised levee. Both areas are periodically inundated and in general it may be remarked that *Nauclea* is lower in height on the more frequently flooded sites, i.e. the lower area in Figure 4.

Profile Plot

Swamp Forest, Ox Bow Lake Edge
Tanjong Bulat Near Pin, Sungei Kinabatangan
Size 200 Feet X 25 Feet



Ag	Aglaia sp.	Ea	Eugenia sp (a)	La	Litsea angulata	N	Nauclea orientalis
A	Antidesma sp	Eb	Eugenia sp (b)	Lc	Litsea caulocarpa	Pt	Pterospermum stapfianum
C	Crudia venenosa	F	Ficus racemosa	Mm	Mallotus muticus	Sa	Santiria laevigata
Db	Dillenia borneensis	G	Garcinia bancana	Mr	Mallotus ricinoides	S	Swintonia sp.
D	Dillenia excelsa	H	Horsfieldia grandis	M	Memecylon laevigatum	U	Unidentified
Di	Diospyros tuberculata	P	Licuala sp	Mi	Microcos crassifolia		

FIGURE 4

(g) *Mallotus muticus*

This species is also illustrated in Figure 4. It grows in dense gregarious stands on periodically inundated newly formed soil as a small tree. It is also seen in more mixed stands as a larger tree on older land which is more or less permanently swampy in association with such species as *Brownlowia peltata*, *Horsfieldia irya* and the only dipterocarp found in such sites, *Vatica subcordata*.

(h) *Dipterocarpus warburgii*

This is a species of river banks and riverain swamps on the East Coast and it is also present in swampy forest at Banggi Island and in Gunong Lumaku F.R. Figure 5 illustrates the junction of dryland dipterocarp forest with *D.warburgii* swamp. Common riverain associates are *Pometia pinnata*, *Dracontomelon puberulum*, *Shorea leprosula*, and the palms *Pholidocarpus*, *Salacca* and *Licuala*

(i) *Terminalia copelandii*

Dense stands of this species occur in the lower Kinabatangan in the vicinity of Abai. Other species of *Terminalia* are often characteristic of moist sites within the lowland Dipterocarp forests.

(j) *Campnosperma coriacea*

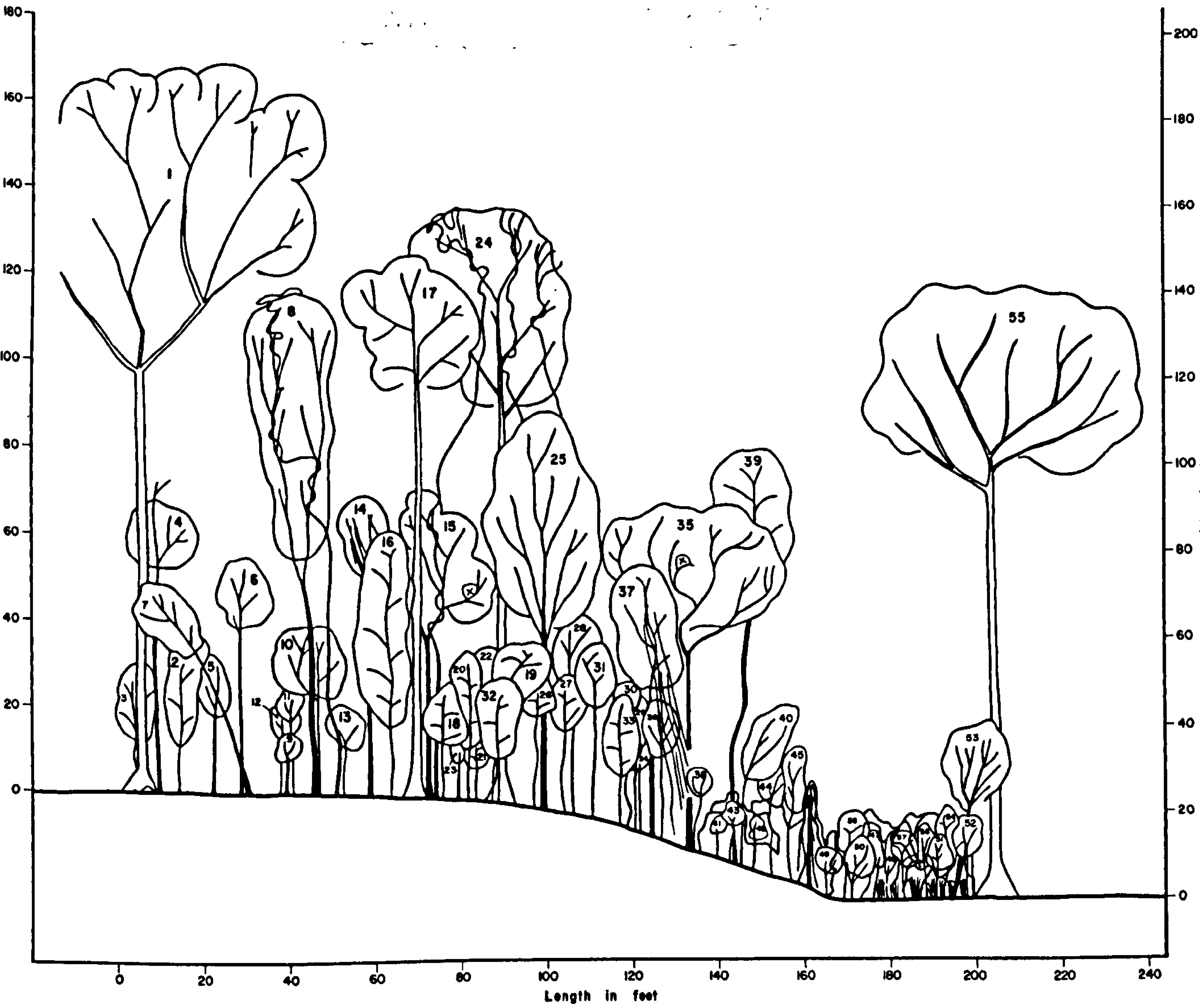
This species forms dense stands locally, e.g. behind mangrove swamp in Dewhurst Bay.

(k) *Lophopetalum multinervium*

Freshwater swamps in most areas have patches of forest of this species. Sometimes the palm *Pholidocarpus* is an associate, e.g. on Serudong and Silimpopon rivers in southern Kalabakan F.R. (cf more developed peat-swamp 4.2.(c)).

FIGURE 5 PROFILE PLOT

Dipterocarp forest impinging on *Dipterocarpus warburgii* swamp forest.



Legend for Profile Plot

1 Shorea superba
2 Notaphoebe malabonga
3 Polyalthia tenuipes
4 Euphoria cinerea
5 Mallotus penangensis
6 Scaphium macropodum
7 Mallotus penangensis
8 Pometia pinnata
Akar on tree No. 8 (Fagraea sp.)
9 Ganua kingiana
10 Dimorphocalyx muricatus
11 Dacryodes rostrata
12 Polyalthia tenuipes
13 Aporosa elmeri
14 Palaquium beccarianum
15 Unknown
16 Mallotus penangensis
17 Shorea macroptera
18 Ganua kingiana
19 Mallotus penangensis
20 Mallotus penangensis
21 Horsfieldia fragillima
22 Mallotus penangensis
23 Mallotus penangensis
24 Diospyros bantamensis
25 Homalium panayanum
26 Garcinia parvifolia
27 Mallotus penangensis
28 Shorea accuminatissima
29 Scaphium affine
30 Mallotus penangensis
31 Mallotus papuanus
32 Mallotus penangensis
33 Mallotus penangensis
34 Shorea acuminatissima
35 Eusideroxylon zwageri
36 Diospyros carpinifolia
37 Dipterocarpus warburgii
38 Alseodaphne oblanceolata
39 Vatica oblongifolia
40 Crudia reticulata
41 Knema latericia
42 Diospyros carpinifolia
43 Litsea oppositifolia
44 Diospyros curraniopsis
45 Diospyros frutescens
46 Dead
47 Mallotus muticus
48 Unknown
49 Baccaurea parviflora
50 Crudia reticulata
51 Dillenia excelsa
52 Microcos elmeri
53 Eugenia polyantha
54 Microcos elmeri
55 Dipterocarpus warburgii
56 Microcos elmeri
57 Unknown
58 Ficus taremifolia
Orang hutan nest
Bamboo
Climbers

Other species found in freshwater swamps include:

Amoora rubiginosa
Baccaurea bracteolata
Campnosperma auriculata
Cratoxylon ligustrinum
Dillenia excelsa
Diospyros tuberculata
Duabanga moluccana
Elaeocarpus griffithii
Eugenia cerasiformis
E.perpuncticulata
Euonymus castaneifolius
Gardenia tubifera
Homalium foetidum
H.caryophyllaceum
Hydnocarpus borneensis
H.subfalcata
Intsia palembanica
Jackia ornata
Kokoona ochracea
Litsea cylindrocarpa
Mezzetia leptopoda
Neesia malayana
Neonauclea barnardoi
Octomeles sumatrana
Pentaspodon motleyi
Persea bancana
Planchonia valida
Rauvolfia sumatrana (shrub)
Rinorea longiracemosa
Santiria laevigata
Terminalia foetissima
T.phellocarpa

4.4. Riparian Forest

Though of limited extent there are a number of distinctive forms of riverain forest. Composition is to some extent influenced by tidal influence, stream width, flow and altitude (Symington 1943). The lower reaches have been dealt with under mangrove forest and some of the riverside types in regions liable to flood are covered in the section on freshwater swamp. There is some overlap.

(a) *Heritiera globosus*

This species occurs at the limit of tidal influence with *Nipa fruticans*, *Gluta velutina* and *Vatica papuana* (Meijer 1968).

(b) Mixed stands on recent alluvial deposits

Here the forests are in a state of change. Many of the *Nauclea* stands (cf 4.3 (f)) are occasionally killed by the effects of flooding and all stages of growth may be seen. The general appearance of the *Nauclea* forests is of narrow stag-headed crowns and stagnant growth levels at heights between 10 and 20 metres. The most spectacular stands are of *Octomeles sumatrana* (40 m or more in height, 100 cm diam.) and, to a lesser extent, of *Anthocephalus chinensis* and *Duabanga moluccana*. All three are colonising, nomadic species capable of rapid growth on fresh alluvia. The left hand side of Figure 4 illustrates the nondescript riverain forest on alluvia where such species have either been replaced or could not develop. Such mixed forest is typified by the presence of *Pterospermum stapfianum*, *Mallotus*, *Dillenia* and *Ficus* spp. with many lianas and *Licuala* palms.

Species of the river edge include *Lagerstroemia speciosa*, *Crataeva religiosa*, *Kleinhova hospita* and *Planchonia valida*.

(c) *Ficus racemosa*

Gregarious riverside stands of this species are seen on many river banks. The mature trees are lofty (40 m or more) with large boles (100 cm diam.) but often fork at below 15 m to give wide spreading crowns. The *Saraca* spp. are typical of more mature forest (see below).

(d) Rocky streams

Dipterocarpus oblongifolius is usually a bent and twisted tree which overhangs undisturbed rocky streams, together with *Saraca lanceolata*, *S.palembanica* and *Eugenia* species. e.g. *E.barringtonioides*, *E.media*, *E.jambos*, *E.rejangensis*, *E.kingii* and *E.chlorantha*. Occasional trees of *Albizia chinensis*, *Octomeles*, *Parkia speciosa*, and *Intsia palembanica* are found on the banks of rocky streams together with the shrubs: *Antidesma linearifolium*, *Croton vinimalis*, *Aglaia rivularis*, *Scyphostegia borneensis*, *Psychotria iteophylla* and *Neonauclea strigosa*. The red-stemmed *Tristania clementis* is locally common, especially on shallow leached soils.

(e) High Forest

Where the dipterocarp forests impinge on rivers then *Shorea leprosula, Parashorea tomentella* and *Koompassia excelsa* are particularly noticeable, with the palm *Arenga retrofloresoens*. *Shorea leprosula* is perhaps the most common species of low-lying moist areas, while alluvial creeks are the habitats of *Shorea seminis, Dipterocarpus exalutus* and, sometimes, *D.tempehes*, with the non dipterocarps *Duabanga moluccana, Alstonia, Anthocephalus* and Myristicaceae. Species of *Saraca* are found near the banks of streams of all sizes on alluvial flats as well as more rocky sites. *Dracontomelon puberulum* and *Pometia pinnata* also favour such sites, especially where *D.warburgii* swamps impinge on rivers (4.3 (h)). *Shorea macrophylla* and *S.mecistopteryx*, both illipe nut species with large fruits, are generally more common near streams, in low-lying and hilly areas, than away from them.

(f) Gallery Forests

Gallery forests are areas adjacent to water courses in open, cleared country where large tree species are able to develop and maintain themselves due to the favourable moisture regime, and to some extent as a result of deliberate preservation by man. Such areas in West Coast districts have occasional relics from the former high forest, e.g. *Intsia palembanica* but the common species are nomadic, e.g. *Sterculia foetida, Parkia speciosa, Anthocephalus chinensis* and *Octomeles sumatrana*.

5. Beach Forests

These forms are very variable but a number of distinctive associations occur.

5.1. *Casuarina equisetifolia*

This species occurs on sandy beaches or banks above tide level as a narrow strip. The trees are often large, to 30 m height and 60 cm diam. *Casuarina* is common on all coasts and is often seen as a decorative remnant in developed areas, e.g. Tanjong Aru beach at Kota Kinabalu and at Kudat and Tawau beaches. *Garcinia celebica* and *Planchonella obovata* may occur just behind the *Casuarina* strip but are more properly described as constituents of the strand flora.

5.2. Strand Flora

The term "*Barringtonia* formation" has been used for the assemblage of species found on sand ridges close to the sea (Schimper 1903). The name derives from *Barringtonia asiatica* which, as with many of the species occurring in similar habitats, is found thoughout coastal and island locations of the Malesian region. *Pandanus tectorius* is particularly abundant on Balembangan Island, lining water courses behind mangroves, but *Pandanus odoratissimus* is often found right on the beach edges elsewhere as a large bush (Meijer 1968). *Terminalia catappa, Calophyllum inophyllum, Pongamia pinnata, Morinda citrifolia, Garcinia benthamii, Hernandia peltata, Peltophorum pterocarpa, Pterocarpus indica,* and *Pericopsis mooniana* are all tree species of the strand flora.

Occasional mangrove trees may be present where a little alluvium is present in the tidal margin with sand (cf Wyatt-Smith 1953) especially on rocky islands. The strand flora may be behind a *Casuarina* fringe; directly adjacent to the sea; behind a thin strip of mangroves, e.g. at Kampong Sibumbum, Banggi Island *Heritiera littoralis* (see 4.1 (e)) occurs mixed with *Planchonella obovata* and *Serianthes grandiflora* in a sand strip between the mangroves and dryland Dipterocarp forest; or transitional to coastal padang, e.g. Anthoshorea at Sabahat.

A number of seaside shrubs common to the strand and coastal padang include: *Premna corymbosa, Scaevola sericea, Hibiscus tiliaceus, Thespesia populnea, Cordia subcordata,* and *Guettarda speciosa.*

5.3. Rocky Shores

Mangroves are more noticeable on rocky shores as silt tends to accumulate between rocks. *Cycas circinalis* is present on coral detritus (Gibbs 1913) and on rocks overhanging beaches on coasts and islands in Darvel Bay and the Kudat area. The conifer *Podocarpus polystachys* occurs just above sandy beaches or mixed with mangroves as on Balembangan Island. Other species of rocky coasts are *Myristica guatteriifolia, Eugenia reinwardtiana* (Sakar Island), *E.roseomarginata* (Malawali), *Pemphis acidula, Canarium asperum, Gelonium glomerulatum, Diospyros maritima.* *Dryobalanops aromatica* is found in coastal scrubby forest near Sipitang.

5.4. Island Vegetation

The vegetation of small islands owes much to sea and bird dispersal (Wyatt-Smith 1953) and is often poor in dipterocarp species. Selangan Island is of particular interest as here the conifer *Podocarpus rumphii* is abundant, but absent elsewhere, similarly *Vavea amicorum.* Growth records of both these are available as the island was an early Forest Reserve and was formerly much visited. Stands of *Gymnostoma nobile* on ultrabasic rocks at Malawali (and also in Darvel Bay) and on giant podsols behind the *Casuarina equisetifolia* on Balembangan are also of interest. Larger islands carry dipterocarp forests.

6. Limestone

Most limestone habitats in Sabah are unable to support large trees owing to the steep and broken nature of the terrain, with only occasional patches of deep soil in gullies. Anderson (1963) has described the aspect types of the more extensive limestone areas of Sarawak. Of dipterocarp species *Hopea nutans* is consistently present in limestone locations in Sabah, while *Shorea guiso* occurs at Karakit, Banggi Island and at Gomantong (Wood in file). Wood described the Gomantong forest as open scrubby with scattered trees to 20 m, with occasional larger ones to 30 m, and a general stratum of shrubs at 3 m high. In open places many herbs are present, which are absent in adjoining closed dipterocarp forest on shales and sandstones including species of Amarantaceae, Acanthaceae and Compositae. Common trees include *Hopea nutans*, *Murraya paniculata* and a *Eugenia* sp.

At Tanjong Siri, Balembangan Island large trees of *Alstonia subspathulata*, *Koordersiodendron pinnatum*, *Hopea nutans*, *Dyera costulata*, *Barringtonia currenii* and *Palaquium rostratum* form a scattered, open forest, mainly at the lower levels, growing to 25-35 m high and up to 80 cm in diameter. Medium sized trees of the main canopy, and dominating the upper levels are 15-18 m high and include *Eugenia attenuata*, *E.claviflora*, *Diospyros* sp., *Calophyllum canum* and *Aglaia denticulata*. Small trees include *Kopsia mitrephora* (found in all limestone areas), species of *Ardisia*, *Timonius* and *Symplocos* with gaps colonised by *Pterospermum elongatum*, *Pterocymbium tinctorum*, *Ficus* sp. and *Mallotus* sp. Other species which may be calcicolous in Sabah are *Excoecaria cochinchinensis*, *Drypetes cumingii*, *Wetria macrophylla*, *Xylosma suluense* and *Lagerstroemia crassifolia*.

7. Heath Forests (Kerangas of Brünig)

These forests are variable, but always distinctive. Their characteristics include: generally low height, small girth, paucity of species, tendency towards 2-storied structure, few lianas, low epiphytes, sclerophyllous characters and they show similarities with peat swamps (Ashton 1958). At the end of this section an account of forest types on ultrabasic rocks will be given: these have some similarities, floristically and structurally with Heath Forests, though the forests developed on ultrabasic colluvium are more properly described as dipterocarp forests.

Wood (1955 a) suggested a broad division of Heath forests into lowland and montane forms, but a division into coastal and inland forms seems more appropriate. Browne (1952) described the Sarawak kerangas forests and distinguished between two types of sandy soil, that derived from weathered tertiary sandstone and that developed under marine conditions; he preferred the term "kerangas" for the latter, and "moss kerangas" for the edaphic occurrence of the type at moss forest altitudes. The latter I have described under Montane Forests. Brünig's classification (1969) includes both level and steepland forms.

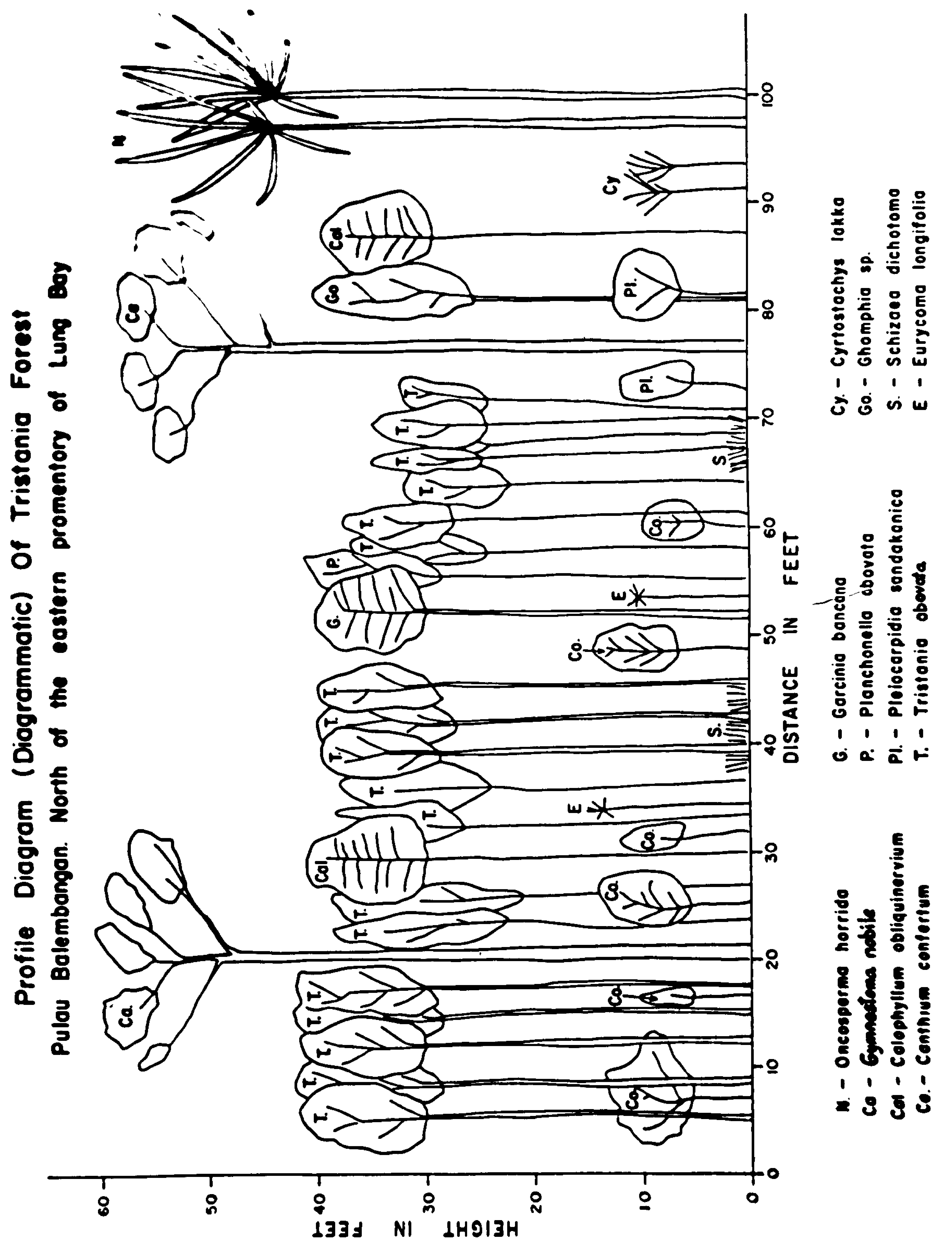
7.1 Coastal Padang

(a) *Gymnostoma nobile/Tristania obovata*

This is found on rather open vegetation on sandy soils, often disturbed by fire and cultivation, soils podsols mainly of marine terrace origin. In Marintaman-Mengalong F.R. stands of *Gymnostoma nobile* and *Tristania obovata* probably represent original natural vegetation which reappears on Balembangan Island and sporadically on the coastal platform in the Tawau area on Kubota soils (Nicholson in Paton 1959, Paton 1963). In the latter *Gymnostoma* is absent but *Eugenia zeylanica* is abundant in the lower canopy. The *Tristania* trees rarely exceed 20 cm diam. or 18 m height, but may be overtopped by *Gymnostoma* (Figure 6) when present. This type has affinities with 3(d), 4.2(b), Malawali ultrabasic 5.4, etc. Similar forest has been described in Kalimantan (Dilmy 1963).

(b) Miscellaneous

In open, fire influenced, areas on coastal marine terrace platforms, leached sandstone hills, e.g. Bukit Pasir, Kota Kinabalu and Buli Sim Sim, Sandakan (see 7.4 below) and on inland burnt podsol terraces (7.3) *Baeckia frutescens* occurs as a low bush to small tree. This species may well be a natural climax species on some highly leached, very deficient sandy soils. In typical coastal padang sites on the West Coast it occurs with *Rhodomyrtus tomentosa*, several *Eugenia* species, e.g. *E.cerina, E.claviflora, E.alcine, E.leucoxylon*. *Dillenia sumatrana, Gleichenia linearis* (fern), *Styphelia abnormis* and *Decaspermum fruticosum* are indicative of burnt areas



Profile Diagram (Diagrammatic) Of Tristania Forest
Pulau Balembangan. North of the eastern promentory of Lung Bay
HEIGHT IN FEET
DISTANCE IN FEET
N. - Oncosperma horrida
Ca - Gymnacloma nobile
Cal - Calophyllum obliquinervium
Co. - Canthium confertum
G. - Garcinia bancana
P. - Planchonella obovata
Pl. - Pleiocarpidia sandakanica
T. - Tristania obovata
Cy. - Cyrtostachys lakka
Go. - Ghomphia sp.
S. - Schizaea dichotoma
E - Eurycoma longifolia

FIGURE 6

Fagraea fragrans and *F.elliptica* are capable of reaching large sizes in open grassy or *Gleichenia* dominated areas, and examples are found in Marintaman-Mengalong F.R., at Kudat, Sandakan and in the Sook Plains.

Endospermum beccarianum was formerly abundant in coastal padang near Sandakan, with *Vatica* sp. Figure 7 illustrates an area of uncertain ecological status, probably a disturbed coastal padang forest similar to those described in the Sugut by McCredie (1970) where the palm *Cyrtostachus lakka* (cf 4.2(b)) and the small tree *Pliomele* sp. occur with *Tristania, Eugenia* and *Ixonanthes reticulata* i.e. marginal with 7.4 below. Moist areas within the coastal padang with *Eugenia palawanensis, Xylopia ferruginea, Ternstroemia aneura, Ploiarium alternifolium (Archytaea vahlii), Myristica lowiana* and *Lophopetalum rigidum* are marginal to the next type.

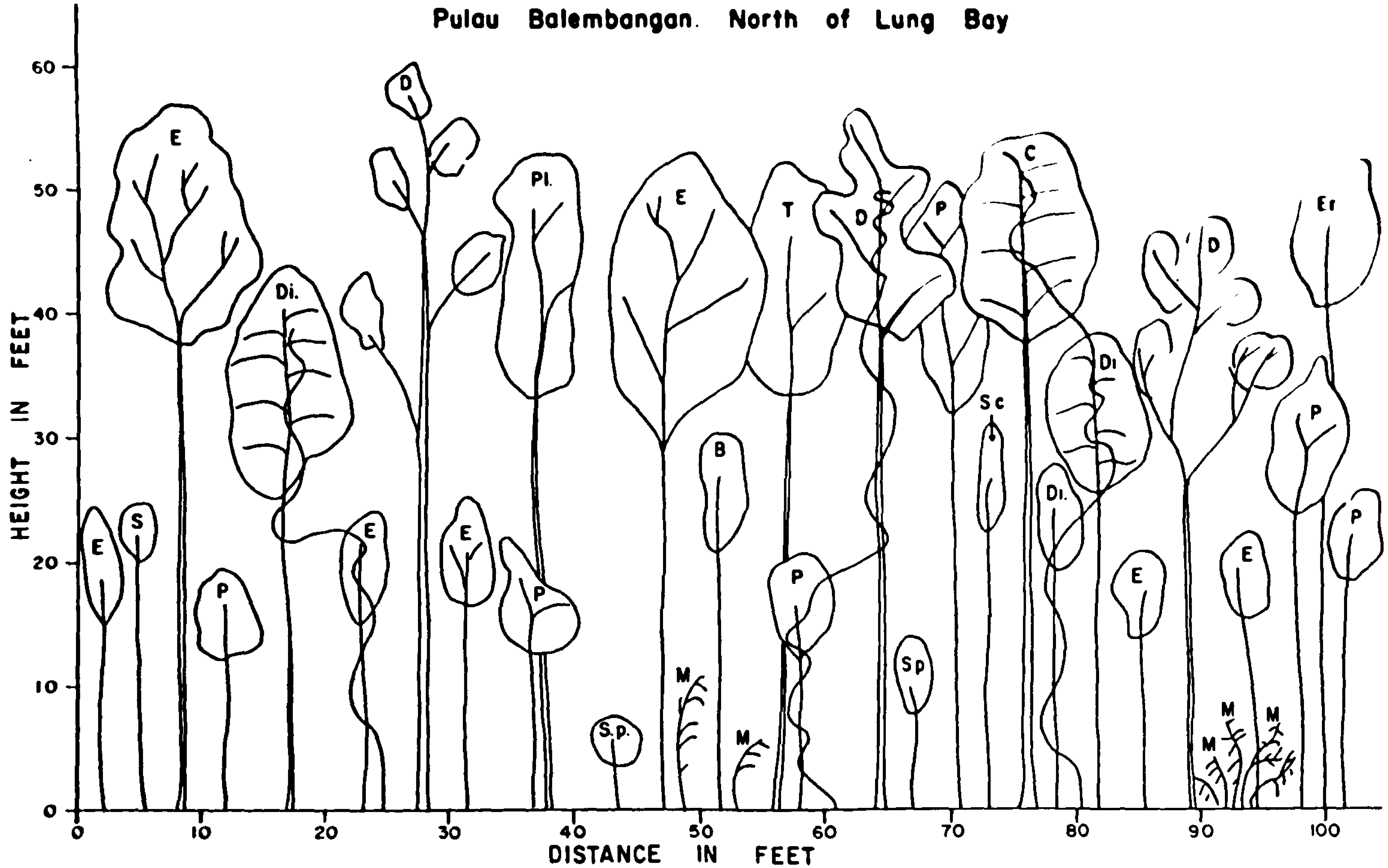
7.2 Swampy Padang

This type is intermediate between peat swamps and dry Heath forests. Areas of white sand with surface peat present occur in coastal situations on both sides of the country, and inland within the terraces of the upland plains.

(a) *Dryobalanops beccarii*

This species occurs in dense gregarious stands on slightly raised old beaches within otherwise waterlogged sites at the mouths of the Segama and Sugut Rivers. Locally the species forms 100 per cent of the canopy with trees 60 m or more in height, but trunks are mainly hollow. *Alstonia, Campnosperma, Planchonia, Nauclea, Gonystylus,* and the palm *Pholidocarpus* occur in the adjacent swamps (A.R.R.B. 1960).

Profile Diagram (Diagrammatic) Of Dyera/Eugenia Forest
Pulau Balembangan. North of Lung Bay



D - Dyera costulata
P - Pternandra SAN 69621
C - Calophyllum obliquinervum
M - Pliomele sp.
E - Eugenia palawenensis
Di. - Diospyros elliptifolia
Pl. - Planchonella obovata
Sp. - Symplocos polyandra
S - Symplocos sp.
Sc - Symplocos celastifolia
B - Buchanania sp.
Er. - Ervatamia
T - Timonius villamillii

Forest Department, Sabah 1971.

FIGURE 7

In the Labuk region *Dryobalanops beccarii* occurs on high level alluvium in association with *Santiria laevigata*, *Amoora rubiginosa*, *Stemonuros scorpioides*, *Barringtonia macrostachya* and also *Gonystylus forbesii*, *Stemonuros umbellatus*, *Santiria megaphylla*, *Ixora griffithii*, *Diospyros evena* and *D. euphlebia*.

(b) *Hopea pentanervia*

This species is an important constituent of the *Dr.beccarii* stands (7.2(a)) where surface accumulation of peat is high, e.g. formerly at the site of Telupid airstrip. However it also occurs in swampy padang forest as a frequent species. e.g. Tavai Plateau and in the Pelawan and Sook valleys. The forests of the Tavai Plateau are similar to those of the Merurong Plateau in Sarawak, described by Brünig (1959): *Gymnostoma sumatrana*, several conifers, and small dipterocarps occur on a range of sites from moist peaty with *Ploiarium* to dry leached sites with *Tristania* on ultrabasic colluvial material. In the Sook and Pelawan valleys *Hopea pentanervia* occurs on moist peaty sites with *Dactylocladus stenostachyus* and *Dryobalanops rappa*.

Other species of swampy padang sites are:

Alseodaphne insignis	*Ilex cymosa*
Ctenolophon parviflorus	*Mezzetia leptopoda*
Eugenia cerina	*Pandanus ridleyi*
E.leucoxylon	*Parinari asperula*
E.sarawakensis	*Pternandra coerulescens*
Horsfieldia irya	

7.3. Inland Dry Heath Forests

(a) *Dacrydium elatum*

Natural forests on Baiyo series pdosols in the Sook Plains and Pelawan valley occur with *D.elatum* growing in pure stands. The trees are not as large as those of the *Dacrydium/Gymnostoma* Type (4.2(b)). A one acre plot (0.4 ha) in the Sook (R.P.266) contained the following numbers:

Girth (inches)	12-23	24-35	36-47
Diam. (cm)	10-19	20-29	30-38
Numbers	104	84	18

This represents the best growth with the trees to 24 m high. Elsewhere the forests are lower and the *Dacrydium* is mixed with *Eugenia* species, *Diospyros* sp., *Linociera plurifolia* and *Cratoxylum arborescens*. In burnt areas the fern *Pteridium* occurs with *Baeckia*. In the Pelawan valley the *Dacrydium* is mixed with *Tristania*.

(b) *Dryobalanops rappa*

Mesapol F.R. near Sipitang contains a unique stand of *Dryobalanops rappa* forest on a flat sandy site, probably of marine terrace origin. This species forms the emergent canopy to 50 m and the following species are also present:

Baccaurea bracteata
Combretocarpus rotundatus
Cratoxylon arborescens
Lindera polyantha
Dillenia pulchella
Diospyros evena
Eugenia leucoxylon
Eugenia lineata
E. spicata
Garcinia bancana
Gonystylus bancanus
Hopea nutans
Litsea turfosa
Melanorrhoea beccarii
Rapanea avenis
Sindora beccariana
Stemonurus grandifolius
Sterculia spoidifolia
Vatica albiramis

7.4 Sandstone Escarpments

Heath forests occur on highly leached sandstone soils and are particularly evident in the Sandakan area, e.g. Berhala Island, Sim Sim Hill, Mt. Walker, Leila and in Sepilok F.R. Floristically they are similar to the forests on the flat low-lying coastal padangs, but also have similarities with dipterocarp forests on sandstone hills. Sepilok stands have been described elsewhere (Fox 1972).

Tristania clementis occurs in pure stands in many places as a low tree of small girth, and several species of *Eugenia* are found, e.g. *E.tawahense, E. caudatilimba, E.elopurae, E.bankense, E.rostrata, E.lineata, E.ochneocarpa,*

Other species typical of the Sandakan area are:

Brackenridgea palustris	*Endospermum malaccensis*
Calophyllum retusum	*Fagraea elliptica*
C.obliquinervium	*Ixonanthes reticulata*
Cleistanthus sumatranus	*Melanochyla beccariana*
Diospyros polyalthioides	*Myristica cinnamomea*
Elaeocarpus pedunculatus	*Parkia singularis*
E.floribundus	*Sarcotheca glauca*

Many of the species given under 7.1, 7.2 are also present. Dipterocarps present in this type of forest include: *Cotylelobium melanoxylon, Shorea macroptera, S.multiflora, Vatica micrantha* and *V.oblongifolia*.

It is almost certain that the forests of the sandstone cuestas in Sepilok F.R. are undisturbed, but many of the more accessible areas are by no means natural. Leila F.R. was partly cultivated during the Japanese occupation (F.D.A.R. 1947) and many of the other areas have been cut over and occasionally burnt. Stands of *Tristania* are often encountered in mountainous areas, and heath forests with trees of this genus occur in the Crocker Range and on Mt. Lumaku at 600-1100 m (F.D.A.R. 1955). Brünig's classification (1969) includes transition between dipterocarp and Heath forest and he noted the tendency for the latter to occur on sharp scars and ridges.

7.5 Forests on Ultrabasic Rocks

Forests occurring on soils derived from ultrabasic (see Soils, Chapter 2) parent material are often distinct from those on adjacent, different soils. Examples have been mentioned above viz:

Dacrydium gibbsiae (3(b)), *Gymnostoma/Tristania* (3(d));
Gymnostoma nobile (5.4), *Hopea pentanervia* (7.2(b)) etc.

Shallow skeletal soils have vegetation tending to Heath forest while dipterocarp forests occur on deeper, colluvial soils. These are given separate treatment here, though affinities with main dipterocarp forests will be mentioned in Chapter 4. As these forests are either poor in timber volumes or in places difficult of access they have hitherto been given less attention than forests comprising the optimum dipterocarp communities.

(a) Sea level

Gymnostoma nobile forms gregarious stands on ultrabasic islands in Darvel Bay, at Malawali (cf 5.4), and on Banggi Island.

(b) Low Coastal Hills

At Sakar Island, Darvel Bay, coastal dipterocarp species (allied to those of the *Parashorea malaanonan* forests, see Chapter 4) including *Shorea guiso, S.bracteolata, S.gratissima, Hopea nutans, Vatica albiramis, Dipterocarpus grandiflorus* are present, reaching 40 m or so in height. *Borneodendron aenigmaticum* a species endemic to the ultrabasic soils is also present. *Shorea bracteolata* and *S.gratissima* also occur on low hills at Malawali Island with the conifer *Podocarpus neriifolius*.

Mt. Silam, also in Darvel Bay, is an ultrabasic mountain rising from sea level to 880 m, with a range of forests changing with altitude (Wood 1955 b). Dipterocarp forest on mixed colluvium at the base gradually gives way to species more typical of ultrabasic. These include *Dipterocarpus lowii*, *Shorea atrinervosa*, *S.kunstleri*, *S.laxa*, *S.multiflora*, *S.venulosa* and *Vatica mangachapoi* with smaller trees of *Hopea nutans*, *Vatica micrantha* and *Shorea obscura*. *Borneodendron aenigmaticum* is common and reaches 80 cm diameter. Other large tree species include:

Drypetes sp.	*Parinari cordata*
Eugenia caudatilimba	*Parishia* sp.
E.napiformis	*Podocarpus neriifolius*
Garcinia bancana	*Santiria laevigata*
Linociera philippinensis	*Xylosma luzonense*
Melanorrhoea inappendiculata	

At lower levels the forest is 35-45 m high and gradually decreases in height with altitude. At 250-550 m above sea level the upper canopy is 20-30 m, down to 11 m on exposed ridges and from 600 m the forest is generally 10-15 m high. At these levels *Schima noronhae*, *Dacrydium elatum*, *Garcinia* sp., *Calophyllum* sp., *Tristania grandifolia*, *Pliomele* sp., and *Eurycoma longifolia* are present, gradually merging with 7.5 (c). Of the commoner dipterocarps *Vatica mangachapoi* is frequent to 450 m, *Shorea laxa* is absent at lower levels, but common to 600 m, being the highest dipterocarp recorded. *Shorea venulosa* is also present at higher levels while *Dipterocarpus lowii* is locally dominant on ridges at 60-250 m (see 7.5 (d) and Figure 9).

(c) Montane Forests

Dacrydium gibbsiae on Kinabalu (3 (b)); the summit forests with *Gymnostoma/Tristania* on Mt.Silam etc. (3(d)); and the mixed stands on Tavai Plateau (7.2(b)) may be classed as montane forests.

(d) Hills in sedimentary areas

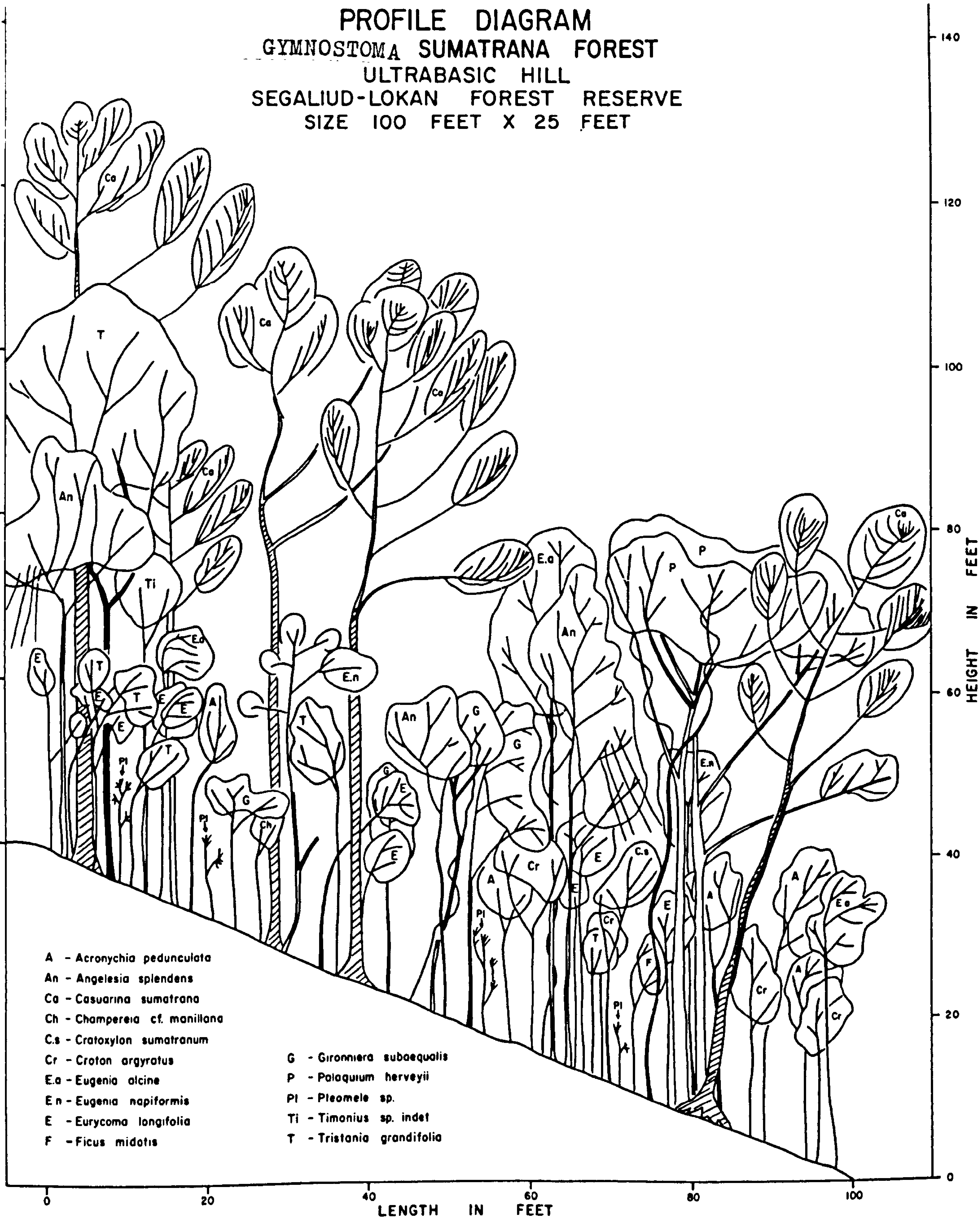
Local intrusions of ultrabasic rock at a number of places carry distinctive forests. Figures 8 and 9 illustrate two different types of forest, *Gymnostoma (Casuarina) sumatrana* in Figure 8 on a hill at 140 m above sea level, and *Dipterocarpus lowii* in Figure 9 at 80 m. *Tristania grandifolia* occurred in both areas and was locally abundant. Both hills are near the Sabah Timber Co. quarry in the 1969/70 coupe area in Segaliud-Lokan F.R. Maximum bole diameter in both areas was about 60 cm and, as illustrated, canopy height was about 25 m. Other large trees included *Palaquim herveyii*, *Rapanea capitellata*, *Buchanania arborescens* and *Eugenia* species.

Tristania grandifolia forest was also seen on an ultrabasic ridge in the 1971 coupe area of the Chung Chao Loong concession area at Kuamut F.R. with species of *Eugenia* and lower down a *Shorea* (San 72810) in more mixed forest. The forest on Lawa Lawa Hill, which rises from a patch of *Oncosperma* (4.1(d)) behind mangroves in the delta of the Segama River, is scarce in Dipterocarpaceae but is well represented in *Eugenia* species with a *Pternandra* sp. common and several Fagaceae.

(e) Main Ultrabasic Ranges

In the Tavai area a similar range of forests to those of Mt. Silam occur, but with more variety and on a larger scale. On low-lying colluvium off the Telupid Road Meijer (1968) reported

FIGURE 8



Forest Department, Sabah 1971

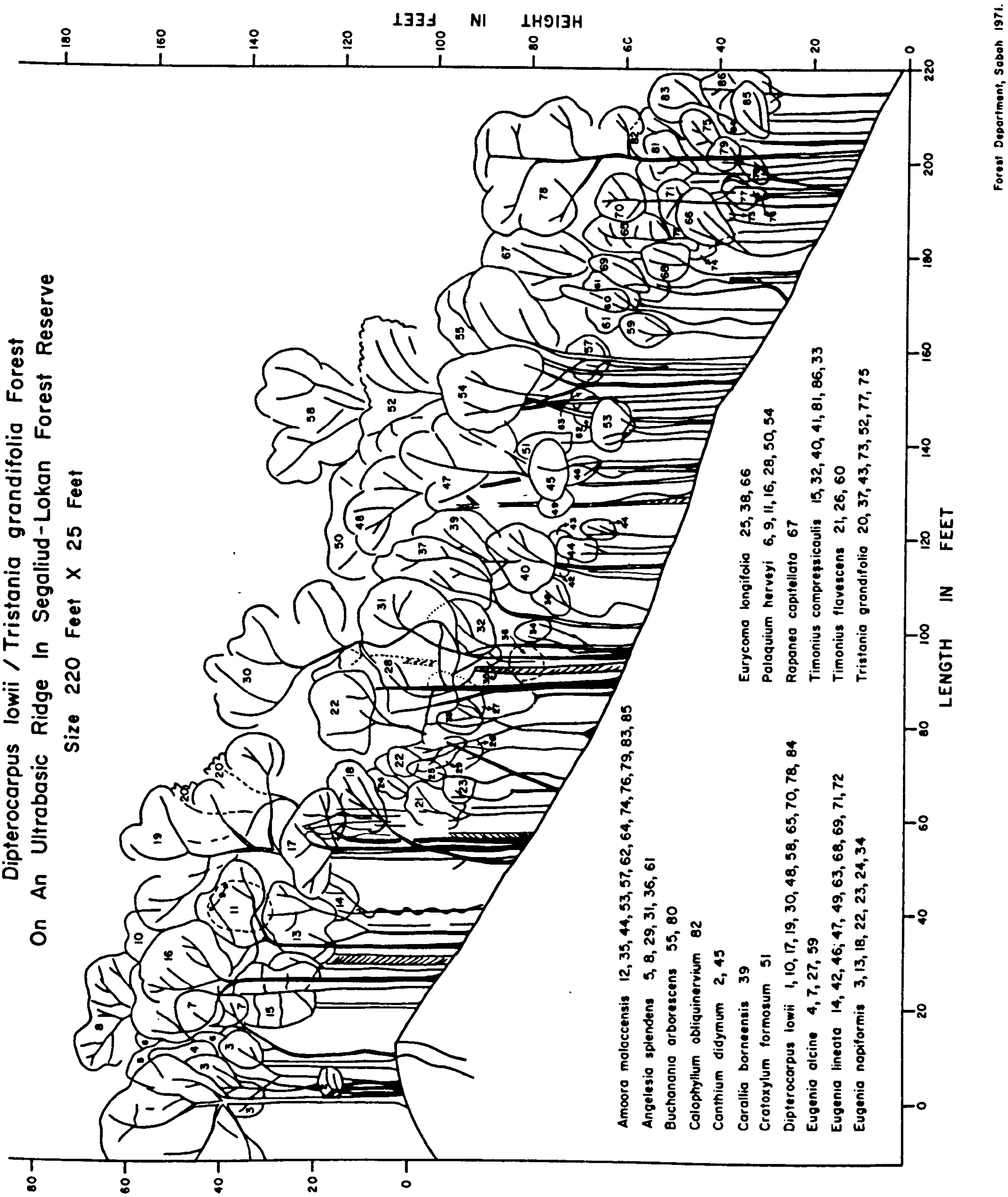


FIGURE 9 PROFILE DIAGRAM

Dipterocarpus lowii/Tristania grandifolia

Forest on an ultrabasic ridge in

Segaliud-Lokan Forest Reserve.

Dipterocarpus acutangulus	*S.glaucescens*
D.confertus	*S.kunstleri*
D.geniculatus	*S.laxa*
D.pachyphyllus	*S.macroptera*
Dryobalanops beccarii	*S.mecistopteryx*
Shorea acuminatissima	*S.ovalis*
S.domatiosa	*S.parvifolia*
S.exelliptica	*S.pauciflora*
S.fallax	*S.smithiana*

On steeper slopes where soil is shallower and less mixed the species include *Dipterocarpus lowii, Vatica mangachapoi, Hopea nutans, Shorea atrinervosa, S.multiflora* and *Borneodendron aenigmaticum*. Other large trees on the television station hill at Mile 83 include *Shorea laevis, Hopea argentea, Ixonanthes reticulata* and *Trigoniastrum hypoleucum*.

Dipterocarpus lowii and *Heritiera simplicifolia* occur as large trees on the lower foothills of the Tavai Range above the Karamuak River. On Tingka Hill at the confluence of the Kinabatangan and Karamuak Rivers the following are present:

Dipterocarpus gracilis	*S.faguetiana*
D.lowii	*S.guiso*
D.pachyphyllus	*S.inappendiculata*
Hopea nutans	*S.isoptera*
Shorea andulensis	*S.venulosa*

On the higher hills *Gymnostoma sumatrana*, conifers, *Eugenia* species and Fagaceae are abundant with the stands decreasing in height with altitude as for Mt. Silam.

(f) Lohan Hills

Nicholson (1962 b) noted *Shorea atrinervosa, S.faguetiana, S.parvifolia, Dipterocarpus confertus, D.ochraceus* and a *Hopea* on ultrabasic at Lohan. There were 3 trees per acre of 8 ft girth (78 cm diam), the largest size present, and basal area per acre for all stems over 10 cm was 160 sq.ft. (37 sq.m/ha). In the Lohan Plain *Parashorea malaanonan* is present on colluvium and *Shorea leprosula* extends to 700 m altitude but by 820 m Fagaceae,

FIGURE 10 PROFILE DIAGRAM

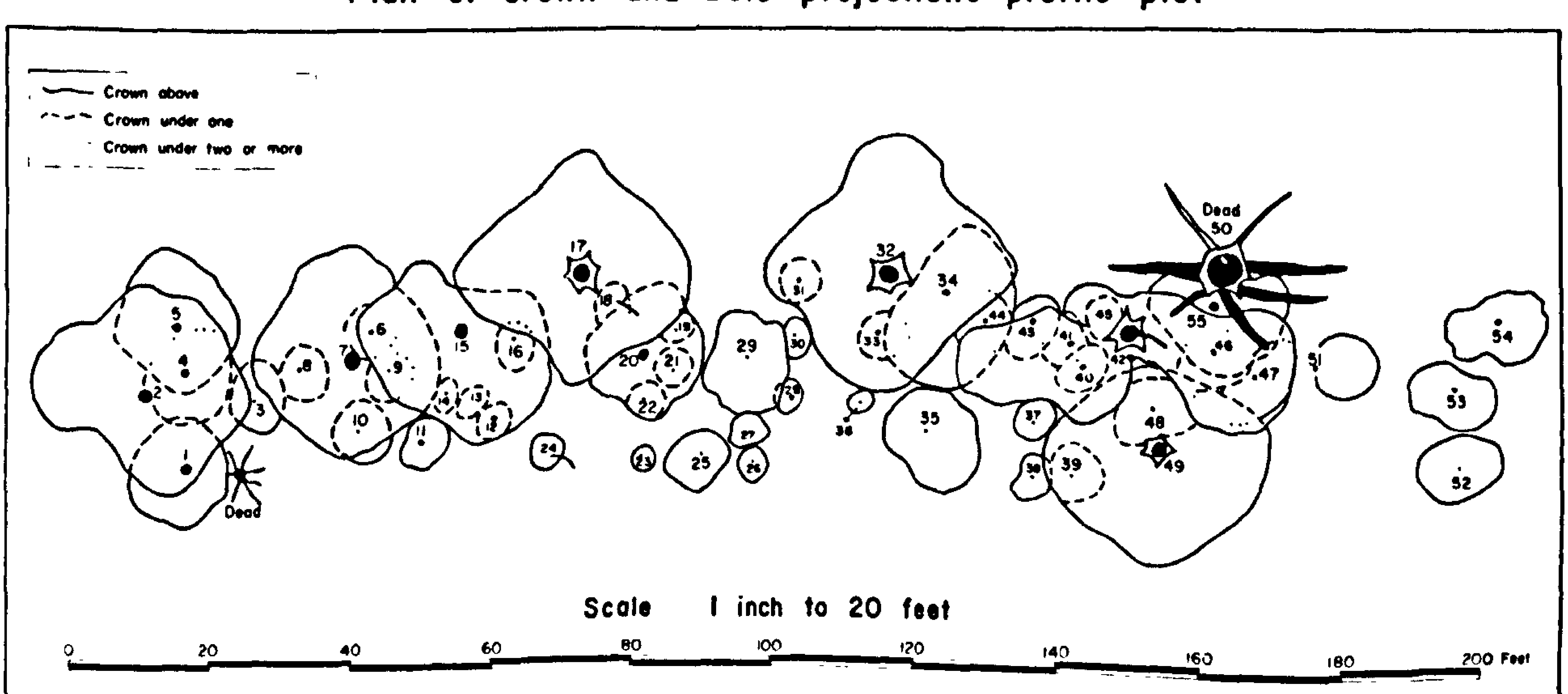
Forest on ultrabasic at Lohan Hills

Profile diagram of plot 30 feet wide, 200 feet long

Legend for Profile Plot

1 Drypetes littoralis
2 Shorea hopeifolia
3 Memecylon costatum
4 Unknown
5 Hydnocarpus gracilis
6 Aglaia gamopetala
7 Lithocarpus confragusus
8 Palaquium stenophyllom
9 Beilschmedia assamica
10 Symphlocos rinaboluensis
11 Aphanamixis pedicellata
12 Eugenea aphanomyrtoides
13 Palaquium stenophyllom
14 Palaquium stenophyllom
15 Hopea dyeri
16 Eugenia castanea
17 Shorea rubra
18 Canthium sp.
19 Knema latericia
20 Xanthophyllum palembanicum
21 Drypetes littoralis
22 Notaphoebe alba
23 Notaphoebe alba
24 Aphanamixis pedicellata
25 Hopea dyeri
26 Eugenea rugosa
27 Dysoxylon alliaceum
28 Unknown
29 Palaquium stenophyllom
30 Callophyllum canum
31 Diospyros macrophylla
32 Shorea rubra
33 Aporosa elmeri
34 Cryptocarya erectinerria
35 Lithocarpus leptogyne
36 Dysoxylon alliaceum
37 Agrostistachys sessilifolia
38 Xanthophyllum trichocladum
39 Palaquium stenophyllom
40 Knema latericia
41 Palaquium stenophyllom
42 Aglaia dubia
43 Shorea obscura
44 Shorea hopeifolia
45 Ardisea colorata
46 Homalium grandiflorum
47 Garcinia microphylla
48 Hopea dyeri
49 Xanthophyllum scortechinii
50 Artocarpus melinoxyhs
51 Callophyllum canum
52 Ardisea elliptica
53 Dysoxylon alliaceum
54 Hopea dyeri
55 Unknown

Plan of crown and bole projections profile plot



Lauraceae and *Eugenia* species are dominant. I have described the forest on a hill south of the Lohan Plain elsewhere (Fox 1969 a) and Figure 10 illustrates this area. Here the largest species are *Shorea almon*, *S. faguetiana*, *S.ovalis*, *S.rubra*, *Dipterocarpus confertus*, *D.ochraceus* and *Hopea dyeri*. The following table summarises measurements in a sample plot in Lohan F.R.

Table 6. Stand Table of 2.3 acre plot (0.9ha) Lohan F.R.

	Numbers of trees in size classes							
Species	Girth(ft.) Diam(cm)	4 39	5 48	6 58	7 68	8 78	9+ 87+	Total	Total 6+
Dipterocarpaceae									
Shorea(Rubroshorea)									
S.almon		-	1	-	-	-	-	1	-
S.ovalis		-	2	-	1	-	2	5	3
S.parvifolia		-	-	-	1	-	-	1	1
S.rubra		1	1	-	2	1	-	5	3
(Richetia)									
S.faguetiana		-	-	-	1	-	-	1	1
Hopea beccariana		-	1	-	-	-	-	1	-
Non-dipterocarps									
Dehaasia caesia		-	-	-	2	-	1	3	3
Palaquium rostratum		1	2	-	-	-	-	3	-
Fagaceae (4 species)		1	1	3	2	1	1	9	7
Other species (14)		3	7	2	3			15	5
Totals		6	15	5	12	2	4	44	23
Per 10 acres/4ha		26	65	22	52	9	17	191	100

In addition to species already given the following also occur on ultrabasic soils:

Anacalosa frutescens
Axinandra borneensis
Castanopsis psilophylla
Ctenolophon parvifolius
Erythroxylum ecarinatum
Homalium panayanum
Kopsia caudata
Magnolia craibiana
Myrsine affinis
Quassia borneensis
Swintonia glauca
Talauma gitingensis
Weinmannia blumei

and the climbing bamboo *Racemobambos gibbsiae*.

8. Secondary Forest

The role of colonising species in forest worked over for timber and managed in an attempt to raise subsequent crops will be dealt with in Part 3. Here I am concerned only with forests derived from fire. Apart from changes in status of riverain forests following flooding I have noted only one example of a natural secondary forest. This was an extensive landslip area in Gunong Rara F.R. where *Duabanga moluccana*, *Octomeles sumatrana* and *Anthocephalus chinensis* formed a new stand in an area presumed to have previously carried a natural dipterocarp forest (see also 3(c) above).

Two types of shifting cultivation have been recognised in Sabah, viz: nomadic and cyclic (Headley *et al* 1951). The latter covers large areas, whereas the former has largely disappeared as populations have settled. The bulk of the area affected consists of the hills of the Crocker Range to about 1250 m with some localised, mainly river bank cultivation in East Coast areas. The Ladang (clearing) Ordinance of 1913 restricted cutting to secondary forests. This rule was unenforceable and undoubtedly the limits of areas involved have been extended. Felling of natural dipterocarp forest for shifting agriculture has probably increased since 1963 coincident with increased population pressure and the relative ease of acquiring such land under title. During 1966-71 valuable stands were burnt off to my knowledge adjacent to Mt. Templar F.R., near Batu Langguyong north of Sook Plains, from there to Tulid and Lanas in the headwaters of the Kinabatangan and on ultrabasic areas of Lohan. In many areas where poorly organised settlement schemes have been attempted dipterocarp forests in the vicinity have been destroyed by fire.

A number of areas of former high population, and presumed cultivation, have been abandoned and gradual reversion to denser forest is proceeding. Examples are the Lokan River and abandoned East Coast tobacco estates. Paton (1963, p.21) discussing *Imperata* covered hillsides near Semporna noted:

> "There is no known reason for the abandonment of these large holdings. It may have been due to unsatisfactory water conditions, or the depradations of pirates".

Surely in this case, as with *Imperata* areas elsewhere, it was probably the presence of the grass, indicative of and accentuating poor soil conditions generally, that lead to abandonment. The succession to fire climax of *Imperata* from dipterocarp forest may pass through the following stages:

(1) Patch or nomadic cultivation allowing establishment of fresh dipterocarp seedlings and regeneration to the original state.
(2) Extended patches isolated from dipterocarp parent trees, regenerating only to pre-existing species capable of root shooting, or to animal or wind dispersed nomadic species.
(3) Two or more seasons of consecutive cultivation preventing effective coppice growth.
(4) Cyclical clearing of (3) some years later, possibly of sufficiently mild a nature as to allow perpetual regeneration to nomadic species.
(5) Accidental or deliberate burning of dry herbaceous regrowth prior to establishment of nomadic tree seedlings.
(6) *Imperata* established and only fire resistant tree species able to survive. If such trees are not available this stage may be omitted and (5) may lead directly to:
(7) Fire climax of *Imperata*.

Clearly succession to *Imperata* will vary from place to place according to cultivation history, soil conditions and surrounding vegetation.

In the Crocker Range old secondary forest is characterised by the presence of such species as:

Adina polycephala	*Litsea cubeba*
Adinandra dumosa	*L.odorifera*
Alstonia macrophylla	*Lithocarpus coopertus*
Bischoffia javanica	*Milletia vasta*
Buchanania arborescens	*Neonauclea gigantea*
Campnosperma auriculata	*Parinari corymbosa*
Carallia bracheata	*P.elata*
Cratoxylon arborescens	*Pentace laxiflora*
Elmerillia mollis	*Prunus javanica*
Endospermum malaccensis	*Toona sureni*
Ilex cissoidea	*Vitex pubescens*
Ixonanthes reticulata	

Occasional patches of such dipterocarps as *Shorea argentifolia*, *S.oleosa* etc. and stands of *Tristania whiteana* are interspersed with the secondary forests. More recently abandoned cultivation is distinguished by the presence of the shorter lived nomads such as *Ficus septica*, *F.moderata*, *F.endospermifolia*, *Macaranga* species, *Alphitonia incana*, *Commersonia bartramii*, *Dillenia suffruticosa*, *Pterospermum stapfianum*, *Trema* species, with some *Duabanga* and *Anthocephalus*. Of these *Alphitonia* and *Trema* are usually abundant in the first few years. At higher elevations *Omalanthus caloneurus* and *Macaranga kinabaluensis* are nomadic, and locally the exotic *Albizia falcatifolium* is extending into secondary forests.

Fire climax savanna-like vegetation is found in the northwest of the State where the fire resistant tree *Antidesma ghaesembilla* stands above *Imperata* grass. *Vitex pubescens* is sometimes present and *Fagraea fragrans* appears to persist for some time in open grassland, but large dead trees in the Sook Plains suggest that it cannot withstand repeated burning. *Baeckia frutescens* is capable of regeneration following fire on the podsols and is common in the Apin Apin and Sook Plains on burnt sites. Fire resistant small tree species present on Latohan Island off Banggi include *Eugenia endertii*, *Brackenridgea hookeri*, *Cleistanthus baramicus*, *Arytera littoralis*, *Memecylon laevigatum* and *Calophyllum blancoi*. Moist pockets and flushes in grasslands can support more woody species including *Dillenia excelsa, Ardisia elliptica* and *Cratoxlum sumatranum*. Malawali ultrabasic grassland has *Guioa diplopetala, Eugenia cerina, E.confertum,* and *Timonius villamilii* which grow as small bushes.

Vegetation of degraded (= burnt) sites on sandstone hills at Kota Kinabalu and Sandakan has been described by Meijer (1962). The nomad *Alphitonia incana* appears to persist longer on such sites than *Trema orientalis* (cf Gibbs 1913). Much of the vegetation of these sites is similar to that described under 7.1(b) and 7.4.

9. and 10. Grasslands and Plantations

Where repeated fires have resulted in the complete loss of tree cover then *Imperata*, as described earlier, is dominant. *Themedea gigantea, Rottboelia* and *Eriachne* may also be present (Meijer 1968). The main grasslands of this nature are found in the Kudat and Kota Belud Districts on impoverished sandstone soils and in the Sook and Keningau Plains on podsolic soils. Grasses more palatable to stock occur in the settled areas of the Crocker Range and in parts of the coastal and inland plains adjacent to areas of rice cultivation.

The main plantation crops are coconuts in Kudat District and in coastal locations elsewhere, rubber in the coastal hills, and foothills of the Crocker Range and oil palm on East Coast volcanic and coastal plain soils.

CHAPTER 4

THE DIPTEROCARP FORESTS

In this chapter item 1 of the vegetation scheme given in Chapter 3 is dealt with in detail. The status of the species comprising the family Dipterocarpaceae is discussed and available evidence from earlier work on composition is reviewed. A classification of dipterocarp forests into types is presented largely based on investigations made during 1966-71 and an account is given of these with particular emphasis on their likely extent, commercial status and species composition. The classification attempts to take particular account of representative species of value and with whose regeneration I shall be concerned with in Part 3.

Literature Review

The Dipterocarpaceae has been known to be the family of main commercial interest, dominating the lowland forest areas, for some considerable time. Only since 1947 however, have botanical studies progressed sufficiently to enable the majority of species to be described (A.R.R.B. 1963). At present detailed information on subspecies or varieties is lacking though clearly this is of importance. Wood and Meijer (1964) mention two forms of *Shorea superba* and Ashton (1969) drew attention to two subspecies of *Vatica oblongifolia* with distinct but oberlapping ranges in Sabah.

Some 160 species of Dipterocarpaceae are presently known from Sabah (Fox 1970 b) belonging to the following 9 genera:

Anisoptera (5), *Dipterocarpus* (25), *Dryobalanops* (6) *Cotylelobium* (2), *Hopea* (19), *Parashorea* (4), *Shorea* (8), *Upuna* (1), and *Vatica* (14).

The genus *Shorea* is conveniently subdivided into 4 sections (Wood and Meijer 1964):

Section	Timber Group	Species	Symbol
Anthoshorea	Melapi	7	An
Richetia	Yellow seraya	12	Ri
Rubroshorea	Red seraya	45	Ru
Shorea	Selangan Batu	20	SB

These symbols are used subsequently to denote sections and similarly the genera *Dipterocarpus* and *Dryobalanops* are abbreviated to *D.* and *Dr.* respectively to avoid constant repetition of full names.

Symington (1943) produced a diagrammatic scheme illustrating the altitudinal distribution of species of the Malay Peninsula and this has influenced subsequent consideration of general dipterocarp ecology in Borneo. Wood and Meijer (1964) illustrated known altitudinal ranges and commented on general ecological distribution with respect to site type, particularly soil and topography. Ashton (1958) pointed out the difficulty of describing any one species as typically of montane, lowland or Heath forest etc., but was able to list 147 Brunei species (Ashton 1964 b) arranged according to altitude and soil types. Allied species may have distinct edaphic ranges which overlap at margins (Ashton 1969). In Sabah the exact geographical ranges of *Parashorea malaanonan* and *P.tomentella*, which together account for up to 20 per cent of the volume of logs exported in post war years and one or the other of which characterise much of the lowland forest, are not known. It is clear, however, that distribution of the latter is wholly within the range of the former (personal communication P.S. Ashton).

Southwest Sabah

The region East Sarawak/Brunei/Southwest Sabah is the richest area in species of Dipterocarpaceae (Wyatt-Smith 1955) and the residual forests of that area in Sabah are akin to those described by Ashton (1964 a etc), in Brunei. On the 120 hectares of Beaufort Hill 39 species of dipterocarps are present, 9 of which are only found in the southwest. Appendix 2, Table 1, gives data for a one acre (0.4 ha) plot in this forest. *Dipterocarpus acutangulus*, *Shorea ochracea* (An), and *Parashorea smythiesii* are large trees characterising the area and probably representative of a much larger area in the vicinity now under cultivation.

More extensive forests remain in the Sipitang Hills and in Gunong Lumaku F.R. In these areas the lowland and hill forests are akin to those of the Kalabakan area, described in more detail below, though again several species are found there and not elsewhere in Sabah. The only extensive area of *Dactyloclados/Gonystylus* peat swamp (4.2(a)) occurs in the same region.

The following species of dipterocarps are found only in the southwest and are not therefore of interest with respect to the regeneration of East Coast forests:

(a) Peat Swamps: *Shorea platycarpa* (Ru), *S.teysmanniana* (Ru), *S.scabrida* (Ru). The latter may be found inland with *Hopea pentanervia* (7.2(b)).

(b) Beaufort Hill: *S.faguetiodes* (Ri), *S.fallax* (Ru), *S.pilosa* (Ru), *S.quadrinervis* (Ru), *S.rubella* (Ru), *S.scaberrima* (Ru), *S.biawak* (SB), *Dipterocarpus lamellatus*, *Anisoptera grossivenia*.

(c) Sipitang Hills:	*S.curtisii* (Ru), *S.ovata* (Ru), *S.slooteni* (Ru), *S.rugosa* (Ru), *Upuna borneensis*.
(d) Gunong Lumaku F.R.:	*Dipterocarpus conformis*, *Vatica maingayi*.
(e) Coastal:	*S.myrionerva* (Ru), *S.revoluta* (Ru), *Dryobalanops aromatica*, *Dr. oblongifolia*, *Hopea philippenensis* (only at Gaya Island).

Rarity

The notion of rarity is useful for eliminating from consideration little known species of limited importance.

Clearly visual observations on rarity are of little use but the infrequency of collections suggests that the following are rare in Sabah: *Dipterocarpus costulatus*, *D.sublamellatus*, *Cotylelobium malayanum*, *S.lamellata* (An), *S.patoiensis* (Ri), and *S.polyandra* (Ri), a group of species collected from the Tawau area. *S.coriacea* (Ru) a Heath species, occurs in Tawau and Sipitang areas; *Vatica albiramis* is a small tree in the Tawau area, but also occurs on ultrabasic.*S.havilandii* (SB) from Lubuk Buaya Hill, Bilit and *Hopea aequalis*, *H.bracteata*, and *H.vaccinifolia* all from Telupid only, may eventually prove to be more widespread but at present are considered rare.

Classification of Species

The remaining species may be classified according to their broad ecological distribution, largely based on topography and drainage, according to the following scheme:

<u>A Predominantly Lowland</u>

Upper altitude limits
150m 300 600 600

1. Abundant
2. Locally Abundant
3. Less Common
4. Marked Site Preference

<u>B Hill and Mountain</u>

1. Mountains 600m+
2. 300m+
3. Ultrabasic
4. Hill species
   (a) common
   (b) less common

In this scheme "swamp" excludes peat swamp, and "heath" covers the range of generally sandy podsolic soils.

Comparison of this scheme with the altitudinal and site classification given by Ashton (1964 b) shows general agreement for species common to Eastern Sabah and Brunei. Species listed as typical of ridges (4.d) extend into hilly areas and are mainly found on sandstone.

Altitude

Altitudinal limits for individual species vary with the overall topography of an area and the heights given in the above scheme, are, as has been suggested earlier, only a general guide. A series of 17 one acre (0.4 ha) plots in Gunong Rara F.R. (R.P. 318) gave the following representation of dipterocarps over 30 cm diameter:

Broad Ecological Distribution

A Predominantly Lowland Species (80)

Upper altitude range

	<150 m	<300 m	<600 m	>600 m
1. Abundant	*P.tomentella*(NE)	*S.smithiana*(Ru) *S.superba*(SB)(a) *S.symingtonii*(An)	*Dr.lanceolata* *D.caudiferus* *S.leprosula*(Ru)(a) *S.gibbosa*(Ri) *S.acuminatissima*(Ri)	*P.malaanonan* *S.leptoclados*(Ru) *S.parvifolia*(Ru) *S.pauciflora*(Ru)
2. Locally Abundant	*S.mecistopteryx*(Ru) *S.almon*(Ru)(EC) *S.waltonii*(Ru)(NE) *D.verrucosus*(S)	*H.nervosa*(Wet) *H.sangal* *S.macrophylla*(Ru)(Rip) *D.applanatus* *S.xanthophylla*(Ri)	*D.pachyphyllus*	*P.smythiesii*(Kal) *S.argentifolia*(Ru) *S.oleosa*(Ru) *S.ovalis*(Ru) *D.confertus*
3. Less Common	*S.virescens*(An) *S.leptoderma*(SB)	*H.ferruginea* *S.foxworthyii*(SB) *S.glaucescens*(SB) *S.hypoleuca*(SB)	*H.dryobalanoides* *D.crinitus* *D.gracilis* *D.humeratus* *D.kerri* *D.palembanicus* *S.domatiosa*(SB) *V.oblongifolia*	*S.hopeifolia*(Ri) *S.parvistipulata*(Ru) *S.scrobiculata*(SB) *V.sarawakensis* *V.umbonata*

4. Locally Abundant with Marked Site Preference

(a) Riverain
S.seminis(SB)
S.pinanga(Ru)
D.exalatus
D.oblongifolius
D.tempehes
Dr.keithii

(b) Swamp
D.warburgii
S.leprosula(Ru)(b)
V.bancana
V.papuana

(c) Coastal
V.mangachapoi
V.maritima
C.melanoxylon
H.nutans
S.bracteolata(An)
S.gratissima(An)
S.guiso(SB)

(d) Ridges
H.beccariana
H.wyatt-smithii
A.costata
D.acutangulus
D.grandiflorus
D.stellatus
S.agami(An)
S.beccariana(Ru)
S.multiflora(Ri)

(e) Heath
H.micrantha
H.pentanervia
A.marginata
Dr.beccarii
Dr.rappa
S.kunstleri(Ru)(a)
S.retusa(Ru)
S.venulosa(Ru)(a)

B Hill and Mountain Species (42)

1. Mountains 600 m and higher

H.dyeri
H.vesquei
H.montana
V.mindanensis
V.odorata
V.vesquei
S.inappendiculata(SB)
S.monticola(Ru)
S.nebulosa(Ru)
S.platyclados(Ru)

2. Mountains above 300 m

H.argentea
H.andersonii
V.dulitensis
S.angustifolia(Ri)
S.dasyphylla(Ru)

3. Ultrabasic

S.andulensis(Ru)
S.carapae(Ru)
S.kunstleri(Ru)(b)
S.venulosa(Ru)(b)
S.laxa(Ri)
S.tenuifolia
D.geniculatus
D.lowii
D.ochraceus

4. Hill Species

(a) Common

H.semicuneata
S.atrinervosa(SB)
S.laevis(SB)
S.superba(SB)(b)
S.amplexicaulis(Ru)
S.faguetiana(Ri)
S.macroptera(Ru)

(b) Less Common

A.laevis
A.reticulata
P.parvifolia
S.ochracea(An)
D.hasseltii
S.exelliptica(SB)
S.maxwelliana(SB)
S.obscura(SB)
S.cristata(Ru)
S.ferruginea(Ru)
S.flaviflora(Ru)
S.rubra(Ru)

<u>Notes</u> Several of the species given under ultrabasic are also present in S.W. Sabah in coastal forest on poor soil.

NE = north east; EC = east coast; S = south; Ta = Tawau; Kal = Kalabakan; Wet = moist sites; Rip = often riveraine

(a); (b) - two forms, or distinct habitats or found in both habitats

D - *Dipterocarpus*
Dr - *Dryobalanops*
S - *Shorea*
A - *Anisoptera*
H - *Hopea*
V - *Vatica*
C - *Cotylelobium*
P - *Parashorea*

Altitude: Species (X=present)	400-530m	550-610m	640m	690-700m	720-760m
Shorea					
Rubroshorea					
S.almon	X	-	-	X	-
S.argentifolia	X	X	X	-	-
S.leprosula	X	X	-	X	X
S.leptoclados	X	X	X	-	-
S.macroptera	X	-	-	-	-
S.oleosa	X	-	-	X	X
S.ovalis	-	X	-	-	X
S.parvifolia	X	X	X	X	-
S.pauciflora	X	X	X	X	-
S.platyclados	X	X	X	X	X
S.smithiana	X	X	-	X	X
Richetia					
S.acuminatissima	-	-	X	-	-
S.faguetiana	X	X	-	X	-
S.gibbosa	X	X	X	X	X
S.multiflora	-	-	X	X	-
Selagan Batu					
S.atrinervosa	-	X	X	X	X
S.foxworthyii	-	-	-	X	-
S.inappendiculata	-	-	-	X	X
S.laevis	-	X	X	X	X
S.leptoderma	-	-	X	-	-
S.obscura	X	-	-	-	-
S.superba	-	X	-	-	X
Anthoshorea					
S.agami	X	X	X	X	-
Dipterocarpus					
D.acutangulus	X	X	-	X	-
D.applanatus	X	-	X	X	X
D.caudiferus	-	X	X	-	-
D.exalatus	-	-	X	-	-
D.humeratus	-	-	-	X	-
D.verrucosus	X	X	-	-	-
Parashorea malaanonan	X	X	X	X	X
P.smythiesii	-	X	-	-	-
Dryobalanops lanceolata	X	X	X	-	X
Hopea beccariana	-	-	-	X	-
H.nervosa	X	X	X	X	-
H.sangal	-	-	X	-	-
Vatica dulitensis	X	X	X	X	X
V.oblongifolia	-	X	-	X	-
Anisoptera costata	X	-	-	X	X
Number of Plots	4	3	3	4	3

These plots were at Mile 39.5 (7) and Mile 45 (10) along the main road from Kalabakan Camp in an area of hills rising gradually from the lowlands. Many of the more typical lowland species occurred on off-ridge sites, e.g.

Shorea leprosula, *S.leptoclados* and *S.acuminatissima*, while the more typical hill species, e.g. *Shorea atrinervosa*, *S.platyclados* and *Vatica dulitensis* followed spurs downwards. Classification of types involving subdivision of hill and lowland forms of dipterocarp associations is consequently unmappable on a large scale and classification must consider both within one framework.

Forest Types Within the Dipterocarp Forests

Methods of assessment used in Sabah have varied from large scale enumerations to determine the commercial status of specific tracts down to small plots used to record growth over time of the natural forest.

Enumerations.

Early enumerations used group names for the majority of trees recorded, e.g. "medang" (Lauraceae), "kedondong" (Burseraceae), and "nyatoh" (Sapotaceae). Single species names were used for *Eusideroxylon zwageri*, the most important non dipterocarp occurring in any quantity in the lowlands and often characterising the forest, and for the more common Leguminosae. Distinctions between dipterocarp genera and the groups within *Shorea* were generally sufficient to enable data to be quoted. The earliest record is given by Foxworthy (1916) for 680 ha of sample with an average volume of 2613 cu ft/acre (243 cu m/ha). This summarised enumerations of 20,000ha in the Lahud Datu/Segama area; 14,500 ha on Sebatik Island; and 37,000 ha in the Tawau area. The most abundant groups were:

Rubroshorea 20 per cent	*Parashorea* 9	*Eugenia* 3.6
Selangan Batu 8.5	*Dr. lanceolata* 3.5	*Koompassia malaccensis* 2.2
Richetia 6.4	*E. zwageri* 6	Sapotaceae 1.6
Dipterocarpus 11	*Koompassia excelsa* 3.5	*Sindora* 1.4

Of these *Parashorea* was most abundant in the Lahud Datu/ Segama area, *Eusideroxylon* on Sebatik, *Dipterocarpus* in Serudong (West Tawau), and Rubroshorea in Apas (North Tawau). Most of the areas enumerated earlier have been logged over, and summary data is all that is available on which to assign types. Volumes, as cubic feet/acre, for individual areas were:

Lahud Datu/Segama /	2000	Lower Apas	1900
Serudong	3000+	Suan Lamba	2040
Bambarao River (Tinagat)	1210	Semawang(Labuk Bay)	2600

Other early enumerations included Sepilok (F.D.A.R. 1931); Timbun Mata Island (F.D.A.R. 1932); Tanjong Batu River, Dewhurst Bay (F.D.A.R. 1932). *Eusideroxylon* was the most abundant species in the latter area. Keith (1935) gave the following percentages for two areas near Tawau:

Table 7. Summary of Early Enumeration Data

Location	Sample Acreage	Volume /acre	Percentage Volume Composition Dipterocarp Groups Rubroshorea	Selangan Batu	*Dipterocapus*	*Parashorea*	*Dryobalanops*
1 Silabukan	320	1730	31	6	4	49	10
2 Gum-Gum/Samawang	128	2570	25	1	18	29	13
3 Merotai/Umas Umas	160	1860	29	12	7	24	10
4 Serudong/Kalabakan	132	1150	25	16	18	4	3
5 Segama/Dent	160	1510	18	3	7	39	23
6 Tungud/Bongaya	320	1210	20	8	32	4	14
7 Pagagau	320	1130	24	3	12	27	10
8 Jembongan Island	152	1780	21	4	16	3	40
9 Unknown	501	840	20	23	22	14	2
10 Gomantong	84	1160	29	3	19	22	17
11 Balung/Magdalena	256	1500	34	14	6	21	10
12 Lucia/Magdalena	128	1090	11	30	11	4	2
13 Dent Peninsula	68	1130	22	7	16	11	19
14 Telewas	302	470	4	4	1	85	P
15 Segama/Tingkayu	136	890	16	17	5	51	3
16 Sugut Kaindangan	264	720	23	5	11	15	26
17 Ulu Lukutan	64	1460	42	23	4	7	16
18 Bt.Rumanas/Liawau	22	805	-	-	P	7	-
19 Keningau	18	530	25	-	-	8	8
20 Apin Apin/Kitau	16	280	-	27	-	-	-
21 Tambunan	18	383	-	P	-	5	-
22 Sinsuron/Penampang	58	462	-	P	-	-	6

P = Present (less than 1%)   Nos. 1-9 F.D.A.R. 1952 Page 6; Malayan Forester 1952 page 211
Nos.10-22 F.D.A.R. 1953 Pages 34-35

Species	Silimpopon	Merotai
Rubroshorea	29	44
Selangan Batu	14	3
Dipterocarpus	18	15
Parashorea	6	5
Dr. lanceolata	2	4
E. zwageri	2.7	4.3

A number of enumerations by species groups made in the early 1950's are summarised in Table 7. It is believed that the 1952 enumeration volumes were for trees of 8ft girth (78 cm diam) and over, down to 6ft (58 cm) for Selangan Batu, but in 1952 over a general limit of 6ft. The last four entries of Table 7 refer to areas influenced by shifting cultivation and mainly over 600 m altitude, in the Crocker Range. In these areas *Pterospermum* and *Toona* figured prominently. *Hopea* and *Vatica* were also important constituents of higher forests in the Crocker Range and of the Lucia/Magdalena enumeration.

These earlier enumerations may be compared with later data, presented in the Appendix in more detail:

Forest Reserve:	Segaliud-Lokan	Kuamut	Kalabakan (Luasong)	(Umas Umas)
Appendix	(1) Table 1	(1) Table 3	(1) Table 5	(2) Table 2
Species Group	(Percentage representation of trees 5ft +)			
Rubroshorea	27	41	18	25
Selangan Batu	4	7	3	5
Dipterocarpus	11	8	8	7
Parashorea	21	13	18	5
Dryobalanops	11	8	23	6
Eusideroxylon	6	2	5	18

Clearly most of the forests have representatives of all the major groups when large scale enumeration data is examined. However, There is a considerable range in both relative proportions and individual species contents and

Keith's (1935) "single well-defined association" needs qualification. As Ashton (1964 b), Wood and Meijer (1964), and Nicholson (in Paton 1959) have shown distinctive differences exist between dipterocarp forests on different soils. The forests may be conveniently classified on floristic grounds according to the presence of the most abundant species, genera or groups in a similar manner to that adopted by Wyatt-Smith (1961 b) for Malaya, viz:

Classification of Forest Types

<u>Lowlands</u>

A. *Parashorea malaanonan* Forest

P. malaanonan is the most abundant emergent species in the Darvel Bay area from the east (Silabukan F.R.), through Lahud Datu to the Semporna peninsula. This is a coastal type and *S. guiso* is usually present.

B. *Parashorea tomentella/Eusideroxylon zwageri* Forest

This type covers the north-eastern lowlands, lower parts of the Kinabatangan and Segama drainage and extends westwards into the Lokan peneplain.

C. *Rubroshorea/Eusideroxylon* Forest

This type occurs in the south of the country from east of the Kalumpang river westwards into Kalabakan and Gunong Rara F.R.'s and on Sebatik Island.

D. *Rubroshorea/Dipterocarpus* Forest

Occuring on poorer soils and locally within the other main types but is extensive in some areas and the term may be provisionally used for all little known interior areas.

E. *Parashorea malaanonan/Dryobalanops lanceolata* Forest

This is the most common association on shale and other non-sandstone hills in the west of the country, but at lower elevations than Types F and G.

Hills

F.Selangan Batu Forest

The most frequent species of this type is *S.laevis* and the type occurs on steeper and higher hills than Type E in the south, interior and west of the country.

G.Dipterocarpus/Richetia Forest

This type occurs on sandstone escarpments in the east and north, mainly in coastal locations.

These types are not wholly exclusive nor do they embrace all combinations of species likely to be found. In many cases altitudinal change results in type change over comparatively small areas; and as many areas have not been studied in floristic detail a map of these forest types has not been prepared. Subsidiary combinations will be described under the main types and affinities pointed out. Clearly the basis has similarities with the Malayan types described in Chapter 3 and hopefully a regional classification of the dipterocarp forests may eventually be produced.

This classification is largely based on sample plot data taking account of the larger trees, i.e. over 6ft girth, a method long used by foresters elsewhere but not hitherto for Borneo. The method is akin to that for which Williams and Webb (1969) claim to have demonstrated numerical justification. The rest of this chapter is devoted to an account of the types with most attention being given to the lowland forests of greater commercial interest.

Type A *Parashorea malaanonan* Forest

Coastal areas of Darvel Bay contained a high proportion of this species with few other trees growing as emergents. The Mostyn area, cleared in the early 1950's for the establishment of oil palm plantations, where porous loamy soils are developed on volcanic basalt lava, had a timber stand exceeding 2000 cu ft/acre (180 cu m/ha) with 80 per cent being *P.malaanonan* (F.D.A.R. 1952). Further north on hilly ground in the Silam area with soils derived from the Basement Complex, coastal areas yielded 90-98 per cent of the type species (Walton 1955).

A summary of stocking data for plots totalling 3.4 acres (1.4 ha) enumerated from 12 ins girth (10 cm diam) in the Silam area is given in Appendix 4, Table 1. *P.malaanonan* is the most abundant large tree with 38 per cent of trees over 6ft and 54 per cent of those over 9ft girth. Other emergent species are typically *Shorea guiso* (SB), and *Hopea sangal* (though this species is often small) with the Rubroshorea species such as *S.leprosula, S.parvifolia* and *S.leptoclados* also present, the latter locally abundant.

Eusideroxylon zwageri is absent in the Silam area and the most common species of the main canopy are *Hopea sangal, Cynometra elmeri,* small trees of the emergent species, large *Diospyros* spp., *Eugenia* spp., *Meiogyne virgata, Sympetalandra borneensis,* and *Dialium platysepalum.* In the lower canopies the genus *Diospyros* is well represented and *Aglaia, Dillenia, Hydnocarpus, Meiogyne, Paranephelium* and *Teijsmanniodendron* are also frequent.

Figure 11 illustrates the profile characteristics of this forest. Individual large trees occur of 9-12 ft girth (90-120 cm diam) and 160 ft (50 m) or more in height.

PROFILE PLOT, SILAM

Parashorea malaanonan, Shorea guiso

FIGURE 11

Dryobalanops lanceolata, *Dipterocarpus* spp. and *Koompassia excelsa* are scarce.

The Lormalong Settlement Scheme near Mostyn where the chert spilite is adjacent to basalt carried a similar forest on low-lying land with *P.malaanonan*, *S.guiso* and *H.sangal*. Other large tree species in this area were the dipterocarps *S.parvifolia*, *S.leprosula*, *S.seminis* (S.B.) *H.nervosa*, also *Barringtonia anacardifolia*, *Enicosanthum grandifolium*, *Alangium griffithii* and *Planchonia valida*. The lower Tingkayu River area, passing through the Chert Spilite Formation and felled over in the late 1960's had, in addition to *P.malaanonan*, *S.argentifolia*, *S.seminis*, *D.caudiferus* and *Koordersiodendron pinnatum*, *Dracontomelon puberulum*, and *Planchonia*. Higher up the Tingkayu on the alluvium *Eusideroxylon zwageri* was a constituent of an essentially similar forest with the following other non-dipterocarps as trees of the main canopy: *Ganua kingii*, *Irvingia malayana*, *Castanopsis* sp., *Beilschmiedia tawahense* and *Mallotus penangensis*.

The forests of Timbun Mata Island on the Chert Spilite Formation also belong mainly to this type. *P.malaanonan* is locally gregarious on steep slopes (Figure 12) with *S.guiso*, *Cynometra elmeri*, *Pterocymbium tinctorum* and *Pterospermum stapfianum* (the two latter seral species suggesting frequent windfalls), also with palms and lianas abundant. On less steep slopes, though still the predominant species, *P.malaanonan* is found in association with the Rubroshorea species *S.leptoclados*, *S.leprosula*, *S.smithiana*, and *S.ovalis* and, infrequently *Dr.lanceolata* and *D.caudiferus* (Figure 13). Local occurrence of *Drypetes/Cynometra/Dialium* on dry, rounded hills (Figure 14)

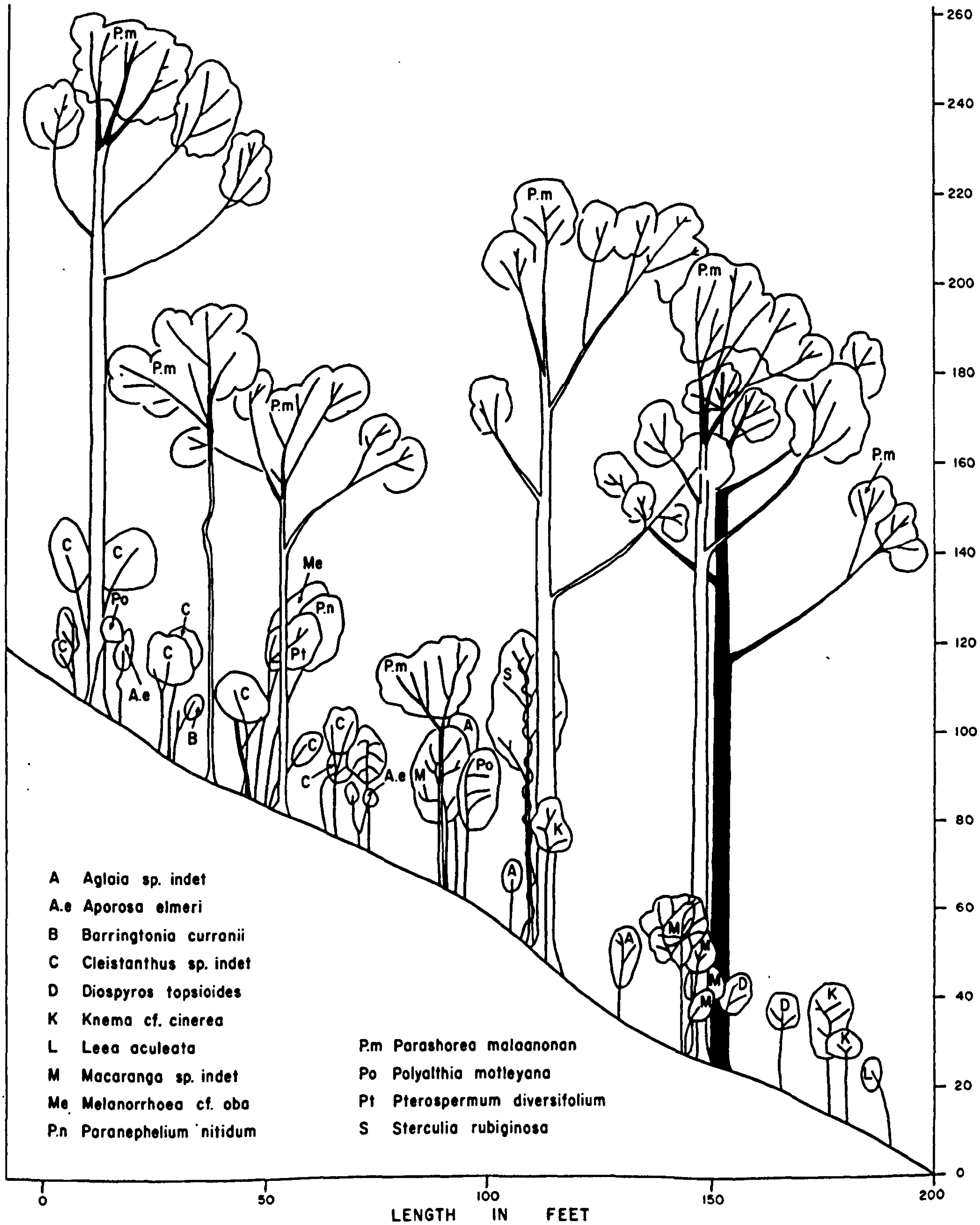
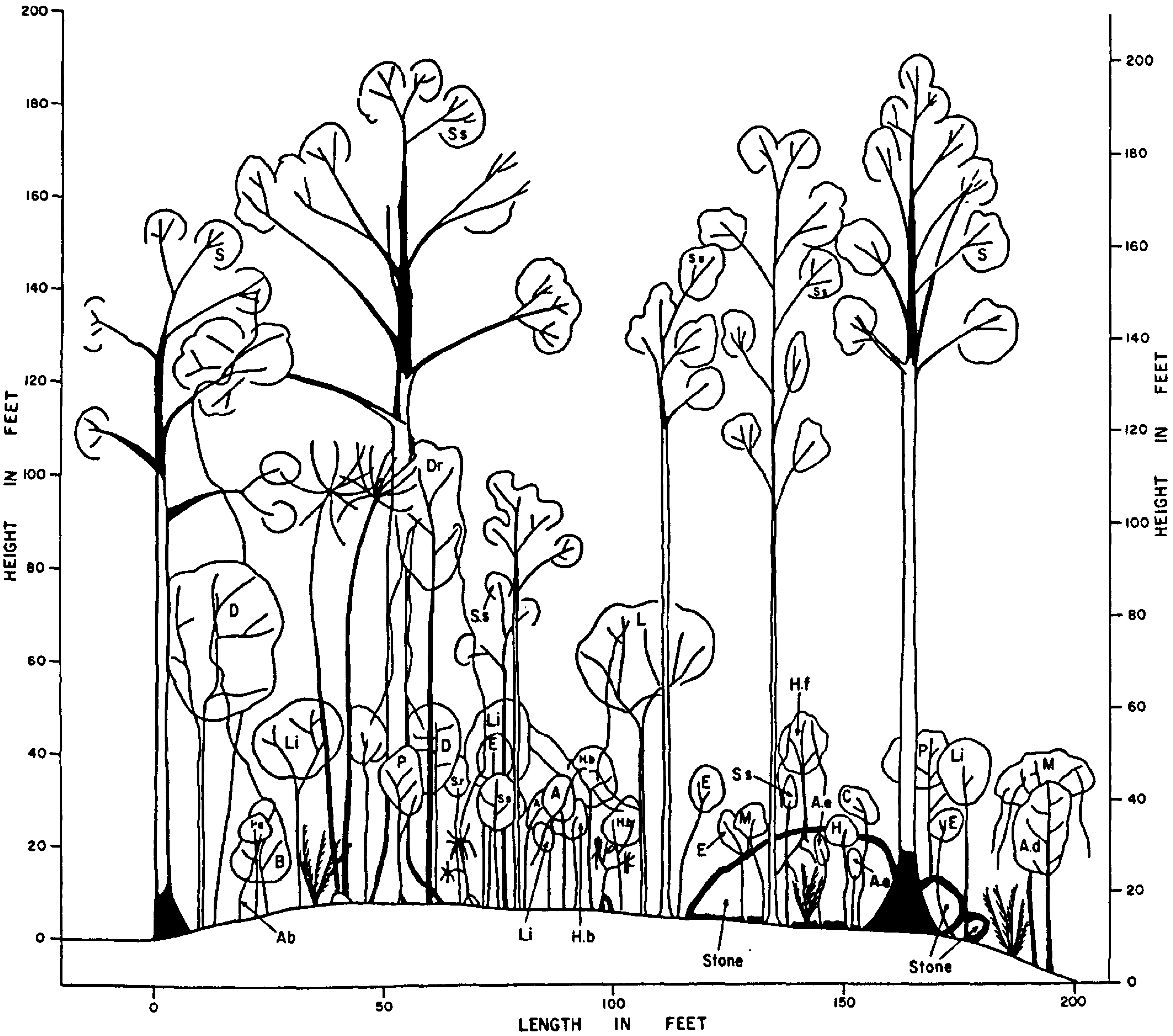


FIGURE 12 PROFILE DIAGRAM

Parashorea malaanonan Forest

on Timbun Mata Island

Forest Department, Sabah. 1971.

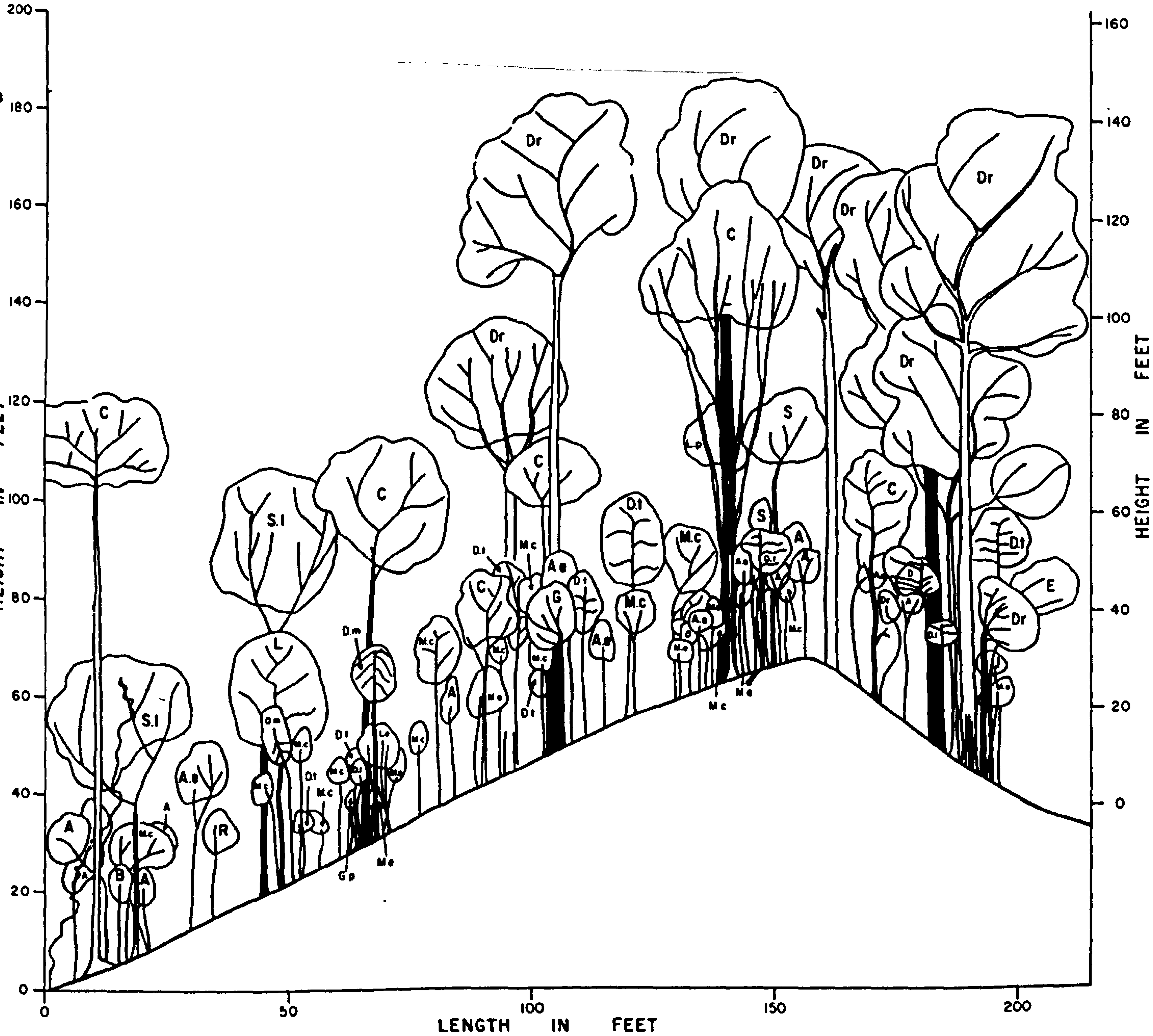


A	Ardisea sp. indet	D	Diospyros topsioides	H.b	Hydnocarpus borneensis	P	Paranephelium nitidum
A.e	Aporosa elmeri	Dr	Dryobalanops lanceolata	L	Lithocarpus sp. indet	P.a	Ptychopyxis arborea
Ab	Abarema sp. indet	E	Eugenia sp. indet	Li	Litsea sp. indet	S	Shorea faguetiana
A d	Artocarpus dadah	H	Heritiera simplicifolia	M	Mallotus lackeyi	S.s	Shorea smithiana
B	Baccaurea sp. indet	H.f	Homalium foetidum	O	Oncosperma horrida	S.r	Sterculia rubiginosa
C	Cynometra inaequalis						

FIGURE 13 PROFILE DIAGRAM

Forest Department, Sabah. 1971.

Grove of Shorea smithiana in Type A Forest on Timbun Mata Island



A	Aglaia sp. indet	D.t	Diospyros topsioides	G	Garcinia sp. indet	M.c	Memecylon costatum
A.e	Aporosa elmeri	Dr	Drypetes cf. subcubica	I	Irvingia malayana	Me	Memecylon edule
B	Barringtonia curranii	Dm	Drypetes macrophylla	L	Lansium sp. indet	R	Randia sp. indet
C	Cynometra inaequalis	E	Eugenia sp. indet	Le	Leea cf. aculeata	S.I	Santiria laevigatum
D	Diospyros sp. indet	G.p	Guioa pleuropteris	L.p	Linociera philippinensis	S	Shorea guiso

FIGURE 14 PROFILE DIAGRAM

Forest Department, Sabah 1971.

Drypetes/Cynometra/Dialium Forest on Timbun Mata Island with *P.malaanonan* absent may represent late secondary forest following fire. *Diospyros macrophylla* is the commonest species of the genus on Timbun Mata, and in the Darvel Bay area generally where perhaps the genus reaches its greatest abundance in both species and density in Sabah. This species was one of the most abundant species of non-dipterocarps recorded in R.P. 233 at Silam, which covered 30 acres (12 ha) along with: *Koordensiodendron pinnatum, Phoebe macrophylla, Nephelium mutabile, Neonauclea bernardoi, Lophopetalum javanicum* and *Dillenia excelsa.*

The unfelled forest just above the sea at Silam is almost pure *S.guiso* as are some of the other Darvel Bay areas (cf Forests on Ultrabasic Rocks, 7.4(b)).

Plots laid down in the Mostyn area on different soils (A.R.R.B. 1960) gave the following stocking values for stems over 12 ins girth:

Soil	Stems/ acre	B.a./ acre	No. 8 ft.g.+	B.a. 8 ft+
Mountain	193	156	4.8	47
Ridge	156	113	5.0	36
Old lake bed	191	144	5.0	42
Basalt	154	151	7.4	73
Coastal Platform	159	134	3.0	31

There were few specific differences but *Dipterocarpus* was absent on the volcanic soil. More detailed work on the only remaining forest on basalt (Madai F.R.) in the area showed the preponderance of *Parashorea malaanonan.* A relascope survey of 158 acres (64 ha) gave total basal area as 139 sq.ft./acre with 5.8 stems over 8 ft. girth of basal area 53 sq.ft. *P.malaanonan* comprised 31 per cent of all stems and 62 per cent of those over 8 ft girth.

A complete stand table for 2 plots totalling 5 acres (2 ha) of this forest is given in Appendix 3,

Table 1. As on the Chert Spilite *Eusideroxylon* is absent and *Dr. lanceolata* occurs mainly as smaller trees. *Shorea pauciflora* at least locally, is the commonest emergent associate of *P. malaanonan*.

The olivine basalts of the Tawau area have different types (discussed below) e.g. Type C on the flatter areas, Type E on steep slopes marginal with Type F. All are deficient in *Dipterocarpus* however, and in this respect similar to the Madai forests. In contrast the forest on Mull Hill, a basic intrusion in the Tawau area, is floristically similar to the Madai basalt. Table 8 illustrates stocking of large trees on a representative sample across this hill.

Table 8. Stand Table 16 plots of 0.1 acre, Total 1.6 acres (0.6 ha) Mull Hill

Species		Numbers of Trees in Size Classes						
	Girth (ft.)	6	7	8	9	10	10+	Total
	Diam (cm.)	58	68	78	87	97	107+	
Dipterocarpaceae								
Shorea (Rubroshorea)								
S. leprosula		1	-	-	-	-	-	1
S. leptoclados		-	2	-	-	1	-	3
S. pauciflora		1	1	-	-	1	1	4
(Richetia)								
S. acuminatissima		1	-	1	-	-	-	2
(Selangan Batu)								
S. guiso		1	-	1	-	-	1	3
Parashorea malaanonan		-	1	2	1	-	2	6
P. smythiesii		1	1	1	-	-	-	3
Non-dipterocarps (4 species)		1	1	1	1	-	1	5
Totals		6	6	6	2	2	5	27
Per 10 acres/4 ha		37	37	37	12	12	31	166

P. malaanonan and *S. pauciflora* are the commonest larger species, *S. guiso* and *Drypetes kikir* (cf *Drypetes* on Timbun Mata, Figure 14), are present and nearby are *Scaphium longipetiolatum*, *Shorea symingtonii* (An~~p~~), and *S. superba* (SB).

Summed data for 4 plots of 1 acre (1.6 Ha) is given in Appendix 4, Table 2, for the forest at Tangah Nipah, east of Lahud Datu on the Tabanak Conglomerate Formation. The genera *Dipterocarpus*, *Dryobalanops* and *Eusideroxylon* were all absent in this area where *Shorea guiso*, *Cynometra elmeri*, *Koordersiodendron pinnatum* and *Sympetalandra borneensis* were present as associates of *P.malaanonan*, with several Rubroshorea species present, including *S.argentifolia* locally abundant. North of Lahud Datu, across the Segama River, on the Labang Formation Type A merges with Type B. In the area felled 1967-68 by Timber Producers of Sabah part contained Type A species, *P.malaanonan*, *Hopea sangal*, *Cynometra elmeri*; and *P.tomentella*, *Eusideroxylon zwageri*, *Dryobalanops lanceolata* with *Dipterocarpus* spp. occured in another part.

Further east of Lahud Datu in Silabukan F.R. the *P.malaanonan* type is represented in the Bakapit Catchment area. A Telascope survey in Block 11 covering 173 acres (70 ha) of V.J.R. No. 14 (A.R.R.B. 1964) gave total basal area over 12 ins as 119 sq.ft./acre with 3.5 stems over 8 ft. girth of basal area 29 sq.ft. The geology of this area is rather mixed being described as the Tungku Formation, with *P.malaanonan* forests occurring on volcanic breccia. Appendix 4, Table 3 tabulates species recorded in R.P. 271C and D inside the uncut Catchment area; though *P.malaanonan* does not occur in this sample its common associates *Hopea sangal* and *Cynometra elmeri* are present. *Eusideroxylon zwageri* occurs on the carbonaceous sandstones and clays with conglomerate, further east and north in Silabukan F.R., while in the hills of the Bagahak Range Type E is predominant (see below). Type A reappears on the Togopoi Formation at the end of the Dent Peninsula.

East of Silabukan F.R. coastal forests on podsols at Sabahat are similar to, but taller than, those on ultrabasic at Malawali Island with presence of the Anthoshorea species *S.bracteolata* and *S.gratissima*. These are similar to forests in coastal Pahang described by Beveridge (1953). They occur as emergents to 30 m above a low scrub tangle on white sands just behind the *Casuarina equisetifolia* fringe at Sabahat, whereas on Malawali they are found on slopes (where *Gymnostoma nobile* is absent) with *Eugenia alcine* in a low forest to 20 m. *Shorea bracteolata* is also present elsewhere on the northern islands under *Gymnostoma* with *Calophyllum obliquinervium*, *Santiria laevigata*, *Eugenia* and *Tristania*.

The lowland forest on Banggi Island has affinities with the Darvel Bay *P.malaanonan* forest. This species and *S.guiso*, *Hopea sangal*, and *Koordersiodendron pinnatum* are all present, but the most characteristic tree is *Dipterocarpus warburgii* (elsewhere a tree of riverain swamps, 4.3(h) above), and *D.gracilis* is also common. Coastal limestone forests also have affinities (6 above). One further forest requiring mention is the coastal association at Kampong Sibumbong, Banggi Island, of *S.guiso*, *S.bracteolata*, *Cynometra elmeri*, *Koordersiodendron pinnatum*, *Dipterocarpus gracilis* and *Semecarpus* sp. as large trees. This merges inland with an ultrabasic forest with the dipterocarps *Cotylelobium melanoxylon*, *Vatica papuana* and *V.umbonata* present as small trees under an emergent canopy of *Gymnostoma nobile*.

The *P.malaanonan* type of dipterocarp forest is probably the most commercially valuable. The main areas of managed forest containing this type are parts of

Silabukan F.R., Silam Extension and Ulu Segama F.R. and parts of Tingkayu F.R. The main occurrence is coastal, and is associated with comparatively good soils and low rainfall.

Type B. *Parashorea tomentella/Eusideroxylon zwageri* Forest

Apart from the swamps and sandstone escarpments this Type covers much of the Sandakan area from the Segama River northwards, through Paitan and Sugut and well into the centre of Sabah along the major rivers. Within this area the most well known areas (floristically) are Sepilok and Segaliud-Lokan F.R.'s.

A forward enumeration covering 59 sq. miles (150 sq.km), made by Sabah Timber Co., in the forest between the Lokan River and the Labuk Road, on the Lokan Peneplain, gave an average per acre stocking of 1050 cu.ft. Percentage representation of major groups were similar to my more detailed, but less extensive, enumeration made on the Garinono Formation summarised in Appendix 1, Table 1. Differences are due to the increased hilliness of the larger area with corresponding increased representation of species characteristic of Types F and G. Generally, however it may be noted that this forest Type has about 20 per cent *Parashorea* (of trees 6ft girth and larger, 58 cm diam) and though *P.malaanonan* is present, the main species is *P.tomentella*. Its principal associates are *S.leptoclados* Ru *Dr.lanceolata* and *D.caudiferus*. These four dipterocarps generally account for 40 per cent or more of the larger trees. Examples of stocking for representative plots in this forest type are given in Appendix 2, Tables 3-7, and Appendix 3 Table 2.

In Sepilok F.R. *P.tomentella* and *S.leptoclados* are most typical of the Type with abundant *E.Zwageri* in the main canopy below the emergents, on low-lying alluvial soils or soils derived from mudstones and shales. A stand table of species present in R.P. 18 is given in Appendix 3, Table 2, representative of an alluvial site. R.P.292/1 on undulating mudstone/shale is summarised in Appendix 2, Table 3. In addition to *S.leptoclados* the following Rubroshorea species are present: *S.almon*, *S.argentifolia*, *S.macrophylla*, *S.macroptera*, *S.mecistopteryx*, *S.ovalis*, *S.leprosula*, *S.parvifolia*, *S.pauciflora* and *S.waltonii*. The other three groups of *Shorea* are also represented but Selangan Batu and Richetia become more common on undulating land, while Anthoshorea is scarce. Several species of *Dipterocarpus*, besides *D.caudiferus* viz: *D.applanatus*, *D.gracilis*, *D.humeratus* are present, often occurring locally, in groves. *Hopea nervosa* is the only member of its genus consistently present and trees of the genera *Cotylelobium*, *Vatica* and *Anisoptera* are scarce. Figure 15 illustrates this forest in Sepilok, on a low mudstone hill rising from alluvium. Besides *Eusideroxylon* other genera of the main canopy include *Diospyros*, *Hydnocarpus*, *Chisocheton* and *Lithocarpus*. *Sympetalandra borneensis* occasionally reaches emergent status. The lower canopy contains small Anonaceae, Euphorbiaceae, *Eugenia* spp., and *Diospyros*. Lianas are frequent and seral, moisture loving species such as *Anthocephalus chinensis* and *Octomeles sumatrana* are found in low-lying areas which are often flooded.

Abundance of *Eusideroxylon zwageri* varies from place to place and is often scarce over wide areas. West

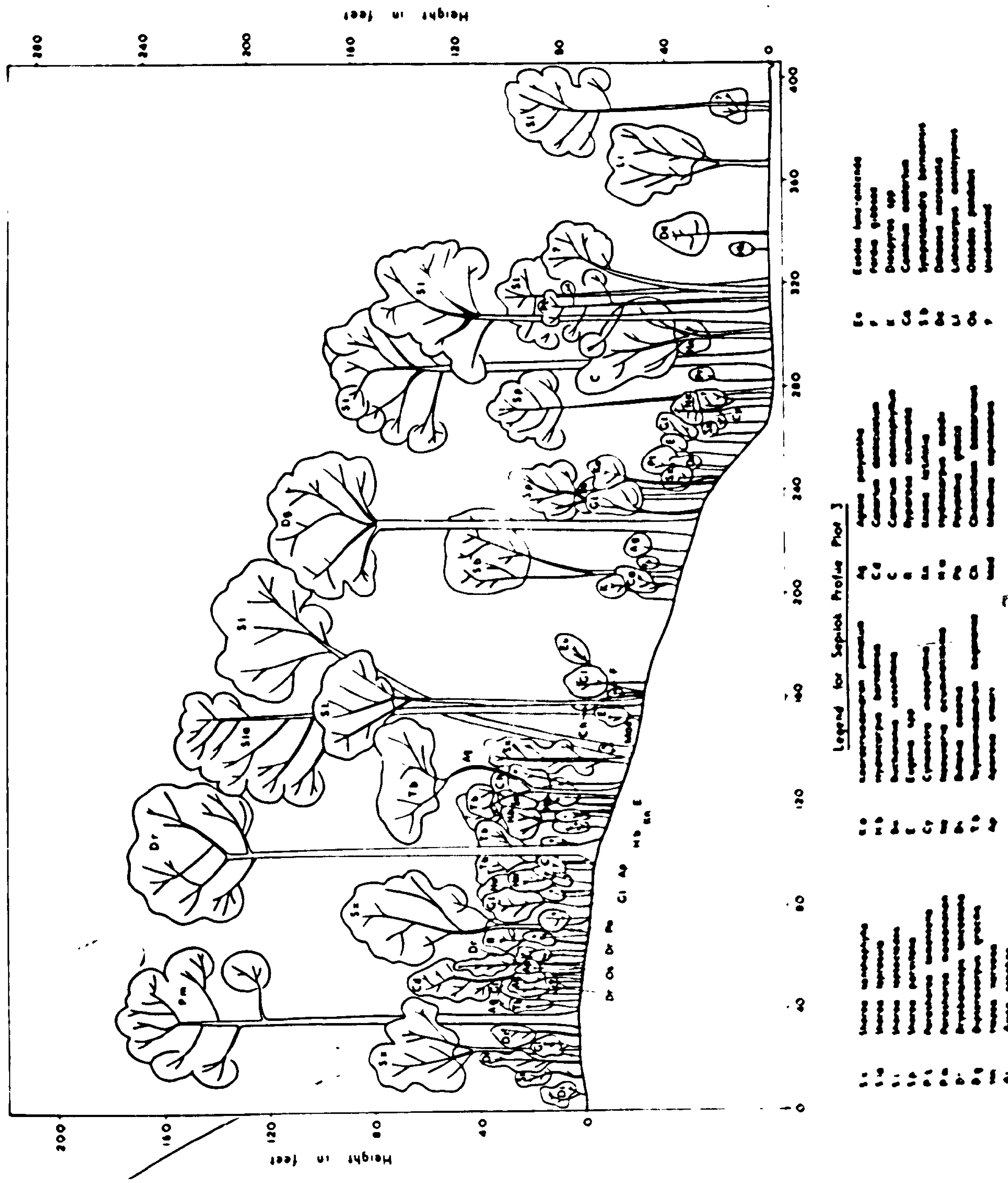


FIGURE 15 PROFILE DIAGRAM
TYPE B FOREST in Sepilok
Forest Reserve

of Sandakan land on the Garinono Formation formerly carrying this Type has now been planted to rubber and oil palm, except for small reserved areas at Garinono (Figure 58). Elsewhere the only traces of Type B are occasional unfelled large specimens of *Koompassia excelsa* and *Shorea superba* (SB) with patches of dead, but uncut, *Eusideroxylon* standing over rubber trees. The Garinono area has figured prominently in discussion of silviculture (Meijer 1970) and will be dealt with in Part 3. A representative stand table is given at Appendix 2, Table 4.

Further west the Mile 42 Virgin Jungle Reserve in Segaliud-Lodan F.R. serves as a memorial to the former extensive *P.tomentella/Eusideroxylon* forest and Appendix 1, Tables 1-2 are based on work in this area. Statistical parameters for small trees have been summarised elsewhere (Fox 1967 a).

Two adjacent profile diagrams from this area are illustrated in Figures 16 and 17. These show the patchy nature of the canopy in comparison with some other areas. There is no evidence of any past disturbance but patchiness may be due to higher mortality following faster growth rates than in some of the other types. The entire Type is characterised by abundance of lianas and climbing bamboo (*Dinochloa scandens*) and elephants may have been responsible for the spread of the latter, contributing to patchiness.

Appendix 2, Table 5 gives summary stocking data for R.P. 242, a plot of 10 acres (4 ha) in which all trees over 4 ft girth (39 cm diam) were measured. Here *Eusideroxylon* was scarce and *P.tomentella, Dr.lanceolata,* and *S.leptoclados* together accounted for 43 per cent of all stems and

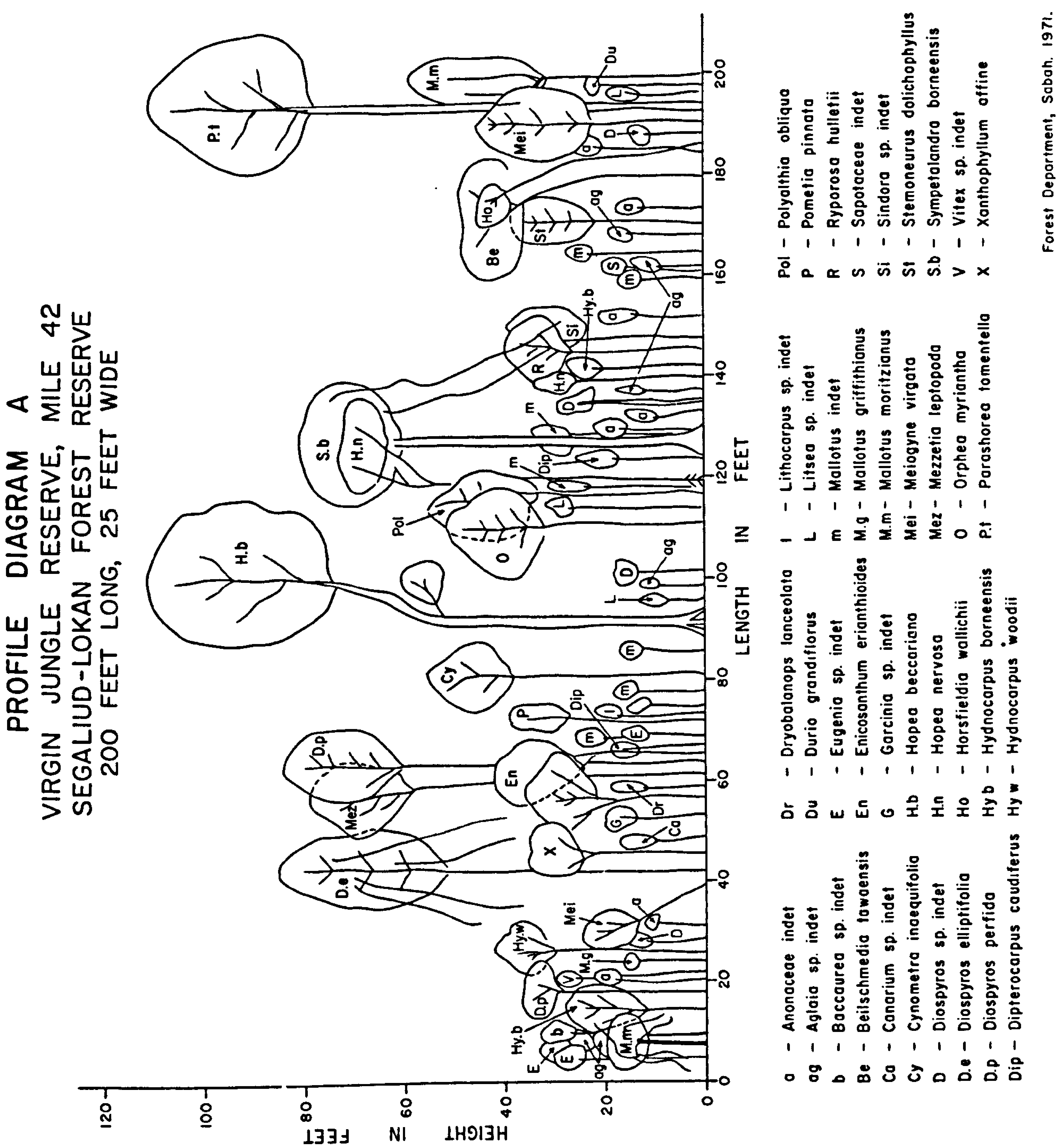


FIGURE 16 PROFILE DIAGRAM

(A) TYPE B FOREST *Parashorea tomentella/Eusideroxylon zwageri* in Segaliud-Lokan Forest Reserve

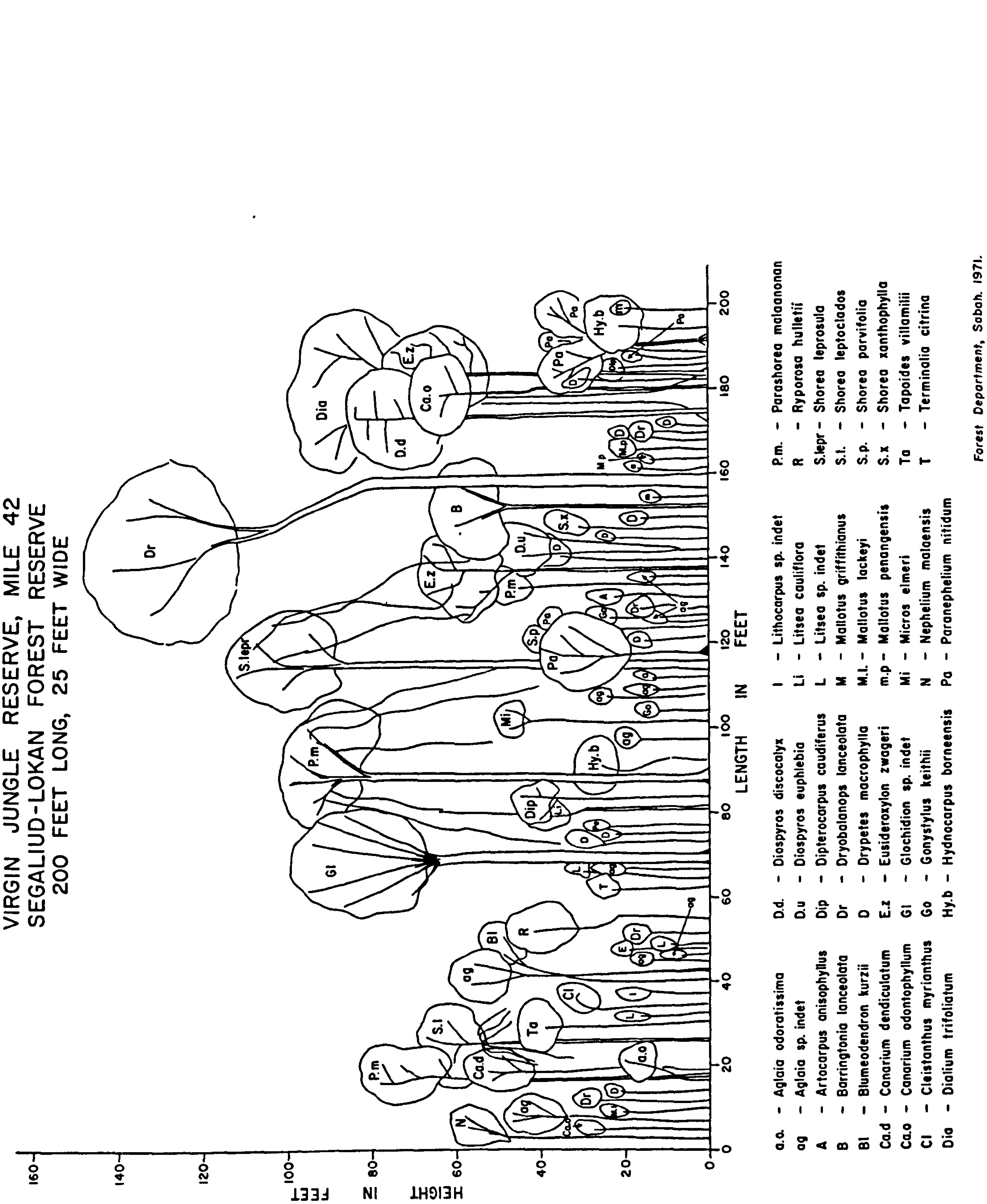


FIGURE 17 PROFILE DIAGRAM

(B) TYPE B FOREST *Parashorea tomentella*/*Eusideroxylon zwageri* in Segaliud-Lokan Forest Reserve

This adjoins Figure 16 which can be superimposed on it to illustrate the forest in depth.

56 per cent of those over 6 ft girth (58 cm diam). Both this area and RP 257 (see Table 9) where *Eusideroxylon* was totally absent, are in the headwaters of the Segaliud River, the soils being red/yellow latosols on sedimentary shales of the Garinono Formation.

Table 9. Stand Table R.P.257 17.8 acres (7 ha) Segaliud-Lokan F.R.

Species	Numbers of Trees in Size Classes Girth (ft.) / Diam (cm.)	6 / 58	7 / 68	8 / 78	9 / 87	10 / 97	10+ / 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S. leprosula		1	2	-	2	3	1	9
S. leptoclados		1	-	5	4	2	17	29
Others (7 species)		2	2	1	1	-	5	11
(Richetia)								
S. acuminatissima		-	-	-	1	-	2	3
(Selangan Batu)								
2 species		-	1	-	-	-	1	2
(Anthoshorea)								
S. agami		-	1	1	-	-	1	3
Dipterocarpus caudiferus		2	2	-	2	-	2	8
D. gracilis		2	2	1	1	-	2	8
Parashorea tomentella		11	7	5	5	3	12	43
Dryobalanops lanceolata		4	5	2	2	1	13	27
Non-dipterocarps (7 species)		2	1	1	1	2	3	10
Totals		25	23	16	19	11	59	153
Per 10 acres/4ha		14	13	9	11	6	33	86

Height measurements taken in RP 257 when the trees were felled are shown in Table 10.

Table 10. Height Measurements in R.P. 257

Species	(Heights Metres) Girth (ft) / Diam (m)	6-9 / 0.6-.96	10-13 / 97-1.15	14+ / 1.16+	No. greater than: Ft. 160 / M. 50	180 / 55	200 / 60
	Min	31	42	45			
P. tomentella	Mean	43	52	56	17	7	5
	Max	56	68	65			
	Min	40	43	43			
S. leptoclados	Mean	49	52	58	20	15	4
	Max	59	58	67			
	Min	29	44	43			
Dr. lanceolata	Mean	40	52	57	10	7	3
	Max	46	64	65			
	Min	36	-	-			
D. caudiferus	Mean	45	51(1)	45(1)	2	-	-
	Max	54	-	-			

This shows that canopy heights vary considerably (cf Figures 15-17). Maximum heights for the other species present were: *S. leprosula* 54m, *D. gracilis* 60m, *S. waltonii* 66m, *S. macroptera* 49m, *S. mecistopteryx* (1)40m , *S. agami* 46m, *S. smithiana* 40m, *S. acuminatissima* 56m, *S. almon* 45m, *S. parvifolia* 56m, *S. pauciflora* 56m, *S. superba* 55m, *S. hypoleuca* 37m, and of the non-Dipterocarps: *Duabanga moluccana* 50m, *Sindora irpicina* 34m, *Scaphium longipetiolatum* 48m, *Litsea firma* 46m, *Amoora cucullata* 54m, *Koordersiodendron pinnatum* 30m, and *Pentace chartacea* 37m.

RP 245/1, a climber cutting experiment (Chapter 6) consisted of 10 one hectare plots randomly placed in approximately 640 acres (259 ha) of the Kolapis area of Segaliud Lokan F.R. This is still on the Garinono Formation where red/yellow podsolic soils are developed on alluvium, low mudstone hills and mixed sandstone and mudstone colluvium. A summary of commercial species present prior to felling is given in Appendix 2, Table 6. The area is mainly low-lying and floristically the forest was akin to that described for similar areas in Sepilok. *Eusideroxylon* was again abundant and the species preferring moist sites, e.g. *S.mecistopteryx, D.applanatus, D.gracilis* were well represented, with local presence of e.g. *D.pachyphyllus* and *S.smithiana* associated with more leached, sandy soils. West of the Kolapis area strips and patches of land occur with leached whitish/yellow sandy profiles where *Dryobalanops beccarii* appears. Farther west, e.g. at Mile 60 on the Labuk Road, and near Telupid, old raised terrace deposits carry patches of forest characterised by this species. The *Parashorea tomentella* forest, with *Eusideroxylon* much scarcer and *S.parvifolia* with Selangan Batu more abundant, extends into the hilly land up to the ultrabasic mountains near Telupid. West of these mountains towards Paginatan the forests in the valley floors are characterised by *S.argentifolia* and on the hills by the *P.malaanonan/Dr.lanceolata* type (Type E). North of the Labuk River the *P.tomentella/Eusideroxylon* forest continues in the alluvial lowlands.

Plots made in the vicinity of the camp site on the Lokan River inside the Orang Hutan Sanctuary area confirmed the presence of the same form of forest on low-lands well into the southern part of the Lokan Peneplain. On low mudstone and shale hills and the slopes of low dissected terraces *Eusideroxylon* is locally abundant. On podsol soils developed on the tops of the terraces it is absent and the species more tolerant of poorer, leached, soils are present, e.g. *Dipterocarpus confertus, D.pachyphyllus, Shorea exelliptica* (SB), *Fagraea gigantea* and species of *Santiria* and *Dacryodes* etc. In moister places *P.tomentella* and the common Rubroshorea species are present with *Shorea seminis* (SB), *Hopea nervosa* etc. Figure 5 illustrates the margin of *D.warburgii* swamp forest (4.3(h)) with this forest type.

In the lower Kinabatangan *Shorea leprosula* is locally abundant on low-lying areas within this forest Type and some moist areas have dense stands of *S.macrophylla* (a species often saved from felling as it is an important illipe nut tree) in association with *Eusideroxylon*. On low mudstone hills in Tenegang F.R. *Diospyros discocalyx* is frequent as a large tree and up-river at Pin, Balat and Kuamut *Koompassia excelsa* is abundant on low-lying land. Throughout the Kinabatangan area however *P.tomentella* is generally the most frequent species over wide areas.

Appendix 1, Tables 3 and 4 summarises an enumeration in Kuamut F.R. on the Labang Formation (Fox 1969 b). The main differences from the Segaliud-Lokan data are lower abundance of *P.tomentella* more *S.leptoclados*, absence of *Dr.keithii* (this is present in the lower Kinabatangan and Segaliud-Lokan forests as a stream side tree in alluvial areas where rounded quartz pebbles are present in the profile); absence of *D.grandiflorus* a high ridge species when found far from the sea; high proportion of *S.macrophylla* common on low-lying alluvial land; stronger representation of Rubroshorea species more typical of sandy soils: *S.beccariana*, *S.smithiana*; increased representation of the selangan batu species, apart from *S.superba*, due to greater hilliness of the area; and similarly a lower proportion of *Eusideroxylon*.

A random sample of 17 one hectare plots in 700 ha of the 1971 coupe area of Chung Chao Loong's concession in Kuamut F.R., south of the enumeration sample, and on an area marginal between the Labang and

and Chert Spilite Formations, is summarised in Appendix 2 Table 7. In this area *S.pauciflora* was locally much more abundant than *S.leptoclados* with 10 per cent of the stems over 5ft girth (48 cm diam) but the four species: *P.tomentella*, *Dr.lanceolata*, *S.leptoclados*, and *D.caudiferus* accounted for 38 per cent of this class. Further south the Chert Spilite Formation contains more *P.malaanonan*.

Type B is of more importance in terms of total land in Forest Reserves than Type A. As the soils, mainly sedimentary, are less rich the areas of this type are likely to remain under forest management for a longer time than those of Type A. Development of the low-lying alluvial forest areas near the major rivers is also hindered by frequent flooding. The main forest reserves of commercial importance containing Type B forests are Segaliud-Lokan, Kretam, Sapagaya, Tenegang, Kuamut, and Pinangah, and the areas are characterised by comparatively high rainfall and gently undulating to moderately hilly land.

Type C. *Rubroshorea/Eusideroxylon zwageri* Forest

This term may be used to describe those forests in which the Rubroshorea species form the majority of large trees and where the *Parashorea* species, *Dipterocarpus* species, and *Dryobalanops lanceolata* are comparatively less abundant. *E.zwageri* is a common associate of *S.parvifolia*, *S.leprosula*, *S.mecistopteryx*, *S.macroptera*, *S.oleosa* and *S.argentifolia* etc., in the Tawau region.

Some 14 Rubroshorea species were represented by 3 or more stems and comprosed 39 per cent of the trees of 6ft girth (58 cm diam) and over, in a set of 23 randomly placed 1-ha plots in about 500 ha of forest on the Karito Estate. This area was one of the last areas of little slope, with well drained loamy soils developed on volcanic olivine basalt, cut over prior to agricultural development. A summary stand table of this set of splots is given in Appendix 2, Table 8. *E.zwageri* was particularly abundant and comprised 26 per cent of the stand, as defined above. The common Rubroshorea species in this area were *S.mecistopteryx*, *S.macrophylla*, *S.parvifolia*, and *S.ovalis*. *Dr.lanceolata* was not represented and the genera *Parashorea* and *Dipterocarpus* were scarce, as was *S.leptoclados*, in this area the least common of the Rubroshorea species.

Karito Estate is on the western Tiger exposure of basalt; unfortunately detailed information from that of the Quoin area obtained by G.H.S. Wood (Paton 1963) is not now available but studies on remaining, hilly, areas show the forest to be of Type E. *P.malaanonan/ Dr.lanceolata* (see below) with *S.leptoclados* present. The summary data given in Paton reported *Eusideroxylon*, *P.malaanonan*, *S.leptoclados*, and *Dr.lanceolata* as common, with *Dipterocarpus* absent. The floristic history of these areas [illegible] the study but it would seem from available evidence that the predominance of the Rubroshorea group extends westward into lower central Sabah, whereas the grouping *P.malaanonan*,/*S.leptoclados*/*Dr.lanceolata*, though often present on hills, is more akin to Types A and B in the east of the State.

Locally *Koompassia excelsa* is common on the basalt and a striking stand of this species stood over young cocoa until recently at Tiger Estate (this is illustrated in Plate 9 of Wilford 1967 a). Much of the Umas Umas area of Kalabakan F.R., the lower part on the Sebatik Formation of sandstones and shales, and the upper on the similar Umas Umas Formation with additional mudstone, also carries Rubroshores/*Eusideroxylon* forest with *Eusideroxylon* and *Koompassia excelsa* abundant on low-lying alluvial areas. Plots in the vicinity of Umas Umas camp (R.P. 275) are particularly rich in medium sized trees of *S.parvifolia*.

Further north in areas worked over during 1968-71, e.g. R.P. 307A (Appendix 2, Table 3) *Dillenia borneensis* is locally abundant as a main canopy, but not emergent species. In these areas, to be discussed in more detail with respect to species relationships later, *Shorea parvifolia* is the most abundant Rubroshorea. This dominance is believed to occur westwards into the forests of Brunei and Sarawak. Ashton (1964 etc) used this species to distinguish between the main forms of dipterocarp forest in Brunei.

Similar forests existed on Sebatik Island, and the Merotai area (F.D.A.R. 1947) and probably extend into northeastern Kalimantan. Two to three stems per acre (5-7/ha) of *Eusideroxylon* of 44 cm diam and larger, are an average for these forests, including hillsides. *Dr.lanceolata* is abundant in some areas, *Parashorea* (mainly represented by *P.tomentella*) and *Dipterocarpus* less so.

The area sampled by R.P. 307A was worked over in 1968-69. The 2.5 per cent sample estimated per acre volume of sound commercial stems as 2234 cu ft/acre

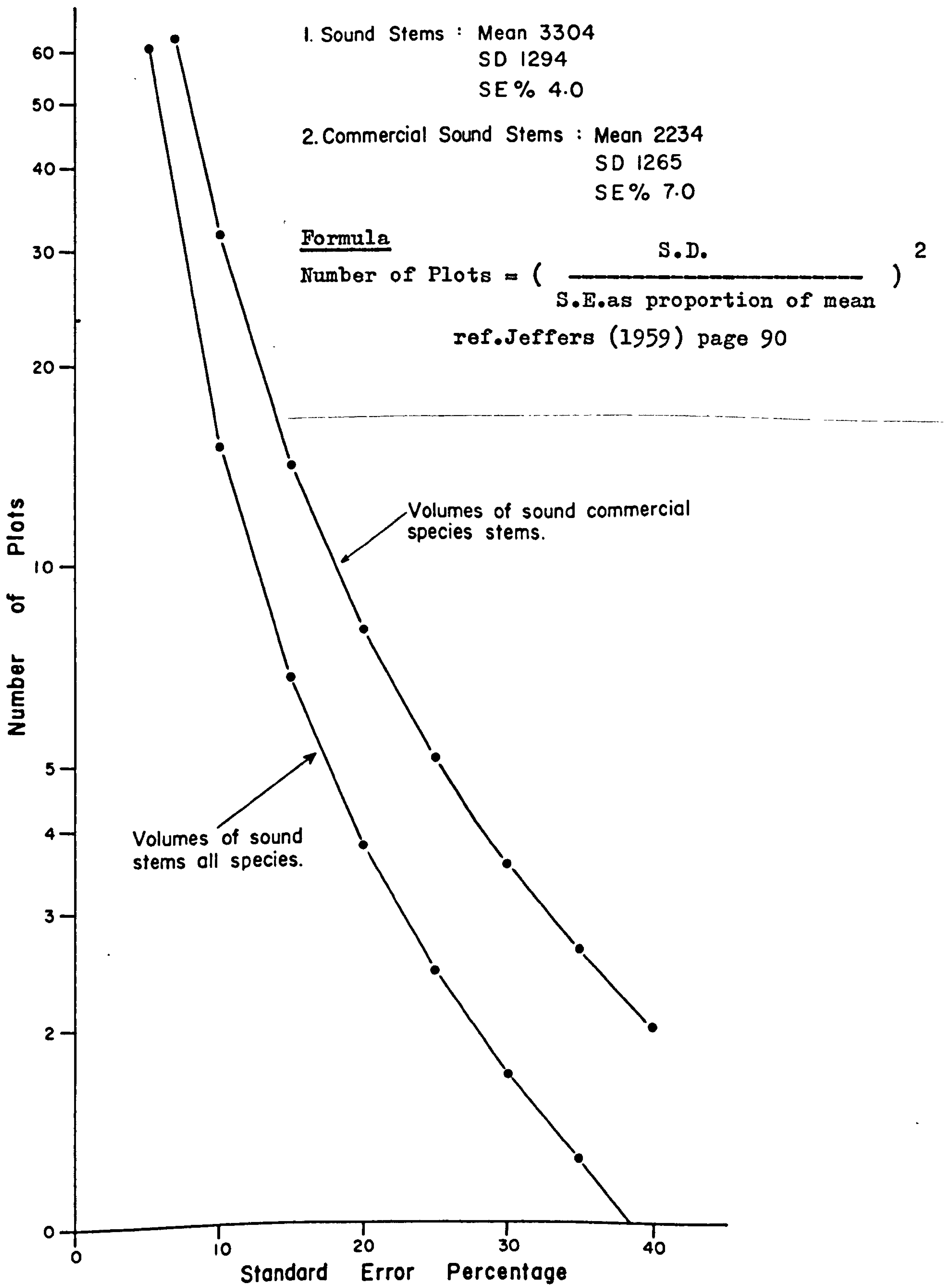
(199 cu m/ha) with S.E. per cent 7.0, and of all sound stems at 3304 cu ft/acre (294 cu m/ha) S.E. per cent 4.0. Figure 18 gives the efficiency with respect to standard error percentage of different numbers of plots for these two parameters, and Figures 19-22 illustrate the relationships of stems, basal areas and volumes for the 63 plot sample. There was a significant correlation between numbers of stems and basal area, and the best stem volume relationship (Figure 22) was that for sound commercial volumes and stems (r=0.800). Actual outturn for this area achieved by Wallace Bay Co. was 1519 cu ft/acre (135 cu m/ha) so that the enumeration overestimated production by about 50 per cent, a figure often used to allow for defect, felling damage etc., (Francis 1966). By individual square mile compartments outturn compared with estimates as follows:

Compartment	Outturn	Enumeration	SE per cent	Difference	Diff per cent
17	1384	2874±420	15	+1490	52
16	1695	2418±268	11	+723	30
21	1543	1920±258	13	+377	20
20	1425	1624±204	13	+199	12

A 16 plot sample in Compartment 23, of the 1969 coupe, adjacent to this area was more hilly and contained less *Eusideroxylon*; more *S.laevis* (SB); rather more of the Rubroshorea species more characteristic of hilly areas, e.g. *S.parvifolia, S.smithiana* and less *S.leptoclados* and *S.leprosula*. Similar proportions of *P.tomentella, Dr.lanceolata, Eugenia* species and *Dillenia borneensis* were present, however. This sample, R.P.307B, is summarised in Appendix 2, Table 9.

FIGURE 18 R.P.307A KALABAKAN FOREST RESERVE

Numbers of Plots necessary to achieve different Standard Error Percentage levels based on a 63 plot sample in 4 square mile area.

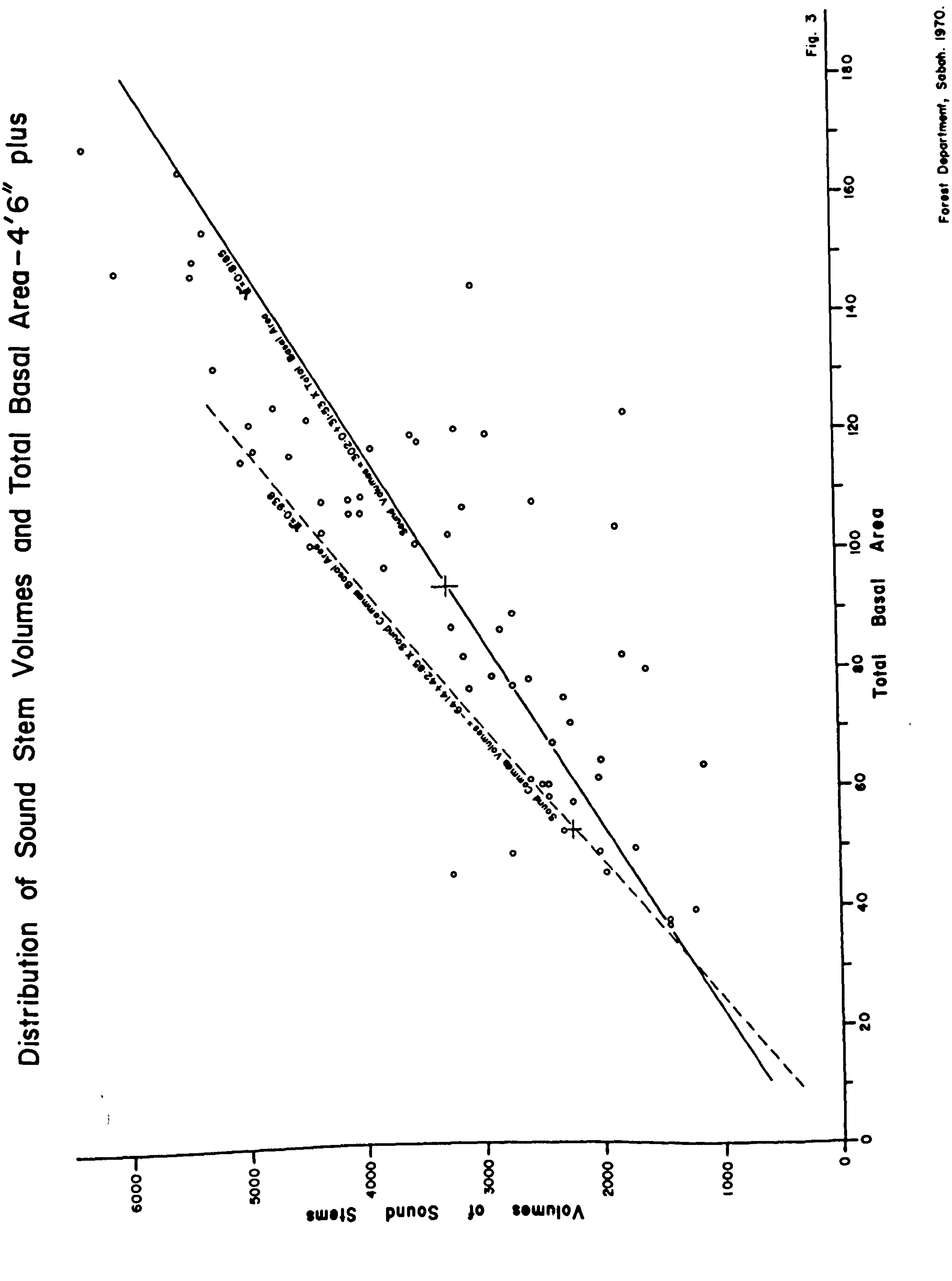


(Vertical axis is number of plots, log. scale)

Forest Department, Sabah 1970.

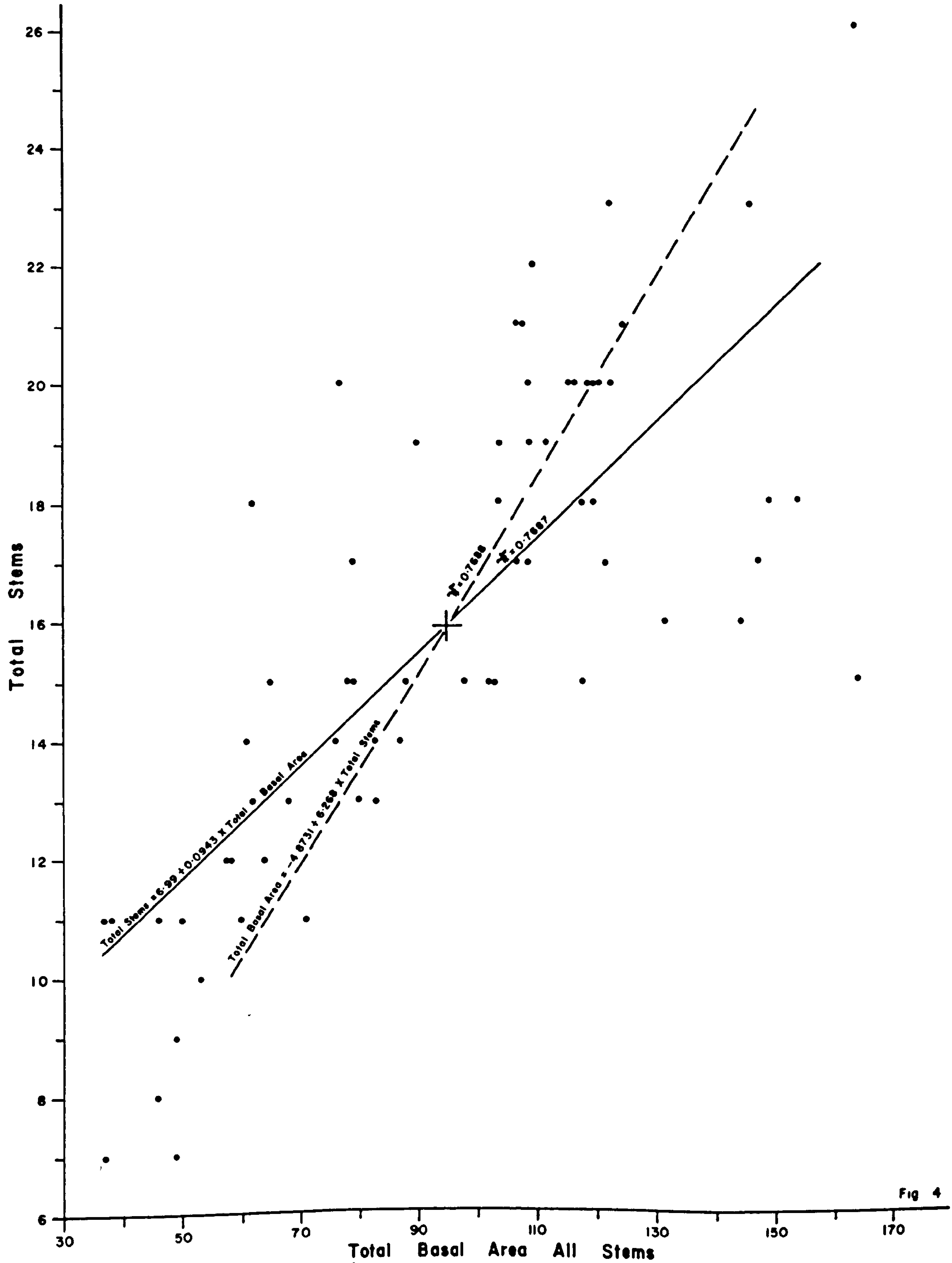
FIGURE 19 R.P.307A KALABAKAN FOREST RESERVE

Distribution of sound stem volumes and total basal area, for stems of 4.5 feet girth and over, 63 plots of one acre.



<u>FIGURE 20</u> R P. 307A <u>KALABAKAN F.R.</u>

Distribution of Total Stems and Total Basal Areas — 4′ 6″ plus



(Vertical axis is total stems)

Forest Department, Sabah 1970

FIGURE 21 R. P 307A KALABAKAN F.R.

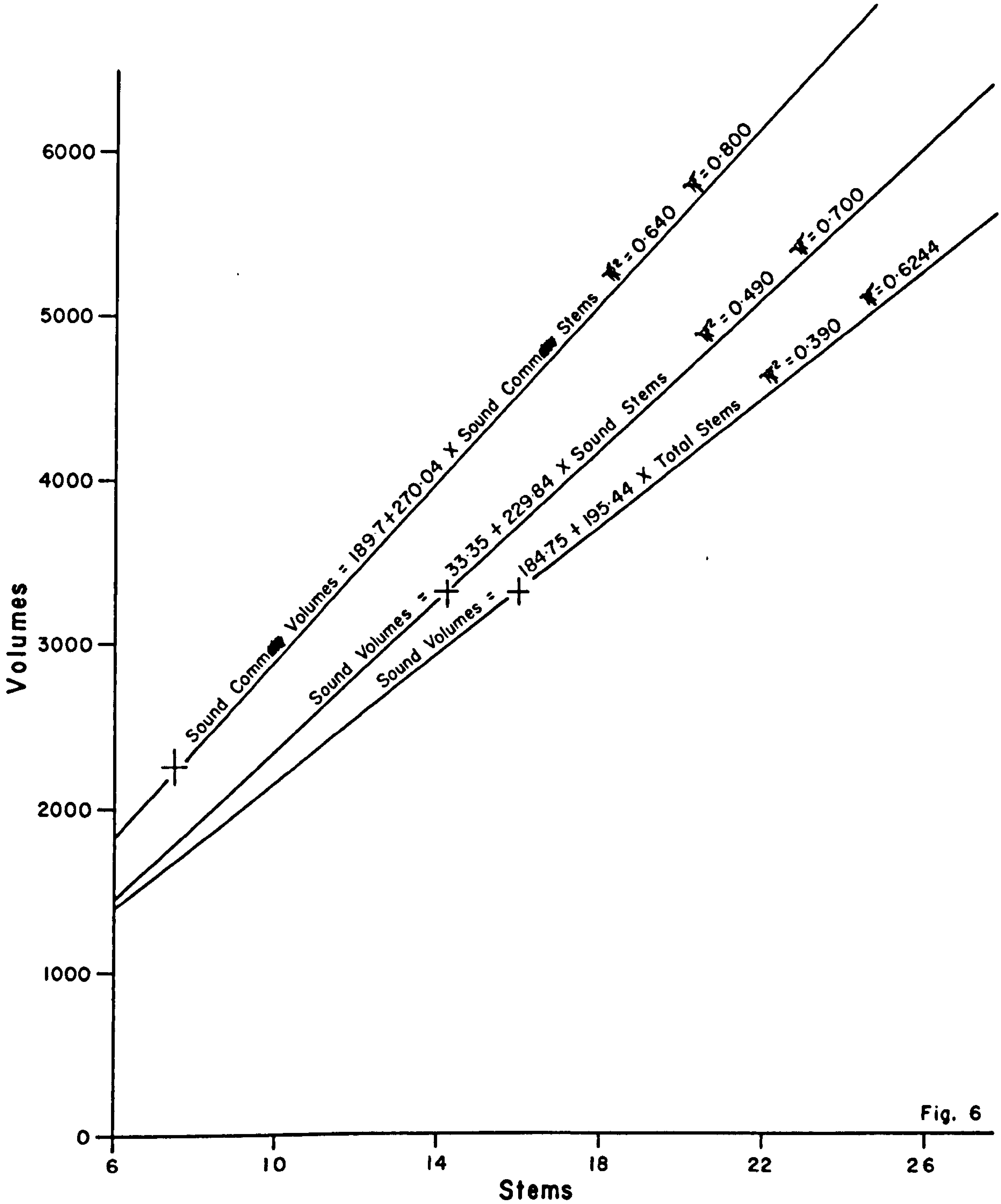
Distribution of Sound Stems and Sound Basal Area

(Vertical axis is sound stems)

Forest Department, Saboh 1970

FIGURE 22 Kalabakan F.R.

R. P. 307A
Regression of Volumes on Stems



Forest Department, Sabah. 1970.

R.P. 271A may be taken as representative of the former forest in the lower Umas Umas River drainage area (Appendix 2, Table 10). *Eusideroxylon* was again abundant and other non-dipterocarps reaching 6 ft girth (58 cm diam) or larger included species of the genera *Hydnocarpus, Parinari, Xanthophyllum, Baccaurea, Lithocarpus, Eugenia, Sandoricum, Sindora, Alstonia, Notaphoebe, Sterculia, Parishia, Canarium* and *Artocarpus*, as well as the more common Leguminosae, e.g. *Dialium indum, Koompassia excelsa* and *Cynometra elmeri*. Other species present in larger sizes were *Afzelia borneensis, Castanopsis elmeri, Pentaspodon motleyii, Alangium javanicum, Cryptocarya tawaensis,* and *Elmerillia mollis*.

Further west in Kalabakan F.R. in the Brantian area, where the Chert Spilite Formation extends southwards the forest is of the same Type. R.P. 303 was a series of randomly placed circular 0.4 ha plots in the northern half of Compartment 442 (Appendix 2, Table 11). Species in this area will be described below. R.P. 245/2, a set of 10 one hectare plots, was placed in the same area. Both samples averaged 5 stems per acre (12.4/ha) of Rubroshorea species of 6 ft girth and over (58 cm diam+). In the hillier parts of this area *Dipterocarpus confertus, D.verrucosus, S.multiflora* Ri, *S.laevis* SB, and the Rubroshorea species *S.matcroptera, S.smithiana,* and *S.pauciflora* were more abundant, similar to the 1972 coupe area of Umas Umas described below as Type D Rubroshorea/ *Dipterocarpus*. *S.parvifolia* was less abundant in the Brantian area, other important Rubroshorea species included *S.mecistopteryx, S.oleosa,* and, locally, *S.ovalis, S.leprosula* and *S.pauciflora*. *Koordersiodendron pinnatum* was fairly common in this area.

S.parvifolia and *E.zwageri* were probably the most abundant species in the now regenerating areas in the lower Kalabakan on sedimentary mudstones, shales and sandstones of the Kalabakan Formation. Inland in the vicinity of Luasong Camp a large area of forest in steep dissected country threaded with streams, where quartz pebbles are frequent in a red brown matrix of sandy clay soil, *Dryobalanops keithii* is exceptionally abundant. The enumeration referred to earlier (Appendix 1, Tables 5 and 6) passed through this area and 2 plots of 10 acres (4 ha) were also established within it. R.P.271F (Appendix 2, Table 12) felled in 1969 contained 32 stems/acre (7.9/ha) of *Dr.keithii* of 6ft girth and larger; 3.6 (8.9) of *E.zwageri* and 1.9 (4.7) of Rubroshorea species, the most abundant in larger sizes being *S.pauciflora* and *S.oleosa*. *Dipterocarpus caudiferus* and *Dr.lanceolata* were also well represented but the genus *Parashorea* was scarce. This plot was near to Luasong Camp on gently undulating land. R.P.353 an increment plot in a large Virgin Jungle Reserve, summarised in Table 11, and given in more detail in Appendix 3, Table 3, on more hilly ground, but still well watered, had fewer large trees but a higher proportion of them are of *Dr.keithii*. Here *E.zwageri* is scarce, Rubroshorea species, though similar, are represented by fewer large trees, and both *P.malaanonan* and *P.smythiesii* are well represented, the latter being a frequent stream side tree in the Luasong area generally. Gregariousness of *Dr.keithii* is illustrated in Figure 23 by graphical presentation of standard errors of the Luasong enumeration data (i.e. Appendix 1, Table 5) for individual species.

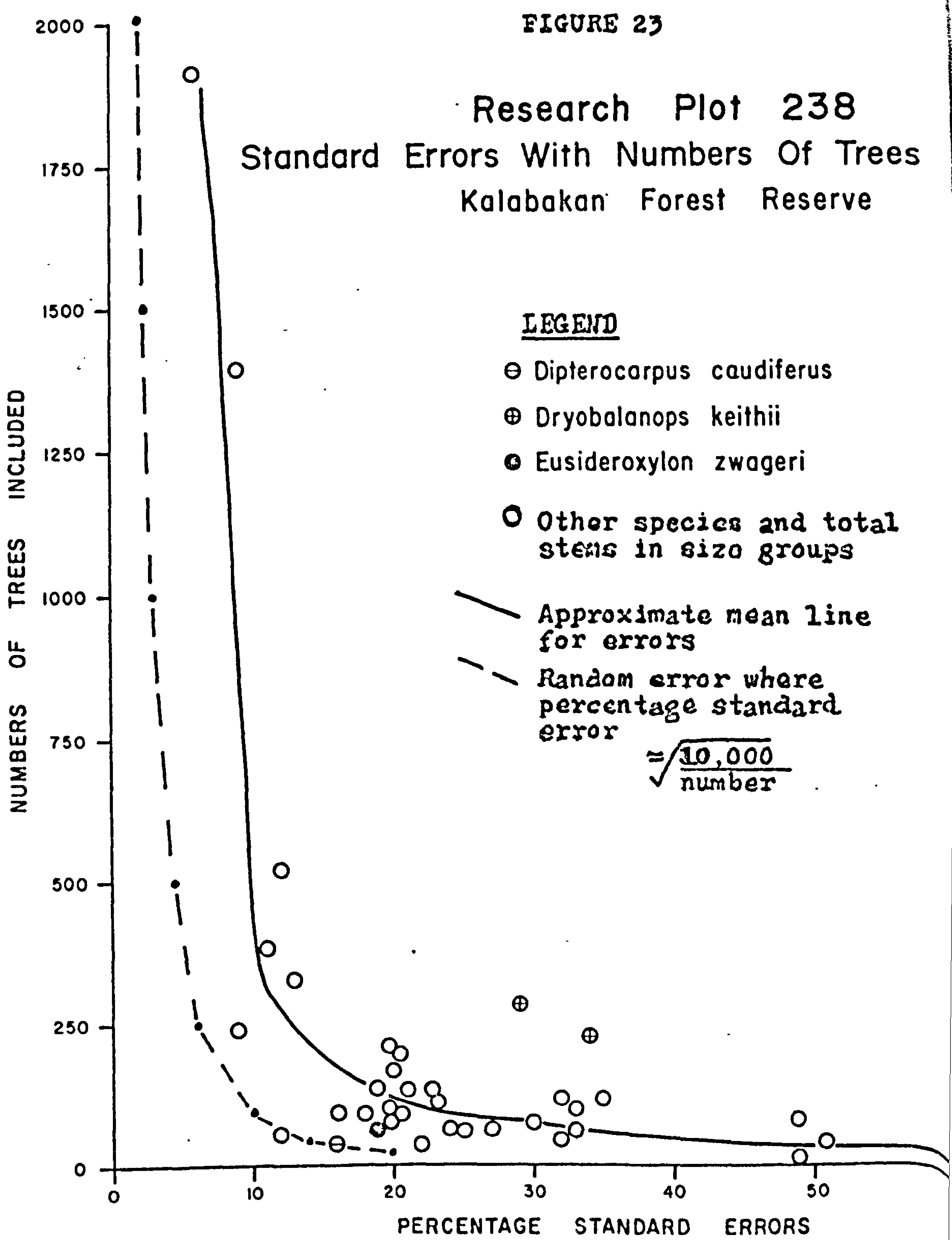


FIGURE 23
Research Plot 238
Standard Errors With Numbers Of Trees
Kalabakan Forest Reserve
LEGEND
Dipterocarpus caudiferus
Dryobalanops keithii
Eusideroxylon zwageri
Other species and total stems in size groups
Approximate mean line for errors
Random error where percentage standard error ≈ $\sqrt{\frac{10,000}{number}}$
NUMBERS OF TREES INCLUDED
PERCENTAGE STANDARD ERRORS
2000
1750
1500
1250
1000
750
500
250
0
0
10
20
30
40
50

By comparison both *D.caudiferus* and *E.zwageri* were more scattered in their distribution. Species distribution within R.P. 353 is discussed and illustrated (Figure 31) later.

Table 11. Stand Table R.P. 353 10 acres (4ha) Kalabakan F.R. (Luasong).

Species	Numbers of Trees in Size Classes Girth (ft) / Diam (cm)	6 / 58	7 / 68	8 / 78	9 / 87	10 / 97	10+ / 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S.leptoclados		-	-	1	1	1	-	3
S.oleosa		3	-	-	-	-	-	3
Others: 3 species		-	1	-	1	-	1	3
(Richetia)								
4 species		2	1	1	3	-	-	7
(Anthoshorea)								
S.agami		1	-	-	-	-	-	1
Dipterocarpus caudiferus		3	-	-	1	-	1	5
D. species		-	-	-	-	2	1	3
Parashorea malaanonan		2	4	7	6	-	2	21
P.smythiesii		1	3	1	3	-	1	9
Dryobalanops keithii		20	15	13	5	3	2	58
Dr.lanceolata		-	-	1	-	-	-	1
Non-dipterocarps		6	4	3	-	-	1	14
Totals		38	28	27	20	6	9	128

A series (R.P.256) of one acre (0.4ha) plots placed along the Luasong/Gunong Rara Road, which runs north into the Kuamut River drainage, show that the Rubroshorea/*Eusideroxylon* type, with *Dr.keithii* in the valleys, gradually changes to Type E, *P.malaanonan/ Dr.lanceolata* forest. At Mile 18-20 *Eusideroxylon*, though present, is scarce, *Dr.lanceolata* is also scarce, there are few *Parashorea* trees, and *P.smythiesii* is the most abundant. *Dipterocarpus caudiferus* is present and of non-dipterocarp species *Eugenia* species are abundant at lower elevations and *Scaphium longipetiolatum* in the hills. The most abundant Rubroshorea species are *S.parvifolia*, *S.leprosula, S.leptoclados, S.ovalis* and *S.pauciflora* (Table 12).

Table 12. Stand Table R.P. 256 10-1 acre Plots (4ha) Mile 18.5-19.5 Luasong/Gunong Rara Road, Kalabakan F.R.

Species	Numbers of Trees in Size Classes Girth (ft) / Diam (cm)	6 / 58	7 / 68	8 / 78	9 / 87	10 / 97	10+ / 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S.leprosula		2	2	1	1	-	2	8
S.leptoclados		-	2	-	1	-	3	6
S.parvifolia		2	-	1	3	3	2	11
S.pauciflora		1	-	-	1	-	3	5
S.ovalis		-	1	-	1	2	1	5
Others 5 species		3	1	1	1	-	5	11
(Richetia)								
4 species		1	3	-	1	1	1	7
(Selangan Batu)								
2 species		-	2	-	-	-	-	2
Dipterocarpus								
(5 species)		1	2	4	2	1	1	11
Parashorea malaanonan		1	3	-	-	-	-	4
P.smythiesii		3	1	-	1	-	-	5
Dryobalanops keithii		2	4	2	3	2	3	16
Dr.lanceolata		-	-	-	1	-	-	1
Other Dipterocarps		3	2	-	1	-	-	6
Non-Dipterocarps		13	9	15	5	2	2	46
Totals		32	32	24	22	11	23	144

The main commercial forests of this Type are in the Kalabakan area, as the description has emphasised. As markets have improved higher yields have been taken from these forests, and though not as valuable as Type A they certainly compare favourably with the forests of Type B.

Type D. Rubroshorea/*Dipterocarpus* Forest

The forests described by Nicholson (in Paton, 1959) on the Grading family of soils were deficient in the otherwise common Rubroshorea *S.leptoclados* and the genus *Parashorea*, though *P.smythiesii* was present. The whole of the coastal depositional platform of the Tawau/ Semporna area is placed in this Type, from east of the volcanic and intrusive igneous area north of Tawau across the lower Kalumpang and eastwards to the Mt. Pock volcanic area. This type is characterised by the presence of a number of *Dipterocarpus* species: *D.applanatus, D. acutangulus, D.pachyphyllus, D.verrucosus, D.humeratus, D.grandiflorus, D.confertus, D.palembanicus*, and *D.kerri* all being known from the Apas-Balung region. Rubroshorea species present include *S.parvifolia, S.pauciflora, S.leprosula, S.oleosa* and *S.ovalis*. The soils are generally sandy latosols, with, in places, patches of the Kubota podsols (cf 7.1 (a) above) which when not highly leached, carry the same form of forest.

A profile of the forest in such an area is illustrated in Figure 24 where *D.acutangulus* and *Heritiera simplicifolia* form the emergent canopy at 35-50 m while *S.multiflora* (Ri) and smaller *D.acutangulus* trees form the main canopy at 30-37 m. Unfortunately little remains of this forest Type as the main Apas-Balung area has all been logged off and is destined for agricultural development. Patches of, often almost pure, *Dipterocarpus* forest may be seen along the Semporna Road, on the lower slopes of Mt. Wullersdorf; other residual areas occur on the generally poorer soils, e.g. at Baradaya F.R., Pang Burong F.R. etc.

Northwards up the Kalumpang valley towards Kunak *S.leptoclados* and the *Parashorea* species become abundant, but the Rubroshorea/*Dipterocarpus* Type extends up the broader ridges into the hills. In the lower areas described in Paton (1959) *Eusideroxylon, Eugenia* species, *Koompassia excelsa* and *Castanopsis* were present.

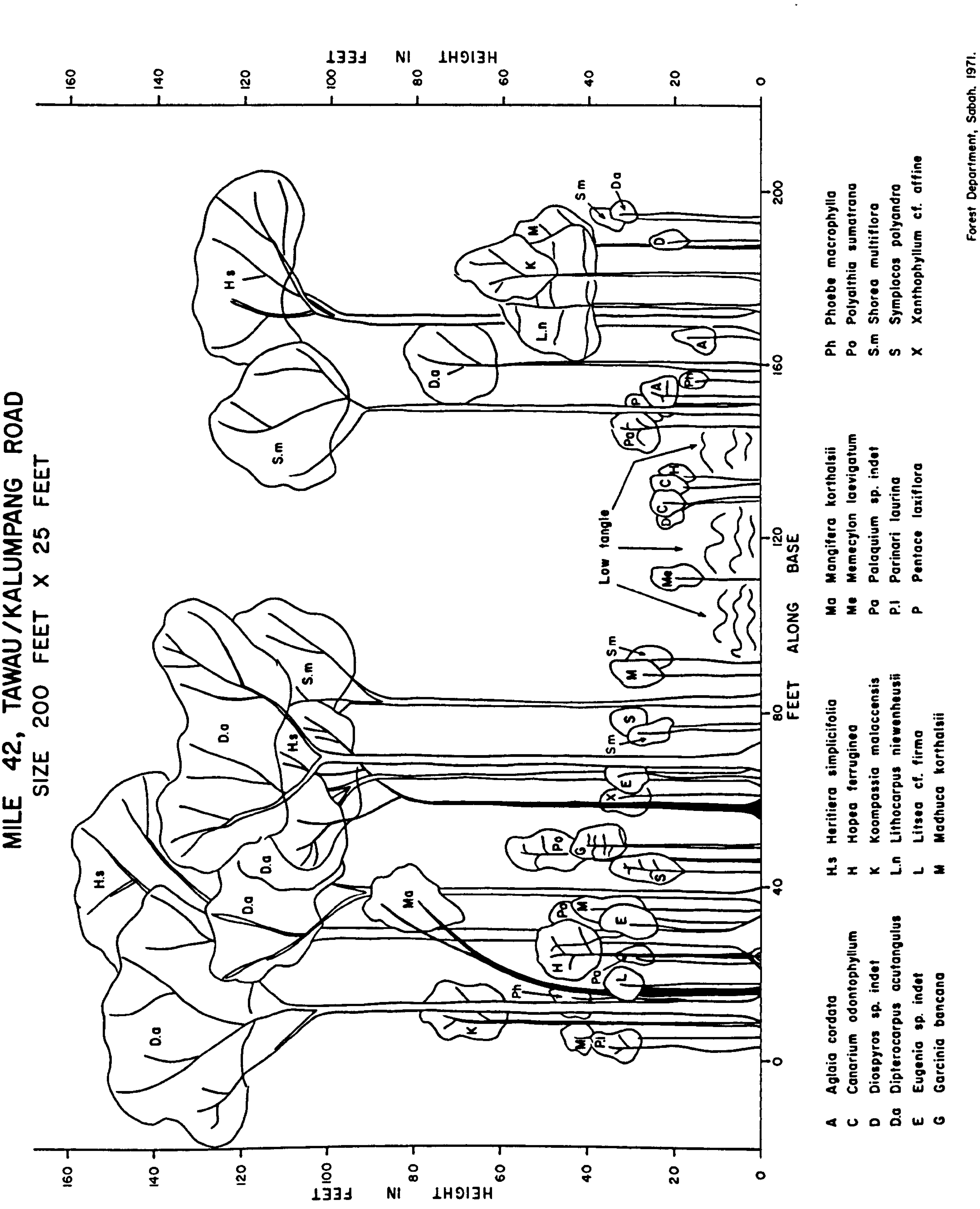


FIGURE 24 PROFILE DIAGRAM

TYPE D FOREST Rubroshorea/Dipterocarpus forest at Mile 42 Tawau/Kalumpang Road

Though these forests were described as often having a higher basal area than the *Parashorea* forests (Types A, B and E) the larger trees rarely exceeded 12ft girth (116 cm diam) and this is the main distinction from the forests of Type C, coupled with less *Dipterocarpus* in the latter. The stands described carried higher numbers of stems and the canopy was said to be more uniform. In this sense the Type is most similar to Type G *Dipterocarpus*/Richetia.

Elsewhere in the Tawau area the Rubroshorea/ *Dipterocarpus* Type occurs on the lower slopes of Mt. Andrassey where yellow/brown loamy soils of the Tajong series are developed on andesite ash material. Locally within the Rubroshorea/*Eusideroxylon* Type where *Dipterocarpus* is abundant Type D may be typical: an example occurs in the upper Umas Umas valley where *D.verrucosus* is abundant with the Rubroshorea species *S.argentifolia*, *S.ovalis* and *S.smithiana* in the 1973 coupe area; and may well occur as the dominant type over wider areas at present placed in Type D. *Dipterocarpus* species are particularly abundant in the Serudong and Selimpopon areas of southern Kalabakan F.R.

Localised areas around Sandakan Bay may be placed in this Type, e.g. *D.palembanicus* with *S.oleosa* (Ru) and *S.isoptera* (SB) at Sekong Kechil. At the boundaries with ultrabasic and sedimentary formations in the Telupid area *D.geniculatus*, *D.confertus*, *S.argentifolia* and *S.ovalis* are found along the trail to Karamuak with *S.argentifolia* extending westwards across central Sabah. On ultrabasic colluvium in the lower foothills *Heritiera simplicifolia* is locally abundant with *Dipterocarpus* species. North of Sandakan *Dipterocarpus* species occur extensively in Bongaya F.R. and locally elsewhere, but much of this forest is on sandstone of the Bongaya Formation and is of Type G. Some of the hills of this general area carry forest marginal between Types B and G, e.g. *D.confertus*, *D.stellatus*, *S.macroptera*, *S.smithiana* and *S.ovalis* occur with *Hopea beccariana* and *S.hypoleuca* in the Sugut area.

West of Sandakan in the higher parts of inland Deramakot F.R. stands of *D.acutangulus*, *D.grandiflorus*, *S.macroptera* and *S.pauciflora* occur above Type B on shale hills. West of the Kuamut River, inside Kuamut F.R., e.g. at Sungei Bangon, stands of *D.confertus*, *D.kerri*, *D.pachyphyllus*, *S.ovalis*, *Scaphium longipetiolatum*, *Heritiera simplicifolia* and *Eusideroxylon zwageri* are present on gentler dip slopes of the sandstone cuestas.

Residual forests in central Sabah are of a similar type. Between Batu Lunguyon in the upper Sook valley and Lanas in the headwaters of the Kinabatangan River, *S.argentifolia* with *Eusideroxylon zwageri* on lower slopes are mixed with stands of *D.confertus*, *D.pachyphyllus*, *D.humeratus*, *S.beccariana* (Ru), *S.smithiana* (Ru), *Dyera costulata*, *Shorea ochracea* (An) and with *S.laevis* (SB) on steeper slopes. These forests occur on sedimentary rocks of the Sapulot Formation and are similar to forests in the Witti Range, east of Sook, and also east of Nabawan in the Maitland Range in the southern headwaters of the Kinabatangan. In the latter area species of *Dipterocarpus*, the Rubroshorea species *S.oleosa*, *S.macroptera*, *S.argentifolia* and *Heritiera simplicifolia* are all common.

Much of the land area now affected by shifting cultivation probably fell in this forest Type; relict isolated patches of *S.argentifolia*, *S.parvifolia* and *S.oleosa* in the lower hills of the Crocker Range east of Penampang, support this supposition. Forests on ultra-basic soils at Ranau (Figure 10) are of the same general Type with *Dipterocarpus ochraceus*, *D.confertus* and the Rubroshorea species *S.almon*, *S.ovalis* and *S.rubra* common, but at higher altitudes and with more Fagaceae present. The forest at Beaufort Hill (Appendix 2, Table 1) in the south-west is essentially similar, but with elements of Types F and G present.

Though Type D is fairly widespread it is less important in the context of regeneration than the three described previously. On the lower areas access and population pressure are increasing the conversion of the type to agriculture despite the generally poor soils while much of the interior forests have been, or are being, destroyed by shifting cultivation. Restricted logging in hill areas where Type B or C occupy gentler slopes or valleys may well extend logging into more of the Type D areas. In the past such areas, e.g. Serudong, Silimpopon, have been less attractive to logging interests as the *Dipterocarpus* component often produces sinking logs.

Type E. *Parashorea malaanonan/Dryobalanops lanceolata* Forest.

This Type is primarily found on steeper slopes than the others described thus far and may be considered as marginal between lowland and the hill dipterocarp Types which follow (i.e. Types F and G). In eastern

Sabah this Type is present in Silabukan F.R. on mixed volcanic and sedimentary soils where *S.leptoclados* and *Eusideroxylon zwageri* are common associates, and presence of these is one of the main distinctions between Types A and E in this area. A telascope survey in Block 42 near Pangaruwon River in Silabukan F.R. sampling 70 acres (28 ha) gave the following:

Stems/acre	B.a/acre	No.8ft.g.+	B.a.8ft.+
136	147	9.1	78

This indicates more large trees than similar surveys in Type A stands in the vicinity. Table 13 summarises stocking data for commercial species only in six plots of 1 ha(2.5 acres) in the area felled in 1969 (RP 245/3) in the Bagahak Range area of Silabukan F.R. *Eusideroxylon* was absent in this rather hilly area and of particular note are absence of *Dipterocarpus* species other than *D.caudiferus*, predominance of *S.leptoclados* of the Rubroshorea, absence of selangan batu (though Type F is locally represented by *S.laevis* within the reserve), and abundance of Richetia mainly *S.hopeifolia*, *S.faguetiana*.

Table 13. Stand Table RP 245/3 Silabukan F.R. 6ha

Species	Numbers of Trees in Size Classes Girth(ft) Diam(m)	6 58	7 68	8 78	9 87	10 97	10+ 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S.argentifolia		-	-	1	-	-	-	1
S.leprosula		1	3	1	3	-	-	8
S.leptoclados		3	3	8	7	4	2	37
S.oleosa		2	-	-	-	-	-	2
S.parvifolia		-	1	-	-	-	-	1
(Richetia)								
3 species		2	3	2	7	7	2	23
Dipterocarpus caudiferus		1	2	3	-	-	1	7
Parashorea malaanonan		1	3	3	3	2	3	15
Dryobalanops lanceolata		3	1	3	5	2	3	17
Hopea beccariana		-	-	-	1	-	1	2
Totals		23	16	21	26	15	12	113
Per 10acres/4ha		15	11	14	17	10	8	75

This area had representation of smaller trees 1-5 ft girth (10-57 cm diam) of commercial species totalling 19.7/acre (48.6/ha) with 27 per cent Richetia, 22 per cent *S.leptoclados*, 13 per cent *P.malaanonan* and 10 per cent *Dr.lanceolata*. As with other *Parashorea* forests canopy was irregular and distribution of large trees patchy but with sizes well over 16 ft girth (166 cm diam) Of the non-dipterocarps present *Sympetalandra borneensis* was particularly abundant, with species of Anonaceae in the understorey.

S.leptoclados is common in parts of Kalumpang F.R. north of Type D, on the Kalumpang Formation and is also abundant on remaining basalt in the Quoin area and on andesite, dacite etc. in the Tawau Hills F.R. with the two type species. Nicholson (in Paton 1959) reported the same form of forest on Kawa soils developed on intrusive doleritic rock. Locally very large trees were found in the Quoin area (e.g. a *Shorea superba* SB of 32 ft girth (310 cm diam) at 5 m from the ground with total height of 76 m), but relatively short boles were attributed to the lack of a competing main storey; blanks with climber tangles were frequent throughout the area of basalt soils. Mean values for 11 half-acre plots on basalt soils showed total numbers over 1ft g (10 cm diam) as 145/acre, with B.a. 170 sq.ft/acre of which 31 were dipterocarps and 8.4/acre over 8ft g of which 6.5 were dipterocarps. *Dipterocarpus* was absent, except as small trees. Recent plots established across Quoin and Bald Hills, both basalt, are summarised here, (Table 14a, b).

Table 14a. Stand Table Quoin Hill 11 Plots Totalling 1.1 acres (0.45 ha).

Species	Numbers of Trees in Size Classes Girth (ft) Diam (m)	6 58	7 68	8 78	9 87	10 97	10+ 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S. leptoclados		-	-	-	-	-	2	2
Parashorea malaanonan		-	1	1	3	1	1	7
Dryobalanops lanceolata		1	-	1	-	2	4	8
Anisoptera costata		-	-	-	-	1	-	1
Non-Dipterocarps		2	-	-	-	-	-	2
Totals		3	1	2	3	4	7	20
Per 10acres/4ha		27	9	18	27	36	64	181

Table 14b. Stand Table Bald Hill 7 Plots Totalling 0.7 acres (.28 ha)

Species	Numbers of Trees in Size Classes Girth (ft) Diam (m)	6 58	7 68	8 78	9 87	10 97	10+ 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S. leptoclados		-	-	-	1	1	-	2
S. leprosula		-	-	1	-	-	-	1
S. pauciflora		-	-	-	-	1	-	1
Parashorea malaanonan		-	-	-	1	1	-	2
Dryobälanops lanceolata		-	-	1	1	1	-	3
Non-Dipterocarps		1	1	-	-	-	-	2
Totals		1	1	2	3	4	-	11
Per 10acres/4ha		14	14	29	43	57	-	157

Other dipterocarp species present in these areas but not included in the samples were *S. macroptera* Ru, *S. superba* SB, *Parashorea smythiesii*, *Hopea beccariana* and *Dipterocarpus applanatus*, the latter as a small tree only.

Appendix 2, Table 13 summarises data for 10 plots of lacre (0.4ha) in the Tawau Hills F.R. representing a random sample in 4115 acres (1665 ha) of the 1969 coupe of Gaya Timber Co. This area, long considered an area of hill protection forest on highly erodable dacite and andesite hills from 170-300 m altitude, contained variable stands in alluvial valleys, on steep slopes and high crests. The latter higher up and outside felling areas were not sampled but contained forest of Type F. As an aid in suggesting high girth limits for felling control to minimise erosion yield estimates were made according to various levels of minimum felling size (Figure 25). The summary only refers to commercial species the largest of which were *P.malaanonan* and *Dr.lanceolata* to 16 ft g and over (155 cm diam+) with *S.leptoclados* and *S.smithiana* also reaching sizes in excess of 12 ft g (116 cm diam+). The first three of these four species accounted for 90 per cent of measured trees larger than 6 ft girth (58 cm diam) and clearly typified this area.

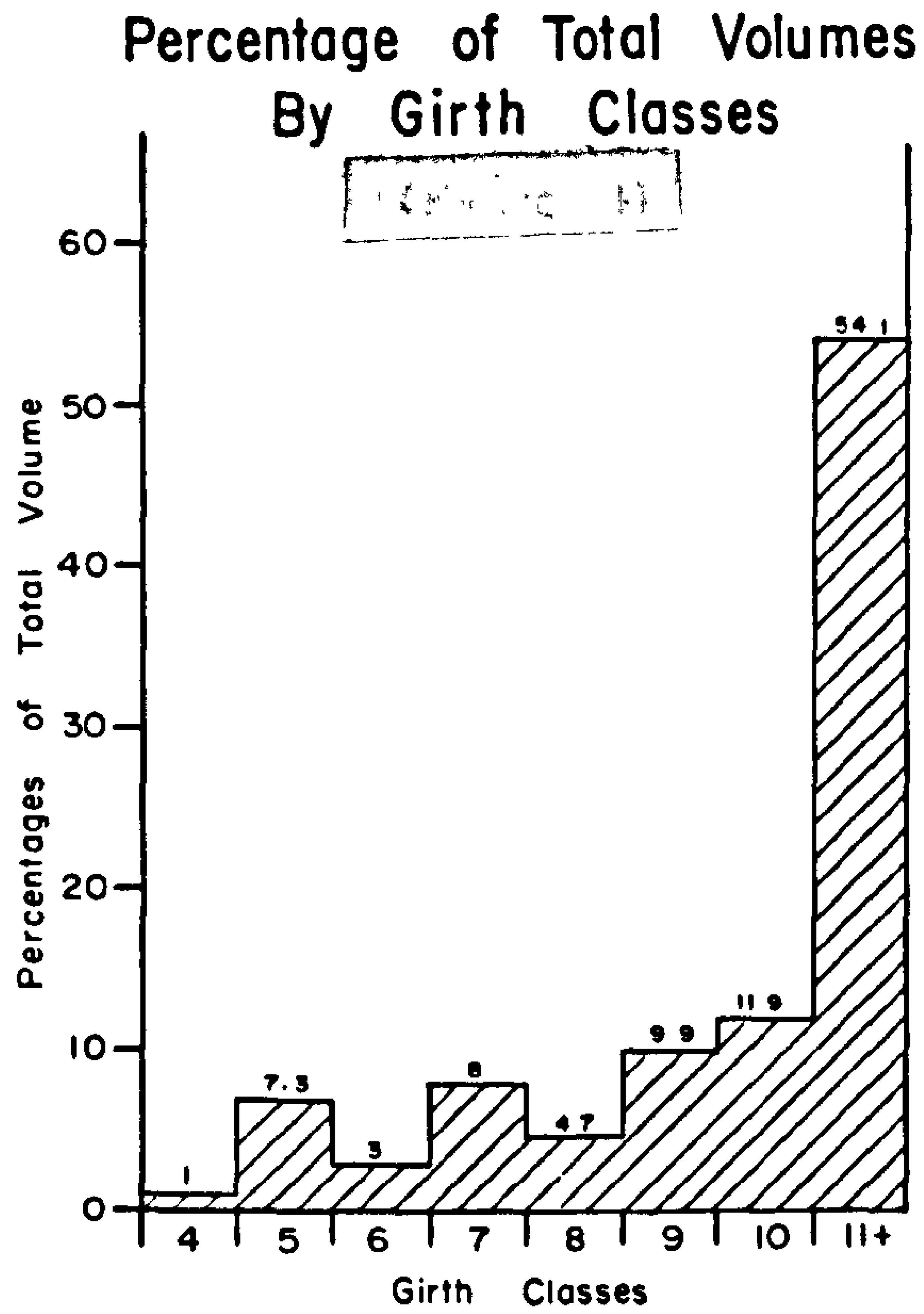
The *P.malaanonan/Dr.lanceolata* Type is represented at lower levels in the mountainous Gunong Rara F.R. Plots placed at Miles 39-41 along the Luasong/Gunong Rara Road (Table 15) reveal the absence of *Eusideroxylon*, scarcity of certain Rubroshorea species,

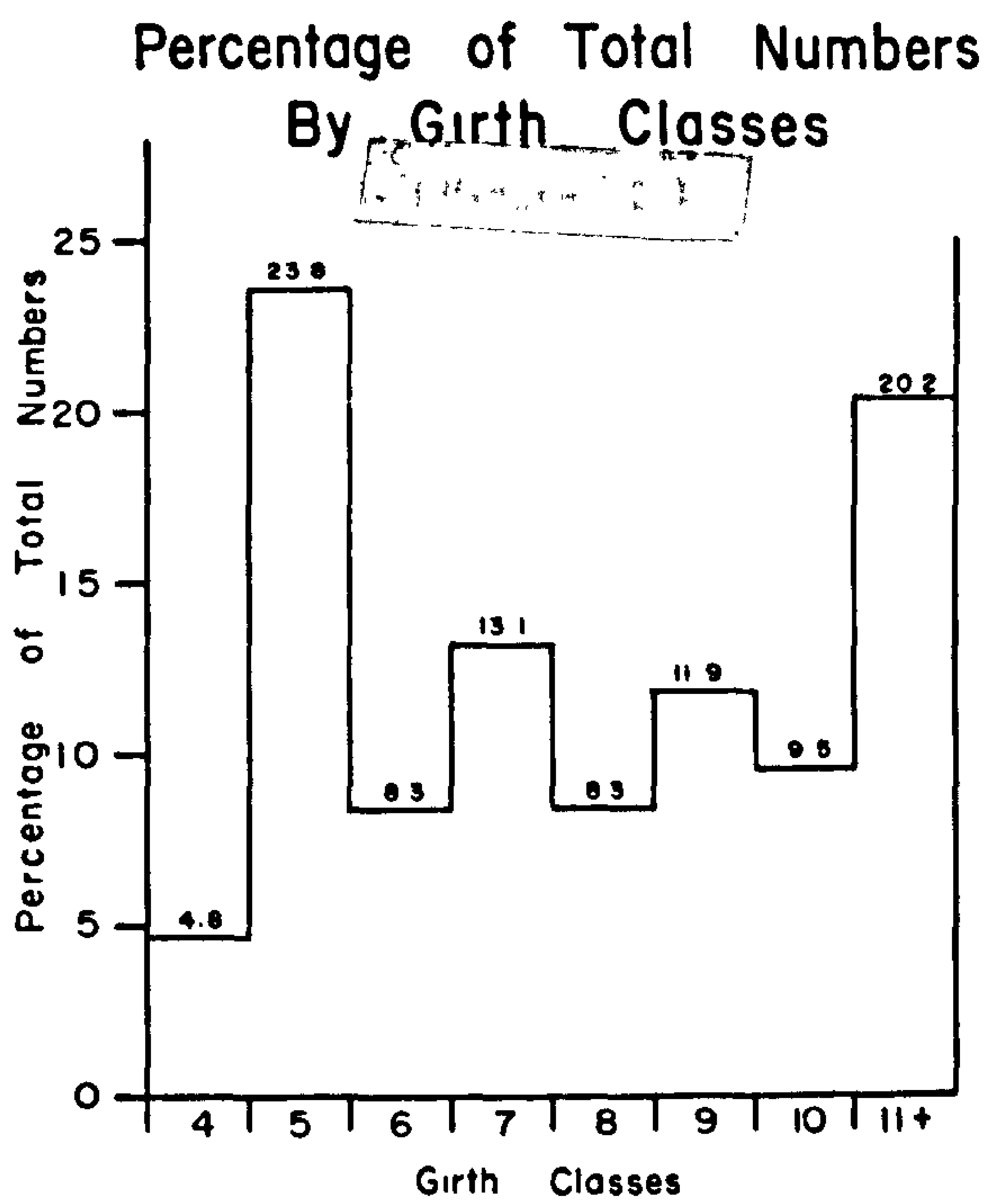
Table 15. Stand Table RP 256 10 one acre plots (4ha) Gunong Rara F.R. (M 39-41).

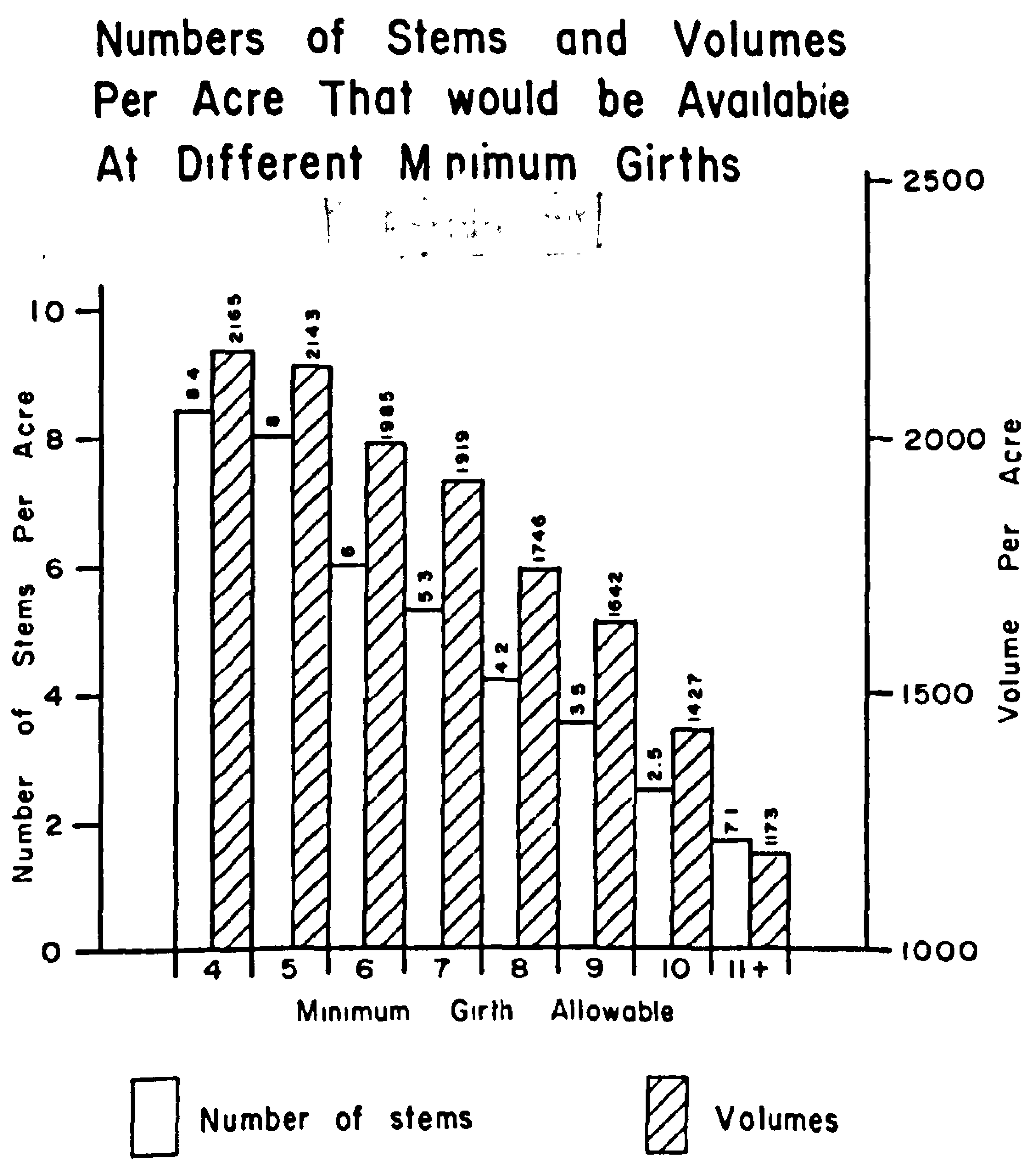
Species	Numbers of Trees in Size Classes						
Girth (ft)	6	7	8	9	10	10+	Total
Diam (m)	58	68	78	87	97	107+	
Dipterocarpaceae							
Shorea: Rubroshorea:							
S.leptoclados	3	3	1	2	1	1	11
S.parvifolia	1	5	2	4	2	3	17
Others 5 species	9	4	2	4	-	3	22
Dipterocarpus caudiferus	3	-	-	1	-	-	4
Parashorea malaanonan	14	6	5	7	3	3	38
P.smythiesii	2	-	-	-	-	1	3
Dryobalanops lanceolata	5	2	2	1	-	-	10
Non-Dipterocarps	1	2	2	-	-	-	5
Totals	38	22	14	19	6	11	110

FIGURE 25 R.P.339 Tawau Hills F.R.

YIELD ESTIMATES AT DIFFERENT FELLING LIMITS(see Appendix 2,Table 13 for species)







Forest Department, Sabah. 1970

e.g. *S.leprosula* and *S.ovalis*, scarcity of *Dipterocarpus* species, increased frequency of *Dr.lanceolata*, compared with the Luasong area (e.g. Tables 11, 12) and high representation of *Parashorea*. *S.pauciflora*, in addition to the 2 Rubroshorea listed, is comparatively abundant, and affinities of the forest in this area clearly lie with Type B to the north in Kuamut F.R. (cf Appendix 2, Table 7) and to Type C nearer the coast in Kalabakan F.R. Limited occurrence of the Type E assemblage of species is known for shale ridges in the higher hills of Gunong Rara, but its full extent is not at present known.

The Type also occurs on the basalt mountains in the Labuk Valley area of central Sabah where Meijer (1968) noted high incidence of *Rinorea longiracemosa* and *Diospyros* species. The same forest probably occurs on the isolated granodiorite peaks northeast of Ranau in the headwaters of the Sugut River near Paginatan. Relict gallery forest containing *S.acuminatissima* (Ri), *E.zwageri* and *P.malaanonan* in the Sook Plains suggests that the type was formerly present in the area on present day grassland areas of non-podsol soils. Further west the forest in Mandalom F.R. is partly of this type and partly of Type F Selangan Batu Forest. Appendix 3 Table 4 gives summary stocking data for 7 plots combined in this reserve, mainly in Type F forest. Here Type E is represented by *P.malaanonan* and *S.acuminatissima* on the lower slopes petering out at about 600 m altitude.

At Pangie on the lower slopes of hills in the Gunong Lumaku F.R., where the Temburong Formation extends into the Crocker Range, R.P. 15 (Appendix 2, Table 14) is representative of the *P.malaanonan/Dr.lanceolata* Type.

In this area it again gives way to Type F on the steeper, higher slopes. A relascope survey in the vicinity of R.P.15 gave the following:

Stems/acre	B.a./acre	No.8ft g.+	B.a. 8ft+
205	168	6.0	59

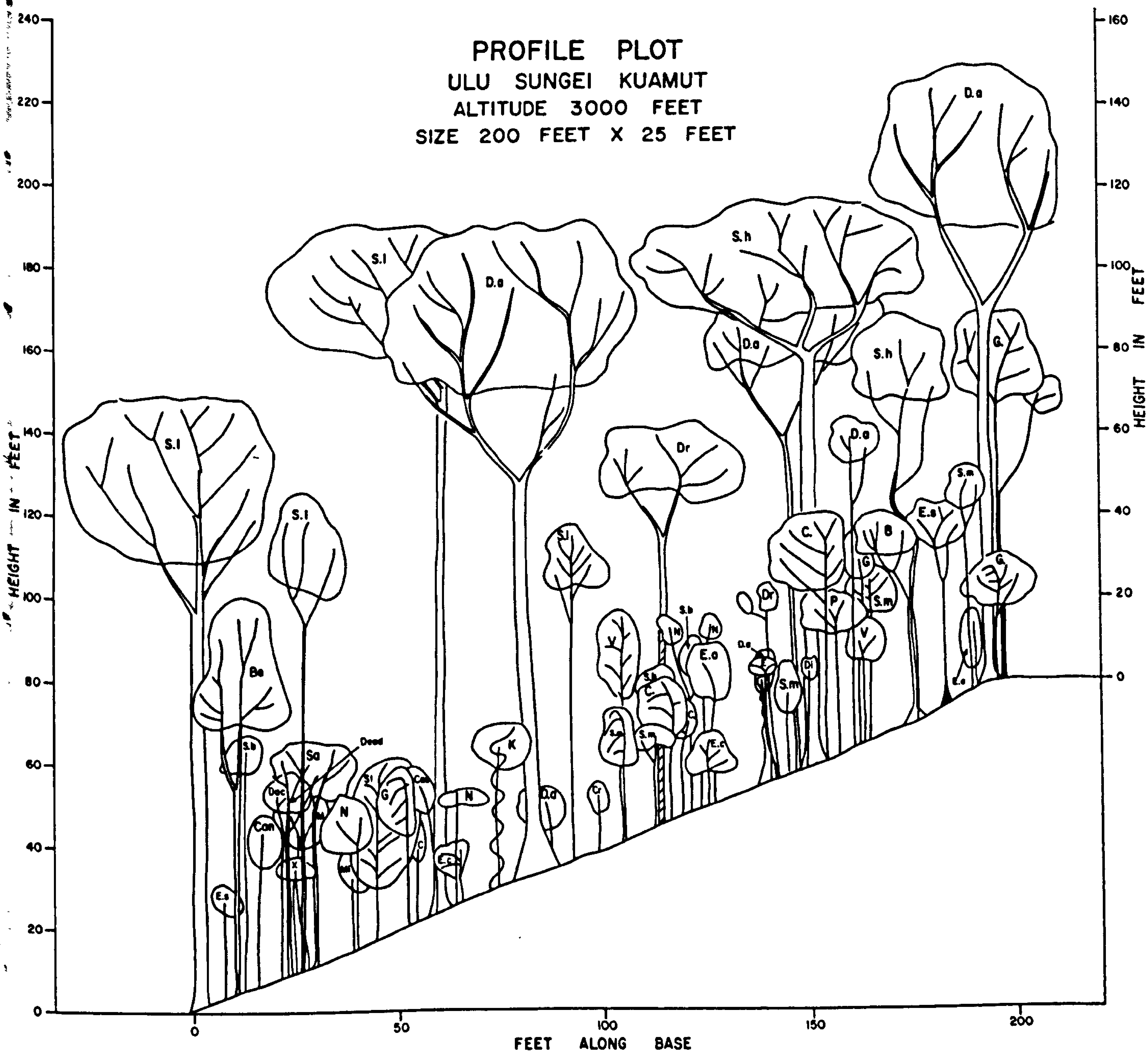
Elsewhere in the Crocker Range this type has been largely eliminated, as with Type D, by shifting cultivation, though it is still present inside, and adjacent to Mt.Templar F.R. Here Richetia is represented by *S.faguetiana* and *S.kudatensis*; *S.leptoclados* is uncommon and Rubroshorea is represented by *S.ferruginea* and *S.smithiana*; and both the type species are abundant. Small patches remain in the Sir James Brooke Range at the northern extremity of the Crocker Range, on the lower slopes of Timbang Batu Hills to the southeast of Marudu Bay, and in Labuan F.R. near Kudat. *Dipterocarpus warburgii* is present in this forest Type in both Mt. Templar F.R. and the foothills to the east of Gunong Lumaku between Tenom and Tomani.

At present the only important area of commercial managed forest of Type E is that in Silabukan F.R. As the Type generally occurs on steeper slopes exploitation is both more difficult and potentially more likely to lead to severe erosion than with Types B and C. However the principal species components are important in regeneration considerations where *P.malaanonan*, *S. leptoclados* or *Dr.lanceolata* are abundant within the main commercial forests.

Type F Selangan Batu Forest

This type is the 'Hill Dipterocarp Forest' in the sense of Symington (1943) and is present in the higher hills or on steep slopes at lower elevations within a matrix of one or the other of the preceeding lowland Types. Forests dominated by *Dipterocarpus* species and with Richetia abundantly representing the genus *Shorea*, which occur on leached sandstone hills, are reserved for Type G, though distinction between F and G is sometimes uncertain. For example Figure 26 represents a profile in forest at 920 m on steepland to the west of the Kuamut River, probably typical of much of the highland, apart from the sandstone cuestas, in the Kuamut area on the Tanjong Formation. Here both *Dipterocarpus acutangulus* and *Shorea multiflora* (Ri), typical associates of Type G in Sepilok F.R. (Figures 27, 28) are present. However the hill species represented in Figure 26 viz: *S.laevis* (SB), *S.hypoleuca* (SB) and *Vatica dulitensis* are absent from leached sandstone hills.

As I have suggested above the Type is often found at higher elevations than Type E, and is present in most hilly areas, with elements present on hills within areas already classed in a preceeding type, e.g. Appendix 2, Table 2. Table 16 summarises data for ten plots of one acre over the altitude range of 490-690 m on the Tanjong Formation in Gunong Rara F.R. Though a wide range of species are present (see also R.P. 318 discussed under "Altitude" above) it should be noted that both *Parashorea* and *Dryobalanops* are scarce, and that species of the group Selangan Batu have increased in numbers and species (cf Tables 12 and 15, representing plots in the same series, R.P. 256). *S.leptoclados*, *Eusideroxylon* and *Hopea nervosa* are all absent and elements of the higher level forests, i.e. Upper Dipterocarp Forests (2(a)) of the general classification scheme, are present.



B Baccaurea cf. parviflora
Be Beilschmedia micrantha
C. Calophyllum blancoi
C Calophyllum tetragonum
Con Canarium latistipulatum
Cas Castanopsis sp. indet
Cr Croton argyratus
Dac Dacryodes macrocarpa
Di Diospyros sp. indet
D.a Dipterocarpus acutangulus
Dr Drypetes microphylla
E.c Eugenia chrysantha
E.o Eugenia ochneocarpa
E.s Eugenia spicata
E Eurycoma longifolia
G Garcinia cf. trianii
G. Garcinia parvifolius
K Knema kunstleri
M Memecylon laevigatum
Mi Michelia montana
N Nephelium cf. maingayi
P Pentace borneensis
Sa Sarcotheca sp. indet
S.b Shorea beccariana
S.h Shorea hypolenca
S.l Shorea laevis
S.m Shorea multiflora
St Stemonurus malaccensis
V Vatica dulitensis
X Xanthophyllum affine

Forest Department, Sabah. 1971.

FIGURE 26 Selangan Batu Forest TYPE F

Table 16. Stand Table RP 256 10 one acre plots (4ha) Gunong Rara F.R. (M 39-43)

Series	Numbers of Trees in Size Classes Girth (ft) / Diam (m)	6 / 58	7 / 68	8 / 78	9 / 87	10 / 97	10+ / 107+	Total
Dipterocarpaceae								
Shorea (Rubroshorea)								
S.pauciflora		3	2	-	1	-	3	9
S.platyclados		-	-	-	1	1	1	3
S.smithiana		-	1	-	-	-	3	4
Others 5 species		4	2	2	3	-	3	14
(Richetia)								
3 species		3	3	-	-	1	2	9
(Selangan Batu)								
S.atrinervosa		1	2	2	3	1	-	9
S.laevis		6	2	-	3	-	9	20
Others 4 species		2	-	-	-	1	1	4
(Anthoshorea)								
Shorea sp.indet		-	2	1	1	-	-	4
Dipterocarpus species 5		2	1	2	1	-	1	7
Parashorea species 2		-	1	-	1	-	-	2
Dryobalanops lanceolata		-	-	1	2	-	-	3
Other Dipterocarps		1	1	1	1	1	1	6
Non-Dipterocarps								
Fagaceae		1	2	-	-	-	1	4
Scaphium longipetiolatum		2	2	1	-	-	-	5
Other Non-Dipterocarps		21	8	4	4	2	1	40
Totals		46	29	14	21	7	26	143

Reference has been made to the presence of this Type in Mandalom F.R. (Appendix 3, Table 4). In this area *Ochrosia glomerata* is exceptionally common as an understorey plant associated with *S.laevis*. The range of altitudinal occurrence of the type in Mandalom is 460-760 m. *Tristania whiteana* is an associate of *S.laevis* on ridges in the Crocker Range and in Gunong Lumaku F.R. Selagan Batu forest occurs on the upper slopes of a sandstone hill at Pinawanti, Kudat District where it is represented by *S.laevis*, *S.hypoleuca*, *Hopea beccariana* and *S.smithiana*. It is also found on ridges and hill crests in the Sir James Brooke Range and in the Timbang Batu Hills. At the latter locality *S.laevis* is found with *Hopea semicuneata*, *Irvingia malayana*, *Castanopsis hypophoenicia*, and *Lithocarpus conocarpus*.

Similarly *S.laevis* and *S.obscura* are found with Fagaceae above the *P.malaanonan/Dr.lanceolata* type in Mt. Templar F.R. The hills east of Sipitang and behind Mesapol largely contain Type F forests and local occurrence at comparatively low elevations have been noted in the hills behind Tawau, e.g. *S.laevis* on tuff in the 1967 coupe of Tawau Native Special Licence and also on hills above the Merotai Besar River, in the same area.

A small area in Block 82 of Silabukan F.R. where *S.laevis* was locally abundant on a broad ridge, with *S.leptoclados* nearby was surveyed by relascope in 1964 (A.R.R.B. 1964) with the following result covering some 80 acres:

Stems/acre	B.a./acre	No.8ft.g.+	B.a.8ft.+
177	166	7.2	76

Other species of the Selangan Batu group not listed here, but which are found in forests comprising this Type include: *S.inappendiculata*, *S.maxwelliana*, *S.foxworthyii* and the hill form of *S.superba*.

The Selangan Batu forests are of less commercial value, by present day standards, than the other forest Types and stands of *S.laevis* are often left behind, or only partially exploited, when they are encountered within Types A, B, C, D or E.

Type G *Dipterocarpus*/Richetia Forest

This Type is best known from coastal locations where it occurs on sandstone hills and ridges with dip and scarp slopes of high amplitude. The soils are often comparatively deep red/yellow podsolic sandy loams to sandy clay loams with depth. The Type is often associated with Heath forest (7.4) on leached sandy soils on cuestas, ridges and steep slopes. The best known examples of Type G forest are those of Sepilok F.R. of which R.P.17 has received the greatest attention. A summary stand table of this is given in Appendix 3, Table 5. Stand tables for two ten acre (4ha) plots, R.P. 292/2,292/3 are summarised in Appendix 2, Tables 15, 16. In this Type of dipterocarp forest *Parashorea* species, *Dr.lanceolata* and *Eusideroxylon zwageri* are all scarce. A number of Rubroshorea species are present of which *S.smithiana* and *S.macroptera* are probably most typical, while others may be locally abundant, and in Sepilok *S.beccariana* falls into this category. Anthoshorea and Shorea (Selangan Batu) sections of *Shorea* are represented but the most typical species is the Richetia *S.multiflora*. The largest, dominant, species forming the emergent canopy are *Dipterocarpus*, and *D.confertus*, *D.grandiflorus* and *D.acutangulus* are all represented in Sepilok F.R.

Two profile diagrams (Figure 27, 28) show the general structure of the forest, with *Dipterocarpus* emergent to 50 m, a main canopy largely composed of *S.beccariana* at about 36 m, a second layer at 18-24 m with *S.multiflora* and an understorey.

Other species typically present include *Gluta renghas*, *Lophopetalum beccarianum*, *Tapoides villamillii*, *Persea bancana*, *Ganua kingii*, *Pentace borneensis* and *Teijsmanniodendron glabrum*. In comparison with the *Parashorea* and Rubroshorea forests this Type often has a more even structure. Though gaps due to lightning damage occur on exposed ridges, and patches may suffer landslides from time to time, the characteristic occasional tangles of climbers and bamboo of the lowlands

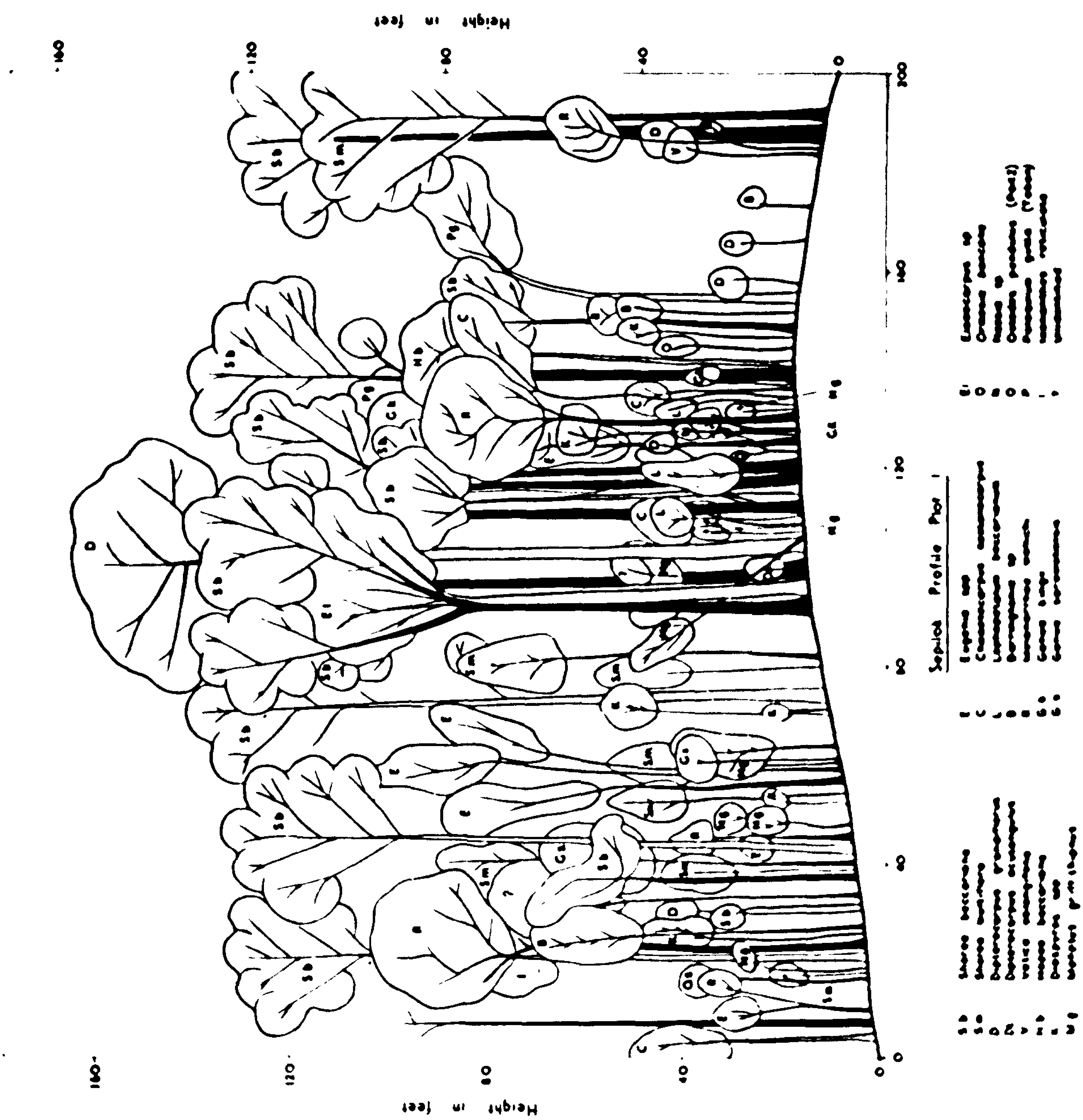


FIGURE 27 PROFILE DIAGRAM

TYPE G FOREST *Dipterocarpus*/*Richetia*

Sepilok Forest Reserve

are less noticeable, possibly due to a lower mortality rate which may be associated with slower growth of the dominant species. The largest trees of this Type are shorter in height and smaller in girth than those of most of the lowland Types, but stem numbers and basal area are high due to denser lower canopies.

The Type is mainly confined to the sandstone exposures within those geological formations coloured yellow on Map 3. The Sepilok occurrence is on the Sandakan Formation, which is allied to the Tanjong Formation. *Dryobalanops beccarii* occurs on the sharp ridges of exposures of the Tanjong Formation at Bangon River, west of Kuamut, as a scatterred tree in a form of *Dipterocarpus*/Richetia forest where the common species are *D.acutangulus,* the Richetia *S.faguetiana* and the Rubroshorea *S.ovalis*. *Scaphium longipetiolatum* is common here. Elsewhere in the Sandakan area the main association of *D.acutangulus/S.multiflora* is a feature of sandstone hills of the Tanjong Formation impinging on the Kinabatangan River at Sukau, Bilit, and Batu Puteh and also east of Lumerau River in the Segama River delta on the Ganduman Formation.

D.grandiflorus is abundant on the long sandstone escarpment east of the lower Umas Umas River. This species also occurs on coastal Chert-Spilite on Sakar Island in Darvel Bay and on sandstone at Sungei Paliu in the Labuk River delta. The Obar Ridge of the Bongaya Formation in the lower Sugut area has both *Dipterocarpus*/Richetia forest on the less leached slopes and Heath forest of Type 7.4 on the poorer soils. Species characteristic of Type G in this area include

D.confertus, *D.stellatus* the Rubroshorea species *S.macroptera*, *S.smithiana*, and *S.ovalis* with *S.kudatensis* representing Richetia and *S.agami* Anthoshorea. Both in this area and in the Serudong area of lower Kalabakan F.R. the Type is marginal with Rubroshorea/*Dipterocarpus*, but on some low-lying coastal areas, e.g. at Sungei Pirit, Mamahat it is marginal with *Dryobalanops beccarii* swampy padang forest (Type 7.2(a)).

In the north of the State the Type occurs on sandstone hills of the Kudat Formation, e.g. at the southern end of Bengkoka Peninsula the association *D.grandiflorus*/*S.kudatensis* occurs with *S.ovalis*, *S.oleosa* and *S.cristata*. At Lajong F.R. near Kudat the Richetia species *S.faguetiana* and *S.kudatensis* are found with *S.smithiana* and small trees of *Decaspermum fruticosum*, *Calophyllum obliquinervium*, *Buchanania arborescens* and *Eugenia palawanensis*. A coastal forest of similar type at Balembangan Island on Chert-Spilite has *D.grandiflorus* and *S.kudatensis* as large emergents to 36 m over a main canopy of *Tristania clementis*, *Oncosperma horrida*, *Shorea xanthophylla* (Ri) and *Cotylelobium melanoxylon*. The latter species is typical of dry leached sites in general (cf Figure 7).

The forests of this Type though difficult to distinguish on aerial photographs from the others, are inherently less valuable as the larger trees are often hollow. The soil is unsuited to agriculture and any canopy opening accelerates erosion.

Part 2. Concluding Remarks

The classification of vegetation outlined in Chapter 3 gives considerable emphasis to the variation of species presence with soil type, moisture and altitude. Apart from the peat swamps of the West Coast, and possibly some of the mangrove forests, the bulk of the vegetation forms described in Types 2 to 10 of the general classification are of little or no commercial value in the sense of timber production. Attempts at the growing of trees in grasslands may change the picture in the future. Similar considerations apply to other land uses. Agriculture, of a sort, is the cause of secondary forest growth and the origin of some of the grasslands but the poorer soils and swamps hold little prospect for easy cultivation. The bulk of fresh development is in the conversion of dipterocarp forests to agricultural plantations.

However, I believe it is eminently desirable that examples of all the vegetation types described be preserved for posterity prior to their inevitable disappearance through the effects of better communications and increased pressure on the land generally. The preliminary nature of this presentation emphasises the need for further study of the vegetation.

The classification of dipterocarp forests into seven main Types (excluding a detailed consideration of forests on ultrabasic rocks) is largely based on differences in abundant species. The genus *Parashorea* distinguishes the forests of Sabah from those of the Malay Peninsula, and of Sarawak and Brunei; affinities exist with the forests in the Philippines where the genus is well represented. Coastal occurrence of Type A is associated both with relatively good soils and with low rainfall. *P.tomentella* is apparently confined to East Coast locations with higher rainfall and *Dipterocarpus* reaches greatest abundance on comparatively poorer, often older, soils. A considerable overlap of the common Rubroshorea species exists between the Types described and local abundance of *Eusideroxylon* will be seen in Part 3 to have important silvicultural implications.

Much of the data presented subsequently must of necessity be related to the dipterocarp forests as a whole; this is particularly so with my consideration of the natural forest (Chapter 5) as much of the long term work has been concentrated in few areas. However the spread of species through the main lowland forests, with the more valuable groups being generally abundant and a large number of dipterocarps decidedly less common, should not greatly detract from the bias inherent in such limitations.

Considerable scope now exists to test the reality of Types enumerated with respect to silviculture. Are the species of importance in the natural forests regenerating themselves and are there any differences in growth rates between areas? Do the associated environmental factors of soil, topography and rainfall influence the behaviour of principal species within the Types? Does the pattern of succession differ between the Types?

Long term management considerations will only be able to take account of different Types within the dipterocarp forests if some of the answers to these questions suggest different growth patterns. Short term harvesting considerations are obvious and estimates of species groups composition has long been a main interest of the timber firms.

Part 3. Natural Regeneration of the Dipterocarp Forests

CHAPTER 5

THE UNDISTURBED NATURAL FOREST

Dipterocarp forests give the appearance of constancy but in reality are changing continuously. As old trees fall gaps are colonised by available forms and locally growth rates exceed the norm. Basal areas of stands in an undisturbed state change gradually but average values over wide areas remain more or less constant over a period of years as growth is balanced by loss. Within the forest individual trees may be increasing in girth, or height, at different rates varying with the species, its general role in the stand and with crown size, availability of light and other factors.

Seedfall replenishes the stocking of seedlings from time to time and relative abundance of seedlings may influence the chance of different species successfully colonising gaps. These dynamic aspects are of importance to an understanding of the process of regeneration, and the time necessary for regenerated stands to reach maturity. Schulz (1960) has drawn attention to basic problems concerning regeneration:

> "What is the normal age class representation of the leading dominants and how does the growth rate of the tree vary during the successional stages of development? At what stages does the heaviest mortality (and most intensive selection) occur?
>
> (Richards 1952, p 40)
>
> "To what extent are the species regenerating and reproducing a forest which is of substantially the same form and composition as those that now exist? Are the emergents regenerating periodically or continuously? How do the emergents regenerate and attain their position?
>
> (Jones 1956)

The preceeding analysis of forest Types has drawn attention to some of the major groupings of species. Before going into dynamic aspects of the stands further detail is presented on the distribution of species. This is considered necessary to illustrate variation, site preferences, and the relationship of trees to each other.

Species Distribution

R.P.17 Sepilok F.R. (unfelled)

The most well known sample plot in Sabah is R.P. 17 (4.5 acres) in Type G Forest, Sepilok F.R. (Nicholson 1963a, Austin and Greig-Smith 1968, Fox 1972). Figure 29 illustrates topography, drainage and distribution of stems of 12 ins girth (10 cm diam) and over. Fifteen of the commonest species, including 8 dipterocarps are shown separately. The area is steep land with ridges of high amplitude. Contour intervals shown are 5ft (1.5 m) and the ridges, rising some 30 m from the stream beds are about 40-45 m above sea level. The ridges have greater density of stems, and basal area. The two species described above as characteristic of the Type in this area, i.e. *Dipterocarpus acutangulus* and *Shorea multiflora* are clearly confined to ridge sites. Species predominantly found in the valleys are *Teijsmanniodendron* sp., *Shorea macroptera* and (not shown) *Moultonianthus leembrugianus*. Most of the other species illustrated are found predominantly on the ridge sites but *Lophopetalum* and *Ganua* appear to show little preference. The proportion of the area with ridges is considerably more than that with valley sites.

Many of the species show gregariousness in the sense that two or more stems of the species may occur close together, and this is especially so with *S.multiflora*, *S.beccariana* and *Hopea beccariana*. Nicholson (1963a) suggested that *S.smithiana* may be a recent species in

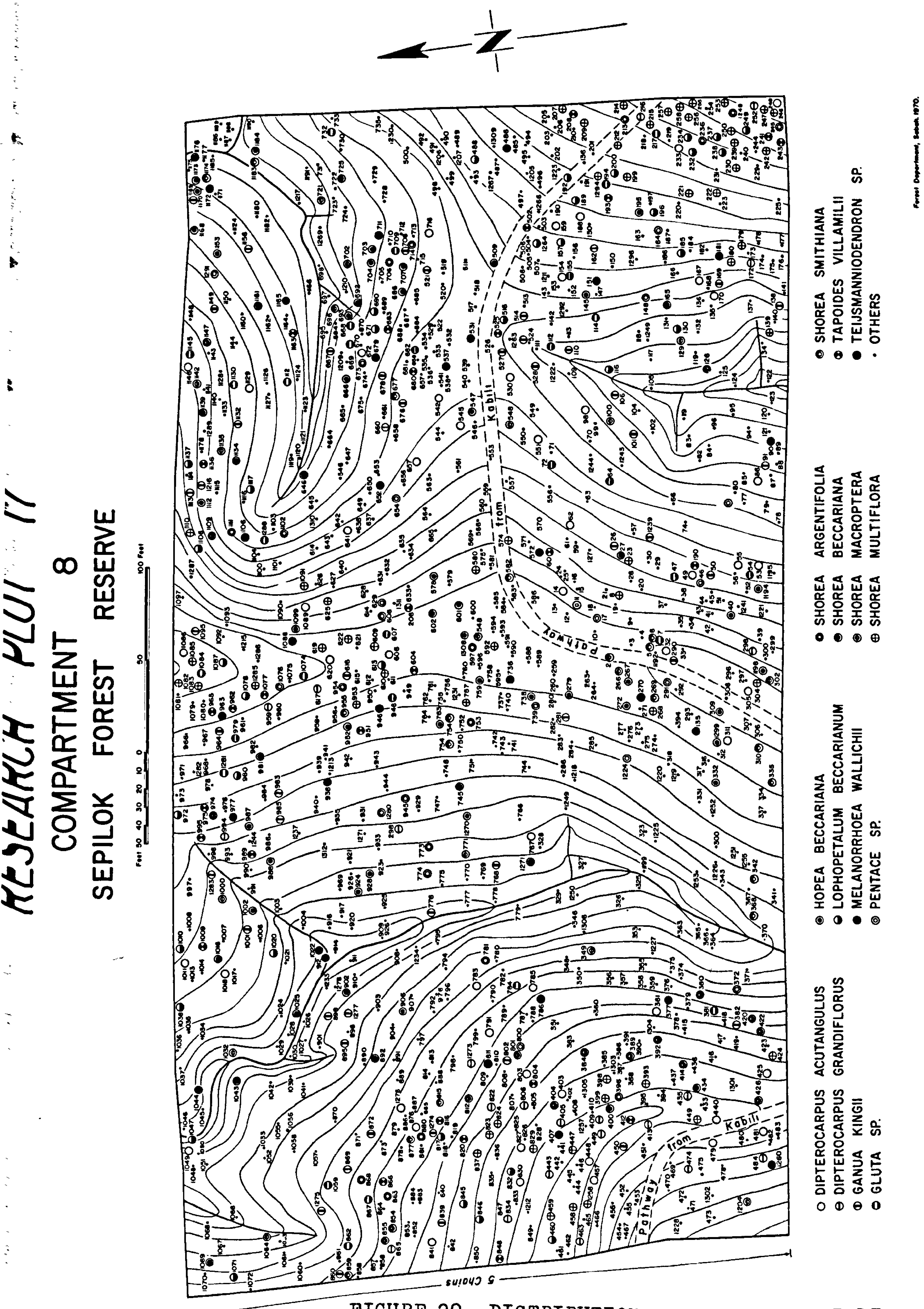


FIGURE 29 DISTRIBUTION OF TREES IN R.P.17

Sepilok Forest Reserve

R.P.17 because of its lack of larger trees (cf Appendix 3, Table 5). Present numbers suggest that if this is so then it could have ascended the central ridge from the south. Further long term study of the area may confirm this suggestion but it is already clear that species composition does change and a number of species present in 1956 have since been lost. These include *Shorea leprosula* and *Voorders̈iodendron pinnatum*, and as with all losses so far (13 species, Fox 1972), they were represented by singles or very few trees, and are marginal to the Type as described in Chapter 4. However the important point is that site changes at margins of given areas may well allow additional species to be considered: this often means that scarce individuals in a given wide area may be abundant elsewhere, or locally on a favourable site within the wide area. Two examples of species distribution in samples covering large areas are given below.

R.P.242 Segaliud-Lokan F.R. 10 acres (4 ha) (felled).

Size distribution of common species is illustrated in Figures 30 and 31. Figure 30 is an example of Type B summarised in Appendix 2, Table 5. The sub plot within it was used for regeneration growth study and is discussed in Chapter 7. The three species of greatest abundance in this area: *Parashorea tomentella, Dryobalanops lanceolata Shorea leptoclados,* though well scattered in R.P.242 showed, to some extent, patchy or clumped distribution. Large individuals of *S.leptoclados* were closer together than the other two, and smaller trees were also closer to presumed, larger, parent trees. Clumping of individuals was noticeable with the less common *Dipterocarpus caudiferus, D.gracilis, S.macrophylla* (Ru) and *S.parvifolia* (Ru).

FIGURE 30 DISTRIBUTION OF COMMON SPECIES R.P.242
Segaliud-Lokan Forest Reserve. Area 10acres (4hectares)

LEGEND

(a) Showing location of sub-plot used to record seedling growth.

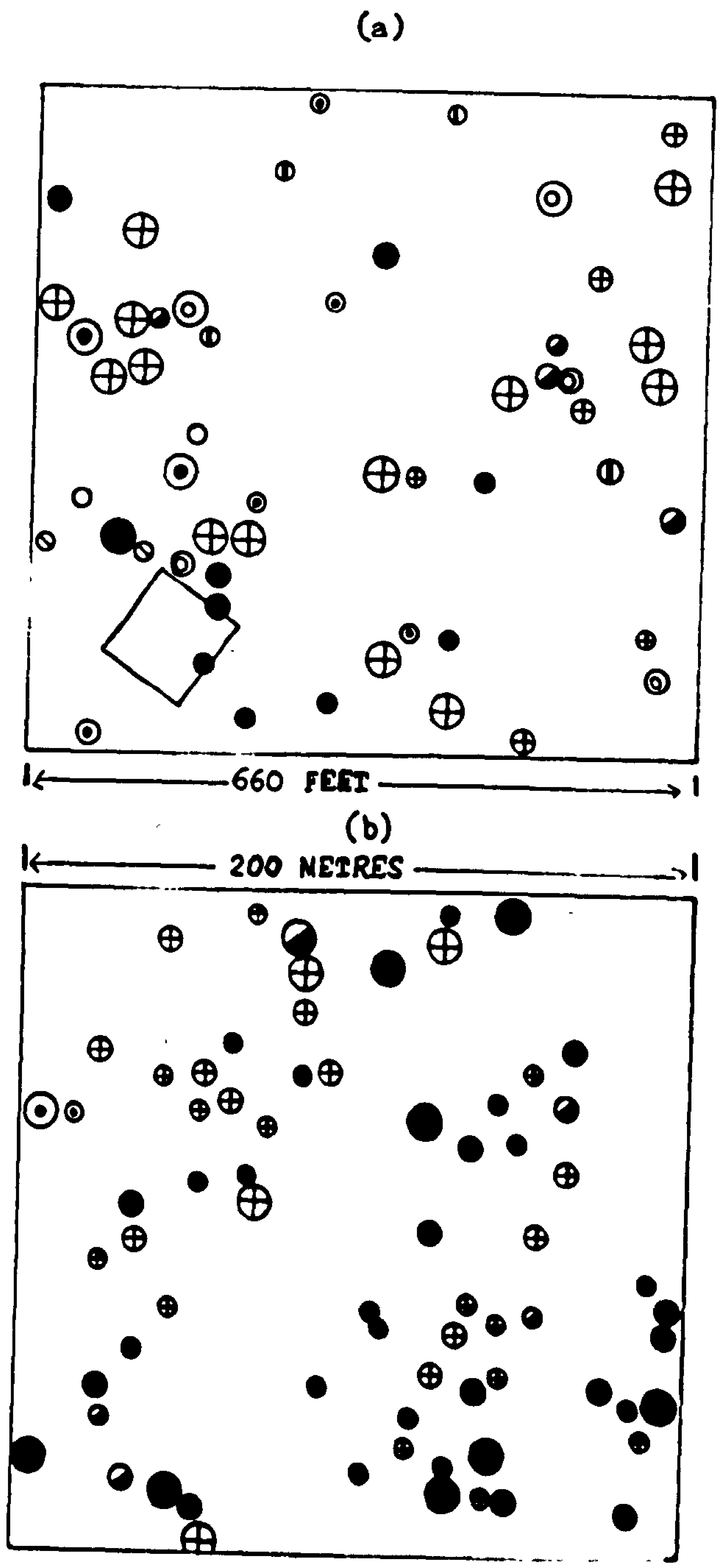
- ⊕ S.LEPTOCLADOS
- ⦿ S.PARVIFOLIA
- ⃠ S.PAUCIFLORA
- ◎ S.WALTONII
- ● D.CAUDIFERUS
- ◐ D.GRACILIS
- ⦶ H.SANGAL
- ○ EUSIDEROXYLON ZWAGERII

(b)

- ● P.TOMENTELLA
- ◐ P.MALAANONAN
- ⊕ DR.LANCEOLATA
- ⊙ S.MACROPHYLLA

SIZE CLASS SYMBOLS FOR BOTH (a) AND (b):

○ GIRTH 4-6feet(38-67cms diameter) ○ GIRTH 7-9 feet(68-96cms diameter) ◯ GIRTH 10feet and over (97cms diameter and over)



Individuals of *S.waltonii* were all at least 60 m apart, suggesting more random distribution.

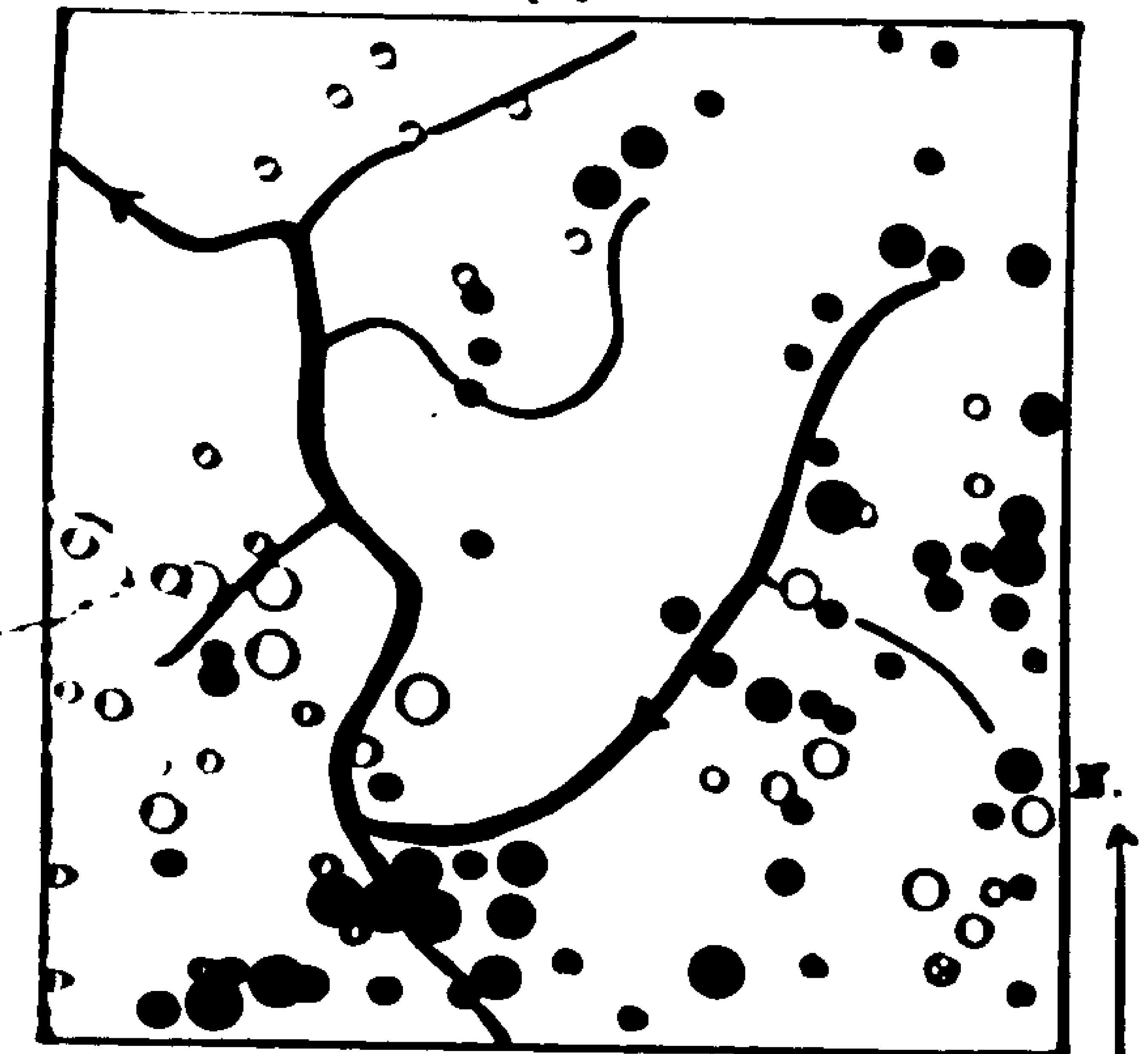
This area was of gently undulating topography with total amplitude in height not more than 20 ft (6 m), similar to R.P. 228 discussed in more detail below, but of considerably less amplitude than other areas described in this section.

R.P.353 Kalabakan F.R. 10 acres (4 ha) (unfelled)

Size class distributions of 15 dipterocarps of 12 ins girth and over (10 cm diam+) are illustrated in Figure 31 for R.P.353. The area is classed as Type C Forest, with local abundance of *Dryobalanops keithii* (Appendix 3, Table 3). This species is seen to be mainly concentrated in the valleys and low lying areas, with its greatest abundance in the northwest quadrant of the plot where 28 of the 58 trees of 6ft girth (58 cm diam) and over are found (Figure 31(d)). Reproduction of smaller sized trees is present at up to 36 m from parent trees, and extends up the valleys into the more hilly parts. Abundant seedling regeneration in nearby felled areas suggests that this species is able to maintain its position following felling. Aggregated distribution is also shown by *Dipterocarpus caudiferus*, but with smaller trees present up to 55 m from parent trees. The few individuals of *D.exalatus* are scattered whereas *D.acutangulus* trees are clustered on a steep slope above the river. The pattern of *D.verrucosus* is similar to *D.caudiferus* though stem numbers were fewer.

Dryobalanops lanceolata is present on the higher land in the south of the area where *Dr.keithii* was scarce. *Parashorea malaanonan* similarly is much more abundant in

(a)



(b)

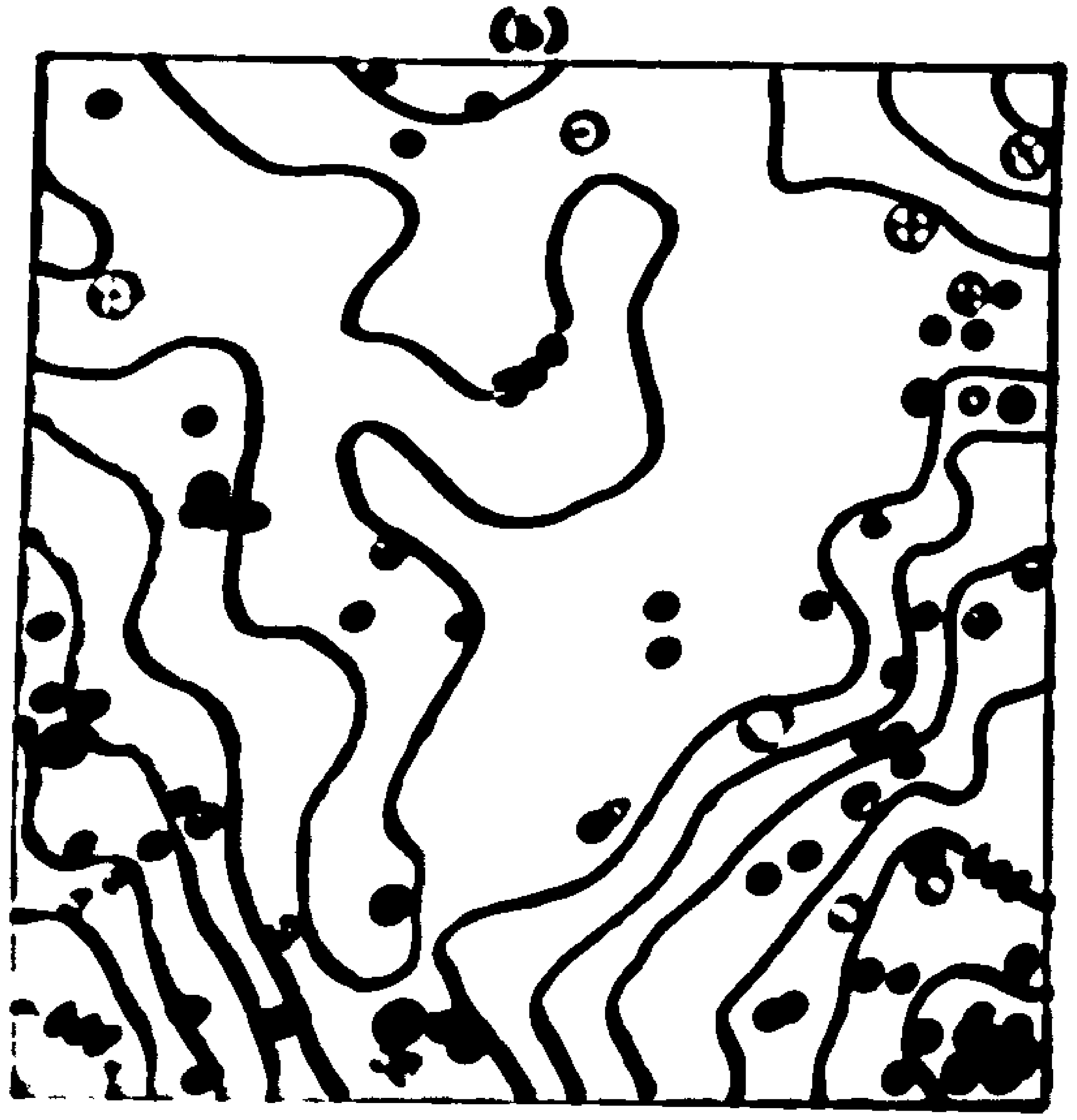


FIGURE 3 DISTRIBUTION BY SIZES, DIPTEROCARP SPECIES IN R.P.353 KALABAKAN F.R. Plot area 10 acres(4hectares).

LEGEND:(a),(b),(c), ◯ Trees 9ft. girth and larger(87cms.diam.); ○ Trees 6-8ft.girth(58-86cms. diam.); ○ Trees 3-5ft.girth(30-57cms.diam.); ◦ Trees 1-2ft.girth (10-29cms.diam.)

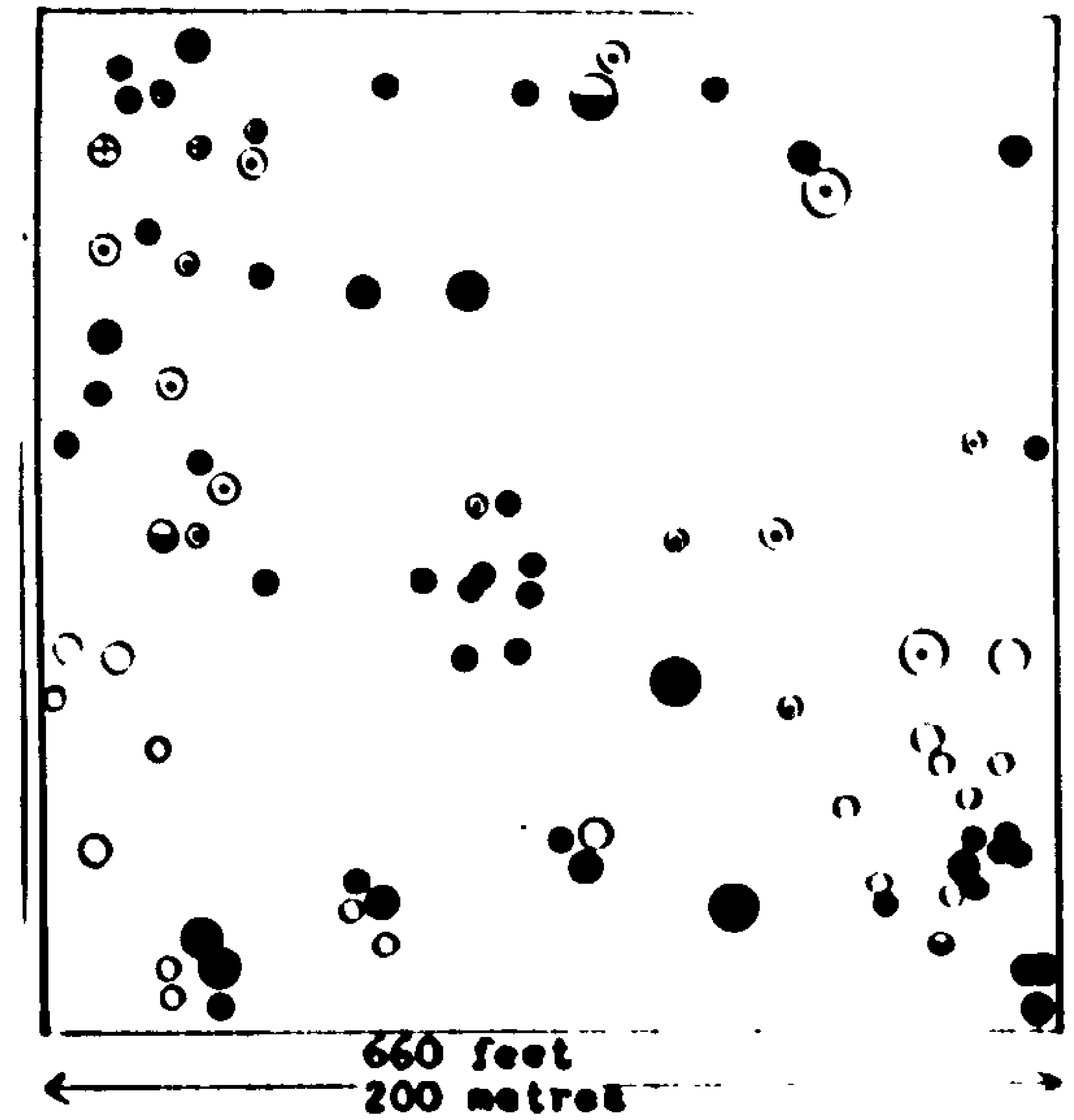
(a)Drainage indicated; ● Parashorea malaanonan; ⊗ P.tomentella; ◯ P.smythiesii.

(b)Contour interval 20ft(6m.); ● Shorea oleosa ⊕ S.leptocladoe: ⊖ S.parvifolia; ⊙ S.smithiana: ⊗ S.leprosula: ◯ S. pauciflora.

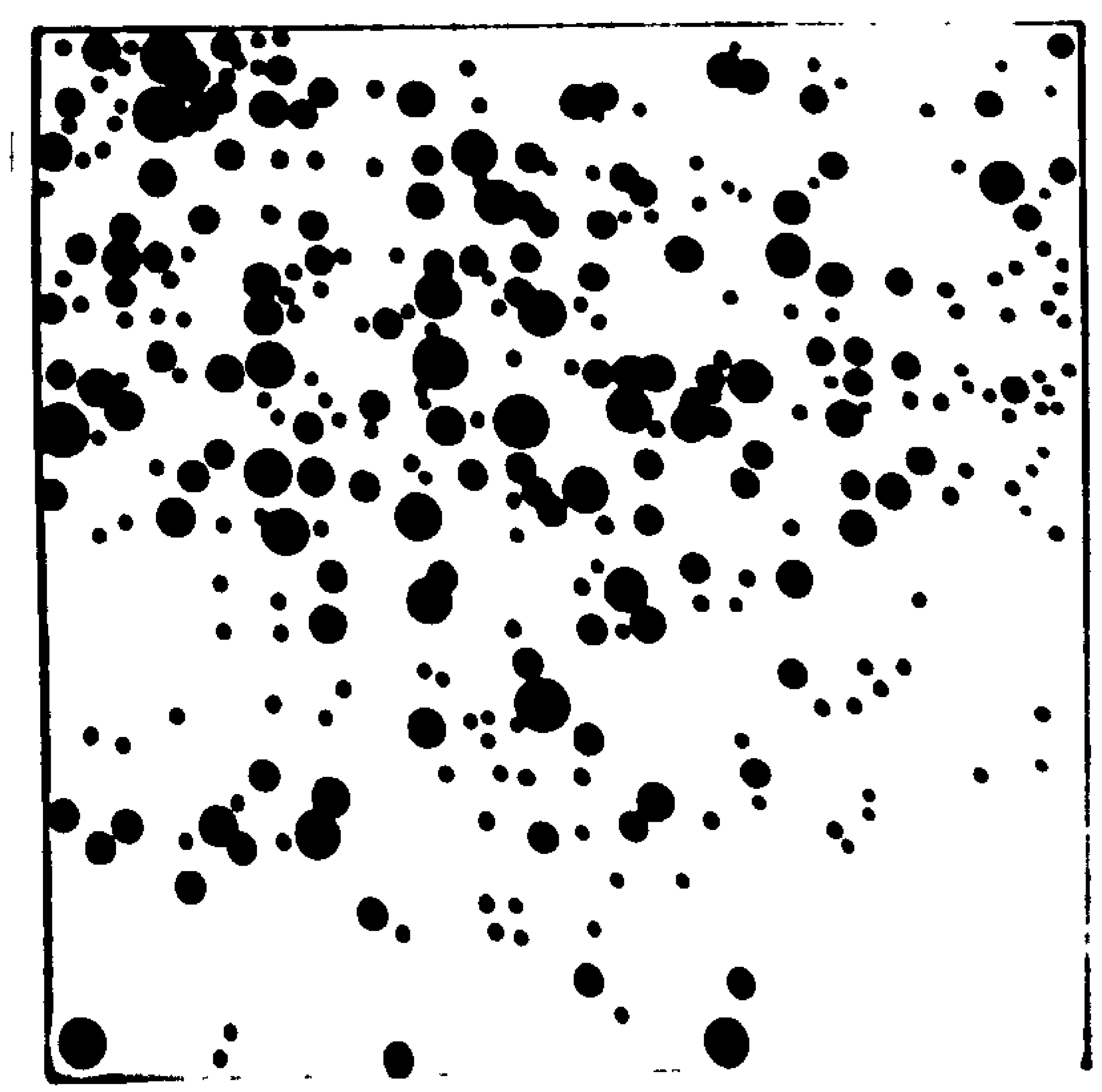
(c) ● Dipterocarpus caudiferus; ⊕ D.acutangulus: ⊙ D.verrucosus: ⊖ D.exalatus: ◯ Dryobalanops lanceolata.

(d)Dryobalanops keithii only: ● Trees 10ft.girth and larger (97cms.diam.); ● Trees 8-9ft. girth(77-96cms.diam.); ● Trees 6-7ft.girth(58-76 cms.diam.); • Trees 3-5ft.girth(29-57cms. diam.); • Trees 1-2ft.girth(10-28cms.diam.)

(c)



(d)



the south and east. *P.tomentella* was recorded in smaller sizes only in the southeast while *P.smythiesii* is more frequent on lower, valley sites. Figure 31(a) shows little site overlap between *P.malaanonan* and *P.smythiesii,* and that smaller trees of both tend to occur near the parent trees. Distribution of Rubroshorea is illustrated in Figure 31(b). *Shorea oleosa* is well represented on lower sites but with larger individuals higher up the valleys; stems fairly close, none more than 24 m apart. Of the others *S.parvifolia* is mainly in the south, *S.smithiana* is scarce and scattered, one large *S.leprosula* in the northeast has, significantly, no smaller trees nearby, *S.pauciflora* is mainly grouped on a hillside and *S.leptoclados* is mainly present in the lower situations.

Other species of interest in R.P.353, but not illustrated, are *Intsia palembanica* with three large trees, and no smaller ones, all in the extreme south, 5 individuals of *Eusideroxylon zwageri,* scattered, but all in valley sites, and *Hopea nervosa* mainly in moist places. *Duabanga, Saraca, Neonauclea, Brownlowia* and a number of small Myristicaceae are also present in moist sites.

R.P.228 Segaliud-Lokan F.R. (Unfelled)

The most ambitious single plot established for the study of natural forest is R.P.228. This is a rectangular block occupying 125 acres (50 ha) in the Mile 42 Virgin Jungle Reserve (Figure 47) in Type B forest at Segaliud-Lokan F.R. All trees of 5 ft girth (48 cm diam) and over are illustrated in Figure 32 with symbols for the common species *P.tomentella, Dr.lanceolata, D.caudiferus, S.leptoclados, S.parvifolia* and *Eusideroxylon zwageri* which together account for 64 per cent of the trees present.

FIGURE 32 DISTRIBUTION OF TREES IN R.P.228

Parashorea tomentella Shorea leptoclados S. parvifolia
Dryobalanops lanceolata D. caudiferus E. zwageri

Representation of groups was similar to the enumeration sample (Appendix 1, Table 1). A total of 24 dipterocarp species was recorded of which 5 were represented only once and a further 5 by less than 5 individuals (Table 17).

Table 17 Stand Table R.P.228 Segaliud-Lokan F.R.

Area 50 ha (125 acres).

Numbers of Trees in Size Classes

Girth class(ft) / Diam (cm)	5 / 48	6 / 58	7 / 68	8 / 78	9 / 87	10 / 97	11 / 107	12 / 116	12+ / 116+	Total
Dipterocarpaceae										
Parashorea tomentella	57	36	33	47	31	22	15	18	15	274
P. malaanonan	9	3	-	-	-	2	-	1	-	15
Shorea										
(Rubroshorea)										
Shorea almon	4	2	1	-	2	1-	3	1	-	14
S. argentifolia	-	1	-	-	-	-	-	-	-	1
S. leprosula	9	6	8	14	7	6	2	1	-	53
S. leptoclados	32	29	23	21	33	21	22	19	40	240
S. mecistopteryx	-	-	-	1	-	-	-	1	-	2
S. parvifolia	20	18	13	17	10	6	1	4	1	90
S. pauciflora	-	-	-	1	-	-	-	-	2	3
S. smithiana	3	-	1	1	1	-	1	-	4	11
S. waltonii	3	3	2	4	4	2	-	2	4	24
(Richetia)										
S. acuminatissima	-	2	-	1	-	-	-	-	-	3
S. gibbosa	3	1	1	-	3	-	-	2	7	17
S. hopeifolia	-	-	1	-	-	-	-	-	-	1-
(Selangan Batu)										
S. isoptera	6	4	4	5	2	-	-	-	1	22
S. superba	3	2	4	4	7	-	2	2	5	29
(Anthoshorea)										
S. agami	-	1	-	1	-	1	-	-	-	3
Dr. lanceolata	21	29	28	22	27	13	9	11	10	170
D. caudiferus	21	15	15	21	12	10	7	2	2	105
D. gracilis	-	1	-	-	-	-	-	-	-	1
Anisoptera costata	-	-	1	-	-	-	-	-	-	1
Hopea beccariana	1	-	-	-	-	-	-	-	-	1
H. nervosa	5	5	1	-	-	-	-	-	-	11
H. sangal	-	-	2	2	-	-	-	1	-	5
Non-Dipterocarpaceae										
Eusideroxylon zwageri	15	13	10	2	3	4	1	-	1	49
Pterospermum elongatum	21	9	2	-	-	-	-	-	-	32
All other species (91)	113	67	31	27	15	4	8	1	7	273
Totals	346	247	181	191	157	92	71	66	99	1450
Per 10 acres/4 ha	28	20	14	15	13	7	6	5	8	116

The following illustrates variability in local representation of the common species:-

Table 18 Numbers of Hectare (2.5 acre) Sub-Plots in which Common Species are Represented by Different Numbers of Trees (50 sub-plots)R.P.228

Nos of Trees/Plot	0	1	2	3	4	5	6	7	8	9+	Mean	$\frac{V}{M}$
Species					Numbers of Sub-Plots							
P.tomentella	0	3	2	4	8	12	6	5	5	5	5.48	1.19
S.leptoclados	0	5	5	7	7	10	4	3	5	4	4.80	1.41
S.parvifolia	12	14	10	5	5	3	1	0	0	0	1.80	1.45
Dr.lanceolata	4	3	11	14	5	3	6	2	1	1	3.40	1.57
D.caudiferus	10	16	7	5	7	1	2	1	1	0	2.10	1.85
E.zwageri	24	15	5	3	1	1	1	0	0	0	0.98	1.90

$\frac{V}{M}$ = Variance Mean Ratio, see below

Further detail for 24 dipterocarps and 11 of the most abundant non-dipterocarps is given in Appendix 5, Table 1. Only two species reach high local density to be rated as similar in local abundance to *Dr.keithii* in Figure 31. These are *Shorea isoptera* SB which has 22 individuals in sub plots D2, E2 on raised ground (probably a local exposure of sandstone) and *Saraca lanceolata* abundant in sub-plots F1, G1 (Figure 32) coincident with a high frequency of small streams.

Data of Table 18 analysed to test departure from randomness using the methods given by Greig-Smith (1957, p.61-63) suggested contagious distribution with variance/mean ratio greater than unity. However statistical analysis gave the following results:

(a) χ^2 test of goodness of fit: the expected numbers of sub plots containing 0,1,2,3, etc. stems calculated from the Poisson series with observed means, compared with observed numbers suggested regular (i.e. random) distribution for *P.tomentella*. Only *D.caudiferus* (< 2 per cent) showed probability of having the observed distribution by chance of less than 5 per cent. The other 4 main species had greater probability of the observed distributions occurring by chance.

(b) The *t* test and index of dispersion suggested that the probability of the chance occurrence of the observed variance/mean ratio of 1.19 for *P.tomentella* was high (20 to 40 per cent) but less than 5 per cent for *Shorea leptoclados* and *S.parvifolia*. The other three species had probabilities of less than 1 per cent and it is concluded that these, i.e. *Dr.lanceolata*, *D.caudiferus* and *Eusideroxylon zwageri* are contagiously distributed.

Variation in size class representation within hectare sub-plots is shown in Appendix 5, Table 2. Though statistical significance cannot be attached to these the extremes are of interest in predicting future crop density. The overall range per hectare in numbers 5 ft g and over is 14-39, and for trees in classes 5-8 ft g from 9 to 29. Figure 32 suggests that the major species are often grouped at a smaller scale than that of the hectare sub-plots (Table 18) for example: *S.leptoclados* occurs in small groups of 3-4 stems in sub-plots A1, A5, B2, etc., *Dr.lanceolata* in A2, A3, A5, B2, etc., *S.parvifolia* in groups of 2-3 stems in A3, B1, B4, C1 etc. *D.caudiferus* is less frequently as clearly grouped at the smaller scale, but 5 of the 8 stems in A3 are adjacent, as are 3 out of 4 in A5. *E.zwageri* is most abundant in the eastern half of the area and small groups of three stems occur in H1, J1 and J3. *P.tomentella* is well scattered throughout and trees of this species are often adjacent, probably due more to general frequency than to definite parent tree relationships. A number of the low frequency species are found on moist sites generally, and are so distributed in R.P.228, e.g. the *Terminalia* species, and Myristicaceae, e.g. species of *Myristica*, *Horsfieldia*, and *Knema* (cf Poore 1968).

In earlier publications I have discussed the joint occurrence of species in enumeration booking plots (0.2 acres, 0.08 ha) for Segaliud-Lokan (Fox 1967a) and Kuamut (1969b). At this size of sample unit common species showed little in the way of definite grouping in the Segaliud-Lokan example. Of particular interest was the tendency for *P.malaanonan* and *Dr.lanceolata* to occur jointly, and *S.parvifolia* was distributed more widely than *S.leprosula* (Appendix 5, Table 3). This is confirmed for R.P.228 (Appendix 5, Table 1).

The Kuamut enumeration covered a greater range of topographical conditions and species coincidences (Appendix 5, Table 4) emphasised some of the Type groupings described earlier. In general, however, joint occurrences with other species in both enumeration samples reflected relative abundance.

A summary of species coincidence in the plots of R.P.350 also in Kuamut F.R. (summarised in Appendix 2, Table 7), at the sampling level of the one acre plot (0.4ha), is given in Appendix 5, Table 5. This smaller number of individual sample units, 17 versus 479 for the enumeration, revealed little apart from the general tendency of the abundant species to occur in descending order of frequency with the others. In both enumeration samples contagion at the 0.2 acre level was most pronounced with *Dr.lanceolata* (Appendix 5, Tables 8 and 9). Three of the less common dipterocarp species in Segaliud-Lokan showed distinct grouping, namely *D.acutangulus*, *Dr.keithii* and *S. mecistopteryx* (Appendix 5, Table 8). The Selangan Batu species in Kuamut viz: *S.hopeifolia*, *S.superba*, *S.isoptera* and also *S.beccariana* Ru, *D.humeratus* and *Saraca lanceolata* all suggested contagion at this level. (Appendix 5, Table 9).

Species Distribution Over Wide Areas

R.P. 307A Kalabakan F.R. (Felled)

Four square miles in the Umas Umas area of Kalabakan F.R. randomly sampled by 63 circular plots of

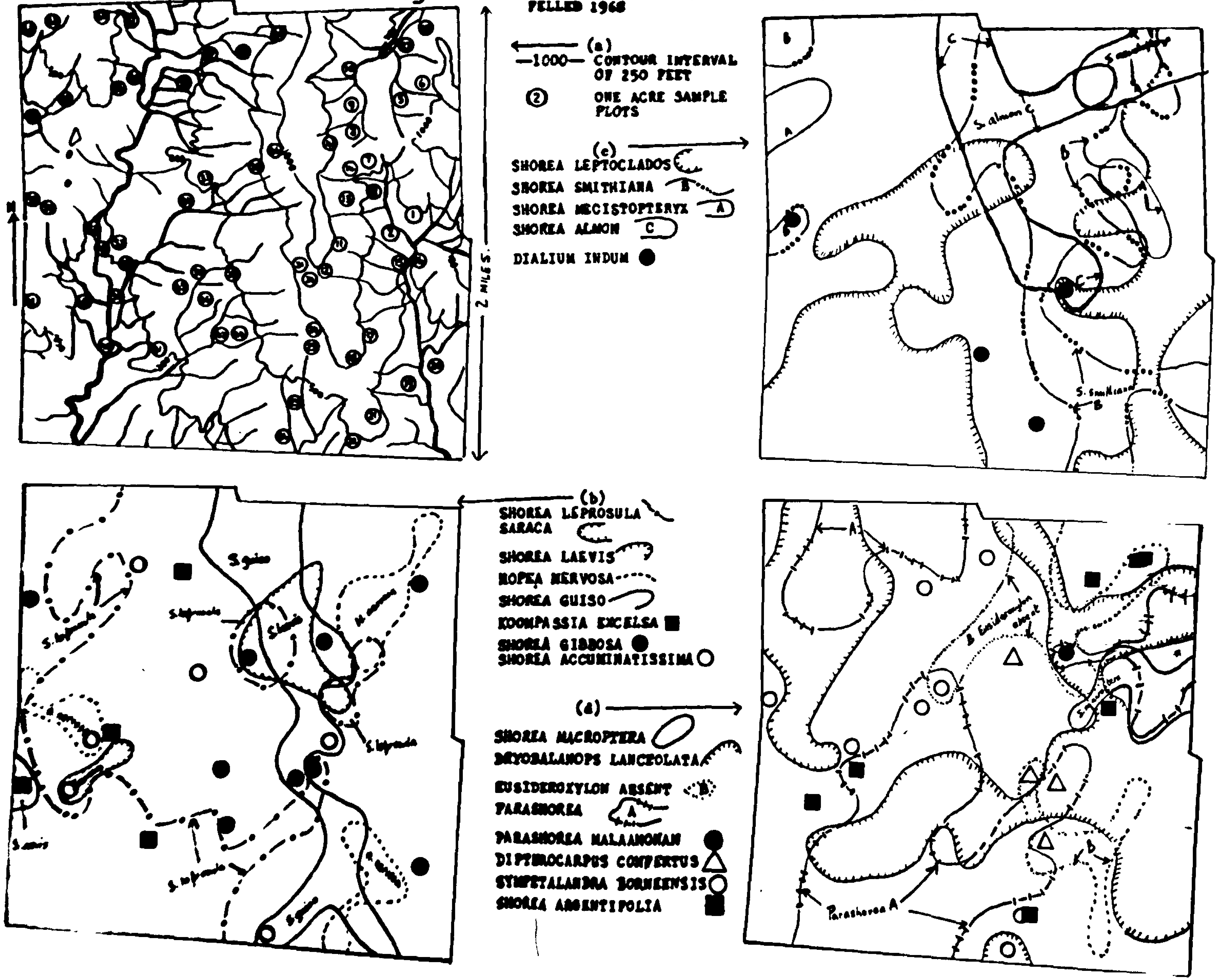
1 acre (0.4 ha) provides a useful illustration of species distribution over a wide area. A stand table summary is given at Appendix 2, Table 2. The area is hilly, dominated by a ridge running north to south through the eastern half (Figure 33(a)). The highest elevation is 1150 ft (350 m) falling away to 150 ft (46 m) in the southwest. The western half is bisected by a river flowing north/south and a range of topographical sites occur from riverain flats, gentle spur and valley slopes to steep ridges in the higher areas. The area has been described above as Type C Rubroshorea/*Eusideroxylon zwageri* forest. Species distributions are illustrated with reference to the plots in Figure 33 and with respect to altitude in Figure 34. Association analysis (Williams and Lambert 1960, 1961) of the 43 most abundant species is illustrated in Figure 35 and plot basal areas are given in Figure 36.

Seventy five species (or groups) totalling 1006 stems of 4.5 ft girth and over were recorded. The 13 most abundant are listed with plot representation, percentages, maximum sizes and variance/mean ratio in Table 19:

Table 19. Abundant Species R.P. 307A Kalabakan F.R.

Species	Stems	Plots	Percent No.	Max. Size (ft)	v/m ratio
Eusideroxylon zwageri	179	51	18	17	1.61
Dillenia borneensis	102	45	10	10	1.36
Shorea parvifolia	91	49	9	16	1.02
S. leptoclados	38	23	3.8	15	1.66
S. smithiana	35	22	3.5	17+	1.37
S. leprosula	29	19	2.9	13	1.53
S. pauciflora	29	18	2.9	16	2.16
Parashorea tomentella	44	21	4.4	14	2.57
Dryobalanops lanceolata	62	32	6.2	16	1.73
Dipterocarpus caudiferus	38	19	3.8	16	2.75
Shorea guiso SB	27	13	2.7	16	3.05
Eugenia species	50	25	5	12	2.09
Fagaceae	56	37	5.6	9	1.02

FIGURE 33(a - d) COMPARTMENTS 20,21,16,17 UMAS-UMAS KALABAKAN F.R. FELLED 1968



The tests of significance mentioned above suggested contagion for all species of Table 19 except *Shorea parvifolia* and Fagaceae. The t test showed that all except these two were likely to have observed plot/number distributions at less than 5 per cent probability, but the χ^2 test suggested probabilities of 5 to 20 per cent for *Dillenia, S.leptoclados, S.leprosula* and *S.pauciflora*, in addition to the high probabilities of *S.parvifolia* and Fagaceae.

Divisions in association analysis took place at low values of maximum χ^2, with the initial propulation having maximum χ^2 of 10.87. This is similar to the experience of Poore (1968) with trees of 3ft and larger in a total block area similar to the total sample area in this case. The 11 groups of plots illustrated in Figure 35 were largely explained by topographical differences, as the following discussion of species distribution brings out.

The two most abundant species, *Eusideroxylon* and *Dillenia* were widespread but the former was absent on steep slopes of the main ridge (Figure 33(d)). The 12 plots in which it was absent lay between 500 and 1040 ft (150-320 m) and 11 of these are sorted out at the second division of association analysis, with an average altitude of 730 ft compared with the overall plot mean altitude of 570 ft. When present in the higher hills *Eusideroxylon* was less abundant than in the lowlands:

No/Acre (stems	Number of Plots Observed	Expected	Altitude Range (feet)	Mean
0	12	3.7	500-1040	730
1	7	10.5	330-980	700
2	11	14.9	290-970	630
3	10	14.1	300-960	520
4	6	10.0	170-920	420
5	10	5.7	200-880	430
6+	7	4.1	260-850	470

Distribution of *Dillenia* was largely similar to *Eusideroxylon*: of the 18 plots in which *Dillenia* was absent 8 also had no *Eusideroxylon*. *Dillenia* was strikingly absent from the southern end of the main ridge, from a group of plots on slopes to the west of the main ridge, and in some of the alluvial flats. Local abundance of this species has not been recorded elsewhere in the State, while as I have shown in the previous chapter, *Eusideroxylon* is a feature of the Tawau area generally, and elsewhere in Sabah.

Shorea parvifolia was the next most widespread species to *Eusideroxylon* but averaged under 2 per plot compared with over 3, and its more or less random distribution and importance characterise this area for regeneration considerations as does *Parashorea tomentella* for R.P.228 discussed above. Its occurrence in plots was;

No/Acre (stems)	0	1	2	3	4	5
Number of Plots						
Observed	14	23	17	3	4	5
Expected	14.9	21.4	15.4	7.4	2.7	1.2

Though absence is largely accounted for by chance, with the 14 plots rather scattered, three plots in the river flat area probably fall outside the optimal site range for *S.parvifolia*. Here the stand was characterised by the presence of *Dipterocarpus caudiferus*, *S.leptoclados*, and *Hopea nervosa*. Some of the species more typical of ridge and hill areas viz. *Dr.lanceolata*, *S.smithiana*, *S. pauciflora*, *S.guiso*, *S.superba* and *D.confertus* were more commonly found with *S.parvifolia* than with *Eusideroxylon* (Appendix 5, Table 6).

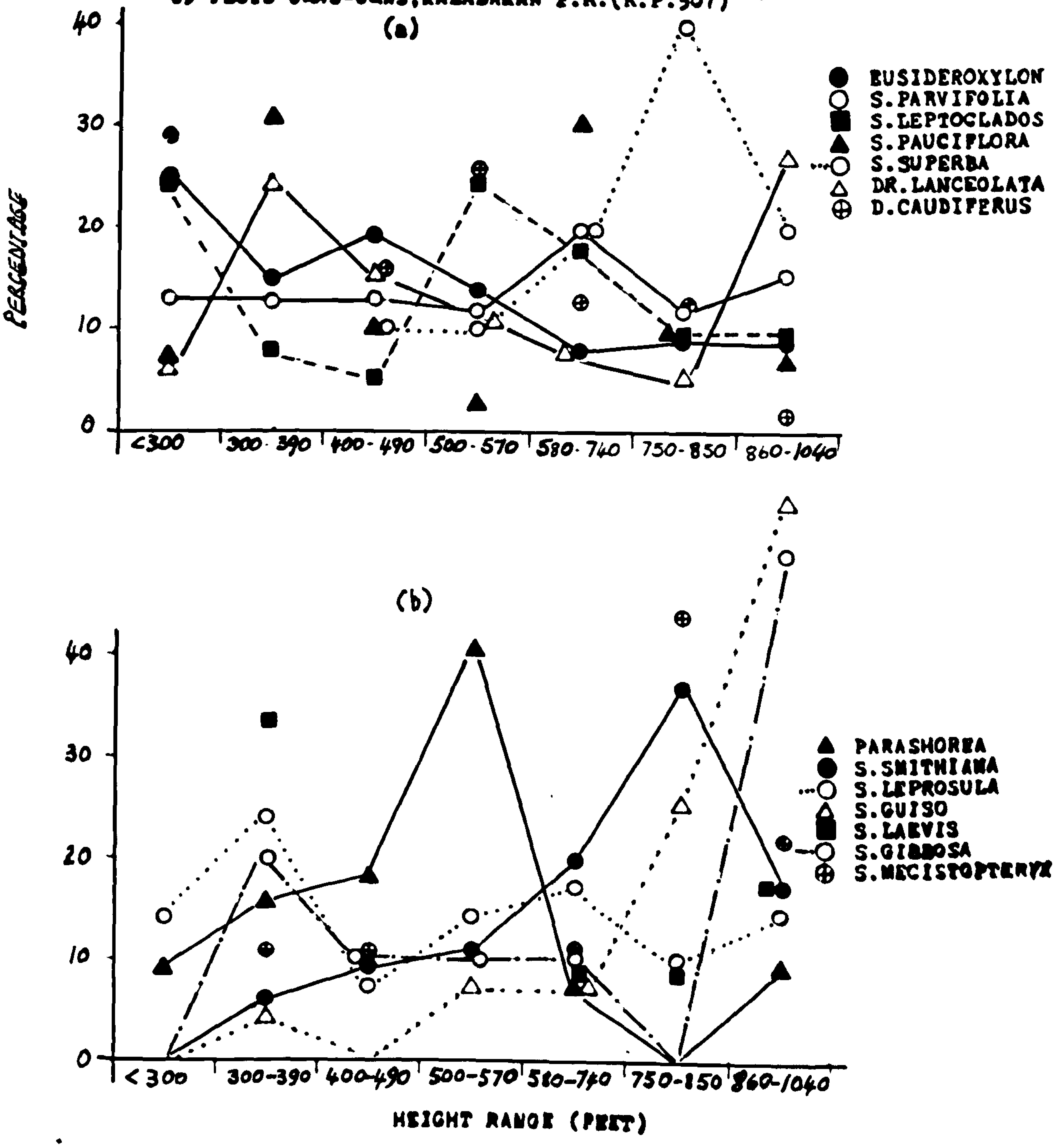
Dryobalanops lanceolata, present in half the plots, was widely distributed (Figure 33 (d)), but absent on some of the steep, western parts of the main ridge and from some low lying areas. It was locally abundant, e.g. 7 stems in plot 32, 4in plot 45; 13 plots had 2 stems, and the same number had one only. It was present over the range of altitudes and sites and was more consistently present with *S.parvifolia*, *S.pauciflora* and *S.gibbosa* than with *Parashorea tomentella*, *D.caudiferus*, *S.smithiana* and *S.leprosula*.

Shorea leptoclados predominantly a species of the valleys and lowlands extended up the valleys into the hills, but avoided steeper slopes (Figure 33 (c)). The species found with it included *E.zwageri*, *D.caudiferus*, *S.leprosula* and *Hopea nervosa* in more level valley sites, while *S.laevis* was present in higher areas. *S.smithiana* was present mainly in the hills extending down the ridges into the lowlands, in contrast to *S.leptoclados*, with whose absence it was strongly correlated (Figure 33 (c)). *S.smithiana* occurred in only 3 plots below 500 ft (150 m) viz: 20, 22, 54 and the mean altitude of plots in which it was present was 710 ft (220 m).

In Figure 34 all plots are divided into 7 more or less equal sized groups based on their altitude range and species occurrence is shown as a percentage of total numbers for 14 species. This presentation suggests abundance of *S.leptoclados* in the lower range, and in the middle, while complete absence of *S.smithiana* was also negatively correlated with *P.tomentella* whereas its closest associates were *S.parvifolia* and the Selangan Batu species *S.guiso* and *S.superba*. The species was locally abundant, 3 stems occurred in each of plots 4, 9 and 13.

P.tomentella was present over much of the lowland area (Figure 33(d) and was more strongly correlated with

FIGURE 34 PERCENTAGE DISTRIBUTION OF INDIVIDUALS OF COMMON SPECIES OVER THE ALTITUDE RANGE 63 PLOTS UMAS-UMAS, KALABAKAN F.R. (R.P. 307)



Dr.lanceolata, *S.pauciflora* and *S.gibbosa* than with *S.leptocladoss*, *D.caudiferus*, *S.leprosula* and *H.nervosa* (Appendix 5, Table 6). It was locally abundant at 400-500 ft (120-150 m), as shown in Figure 34, and had 8 stems in plot 33, 5 in plot 46 and 4 each in plots 29 and 60. *P.malaanonan* was only recorded in plot 4 at 1040 ft where *S.guiso*, *S.smithiana* and *Dr.lanceolata* were common.

Dipterocarpus caudiferus showed strong aggregation in its plot representation, viz. present in main eastern valley plots 1, 2, 8, 13, 14 and 16, and in lowland in the west: plots 47, 48, 49, 50, 52. Other occurrences were scattered but 8 individuals in plot 38 and 4 in plot 58 emphasise its tendency, along with most members of the genus, to occur in groves. It was present over a range of altitudes (Figure 34), but was scarcer on the higher hills, and its presence was poorly correlated with a number of species (Appendix 5, Table 6), its closest associates being *E.zwageri*, *S.leptoclados* and *S.argentifolia*.

Other *Dipterocarpus* species were *D.confertus* in 4 plots as singles, but with 4 stems in plot 31 and present with *Vatica micrantha*, *S.guiso*, *S.leprosula*, *S.smithiana* and *S.parvifolia*. *D.applanatus* was present on moist sites as single small trees in plots 17 and 40, where *Horsfieldia* sp. and *Aquilaria malaccensis* were present respectively. *D.gracilis* was present in plot 13, probably a moist site in this hillside plot. *D. grandiflorus* was represented by two trees in plot 18, on the steep southern face of the main ridge with *Anisoptera costata*, probably a well drained, rather leached site, and *S.smithiana*, *S.superba* and *S.guiso* were also present. *Anisoptera* was also in plot 41, a moist site, with *Anthocephalus chinensis* and *Neesia* sp. present.

S.leprosula was mainly in the lowlands, but also locally present in the hills and absent in lower valleys and from plots in the centre of the area (Figure 33(b)). Its most frequent associates were *Eusideroxylon*, *S.leptoclados*, *S.smithiana*, *S.laevis* and *D.confertus*. *S.pauciflora* was found with *S.parvifolia*, *Dr.lanceolata* and *P.tomentella* but less so with *S.smithiana* and *S.leptoclados*. There was a noticeable concentration of *S.pauciflora* in the plots in which it occurred and 6 stems were recorded in plot 8.

S.guiso was confined to the main ridge and spurs running off it, from 330-1040 ft (100-320 m), and was mostly found with *S.smithiana* and *S.almon*. *S.guiso* was locally gregarious with 7 stems in plot 31 and 4 in plot 40, and its greatest abundance was in the higher altitude plots (Figure 34). *S.laevis*, predominantly a hill species (cf Type F), only present in four plots was gregarious in two: plot 35 had 5 trees and plot 51 had 4, the former at 710 ft and the latter at 330 ft. The other Selangan Batu species *S.superba* was localised on ridges over 400 ft (125 m), mainly at the south of the main range. Its only main associate was *S.smithiana* though several species were scarce with it, e.g. *E.zwageri* and *Dillenia*.

The generally small tree *Hopea nervosa* was present in 11 plots, mainly valley sites through the altitude range (Figure 33 (b)) found with most common species, but less so with *Dr.lanceolata* and *S.smithiana* Plots with *H.nervosa* present account for the single records of *Pometia pinnata* (plot 28), *Horsfieldia* sp (17) and *Alstonia* sp (55) all of which are typically species of moist habitats.

Hopea sangal was uncommon, absent from the higher hills, only present in the western half and was more abundant on the lowlying alluvial flats.

S.argentifolia (Figure 33 (d)) was present in 7 plots and found with *D.caudiferus* and *S.pauciflora* on flattish alluvial areas in the west and valley sites elsewhere. *S.almon* (Figure 33(c)) was present in the western part of the main ridge, mainly on steep slopes with *S.guiso*. This species and *S.mecistopteryx* were present in 7 plots only. The latter species was found in upper valley areas and was not found with the Selangan Batu species *S.superba*, *S.laevis*, and *S.guiso* (Appendix 5, Table 6). *S.gibbosa* was present in 9 plots often with *Dr.lanceolata* and more characteristic of the hilly areas than the other Richetia *S.acuminatissima* (Figure 33 (b)).

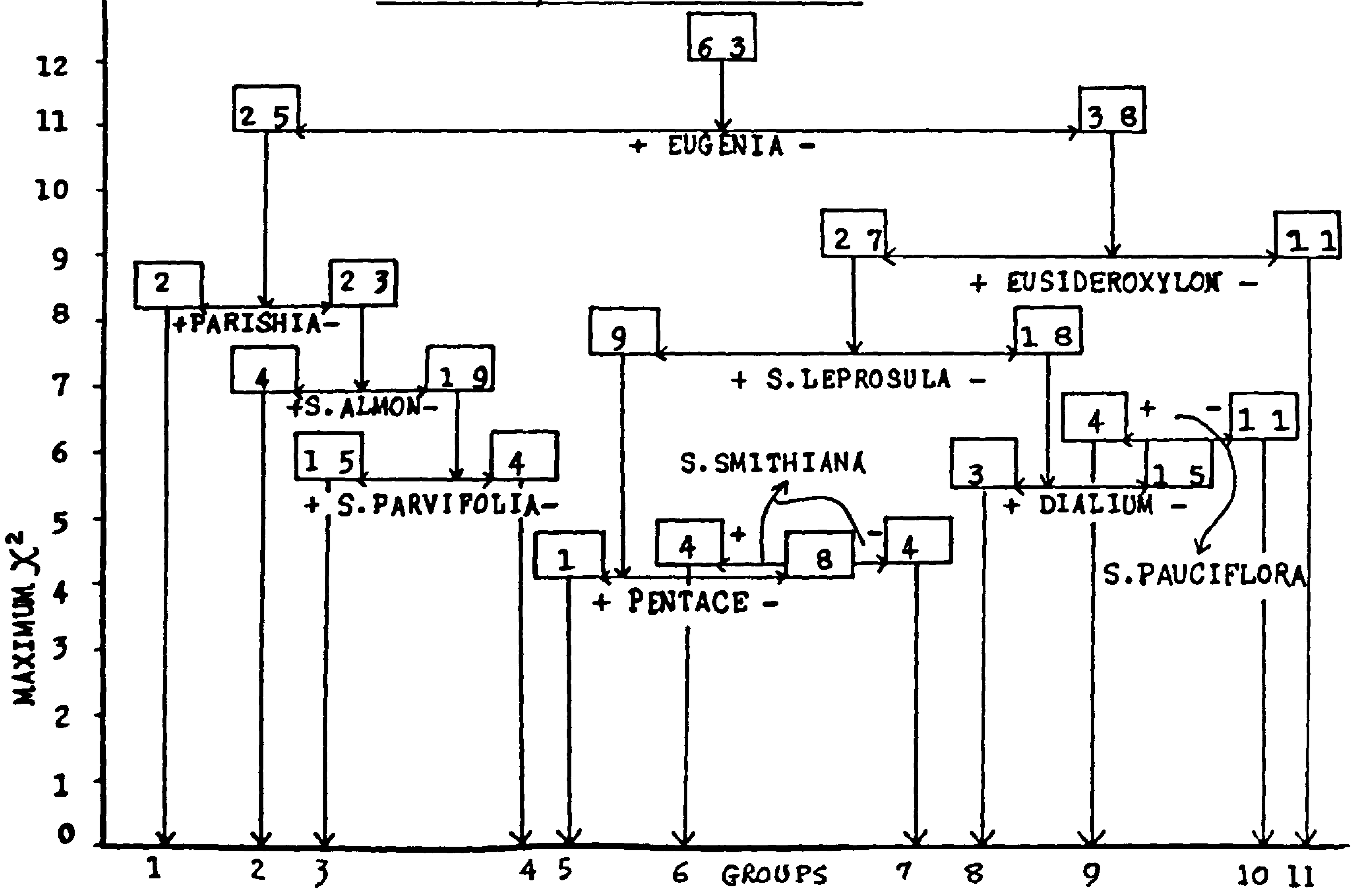
Other dipterocarp species recorded were less common than those described so far. *S.beccariana* had 4 stems in plot 2, a ridge site, and was not recorded elsewhere. *S.ovalis* was represented once only, in plot 1. *S.macroptera* occurred once each in three plots east of the main ridge in valleys (Figure 33(d)) with *S. mecistopteryx* and *S.leprosula*. Others were *S.symingtonii* one small tree in each of two plots; and unidentified Selangan Batu in plots 1 and 42; an unidentified *Vatica* in plots 11 and 36; *V.umbonata* 1 in plot 10; *V.oblongifolia* 1 in plot 26, 2 in 27; and *Vatica micrantha* had 6 stems in plot 31 (cf *D.confertus* above).

Other, non dipterocarp, species included *Castanopsis* sp. which occurred scattered throughout the area, mainly as a small tree, particularly with *S.smithiana*. Large individuals of *Eugenia serrata* and *E.polyantha* have been recorded from the vicinity

(Appendix 2, Table 10) but the actual species present in the area under discussion here were not recorded. Distribution of trees of the genus was more localised than *Castanopsis*, e.g. *Eugenia* was recorded from only 5 plots east of the main range, probably all valley sites, and was particularly abundant in the low lying areas. The genus was generally present with *Eusideroxylon*, *S.pauciflora* and *S.acuminatissima*. *Sympetalandra borneensis* was scattered (Figure 33(d)) but, in common with *Koompassia excelsa* (Figure 33(b)) restricted to lower areas. *Dialium indum*, a species of moderately steep hills or ridges, mainly at lower altitudes, is also illustrated (Figure 33(c) and Figure 35). Other genera recorded were *Canarium*, *Palaquium*, scattered, and *Lithocarpus*, mainly present on the steep, western slopes of the main ridge.

As the plots were randomly located (the principal objective of the work being to estimate timber outturn from the whole area cf Figures 18-22 above) they undoubtedly straddle distinctive site boundaries. The relative abundance and distribution of species therefore may be distorted slightly by, for example coincidence of a moist valley and a sharp ridge. Breakdown of constituent species into groups must reflect the large scale distribution of the more common species and local abundance. The groups divided by association analysis are not discrete, reproducible associations. The 25 plots with *Eugenia* present were mainly at lower altitudes and if the four plots with *S.almon* (i.e. second group of Figure 35), which were hillside/valley locations, are excluded the remaining 21 plots average 431 ft. compared with the overall altitude mean of

FIGURE 35 ASSOCIATION ANALYSIS R.P.307 USING $\sqrt{\chi^2/N}$ FOR 43 SPECIES



570 ft. These plots were mainly in valley or flat locations. The tenth group, with *S.pauciflora* absent, consisted of upper valley plots averaging 570 ft, and those of the other large group, as mentioned earlier, were higher, and mainly on ridge or hillside sites (i.e. the 11 plots with both *Eusideroxylon* and *Eugenia* absent).

Regeneration of *S.parvifolia* is likely to be of greatest importance over the area as a whole, supplemented by *S.leptoclados* and *Parashorea tomentella* on lower sites and *S.smithiana, S.leprosula, S.almon* etc. on steeper places. *Eusideroxylon* trees of smaller size are likely to be abundant and this species must also be considered.

Basal area plotted with altitude (Figure 36) suggests that plots on ridge or hillside/ridge sites generally carry higher basal area than the other sites. This general situation appears for most forests (cf R.P. 17 above) in the region (Wyatt-Smith 1949 a). The corresponding range in basal area (for trees of 5ft+) for the 50 sub plots of R.P.228 is 35-98 sq.ft./acre. The range of basal area suggests flat sites have least, and valley sites most, variation, and that the differing sites have different productivity (cf relations between basal area and other parameters, Figures 19-22).

R.P. 303 Kalabakan F.R. (Felled)

Species distribution varies considerably from area to area. In this section a set of 16 plots randomly sampling 320 acres in Compartment 442, of Brantian (Figure 35) is discussed. A stand table summary for the area, also classified as Type C forest, is given in Appendix 2, Table 11. This hilly area was dominated

FIGURE 36 PLOT ALTITUDE, BASAL AREA AND SITE TYPE
R.P. 307 UMAS-UMAS KALABAKAN F.R.

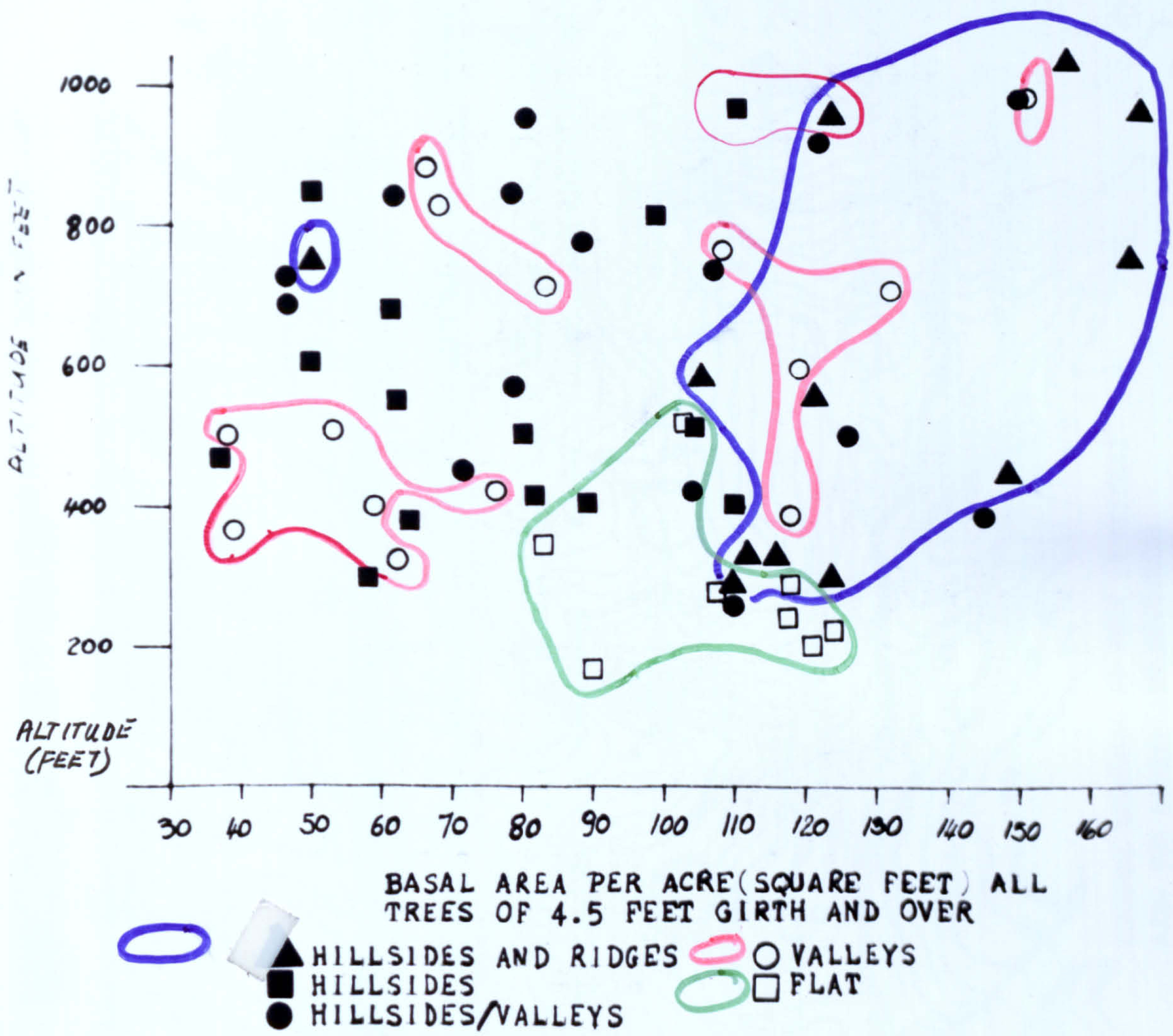
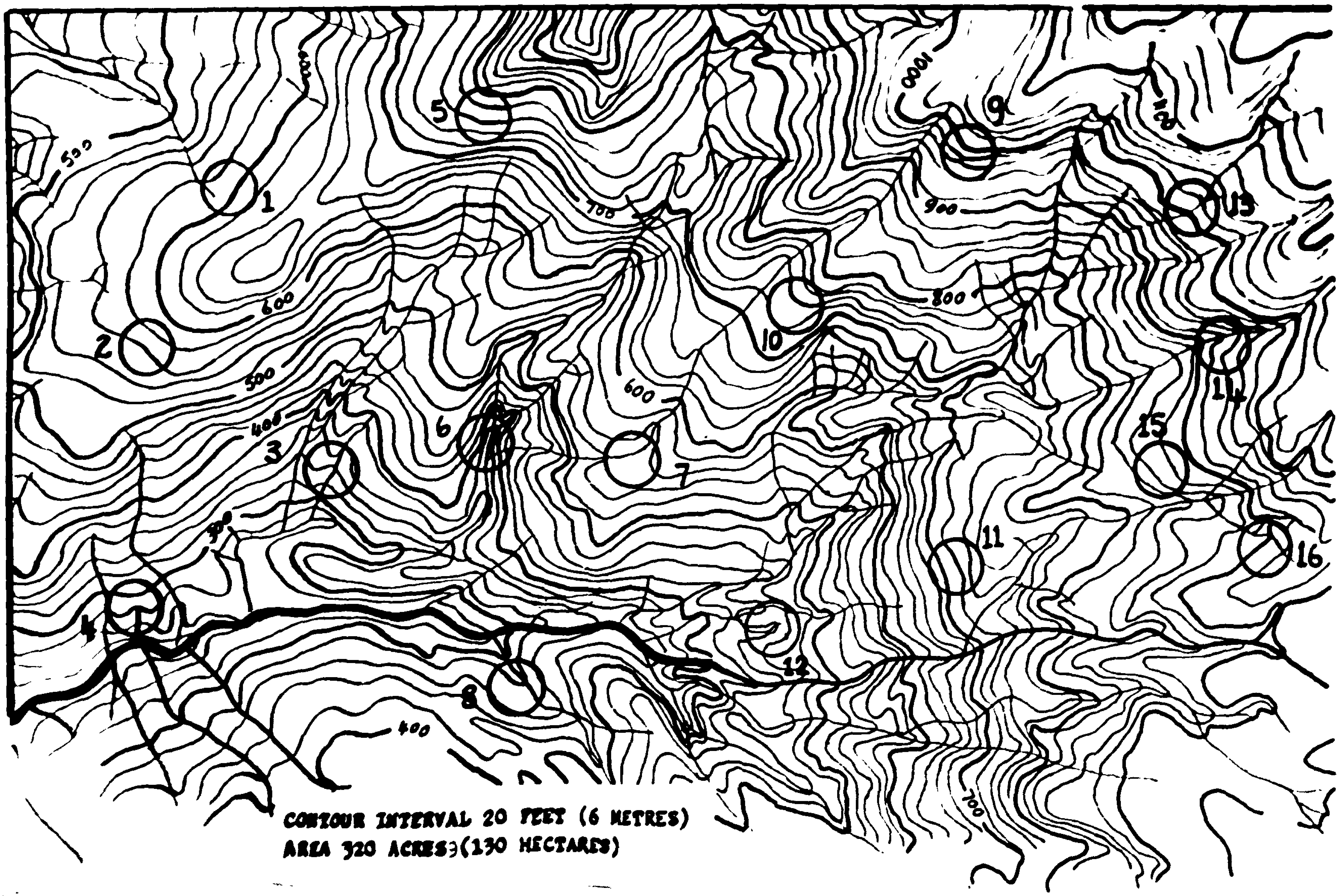


FIGURE 37 LOCATION OF 16 SAMPLE PLOTS OF 1 ACRE COMPARTMENT 442 BRANTIAN, KALABAKAN F.R. - R.P.303



by a river flowing from east to west, with the land rising from 200 ft (60 m) in the southwest to 1200 ft (370 m) in the northeast.

Some 57 species of 4.5 ft girth and over (44 cm diam+) were recorded totalling 292 stems. The most abundant were as follows:

Table 20. Abundant Species R.P. 303

Species	Number	Plots	% No.	Max size (ft)
Shorea mecistopteryx	37	8	13	15
S.oleosa	22	11	7.5	14
Eusideroxylon zwageri	19	11	6.5	11
Eugenia	18	12	6.2	9
S.parvifolia	16	8	5.5	13
Dryobalanops lanceolata	10	7	3.4	14
S.pauciflora	8	5	2.7	13
S.gibbosa	8	3	2.7	15

This area had considerably less *E.zwageri* than R.P.307A, no *Dillenia,* and *S.parvifolia* present in half the samples. A total of 29 species of Dipterocarpaceae were recorded compared with 34 in R.P.307A. Topographically the area was less variable, with both steep ridges and broad alluvial flats absent. Lowlying or gentle slopes held six plots (1, 2, 5, 7, 10, and 11); valleys of little slope five (3, 4, 8, 13 and 16); steeper valleys three (6, 12 and 14); and slightly convex (ridge) slopes had two plots (9 and 15).

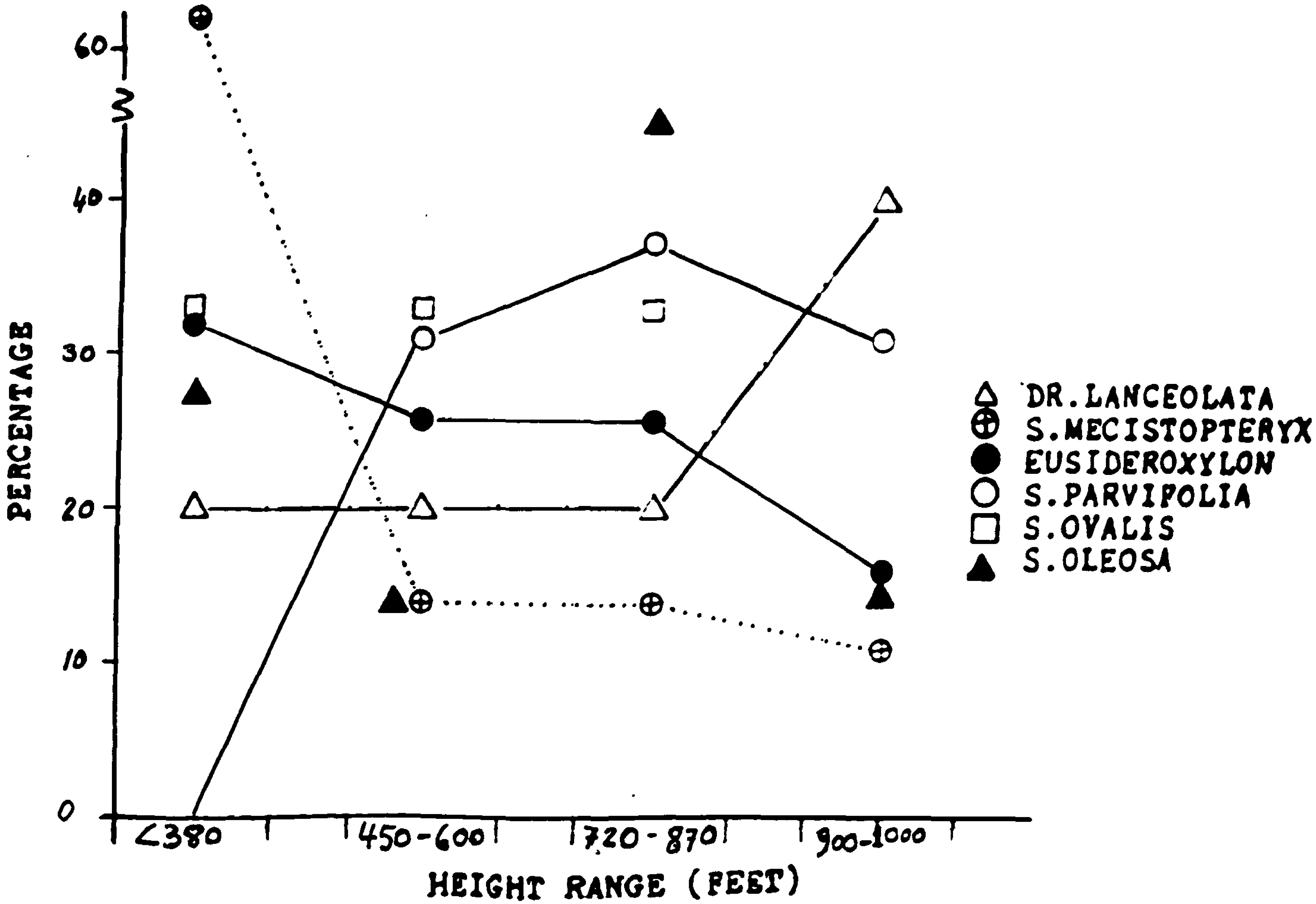
Shorea leprosula, S.smithiana and *Heritiera* sp., were absent in valley plots and *S.pauciflora* was absent on the lowlying land. *S.oleosa, E.zwageri, Dr.lanceolata, P.tomentella, S.ovalis, D.caudiferus* and *Canarium* sp. showed no apparent preference for any of the site categories. *S.mecistopteryx, S.parvifolia* and *Eugenia* spp. also found throughout the area did exhibit some degree of preference. The latter two were more frequent on the flatter land, while 86 per cent of the stems of

S.mecistopteryx occurred in valley plots. *Koompassia malaccensis* and *S.mecistopteryx* were absent on steeper land and *Dr.keithii* was confined to gentle valley sites.

As the sample was smaller than R.P.307A there were a number of single occurrences of less common species. One stem of *S.argentifolia* was present in plot 1, *D.exalatus* and *S.atrinervosa* were only present in plot 7, a gentle valley site. *P.smythiesii* was only recorded in plot 12, and *S.laevis* only in plot 13. The only records of *D.confertus*, *S.agami* and *V.oblongifolia* were for plot 14, an area of steeper land with a ridge abutting onto a valley where *S.mecistopteryx* and *E.zwageri* were absent. *Hopea sangal* was present in plot 15. Unidentified *Dipterocarpus* occurred in plots 2, 5, and 10; and unidentified *Shorea* (Richetia) in 4, 5, 10, 11, 15, and 16. Both of these latter may represent more than one species. The recorded distribution of the Richetia *S.gibbosa* was in plots 6, 7, and 9 with six individuals in plot 9. *S.leptoclados* was recorded once, in plot 5.

Appendix 5, Table 7 shows joint occurrence of species in plots. The major species showed changes in their proportional representation with altitude (Figure 38) not dissimilar to that for the Umas Umas distribution. Figure 38 gives 4 values for each of 6 species, based on 4 plots in the altitude ranges shown. The major division relating to species concurrence was between predominantly valley species and others. In valley sites *S.mecistopteryx* was mainly found with *E.zwageri*, *Eugenia* spp, *S.ovalis* and *Canarium odontophyllum*. On flat land and gentle slopes *P.tomentella* was found with *S.gibbosa*

FIGURE 38 PERCENTAGE DISTRIBUTION OF INDIVIDUAL SPECIES OVER THE ALTITUDE RANGE 16 PLOTS BRANTIAN, KALABAKAN F.R. (R.P.303)



Eusideroxylon zwageri and *D.caudiferus* and to a lesser extent with *Dr.lanceolata*, *S.leprosula*, and *S.smithiana*. The range of *S.oleosa* encompassed that of *Heritiera* sp, *Scaphium* sp, *Irvingia malayana*, *Sindora* sp, *Dialium indum* and *S.laevis*, all of which are typically of stronger slopes. A number of other species were found most frequently with *S.oleosa*.

Association and Aggregation

The foregoing analysis suggests that areas of more homogeneous physiography have less definite groupings of species and that local hilliness or swampiness are probably the main environmental factors accounting for definite species groupings (cf Cousens 1951). This does not exclude local changes in soil, which have been dealt with in describing the main Types, e.g. the presence of *Dr.beccarii* on sandy soils in Segaliud-Lokan F.R. on the Lokan Peneplain in a matrix of Type B forest. In the more homogeneous forests there is absence of association among the commoner species (cf Poore 1968) but due to gap regeneration a pattern of clumps, often family groups (e.g. *S.smithiana* in Figure 13) arises as a result of chance. Clumping is more noticeable with the Dipterocarpaceae than with trees of other families whose fruit is dispersed by wind or animals (Ashton 1969). The heavy fruits of *Eusideroxylon* (cf Richards 1952) are probably mainly responsible for clumping.

In any given area the abundant species are generally well distributed and, apart from localised site differences, it may be assumed that the areas of low amplitude will regenerate to a mixture of the species abundant in the natural forest. On the wider scale it is to be expected that different groupings in the natural forest, on the differing site categories, will be reflected in regeneration composition. Subsequent examination of the mechanism of seedfall and distribution patterns will attempt to illustrate varied species survival chances.

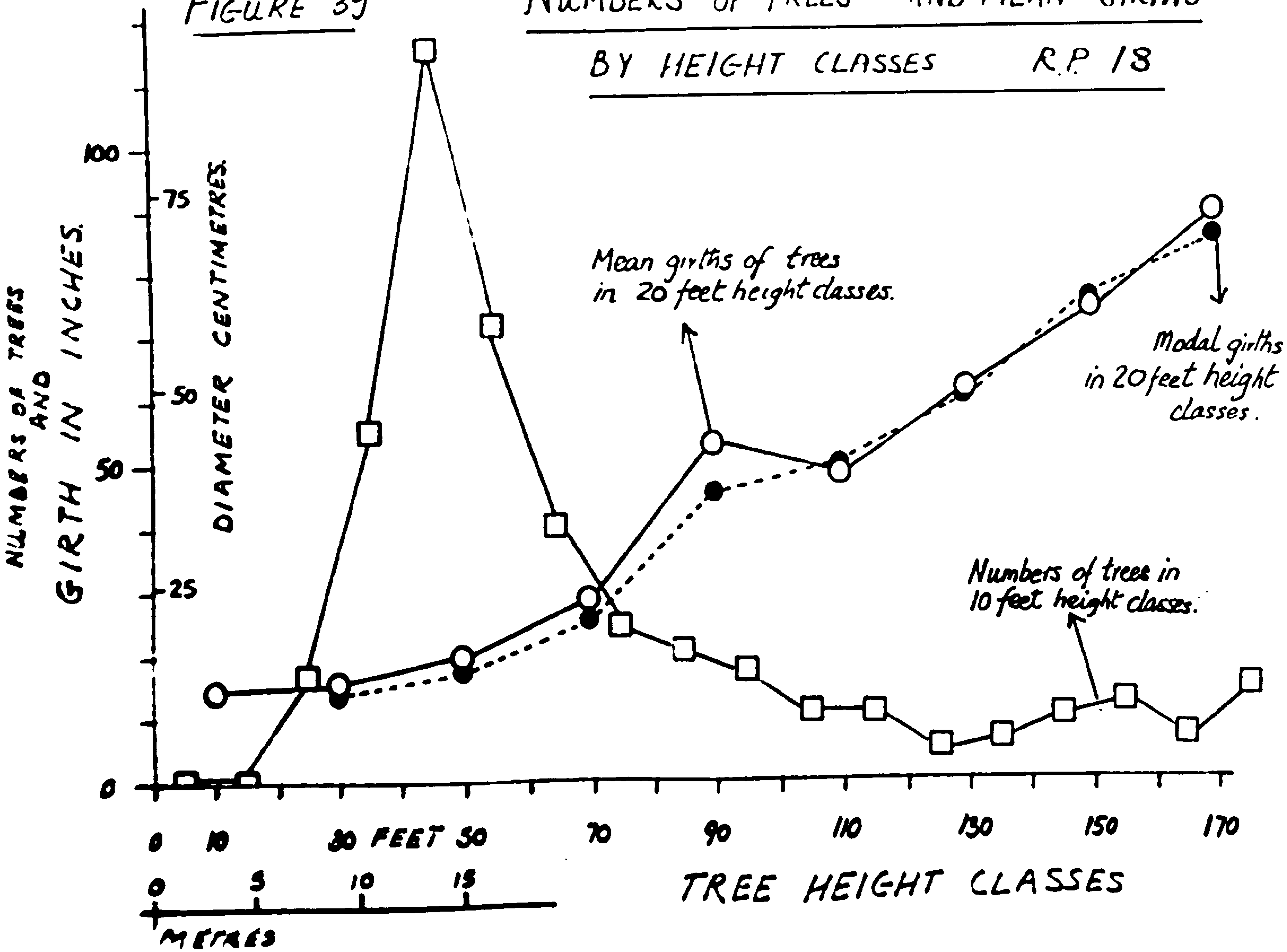
Structure

Profile diagrams illustrating the structure of typical stands within the natural dipterocarp forests have been given in Part 2. The most important feature of the natural stands is that the taller trees are emergents above the heterogeneous lower layers where "space is filled at all levels according to the chance development of trees" (Nicholson 1958 d). For sizes up to 8 ft g (78 cm diam) mean height increases regularly with girth (R.P.55 : A.R.R.B. 1962). This is illustrated for trees in R.P.18 (cf Appendix 3, Table 2), in Figure 39. Individuals of small girth may reach the canopy e.g. from 5 ft g in R.P.55, Type A, and from 3-4 ft g in Segaliud-Lokan, Type B (Nicholson 1962 a). Similarly squat understorey trees may reach 6 ft g and I have mentioned earlier the general subordinate status in the canopy of *Eusideroxylon zwageri*, which on occasion has large girth boles. On average trees of 7 ft g and larger reach the canopy in Segaliud-Lokan (Fox 1967 a).

The emergent storey is often discontinuous in lowland areas (Figures 16, 17) and on steep slopes, but on ridges and in some dense lowland areas, e.g. Type D (Figure 24) it tends to be more or less continuous as a main storey. The taller trees often reach 60 m (Table 10) but occasional individuals, especially of *Koompassia excelsa*, may reach 80 m. Burgess (1961) described the structure of three profiles in detail, two in Type B at Segaliud-Lokan and Gum Gum and one at Kalumpang in Type A. The latter had a more continuous canopy than the former two but it is difficult to draw more than very general conclusions from limited samples of this nature. A generalised height statement is that beneath the taller

FIGURE 39

NUMBERS OF TREES AND MEAN GIRTHS BY HEIGHT CLASSES R.P. 18



trees a poorly defined discontinuous storey from 18-34 m stands over a well marked main storey from 6-18 m. Ashton (Letter:M.F. 1965 p.144-148) has suggested that layers are scarcely discernable but the most convenient description of the dipterocarp forest as a whole is of a three layered forest (Robbins and Wyatt-Smith 1964). Consideration of the distribution of stem numbers in height classes (Figure 39 and Nicholson 1962 a) certainly suggests the presence of definite layers even if they cannot be clearly "seen" on the ground.

Structure of regenerating stands, though basically likely to approximate the general form of natural stands, may be more even, and evenness should certainly be aimed at to maximise the use of crown space. However the species comprising regenerating stands will tend towards similar shapes and roles in the canopy as they have in the natural forest. The aims of silvicultural intervention include that of increasing the representation of the common Dipterocarpaceae (or at least attempting to achieve satisfactory presence) suggesting the possibility of two layered stands. This would be a main canopy of valuable trees over an understorey, possibly consisting of poles of the same species but differential growth rates and the effects of competition may result in reassertion of the three layer tendency.

Growth Rates in Natural Forest

Undisturbed conditions.

Sample plots in Sepilok F.R. give longest consistent measurement information on natural growth rates (Fox 1972). Growth rates for some common species in R.P.17 are illustrated in Figure 40. Nicholson (1963 a)

FIGURE 40 R.P.17 CURRENT ANNUAL INCREMENTS

1958-62

Some Current Annual Increments By Girth Classes Of The More Abundant Fastest Growing Species In Research Plot 17

Based on Data for 1958 – 1962. After Nicholson (1965). Girth Classes as at 1960.

——— Indicates no representation in the girth classes crossed.

* Species with individuals having CAI of one inch or more.

Forest Department, Sabah. 1971.

discussed these with respect to probable ages of trees. In this plot the Rubroshorea species *Shorea argentifolia*, *S.mecistopteryx*, *S.macroptera*, and *S.smithiana* had individuals with current annual increments of girth of one inch (0.8 cm diam) or more and higher average increments than the *Dipterocarpus* trees present in the plot. Increments of all trees taken together show that smaller trees, (including many individuals of understorey species) have lower increments than larger trees. This is true also for species of Rubroshorea and the peak at 6-7 ft grith (58-68 cm diam) is reflected in the graphs of these species.

Considerable variation in growth rates of individuals of the same species and size was largely accounted for by comparative crown differences; in general trees with larger crowns grow faster. Some of the smaller dipterocarp trees with medium sized crowns of small horizontal branches, giving a crown of some depth, were more vigorous, and possibly younger, than similar sized trees with flatter, less branched, or ascending branch, crowns. Emergent trees and most of those with large cornws had access to light. Individual trees with large crowns and relatively good increments occurred in many species. In addition to the four Rubroshorea species given above, another 5 species had individuals with C.A.I. girth of 1.0 ins or more, and a further 26 species were able to grow at 0.5 ins or better per year. Species illustrated in Figure 40 are from these 35 species, and represent 28 per cent of trees considered in the plot.

Over the 10 years 1958-68 dipterocarps in R.P.17 grew at the following average rates (Rate = current annual increment, in inches girth per annum; No. =

number of increments included; Max. size = girth class of largest tree included):

Species	Rate	No.	Max Size
S.argentifolia(Ru)	.76	8	8 ft
S.smithiana(Ru)	.44	17	6
S.mecistopteryx(Ru)	.42	15	7
H.beccariana	.41	37	4
S.faguetiana(Ri)	.39	7	11
S.beccariana(Ru)	.34	24	9
D.acutangulus	.34	59	15
S.macroptera(Ru)	.32	16	9
S.parvifolia(Ru)	.28	5	5
S.multiflora(Ri)	.27	53	5
S.glaucescens(SB)	.21	5	9
D.grandiflorus	.20	20	9
V.papuana	.19	4	3
S.virescens(An)	.19	1	3
H.semicuneata	.18	3	6
V.micrantha	.15	2	3
S.foxworthyii(SB)	.14	2	5
V.oblongifolia	.11	4	3
D.confertus	.09	7	10
P.tomentella	.05	1	8
P.malaanonan	.01	1	12

Comparatively low rates for *Parashorea*, with only two trees considered, may reflect the fact that the species are normally absent from stands of Type G forest.

Data on growth rates for R.P.18 (Type B) is also given in Fox 1972. Over the twelve year period 1957-69 nine trees, 4 of *S.leptoclados*, 2 of *P.tomentella* and 1 *S.waltonii*, maintained average growth rates in excess of 1.0 ins of girth per annum. Rates for individual species are as follows.

Species	Rate	No.	Max size
S.waltonii(Ru)	1.11	2	7 ft
H.nervosa	.68	3	3
S.leptoclados(Ru)	.62	37	11
S.leprosula(Ru)	.51	2	7
S.parvifolia(Ru)	.48	7	8
S.symingtonii(An)	.48	1	5
P.tomentella	.36	20	7
S.xanthophylla(Ri)	.32	14	3
S.seminis(SB)	.29	1	1
D.applanatus	.23	8	10
D.caudiferus	.23	5	9
S.almon(Ru)	.23	2	2
Dr.lanceolata	.18	5	11
D.exalatus	.15	[illegible]	4

Compression of data into this form obscures the trend of increasing increment with size, but for the more abundant species reaching larger sizes the ranking shows clearly that the Rubroshorea group, in general, grow faster than other groups of *Shorea* and the other dipterocarp genera. Figure 41 illustrates comparative growth rates for R.P's 15, 17, 18 and 54, all natural undisturbed stands, in which all trees were measured over 3-4 year periods. The average growth of a tree, all sizes combined, under natural conditions, is of the order of 0.20 inches of girth per annum (0.16 cm diam) rising to 0.50 ins (0.40 cm diam) for trees over 5ft girth.

The importance of *Eusideroxylon zwageri* has been stressed earlier. It has low growth rates: in R.P.18 the average C.A.I. over 12 years was 0.19 ins girth. Fuller measurements for R.P. 3, also in Sepilok F.R., are illustrated in Figure 42. This shows that individuals through the size range can grow at up to 0.50 ins per annum, but that average growth is well under this.

Growth Rates in Openings

Intervention in the natural forest, e.g. felling, poisoning, etc. influences growth rates, which tend to rise, especially for the smaller individuals. Figure 41(c) illustrates the growth of the best trees of commercial species in 0.5 chain squares (10 m x 10 m) within two plots of 2.5 acres (1 ha). One plot received a liberation treatment, in which all stems of non-commercial species were poisoned, the other being a control (natural forest of Type A). Increased increment occurred on measured stems in the smaller size classes following liberation.

FIGURE 41 CURRENT ANNUAL INCREMENTS BY GIRTH CLASSES - NATURAL FOREST

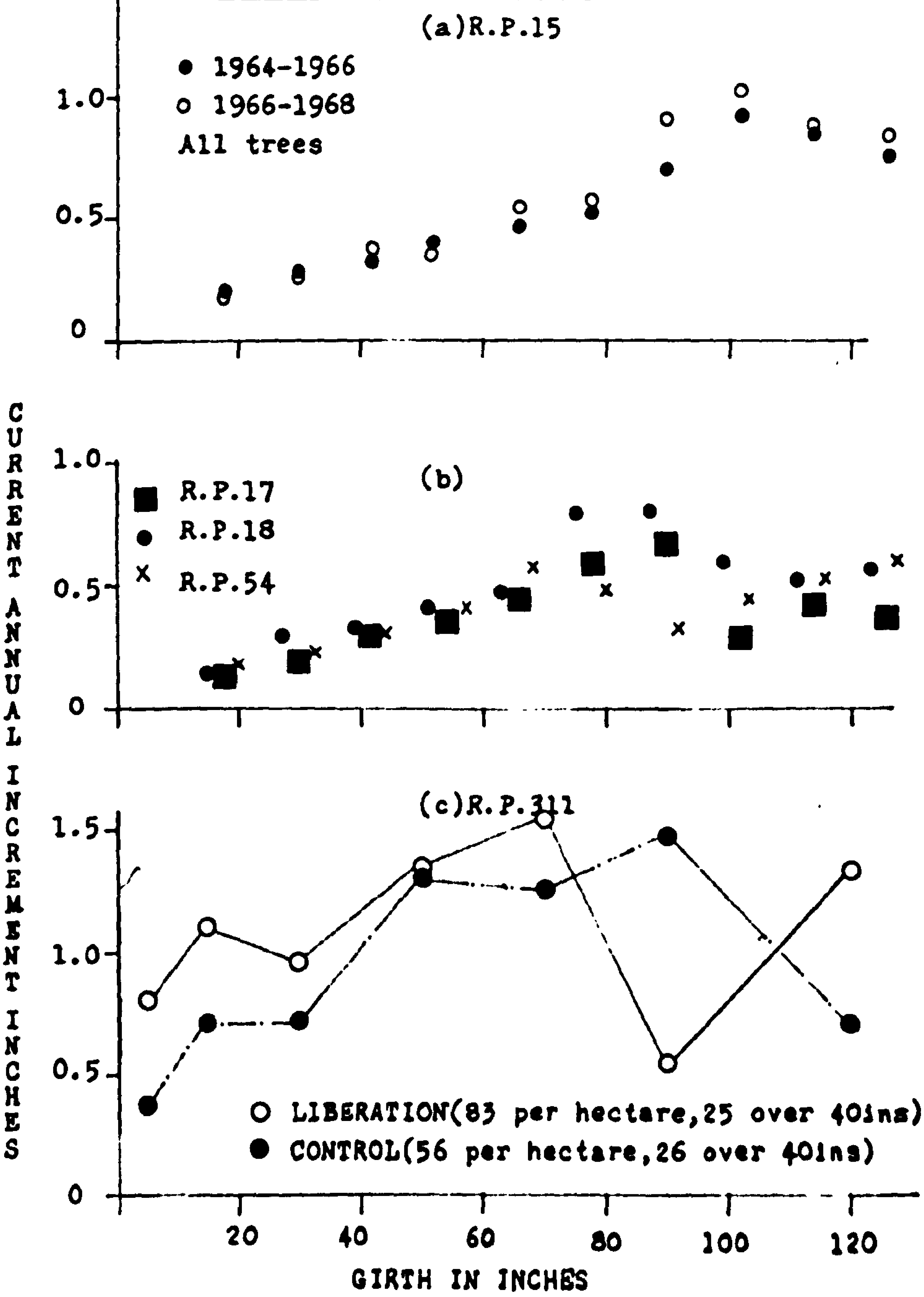
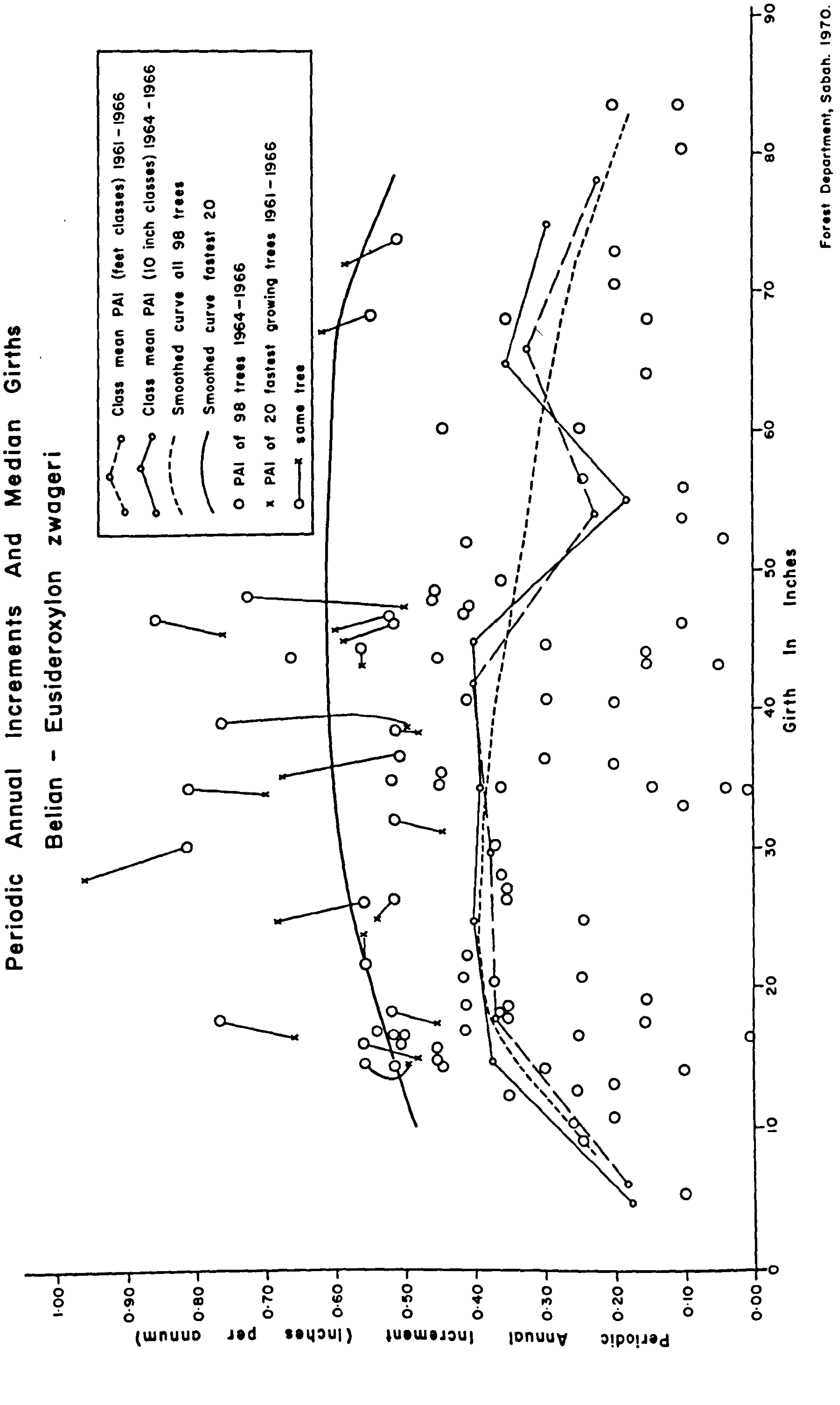


FIGURE 42 R.P.3

Increment of *Eusideroxylon zwageri*

Sepilok Forest Reserve



Measurement of 150 stems of *S.macrophylla* at Tenegang F.R. in logged over Type B forest gave an average C.A.I. of 1.35 ins girth for trees 5-15 ft girth for the period 1962-67, Table 21 summarises measurements of all trees in this plot (R.P. 86) according to broad categores of crown size:

Table 21. Numbers and Current Annual Increments for *Shorea macrophylla* in R.P.86, Tenegang F.R. (ø inches).

Period	Crown Size: Large		Medium		Small		Total
	No.	C.A.I.	No.	C.A.I.	No.	C.A.I.	C.A.I.
1962-63	63	1.4	98	1.1	21	0.8	1.2
1963-64	43	1.3	101	1.0	28	0.7	1.0
1964-65	44	1.1	96	0.9	31	0.5	1.0

(A.R.R.B. 1963, 1964, 1965)

Examples of increased increment following thinning of dense second growth dipterocarp stands (R.P.'s 4, 16) are given in Fox (1972). In these examples the smaller stems showed greater responses to opening than the emergents, and a number of seedlings grew into the lowest measurement class (12 ins +, 10 cm diam).

R.P.53 is a 20 acre (8 ha) plot in Segaliud-Lokan F.R. logged over in 1962. Dipterocarp trees originally in the size range 1-5 ft girth were measured during the period 1959-1971. Trees measured before logging (301) had average C.A.I. between 0.40 and 0.53 for individual years; the trees remaining after felling (127) had average C.A.I's of 0.82 in 1963, and 1.36 in 1964, but growth subsequently fell off to 1.22 in 1964 and 1.13 in 1965. Those surviving to 1970 (105) had an average C.A.I. for 1959-1962 of 0.53 in, and of 1.11 during 1963-70, having grown, on average, twice as fast in the 7 years following felling as in the three years prior to felling.

Increments before and after felling for R.P.53 are illustrated in Figure 43 and will be discussed in more detail in Chapter 7. Table 22 gives a summary of increments by size classes, showing clearly that increment of larger trees is unaffected by intervention and that the greatest gains are for trees in the sizes 1-3 ft girth (see also Table 40).

Table 22. Average Current Annual Increments by Size Classes for Survivors to 1970. R.P.53 Segaliud-Lokan F.R.

Girth Classes (in)	Prior to Felling (1959-62) C.A.I. (in)	(No.)	After Felling (1963-70) C.A.I. (in)	(No.)	Percentage Change
12-19.9	0.27	(30)	0.51	(12)	189
20-29.9	0.58	(23)	1.11	(30)	191
30-39.9	0.69	(18)	1.29	(16)	187
40-49.9	0.51	(9)	1.19	(19)	233
50-59.9	0.67	(11)	0.89	(9)	132
60-69.9	0.54	(10)	1.15	(6)	213
70+	1.12	(4)	0.88	(13)	negative

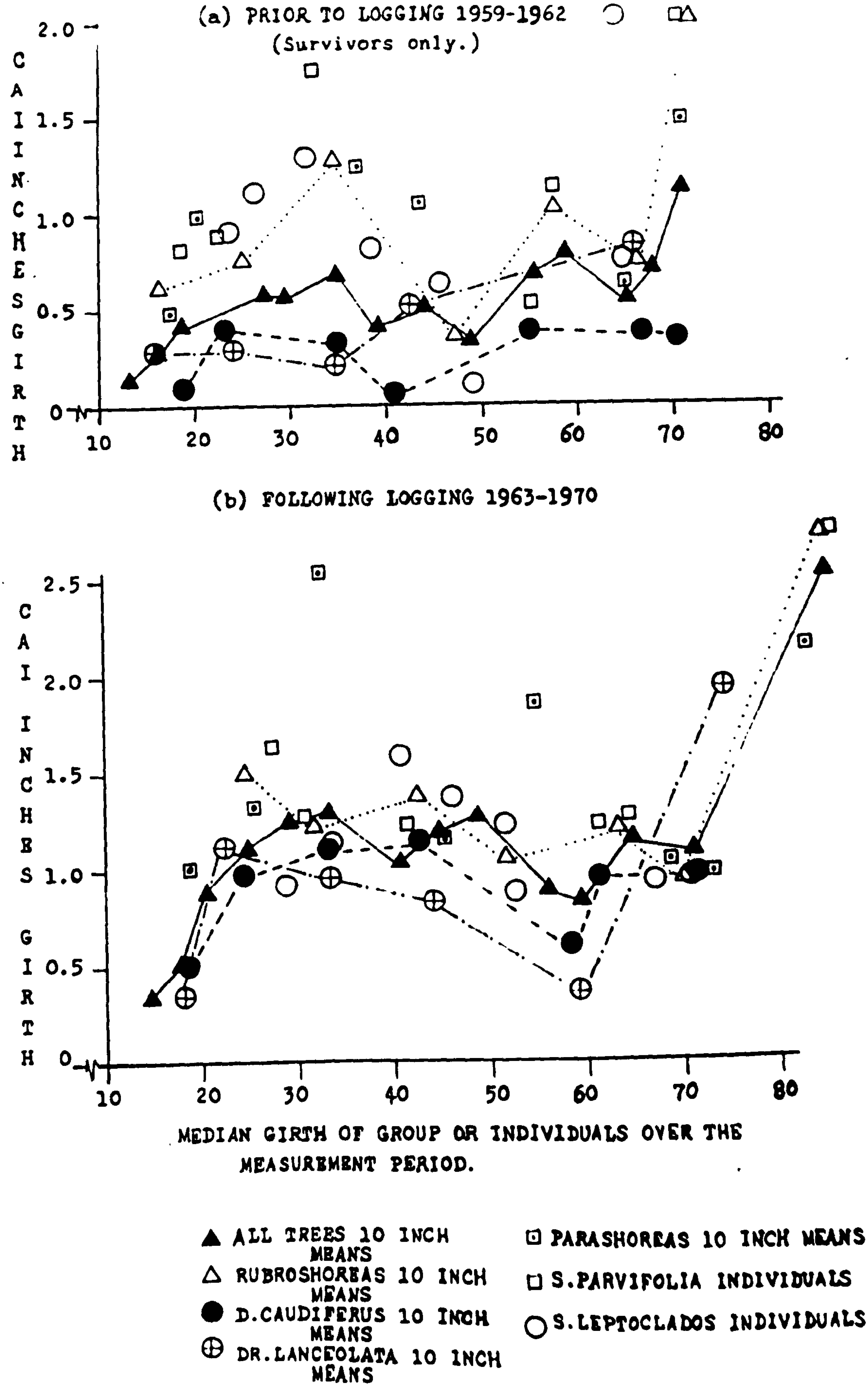
(Numbers in brackets are the trees in size class contributing to increment, at half way through the period)

An unpublished summary of early sample plot records, subsequently lost in the 1961 Forest Department fire, was made in 1957 (Nicholson 1957). The growth of trees as summarised tends to reflect the likely growth of opened forest; all plots were treated from time to time to favour the growth of measured trees. Table 23 is an abridgement of this data.

Table 23. Current Annual Increments by Girth Classes (ins)

Species Girth Class (ft)	<1	1	2	3	4	5	6	7	8	9
P. tomentella	0.7	1.0	1.4	1.7	1.8	1.7	1.5	1.3	1.1	1.0
S. argentifolia (Ru)	0.1	0.3	0.5	0.7	0.9	1.0	1.0	0.7		
S. leprosula (Ru)	0.3	0.8	1.3	1.4	1.4	1.3	1.0	0.7		
S. leptoclados (Ru)	0.6	1.7	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.4
S. macroptera (Ru)	1.0	1.1	1.1	1.2	1.2	1.3				
S. parvifolia (Ru)	0.2	0.7	1.0	1.0	1.1	1.1	1.1	1.2	1.1	1.1
S. smithiana (Ru)	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	
S. acuminatissima (Ri)	0.3	0.9	1.2	1.3	1.4	1.5	1.5	1.5	1.5	
Dr. lanceolata	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0
D. species	0.3	0.5	0.6	0.7	0.8	0.8	0.9	0.9	0.9	1.0
Hopea nervosa	0.4	0.8	1.1	1.2	1.3					
E. zwageri	0.4	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3

FIGURE 43 R.P.53 CURRENT ANNUAL INCREMENT AND MEDIAN GIRTHS



(After Nicholson 1957).

Figures for smaller size classes are not based on vigorous trees, and as I have shown, values for opened forest are higher.

Age and Mortality in Natural Forest

In the absence of annual rings age can be estimated by considering the length of time taken for trees to pass through size classes, by repeated measurements (Brown 1919, Osmaston 1956, Nicholson 1963a). Reference may be made to Nicholson (1963a) and Sepilok Handbook (Fox 1972, Table 20) for information on R.P.17 The time taken to reach a given size clearly depends on the individual tree history. Understorey trees in a state of suppression may persist with little growth for many years and reach a great age. Similarly an emergent dipterocarp tree may have grown in a windfall gap from seedling size into the canopy in a comparatively short time. Such estimates are weighted heavily by the very small increments of the smallest class, e.g. *Shorea argentifolia* may be shown on basis of Table 23 to take 200 years to reach a girth of five feet, whereas *S.leptoclados* would require only 44 years. Clearly then individual emergent trees in the natural forest may have a great range of age for any given bole size.

Age of trees in the natural forest is of less interest with respect to regeneration than seedbearing ability and likely survival of individuals. Both are probably more closely related to size than to age, and the term "physical age" reflects this. Later consideration of growth rates in regenerating stands will be concerned with the time taken by trees to reach certain sizes, and the basis of importance will be time from felling.

Analysis of mortality in the natural forest requires long term study, preferably of large areas. R.P.228 referred to above will provide valuable data on the longevity and rate of mortality for larger trees. Deaths in R.P.17 over the period 1956-1968 are discussed in Sepilok Handbook (Fox 1972). Two thirds of the deaths in this period were of trees in the 1ft class, the lowest measurement class, and many of these deaths were of trees recruited into measurement during the period. Rates of mortality in R.P.18 over the 12 year period 1957-1969 were as follows:

Girth Class (Ft)	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number in 1957	255	70	38	35	17	19	11	4	3	0	3	2	457
No. died 1957-69	60	19	14	4	5	1	0	1	0	0	0	1	105
Mortality percent.	24	27	37	11	29	5	-	25	-	-	-	50	23

For trees of 5 ft and larger the mortality percent was 13.5 or a little over 1 percent per annum. Mortality was offset by ingrowth and there were 59 trees of 5ft and over in both 1957 and 1969.

Clearly at any given time the changes taking place locally within the natural forest are adjusting overall stocking and mortality of smaller trees is largely due to competition for space, while larger trees eventually become moribund. Variation in numbers of large trees in size classes within the forest (cf Appendix 5, Table 2) reflects this state of dynamic equilibrium.

Seedfall, Germination and Seedling Behaviour

Dipterocarp trees in Sabah generally flower from April until the middle of the year, and fruit falls from August to October. An analysis of the exceptionally heavy flowering in 1955 by Wood (1956), with a summary of records for earlier years, suggested periodicity of flowering. Heavy flowering, at least in East Coast areas, occurred in 1925, 1934 and 1955, with quite heavy flowering in 1947 especially on the West Coast. Flowering was recorded in intermediate years and was locally heavy in restricted areas. Wood attributed the suggestion that heavy flowering is preceeded by a relatively dry year to Keith, but was unable to substantiate this from available rainfall records. He did accept that heavy flowering occurs, generally, on a 9-11 year cycle and that it may be preceeded by a short period of heavy rain followed by a dry spell. The 1955 flowering also occurred in Sarawak and in both States heavy flowering of non-dipterocarps also occurred.

Gregarious flowering of dipterocarps, and other emergents, in the Temerloh area of Malaya in 1963 has been attributed by Poore (1968) to lower than average rainfall during 1958-62 and an unusually dry period in early 1963. Similarly McClure (1966) reported dipterocarp flowering at Ulu Gombak after a dry spell in 1963. These observations tend to confirm Wood's (1956) suggestion of a period of gradual physiological preparation followed by the dry spell trigger. Meijer (1970) suggests that a 9-12 year sun activity cycle may cause the dry spell which triggers flowering. The trigger notion was first mentioned by Blanford (1929). He noted that some flowering occurred somewhere each year in Malaya, and that local anomalies also exist with respect to rainfall. His suggestion that rainfall preceeds flowering ignored the previous weather conditions during which it may be assumed that trees undergo physiological preparations.

Periodicity

A major difficulty in discussing periodicity is the variation is subjective estimates of areas involved, and what constitutes heavy flowering. My impression of the flowering in 1967 was that it was unusually heavy, widespread and rated with that of 1955; doing so would have re-inforced the 9-12 year cycle theory. However it later appeared that Sandakan district was mainly involved; dense flowering occurred in 1968 in the Kalabakan/Gunong Rara areas; and the official record for 1967 reported flowering as "Widespread but not general or profuse". Recent establishment of a number of phenological trails in a number of Forest Reserves in Sabah (A.R.R.B. 1970) should eventually give more detailed information on periodicity, quantity and extent of flowering. Nicholson's (1958 a) summary statement that some species flower erratically every year with heavy flowering every 3-6 years with many species flowering only at long intervals and extremely heavy flowering occurring every 9-11 years is borne out by subsequent statements in Forest Department Annual Reports, Regional Notes in the Malayan Forester, and my own observations. These may be summarised as follows:-

1958 End of 2 month drought in May followed by flowering of *Parashorea* etc. Referred to as a good seed year by Burgess (1959) but much fruit was non-viable due to the coincidence of dry weather with fruit formation.
1959 Tawau/Apas area flowering for second year in succession.
1960 Widespread, not heavy - mainly in North-East but also Tawau/Apas miles 8-20. Partial leaf fall as a result of fruiting. Many fertile collections made from 1500-3000 feet and on ultrabasic.
1961 Light, widespread - little in the Sandakan area, sporadic in Lahud Datu after prolonged wet weather. Corner (1962 a) reported *Shorea monticola* flowering at 4-5000ft in July-August and *S.platyclados*, later, at 3400 ft.
1962 Heavy in some areas.
1963 Good year - heavy widespread flowering of most species.
1964 Confined to the South-West of the State.
1965 Mainly in hills in West Coast areas, sporadic in Kalabakan and Mostyn.
1966 Poor, sporadic, in Sandakan, Silam, Pangie (Gunong Lumaku F.R.).
1967 Widespread in North-East as far south as the Segama River and locally heavy.

1968 Widespread and heavy from Mostyn south and westwards through Kalabakan and Gunong Rara Forest Reserves.
1969 Locally heavy - Timbun Mata Island and coastal areas of Darvel Bay.
1970 Widespread in Sandakan area.

Ashton (1969) suggests that related species, e.g. different Richetia species, flower just out of step with each other in a given locality. Wood (1956) showed this to be so with Anthoshorea, Rubroshorea and Selangan Batu. Accurate records are again difficult to substantiate without consistent standardised observations over a number of trees, but there is no reason to doubt the assertion. There is also a general lapse between the more common widespread species. The first to be noticed are usually the two common *Parashorea* species and *Dryobalanops lanceolata*, perhaps because they are so abundant. *Shorea macroptera* was the first species to be recorded (April 18th; Sepilok) in 1955, but was not noted until May 6th 1967 after many other species had commenced at Garinono (Meijer in file). In 1970 this species was observed with young fruit on May 11th in Deramakot F.R. at a similar stage of maturity to *P.tomentella* and *Dr.lanceolata*. Of the common Rubroshorea *S.leptoclados* generally flowers after *S.parvifolia* and *S.leprosula*; Wood noted that *S.mecistopteryx* flowered earlier and *S.smithiana* later than the others.

Flowering differs in time of onset from one locality to another; Wood suggested a delay of two weeks with increased altitude for the same species. In 1967 trees flowered in Lahud Datu about a week later than at Sandakan. Due to the spread of flowering over the active shoots in the crowns the canopy when seen from above shows up individual species flowering over wide areas at any given time. This was particularly so with *P.tomentella* on coloured aerial photographs taken in 1967 in the Sandakan area and also strikingly evident when I flew across Gunong Rara and Kalabakan F.R.'s in April 1968 with *P.malaanonan* crowns white over many miles of unidsturbed natural forest. Though *Parashorea* and *Dr.lanceolata* tend to have earlier fruitfall (as well as flowering) than other species (Wood (1956) observed that fruit of the later flowering species matured faster.

During heavy flowering large non-dipterocarps, e.g. *Koompassia excelsa* (and other Leguminosae), *Heritiera simplicifolia* (cf Poore 1968) and fruit trees are also conspicuous. Flowering may be absent in the mountains and in the peat swamps when dryland forests have gregarious flowering: these areas possibly having locally modified climates. In so far as gregarious flowering must represent a summation of climatic effects defining seasonality (Corner 1962 a) the three main areas of Eastern Sabah, viz: *P.tomentella/Eusideroxylon* in the North East; *P.malaanonan* in Darvel Bay; and the Rubroshorea/*Eusideroxylon* Type in Kalabakan/Gunong Rara; are not only floristically and climatically different, but show differing physiological responses. Of the three the Darvel Bay area appears to have more frequent, and the North East least frequent flowering.

Accurate data on the periodicity of individual trees is again lacking. Limited data for common species in Sepilok is given in Sepilok Handbook (R.P.'s 51, 61). Marked seed trees of *P.malaanonan* in Silabukan fruited in 1967/8 and again in 1970; and 4 out of 7 trees o f

P.tomentella (R.P.243) in the mid-Kinabatangan (emergent unfelled trees standing over regenerating forest) flowered profusely in both 1967 and 1970. It is probable that continued observation will confirm the supposition that the more common species flower and fruit more regularly than rarer species (Wyatt-Smith 1954) which these limited observations suggest.

Age and Size of Flowering

Several emergent *Parashorea tomentella* over logged forest which flowered in 1970 in the Kinabatangan area were as small as 5 ft girth (48 cm diam). Small trees of *P.malaanonan* at Silabukan F.R. in more closed forest also flowered, but did not produce viable fruit (A.R.R.B.1970). *Shorea leprosula* trees of second growth in an open stand at Sepilok F.R. fruited in sizes from 4-6 ft girth. It would appear that trees of the common emergent species do not generally flower until they are in the upper emergent canopy. Examination of the high, closed, regenerated forest at Garinono in 1967 suggested that the size limit of dipterocarp flowering was of the order of 6 ft girth (Meijer 1970). Smaller girth trees of the non-emergent species. e.g. *Hopea nervosa, Vatica* species and *Shorea multiflora* flower at smaller sizes. It is suggested that the phase of flowering activity for individuals is independent of age and the size of a tree when flowering commences is dependant on canopy position. This is of considerable importance for further seedling recruitment into regenerating stands. The data presented by Ng (1966) for planted stands suggests that viable seed can be obtained from several species within 30 years of planting at, say, 5 ft girth if a mean girth increment of 2 ins per annum is achieved. First "recorded" ages of flowering for species found in Sabah reported by Ng wereas follows.

H.nervosa 25-27; *P.malaanonan* 22; *S.agami* (An) 17-23; *S.argentifolia* (Ru) 22-25; *S.beccariana* (Ru) 23; *S.guiso* (SB) 22; *S.leprosula* (Ru) 24-28; *S.parvifolia* (Ru) 25; *S.smithiana* (Ru) 24; *S.multiflora* (Ri) 20-23.

Of the 84 stands (50 species) reported, 61 stands were planted in 1930, 1931, 1935 or 1938 and the pattern of first flowering is confounded by the occurrence of years of gregarious flowering. 1955 and 1958 were presumably such years:

Number of stands - of 61 (After Ng 1966)

Year 1st Flowering@	Year of Planting 1930	1931	1935	1938	Total
1949	1	0	0	0	1
1955	13	4	2	2	21
1957	2	3	1	1	7
1958	8	5	5	0	18
1961	1	4	1	3	9
1962	0	0	0	1	1
1963	1	1	0	0	2
1965	0	1	0	1	2
Total	26	18	9	8	61

(@ Only one other year had a record, 1964, *Hopea* sp)

Sabah species reported by Ng as not flowering included *S.laevis* (SB) planted 1929, *Dr.lanceolata* planted 1941, and *D.grandiflorus* planted 1931. In Sabah *S.laevis* and other Selangan Batus, hill species of Richetia and some of the *Dipterocarpus* species, all comprising elements of Type F and G are less frequent in flowering than Rubroshorea, *Parashorea* and other common species of the lowland types, though many of them give a little fruit each year.

Within a particular stand flowering activity is confounded by composition. A dense stand of *P.malaanonan* at Mandalom F.R. (Figure 44) fruited in *toto* throughout 1967-69, probably with different individuals contributing to recorded seedling stocking. Provided a good flowering year occurs planted, and by inference dense well grown

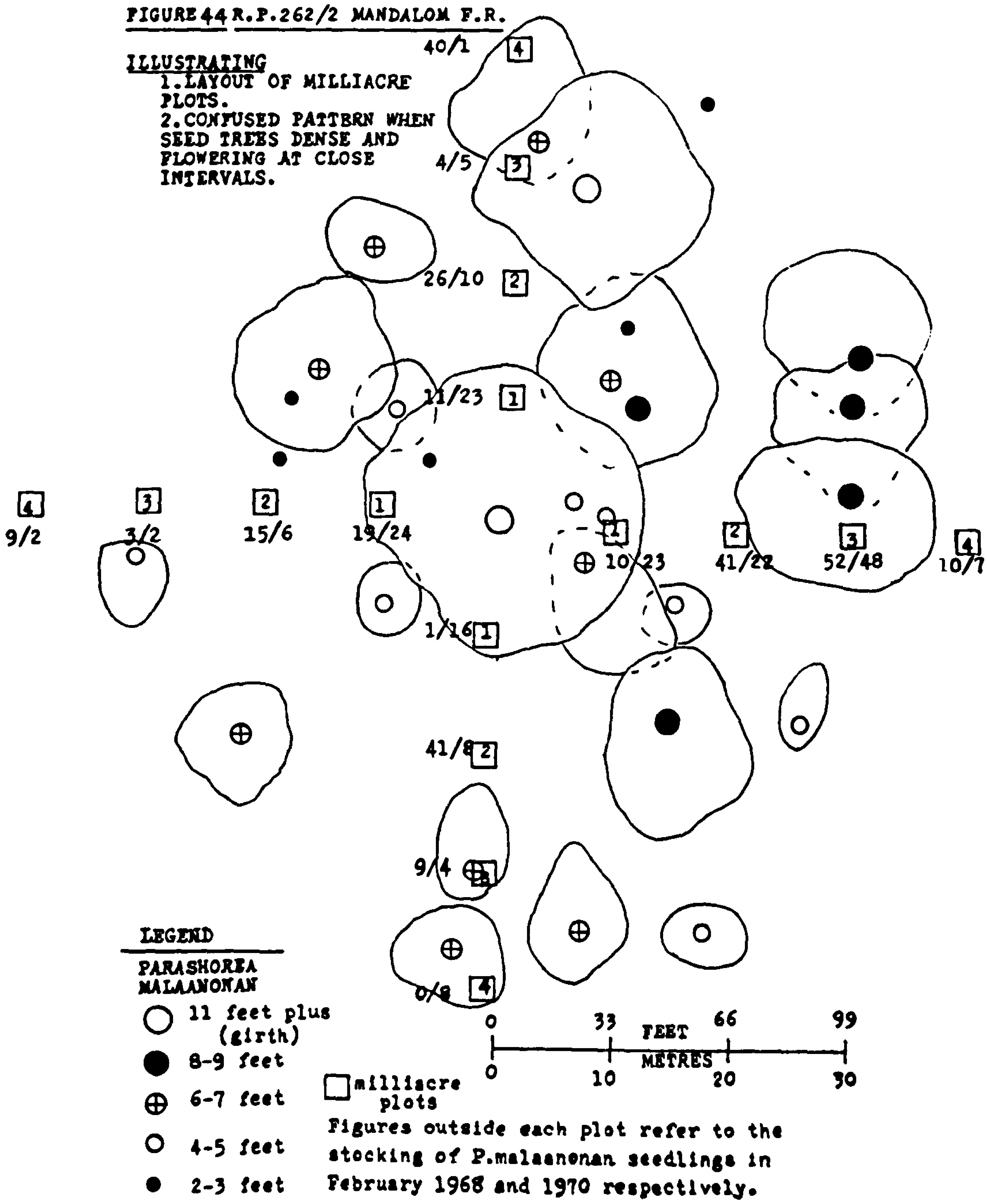


FIGURE 44 R.P.262/2 MANDALOM F.R.

ILLUSTRATING
1. LAYOUT OF MILLIACRE PLOTS.
2. CONFUSED PATTERN WHEN SEED TREES DENSE AND FLOWERING AT CLOSE INTERVALS.

stands of natural regeneration, stands of most common species will flower at 20-30 years of age in closed conditions, and from 4-6 ft girth in open conditions, provided the trees are in the canopy. Ashton (1969) has suggested 60 years for first flowering in natural forest, a period representing the longer time necessary for even fast growing individuals to reach the canopy.

Factors Affecting Fruit Production

Pollination is effected by bees, and probably by small moths; flowers typically opening at night and corollas are shed by the following noon (Ashton 1969). Wind is not a common pollination vector and may damage flowers. Flowering over a wide area in 1951 gave little fruit as high wind and rain damaged flowers (M.F. Reg. Notes). In some cases apparently heavy flowering on individual trees fails to result in fruit. This occurred with individuals of *S.gibbosa* (Ri) (R.P.244); *P.tomentella* R.P.243; and *P.smythiesii* (R.P.248); during 1967-68 at Segaliud-Lokan, Kuamut, and Beaufort Hill respectively. Fruit may similarly be affected by weather (see note for 1958 above). Considerable losses on the tress may be due to bird and bat feeding, and there are numbers of insects whose larvae live in dipterocarp fruit. Quantities of unripe fruit may be blown off the trees, and ~~when~~ ripe fruits on the ground are attractive food for wild pig, jungle rats and squirrels. Landon (1955) suggested that most fruit is damaged unless fruiting is heavy and though Poore (1968) suggested that insect damage may be high in heavy fruit years, found no evidence of abundance leading to high rodent populations. Ground squirrels were a severe pest when dipterocarp seed was sown in a forest nursery at Lungmanis in 1967, and pig migration in the forest areas may well be associated with occurrence of heavy fruiting.

Seasonality. Leaf fall sometimes preceeds flowering, Meijer (1967) noted that *S.glaucescens* (SB) and *D.grandiflorus* tended to be regular in this way and McClure (1966) observed that *Anisoptera laevis* regularly shed its leaves with or without flowering. Detailed observations by Nicholson (1958 b) on 5 individuals of *S.smithiana* (Ru) showed that new leaves were produced in February when rainfall was low and that this coincided with reduced growth of the bole. Complete leaf fall was not observed, though many trees were comparatively bare in natural forest in the Sandakan area during the long dry spell in early 1969. Measurements at this time and at other times during 1968-70 showed considerable fluctuations in growth of bole size within species. Averaging of growth measurements over periods, together with utilizing the principle of re-measuring sample trees at approximately the same time of year for succeeding measurement years tends to eliminate abnormal growth records for single trees. The same principle may be expected to apply for larger trees when growth of the bole may fall off co-incident with flowering activity. Ashton (1964 c) noted a tendency for the Selangan Batus to change leaves at the onset of the dry period in Brunei (April/July) but most species were not seasonal and tended to change leaves gregariously between April and October, presumably in response to local climatic influences. The phenological observation areas referred to above will eventually throw more light on the relationship of leaf fall and flushing to flowering, dry weather and bole growth. My observations to date suggest that new leaves are produced in definite flushes, often coinciding with the commencement of the heavy rain period October/December in North Eastern Sabah. Leaf fall is more or less continuous, but particularly heavy in periods of drought and though it may preceed flowering at the same time of the year it is not always specifically related to flowering individuals.

Other families of trees, but not the large emergent species, flower more regularly in Sabah, e.g. Fagaceae March/April, and the important fruit trees of Moraceae, Sapindaceae, Bombacaceae and Meliaceae produce their fruit during August/October. Certain Leguminosae (mainly of the sub-group Mimosoidae, e.g. *Parkia, Albizzia*), *Sterculia* species, Rubiaceae etc., shed their leaves during February to April and produce fruit prior to the new flush (cf McClure 1966). In general there are 2 fruiting seasons in Sabah for monkey and ape activity (Meijer 1969). A number of jungle animals assist in the dispersal of non-dipterocarp fruit, e.g. *Mangifera* species carried by elephant, Legúminosae and Sapotaceae by musang, and it is probable that seed of *Anchocephalus chinensis* and other invasive species, some of which fruit the year round, is distributed by bats and birds.

Dispersal and Germination

Fruits of the majority of common Dipterocarpaceae have wings, 5 long wings in *Dryobalanops*, 2 in *Dipterocarpus* and *Anisoptera* and 3 long and 2 short in *Parashorea* and most *Shorea* species. The fruits drop from the tree when ripe and glide spirally down to land with the wings uppermost in the manner of a shuttlecock, or, in *Dipterocarpus*, with the wings lying on the ground. Both Poore (1968) and Ashton (1969) quote the description of Webber (1934) of a pre-storm wind lifting fruits into the air and carrying them for half a mile. This is possibly the furthest recorded distance of dispersal and Sabah species mentioned included *Shorea leprosula*, *S.parvifolia*, *S.macroptera*, *Dipterocarpus* spp. and *Hopea* species, mainly of lighter seed. Poore (1968) suggested that *S.macroptera* has largest wings with respect to weight and could thus be carried furthest. The following length weight ratios were determined from fruit collected in 1967-68 in Sabah:

Ratio of length in centimetres
over weight in grams

P.tomentella	1.9-2.9	*D.caudiferus*	1.1
P.malaanonan	3.8-4.5	*D.confertus*	4.9
Rubroshorea:		*D.grandiflorus*	0.4-0.6
S.argentifolia	7-10	*D.crinitus*	8
S.beccariana	0.7	*D.gracilis*	5
S.leprosula	11.6	*Dr.lanceolata*	1.5-2
S.macroptera	7.5	*Dr.aromatica*	2.6
S.macrophylla	0.2-0.3	Anthoshorea:	
S.mecistopteryx	0.9	*S.agami*	1.6
S.parvifolia	15	*S.gratissima*	5.7
S.pauciflora	1.5	Selangan Batu:	
S.smithiana	1-1.4	*S.foxworthyii*	2.7
Richetia:		*S.glaucescens*	3.2
S.xanthophylla	1.1	*S.leptoderma*	9.4
S.kudatensis	5.7		
S.faguetiana	3.3		

(Where 2 values are given data from more than one batch of seed is involved)

Those species with ratios lower than 1 in the above list tend to be gregariously distributed and several groups of species may be mentioned, though it should be stressed that further information on dynamics involved is needed, in particular the relation between wing area and weight. Species with small wings and low overall weight, e.g. *S.parvifolia*, *S.leprosula* and some Richetia may be expected to be well distributed. Species with long wings, and especially when the wings are broad, possess the ability, if caught by the wind, to travel some distance, e.g. *S.macroptera*, *S.almon*, *S.waltonii*, *S.smithiana* and *Parashorea*; heavy seeded species, e.g. *S.mecistopteryx*, *S.macrophylla* and those with no wings, e.g. *S.oleosa*, (Ru); *S.multiflora* (Ri); *S.seminis* (SB); *D.tempehes*; and *V.oblongifolia*; clearly cannot travel far from the parent trees (cf distribution discussed above).

Distance of Distribution

Limited data is available on the distance of distribution from parent trees. Ashton (1969) quotes Ridley (1930) as giving an estimate of 270 feet (82 metres) for the limit of distribution from isolated parent trees. Observations in Sabah suggest that the common species of *Parashorea* and Rubroshorea are rarely found more than 150 feet (46 metres) from parent trees but when such trees are isolated examples of 300 feet or so have been noted, particularly with *S.parvifolia*. *P.tomentella* seed may travel downwind for 400 feet (A.R.R.B. 1960), and the absolute limits of distribution are dependant on wind force at the time of fruit ripeness. The following data (Table 24) summarises observations from fruitfall plots:

Table 24 Percentage Fruitfall at Different Distances From Parent Trees.

Species	Distance (Ft)	33	66	99	132			
	(m)	10	20	30	40	Total	Condition	Place
		(Percentage fruitfall)						
S.argentifolia (Ru)		60	30	8	2	193	Open	B
S.argentifolia (Ru)		42	8	50	0	12	Logged	K
S.leprosula (Ru)		39	29	19	13	552	"	K
S.oleosa (Ru)		98	1	1	0	435	"	K
S.parvifolia (Ru)		70	22	7	1	293	"	K
S.smithiana (Ru)		60	40	0	0	15	"	K
S.smithiana (Ru)		53	10	21	16	19	"	K
S.glaucescens (SB)		94	0	6	0	26	Open	B
S.kudatensis (Ri)		33	30	25	12	287	"	B
Dr.aromatica		36	33	23	8	210	"	B
Dr.lanceolata		100	0	0	0	2	Logged	K
Dr.lanceolata		25	25	28	22	39	"	K

Continued

Table 24 (Continued)

Species	Distance (Ft) (m)	33 10	66 20	99 30	132 40	Total	Condition	Place
D.crinitus		53	10	21	16	19	Logged	K
P.malaanonan		38	27	19	16	224	"	S
P.malaanonan		25	31	29	15	313	"	S
P.malaanonan		25	25	28	22	544	"	S
P.malaanonan		32	41	19	8	208	"	S
P.smythiesii		81	15	2	2	91	Natural	K
P.tomentella		33	24	24	19	450	"	A

B = Klias Peninsula relict forest; K = Kalabakan F.R.; S = Silabukan F.R.; A = Arawon, Deramakot F.R. Heights were not recorded, but all trees were over 100 ft tall.

It should be noted that the quantities of seed produced vary very considerably between species and between trees. The layout of plots given in Table 24 was illustrated in Figure 44 for Mandalom F.R. Each value at a given distance is the number of seed that fell in 4 milliacre plots at that radius from the parent tree expressed as a percentage of the total seeds recorded on 16 plots. Examples given had reasonable certainty of no other fruiting tree of the same species present within 200 ft, though this may not have been so with all examples of *Parashorea*. The Rubroshores species, *S.smithiana*, *S.almon* and *S.waltonii* appear to produce fewer numbers of fruits than the more common species: *S.parvifolia*, *S.leptoclados*, *S.leprosula*. Though the figures given for *Dr.lanceolata* are low this species generally produces more fruit than the sparse fruiting Rubroshorea species. The distribution of *S.oleosa* with wingless fruit is of particular interest.

Germination. Quantities of seed collected in 1967-68 from several areas were sown into polythene pots and conventional seedbeds, but germination figures are not given here for two reasons. Firstly germination under natural conditions results in losses at all stages due to insect, animal, physiological, and micro-climatic effects (survival of recruitment resulting from the seedfall of Table 24 will be discussed later). Secondly when fruits are collected from the ground a considerable quantity are ignored due to obvious defect; further losses follow breakage of radicles developing in transit. Considerable delays were involved, due to communication and distance factors, in sowing the seed batches. Collection of apparently sound seed followed by comparatively rapid sowing in Brunei in 1969 resulted in about 50 per cent germination for several common species, in seed beds. More recently a large batch of *Dr.beccarii* gave 83 percent germination in polythene pots and 63 percent in conventional seedbeds (personal communication I.P. Tamworth).

Providing freshly fallen sound ripe seed is sown almost immediately after collection in rodent-proof nurseries high germination rates may be expected. Barnard (1950a) quoted figures of 80 per cent and suggested careful examination of fruit colour be made to increase survival. For *Dr.aromatia* 92 per cent germination was achieved when seedcoats were green with the wings turning colour compared to only 34 per cent when seedcoats were brown, wings dry and radicles emerging. Selected seed of *S.curtisii* (Ru), possibly not quite ripe as it required 7-10 days to germinate, gave only 10 per cent survival to seedlings (Cockburn and Wong 1969). Ismail (1964) suggests sowing seed when the radicle is just emerging, and removal of the testa as it peels off the cotyledons to enhance early growth. He suggests that species of *Dipterocarpus* tend to have lower germination percentages than other genera, and this is borne out by poor success in raising plants of this genus in Sabah.

Emergence of the radicle occurs within 5-8 days of fruitfall for a number of species (Barnard 1950a) and under moist ground conditions may be almost immediate. To date no method of delaying germination has been found which retains viability. Barnard's storage in sawdust merely kept the radicle alive for 7-14 days, after which deterioration was rapid and all stored fruit was dead after 28 days. Cockburn and Wong (1969) indicate that germination uses up starch and fat resources in the cotyledons within about 20 days. Clearly under natural conditions germinating seedlings must root fairly rapidly in moist humus or soil if they are to survive.

In a follow up to his initial investigation (Nicholson 1960) into light requirements Nicholson found that *P.tomentella* seedlings failed to develope from seed germinated in non-forest soil (R.P.64: A.R.R.B. 1961). After 8 months only 32 per cent had leaves and the remainder were existing on the cotyledons. This may have been a mycorrhizal effect; Singh (1966) has recently demonstrated mycorrhiza on all species examined. Wildings dug from the forest were later grown successfully. Notwithstanding there are many examples of successful germination and growth of both *P.tomentella* and *Dr. lanceolata* on exposed subsoil or roadstone following logging. Seeds germinating in dry weather do not survive in such places however, and seedlings are prone to die from scorch or severe wilting under open conditions in dry weather (Wyatt-Smith 1961, Gill 1968).

Germination commences with the radicle emerging and bending into the soil, followed by growth of the plumule about 2 weeks later. In *Parashorea* the cotyledons fold out into two fleshy segments carried up about two inches from the root collar and the first five leaves are thin, strap-shaped. In *Dryobalanops* the cotyledons fold out into a large mass opposite a smaller one, forming a broad lobe carried µp a similar height, and the first two pairs of lanceolate leaves are opposite with stipules between them. *Shorea* is similar but cotyledons usually fold into more or less equal segments, and the first leaves of many species, besides being borne in opposite pairs, have pronounced acuminate tips. In *Dipterocarpus* and *Vatica* the cotyledons remain inside the testa and are joined to the plumule by connections close to the soil surface.

After one or more pairs of opposite leaves, which may persist for some time if the seedling remains shaded, the stem continues to grow a little and produces spirally arranged leaves. Growth continues under light conditions or is resumed when the canopy is lightened, by growth of branchlets from the axils of the spirally arranged leaves. Branchlets may be horizontal, ascending or drooping and also have alternate leaves. In some Rubroshorea, e.g. *S.smithiana, S.almon, S.waltonii,* the young seedling does not branch until about 4 feet high, and may become rather thick, similarly some *Dipterocarpus*. *Parashorea*, and the common Rubroshorea species are thinner stemmed and usually have ascending branchlets. (The typical young seedling form of *S.leptoclados* is illustrated at page 12 of F.D.A.R. 1952). *Dr.lanceolata* tends to horizontal branching at first. As the trees grow larger there is a tendency for leaves to occur at the end of growth flushes in bunches and to appear whorled. They remain monopodial with comparatively narrow crowns and few branches (*H.nervosa* may branch excessively as a small tree) under shaded conditions. Larger trees and those in open conditions have sympodial or rounded crowns, and branches are shed continuously until this stage is reached.

Heritiera simplicifolia and *Koompassia excelsa* amongst the non-dipterocarp emergents also have winged seed and comparatively short viability periods. Many Leguminosae have seed which may persist ungerminated but viable for some years and this is also the case with such nomadic species as *Anthocephalus chinensis*. The seral species require light/warmth for their germination and in this respect, and their inability to tolerate shade as seedlings, are fundamentally different in behaviour to the Dipterocarpaceae.

Survival and Growth

Natural regeneration following felling relies on the presence of seedling regeneration. Walton (1948) discussed the inevitable disappearance of a proportion of seedlings where there is high density at any given time and suggested that seedlings may survive or be replenished from time to time by fresh fruit falls. His observations suggested that the less frequently fruiting species tended to survive longer (e.g. *S.maxwelliana* (SB) and *Hopea* species) than the Rubroshorea which tended to disappear. Wyatt-Smith (1954) suggested that *S.parvifolia* (Ru) probably flowered more frequently than most species, in Malaya, and was more tolerant of dense shade. This species has a high turnover rate in Sepilok

(Sepilok Handbook) but can survive, and grow in *belukar* stands and on cut strips through the natural forest in Sabah, in a similar way to the seeding in from isolated seedbearers reported from Malaya (Wyatt-Smith 1949 c).

Information presented here is based on seedling counts and measurements from milliacre plots, one thousandth of an acre ($\frac{1}{2500}$ of a hectare), generally square in shape of side 6.6 feet (2 metres); the technique first outlined by Browne (1936) and using marking methods similar to those described by Barnard (1956). Table 24 above showed the proportion of fruitfall decreasing with distance from the parent tree; seedling stocking and recruitment similarly decrease. Local patches on the forest floor may consist of a single species (cf Figure 44) or a mixture of several, depending on past fruitfall history and distance from respective parent trees. At any given time the convention of milliacre stocking (that is presence of one seedling being sufficient for a milliacre plot to be counted as stocked) gives values of the order of 800 stocked plots per acre (2000/ha) in the natural forest (Nicholson 1965). Individual plots may be vacant by chance or if they happen to fall in a water-course, site of a fallen tree etc. Where the dipterocarp forests merge with freshwater swamp or riverain forest stocking is unlikely to be high, and is also generally low on the steeper hillsides.

The difference between stocking by plots and total stocking is of some importance. When more than one seedling occurs on a given milliacre then there is more chance of survival. With highly stocked plots few seedlings are able to survive when canopy opening stimulates growth due to competition. Table 25 gives stocking data for 50 milliacre plots forming a systematic sub-sample of 1 per cent of the total area of two 1 hectare plots in Madai F.R. (see Appendix 3, Table 1). Average total seedling stocking was 31, 780/acre (78,000/Ha) and the area sampled was 98 per cent stocked, i.e. 49 out of the 50 milliacre plots had at least one seedling, equivalent to 980 stocked plots per acre. Plot 1 is illustrated diagrammatically in Figure 45 showing approximate seed tree positions. Whereas 61 per cent of the seedlings occured in 32 per cent of the samples at

Table 25. Seedling Stocking R.P.311 Madai F.R. at 1970
Numbers of seedlings in milliacre plots

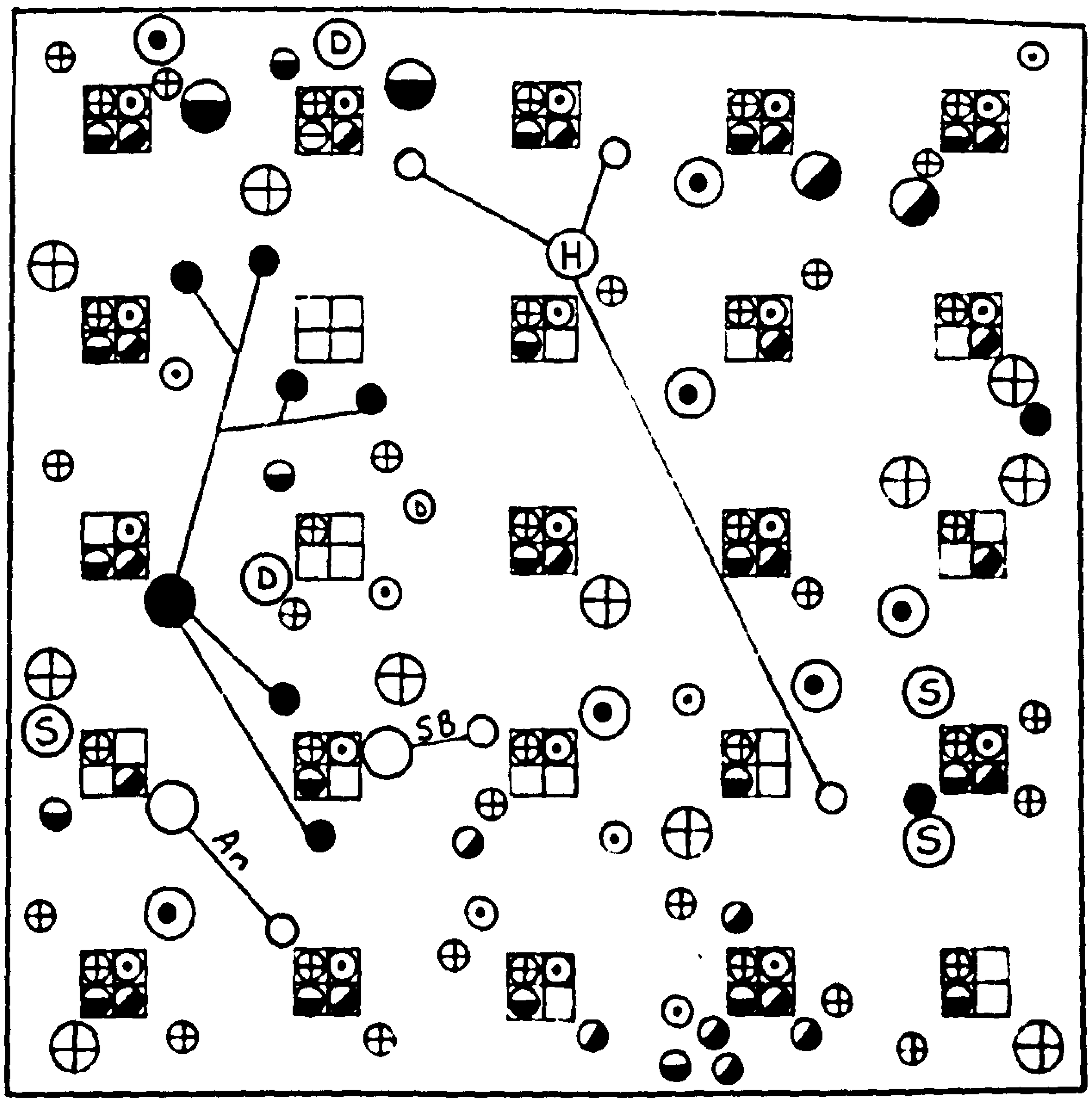
All seedlings				-29	30-				
No. of Plots	1	6	13	9	5	6	5	5	50
Total seedlings	0	34	193	220	173	277	279	413	1589
Per cent Seedlings	0	2.1	12.1	13.8	10.9	17.4	17.5	26	100
Per cent Plots	2	12	26	18	10	12	10	10	100
Numbers of Plots									
P. malaanonan	5	13	9	5	6	5	5	48	
S. leptoclados Ru	2	9	6	4	6	3	2	32	
S. parvifolia Ru	2	10	9	5	6	5	5	42	
S. leprosula Ru	5	7	6	5	5	5	3	36	
S. pauciflora Ru	-	-	3	-	2	1	2	8	
Dr. lanceolata	-	2	1	-	-	-	1	4	
S. guiso SB	-	2	-	-	1	-	-	3	
Numbers of Seedlings									
P. malaanonan	19	106	53	86	93	208	69	634	
S. leptoclados Ru	2	37	45	11	69	7	33	204	
S. parvifolia Ru	4	34	67	42	63	49	281	540	
S. leprosula Ru	9	8	32	34	24	9	25	141	
S. pauciflora Ru	-	-	22	-	27	6	3	58	
Dr. lanceolata	-	3	1	-	-	-	2	6	
S. guiso	-	5	-	-	1	-	-	6	

the higher stockings, 28 per cent of the seedlings were found in the 58 per cent of plots with fewer than 30 seedlings. The 4 most abundant species all exhibited gregariousness of seedlings with respect to nearness of

FIGURE 45 PARENT TREES AND SEEDLINGS.

AREA 2.5 ACRES - 1 HECTARE

R.P.311 Madai Forest Reserve



LEGEND (Potential seed/parent trees are those 5 ft+)

SEEDLING STOCKING (SPECIES AS BELOW)

PARASHOREA MALAANONAN

SHOREA PARVIFOLIA

SHOREA LEPTOCLADOS

SHOREA LEPROSULA

An SHOREA SYMINGTONII

SB SHOREA SUPERBA

DRYOBALANOPS LANCEOLATA

SHOREA PAUCIFLORA

HOPEA SANGAL

SHOREA GUISO

POTENTIAL SEED TREES, NO SEEDLINGS

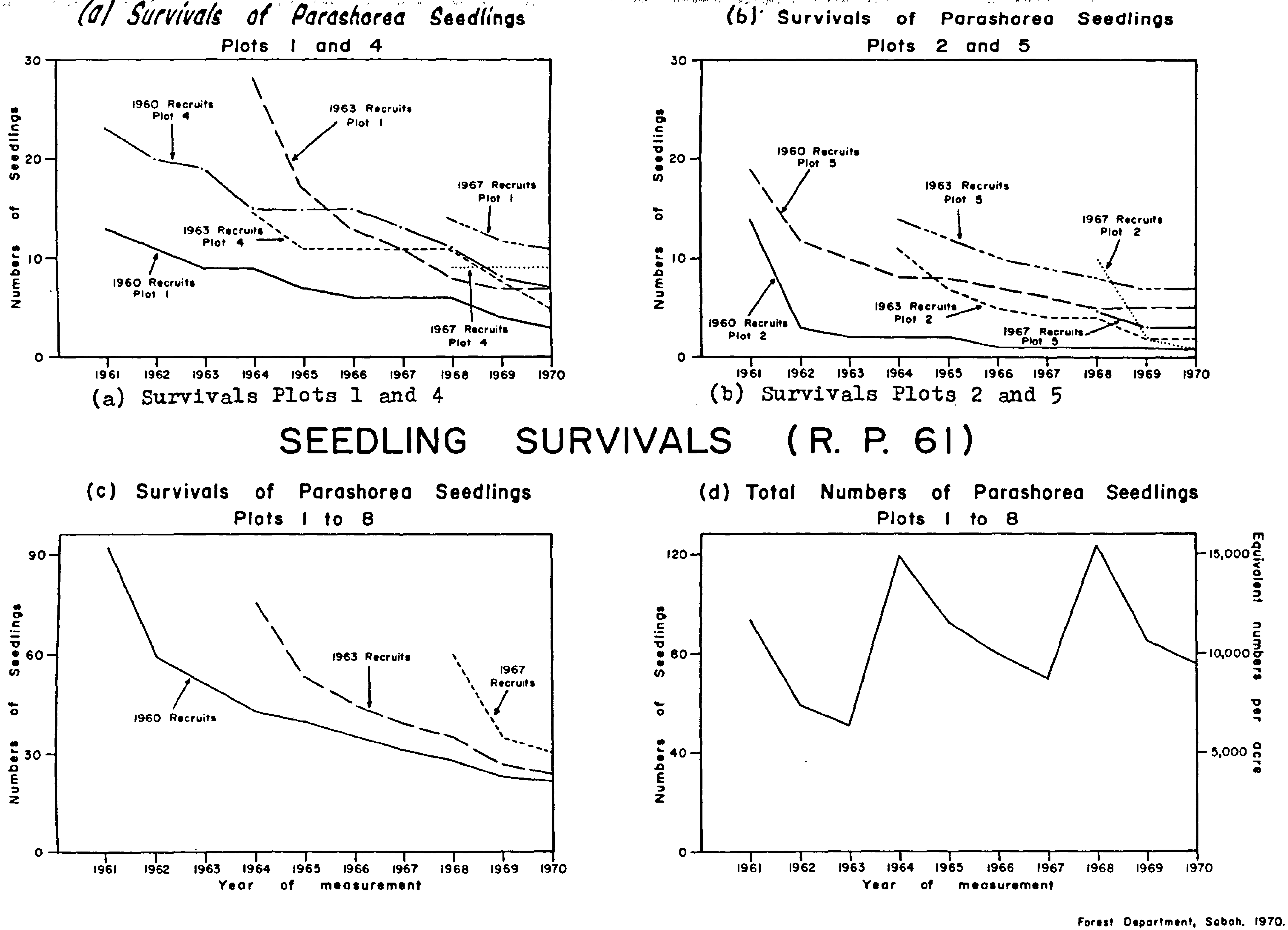
SMALLER TREES

mother trees: *P.malaanonan* had 267 seedlings in 6 plots in each of which it had more than 30 seedlings; *S. parvifolia* had 272 seedlings in 4 such plots; *S.leptoclados* had 126 seedlings in 7 plots in each of which it had 10-29 seedlings; and *S.leprosula* was represented by 10-19 seedlings in 5 plots, totalling 77 of this species. In the only empty plot area (Figure 45) due to a fallen tree 4 pole size trees of *S.pauciflora*, at an average distance of 70 feet from their most probable parent tree, stood ready to fill the gap (seedlings of this species only occurred within 90 feet of parent trees in this example). Seedlings of *S.guiso* were scarce, none being found in the milliacre plots near the three large trees illustrated.

Following a seed year stocking is at its highest. Nicholson (1958 a) found that following the 1955 fruitfall the lowest stocking on random samples of 0.005 acres was 8 seedlings, representing 4000 per acre, many areas being more highly stocked. Fluctuation in numbers of seedlings may influence density and subsequent growth of natural regeneration as more are likely to survive when numbers are high. Survivals of *P.tomentella* seedlings in relation to years of recruitment are illustrated in Figure 46. The high loss of seed during the germination period is matched by further losses of germinated seedlings in the first year following fruitfall. This is not considered a serious hazard in terms of regeneration and deaths occur firstly amongst seedlings which have lost out in the competitive struggle. Further data on the rate of depletion was obtained from plots around flowering trees established in Segaliud-Lokan M 42

FIGURE 46

SEEDLING SURVIVALS (R. P. 61)



(a) Survivals Plots 1 and 4

(b) Survivals Plots 2 and 5

Virgin Jungle Reserve (R.P. 244) in 1967. Plot positions for the seed trees are shown as black circles in Figure 47. Here pre-existing seedlings of the same species as the parent tree were pulled up and counted on 48 milliacre plots strung out at 33, 66, 99, 132, 165 and 198 feet (10, 20, 30, 40, 50, 60 metres) along 8 radii. A summary of survivals following germination, of the same species as the parent, is given in Table 26:

<u>Table 26.</u> Survival Data 9 Trees in Segaliud-Lokan F.R.

Species	Nos. of Seedlings Recorded Length of Time after Fruitfall Ceased (Months) 0	1	3	6	9	21	33	44	No. of Seedlings Prior to Fruitfall
P.tomentella	535	339	316	306	281	206	185	165	90
P.tomentella	671	399	269	267	221	154	125	82	60
P.tomentella	628	266	246	220	195	89	78	63	82
D.caudiferus	115	16	6	6	5	5	5	5	271
Dr.lanceolata	123	27	9	9	6	4	2	1	33
S.parvifolia(Ru)	74	21	12	6	5	5	5	5	3
S.almon(Ru)	36	35	22	20	19	16	14	9	2
S.superba(SB)	1749	112	1	1	-	-	-	-	79
S.gibbosa(Ri)	1176	229	216	212	148	117	91	80	11

The largest loss is during the establishment process, discounted in Figure 46 as the recruitment counted in R.P.61 was that surviving some 5-6 months following fruitfall. In Table 26 the numbers established at 9 months exceeded seedlings pulled up (which represented an indefinite period of recruitment and survival, perhaps extending over many years), for *P.tomentella, S.parvifolia, S.almon,* and *S.gibbosa* but not for the others. Little is known of the pattern with *S.superba* but both *D.caudiferus* and *Dr.lanceolata* seedlings when established can persist for some time in shaded conditions.

Survivals up to 24 months following fruitfall are given in Table 27 for the trees whose seed distribution from the parent was given earlier (Table 24). Numbers refer to the sum of 16 plots on 4 radii. The rate of attrition falls off rapidly after 9 months with most species - *S.argentifolia* continues dying off, confirming observations in Sepilok F.R. (R.P.51). In so far as comparability is possible there is little difference in general survival between natural forest (Table 26) and regenerating forest (many in Table 27).

Table 27 Survival Data for 19 trees as in Table 24. Nos. of Seedlings Recorded

Species	Length of Time after Fruitfall Ceased (Months) 0	1	3	6	9	12	18	24	
S.argentifolia	193	?	?	83	71	62	37	31	
S.argentifolia	11	0							
S.leprosula	424	191	191	124	90	81	75	73	
S.oleosa	385	283	282	234	92	79	78	75	
S.parvifolia	226	78	77	58	28	25	22	22	
S.smithiana	7	2	2	1	1	0			
S.smithiana	3	1	1	1	1	1	1	1	
S.glaucescens	20	?	?	16	16	10	7	4	@
S.kudatensis	287	?	?	264	255	----	further	fruit fell	
Dr.aromatica	61	?	?	20	18	16	6	5	
Dr.lanceolata	1	0							
D.crinitus	9	5	5	5	5	3	3	3	
P.malaanonan	164	153	108	90	78	78	76	66	
P.manaanonan	287	233	173	158	138	130	123	80	
P.malaanonan	246	184	145	135	120	111	100	98	
P.malaanonan	208	133	56	?	32	28	?	21	
P.smythiesii	44	25	25	15	15	15	14	12	
P.tomentella	370	252	133	95	78	73	68	32	

? observation missed @ damaged by fire

Numbers of seedlings in R.P. 51 Sepilok F.R. have fluctuated between 23,000 and 93,000 per acre (57-230,000/ha) over the period 1958-70. With changes in numbers changes in composition have occurred reflecting frequency of fruiting and relative longevity of seedlings. Representation of the five most frequent species was as follows:-

Species Stocking 12 Milliacre Plots R.P.51
Sepilok F.R.

Year	1958		1961		1964		1970	
Species	Plots / Seedlings		P / S		P / S		P / S	
S.parvifolia(Ru)	9	73	9	42	11	357	9	21
S.argentifolia(Ru)	2	2	1	1	10	194	4	8
S.leptoclados(Ru)	10	90	10	68	11	226	10	56
S.macroptera(Ru)	3	141	5	111	6	217	6	119
S.acuminatissima (Ri)	8	70	10	129	12	97	12	61
All seedlings:		405		345		1116		364

Seed fell in this area in 1960, 1961, 1963 and 1968 and recruits were recorded in the following years. *S.parvifolia* may be shortlived as a seedling under natural conditions; only two survivors during the period 1958-70 were present in R.P.51. Recruitment occurred in 1961 and 1964 and the population showed considerable fluctuation. *S. acuminatissima* had 4 survivors over the 12 years and came into all plots in 1964 reflecting, possibly, more trees fruiting in 1963 than in earlier years and the pattern of recruitment suggests strongly that different individual parent trees fruited prior to 1958, in 1960, 1963 and in 1968. Though very large numbers of this species were recorded in recruitment years many seedlings died at about 4 ins height with only the first leaves showing. This is ~~s~~ similar to observations with other light, winged, Richetia. *S.leptoclados* was only recruited in 1964 but its seedlings persisted longer in Sepilok than *S.parvifolia*. *S.macroptera* was also only recruited in 1964 and was very localised in its distribution, despite high numbers; seedlings of this species appear to be the longest lived of Rubroshorea in the area. *Hopea nervosa* only fruited in 1961 and most seedlings died within 2-3 years. *S.argentifolia*, as in the other areas, tended to die off rapidly following widespread recruitment, but its seedlings grow more rapidly in height in the natural forest than other species, and a few may well survive for a long time. *S.waltonii*, scarce in R.P.51 was very persistent and grew well, as did *S.smithiana*, which was even less abundant. *Dr.lanceolata*, *P.malaanonan*, *S.leprosula* came in as one or two seedlings only but did not persist.

Overall numbers of seedlings in much of Segaliud-Lokan F.R. are generally lower than the numbers given for Sepilok and Madai F.R.'s, though stocking using the linear milliacre convention may be equally as high. R.P.212 a series of 18 randomly placed plots in the Mile 42 V.J.R. (positions are illustrated in inset to Figure 47) had an average stocking of 11,500/acre (27, 300/Ha) in 1966 and 9,500 (23,500) in 1970. Species composition was as follows:

Species Stocking 18 Milliacre Plots R.P.212 Segaliud-Lokan F.R.

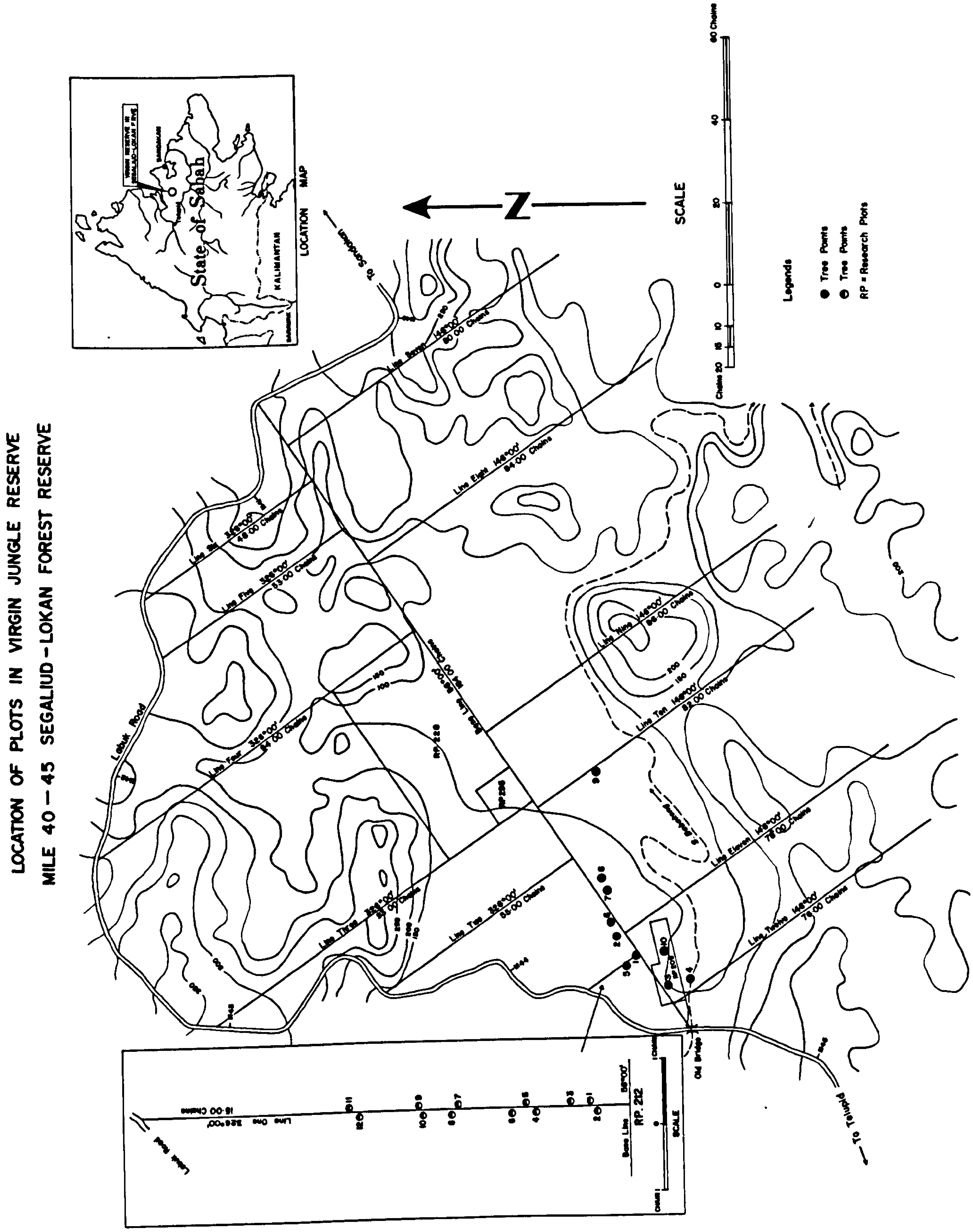
	Year			
Species	Plots/Seedlings		Plots/Seedlings	
S.leprosula(Ru)	0	0	3	7
S.leptoclados(Ru)	11	85	9	29
S.parvifolia(Ru)	4	13	7	29
S.waltonii(Ru)	1	1	2	2
S.acuminatissima(Ru)	0	0	4	7
S.symingtonii (An)	4	4	2	2
S.hypoleuca(SB)	3	8	1	1
S.scrobiculata(SB)	1	1	1	1
P.malaanonan	2	2	2	2
P.tomentella	8	28	11	41
Dr.lanceolata	9	13	7	11
D.caudiferus	12	33	13	28
H.ferruginea	7	19	4	11

Change in total stocking per acre for the 480 milliacre plots of R.P.244 in the same area, but not a random sample was:

FIGURE 47 LOCATION OF PLOTS IN

Mile 42 Virgin Jungle Reserve

Segaliud-Lokan Forest Reserve



Year	Deaths	Recruits	Stocking	Percentage Rubroshorea	Percentage Parashorea
1969	-	-	4198	29	56
1970	479	794	4513	35	52
1971	889	130	3754	33	55

During the period 1966-70 for R.P.212 *D.caudiferus* (1); *P.tomentella* (3); *S.leprosula* (3); *S.acuminatissima* (4); *S.parvifolia* (5); entered plots numbered in brackets in which they were absent in 1966. The overall species composition order changed by both plot representation and total seedlings. Despite these changes considerable numbers of seedlings, from any one recruitment, do survive a number of years. Barnard (1956) showed that 60 per cent of milliacre quadrats were still stocked 5 years after a seedfall; this is generally exceeded in Sabah as each milliacre carries more seedlings than in Malayan forests. The three longest seedling studies for which survival percentages with time are available are R.P.'s 51, 61 in Sepilok F.R. and R.P.46 in Silabukan F.R.; the first all species, mainly Rubroshorea, the latter two *P.tomentella* and *P.malaanonan* only, respectively. Survivals are given in Table 28.

Table 28 Survival as a Percentage of Recruitment

R.P.	51(12 milliacres)					61(8)			46(12)	
Seedfall Year	?	1960	1961	1963	1967	1960	1963	1967	1958	1963
Recruitment	1958	1961	1962	1964	1969	1961	1964	1968	1959	1964
Total recruits	405	89	31	892	63	92	76	60	17	123
Percentage survivors										
1 year	88	79	77	63	90	64	70	58	65	85
2	68	62	48	47		55	59	50	59	77
3	59	39	42	34		47	51		59	(?)
4	51	30	32	25		43	46		47	60
5	43	28	23	19		38	36		35	
6	37	22	19	16		34	32		35	
7	33	20	19			30			35	
8	30	17	19			25			35	
9	29	10				23			35	
10	26									
11	26									
12	26									
	(To 1970)					(To 1970)			(To 1968)	

Original seedling establishment in R.P.51 was during the period prior to 1958, whereas in the other two it dates from plot establishment. A substantial number of seedlings in R.P.51 have survived at least 12 years, and may well date from the 1955 flowering. Lower rates of subsequent survival are no doubt largely influenced by density of seedlings pre-dating any particular fruit-fall which may be assumed to be in comparatively strong competitive positions.

Growth of seedlings in the natural forest is, on average, negligible after the comparatively rapid elongation following production of the first few leaves after germination. Average heights in inches of surviving seedlings two years after recruitment (of those in Tables 24 and 27 above) were as follows: *P.smythiesii* 6.5; *S.oleosa* 12; *S.parvifolia* 8; *S.leprosula* 7; *S.smithiana* 10(1 only);*D.crinitus* 12; and *Dr.lanceolata* 24. Competition in areas of high stocking not only coincides with high death rates but the overall increment in height is low from year to year. A few individuals, which may be in locally favourable positions may grow faster. A limited experiment in Sepilok drew attention to the importance of root competition. The average 8 month height increment for seedlings in a trenched plot was 2.2 ins compared with 0.8 ins in the control (A.R.R.B. 1963). Breakages and die back of shoots occur from time to time, and individuals of those Rubroshorea with stouter stems are frequently to be seen shooting from below the original leading shoot.

R.P.46 attempted to compare recruitment, survival and growth of *P.malaanonan* seedlings in a more or less undisturbed area with an adjacent felled and girdled area. Both areas were not greatly dissimilar, as the unfelled area had several windfalls of large trees and the adjacent area was only lightly disturbed. Mean heights of surviving seedlings are given in Table 29:

Table 29 Mean Heights of Survivors to 1968 R.P.46 Silabukan F.R.

		Mean Heights (ins) at Years from Recruitment								
(a) 1958-68	Year	1	2	3	4	5	6	7	8	10
Survivors	1968									
Unfelled	4	8.8	11.3	16.3	21.1	25.8	26.4	29.3	33.6	39.3
Felled	2	10.5	19	21.8	32	33	33	32	37	36 @
Both	6	9.3	13.8	18.1	24.7	28.1	28.6	30.1	34.8	38.2
(1960 recruitment all died by 1962)										
(b) 1963-68										
Unfelled	28	8.6	9.8	10.2	-	11.6				
Felled	46	11.8	12.9	13.3	-	14.1				
Both	74	10.4	11.7	12.1	-	13.2				

@ Anomalies due to leading shoot damage

Too few seedlings are involved to confirm that height growth is more rapid in opened areas, but the indication is certainly there. By contrast the 21 seedlings surviving 1960-70 in R.P.61, of *P. tomentella*, averaged 9" in height in 1961, at 1965 4 years from recruitment they averaged 12.6", and at 1970 9 years from recruitment they averaged 16.7". This represents, perhaps, the norm for growth in normal shaded conditions for *Parashorea* and Rubroshorea. Individual seedlings in R.P.51 grew as follows:

Years from 1958	3	5	7	9	12
S.acuminatissima(Ri)	8	8	8	9	9
S.acuminatissima	10	12	13	14	16
S.smithiana(Ru)	11	13	16	17	21
S.waltonii (Ru)	15	16	18	20	26
S.leptoclados(Ru)	9	9	9	10	11
S.leptoclados	11	12	13	14	16
S.macroptera(Ru)	9	10	11	15	17
S.macroptera	10	11	14	17	21

(Heights in inches)

Of the largest 40 seedlings present in 1970, over 17" height, two thirds were survivors from plot establishment in 1958 of which 10 were *S.macroptera*. The remaining third dated from 1964 and 6 of these were *S.leptoclados*. In any given area of natural forest at a given time the proportion of larger seedlings is low. In 1969 total stocking on the 480 plots of R.P.244 was:

	Numbers/acre		
Height(inches)	<̲/12	12-23	24+
Total	2452	1706	40
Percentage	58	41	<1

Height of seedlings does not indicate age, though larger *Dryobalanops* and *Dipterocarpus* in shaded conditions may be assumed to be generally older than smaller ones, and it would seem that there is no reliable non-destructive method, apart from long term measurement, of determining seedling age. At the time of logging the seedlings may be anything from a few months to 20 years old.

So far as is known seedlings from the spectrum of age respond in the same way. A pattern of seedling stocking is exhibited from very high stocking following seedfall after which numbers decline until a low is reached prior to the next seedfall. Thus far in the natural forest total loss of seedlings between seedfalls has not been observed though this may be a possibility not to be overlooked in hilly and marginal areas. Milliacre stocking is generally adequate to allow regeneration.

Light Response

The effect of shade on seedlings in the natural forest is not at present fully understood. Observations in R.P.212 suggested that more seedlings were present under light to medium high shade, than under low shade. Lowest stocking appeared to be under heavy low shade; in this case perhaps not so much lack of light, but difficulty of seed penetration through low shrubs and bamboo tangles being responsible. These categories were based on subjective ranking of individual plots. Measurement of the amount of light reaching the forest floor is notoriously difficult (Barnard 1956) and even the milliacre plot will have differing values over its area, and at different times of day.

Some limited measurements ~~[illegible]~~ with an EEL portable light meter were taken in Sepilok in 1970. This enabled the twelve individual plots to be ranked in order of light reaching the centre of the plots around midday for R.P.51:

	Mean Numbers of Seedlings				Larger Seedlings	
Ranking: 3 groups of 4	1970	1969	1964	1958	16"+	24"+
Most light	15	19	65	18	10	4
Intermediate	21	23	115	37	6	0
Least light	45	49	99	46	28	1

This ranking suggested that fewer seedlings were present, on average, in plots receiving most light. In this area the high shade was considered to be more or less even. The pattern of seedling density in relation to light suggests that more seedlings persist in the plots receiving least light, but that the larger seedlings tend to occur in lighter conditions. No such pattern could be detected from similar measurements with the stocking of *P. tomentella* in the plots comprising R.P.61. Species dominance is, indeed, difficult to discount with respect to R.P.51 where the high density, persistence and growth of *S.macroptera* referred to earlier, coincide with plots receiving least light.

Experiments on the light responses of dipterocarp seedlings to controlled light are summarised by Nicholson (Nicholson 1960 and in A.R.R.B. 1964). In the first experiment (R.P.41) wildings of *Dr.lanceolata*, *S. leprosula*, *S.leptoclados*, *P.tomentella*, and *D.stellatus* exhibited decreased tolerance of shade, in that order. This particular *Dipterocarpus* species (generally of Type G on sandy, open soils) is probably atypical as most members of the genus are at least as tolerant as *Dryobalanops* (cf Barnard 1956). All species tested grew best in early shade, but after about 18 months growth was more rapid in full light. The second experiment suggested that adverse soil temperatures, coupled with low moisture, become limiting in affecting growth and that full exposure may not then give as good a response. Volume and height increase was greatest in 50 per cent light, and though height increase was reduced on sudden exposure, volume increment continued with the stem becoming squatter. Implications of this work for natural regeneration prospects suggest not only differential species growth but considerable variations over unit areas depending on light conditions following felling, local soil exposure, and previous seedling history.

Examples of the natural response to increased light may be observed throughout the natural forest. Seedlings present in gaps caused by windthrow, lightning death or the gradual demise of a large tree, grow rapidly upwards. Large areas, e.g. landslides, are seeded in by nomadic - *belukar* - species, as are abandoned cultivated patches. Without the stimulus of light dipterocarp seedlings remain small, as a shade tolerant community on the forest floor, a completely different class from the fast growing large trees, but the essential precursor to natural replenishment. Light is unnecessary for dipterocarp seed to germinate but survival requires some light. Seed can germinate and seedlings can grow in open conditions, but only if the substrate is moist and amenable to root penetration. The response of natural seedlings to increased light following felling is discussed later together with the question of seeding in of fresh regeneration.

Other Natural Forest Influences

Very little work has been done on other natural forest influences of importance to consideration of regeneration. The following brief account attempts to outline the most important biotic influences affecting regeneration and the prospects of achieving valuable second growth stands.

Climbers (vines, lianas) are present in all dipterocarp forests, possibly reaching their greatest abundance in lowlying areas within Type B (Burgess 1959). The following figures summarise stocking of climbers in natural forest, 10 plots of one acre each at each location are averaged:

	Average Climber Density Per Acre				
	Numbers by Size Classes				
Size (ins diam)	0-0.9	1-1.9	2-3.9	4+	Over 1 in
Location					
Segaliud-Lokan	691	91	40	16	147
Silabukan	240	106	17	3	126
Kuamut	-	71	32	6	109

Climbers compete with tree species for space and can cause damage to young seedling and poles of dipterocarp species. It is considered that damage due to falling is accentuated by large climbers lacing crowns together (Chapter 6). Several species are particularly important in opened areas. Walton (1955) drew attention to *Merremia borneensis* smothering small regeneration and climbing into the crowns of growing poles. *Uncaria* spp and *Mesoneuron sumatranum* are also important invasive species, and, though present in the natural forest, these three become numerically more important after felling.

Bamboo of climbing habit is widespread and often forms dense tangles which can persist for some time. Type B forest in Paitan and Sugut Forest Reserves contains many areas where isolated stems of *Parashorea tomentella* stand over thickets of climbing bamboo through which seedlings have been unable to grow. This condition is apparently natural though it is possible that elephants are of importance in the spread of bamboo and in the development of thickets. Regeneration areas in Segaliud-Lokan F.R. contain patches of bamboo which have, apparently, intensified following logging. However ecological studies have not yet been undertaken. Three species of *Dinochloa* are present in Sabah, viz. *D.ciliata*, *D.pubiramea* and *D.scandens*, the latter being of most importance.

Preliminary observation suggests that vigorous young shoots of climbing bamboo can be controlled by breakage of the shoot. This may assist in restricting spread following opening but elimination of an established substantial tangle would require a chemical method of control. Proposals to investigate the control of bamboo by mechanical and chemical methods are in hand.

Open grassy areas which develop following extensive disturbance are often difficult to return to forest cover, especially where soil compaction has been severe. There is some evidence that deer populations (and also wild cattle) increase in such areas and that browsing may perpetuate the grass. This does not occur in the undisturbed natural forest. Pigs are voracious feeders on dipterocarp fruit, as discussed earlier, and smaller animals are also of some importance. The elephant population is declining but elephants leave their mark on the natural forest by trampling undergrowth and destroying seedlings. They are also more evident in opened forest and have been troublesome in removing plot corner posts, damaging seedling study plots and trampling on planted trees.

Cyriopalus wallacei a Cerambycid beetle causes damage in standing trees in the natural forest, particularly in *Parashorea tomentella* (Thappa 1968). The larvae of this insect feed on the wood and produce circular tunnels through the length of the bole, often of such extent that considerable quantities of timber are wasted. This is discussed in more detail in Chapter 7. A number of insects are important in that their larvae feed on young fruit while still on the tree, thus reducing the quantity available to replenish the seedling population.

CHAPTER 6

REFINEMENT OF THE NATURAL FOREST AND PRE-FELLING SILVICULTURE

Consideration of the natural forest in Chapter 5 suggests that some order can be extracted from the diversity of species and growth. Despite site preferences resulting in some grouping, accentuated by the pattern of seed distribution, limited numbers of well distributed species occur over wide areas. Areas of low amplitude appear more homogeneous but tend to have less even structure than ridge sites. Will second growth stands exhibit layering or more even growth? Growth rates in the section Rubroshorea are higher than other dipterocarp groups and *Eusideroxylon zwageri* grows especially slowly in the natural forest. Growth rates are doubled in gap conditions, small trees with good crowns growing particularly well and seedlings, normally of little growth, able to grow rapidly.

Flowering in Type A forests appears to be more regular (a reflection of drier climate?) than elsewhere but even in Type B areas which appear to flower least there is generally abundant seedling regeneration present in the natural forest. Seed production appears to be less on less common species as well as occurring less frequently. Second growth trees may be expected to flower at 4 ft girth or some 20-30 years from felling, though isolated trees can seed into regrowth. Bole growth is affected to some extent by climatic influences as is survival of seedlings in exposed situations.

Pattern of seedfall suggests that the common species can achieve seedling presence throughout much of the areas where they are abundant and that the less common Rubroshorea species can remain constituents through wider dispersal of fewer seed and greater seedling persistence. Survivors following seedfall can persist for some considerable time and despite changes in relative abundance the common species generally form the greater proportion of the seedling population irrespective of seed years.

In this chapter I shall mainly be concerned with attempts at increasing the retention of advance growth and of ensuring seedling survival following felling by silvicultural intervention and administrative effort. Firstly a review of the trend of silvicultural treatment is given concluding with a brief presentation of the stages in silvicultural management. This is followed by consideration of silvicultural treatment, and other practises, which can be undertaken in the natural forest aimed at minimising damage due to falling and logging.

Review of Silvicultural Treatment

Early silvicultural work was undertaken prior to felling to improve regeneration after felling, as in Malaya (e.g. Blanford 1929). The terminology used was "regeneration improvement felling" or R.I.F. (F.D.A.R. 1949) and work included climber cutting, girdling and felling of *Ficus* bound trees. This was refinement in the sense used by Dawkins (1958) and had its origins largely in the earlier emphasis on production of harder woods which were often species shade tolerant in youth and difficult to regenerate (Wyatt-Smith 1963). Though prescribed for the period prior to felling little work was done outside Sapagaya and Sepilok F.R.'s, partly due to lack of tenure. Brown (1948) noted the customary practice had been to carry out concentrated fellings without cultural operations. Where the pre-felling treatments had been used the forests had often been worked over earlier (Burgess 1959) and were far from natural.

Terminology reflected this with later use of "selection improvement fellings" (F.D.A.R. 1950, 1951) when girdling of undesirable species was used to release dipterocarps some 15-25 years from felling. The individual stands of good second growth in Sepilok F.R. (R.P's 4, 16, 38, 87, 88 and 89) may owe something to pre-felling treatment, but no firm historical data exists for these areas (Fox 1972). Indeed it has been impossible to locate and examine any areas which definitely received early pre-treatment.

An experiment was laid out in 1970 to give information of a comparable nature to the early treatment of R.I.F. This has been referred to in Chapter 5 (Figure 41(c)) and tested the elimination of climbers and non commercial species from natural forest against a control (R.P.311, Madai F.R.). Basal area of the control and treatment plots, each of one hectare (2.5 acres), was as follows, values in square feet per plot:

	Control	Treatment
Before treatment	309	339
After treatment	309	150
One year later	316	155

Corresponding increments in girth for the best 100 (maximum) distributed dipterocarp trees were as follows:

Girth class(ins)	0-9.9	10-19.9	20-39.9	40-59.9	60-79.9	80+
C.A.I.(ins)						
Control	0.38	0.71	0.72	1.32	1.27	1.18
Treatment	0.81	1.11	0.96	1.35	1.56	1.11

These results are similar to the effects of thinning in dense second growth of large size in Sepilok plots (Fox

1972) and show removal of competing stems concentrates increment on smaller trees. Seedling density declined as there was no fruitfall; repeated observations may show increased recruitment from seedlings through to small pole size trees as in the Sepilok plots. Providing seedling stocking is adequate there seems to be no justification for this form of treatment.

Silviculture was later concentrated on felled stands. R.I.F. was done on 11,000 acres (4450 ha) during 1953, following logging, and was defined as opening of the canopy in patches of forest where there had been little or no felling because of a "lack of commercial trees" (Reg. Notes M.F. 1954). The routine advocated by Walton (1948, and letters in the same volume of Malayan Forester) of: milliacre sampling prior to felling; felling with no pre-treatment; 1 or 2 post-felling treatments; and a reduced cut if regeneration absent, to allow a second cut after 20 years or so; was adopted for Malaya (Barnard 1950c), with modifications for Sabah (Nicholson 1958 a) and included no pre-felling treatment. Since regeneration was plentiful, many more of the light wooded species were marketable, and it was difficult, if not impossible, to hold up or divert logging operations, the notion of pre-treatment was discarded.

Latterly increased mechanisation has caused concern over the extent of logging damage to soil, seedlings and advance growth (Fox 1968 a,e). Experiments involving pre-felling techniques to curtail such damage were undertaken (Nicholson 1965) but seedling stocking in the unfelled forest has not, thus far, been low enough for consideration of advance girdling to take account of seed years (cf Malaya, Wyatt-Smith 1961). Marking specifically for felling and for retention was tried with little success (Reg. Notes M.F. 1962) and methods of stimulating growth of seedlings prior to logging were tried (R.P.60). In the latter experiment girdling of understorey species gave no detectable improvement but cutting of climbers and woody stems smaller than 1 ins diameter achieved 130 milliacre plots per acre with seedlings of 5-10 ft height compared with 69 where no treatment was given.

The treatment described above for R.P.311 produced a detectable, though small, overall response as follows:

		Control	Treatment
1970	Seedlings/acre	27,680	35,880
	Average height (ins)	10.0	9.3
1971	Seedlings/acre	26,720	34,160
	Average height (ins)	11.4	14.2
	Change (ins)	+1.4	+4.9

This work needs to be followed up to show if larger seedlings compete more successfully with invasive species following logging. There is some evidence (from R.P.245) suggesting that larger seedlings are more prone to logging damage e.g.:

	Segaliud-Lokan (2 acres)			Kalabakan (1 acre)		
Size class of seedling	<1ft	1<5ft	5ft+	<1ft	1<5ft	5ft+
No./acre before logging	398.5	283	47.5	88	504	96
Percentage	55	39	6	13	73	13
No./acre after logging	265.5	58.5	1.0	28	295	29
Percentage	81.7	18	0.3	8	84	8

Following logging there are proportionally fewer larger seedlings and if, as may be assumed, larger seedlings suffer greater losses (see also Fox 1969 c) then clearly treatments aimed at increasing seedling heights are of questionable value. Quantity of seedlings, on an area basis, is of more interest than increased height. Treatments (or other actions) which result in reduced seedling mortality will be of value, and indeed this should be the principal aim of pre-felling silviculture. Other measures more specifically concerned with reduction of logging damage, assessed with respect to the advance growth stems, include general marking of these trees, climber cutting, and the advance planning of extraction paths. All are considered to have some marked effect on the quantity of seedling regeneration.

Stages in Silvicultural Management

The most recent review of the progress of natural regeneration in Sabah is that of Nicholson (1965). Martyn (1966a) described some of the practical implications involved in silvicultural treatment of large areas of logged over forest. The latter paper also brought up to date the procedure involved in applying the post-felling girdling operations. To take account of recent investigations, described herein, and in the light of increased utilization a formal code (Fox and Hepburn 1972) providing for a sequence of operations has been introduced. This outlines the stages of silvicultural management as a schedule in the following order:-

F = Year of Felling

F - 2 Allocation of Coupe

F - 2 to F - 1 First Silvicultural Treatment (marking and climber cutting)

F Felling

F + 0-1 month Clearance Inspection

F + 0-2 months Assessment of Regeneration

F + 3-6 months Second Silvicultural Treatment (Girdling)

F or F + 5 or F + 10 years Establishment of Yield Plots

F + 0-5 years Selection of Roads for maintenance

F + 10-15 years Assessment of Regeneration

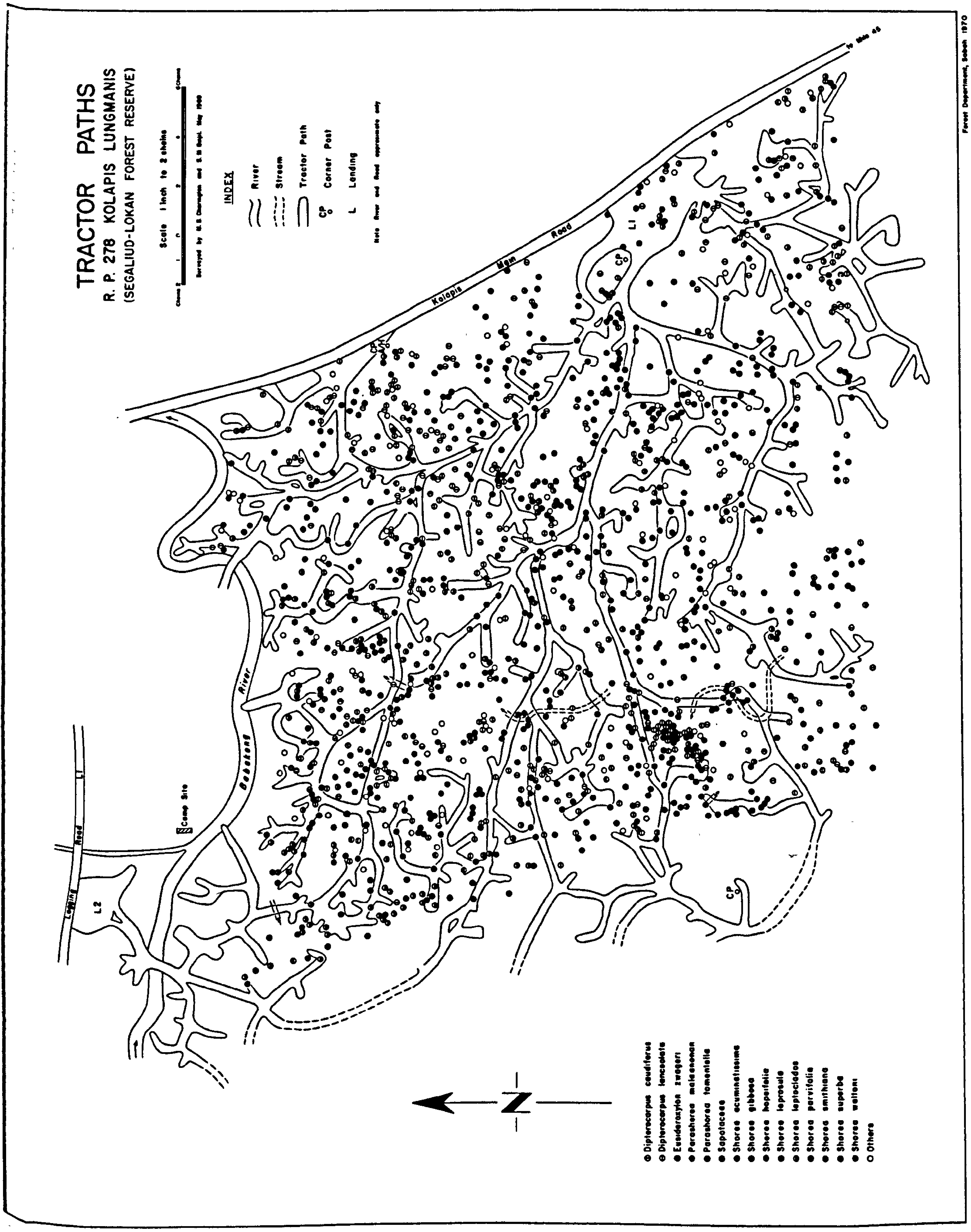
F + 10-15 years Third Silvicultural Treatment (liberation, refinement)

The 1st Silvicultural Treatment consists of protective marking of under-girth commercial trees for retention, coupled with a general climber cutting. The assessment of regeneration following felling is to determine the seedling stocking and on the basis of the results girdling of residual trees may be prescribed. Similarly the 3rd silvicultural treatment, which allows for the release from competition of fast growing valuable species, is preceeded by another assessment.

General Marking of Undergirth Trees R.P.278

An experiment was laid out in 1969 in Segaliud-Lokan F.R. to observe the incidence of logging damage on trees of dipterocarp species smaller than 6 ft girth, marked for retention prior to felling. Survival of these advance growth trees is presumed to infer satisfactory seedling stocking in their vicinity, as well as giving enhanced volumes at the second cut. No penalties were imposed on the operators nor was company cooperation specifically requested; it was assumed that marking would have some effect on the awareness of the personnel concerned with felling and extraction. The main purpose however, was to obtain large scale data on logging damage to these trees. 83.1 acres (34 ha) were marked and completely assessed. A total of 1364 trees were marked and recorded by species and girth (Appendix 6, Table 1) and their distribution is shown on Figure 48. The sample area was a few miles away from that used for R.P.135, an earlier climber cutting experiment (Fox 1968 a) available for comparison, with similar percentage representation of dipterocarp species groups and similar size class representation of undergirth trees:

FIGURE 48 R.P.278 STOCKING OF UNDER-GIRTH TREES PRIOR TO FELLING



Girth class (ft)	Numbers per 10 acres (4 ha) 1	2	3	4	5	Total
R.P.135	63	37	24	20	18	162
R.P.278	70	44	23	15	12	164

Each tree was marked with a large yellow cross on two sides of the bole, numbered consecutively in sub-plots, and marked at the point of measurement. When extraction was completed each tree was assessed for crown and bark damage using the following scale:

Bark	damage	Crown	damage
S0	nil	C0	nil
S1	<1ft long	C1	<25 per cent lost
S2	1<5	C2	25<50
S3	5<10	C3	50<75
S4	10<20	C4	75<99
S5	20 ft +		

Trees with no crown were recorded as broken off. Fallen or missing trees were recorded as one of:

fallen by tractor; near tractor path, not found;
fallen by felled trees:
or probably fallen by felled trees.

A complete breakdown of all trees by damage categories is given in Appendix 6, Table 2, Table 30 summarises the main classes of damage in similar manner to earlier work (Fox 1968 a).

<u>Table 30.</u> Types of Damage by Girth Classes
R.P. 278 Segaliud-Lokan F.R.

Class of Damage	Girth Class (ft) 1	2	3	4	5	Total	Total per 10ac.	Percent-age
(1) No damage	98	70	46	27	20	261	31.4	19
(2) Bark damage no crown damage	7	12	9	8	13	49	5.9	4
(3) Crown damage, no bark damage	84	64	48	29	23	248	29.8	18
(4) Both bark and crown damage	34	30	20	23	21	128	15.4	10
(5) Fallen or broken off	354	192	71	39	22	678	81.6	49
Total	577	368	194	126	99	1364	164.1	100

In comparison with R.P.135 a slightly lower percentage was broken off or fallen, 49 per cent against 53.5 per cent for treatment and control plots combined, and considerably less than for control only:

	RP 135 Climber Cut	Control	R.P.278
No.fallen/ac.	7.0	11.5	8.2
Percent fallen/ac.	44	62	49
No.undamaged/ac.	5.1	2.8	3.1
Percent undamaged/ac.	32	15.1	19
No.marked/ac.	15.9	18.5	16.4

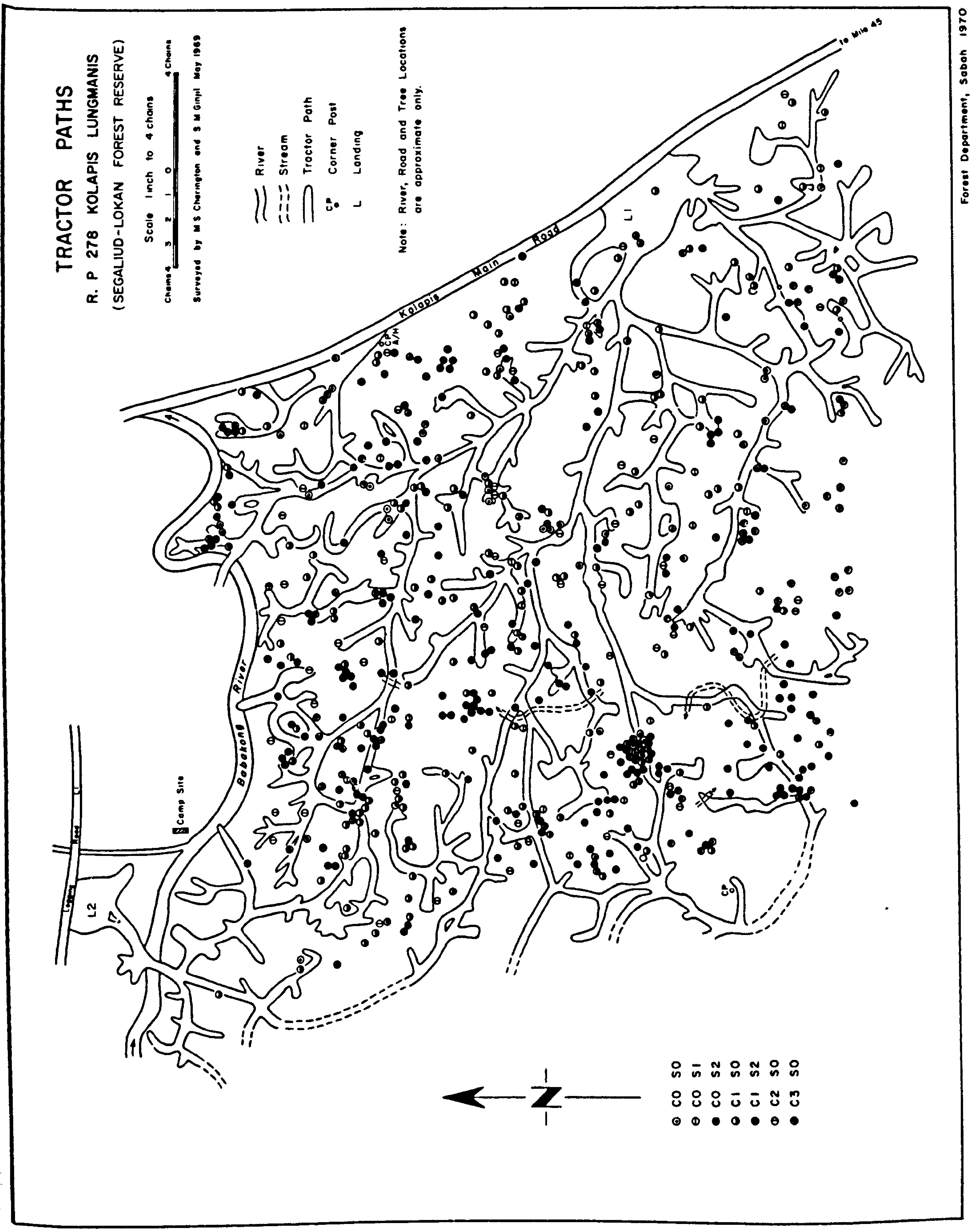
Tree marking only also gave slightly more undamaged trees, and presumed coincidental seedling retention, compared with the control plots of R.P.315. On the basis of this comparison it is concluded that tree marking alone is slightly better than no treatment (it may well be considerably better if penalites were to be imposed), but that climber cutting is likely to result in more undamaged trees. Field scale trials are now in progress using climber cutting and tree marking combined, coupled with firm attempts at company cooperation, with a view to incorporating the operation as a routine silvicultural treatment in the sequence outlined above.

Examination of the pattern of damage shows that the proportion of trees undamaged was highest in the 3ft class, and lowest in the 1 ft class. Fewer trees of the Rubroshorea species were undamaged compared with the other groups, viz: Rubroshorea 14 per cent. *Parashorea* 23 per cent, *Dryobalanops* 24 per cent, *Dipterocarpus* 30 per cent.

Trees considered likely to survive grow, and possibly produce fruit are those with damage categories of C0S0; C0S1; C0S2; C1S0; C1S2; C3S0; according to the above scheme. The stocking per acre of this group is 6.9 which may be referred to as the number with survival

FIGURE 49 R.P.278

DAMAGE CATEGORIES OF SURVIVING TREES



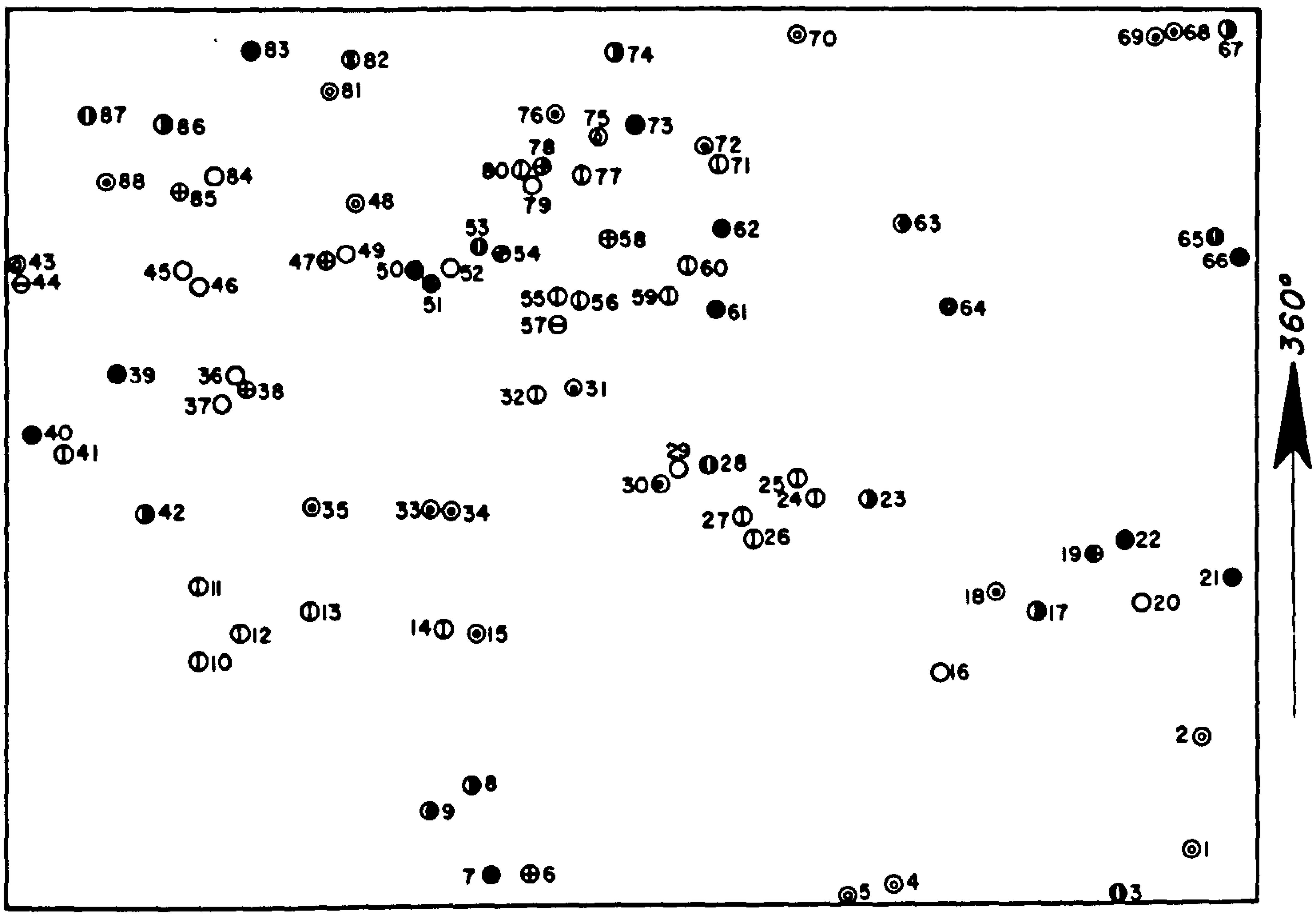
value. Distribution of these trees is illustrated in Figure 49. It should be noted that positions are only approximate in relation to tractor paths and that although completely undamaged trees tend to occur in groups at the limits of felling in poorly stocked areas, they are fairly well scattered though the area. The extreme northwest corner was completely devoid of potential survivors. Much of that area carried a stand of *Octomeles sumatrana* on the alluvial flat bordering the river (cf original stocking, Figure 48).

Detailed effects of the reduction in numbers of standing pole sized trees on an area basis is illustrated in Figures 50 and 51 for sub-blocks (i) (3.5 acres) and (ℓ) (4.0 acres). Sub-block (i) lost 73 per cent of the pre-felling potential (Appendix 6, Table 4) but *P.tomentella* and *S.leptoclados* retained their positions as the most abundant species and 6 out of the 8 trees of four feet and larger survive (Appendix 6, Table 5). Similarly in sub-block (ℓ) (Appendix 6, Table 6) *S.leprosula* and *P.tomentella* remain the most abundant species following felling and 9 out of the 16 trees of 4 ft and larger with survival value remain (Appendix 6, Table 7). Because of the general reduction of trees it is likely that the less common species suffer more and that the more abundant species prior to logging will tend to increasingly dominate local areas. The same inference may be made with respect to seedlings.

Stands logged earlier tend to have more of the harder wooded species remaining after logging, e.g. Selangan Batus and *Dipterocarpus* spp as these were often difficult to sell. Areas rich in *Eusideroxylon*

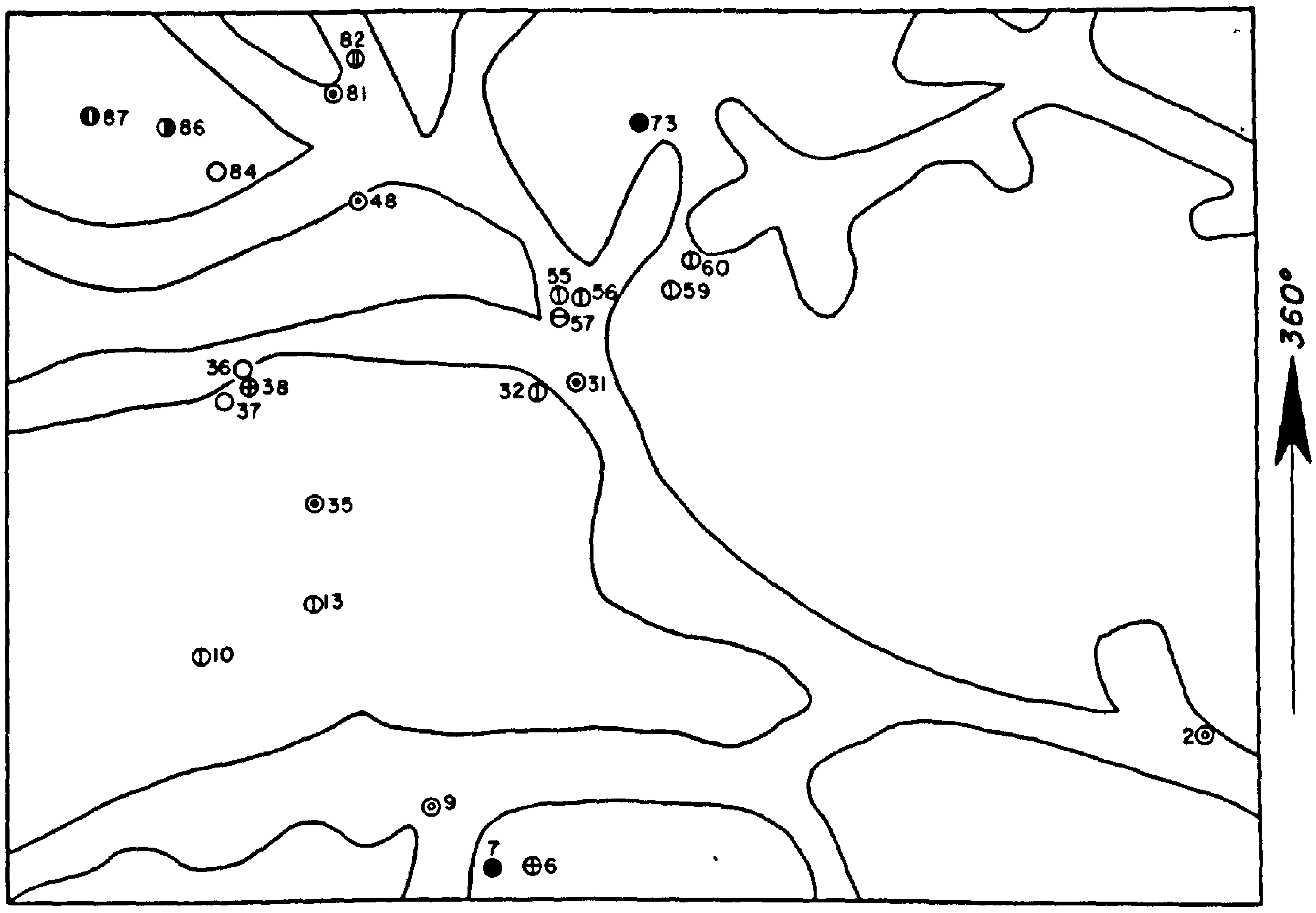
<u>FIGURE 50</u> <u>R.P.278</u>

Sub-block i, Marked Trees Prior to Logging



- ● Anthoshorea (Shorea)
- ● Dipterocarpus caudiferus
- ⦶ Dipterocarpus sp.
- ◎ Dryobalanops lanceolata
- ● Eushorea (Shorea)
- ◑ Eusideroxylon zwageri
- ⊕ Hopea sp.
- ⊛ Parashorea malaanonan
- ○ Parashorea tomentella
- ◑ Sapotaceae
- ⊖ Shorea acuminatissima
- ◎ Shorea leprosula
- ⦶ Shorea leptoclados
- ● Shorea superba
- ● Shorea waltonii

Sub-block i, Standing Trees After Logging and Tractor Paths

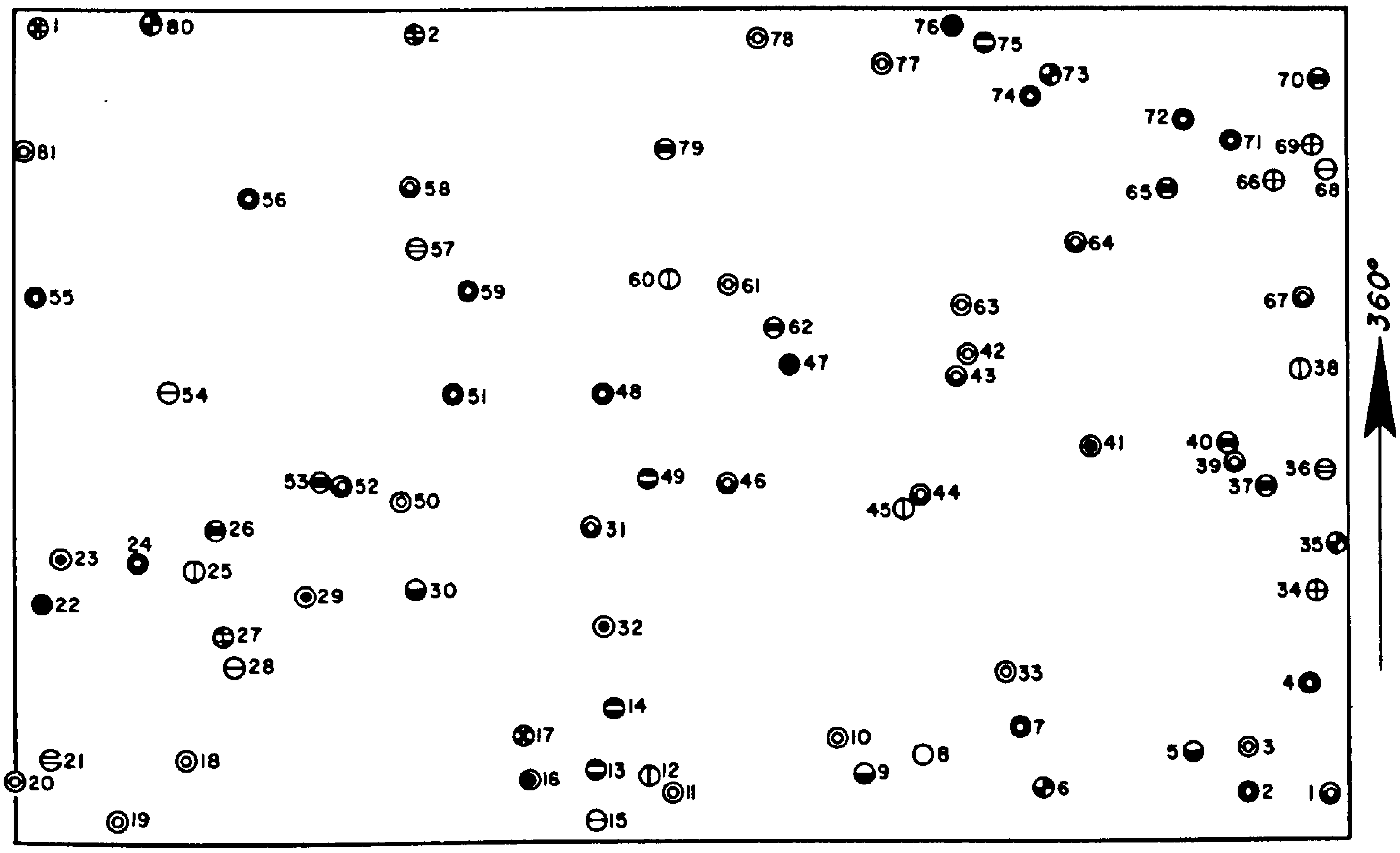


- ● Dipterocarpus caudiferus
- ⦶ Dipterocarpus sp.
- ◎ Dryobalanops lanceolata
- ◑ Eusideroxylon zwageri
- ⊕ Hopea sp.
- ⊛ Parashorea malaanonan
- ○ Parashorea tomentella
- ◑ Sapotaceae
- ⊖ Shorea acuminatissima
- ◎ Shorea leprosula
- ⦶ Shorea leptoclados
- ● Shorea superba
- ● Shorea waltonii

Forest Department, Sabah 1970

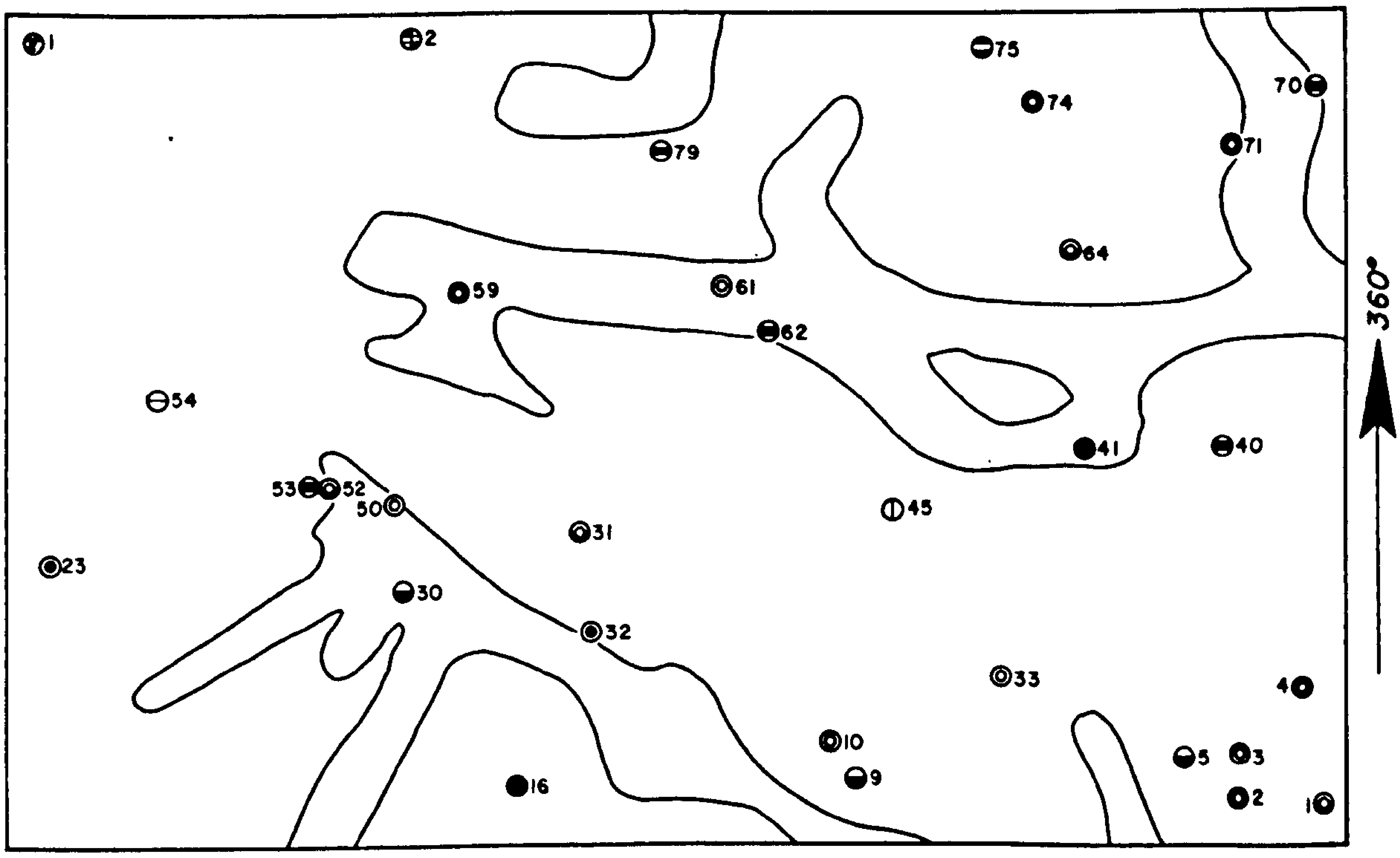
FIGURE 51 R.P.278

Sub-block I, Marked Trees Prior to Logging



- Dipterocarpus caudiferus
- Dryobalanops lanceolata
- Eushorea (Shorea)
- Eusideroxylon zwageri
- Hopea sangal
- Parashorea malaanonan
- Parashorea tomentella
- Richetia (Shorea)
- Sapotaceae
- Shorea acuminatissima
- Shorea almon
- Shorea leprosula
- Shorea leptoclados
- Shorea macroptera
- Shorea mecistopteryx
- Shorea smithiana
- Shorea superba
- Shorea waltoni

Sub-block I, Standing Trees After Logging and Tractor Paths



- Dryobalanops lanceolata
- Eushorea (Shorea)
- Eusideroxylon zwageri
- Hopea sangal
- Parashorea malaanonan
- Parashorea tomentella
- Sapotaceae
- Shorea acuminatissima
- Shorea almon
- Shorea leprosula
- Shorea leptoclados
- Shorea mecistopteryx
- Shorea superba

Forest Department, Sabah 1970.

also tend to have disproportionately high residual stems of that species. The data presented here on survival values is used for comparison with other areas but it must be stressed that numbers are comparatively low as the block encompasses lowlying riverain forest poor initially in Dipterocarpaceae and also that it borders the Kolapis road from the sides of which many trees were damaged or knocked down during the road construction. Smaller plot areas in more uniform forest may have higher numbers. With the increased intensity of felling directional marking to indicate the desirable direction of fall may offer opportunities in minimising damage to undergrowth trees and hence retaining more seedlings on the ground.

Climber Cutting Prior to Felling

During felling the crowns of large trees smash through the trees of lower canopies giving rise to various categories of damage, as described above. It is considered that the presence of climbers lacing crowns and boles together accentuates damage and that cutting of large climbers some time prior to felling (a year or more) reduces damage. However the assessment of levels of damage is complicated by the extreme variability of the natural forest in stocking from place to place resulting in different quantities of material being removed.

Several early experiments involving climber cutting and directional felling (R.P.70A, R.P.78) gave no worthwhile results (A.R.R.B. 1963). A clear demonstration of reduced damage to the advance growth trees was associated with climber cutting in R.P.135 (Fox 1968 a) but it was considered desirable to test the treatment again using randomly sited assessment plots. This was done as R.P.245, and is described here.

The two successfully completed replicates of R.P.245 were at Kalabakan and Segaliud-Lokan F.R.'s Each consisted of 10 one hectare square plots (5 treatment and 5 control) randomly placed in two adjoining areas of forest, one having been climber cut and the other not. This refinement did not remove variation and in any further work the possibility of climber cutting in and around previously randomised plots, ranked according to stocking, will have to be considered.

Rather more trees were measured per unit area than in either R.P.135 or R.P.278 and the following summarises the results:

Table 31. R.P.245 Climber Cutting Experiment (Plots of 1 ha, 2.5 acres)

	Segaliud-Lokan			Kalabakan		
	Nos. of Trees 1<6 ft girth					
Category Plot	Marked	No Damage	Survival Value	Marked	No Damage	Survival Value
Treatment						
1	59	9	23	66	10	17
2	52	13	27	83	7	18
3	62	4	18	85	19	38
4	127	20	36	63	10	14
5	62	10	18	79	4	10
Mean/acre	29.0	4.48	9.76	30.1	4.0	7.76
Control						
1	44	7	15	61	3	9
2	57	7	18	27	0	5
3	52	4	12	91	10	26
4	60	12	30	34	7	14
5	91	13	32	45	0	4
Mean/acre	24.3	3.44	8.56	20.8	1.6	4.64

Higher numbers of stems were destroyed in treatment plots in both areas but numbers free of damage after logging were slightly more. The difference between the means for trees with no damage is not significant using the *t* test for difference with common variance (Dawkins 1968 b, page 2) but is significant if the *t* ratio of the difference between pairs of plots is considered (ibid, page 3). In the latter case the overall difference is highly significant (P<.01) with all pairs whether taken as they come in Table 31, or if ranked in order of numbers of trees. The difference for the Kalabakan plots alone is highly significant, but for the Segaliud-Lokan set the difference has a probability of .25 for the plots as in Table 31 or of .10 if ranked.

Numbers per acre undamaged in all Segaliud-Lokan experiments to date have been: 7.3 (Nicholson 1958c); 5.1 (R.P.135 treatment); 2.8(R.P.135 control); 3.1 (R.P.278); 4.5 (R.P.245 treatment); and 3.4 (R.P.245 control). All these referring to trees from 1 to less than 6 ft.

Survival in R.P.245 control plots was a little better than in R.P.135 but higher numbers were marked in the former. Examination of numbers with survival value (as defined above) for all plots suggests more survivors with more trees marked. There was little difference between treatment and control plots in this and there was considerable range in numbers surviving at higher marking levels. A comparison of girth class distributions of trees with survival value is:

Table 32. Trees with Survival Value
(Numbers of stems per 10 acres (4 ha))

Girth Class (feet)	1	2	3	4	5	Total
Plot						
R.P.278(Seg.-Lok.)	23.4	17.5	12.7	7.9	6.8	68.5
R.P.245 " (C)	29.6	16.0	14.4	15.2	10.4	85.6
" " (T)	35.2	25.6	18.4	8.8	9.6	97.6
" (Kal)(C)	18.4	8.0	10.4	5.6	4.0	46.4
" " (T)	32.0	15.2	16.8	9.6	4.0	77.6

(C) = Control ; (T) = Treatment.

The overall trend of survival with numbers marked, based on graphical smoothing of mean values, was as follows:

Numbers per 10 acres (R.P.245 combined) Marked	Undamaged	Survival Value
400	60	128
300	40	90
200	24	56
100	8	28

In earlier work on felling damage (Nicholson 1958c, Fox 1968a) attention was drawn to correlation between volumes and basal area extracted. This has continued through all studies. Numbers of trees felled are also generally related to damage and Dawkins (1958) suggests that 5-15 per cent of the stand per felled tree is too severely damaged for survival. Correlation of damage categories with basal area extracted was attempted for the earlier work (Figure 52) but edge effects are of great importance. Quantities extracted were highest in Kalabakan for R.P.245, and in Segaliud-Lokan were similar to R.P.135:

Table 33. Quantities Extracted and Damage

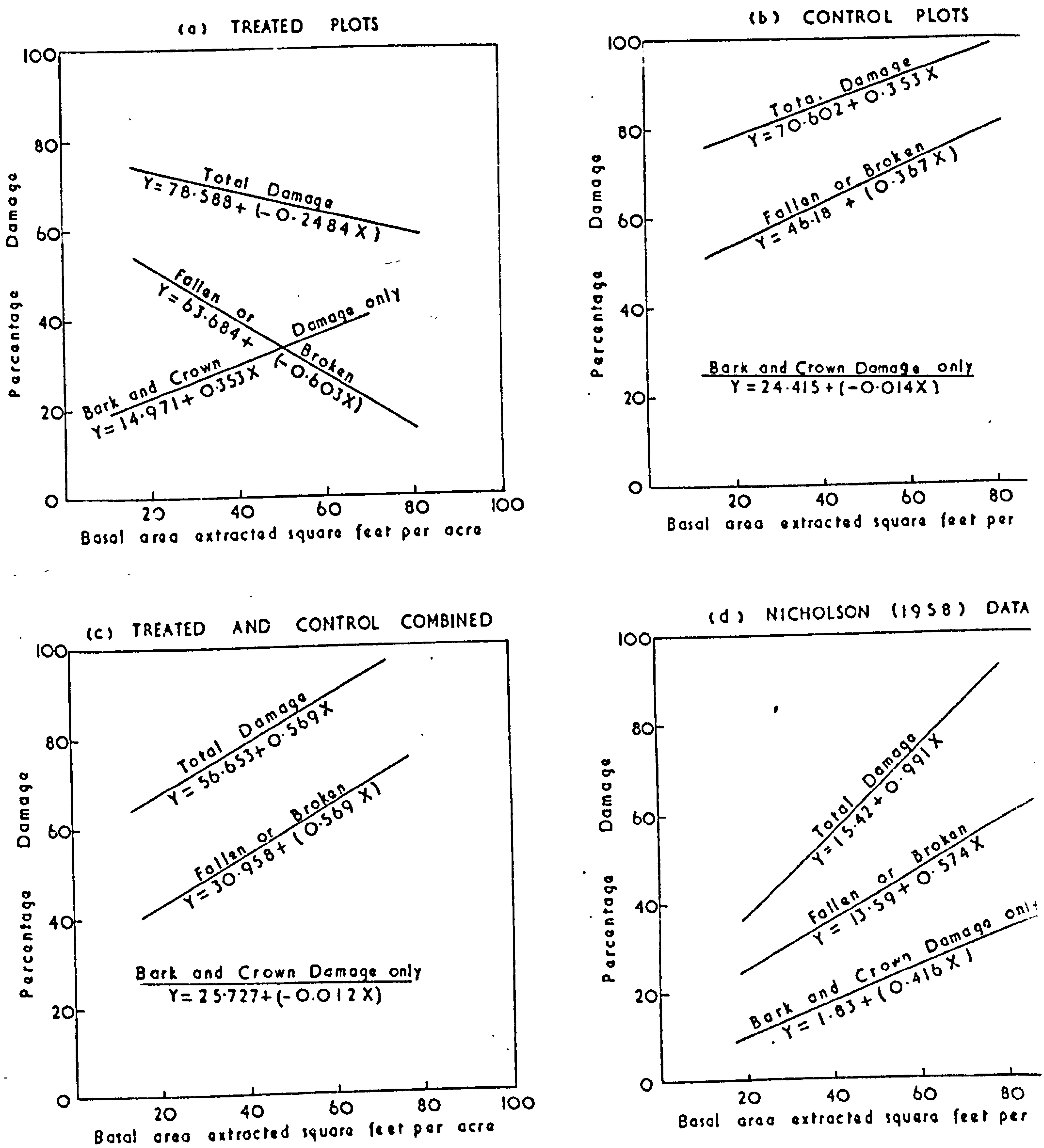
	Quantity Extracted/acre Volume (h.cu.ft)	Basal area (sq.ft.)	Nos.	Damage Total	Percent Fallen/ Broken
Plot					
R.P.135					
(Seg-Lok(C)	2100	44	6.7	86	62
" " (T)	1550	33	6.2	70	44
R.P.245					
(Seg-Lok)(C)	1720	34	4.7	86	55
" " (T)	2160	44	5.8	85	54
R.P.245					
(Kal) (C)	2640	61	9.4	92	63
" " (T)	2040	50	7.8	87	68

(C) = Control; (T) = Treatment

One of the difficulties in interpretation of R.P.135 was that higher volumes were taken from the control plots; this was reversed in R.P.245. The general levels of basal

FIGURE 52 R.P.135 CLIMBER-CUTTING EXPERIMENT

TYPES OF DAMAGE AND BASAL AREA EXTRACTED



areas and volumes per acre removed were as follows:

B.a.	30-40	volumes	1500-2000
B.a.	40-50	volumes	2000-2500
B.a.	50-60	volumes	2500-3000
B.a.	60-70	volumes	3000-3500

Individual plot values and means for basal areas extracted and percentage damage are illustrated in Figure 53. Two control plots in Kalabakan had no surviving undamaged trees (Table 31) and the higher overall damage there must be partly attributed to the fact that steeper slopes were involved than at Segaliud-Lokan. Figure 53(a) suggests that the increase in damage with increased basal area reported for the earlier work has gone and the incidence of total damage is variable within the range 75-100 per cent when basal area extracted exceeds 50 sq.ft./acre. In the context of heavier felling generally even local areas with basal areas extracted of less than 40 sq.ft. suffer 80 per cent or more total damage. Data for percentage fallen or broken off (Figure 53(b)) shows a more linear trend with increasing extraction.

There was no corresponding relationship between basal area extracted and numbers of undamaged trees or of these with survival value. Figure 54 illustrates percentages of these two categories. A much greater range in the proportion of trees with survival value than of undamaged trees is evident.

Clearly the benefits due to climber cutting with respect to increasing survival of advance growth trees are difficult to quantify. However the addition of a single tree per acre of reasonable girth to the number undamaged after felling will do much to assure subsequent seeding and to enhance volume yield at the second cut. The quantity of marked undamaged advance growth may well be increased if company cooperation is obtained.

FIGURE 53 LOGGING DAMAGE AND BASAL AREA EXTRACTED

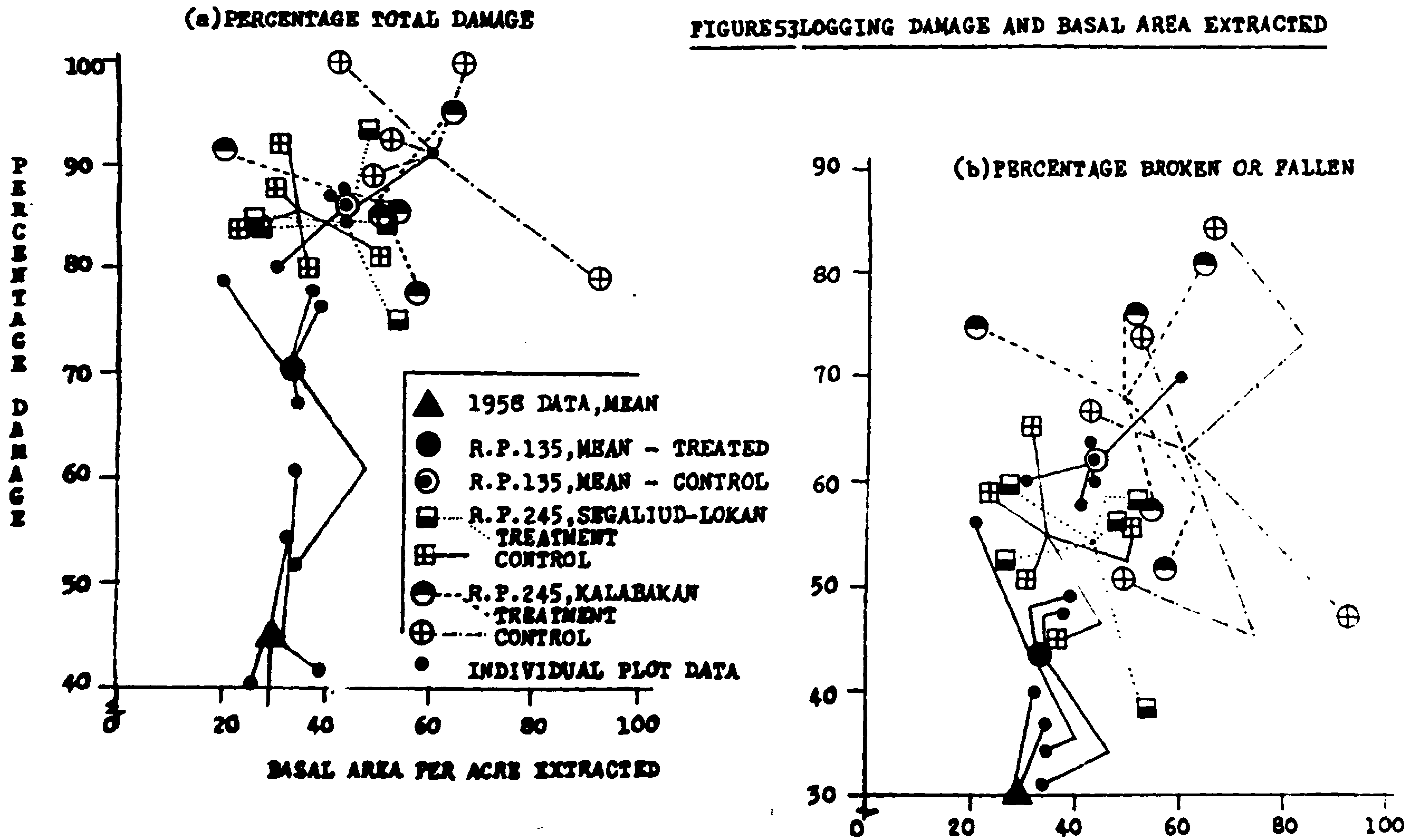
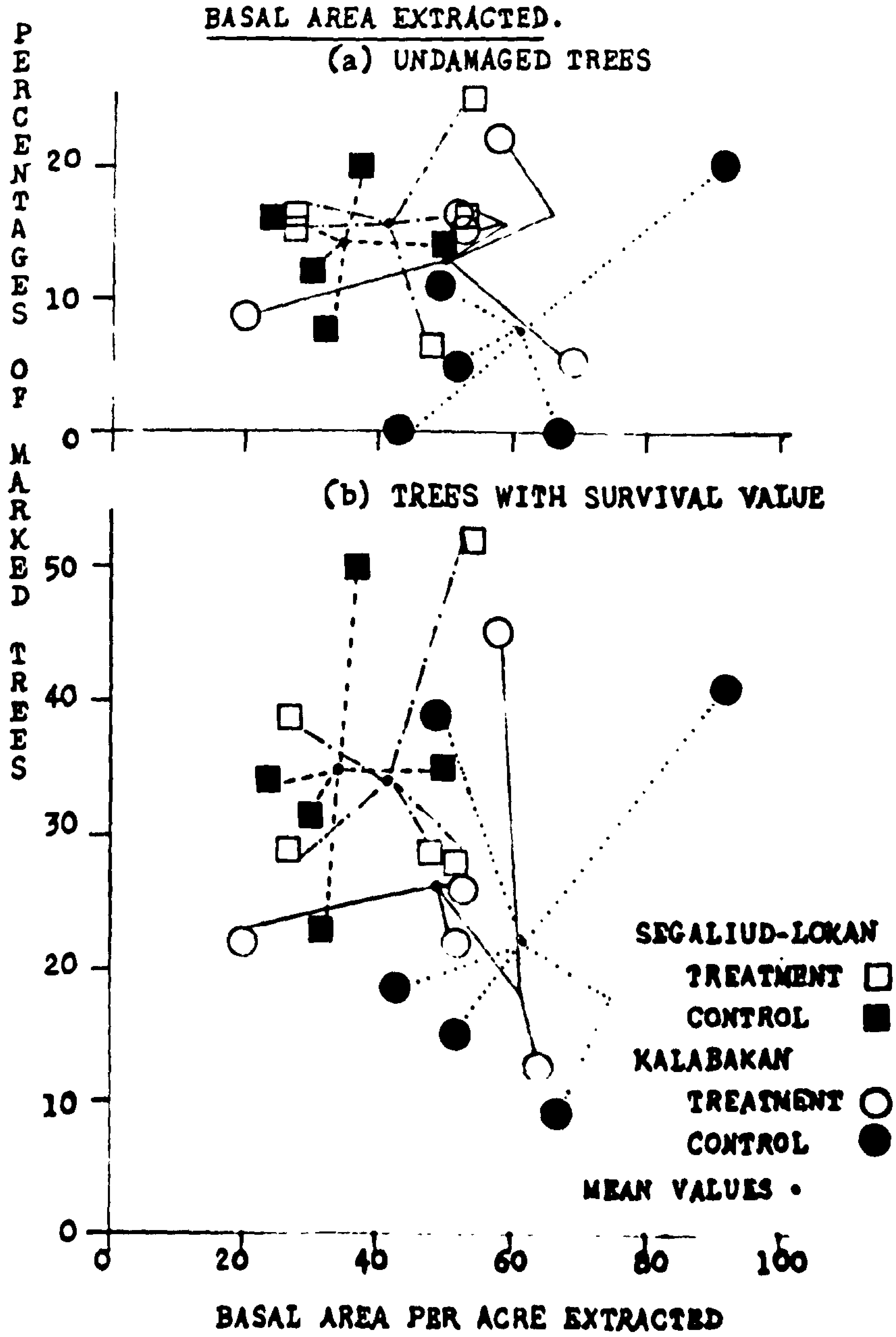


FIGURE54 R.P.245 SURVIVING TREES AND BASAL AREA EXTRACTED.



Advance Planning of Extraction Paths

Much current logging in Sabah is done without any prior planning of extraction routes. The larger and more mechanised operations use metalled roads, which require prior survey, but tractor extraction paths are not, at present, marked out prior to use. Theoretically prior planning would reduce the indiscriminate crawling of tractors as trees may, to some extent, be felled towards the track areas. This would not only increase the efficiency of the operation but also reduce damage to seedlings by fallen debris and tractor path intensity. Investigation of this aspect of pre-felling silviculture depends on the active co-operation of the extracting company.

In 1969 Sabah Timber Co. (S.T.C.) undertook an experiment along these lines in Segaliud-Lokan F.R. Three felling blocks of 10.7, 16.4 and 10 acres (4.3, 6.6 and 4 ha.) were demarcated prior to felling and after all merchantable trees had been measured and mapped, extraction paths were laid out. Felling was then completed and the fallen crown and bole areas were measured. Figures 55, 56 illustrate the type of measurements made. The tractor paths were surveyed when extraction was completed.

The volume of timber removed averaged 2250 cu.ft. per acre (200 cu.m/ha). Some 16 per cent less was removed from R.P.245 in the same general area; this and R.P.278 are the only sources of comparable tractor damage. The three plots all had about the same tractor damage:

Plot No.	1	2	3	Mean
Area(acres)	10.7	16.4	10.8	-
Vol/acre	2904	1913	1918	2250
Percentage				
Tractor paths	21.2	21.1	20.3	20.2
Crown area	15.3	11.7	12.5	13.0
Bole area	5.0	3.4	3.2	3.8

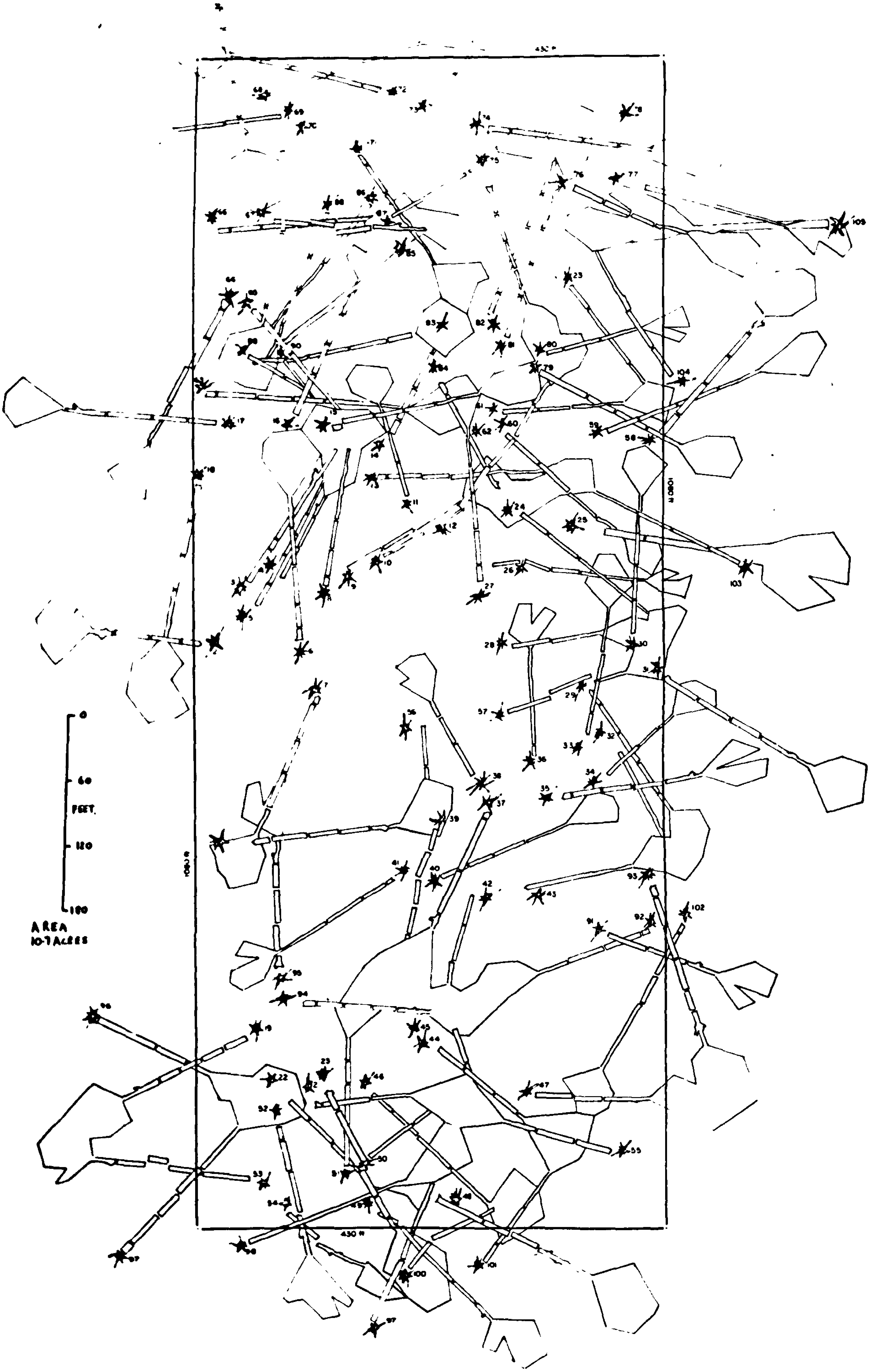


FIGURE 55 SABAH TIMBER CO. EXPERIMENT

FALLEN TREE SURVEY

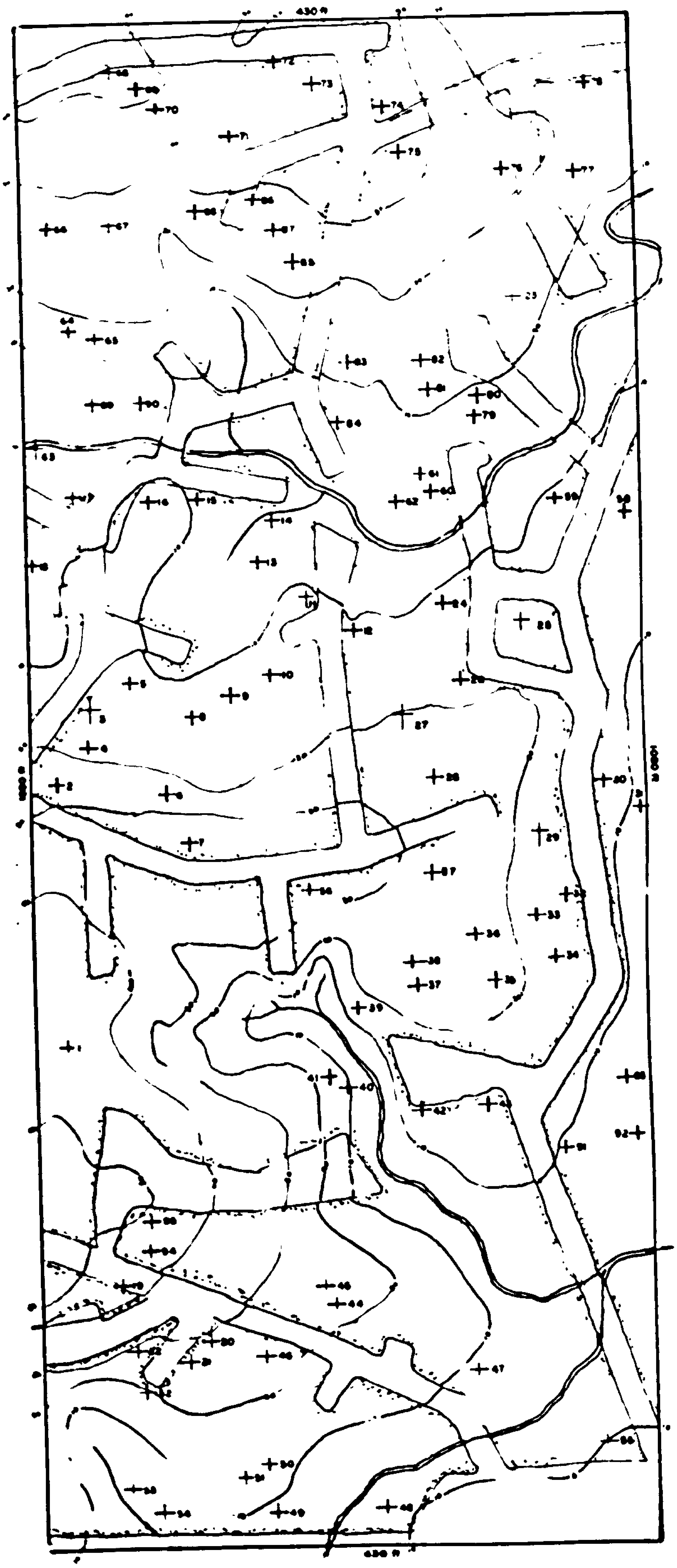


FIGURE 56 SABAH TIMBER CO. EXPERIMENT

TRACTOR PATH SURVEY

Per cent tractor damage in the 10 plots of R.P.245, in Segaliud-Lokan F.R. ranged from 20.8 to 35.1, with the overall mean 27.1 (S.E. per cent 5.2). In R.P.278 tractor path damage amounted to 23 per cent of the total area. The suggestion is that pre-planning may have reduced tractor damage by up to 7 per cent. This form of damage owes much of its variation in local intensity to relative distance from loading point, block area and shape, nature of the terrain and ground conditions. Significance cannot be attached to the comparison.

The variation in tractor path intensity for all R.P.245 plots was as follows:

Table 34. Percent Tractor Damage R.P.245

	Kalabakan			Segaliud-Lokan		
	T	C	All	T	C	All
Mean	22.5	19.7	21.1	25.5	28.6	27.1
Maximum	30.1	24.9	30.1	35.1	31.7	35.1
Minimum	11.0	11.0	11.0	20.8	25.7	20.8

T = Treatment; C = Control

Crown and bole overlap with tractor path damage was not measured, but planimetric analysis of the S.T.C. plotted data suggests that 2-3 per cent of such overlap occurred. Little success was achieved therefore in confining falling material to extraction paths. However the principle of felling onto the paths resulted in considerable crown overlap; reducing the total area of crown debris but concentrating much of it in more limited areas (Figure 55). The value of this in relation to seedling conservation/loss needs further examination.

The reduction in stocked milliacre plots per acre in R.P.245 was from 729 prior to felling to 325 after; tractor damage accounted for 56 per cent and crown debris, fallen trees, etc., accounted for 44 per cent of this reduction. This suggests that smothering by fallen material, which is more damaging to seedlings when in a great mass, may well be of considerable importance. However loss of this nature at the time of logging may be temporary if some seedlings coppice.

Sixty per cent of the felled trees had crown overlap with a mean crown area of 0.0252 acres (0.0101 ha), compared with 0.0257 (0.0104) for trees which landed singly. There was a definite linear relationship between crown area and bole basal area for trees which landed singly with Crown area = 300 + 150 (Bole area). Smaller trees of *Dipterocarpus* spp. and *Dryobalanops lanceolata* had smaller than average crowns whereas the Rubroshorea and *Parashorea* spp. had larger than average crowns throughout the size range. Average crown areas with bole sizes were:

Girth (ft)	6	8	10	12
Crown area (acres)	0.017	0.024	0.034	0.046

Much of the tractor damage is cuased by the use of the blade as counterbalance to log weight. In unstable soil areas, e.g. soft sandstone, cuts of up to 15 ft are eventually made after many passes with the bulldozer towing logs with the blade down. On the TD 25 used in the above experiment the distance between the outer side of the tracks is 8 ft 10 ins whereas the blade is 12 ft 3ins wide. The average width of skid tracks was 16 ft and this is often exceeded.

The network of skid tracks fanning out from landings (Figures 48, 49, 56) results in more damage close to loading points. Landing areas with tractor yarding are generally in the range of 0.5 to 1.5 acres (0.2-0.6 ha) and from 1 to 2.5 acres (0.4-1.0 ha) at spar tree sites in high lead logging areas; ràther larger landings are sometimes made with tractors working to rail lines. These areas are likely to be devoid of regeneration (of dipterocarps) for the first rotation from logging of the natural forest. In total area they probably account for less than 2 per cent of blocks worked by tractors and between 2 and 5 per cent of high lead areas.

Tractor path edges often contain regeneration which can grow up and contribute to "stocking" of tractor paths. Providing tractor path intensity is not more than 20 per cent overall (which can be achieved by pre-planning) and is reasonably well distributed, then the whole area, apart from the landings, should be capable of carrying regeneration. No detailed study of the relationship between tractor path intensity and seedling stocking has been made but for comparative yield projections (Chapter 10) it is assumed that damage in excess of 20 per cent will result in a proportional loss of seedling stocking. There is clearly a need to investigate the actual relationship of seedling loss to tractor path intensity in some detail. If company cooperation cannot be achieved voluntarily then penalties may form the only basis for minimising damage.

Initial tractor paths will undoubtedly be used at any subsequent felling, despite the inevitable erosion which will occur between fellings. Considerably more care should be taken in the layout of paths at the first felling to take account of the economical minimum necessary It may be surmised, though no measurements are available, that the lower tractor damage at Kalabakan (Table 34) was partly due to the area being one of strong slopes where winching in must have been used to some extent and where deviation from initial tracks was probably more difficult than in the gently undulating topography at Segaliud-Lokan F.R.

The First Silvicultural Treatment

Attempts at fostering the quantity of natural regeneration by action prior to exploitation fall into three main categories. These are silvicultural, administrative and company orientated. The latter two may vary at points in the time scale depending on the level of control exercised by the Forest Department and ability or willingness on the part of the companies to abide by rules.

The code outlined above provides for silvicultural intervention prior to felling by marking of undergirth trees for retention and climber cutting. Early coupe allocation may, in some cases, lead to deferment of logging in a given area if seedling stocking is so low as to give rise to doubt over whether satisfactory regeneration can be achieved. This is a management decision, as is the alteration of girth limits (cf Figure 25, and Alabazo Corpuz 1969), but both rely on effective examination of the stand prior to felling.

Action available to the companies involved in logging include restriction of the numbers of bulldozers working a given block, pre-selection of tractor paths and the use of winching in of logs. Careful logging can minimise damage by directional felling and avoiding the creation of blocked water courses, landslips and erosion hazards by skilful bulldozer operation. Careful logging practises can be requested, made the subjects of logging rules, and, in the last resort, regulated by discriminatory fines or the withholding of coupe. The achievement of these depends on effective management.

Though early attempts at refinement may not have been specifically concerned with fostering increased quantities of seedlings, this is the main objective of present day pre-felling silviculture and control. Loss of seedlings results in delay, and may, for practical purposes be irreparable if further seed is not available

CHAPTER 7

THE EFFECTS OF LOGGING

Felling and removal of the large trees has a profound effect on the forest. In the previous chapter pre-logging treatments designed to reduce logging damage were assessed by comparing the amount of damage to soil, advance growth and seedlings. Logging damage as measured by these parameters has increased as the degree of logging has increased in response to bouyant markets. I have earlier referred to the range of ecological conditions resulting from logging as "exploitation ecotypes" (Fox 1968(b)) and in this sense exploitation itself is a major silvicultural tool, despite the difficulties of controlling it.

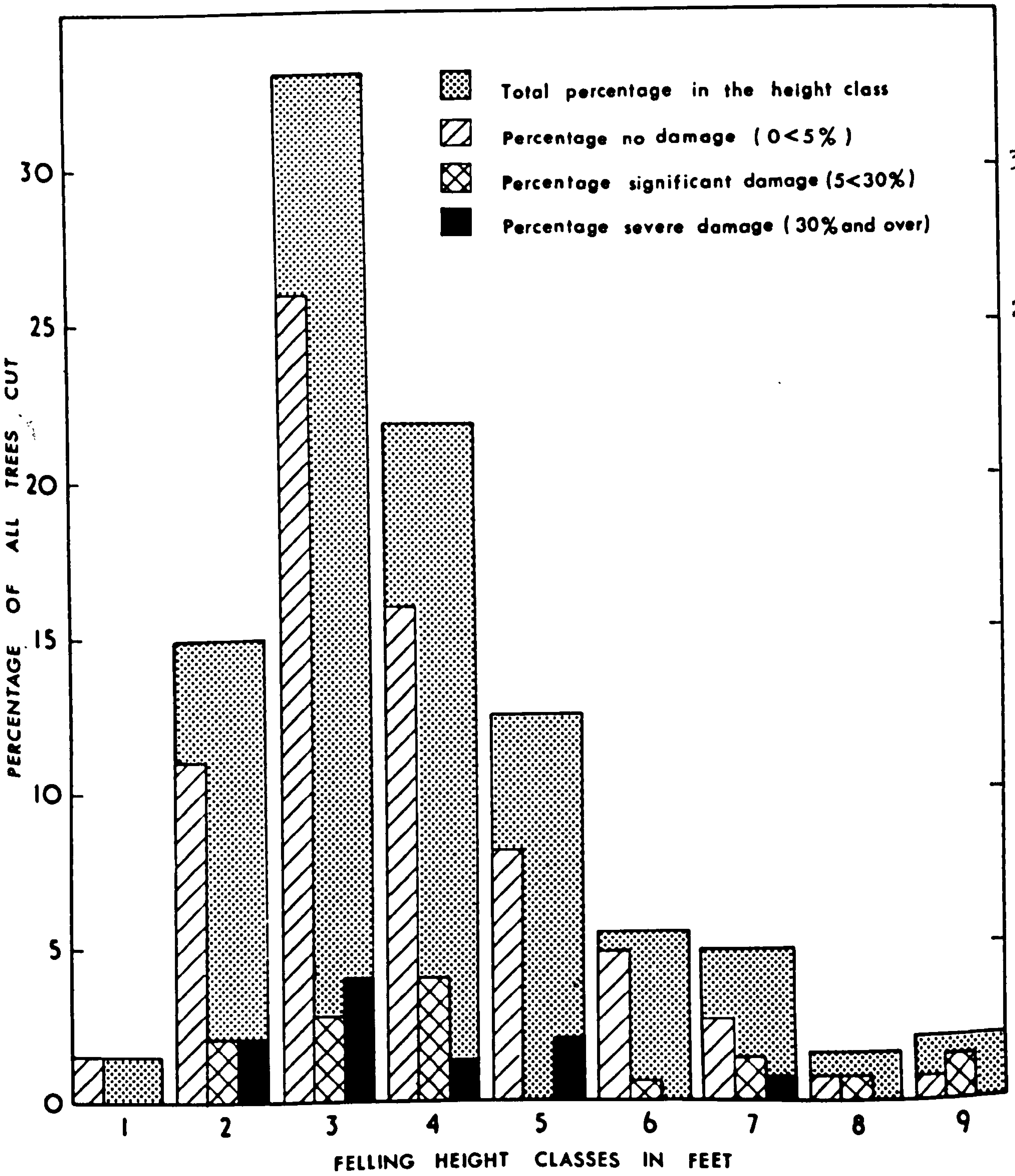
The silvicultural system in use, akin to the Malayan Uniform System (Wyatt-Smith 1963), relies on the felling over of blocks of forest at the same time and not necessarily aiming for a uniformly even-sized or even-aged crop of natural regeneration (Nicholson 1958(a)). In this the philosophy behind the system differs from that put forward by Wong (1966) for West Malaysia, and tree marking to ensure removal (Rahman 1968) is neither necessary nor desirable. Indeed the positive retention of potential seedbearers may be advisable where seedling loss is high and can be predicted.

Considerable loss of timber occurs during felling (Fox 1968(c)) and where this is due to falling *per se* then it may be reduced by felling close to the ground (Figure 57). Changing of girth limits can influence the amount of damage and in hill protection forests the felling limit is usually raised (Alabazo and Corpuz 1969).

FIGURE 57

PERCENTAGES OF TREES CUT

ARRANGED BY HEIGHT OF FELLING



Successful implementation of the pre-felling treatments and planning described earlier may also reduce damage, but the stand as it is after logging is the basis for natural regeneration, successful or otherwise, of the forest.

Logging Methods

Handlogging was in general use between the wars. It could only be used in undulating country on falling grades (Brown 1950) but persisted in peat swamp working until recently. Buffaloes were used to haul split logs on steeper slopes in the West Coast, and this method could be seen, on a small scale, as late as 1967 near Kota Belud. The big impetus to present day logging came with the introduction of the bulldozer, with some scepticism at first (Webb 1950) and a little disbelief ... "The North Borneo Timber's mechanical extraction venture has now had a fair try out ..... while it cannot be said that the operation has proved wildly successful .... the intention is not only to continue but to expand the operation." (Reg. Notes M.F. 1951).

The first machines were D8 caterpillar tractors hauling logs to railway lines (Martyn 1966(b)). Elephants were used for a short while by Wallace Bay Co. but after two years they were returned to Thailand (Reg. Notes M.F. 1953) and by mid 1953 the main firms had 17 tractors and hand logging gangs were being sacked; by the end of 1953 (Reg. Notes M.F. 1954) some 30 tractors were in operation. One company found the cost too high and decided to revert to hand logging; the reversion was short lived. Shortly afterwards Brown (1955) described lack of labour for hand logging as being one of the main factors determining the use of tractors! The elephants were said to be difficult to feed and the trees were larger than they could haul, though a recent report suggests the latter may be fallacious (Whitmore and Ho 1968). By 1955 there were 42 tractors in use and the number rose to 498 in 1964 (Martyn 1966b).

During 1928-34 the British Borneo Timber Co. used a high lead (cable) logging system in the Garinono Bettotan area, this was reputedly unprofitable. High lead logging was re-introduced for hilly country in 1952, firstly by Kennedy Bay Co. and shortly after by Wallace Bay Co. The latter company did not persist, however, but large areas in the Silam/Ulu Segama F.R. and in Silabukan F.R. have been exploited by Kennedy Bay Co using this method. Despite felling probably having been incomplete in the Bettotan area (Brown 1950) this area affords the only reliably dated period for the study of older regenerated stands. The sites of pole trees and research plots in this area referred to in earlier work (Fox 1968(d), Meijer 1970) are illustrated in Figure 58. Nicholson (1963b) drew attention to the fact that high lead logging resulted in a lower loss of seedlings than tractor yarding but that damage to advance growth was more severe.

The great advantage of a short haul has been demonstrated by Brown (1955) who gave production data for the ITD 24 machine. Unfortunately shortage of roadstone in many of the Kinabatangan forests has lead to the use of very long hauls. There is no information on the relationship of haul length to logging damage though it is clear that long hauls result in large landings. These are often in flat areas which become very churned up and incapable of reproducing dipterocarp trees. The same principle will presumably apply to the reworking of rail

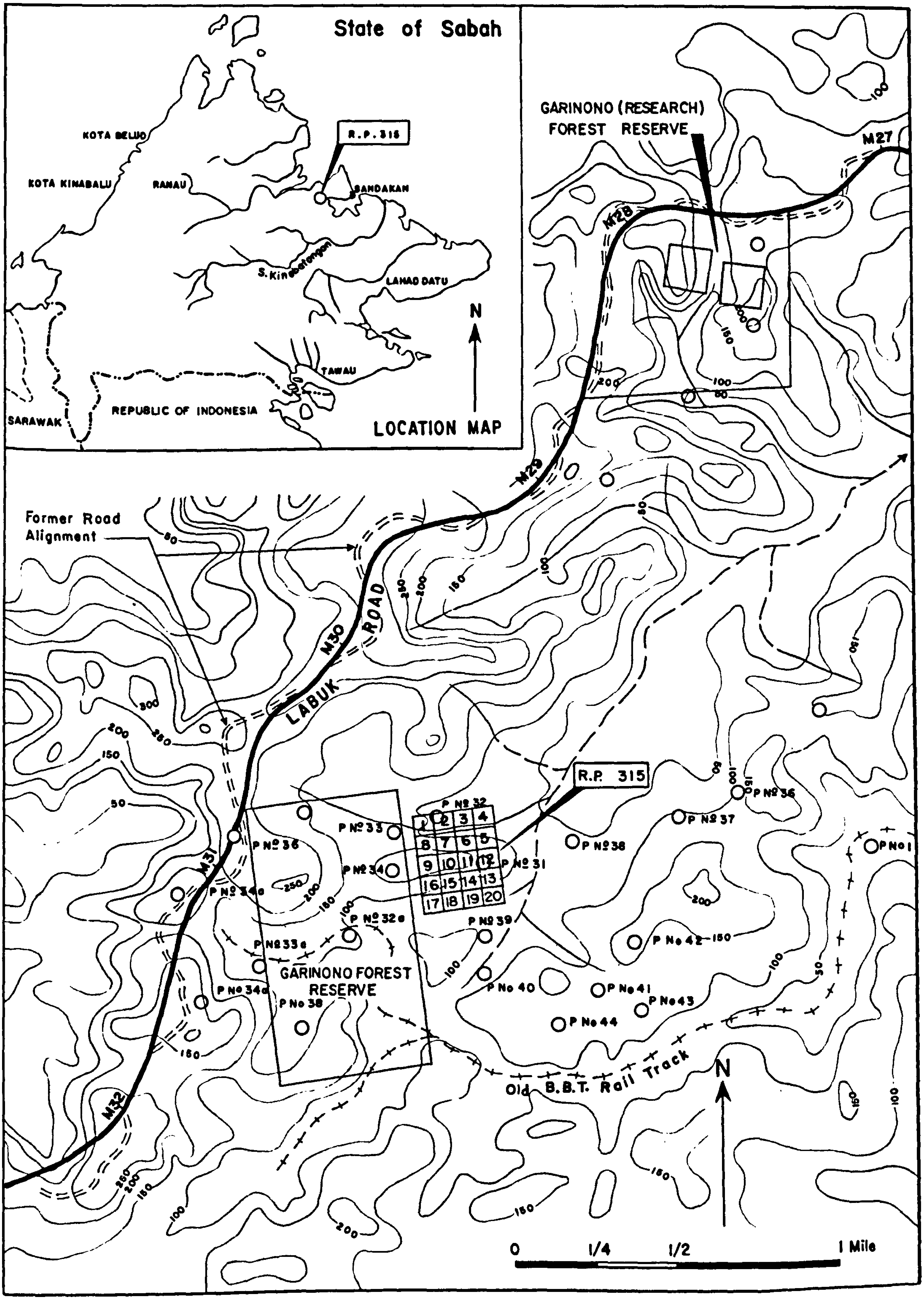


Figure 58 Research Plot 315

Mile 31, Labuk Road, Sandakan.

areas as for tractor paths, namely that the same route will be the most economical at the second cut.

Wheeled skidders were first used in 1953 (Brown 1955) but were not popular as they lost traction on wet mud. Larger models have now found favour and may well replace tractors on long hauls. As tractors have been found necessary to make the path for the wheeled skidder, and to haul logs to a collecting point for it to work from, little in the way of reduction in path intensity can be expected. However the machines do not have heavy blades and the amount of soil removed from main extraction routes should decrease.

Chain saws were introduced for felling in 1961 and by 1965 were in general use. This change also resulted in considerable labour saving, and as with the bulldozer operators, the fellers are extremely well paid relative to earlier times. Nevertheless the skills involved are simple, for most aspects of logging, and no attention has so far been paid to the role of the logging personnel in promoting the creation of conditions favourable to natural regeneration in felling areas.

It is my considered view that many machines used in the forest for hauling logs may be overpowered and used inefficiently. Winching in of logs is rarely done and bulldozer operators frequently tow logs up and down steep slopes. Experimental methods are available for relating log haul performance to soil conditions, taking into account slopes, types of soil, and loads (Chappell and Richardson 1970). These could be usefully examined under Sabah conditions. Hauling of logs often affects the survival and growth of intermediate sized trees by scraping off bark, exposure of roots, or soil compaction effects. These are accentuated in wet weather working (Moehring and Rawls 1970) which is commonly, and perhaps unnecessarily, practised in Sabah. The use of heavy equipment on soils liable to rapid erosion in inland areas may adversely affect adjoining areas (Paton 1963) another aspect of large mechanised logging operations that has received no attention as yet. Proposals to study logging methods have been formulated but shortage of a suitably experienced engineer has delayed this aspect of Forest Department research.

Composition of the Residual Stand

Logging is primarily concerned with the removal of dipterocarps over the felling limit, generally 6 ft girth (58 cm diam), and as shown above dipterocarps comprise high proportions of most stands. Of the non-Dipterocarpaceae reaching large sizes species of the following genera are increasingly felled: *Heritiera, Palaquium, Madhuca, Terminalia, Durio, Mangifera, Sindora* and *Koordersiodendron pinnatum* and *Octomeles sumatrana*. The heavy wooded species *Eusideroxylon zwageri* and *Intsia palembanica* are cut in most areas, but occasionally left. The following genera are not usually cut and marketing prospects for them are poor, mainly due to lack of quantity but also to inherent wood features: *Irvingia, Sympetalandra, Koompassia, Dialium, Diospyros,* (hard species); *Lithocarpus, Planchonia, Canarium, Dillenia, Pentace, Parkia, Melanorrhoea,* (intermediate); and *Duabanga Scaphium, Anthocephalus* and *Alstonia* (soft and rapidly decay).

Table 33 shows the percentages of total volume cut of the major timber groups, from the concession area of Sabah Timber Co. in Segaliud-Lokan F.R. for the years

1956-1971. Undoubtedly some little known species are recorded as "seraya" (white seraya = *Parashorea*, red seraya = Rubroshorea) but the gradual diminution of the proportion taken by the four major groups indicates an increased willingness to take more species. This has been achieved to some extent by pressure of forest

Table 35 Percentage of Total Volume Outturn by Species Groups. Sabah Timber Co. Segaliud-Lokan F.R.

Year	Percentage of Total by Group				Total
	Rubro-shorea	Para-shorea	Dryo-balanops	Diptero-carpus	
1956	44.8	30.3	11.6	11.1	97.8
1957	37.9	28.0	14.2	16.8	96.9
1958	30.7	26.6	21.6	18.2	97.1
1959	33.4	22.0	21.8	18.0	95.2
1960	35.6	18.9	22.9	17.7	95.1
1961	30.0	22.4	22.9	17.6	92.9
1962	33.8	27.5	18.1	13.9	93.3
1963	41.5	23.8	16.8	9.6	91.7
1964	32.5	20.3	23.9	13.3	90.0
1965	36.8	23.7	17.8	13.1	91.4
1966	39.5	21.1	17.5	12.4	90.5
1967	37.4	25.1	17.0	10.6	90.1
1968	45.1	21.3	10.6	13.6	90.6
1969	45.5	20.6	12.7	13.4	92.2
1970	38.8	18.5	9.0	16.3	82.6
1971	41.5	19.2	9.4	14.1	84.2

management, but mainly due to normal commercial pressures: more timbers can be sold of different grades and types when markets are firm. Much of the increased utilisation has come from cutting more Dipterocarpaceae together with a sprinkling of other light to medium weight species which can be sold with the bulk of Dipterocarpaceae as mixed light hardwoods.

When the large commercial trees of sound boles have been removed the stand may consist of (a) large defective commercials, sometimes sound trees of heavier wood, i.e. sinkers; (b) large non-commercial trees; (c) trees of the middle storey which may be of species capable of reaching large size, or of intermediate sized species; (d) trees of the understorey, mainly low forms such as Anonaceae, Euphorbiaceae, *Eugenia* spp., *Diospyros* spp., Rubiaceae, Malastomataceae, Lauraceae, Meliaceae etc., with a sprinkling of poles of species capable of reaching higher stories. No attempt is made to illustrate this but reference may be made to Baur (1964) for illustration of stages in development of typical West Malaysian dipterocarp stands. All categories are mixed and local representation depends on what was there before and what has been knocked down in the process of logging. Clearly with more stems removed more damage is done to the various categories listed above. A typical example of the breakdown of residual non commercial species by size classes is given in Appendix 7, Table 1. This represents a summary of 15 rectangular plots in three strips of 2 x 25 chain (40 x 500 m) inside a rectangular block of 50 acres (20 ha) of felled forest. Of the individual 0.4 ha plots ten contained one or more trees of 6 ft (58 cm) or larger and 11 plots had 8 or more trees over 3 ft girth (30 cm diam) but variation in smaller classes between plots was much greater.

A summary of results of similar measurements for seven different locations is given in Appendix 7, Table 2, in terms of per acre (0.4 ha) by size classes. All species included are of no present value and most would be eliminated when falling in "dense islands of unlogged forest" as defined in earlier girdling rules (Nicholson 1965). Numbers of residuals are lower in low lying moist areas at Lumerau and Kretam F.R.'s but the other areas sampled had comparable stocking of 40-85 stems per acre (100-210 per ha) of 6 ins girth (5 cm diam) and larger.

For stems larger than 2 ft girth (19 cm diam) the range was 9-18 per acre (22-44 per ha) but only a little over 2 per acre (5 per ha) for Lumerau. Non commercial species over the latter size in R.P.233, a 30 acre (12 ha) plot in Ulu Segama F.R., were 14.4 per acre (35.5 per ha) and here residual dipterocarps accounted for a further 3.2 per acre (7.9 per ha). A summary of stocking on the latter area is given in Appendix 7, Table 3. The most abundant single species in R.P.233 were *Diospyros macrophylla* (10.4 per cent), *Nephelium mutabile* (11.1 per cent), and *Koordersiodendron pinnatum* (5.3 per cent) (Fox 1969c).

Damage to Soil, Seedlings and Advance Growth

Attention has been drawn in an earlier paper to changes in soil following logging (Fox 1968 (e)). Logging exposes the soil resulting in more severe fluctuation in surface temperature (cf Chapter 2), loss of nutrients and erosion. Where the surface soil has been scraped off dipterocarp seedlings are generally lost, though with light tractor movement coppicing of damaged seedlings may occur (Strugnell 1947). Exposed soil at the edges of tractor paths will regenerate to invasive species, but, initially, the main paths will become grass (e.g. *Paspalum* spp., *Pennisetum* spp.) or climber (*Mesoneuron, Merremia*) covered. Later woody species may come in, but scars may persist for a long time where the parent rock has been exposed.

At the completion of logging all tractor paths may be presumed unstocked areas so far as dipterocarp regeneration is concerned and the pattern and density of paths will have a profound effect on later overall stocking. Current levels of damage may well represent a general upper limit, though as I have shown, individual areas may well have a higher proportion and clearly the level should be minimised.

Damage to soil affects subsequent reversion to dipterocarp forest in several ways. Erosion is accelerated particularly on steep slopes. The downwash of soil may continuously smother small seedlings. Planting of Dipterocarpaceae on open eroding areas has been unsuccessful; roots have been exposed quickly and both eroding and depositional areas are inimical to growth. Successful natural establishment of dipterocarp seedlings would also be difficult. When natural drainage is blocked back swamps build up behind the obstruction killing off surviving trees and seedlings. Paton (1963) has drawn attention to lack of knowledge of the persistence of soil damage. Observations in early logged areas in Kalabakan confirm that after 10-15 years leaf fall from colonising species and soil aeration by earthworms, etc., sufficiently improves exposed soil that it resembles adjacent undisturbed areas. Compacted landings and main extraction routes may persist with a *Melastoma/Glochidion* thicket for much longer.

Seedling Stocking

The underlying principle of the Malayan Uniform System is the presence of seedlings of Dipterocarpaceae on the ground at the time of felling (Barnard 1950c, Nicholson 1958 a, 1965). Numbers have been shown to be high in the natural forest and lessened following logging due to tractor path damage and smothering by fallen crowns. Linear sampling of seedling stocking (1 seedling being sufficient to stock 1 milliacre plot*, after logging has

* All per acre stocking values in this section are based on milliacres, and can be converted to percentage area by dividing by 10.

been undertaken for some years to record the regeneration potential. As the intensity of felling has increased so the stocking recorded has tended to fall:

Table 36 Seedling Stocking Following Logging Segaliud-Lokan F.R.

Year	Stocked /acre	Plots /ha	Percentage Composition Para-shorea	Rubro-shorea	Dryo-balanops	Diptero-carpus
1962	307	758	39	23	22	11
1963	316	781	35	22	24	8
1964	281	694	36	37	15	8
1965	193	477	25	36	21	9
1966	223	551	27	38	18	13
1967	272	672	37	37	16	8
1968	182	450	40	36	14	9
1969	180	445	49	21	13	10
1970	209	516	27	41	7	9

Table 36 refers to global annual averages of systematic samples through the felled areas for which production percentages were given in Table 35. Prior to felling the stocking per acre was of the order of 600-800 milliacres so that the overall loss is generally in proportion to abundance but may be particularly high for the species of Rubroshorea with large seedlings, and for *Dipterocarpus* spp.

Similar records exist for most working areas from 1961 (A.R.R.B. 1961-1970). Most samples have exceeded 200 stocked plots per acre. Prior to 1971 this form of survey was solely for recording stocking for general records; its diagnostic use will be explained in Chapter 8. Summaries of selected areas for 1966-70 are given in Appendix 8.

Type A
Relative abundance of *Parashorea malaanonan* varied from 5-25 per cent in Kalumpang F.R. to 30 per cent in Silam, Ulu Segama F.R. and 40 per cent or more in Silabukan F.R. The balance of stocking for these areas was mainly of Rubroshorea species (mainly *Shorea leptoclados*, *S.parvifolia* and *S.leprosula*). *Dryobalanops lanceolata* was sometimes important at Silam.

Type B
In Segama River forests *Parashorea tomentella* accounted for 22-30 per cent of stocking; in Kretam F.R. this species was about 20 per cent. In the lower Kinabatangan forests it was generally more abundant with 20-50 per cent, but 20 per cent at Kuamut F.R. in the upper Kinabatangan. Of the Rubroshorea species *Shorea leptoclados* was consistently most abundant followed by *S.mecistopteryx* and *S.parvifolia*.

North of Sandakan in Sapi and Paitan F.R.'s *Dryobalanops beccarii* accounted for 10-20 per cent of stocking with *P.tomentella* generally less than 20 per cent and the Rubroshorea group 45-70 per cent.

Type C
In the Kalabakan F.R. working areas the Rubroshorea group has generally accounted for 30-65 per cent of stocking. The most abundant being *S.parvifolia*, followed by *S.smithiana*, *S.oleosa*, and *S.leprosula*. *Parashorea* species have usually been about 20 per cent.

Tractor damage recorded in linear sampling in the 1967 coupe at Pin F.R. gave 288 plots per acre with damage and 299 with seedlings. This area contained much low lying land. At Deramakot F.R. in rather hilly country 246 plots per acre had tractor damage and 146 contained seedlings. This may be compared with the smaller samples within the climber cutting experiments:

	Segaliud-Lokan		Kalabakan
R.P.	135	245(T&C)	245(T)
Acreage	2.0	2.0	1.0
Seedling stocking/acre			
Before F	630	729	688
After F	224	325	352
Percentage			
Survival	35.5	44.5	51
Tractor damage	43	36	34
Percent area damaged (Table 34)	-	27.1	22.5

Linear sampling frequently tends to over estimate the importance of tractor damage as the entire milliacre is taken to be damaged, whereas only a portion of it may have exposed soil. For example R.P.203 (A.R.R.B. 1966) consisted of a detailed survey of 109 acres (44 ha) which gave 27.4 per cent of the area with tractor paths, but a

2 per cent linear sample recorded 42 per cent so damaged. However the method, easily coupled with the routine collection of seedling stocking data does give comparative results between areas. This may result in administrative action with respect to a company whose extraction damage is shown to be higher than average.

On low lying moist areas where tracked vehicles tend to get bogged and the operators resort to "constructing" new paths losses may be locally higher. Udarbe (1969) found that average stocking for low lying areas in Tenegang F.R. was 229± 52 compared with 470 ± 61 for hilly areas during the period 1962-66. Losses are high in the immediate vicinity of roads or rail lines where disturbance is greater. Nicholson's (1963b) data for high lead logging showed stocking change from 811 plots per acre before logging to 528 after. Areas near spar trees are rendered bare, as are all main drag lines. A recent survey in Ulu Segama F.R. (Extension) of stocking in high lead areas (R.P.283), a few years after logging, showed that for 120-180 ft (40-60m) from spar trees seedling stocking of dipterocarps was negligible to absent.

A second entry into an area to remove smaller sized trees (= relogging) is considered undesirable as additional damage is almost certain to be caused to seedlings already growing vigorously from the stimulus of canopy opening (Fox 1969c). The following summarises stocking change in R.P.233 where relogging was examined in Ulu Segama F.R.:

Seedlings in Height Classes (per acre)

	Total	<1ft	1<5ft	5ft +
After felling				
Number	602.9	41.5	453.3	108.1
Per cent		6.9	75.2	17.9
After relogging				
Number	450	3.7	385.5	60.8
Per cent		0.8	85.7	13.5

As with first felling (see Chapter 6) losses are proportionally greater amongst larger seedlings.

Advance Growth

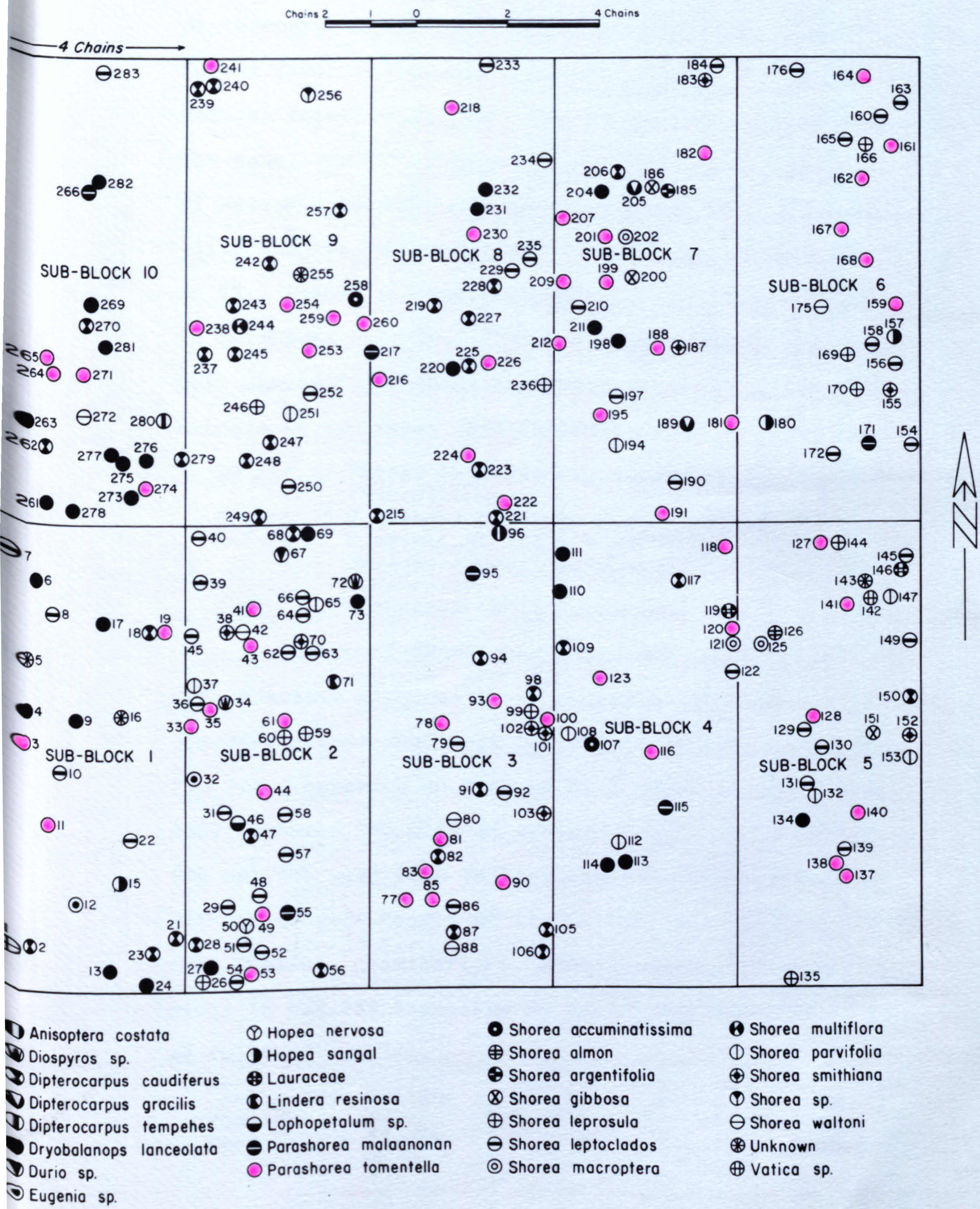
The principal aim of trying for increased retention of undergirth trees (Chapter 6) is to counteract the tendency for increased seedling loss in recent years. Theoretically seedlings are likely to be present on the ground in the vicinity of surviving standing trees. Healthy trees which survive may contribute fruit from time to time; this may be of particular value in ensuring seedling presence at the second cut. As numbers surviving in recent years have declined so the contribution of this class of trees will decline in assessments of older regeneration as stands age.

Figure 59 illustrates surviving advance growth in R.P.135 as at October 1969, three and a half years from felling. Of the 321 survivors following felling 246 were measured in 1969 to study the pattern of growth and survival. This fall in numbers represents a loss in the period since felling of 24 per cent, mainly in the smaller size classes. A further two trees died during 1969-1970. The growth rates of surviving trees in R.P.53 (cf Figure 43, Table 22 above) are discussed below.

Distribution of surviving individuals of *P.tomentella*, *S.leptoclados*, *Dr.lanceolata* and *D.caudiferus* in R.P.135 (Figure 59) is sufficient to allow seedling possibilities over much of the area. In R.P.53 however *D.caudiferus* is locally abundant and the other common species are not as well scattered. This is unlikely to increase representation: seedlings of *Parashorea* and Rubroshorea are generally more abundant, and documented cases exist where they are more abundant as regeneration

FIGURE 59

RESEARCH PLOT 135
SEGALIUD-LOKAN FOREST RESERVE



Forest Department, Sabah. 1971.

in areas originally rich in *Dipterocarpus* (Reg. Notes M.F. 1959).

Growth of Dipterocarp Seedlings

Canopy opening stimulates the growth of dipterocarp seedlings. Felling allows light into the forest floor in the same way that a tree falling in the natural forest would, and the response of seedlings is the same. In R.P.200, Silabukan F.R., the average height of measured seedlings prior to logging was 12.3 inches (31.2 cm) and one year after felling this had increased to 27.1 inches (69 cm). Individual seedlings measured in Kalabakan F.R. (R.P.254) have demonstrated that some well placed individuals can reach, at least, the following heights in two years from felling:

10 ft+	*Shorea leptoclados, S.parvifolia, S.oleosa* (Rubroshorea)
8-10ft	*S.macroptera* (Ru), *S.gibbosa* (Ri)
6-7 ft	*S.smithiana* (Ru), *S.atrinervosa* (SB), *Dr.lanceolata, Dr.keithii, P.malaanonan, H.nervosa*
5 ft	*S.superba* (SB), *D.gracilis*

Groups of dense seedlings grow taller together, with the less vigorous ones gradually dying off. *S.mecistopteryx* seedlings growing in a dense patch, at Pin F.R., covering an area of 0.15 acres (0.06ha) (R.P. 282) numbered 240 with an average height of 27 inches (69 cm) one year from felling and had declined to 144 with an average height of 65 ins (165 cm) eighteen months from felling. Similarly *S.leptoclados* on 4 milliacre plots in R.P.233 increased in height and declined in numbers as follows

Months from felling	5	12	18	25	37	40
Number	128	116	110	99	74	65
Mean Height (feet)	2	3.8	5.1	7.1	9.7	10.4

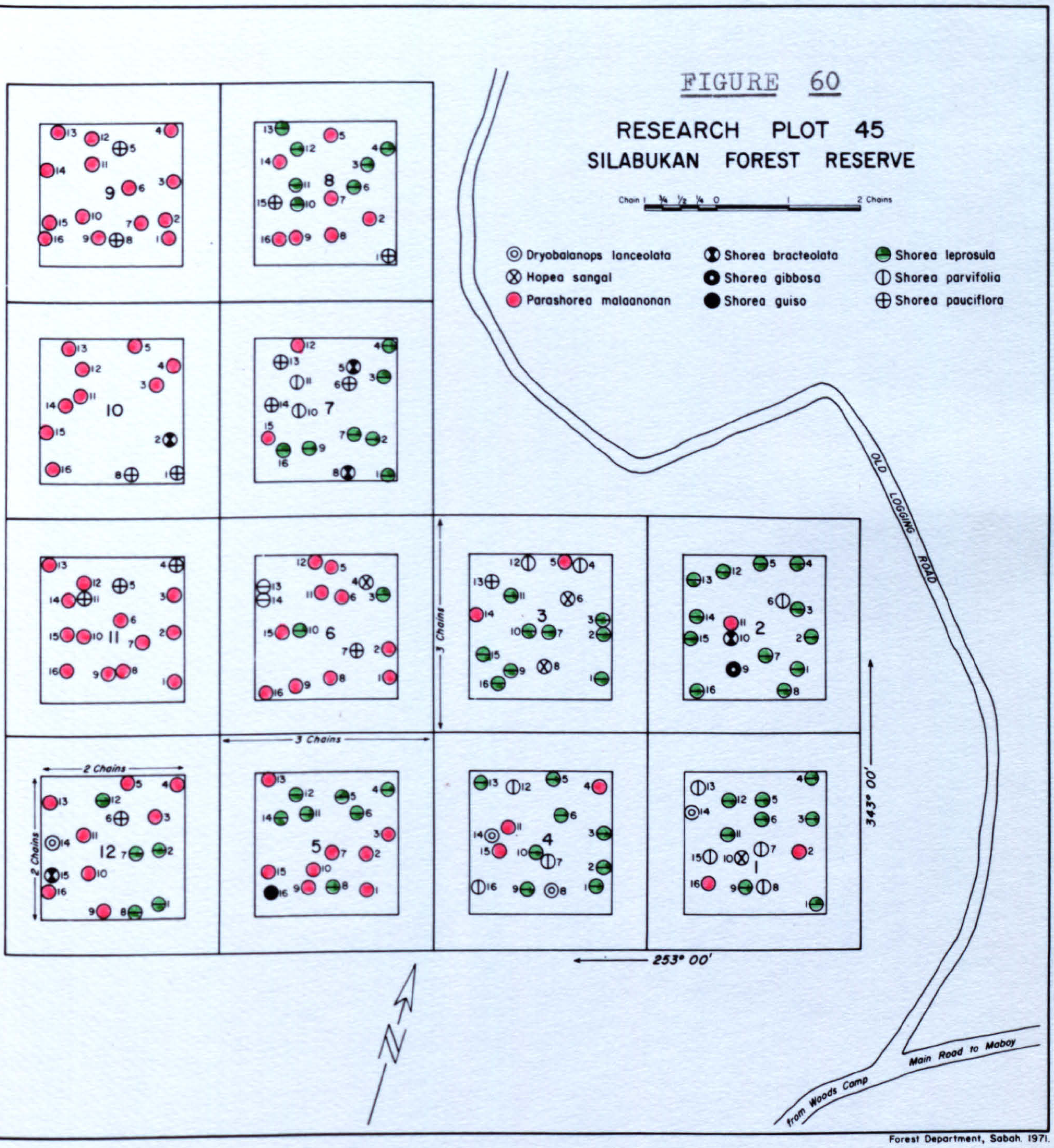
Mean heights on a number of milliacres well stocked with seedlings varied from 1.8 to 5.7 feet at 5 months from felling and from 2.5 to 6.1 feet at 10 months. Individuals of *S.leptoclados*, *S.leprosula* and *P.malaanonan* exceeded 20 feet in height at 3 years from felling.

R.P.45 established in August 1958 in an area felled in late 1955 in Silabukan F.R., which received post logging girdling treatment in May 1957, occupies an area of 10.8 acres (4.4 ha). There are 12 plots of 0.9 acres within each of which the central 0.4 acres has been measured continuously (Figure 60). Within each measured plot the largest dipterocarp stem in each 33 x 33 ft square (10 x 10 m) was recorded at each measurement. This represents a stocking of 40 per acre (100 per ha) based on a sample of 192 (12 x 16) possible measurements. At the 1958 measurement the tallest, evenly distributed 160 dipterocarps per acre averaged 15.1 ft height; the tallest 40 per acre 18.5; and the tallest 25 per acre 23 ft. These trees had grown rapidly from seedlings and the following girth increases were recorded 3-4 years from felling:

Years from F	Best 160/acre	40/acre	25/acre
2.9 (1958)	3.8 ins	5.3	6.8
4.0 (1959)	6.0	8.3	10.4
C.A.I.	1.8	2.4	2.9

The subsequent growth of this plot will be described in Chapter 9.

In an attempt to obtain more detailed data on the growth of individual seedlings following logging a study area of 100 x 100 ft (0.23 acres = 0.09 ha) inside R.P.242 (Figure 30) was demarcated. This area, in Segaliud-Lokan F.R., was felled in June 1967. Dipterocarp



Forest Department, Sabah. 1971.

seedlings were confined to locations where the soil was undisturbed by tractor working and where some shade remained; three such areas occurred in the study area (Figure 61). Stocking of seedlings by species has been as follows:

Table 37 Seedling Stocking In R.P.242 Segaliud-Lokan F.R.

Species Time from F(year)	0	1	2	3.5
Shorea leptoclados	17	16	16	16
S.waltonii	12	11	10	10
S.agami	4	3	3	3
S.gibbosa	1	1	1	1
Parashorea tomentella	13	11	9	9
Dryobalanops lanceolata	8	7	7	7
Dipterocarpus caudiferus	4	4	4	3
Hopea nervosa	1	1	1	1

Approximately 36 per cent of the surface area of the plot possessed one or more seedlings which may reach large size, if they survive. Those likely to survive are marked on Figure 61; growth of invasive species is discussed below. There are 17 seedlings likely to survive. in each case backed by one or more seedlings, which had survived the three and a half years of observation. However, large gaps existing in the centre of the plot are likely to remain dominated by the invasive species and it remains to be seen whether the 17 seedlings will adequately stock the area.

When first measured in August 1967 the seedlings were mainly less than 3 ft (1 m) in height. Average heights of 36 seedlings are illustrated, by species, in Figure 62. Leaf counts made at several measurements suggested that larger seedlings at the start had most leaves and that mortality was related to a poor rate of increase in numbers of leaves. Those seedlings which grew

FIGURE 61 R.P.242 Sub-plot(Figure 30(a))

STOCKING AT 42 MONTHS AFTER LOGGING

(January 1971)

LEGEND

Limit of tractor damage to soil

Abandoned log

Grassy patch

- Dipterocarp seedling
- Seedling most likely to survive
- Anthocephalus chinensis
- Macaranga hypoleuca
- M.gigantea
- Octomeles sumatrana
- Endospermum sp.
- Mallotus ricinoides
- Evodia luna-akende

All symbols refer to the best tree in each 20 x 20 ft.

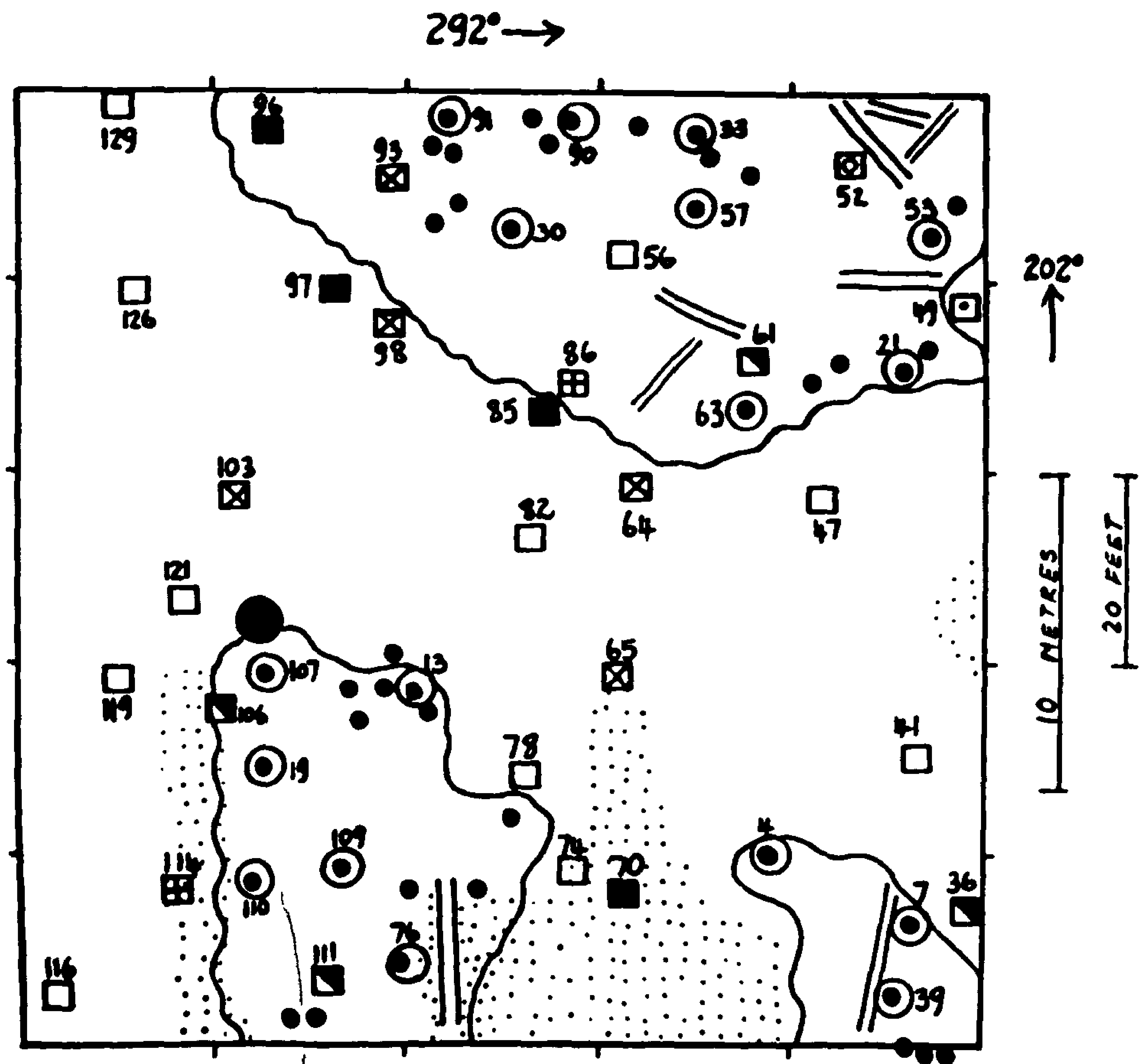
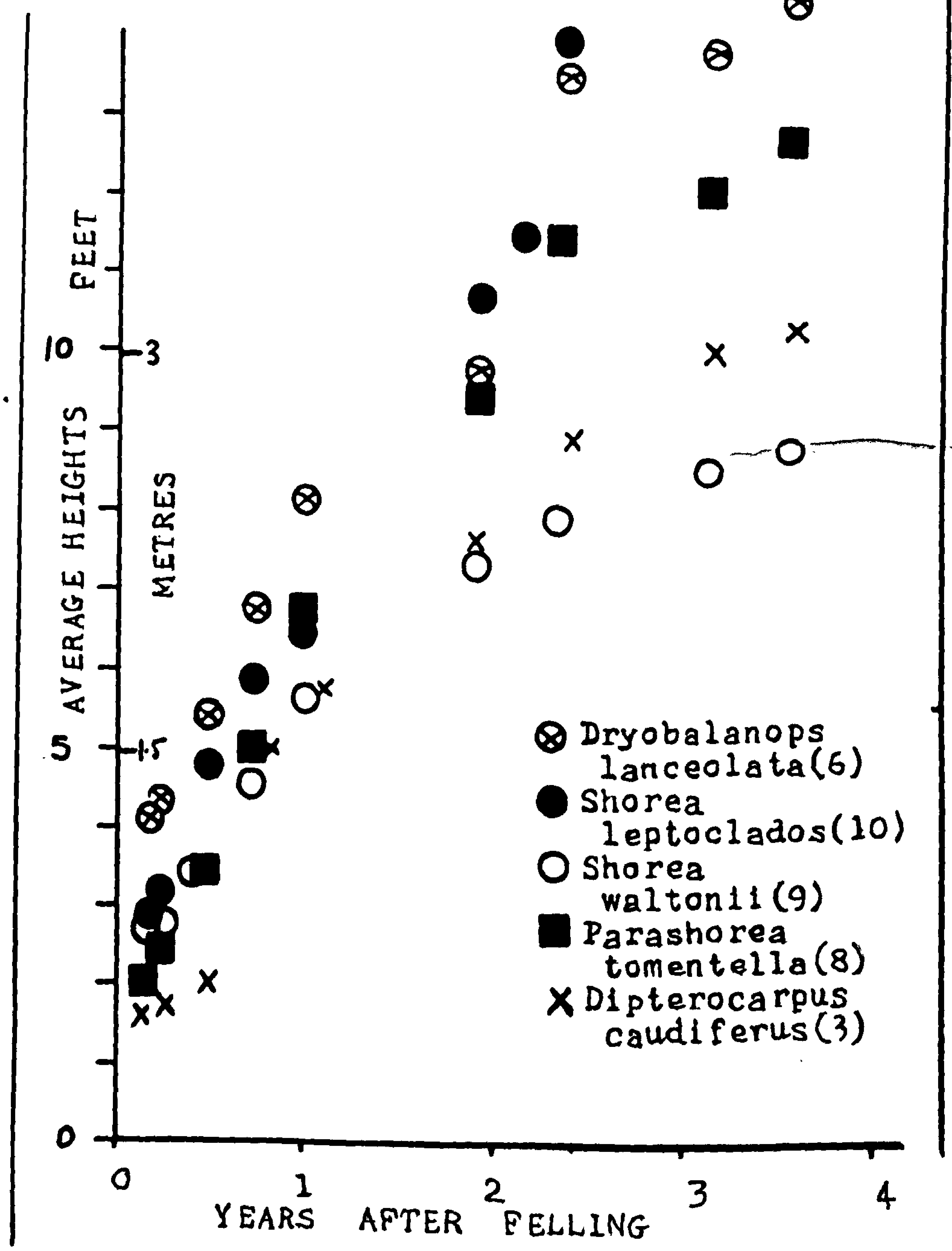


FIGURE 62 R.P.242

AVERAGE HEIGHTS OF SURVIVING DIPTEROCARP SEEDLINGS AFTER FELLING



satisfactorily multiplied their leaf number by six times during the first year following felling. Seedlings of *S.waltonii* had fewest leaves, while *Dr.lanceolata* had most, and *S.leptoclados* increased leaf numbers slightly faster than *P.tomentella* . Measurements of the 17 individual seedlings most likely to survive are given in Table 38. These are equivalent to a stocking per acre of 74, and growth of the best 40 and 25 per acre may be comapred with measurements given above for R.P.45:

Years from F	Best 40/acre		25/acre	
	Av.ht.(ft)	Av.g(ins)	Av.ht(ft)	Av.g.(ins)
2.5	16.5	4.8(est)	18.2	6.2
3.5	19.3	5.8	20.6	7.4

Table 38. Growth of Seedlings Likely to Survive R.P.242

No.	Species	Time from F(Years) 1.0 Ht. (Feet)	Leaves (No)	2.5 Ht. (Feet)	Girth (Ins)	3.5 Ht. (Feet)	Girth (Ins)
7	*P.tomentella*	5.6	23	12	-	14	3.6
19	" "	5.7	53	12.3	-	13	2.8
21	" "	6.7	37	13.2	-	16	3.6
30	" "	7.8	43	11.1	-	12	-
13	*S.leptoclados*	7.6	105	12.5	-	14	-
57	" "	5.8	56	12.8	2.7	14	3.1
63	" "	6.1	89	14.3	3.0	20	4.0
90	" "	9.0	198	20	5.8	25	8.6
91	" "	11.6	204	16.2	5.6	18	8.3
107	" "	5.0	79	13.3	-	15	3.4
4	*Dr.lanceolata*	6.6	166	12	-	12	1.8
76	" "	12.3	many	18	5.7	20	6.2
109	" "	10	375	16	4.4	17	5.3
110	*P.malaanonan*	10.6	127	18	5.5	20	6.8
39	*Shorea waltonii*	8.6	50	14.1	-	16	3.0
33	" "	7.1	45	11.4	2.4	12	2.8
53	*Shorea gibbosa*	13.2	many	21.1	7.9	23	9.2

Thus although distribution of regeneration on the small scale was not as good as in R.P.45, due to tractor path intensity, early growth and overall potential stocking were similar. Early seedling growth in R.P.47 (also Segaliud-Lokan F.R.) exceeded 4 inches girth for the best 160 per acre at three years from felling.

Exposed seedlings often wilt and either die or shoot from a dormant bud below the leader; in exceptionally dry weather large patches of freshly exposed seedlings may die as a result of leaf scorch. Retention of intermediate sized trees in groups and of some side shade over seedlings tends to reduce damage due to exposure. Measurements taken in R.P.47 suggested a slight depressant on growth of seedlings when advance growth was retained, but this has obviously declined in recent years with increased felling damage, and was not significant in R.P.47 (A.R.R.B. 1964). Control over additional removal of remaining shade after felling exists with the post-felling girdling treatment. Several seedlings in the study area of R.P.242 received insufficient light to respond with rapid growth (particularly *S.waltonii*). Seedlings of some species were able to grow producing thinner stems than others of the same species receiving more light (particularly *P.tomentella* and *Dr.lanceolata.*)

Seedbearers, Progeny and Survival of Advance Growth

It is generally accepted that for Sabah the incidence of felling damage on advance growth trees mitigates against polycyclic logging (A.R.R.B. 1964; discussion in Fox 1967 c). When seedlings are present retention of advance growth over 4 ft girth (39 cm diam), even if sound and of good form, has been said to be risky vis-a-vis the seedling regeneration (Wyatt-Smith 1963). Survival may not extend to the rotation and acceptance of advance growth and unfelled unsound trees over the girth limit detracts from the concept of the Uniform System as used in Malaya (Wong 1966).

After 1963 it became compulsory for companies working in Forest Reserves in Sabah to fell all commercial trees over 6 ft girth (Martyn 1966 a) but provision has been made recently (Fox and Hepburn 1972) for retention of seedbearers; such trees have not been eliminated in post logging girdling since 1966 (Martyn 1966a). Malayan work suggests that isolated seedbearers may survive for a number of years from felling (Wyatt-Smith 1954; Note in Mal For 1960 page 133; Wong 1966) despite increased exposure to sun and dry air on the boles which results in stag headedness (Blanford 1929).

Seedfall distribution (for trees in Kalabakan F.R.) discussed earlier came from surviving seed bearers in logged forest (Tables 24, 27) and observations suggest that both *S.parvifolia* and *Dr.lanceolata* can become successfully established under secondary species in regenerating forest. There is every reason to suppose that such recruitment would respond to further canopy opening (R.P.41, 64; discussion in A&R.B. 1964) persist, and grow slowly, in unthinned stands (Barnard and Wyatt-Smith 1949). Seedlings of *S.parvifolia, S.leprosula, S.leptoclados, P.malaanonan* and *Dipterocarpus stellatus* have all appeared under a roadside stand of *Anthocephalus chinensis* in Umas Umas, Kalabakan F.R., in the three years following felling (R.P.286D/26).

Dipterocarp colonisation of bare areas.

I have observed numerous examples of successful dipterocarp seedling establishment and growth onto abandoned roads, tractor paths and other disturbed areas of limited size, where seed trees are available. The area which has received most attention is an old landing at Mile 6, Lungmanis in Segaliud-Lokan F.R. Here ingrowth of dipterocarp seedlings onto a grass covered landing used for loading logs in 1957 has been examined over the period 1966-1971 (R.P.204). Parent trees of most of the common species are found in the vicinity and recruitment has occurred at several times since the landing was abandoned. Seedlings have found little difficulty in establishing themselves in the grass but development to small pole size has differed between species. The area is not large (cf tractor paths, Chapter 6) and is narrow.

Parashorea (mainly *P.tomentella*) trees have grown to over 30 ft (10 m) height but are loosely clad with large leaves and have damar exudate on the stem, this may be due to insect attack or a response to the effect of sunlight on the bole. Trees of *Dr.lanceolata* have grown more slowly (Table 39) but are more densely leafed and apparently suffer less from damar exudate. *S.leprosula* has been able to survive with more stems than other Rubroshorea species but the three common species have all developed squat stems in relation to their heights, compared with trees growing in closed conditions (cf the light response work in Chapter 5, Nicholson (1960)). The three species involved have shallow but well branched crowns, and leading shoots have been replaced from time to time. Table 39 summarises measurements of these trees.

Table 39. Sizes of Trees in R.P.204, Segaliud-Lokan F.R.

Species	Av.Hts.(ft) June 1966	Av.Hts.(ft) August 1968	Av.Hts.(ft) March 1971	Av. Girths (Ins) August 1968	Av. Girths (Ins) March 1971
Dr.lanceolata	9.3(48)	11.8(47)	18.5(44)	4.4	6.1
P.malaanonan	10.9(5)	17.5(5)	29.3(5)	9.7	13.7
P.tomentella	11.0(67)	13.3(58)	20.6(56)	6.2	8.3
D.caudiferus	17.0(2)	17.0(2)	23.8(2)	6.9	15.8
S.leprosula(Ru)	16.3(13)	17.6(11)	33.9(11)	11.9	15.3
S.leptoclados(Ru)	16.5(2)	16.0(2)	32.5(1)	6.4	5.9
S.parvifolia(Ru)	16.0(1)	16.0(1)	22.9(1)	5.6	10.1

(numbers contributing in brackets)

These may eventually form a closed canopy but prospects for re-colonisation of the larger landings by dipterocarps are better where seral species are present to cast some shade.

Growth of Surviving Trees Following Felling

Attention has been drawn earlier to changes in the rates of growth of trees in the range 1 to 6 ft girth following felling in R.P.53 (Figure 43). Prior to felling 301 trees were measured on 20 acres (8 ha), 127 survived the felling but only 105 remained seven to eight years from felling. This is a reduction from 15 to 6.4 and 5.1 per acre (equivalent to 37,16 and 12.6 per ha) respectively and compares with measurements in R.P.135, logged four years later, where 8 per acre survived felling, and 6.1 survived the next 4.5 years (20 and 15 per ha). As I have shown earlier most trees grew faster after felling, the exceptions being mainly in the larger sizes (Table 22). There was also a considerable difference in overall species response as the following figures show:

Table 40. Average Current Annual Increments by Species for Survivors to 1970 in R.P.53 Segaliud-Lokan F.R.

Species	Prior to Felling 1959-62 C.A.I. inches of girth	After Felling 1963-70	Per cent Change	No.of Trees	Max. size (ft)
Parashorea spp(2)	0.95	1.44	152	14	6
Rubroshorea(spp(5)	0.89	1.33	149	21	7
D. caudiferus	0.26	0.85	327	37	6
Dr. lanceolata	0.31	0.95	306	14	6
S. gibbosa(Ri)	0.46	1.82	396	3	3
S. superba(SB)	0.48	0.86	179	3	2
Other dipterocarp species (5, mainly *Hopea*, *Vatica*)	0.55	1.01	184	13	6

The *Parashorea* and Rubroshorea species, fastest growing groups prior to felling, maintained faster rates than *Dr. lanceolata* and *D. caudiferus* after felling, but the latter two showed much increased responses. Individuals of *D. caudiferus* (the most abundant species) showing fastest growth were mainly in the intermediate size classes of the range (Figure 43); greatest changes in rate of growth with *Dr. lanceolata* were at either end of the range. Larger Rubroshorea showed little response and the best response of this group and of *Parashorea* occurred in smaller sizes. Whereas 60 per cent of the trees prior to release had increments of less than 0.5 inches girth per annum (0.4 cm diam) only 16 per cent did so after felling. Similarly increments of 1.0 inch (0.8 cm) or better occurred on 14 per cent of stems prior to felling and on 56 per cent after. Chi-square analysis of numbers of increments in five increment classes, all tree sizes combined (Appendix 9, Table 1) for the two periods gave $\chi^2 = 53$, highly significant.

Classification of crowns in five categories of position (freedom, availability of light) and shape (form) as explained elsewhere (Fox 1970 a) showed that increment was correlated more with crown shape than with position:

Average Crown Scores	All Trees	Trees with C.A.I. (ins.girth) of: 0-0.99	1.0-1.49	1.5+
Mean Position	4.0	4.0	3.8	4.3
Mean Shape	3.2	2.9	3.2	3.7
Totals	7.2	6.9	7.0	8.0

Following logging and girdling most of the measured trees would have had access to light but crown shapes would have been largely dependant on original crown development, as modified by felling damage. As with the natural forest trees with better crowns (note that these categories are largely subjective, qualitative, measures; Nicholson 1963 a, Fox 1970a) tend to grow faster.

Crown damage of category C3 (see Chapter 6) occurred on one *D.caudiferus* with an average C.A.I. following felling in excess of 1.50 inches girth, but other fast growing trees were largely free of crown damage due to felling. Of the 21 trees which had an average C.A.I. of 1.50 or better following felling 9 had some bark damage due to felling, but on only one tree was this extensive. This tree, a *P.tomentella* in the 3 ft class grew exceptionally fast, with an average C.A.I. of 2.70 inches. Increments of surviving advance growth in R.P.47 (see A.R.R.B. 1962-1964) were also higher on trees with larger crowns. The average C.A.I. of 5.5 trees per acre with larger crowns for the first 3-4 years following felling was 1.5 inches, while only 0.5 inches was being put on by 2.0 trees per acre with smaller crowns. There was a tendency for increment to fall away with increased time from felling.

Defect in Surviving Advance Growth

Attempts at estimating defect in natural stands have shown considerable variation in correlation of outturn with standing volume (cf Chapter 4, Type C). In addition to damage during felling second growth stands containing surviving advance growth may suffer additional losses in eventual outturn due to the accumulated effects of the first felling.

Bark damage (and loss of branches in the crown) whether due to falling or extraction may result in fungal decay becoming established. Callus production on the dipterocarps, which produce damar in response to wounding, appears to be of poor quality and especially so with those species having fissured bark (e.g. *S.acuminatissima* (Ri), *Parashorea* species and the Rubroshorea species *S.argentifolia*, *S.leprosula*, *S.parvifolia*, and *S.smithiana*). Nicholson (1958 a) has referred to the susceptibility of dipterocarps to degrade following logging wounds, and though no work has been done on degrade due to fungal agencies, considerable work has been concentrated on some of the insects which cause concern.

"Turning hole" (Malay= *lobang pusing*)damage caused by the Cerambycid beetle larvae *Ceriopalus wallacei* (Thappa 1968) occurs in live trees in most areas. When a stand is cut the damage encountered is the accumulated result of attack over the life of the felled trees. There is no method of eliminating such damage, the remedy lies in different utilisation of the damaged timber. Until recently it was assumed that residual stems of intermediate sized dipterocarp trees would be more prone to attack than trees in the natural forest, as active infestation is most frequent on trees in the 3 ft girth class. Thappa's studies (Thappa, in press) in the Garinono area first cut in 1928, and again in 1969 (to be discussed in detail below, R.P.315) indicated that the level of infestation there was less than in nearby natural stands of similar composition, and that the assumption may be unfounded.

Insufficient detail is available however, and this form of damage may well be serious in some areas, at least locally. Favoured oviposition sites appear to be patches of dried up wood at the base of the crown where branches have come away and where no active damar exudation is possible; unhealthiness is thought to be a pre-requisite for infestation. A range of categories may provide such conditions from a completely undamaged (by logging) stem to one with its upper bole lacerated or with part of the crown broken off. The former is unlikely to become infested unless it suffers damage at a later date, while the latter may be highly susceptible. If a tree is so badly damaged that it will die within 2 years of logging damage being incurred this, though a potential host tree, is unlikely to contribute to increased infestation as Thappa's studies indicate that the larvae of *Ceriopalus wallacei* require nearly 2 years in the tree prior to emergence. It may be assumed that larvae could not survive in dead trees due to drying up.

Examination of the 105 survivors of R.P.53 for visual signs of borer damage due to *Ceriopalus wallacei* showed that incidence was confined to the *Parashorea* trees. The extent of attack was as follows:

Incidence of scar wounds:	Numbers (girth) Old	Old & Recent	Recent	No attack
Parashorea tomentella	4(3-7ft)	1(4ft)	3(2-4ft)	2
P.malaanonan	2(1-3ft)	1(4ft)	nil	1

Confirmation of internal damage necessitates observation of fresh frass below the tree, or cutting into the bole to show tunnels; the recorded attacks which led to scars may not have resulted in internal damage. Nevertheless incidence is sufficiently high to suggest that residual *Parashorea* trees may contribute little in the way of useful volume at the second cut in this area. An earlier experiment (R.P.117) showed that *Parashorea* and *S.parvifolia* were most prone to attack and the incidence of attack on *P.tomentella* was 46 per cent in an after logging survey. There is as yet no evidence that logging wounds pre-dispose trees to attack; there is adequate evidence that otherwise sound stems show signs of attack.

Exposure to wind damage and bark scorch of residual stems is of some importance following felling; especially on thinner barked species, e.g. *S.multiflora* (Ri), *S.mecistopteryx* (Ru) and *Dr.lanceolata*, and smaller stems of *Parashorea* species , *S.parvifolia*, *S.smithiana*, and *S.argentifolia*. Wind damage may further reduce the chances of survival or may cause complete windthrow. Bark damage due to exposure results in longitudinal splits which then crack and dry out disengaging the bark from the cambium.

The Role of Seral (Nomadic) Species

Seed of the secondary or invasive species, which may be classed as nomads in that they are more abundant in opened areas than in natural forest (van Steenis 1956 a, b, 1958) and of some climbers, is relatively long lived and may be present in the soil at the time of logging. Germination is favoured by exposure to heat although a particular species may not appear immediately an area is cleared, and birds, bats, etc., are probably important in distributing seed of nomadic species. Current exploitation which moves from one large coupe to a contiguous one favours dissemination for once present in an area the seed has only to travel a short distance to reach newly felled areas. Many nomadic species fruit as relatively small trees. When dipterocarp seedlings are lost from a particular patch of soil a situation akin to the colonisation of new soils (e.g. river banks) arises and many of the secondary species found in logged forest areas are only found near streams in the natural forest, e.g. *Pterospermum stapfianum*.

Clearly the more open the forest after felling the more nomads that may be expected. It is sometimes asserted that post felling girdling further encourages such species; this is difficult to substantiate, though climbers certainly become more abundant. Most nomads are rapid growing relatively short lived, soft wooded species with light, wide open crowns and they can grow across areas of severe soil damage by spreading from the edges. In narrow areas or small patches of disturbance nomads, climbers and dipterocarp seedlings grow up together in a mass. All combinations exist across the range of exploitation ecotypes from bare areas, pure stands of invasive species to dense patches of secondary growth.

Persistence and Site Preference

The larger nomadic species *Anthocephalus chinensis*, *Duabanga moluccana* and *Octomeles sumatrana* are present on moist sites in undisturbed natural forest, and are capable of persisting for 40 years or more and of reaching 12 ft girth (116 cm diam). Kochummen (1966) has suggested that *Macaranga gigantea* (able to persist for 20 years or so) is eventually replaced as it is unable to regenerate under its own canopy. This phenomenon may well hold for many of the other nomads important in Sabah which persist but do not reach the sizes attained by the three larger species. The following species are moderately persistent: *Pterospermum diversifolium* (and others in the genus), *Pterocymbium tinctorum*, *Endospermum* spp., some *Macaranga* spp., and *Vitex pubescens*. Species of comparatively short life are: *Trema orientalis*, *Geunsia pentandra*, *Commersonia bartramia*, *Omolanthus populneus*, *Alphitonia incana*, *Mallotus ricinoides* (and others) together with some *Macaranga* species.

Some site preferences are evident, though many of the secondary species overlap and actual distribution must often be due to seed source availability. *Anthocephalus* grows vigorously at the edge of tractor paths and landings; *Octomeles* prefers moist places or light soils; and the *Macaranga* species (e.g. *M.hypoleuca*, *M.beccarianum*, *M.gigantea*) generally grow in dense groups on slopes just above roads or tractor paths. *Pterospermum* is found along stream banks but also in dense mats of climbers; in areas where climbers have swamped all vegetation leaving a low tangle, *Pterospermum* and *Pterocymbium* appear to be the only trees capable of poking through. *Trema* requires full light and grows at roadsides or along high lead scars.

Anthocephalus and *Octomeles* are prone to swamping by climbers (*Duabanga* has more rigid branching and is more resistant) and where this occurs the role of nomads is exhausted rapidly. Following their death the climbers either collapse or bind onto taller relicts. Underneath the climber tangle seedlings or coppice of dipterocarps may be present and may gradually move up with the climbers festooned around them. Often however the climbers become so dense that little can survive under them; in this event a good stand of fast growing nomads is better than nothing.

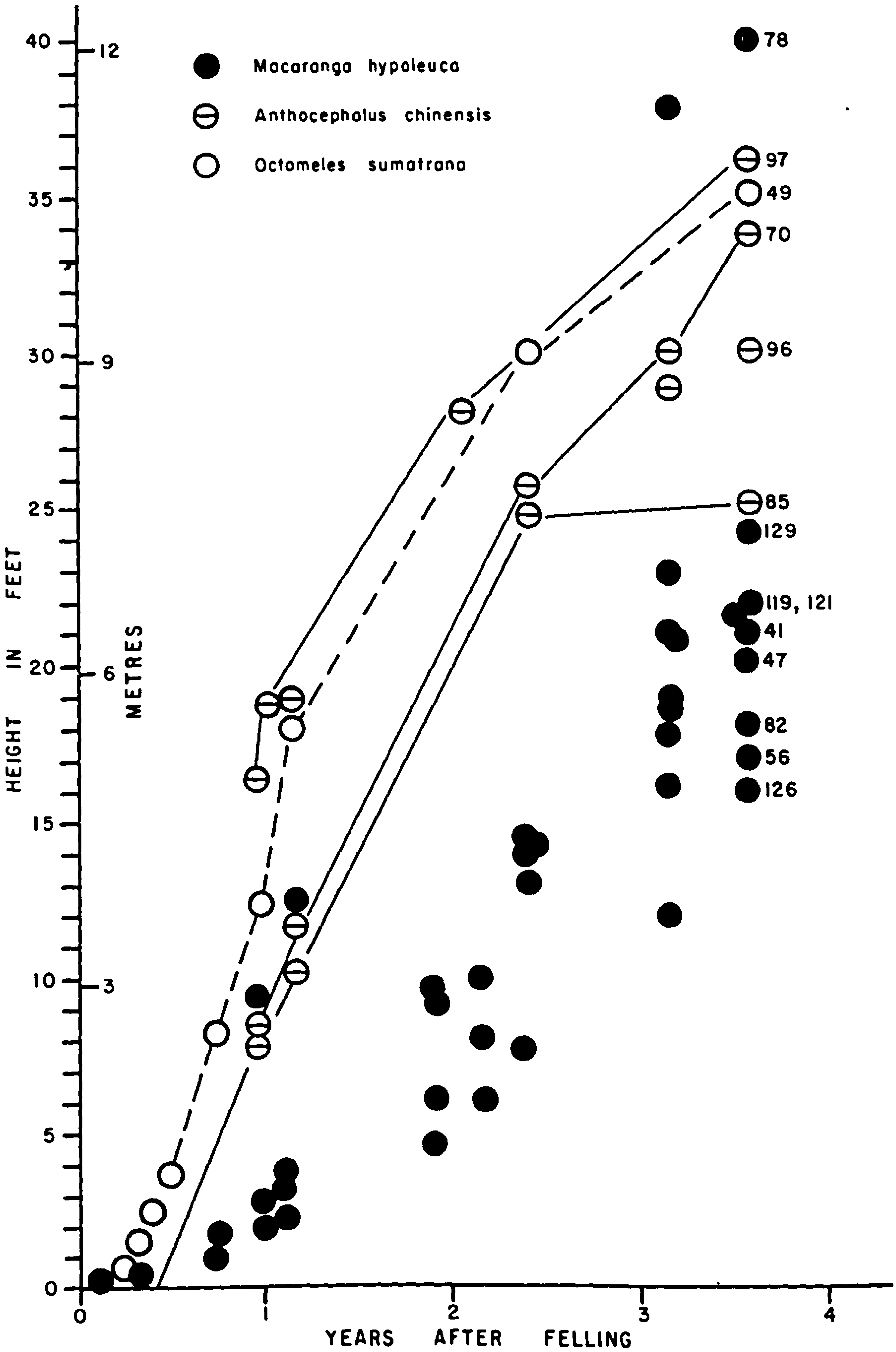
Growth Rates

Secondary species are of considerable interest in terms of their growth rates. As they are generally fast growers there is always a possibility that they could be raised in plantations for industrial cellulose. Most work has been done with *Anthocephalus* for which, perhaps, prospects are best. Little work has been done specifically on succession, except incidental to general dipterocarp growth studies. The study plot in R.P.242 has been referred to above. Two months after felling (August 1967) the grass *Pennisetum* sp. had invaded two patches of bare soil (Figure 61). Other bare areas were not colonised for some time. Individual small seedlings of *Macaranga hypoleuca* were the first trees species found; they were present throughout the plot, on bare soil, in August 1967. However they did not exceed 6 inches in height in the first six months during which time many of them died, often as a result of soil eroding away their roots. After one year surviving *M.hypoleuca* grew more rapidly (Figure 63).

FIGURE 63

R. P. 242

HEIGHTS OF NOMADIC SPECIES



Forest Department, Sabah. 1972.

Other species present at the first inspection of this study area were the climbers *Mesoneuron sumatranum* and *Merremia borneensis*. The latter, though able to completely dominate other nearby tractor paths, did not spectacularly cover bare areas within the study plot. *M. sumatranum* individuals survived at the edges of undisturbed areas and were carried up by woody growth. The next nomadic species observed were *Mallotus ricinoides* and *Endospermum malaccensis*; the latter grew more rapidly in height, but survivals were few, the former was more abundant but tended to fork low and grow squat boles. *Glochidion* sp and *Pterospermum* sp were first recorded at 3 months from felling while *Macaranga gigantea* and *Anchocephalus chinensis* came in at 5 months. Individuals of the latter two species grew rapidly in height and girth but many *Anthocephalus* died off within a year. *Ficus treubii* was also recorded but did not grow very tall. One individual of *Octomeles sumatrana* was present from the first inspection and grew very rapidly (Figure 63).

Octomeles entered a seedling study plot within R.P.233 at 6 months from felling and reached 14 ft height after 2.5 years; the low secondary shrub *Leea aculeata* grew only 3 ft in the same period. *Anthocephalus* varies considerably in its time of appearance following felling but is generally capable of very rapid growth after establishment. Patches of this species in Tenegang F.R. (R.P.331) grew to an average of 5 ft after six months, 10.5ft at one year and 20ft at two years, during which period very high mortality occurred. A patch of *Anthocephalus* on 0.17 acres in Kalabakan F.R. (R.P.254) in which the larger trees were kept in a state of rapid growth by heavy thinning preceeding natural mortality grew as follows:

Table 41. Growth of *Anthocephalus chinensis* R.P.254

Time from F (months)	No/acre	All Trees Mean G (ins)	All Trees Mean Ht (feet)	Survivors at 36 months Mean G (ins)	Survivors at 36 months Mean Ht (feet)
8	265	6.3	17.5	7.3	16.6
13	188	10.3	25.5	11.4	26.6
19	176	15.4	34.7	15.9	34.8
24	147	18.1	39.5	19.0	39.1
31	88	22.2	41.6	23.5	41.1
36	82	24.4	-	24.4	-

A series of 25 plots of 0.1 acre at Umas Umas, Kalabakan F.R. (R.P.286) established in 1969 to record the growth of secondary species, especially *Anthocephalus*, confirmed the rapid growth of secondary stands in basal area as well as height and girth. Growth functions were more or less linear for the first 8 years from felling. Series of 5 plots were positioned in areas worked over at known dates within which *Anthocephalus* was abundant. Table 42 summarises growth trends:

Table 42. Summary of Growth R.P.286 Umas Umas Kalabakan F.R.

	Years from Felling 1	2	3	4	5	6	7	8
Total Basal Area/Acre (sq.ft)	12	19	26.5	34	41	48	56	64
Total Stems/Acre(Nos)	600	550	400	310	280	270	260	250
Mean G largest 40/Acre (ins)	12.5	15.6	19	22.2	25.5	28.7	32	35.5
Mean Ht largest 40/ Acre(ft)	24	31	37	44	50	57	63	69

The initally high numbers represent many nomads unable to survive the intense competition of the first few years. Laternumbers decline less rapidly. Rapid accumulation of basal area is matched by equally rapid height and girth growth of the largest 40 stems per acre (100 per ha). Study of older areas (i.e. felled longer ago) has shown that the growth rate of *Anthocephalus chinensis* declines rapidly after about 7 years (Fox 1968 (f)) though individuals in open conditions may continue rapid growth for longer.

CHAPTER 8

SILVICULTURAL TREATMENT AFTER LOGGING

Immediately after logging has ceased in a given block of forest the area is easily accessible, open, and the potential future crop stands on the ground in embryo. There after growth of residual components and of invasive tree and climber species proceeds rapidly. The easiest time to assess the regenerative potential of the stand is prior to the stage when growth, especially of climbers, renders movement through the forest more difficult. Open landings, tractor paths and other areas with topsoil removed can be seen and their importance assessed. Treatment of a silvicultural nature at this time may consist of further release of seedlings in relatively unopened areas, the elimination of residual non-commercial species and climbers, and remedial work to restore drainage patterns. As the effects of logging have increased in severity so the post logging silvicultural treatment has tended to become merely a tidying up operation.

Subsequent examination of the regenerating stand some years after felling may reveal that the Dipterocarpaceae may be assisted by further silvicultural intervention; or elimination of no longer required seed trees together with any further refinement (Dawkins 1968a).

The major influence on the prospects for a second crop is the effect of logging. This may be likened to the effect of a hurricane in terms of its effect on the upper canopy and the form of the forest is likely to be more even, poorer in species (Wyatt-Smith 1954) but rather patchy overall (Browne 1949). Patchiness is further accentuated by the variable effects of mechanical damage to the soil. Considerable scope exists for attempting to increase yields and maintain rapid growth rates in older stands.

The Problem of Unstocked Areas

If the full potential of a managed forest is to be realised then re-stocking needs consideration. At this stage economic feasability of re-stocking cannot be seriously considered as insufficient is known concerning costs of methods, effects of economy of scale, and of how practical experience may lead to an increase in efficiency. The present consideration then is with technical possibility, what can be done, and what *a priori* is likely to be successful. Clearly re-stocking becomes less necessary if other management factors are capable of reducing the extent of unstocked areas. This appears an unlikely possibility.

Where logging has resulted in the total loss of the desirable dipterocarp seedlings the area will rapidly become colonised to one of the exploitation ecotypes. These may range from nil vegetation (badly eroded subsoil, exposed rock, stagnant water due to blocked drainage) to luxuriant secondary growth of fast growing invasive species, as we have seen above. In between lie a range of conditions. The pattern of colonisation is not clearly understood; for example why *Eupatorium odoratum* (a perennial herbaceous shrub) will dominate some areas, *Merremia borneensis* (climber) others, and yet others will become grassy. Both *Eupatorium* and *Merremia* tend to smother any small seedlings present in the vicinity.

Dipterocarps may later seed into stands of invasive species yet there is an immediate problem of whether to attempt artificial re-stocking of unstocked areas sufficiently soon after felling to enable easy access and to allow growth of planted trees to catch up with nearby natural regeneration areas. Several experimental methods have been attempted but with little success thus far. It must be emphasised that the problem is not of large scale planting but of restoring bare areas, which may be termed group or local enrichment.

Use of Wildings of Dipterocarpaceae

Raising of nursery stock ex seed has been attempted when abundant fruit has been available following a heavy flowering. Since the availability of seed cannot be forecast and nursery work associated with raising Dipterocarpaceae ex seed requires irregular periods of intense activity, large scale formal planting of unstocked areas has not been undertaken. Natural seedlings are present at all times, in a state of dormancy, in unlogged areas and provide a reservoir for use. Lifted seedlings subsequently planted out are termed wildings. Due to the high early mortality of wildings large planting programs can no more depend on wildings than on nursery stock ex seed (Wyatt-Smith 1963).

The most successful species used to date in Sabah is *Dryobalanops lanceolata*, followed by the Rubroshorea species *S.leprosula* and *S.parvifolia* . *Parashorea* wildings may have poor root development (Canabre 1928) and tend to be difficult to handle (Mauricio 1957) as large leaves develop in response to increased light. Assidao (1952) and Cunanan (1950) reported little success with wildings of *P.malaanonan*. Wildings of the Rubroshorea species *S.leptoclados*, *S.parvifolia* , and *S. mecistopteryx*, and of *Dryobalanops lanceolata* planted in Sepilok F.R. (F.D.A.R. 1936) were not successful and compared poorly with *Dipterocarpus caudiferus* raised from seed which attained an average height of 6 ft (2 m) after four years (F.D.A.R. 1938). Considerable damage was caused to these early plantings by animal activity.

In Malaya *Dryobalanops aromatica* has been most frequently used (Wyatt-Smith 1963) and best results are obtained by planting within 18 months of seedfall (Barnard and Setten 1955). Seedlings ex seed of this species can be planted after 3 months and though bare rooted plants show inferior growth to tubed plants, the former is cheaper and much used in parts of Malaya (Ismail 1964). When planting sites are not adjacent to supplies and seedlings are of unknown ages (age/root development possibly affecting transplant survival) immediate transplanting of bare root plants is not possible. Small clay pots have been used in Malaya with considerable success (Anon 1950) and Cimatu (1962) reported the use of grass baskets, old tin cans and sections of bamboo. Polythene pots are the preferred container today and it is desirable to have a hardening off period prior to outplanting during which a number of poor plants can be eliminated. Abdul Latif (1968) described the use of temporary nurseries for potting wildings in Selangor for extensive enrichment planting though the preferred Malayan method is the use of seedlings ex seed (Ismail 1966). Survival of wildings in pots one month after collection at Segaliud-Lokan F.R. (R.P.300) was over 70 per cent for *Dr.lanceolata*, *S.parvifolia* and *S.leprosula*; but less than a third of the plants potted of *P.tomentella*, *S.leptoclados* and *D.caudiferus* survived the same period.

The most inhospitable sites have been tackled in Sabah where little tree growth of any kind is present and temperature ranges are likely to be very high. R.P.104 used wildings of *Dr.lanceolata*, *D.caudiferus*, *P.tomentella* and the Rubroshorea species *S.parvifolia*, *S.leptoclados*, *S.leprosula* and *S.waltonii*. These were planted immediately after collection in 1964 on an abandoned landing with bare disturbed subsoil. Two months later only 21 out of 153 planted remained alive. *D.caudiferus* had 15 survivors, of which 12 survived of the 14 planted with heights of less than 6 ins. Of all wildings larger than 18 ins only 4 out of the 99 planted survived 2 months (Liew 1971). A similar trial in 1966 resulted in total death after 3 months, *S.leptoclados* surviving the longest. These experiments were in Segaliud-Lokan F.R.; other early planting in areas with secondary growth was undertaken in the early 1960's at Pin and Silabukan F.R.

A number of trials during 1967-70 involved standing the potted wildings for several weeks prior to planting. Most of these were failures due to one or more of the following: subsequent erosion of site, deer browsing, machinery disturbance, death probably due to exposure to sun. R.P.276 at Malua F.R. was the most successful of these trials. Four plots of 36 plants each were established in late 1967. All four sites were grassy areas near the main extraction railway with secondary growth in the vicinity. After 3 years survival was 59 per cent and of the species planted *Dr.lanceolata* had 74 per cent survival (16 per cent of total wildings planted) *D.caudiferus* 61 per cent (30 per cent of total) and *P.tomentella* 58 per cent (45 per cent of total). The plots furthest from the rail were more frequented by deer and pig and had lower overall survival.

Table 43 Percentage Survival of Wildings R.P.276 Malua F.R.

Time from planting	Percentage Surviving 1 year	2 years	3 years
Plot 1	86	75	72
Plot 2	98	89	75
Plot 3	72	61	55
Plot 4	72	42	33
Mean	82	67	59
P.tomentella	74	61	58
D.caudiferus	93	73	61
Dr.lanceolata	91	82	74

Height growth became more rapid after the plants were successfully established:

Table 44 Average Heights of Survivors R.P.276 Malua F.R.

	No. planted	Heights (ins) Initial ht.	1yr	2yrs	3yrs
P.tomentella	64	14.8	30.5	53.7	85.6
D.caudiferus	44	13.6	17.2	26.6	48.3
Dr.lanceolata	23	13.9	21.9	48.3	78.9
Mean, all species	144	14.2	23.8	43.4	72.5
Plot 1	36	14.6	33.1	57.7	97.2
Plot 2	36	14.0	22.4	44.4	70.7
Plot 3	36	14.5	21.5	37.0	62.9
Plot 4	36	13.5	16.9	25.0	39.4

Tentative conclusions to date with the use of wilding stock are that planting should be delayed until the sites have some secondary species growth to provide shade and that where possible *Dr.lanceolata* should be preferred. Seedlings ex seed of this species and of the smaller (seedling) leaved Rubroshorea species: *S.leprosula, S.parvifolia* and *S.argentifolia,* should be used when available. As mycorrhiza may be important (Singh 1966) topsoil from natural forest should be included in the potting mixture. The wildings must be carefully handled to avoid root damage and should preferably be lifted in wet weather, planting out during dry spells should also be avoided. Selection of wildings should discriminate against those with larger leaves and favour plants of less than 18 inches in height. The potted wildings should be stood out under partial shade for a month prior to planting and inferior stock ruthlessly eliminated. Subsequent maintenance of planted areas should ensure that the plants are kept climber free and receive adequate light.

At present low success rates rule out the extensive adoption of this method. The same is true of other methods available, but the main criteria for undertaking re-stocking will be the cost and returns from the effort in comparison with other possible operations.

Spot Sowing

Limited experiments with *Maesopsis eminii* (ex Uganda) at Segaliud-Lokan and Silabukan suggest that this species could be used with some success. When more than one seed is sown at a spot it is necessary, later to thin out the plants, and the density of spots should be related to the germination rate expected. Sowing of *Anthocephalus chinensis* seed on bare areas (R.P.104, 242) has been unsuccessful. Limited observations on Leguminous species, e.g. *Albizia falcataria* (tree) and *Leucena glauca* (shrub) suggest that these may be used to restore bare areas. These latter three species have little present value for timber, and the value of *Maesopsis* as a timber producer in Sabah is at present unknown. The only other species I have noted (apart from the secondary species and dipterocarps) able to grow on areas of damaged soil is *Intsia palembanica* (R.P. 220). Seed of this Legume would be easy to obtain and is not seriously prone to animal damage; however it is a comparatively slow grower of poor form.

Planting of Nursery Stock

Nursery stock could be made available from planned over production of material for planting trials in cleared forest (Pollard 1969). Several of the species commonly used for formal planting, e.g. *Pinus* spp., and *Araucaria* spp. are liable to be damaged by animals when planted in small areas, and may produce usable material on a rotation out of step with dipterocarp production. Observations should, however, be made on comparative success of planted species on tractor paths within the large area being planted in Segaliud-Lokan F.R.

Plantations of dipterocarp species (R.P.246) in normal logged forest in Segaliud-Lokan F.R. to serve as examples of growth of blocks of individual species, were started in 1967. Nursery raised seedlings were planted at 10 ft (3 m) intervals in lines 40 ft (12 m) apart. Best growth and survival of species used to date is of *Dr.lanceolata* . Nursery stock of the same species has been planted under stands of *Anthocephalus chinensis* (R.P.254) at Kalabakan F.R. where early growth has been disappointing. Limited plantations of *Dr.lanceolata* under poor forest in West Coast trials have also been of poor growth. *Dr.beccarii* (and some other species) has been used in Brunei in recent years for underplanting of *belukar* areas and enrichment of felled forest. Survival of planted stock in the latter has been better with over 80 per cent surviving the first year, but, again initial height growth has been poor (Personal communication I.P. Tamworth).

In conclusion it is noted that where physical damage has been severe there is little chance of natural restitution. Where stocking is absent but can be induced treatment possibilities exist; enrichment however requires careful supervision and maintenance. Areas adjacent to roads and main tractor paths may offer a better proposition as access to them would be relatively easy and fast growing species could be grown for intermediate yields. A form of compensatory plantations may evolve if the question of ownership of the crop can be resolved; this could entail company work on all aspects of plantation work.

The Second Silvicultural Treatment

Poison girdling of residual non commercial trees, coupled with cutting of large climbers, and sometimes removal of advance growth of dipterocarps has been standard practice for some years. The treatment is based on the results of experiments to test the efficacy of girdling. R.P.'s 11 to 14 consisted of paired plots in which treatments were given to one plot each in areas felled in 1948, 1949, 1950 and 1951. Treatment was in 1952 and treatment and control plots assessed in 1956 showed that girdling increased the average crown status and overall stocking:

Table 45 LS$\frac{1}{4}$ Stocking at 1956 (Girdled 1952)

Plot Felled	R.P.11 1951	R.P.12 1950	R.P.13 1949	R.P.14 1948
Stocked plots/acre (max 160)				
Treated				
All	143	155	135	146
Per cent	90	97	84	91
Per cent, dominant or codominant trees	63	71	65	75
Untreated				
Per cent	70	71	58	45
Per cent dominant or codominant trees	27	26	26	26

A four year delay between felling and girdling did not greatly reduce seedling stocking, but stocking fell off rapidly after more than four years. Of particular interest was the consistent level of stocking (some 25 per cent, or 40 per acre) with good crown status, irrespective of treatment.

A large experiment started in 1957 (R.P.33) compared girdling at 0, 2, 4, 6 and 8 years from felling, with a control. Sampling of stocked plots on the LS$\frac{1}{4}$ principle at 5 years from felling gave the following:

Table 45 LS$\frac{1}{4}$ Stocking Year F+5 R.P.33

Treatment	G0	G2	G4	No G
Stocked plots/acre (max 160)				
All	138	135	143	143
Over 6 ins girth				
All	63	57	44	44
Dominant or codominant	49	40	30	21
No climbers	12	14	12	15
Dom.or codom, no climbers	8	10	8	7

(A.R.R.B. 1963)

In this experiment girdling was done to different size limits, with all trees over the limits, including dipterocarps, girdled. The limit was 2 inches diameter for girdling at year 0, 4 ins for year 2, and to 6 ins diameter for subsequent treatments. Treatment had no significant effect on numbers of stocked plots, but there was a marked increase in size and crown status. Subsequent assessment has been influenced by the different size limits, raising the average size of measured trees in the areas receiving treatment at 2 years from felling.

(Average girths in ins of LS$\frac{1}{4}$ trees)

Treatment	G0	G2	G4	G6	G8	No G
Year 8	5.7	11.3	6.9	6.3	-	5.7
Year 12	8.5	12.2	7.8	8.1	7.2	6.3

However these figures clearly show an advantage of treatment over no treatment, though treatment has not affected the numbers of larger trees with good crown status and free of climbers (Table 46, and *pace* constant in Table 45).

The species content of the area was unaffected by treatment with *Parashorea tomentella* averaging 31 per cent, *Shorea leptoclados* 21 per cent, *Dryobalanops lanceolata* 16 and *Dipterocarpus caudiferus* 14. Survival of seedlings in the experiment as a whole for the first four years (A.R.R.B. 1962) was 33 per cent for *S. leptoclados*, 59 for *P. tomentella* and 75 per cent for *Dipterocarpus caudiferus*; suggesting that *S. leptoclados* seedlings either grow rapidly or die out, whereas the other species can survive competition longer.

Another large experiment started in 1959 was R.P.47, also in Segaliud-Lokan F.R. This compared the effects of (a) no girdling, (b) girdling of non commercial species to 2 inches diameter, (c) as (b) to 6 inches diameter, (d) girdling of all trees, including advance growth of dipterocarps, to 2 inches diameter. Treatments (b) and (c) showed an insignificant, but real, increase in the growth rate of advance growth. The rates of growth of seedling regeneration varied with treatment showing fastest growth in (d). These differences though real were again outside statistical significance (A.R.R.B. 1962). However assessment confirmed the value of treatment in promoting both numbers and status of seedling regeneration, and increasing rates of growth.

As felling has increased in intensity so has the amount of girdling necessary to give dipterocarp seedlings adequate light decreased. Strict interpretation of the earlier rules (Nicholson 1965, Martyn 1966a) has, in some cases, led to more residual stems being killed than necessary, but the rules, of a blanket nature, must have been interpreted with some flexibility as the amount of girdling that could be done was dictated by the residual population. Variations in treatment to take account of the increased intensity of felling are presented subsequently.

Silvicultural conditions for the seedling component may be expected to differ within the Forest Types enumerated earlier and from time to time depending on the effects of logging. In order to continuously assess the condition of crops immediately after felling, and their response to post felling treatment a series of controls (R.P.223) has been instituted. Measurements in these study areas may be used to compare growth rates, e.g.:

Table 47 Average Girths in R.P.223

	Stocking Average (Max 160/acre)	Years from F	Av.girths (ins) Girdled	Control
Replicate(F.R.)				
Tenegang	72	2	3.6	3.8
		3	4.8	4.6
Ulu Segama	58	2	2.3	2.6
		3.5	4.5	4.4
Silabukan	77	2	2.4	3.1
		3	3.1	3.8
Paitan	58	1	6.5	4.1
		3	9.0	5.2

The general philosophy behind the principle of girdling after felling is that the removal of large trees of no value at the start of the succession resulting from felling will assist the dipterocarp seedlings (Wyatt-Smith 1963). The mass of regrowth is expected to rise up so that 3-5 years from felling there is little or no undergrowth and further treatment can be done from below (Barnard 1950 c). If treatment is delayed such that the succession is set back then nothing is gained. The situation in Sabah is generally that easy movement in the forest prior to the period of invasive climber development, and while road (or rail) access is available strongly mitigates in favour of completion of girdling as soon after felling as possible. If this cannot be done within a year or so treatment should be delayed until some years after felling.

Several areas treated a few years after felling have given poor results when secondary species have been killed and climbers have tended to produce tangles. Circumstantial evidence of this resulting in longer rotations will be given in Chapter 9. The experimental results discussed above suggest that if areas are sufficiently opened by felling then treatment could be postponed and combined with removal of climbers interfering with desirable regeneration at the time of the third silvicultural treatment (see below) at 10-15 years from felling. Treatment earlier than 10 years is likely to set back the succession under the conditions of heavy felling in Sabah.

Climber control by cutting at the time of girdling is effective in killing large woody climbers surviving from the natural forest. Experiments have not revealed any species that can regenerate roots from the part above the cut (and if climber cutting is done prior to logging then cutting is not necessary after); and those that can coppice from the ground portion rarely produce shoots of sufficient flexibility to survive.

Barnard (1953, in Wyatt-Smith 1963) reported coppicing by some climber species and a significant reduction in shoot production by damping of the lower end with sodium arsenite. In Sabah the main concern is the influx of *Mesoneuron* and *Merremia* after felling. *Mesoneuron* recruits in R.P.33 had survival percentage of 19 in ungirdled areas over the first two years, compared with 38 per cent in the areas girdled at year 0. *Merremia* can be effectively controlled by spraying with 2 4 5-T but this is expensive and difficult to practise. Control of the invasive climbers is considered best at some ten years from felling when coppice production is unlikely to produce tangles. The problem of shade tolerant climbers described by Baur (1964, page 61) is not evident in Sabah though much work needs to be done on climber ecology generally.

Girdling Method

Numerous experiments have been conducted to compare the use of various alternatives to sodium arsenite (A.R.R.B. 1959-1970, Nicholson 1958 (e), 1959, 1965). Many hormone substances have been shown to be effective in killing trees but they are generally slower acting and trees often persist, eventually breaking off at the point of girdling or spraying. This can cause more damage to vigorous regeneration than the rapid disintegration which follows arsenic treatment; most trees die and disintegrate within six months of girdling with arsenic. Until a rapid acting alternative is found this substance will remain the preferred agent where no danger to life is involved.

Prescriptions are in hand for the use of hormone arboricides in areas where some slight danger to water supplies from the use of arsenic may be present. Of the formulations recently tested "Tordon 101" mixed in equal parts with water, applied in a frill girdle (in the same manner as sodium arsenite) appears the best choice (A.R.R.B. 1970).

Recent experiments on the killing of banyan type *Ficus* (i.e. strangling figs) have shown that these can be killed in six months with sodium arsenite. Formerly these were not girdled as it was considered that the copious exudate of latex would render the poison ineffective.

Assessment of Regeneration Following Felling.

Linear milliacre sampling (LSM) is prescribed to assess regeneration potential after logging and before girdling (Fox and Hepburn 1972). Formerly LSM was undertaken to provide a record of regeneration stocking (see Chapter 7, Seedling Stocking) at the time of post felling girdling (Nicholson 1965). Presence of seedlings of the following species are considered in assessing regeneration stocking:

<u>A Preferred Commercial Species</u>

Dryobalanops lanceolata
Parashorea malaanonan
P.tomentella
Shorea leprosula(Ru)
S.leptoclados(Ru)
S.parvifolia(Ru)
S.smithiana(Ru)

<u>B Desirable Commercial Species</u>

Dipterocarpus caudiferus
D.confertus
D.gracilis
**Dyera costulata*(*Apocynaceae*)
Hopea sangal
Shorea almon(Ru)
S. argentifolia(Ru)
S.gibbosa (Ri)
S.pautiflora (Ru)
S.waltonii (Ru)

<u>C Acceptable Commercial Species</u>

Anisoptera costata
Dipterocarpus crinitus
D.pachyphyllus
**Durio* species (*Bombacaceae*)
**Eusideroxylon zwageri* (*Lauraceae*)
**Heritiera simplicifolia*(*Sterculiaceae*)
**Koordersiodendron pinnatum* (*Anacardiaceae*)
Parashorea smythiesii
Shorea acuminatissima (Ri)
S.agami (An)
S.bracteolata(An)
S.cristata (Ru)
S.hopeifolia(Ri)
S.hypoleuca (SB)
S.gratissima(An)
S.mecistopteryx(Ru)
S.superba (SB)
S.symingtonii(An)
S.virescens(An)
**Sindora* (*Leguminosae*)

* Non-dipterocarp species

If two seedlings of similar size belonging to different lists occur in one milliacre plot then the one from the superior list is recorded. These lists are not exhaustive, in particular many of the less common Rubroshorea species are not listed, and it is suggested that individual lists for particular areas should be developed. As the above list stands account is taken of relative abundance of species in the main commercial forests of Types A, B, C, D and E.

If a milliacre plot is unstocked a note is made of any obvious reason; this allows rapid computation of the extent of tractor damage. Stocking summaries for individual unit areas can, it is believed, provide an indication of what level of girdling, if any, is required. However it must be stressed that at the time of writing this revised practice is still in the process of testing.

Variation in Treatment

The objects of the SecondSilvicultural Treatment (i.e. post felling poison girdling, cf schedule at page 196) are:

(a) To ensure that seedlings of Dipterocarpaceae, where present, have sufficient light for maximum development but are not fully exposed; and that sound advance growth is favoured.
(b) To remove unwanted species and defective stems where these will compete with regeneration, if left.
(c) Where seedlings are deficient to retain sufficient stems of commercial species to aim for maximal stocking. Additional seedling recruitment obtained may respond to the third treatment or the trees retained may be seed sources for the next felling.

LSM should be done as soon after clearance inspection as possible. This inspection, to calculate royalty payable on wasted sound timber, should follow movement of machinery from a given felling block. Ideally the results of LSM should be examined and action decided upon within 2-3 months of felling being completed. 100 stocked plots per acre is the minimum considered for "normal" treatment and 200 per acre is considered the desirable basis for regeneration.

The general treatment rule is that all species not acceptable as regeneration of 12 ins diameter (30 cm) and over are poison girdled and any remaining climbers (not invasive species) are cut through and poisoned on the lower surface. The treatment is omitted in areas of swamp or seasonal flooding when seedling stocking is less than 100 per acre. A series of options are available for general treatment and when there are less than 100 seedlings per acre in dry land forest then option E is used. If the stocking of *Parashorea* and Rubroshorea combined exceeds 300 per acre option B is used:

Option A As general rule, but under or beside stems of acceptable regeneration 3-6 ft girth (30-58 cm diam) with good crowns and not shaded, omit girdling except for any large stems competing with the desirable trees.

Option B As general rule, but also poison all trees over 6 ft girth (58 cm diam) if LSM shows 300 stocked plots per acre (or more) of *Parashorea* and Rubroshorea; or 500 per acre of all listed species. Relic dipterocarps to be left as future seed trees near any large open areas.

Option C As general rule, but where any good groups of acceptable regeneration of 1-3 ft girth are impeded ignore size limits and carry out a liberation treatment to favour such trees.

Option D In areas of unlogged forest within the felling area where adequate seedlings are present:
(1) if small in extent no departure from general rule.
(2) if 2 chains (40 m) in width and of some size reduce girdling limit to 6 ins diam (15 cm).
(3) if greater than 2 chains and also of some length, reduce limit to 2 ins diam (5 cm).

Option E On dry land when stocking is less than 100 per acre cut climbers and release groups of impeded small pole size stems of acceptable species. When such areas are large action is initiated to reduce tractor path intensity, in areas not yet felled, increase the list of acceptable species, consider enrichment, or to omit silvicultural treatment altogether.

In addition trees on stream banks or in standing water are to be left ungirdled and riverain reserves along wider water courses where felling is prohibited are to be untreated. Fruit trees of the following genera are to be left: *Garcinia*, *Nephelium*, *Euphoria*, *Baccaurea*, *Sandoricum*, and residual stems of *Eusideroxylon zwageri* are also not girdled. Bamboo and rotan are to be cut and large *Ficus* trees girdled.

Subsequent Growth of the Stands

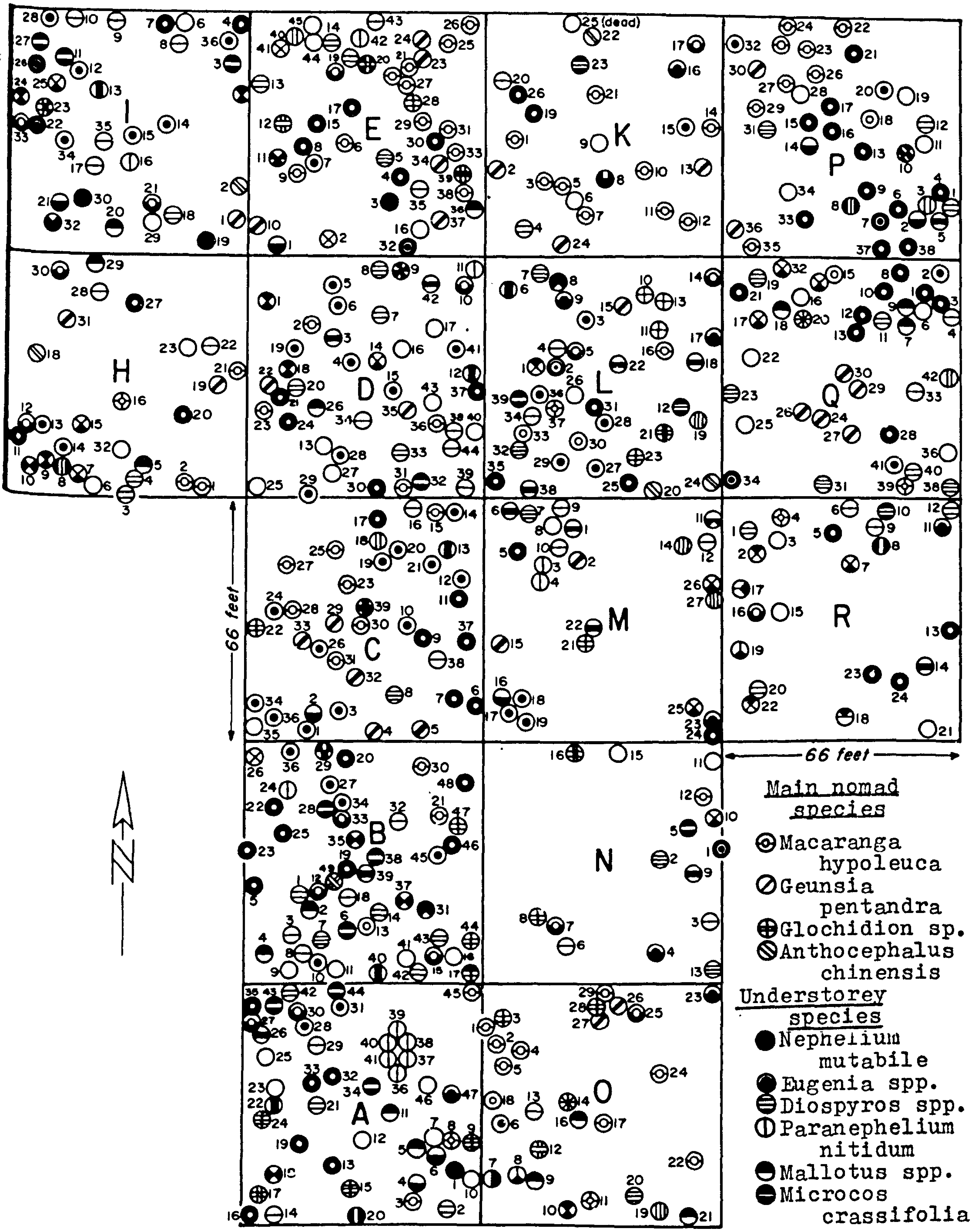
Distribution of species in an area of natural regeneration ten years from felling is illustrated in Figure 64 (R.P.229). This area is used for instruction in identification of species and three broad groups of species are of particular significance. These are the invasive (or nomad) species, understorey species and dipterocarp regeneration. Despite differential growth rates the overall density of most areas results in the dipterocarp regeneration suffering competition not only from the invaders but also from the understorey species (in the main of no commercial value) as these often have a start from well established root stock and are not cut after felling. In many areas residual unkilled relicts of the natural forest, of dipterocarp species and of others, may also be impeding growth of the desirable regeneration. Climbers are also of importance.

Linear Sampling Quarter Chain (LS¼)

Climber growth and general thickening up renders access into the regenerating forest difficult for the first five years or so from felling. Thereafter as competition results in fewer stems and growth carries the climbers up the forest is more easily walked through again. Until 1971 it was standard practice to sample felled areas by LS¼ survey at some five years from felling.

Nicholson (1965) gave figures for species composition in such surveys which showed that the *Parashorea* and Rubroshorea species (mainly *S.parvifolia*, *S.leprosula* and *S.leptoclados*) together accounted for

FIGURE 64 DISTRIBUTION OF SPECIES IN 10 YEAR OLD NATURAL REGENERATION Segaliud-Lokan F.R.F 1957



Main regeneration species

Shorea leptoclados
Parashorea malaanonan
Shorea smithiana
Dipterocarpus caudiferus
Parashorea tomentella
Shorea parvifolia
Shorea leprosula
Dryobalanops lanceolata
Eusideroxylon zwageri

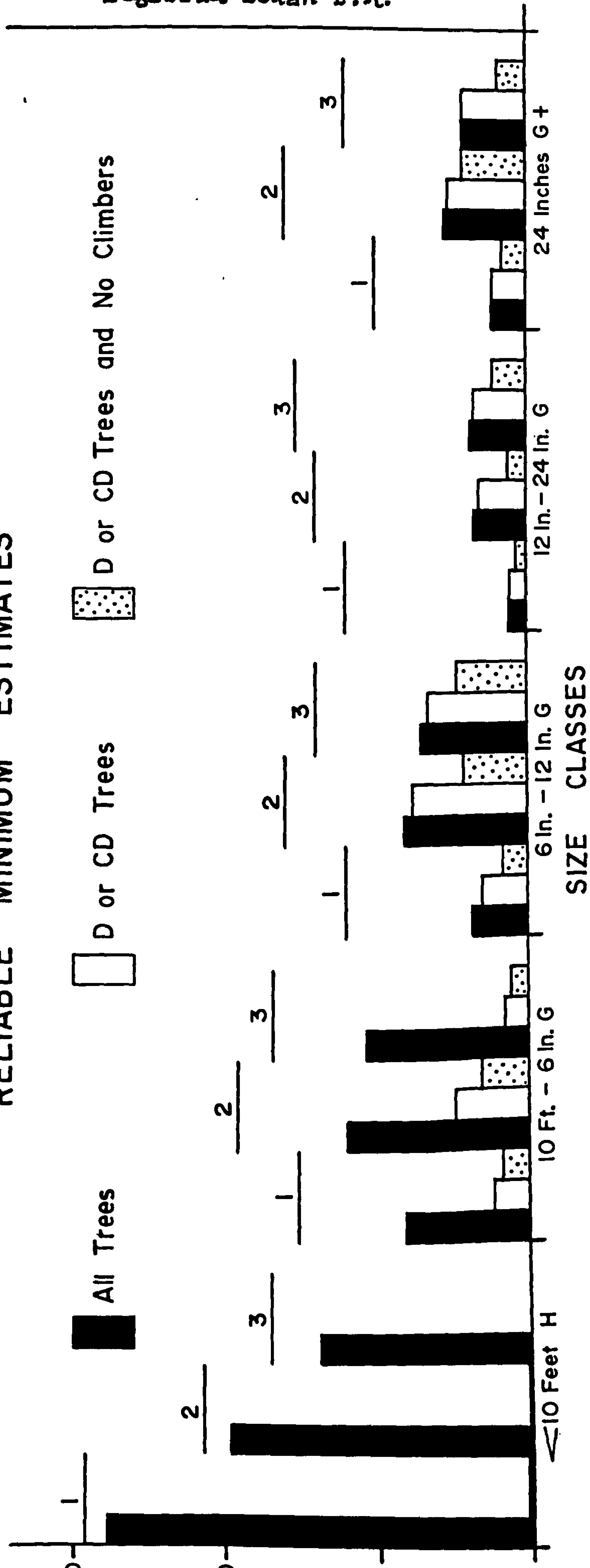
50 to 80 per cent of recorded stocking. With the addition of *Dryobalanops lanceolata* the proportion of "preferred commercial species" lay in the range 76 to 89 per cent. These surveys covered the main types of commercial forest. Overall stocking (of a maximum of 160 stocked plots per acre) ranged from 34 to 112 (=84 to 275 per ha) in sizes from 10 ft height (3 m) and over. The range was 13 to 80 per acre (32 to 200 per ha) for regeneration over 6 inches girth (5 cm diam).

Subsequent surveys of different areas, all at about 5 years after felling, have shown stocking of 16 to 92 (40-227 per ha) for regeneration over 10 ft height, and from 7 to 74 (17-183 per ha) over 6 inches girth. It is apparent that time from felling alone will not be sufficient to determine either when treatments are desirable or the likely rotation necessary to achieve a utilisable second crop. Both points in time for given areas depend on initial stocking and rates of growth, though to simplify management it is necessary to group the regenerating stands into age from felling classes. At the lower levels of stocking at LS¼ ~~sm~~ sampling (i.e. below 40 stocked plots per acre, or 100 per ha) it is unlikely that a good crop will develop unless stocking is well distributed and appropriate treatments undertaken. Generally the areas with lower stocking will develop very patchy regeneration.

Illustrations of the results of linear sampling quarter chain surveys are given in Figures 65, 66. These show stocking per acre by size classes for two areas in Segaliud-Lokan F.R. (the location of Compartment 23 is shown in Figure 67). The term "conventional age" refers to time from felling, and in all subsequent mention of

FIGURE 65 LS¼ SAMPLING

Segaliud-Lokan F.R.



Forest Department. Sabah. 1971.

regeneration age this period is referred to. These illustrations present a compressed picture of development showing that at 5 years (Figure 65) the bulk of the assessed regneration was in smaller size categories whereas 6.5 years from felling a bulge in the size class 6-12 inches girth (5-10 cm diam) was evident and few of the dominant or codominant chosen trees were free of climbers (Figure 66).

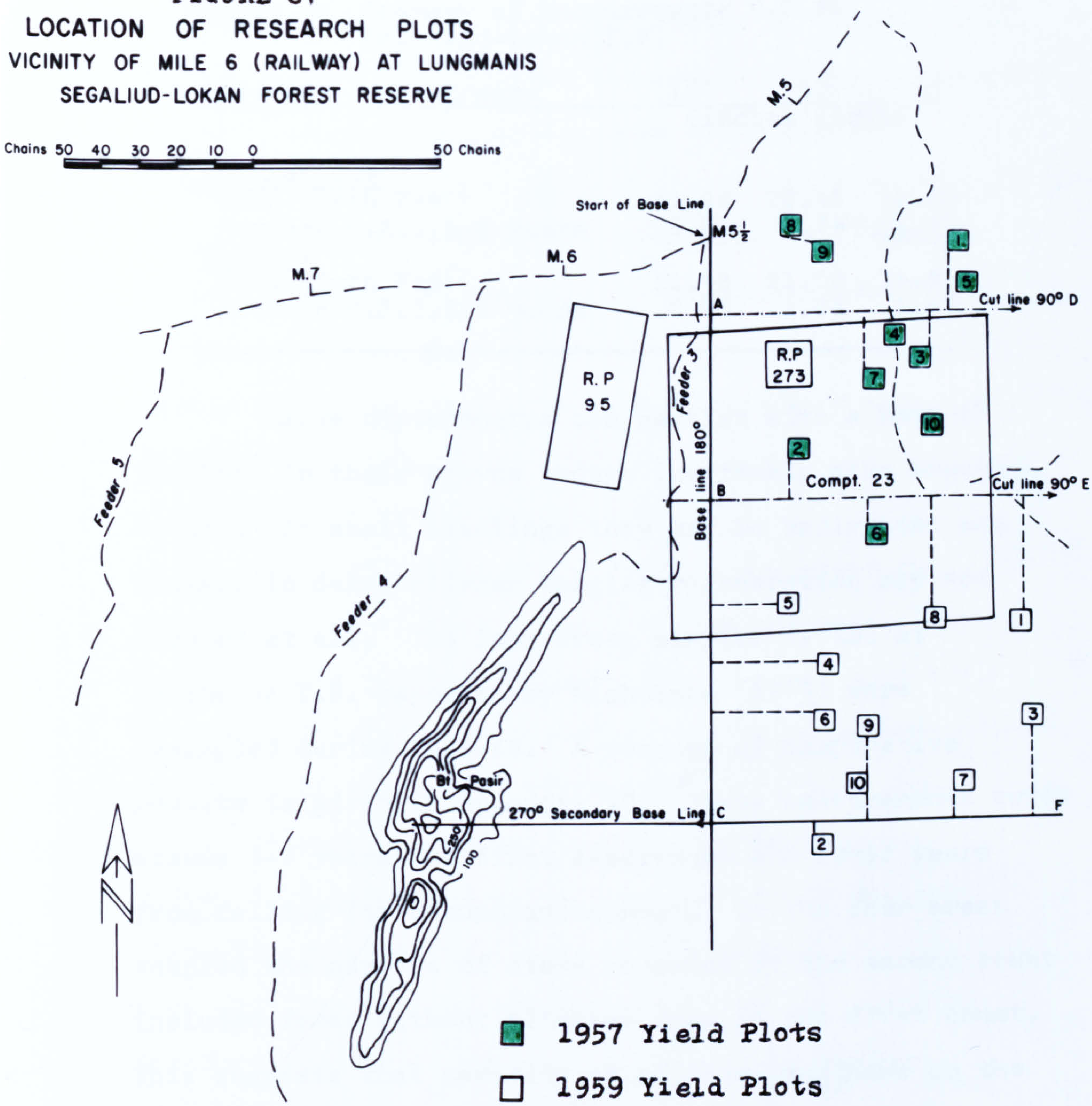
This method of sampling is now relinquished in favour of half chain survey (LS½) at 10-15 years from felling, by which time intervention in the stand can be more meaningful. The area may be judged as "regenerated" or not (Barnard 1950 c) at this stage.

Climbers in Young Regeneration

The invasive climbers (e.g. *Mesoneuron, Merremia*) established after felling lead to stem damage of the young dipterocarps, as well as being competitors with them for light. An experiment laid down in regeneration 5 years from felling in 1963 in the vicinity of the sampled areas referred to above (location R.P.95 on Figure 67) compared growth of regeneration following climber cutting against no treatment control. An immediate significant response was obtained on the increment of measured trees (LS¼ sampling, maximum 160 per acre) and a marked, though not statistically significant, increase in growth of the larger trees. There was little difference in the rate of change of sampled trees (LS sampling measures the best tree at each measurement, and not necessarily the same individuals) due to breakages, etc. between treated and untreated areas. Increment continued to be put on at an increased rate in the treatment areas for 3 years from treatment,

FIGURE 67

LOCATION OF RESEARCH PLOTS
IN VICINITY OF MILE 6 (RAILWAY) AT LUNGMANIS
SEGALIUD-LOKAN FOREST RESERVE



■ 1957 Yield Plots

□ 1959 Yield Plots

but after that the larger trees in control plots were growing at a lightly faster rate.

Table 48 summarises growth rates over the four years from treatment:

Table 48 Summary of Measurements R.P.95 Segaliud-Lokan F.R.

Category	Trees/acre	160	40	25
		(inches girth)		
Climber cut				
Mean girth F+9		11.98	20.45	28.27
Average C.A.I.5-9 years		1.09	1.53	1.83
Control				
Mean girth F+9		11.48	21.00	29.50
Average C.A.I.5-9 years		0.98	1.25	1.56

Large dipterocarps can persist with a mass of climbers in their crowns though inevitably some breakage occurs. As small seedlings they may be badly bent and broken; in dense climber tangles regeneration may not succeed at all. The four areas samples by LS¼ at Kalabakan F.R. reported by Nicholson (1965) were resampled during 1968-69. A summary of comparative results is given in Appendix 10. These measurements cover stands 5-9 years for first assessment and 10-16 years from felling for second assessment. In the four areas sampled the numbers of stems recorded at the second count included fewer without climbers than at the first count. This suggests that severity of climber incidence on the regeneration has increased and that since even the larger trees were affected climber cutting was desirable (treatment has been undertaken recently).

Linear Sampling Half Chain (LS½)

This is now prescribed at 10-15 years from felling to assess the silvicultural condition of regenerating stands. It is a diagnostic sampling and seeks to determine what treatment, if any, is appropriate to increase the status of the regeneration (Fox and Hepburn 1972). Liberation treatments are discussed below. This sampling method uses the same basic recording unit, the half chain square (33 x 33 ft = 10 x 10 m) as the yield plots to be described in Chapter 9. In each sample unit a tree from the regeneration list is searched for and recorded by species, size class and crown freedom (i.e. dominance or position in the canopy) class on a scale of 1 (lower understorey) to 5 (emergent). Climber presence is recorded as merely present or likely to result in stem distortion if not removed. For chosen trees with crown score of 4 or less impeders threatening the growth of the chosen tree are recorded, whether they are within the sampling unit or outside it. Relevant observations affecting the status of the stand are recorded at each sampling unit and relict trees (i.e. those of 6 ft girth or larger, and presumed left from the natural stand) are recorded if within one chain (20 m) each side of the centre of the sampling line.

Figure 68 illustrates a 5 per cent sample LS$\frac{1}{2}$ survey in Silabukan F.R. at 15.8 years from felling. Line summary stocking is given in Appendix 11. In this area 81.5 per cent of stocked plots were affected by impeders and 71 per cent had climber infestation, suggesting treatment as explained at the end of this chapter.

Liberation Treatment in Regenerating Stands

A small thinning experiment was undertaken in 1966 in regeneration 8 years from felling (R.P.95). Four treatment levels were applied: (1) Control, (2) Selective removal of trees competing with the best 160 dipterocarps per acre, (3) Removal of all non

FIGURE 68 LS½ SAMPLING SILABUKAN F.R.

dipterocarps, (4) Retention only of the best 160 dipterocarps per acre. The experiment was in two parts, in one area thinning meant physical cutting of the stems (Fox 1967 (b)), in the other the trees to be eliminated were girdled and poisoned with sodium arsenite. The total area involved was 1 acre (0.4 ha), treatment units were adjacent plots of 0.025 acres. Treatment was randomised within strata of total plot basal areas. After 4.8 years the following growth had occurred:

Table 49 Thinning Trial in R.P.95
Segaliud-Lokan F.R.

Treatment	Cutting		Girdling		Combined	
Trees/acre	80	40	80	40	80	40
	(Average C.A.I. ins girth)					
Treatment level (see text)						
(1)	1.3	1.4	1.4	1.4	1.3	1.4
(2)	1.6	2.0	1.3	1.5	1.4	1.8
(3)	2.2	2.8	1.4	1.6	1.9	2.2
(4)	1.3	1.7	1.7	1.9	1.5	1.8

The numbers involved were 67 representing possible full stocking of 80 per acre, and 35 representing 40 per acre. Mean girths of all trees comprising these two groups were 13.6 and 13.7 inches in 1966 and 21.0, 22.3 in 1971, respectively. From this limited trial it can be seen that some increased growth occurred under all treatments, with cutting generally giving a greater response than girdling; treatment (3) giving best response with cutting and treatment (4) best with girdling. The disadvantage of treatment (4) was that several larger measured trees were damaged by falling material and treatment was followed by rapid ingrowth of nomadic species. in this case of *Mallotus ricinoides, Omalanthus populneus* and *Pterospermum diversifolium*.

R.P. 273 Liberation Experiment

Three areas of regeneration: (A) Segaliud-Lokan F.R. (see Figure 67)(felled 1957), (B) Kalabakan F.R. (F 1956) and (C) Silabukan F.R. (F 1954, Figure 68) were used to study the effect of thinning out competition, by poisoning with arsenic, on the growth and stocking of dipterocarp regeneration. This work was commenced in mid 1968 at Segaliud-Lokan and in 1969 at the other sites. In each area square blocks of side 14 chains (280 m) were demarcated; in each four plots of 5 x 5 chains (= 1 ha) with a 1 chain (20 m) surround were established as measurement plots (see Figure 68). In each consecutive half chain square (10 x 10 m) one dipterocarp tree was selected as the chosen tree, if available, in the manner used for yield plots (Fox 1970 a). Additional trees exceeding 12 ins girth were measured and numbered consecutively. Figures 69 to 72 illustrate tree positions for the plots of R.P.272 C (Silabukan).

In each block 2 plots received no treatment (1 and 4); one plot received a heavy treatment in which all trees of invasive species, and of non commercial species were eliminated (Treatment 2); and the fourth plot received a lighter treatment - elimination of non commercial species only (T 3). Treatment plots also received climber cutting. Chosen trees were subsequently remeasured to determine girth increments. The principal objective of this work was to test whether simple rules, of a blanket nature (similar to those followed in R.P.95 above) could be used for wide scale application to regenerating stands. Soon after treatment it became apparent that indiscriminate girdling had resulted in damage to chosen trees through falling of branches and

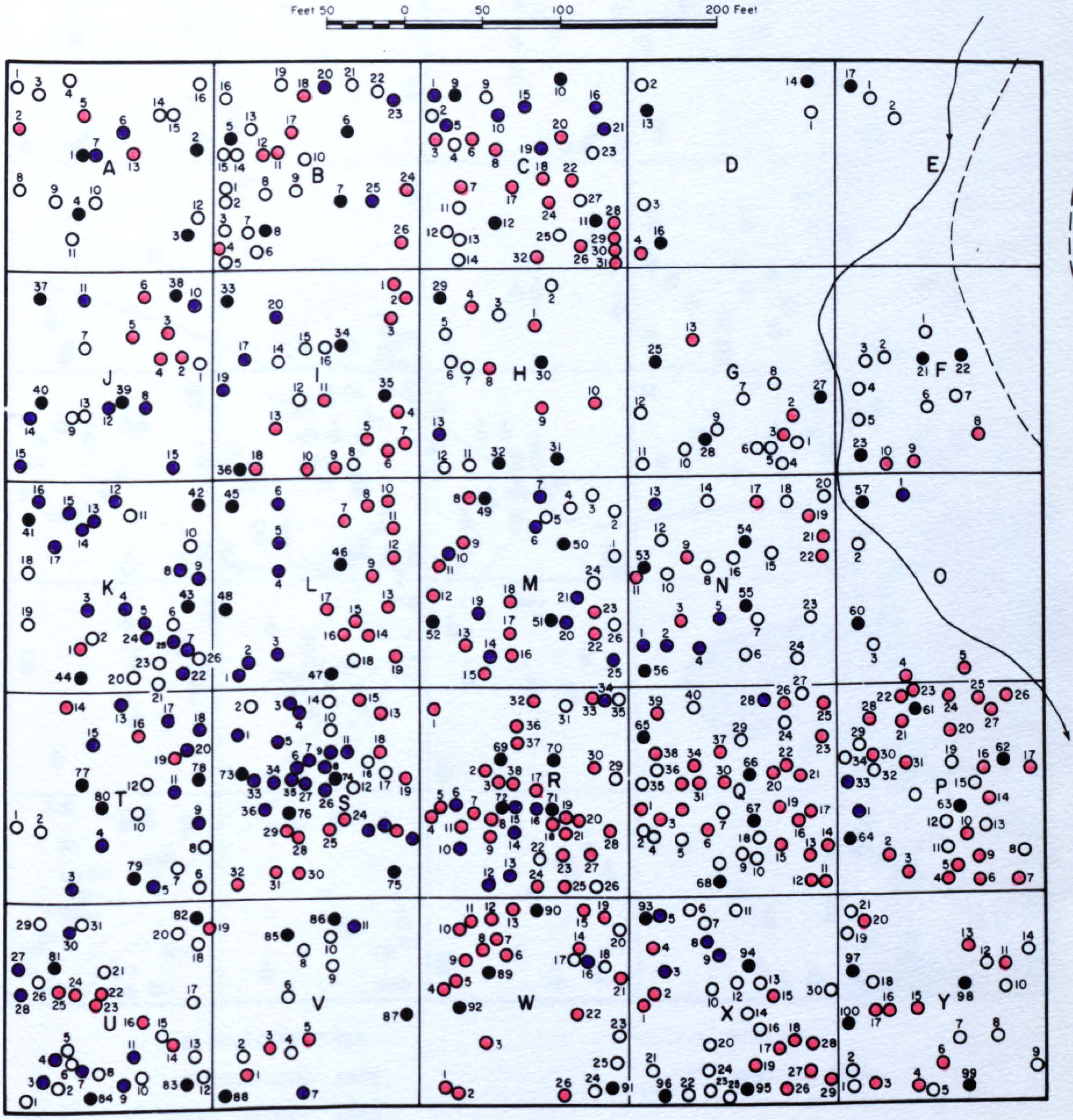
FIGURE 69

RESEARCH PLOT 273/C

TREATMENT PLOT NO. I

BAKAPIT, SILABUKAN FOREST RESERVE

SCALE I Inch to 33 Feet



● SELECTED TREE

○ OTHERS

● Macaranga hypoleuca

● Additional dipterocarps

STREAM

TRACTOR PATH

Forest Department, Sabah. 1971.

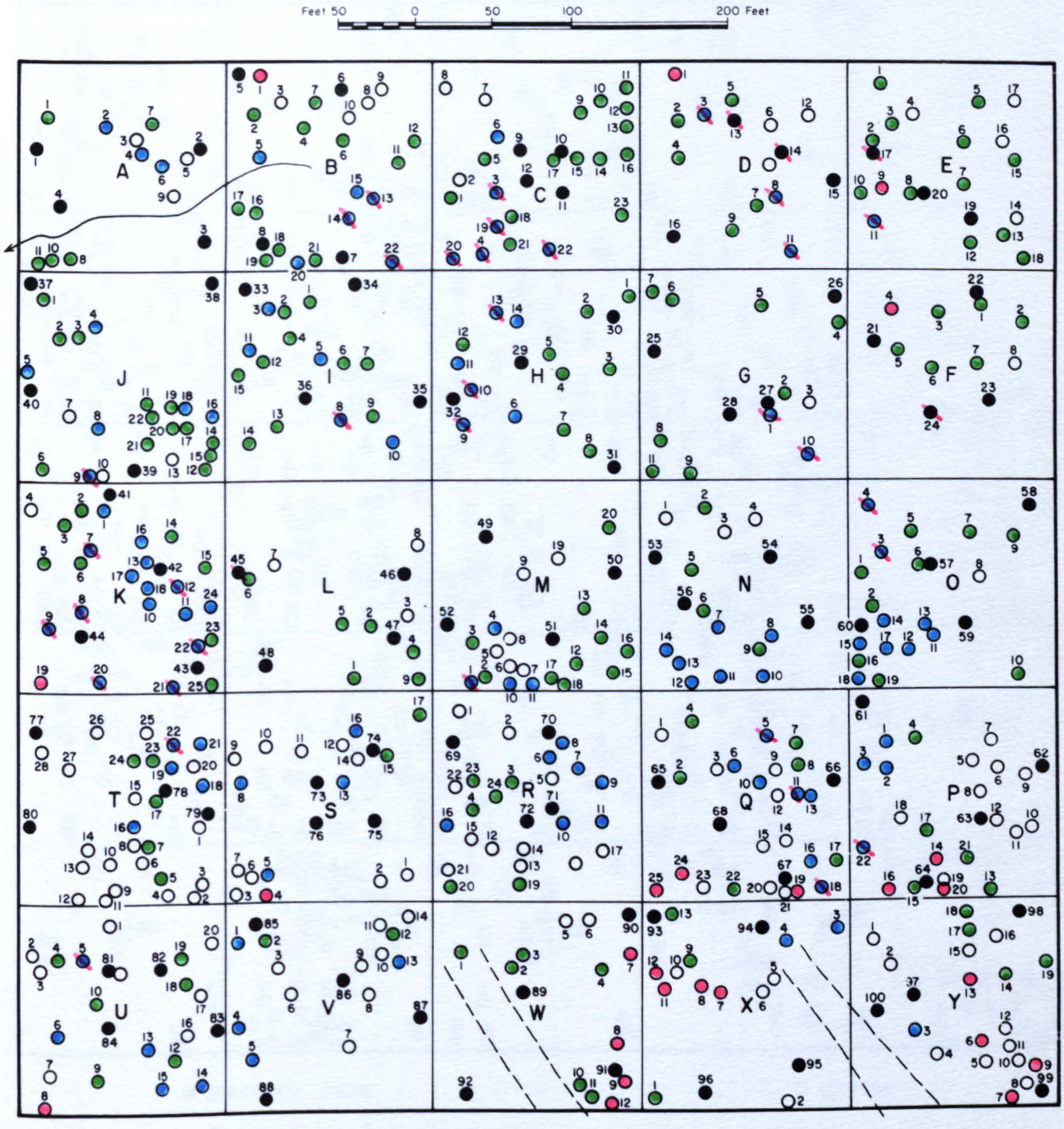
FIGURE 71

RESEARCH PLOT 273/C

TREATMENT PLOT NO. 3

BAKAPIT, SILABUKAN FOREST RESERVE

SCALE 1 Inch to 33 Feet



● SELECTED TREE

○ OTHERS

● Girdled tree

● Dead after 1 year

● but not girdled

● Additional dipterocarps

STREAM

TRACTOR PATH

Forest Department, Sabah. 1971.

FIGURE 72

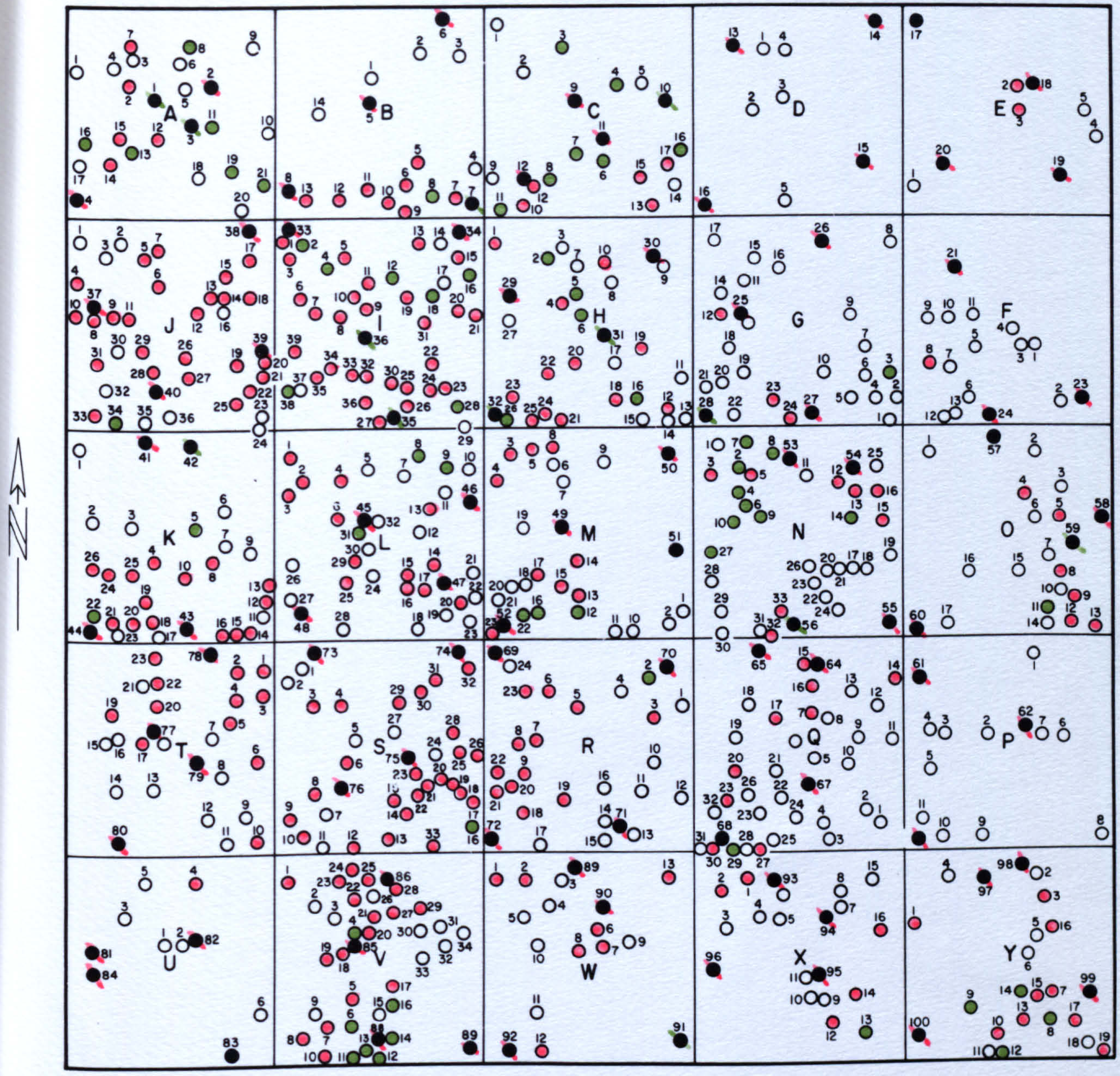
RESEARCH PLOT 273/C

TREATMENT PLOT NO. 4

BAKAPIT, SILABUKAN FOREST RESERVE

SCALE 1 Inch to 33 Feet

Feet 50 0 50 100 200 Feet



● SELECTED TREE ○ OTHERS

● ○ Parashorea malaanonan

● ○ Shorea leprosula

Forest Department, Sabah. 1971.

boles, particularly so in Silabukan Treatment 2, where the average size of chosen trees was comparatively small. In this plot 7 of the chosen trees had been knocked down or killed at 6 months from treatment, growth was poor, and only 57 out of the 74 marked at the start survived one year. This plot (Figure 70) was also the most poorly stocked. In all other cases however treatment resulted in higher average increment on the chosen trees (Table 50) Figures 73, 74 illustrate average current annual increments by girth classes plotted against median girth for the two year periods following treatment for R.P. 273 A (Segaliud-Lokan F.R.) and 273 B (Kalabakan F.R.). The 25 largest, distributed, chosen trees, i.e. the largest chosen tree in each 66 x 66 ft square (20 m x 20 m), are shown individually.

Table 50 Mean Girths and Average Increments (ins)R.P.273

Replicate	A			B			C	
Max.stems /plot(ha)	100	50	25	100	50	25	100	50
Equivalent / acre	40	20	10	40	20	10	40	20
Control Plots								
Initial girth	19.30	20.56	27.40	19.32	22.51	24.98	18.17	19.60
Final girth	21.85	23.83	30.95	21.60	25.82	28.23	19.54	21.37
Av.C.A.I.	1.27	1.63	1.77	1.14	1.65	1.61	1.37	1.77
Stems/Plot (= /ha)	81	49.5	25	90	50	25	94	49.5
Treatment 2								
Initial girth	21.51	19.56	28.78	15.94	18.57	34.16	11.31	11.50
Final girth	25.67	24.53	32.65	20.25	24.19	38.36	12.60	13.11
Av. C.A.I.	2.08	2.48	1.93	2.15	2.81	2.10	1.29	1.61
Stems/Plot (= /ha)	79	47	25	79	48	25	57	39
Treatment 3								
Initial girth	21.44	21.16	33.88	16.26	19.89	24.29	14.71	16.54
Final girth	24.66	25.28	37.37	18.76	23.35	30.14	16.34	18.98
Av. C.A.I.	1.61	2.06	1.75	1.25	1.73	2.92	1.63	2.44
Stems/Plot (= /ha)	77	47	25	88	50	25	94	48

(Note 100 stems per plot are well distributed chosen trees; 50 are those with best increments, one out of each two consecutive chosen trees; 25 are the largest well distributed chosen trees, one out of each four, i.e. each 0.1 acre or 20 x 20 m square).

FIGURE 73 R.P.273 A SEGALIUD-LOKAN FOREST RESERVE. LARGEST 25 DISTRIBUTED CHOSEN TREES PER PLOT AVERAGE CURRENT ANNUAL INCREMENT 2 YEARS FROM TREATMENT. LINES INDICATE MEAN VALUES IN GIRTH CLASSES FOR ALL CHOSEN TREES.

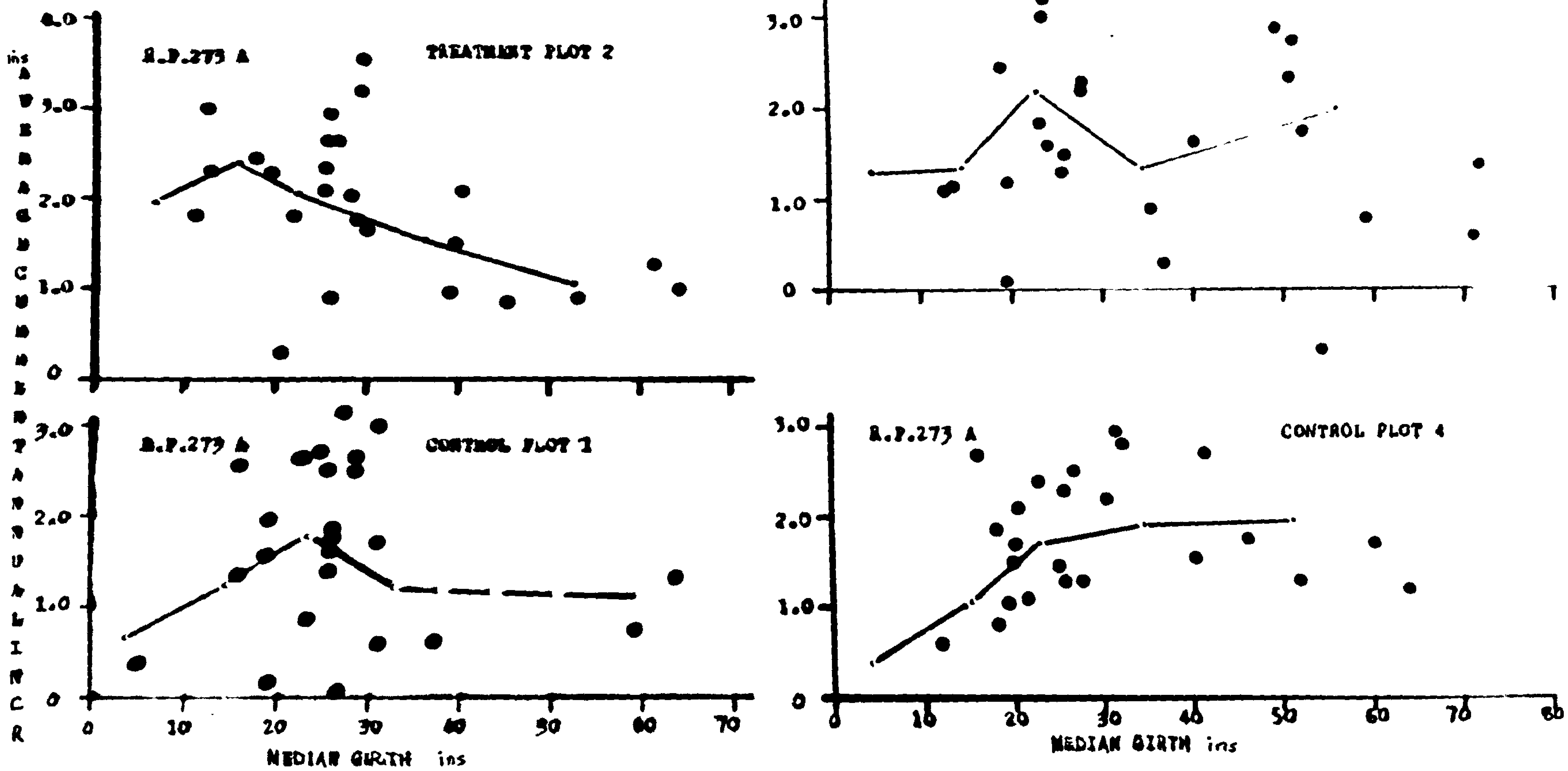
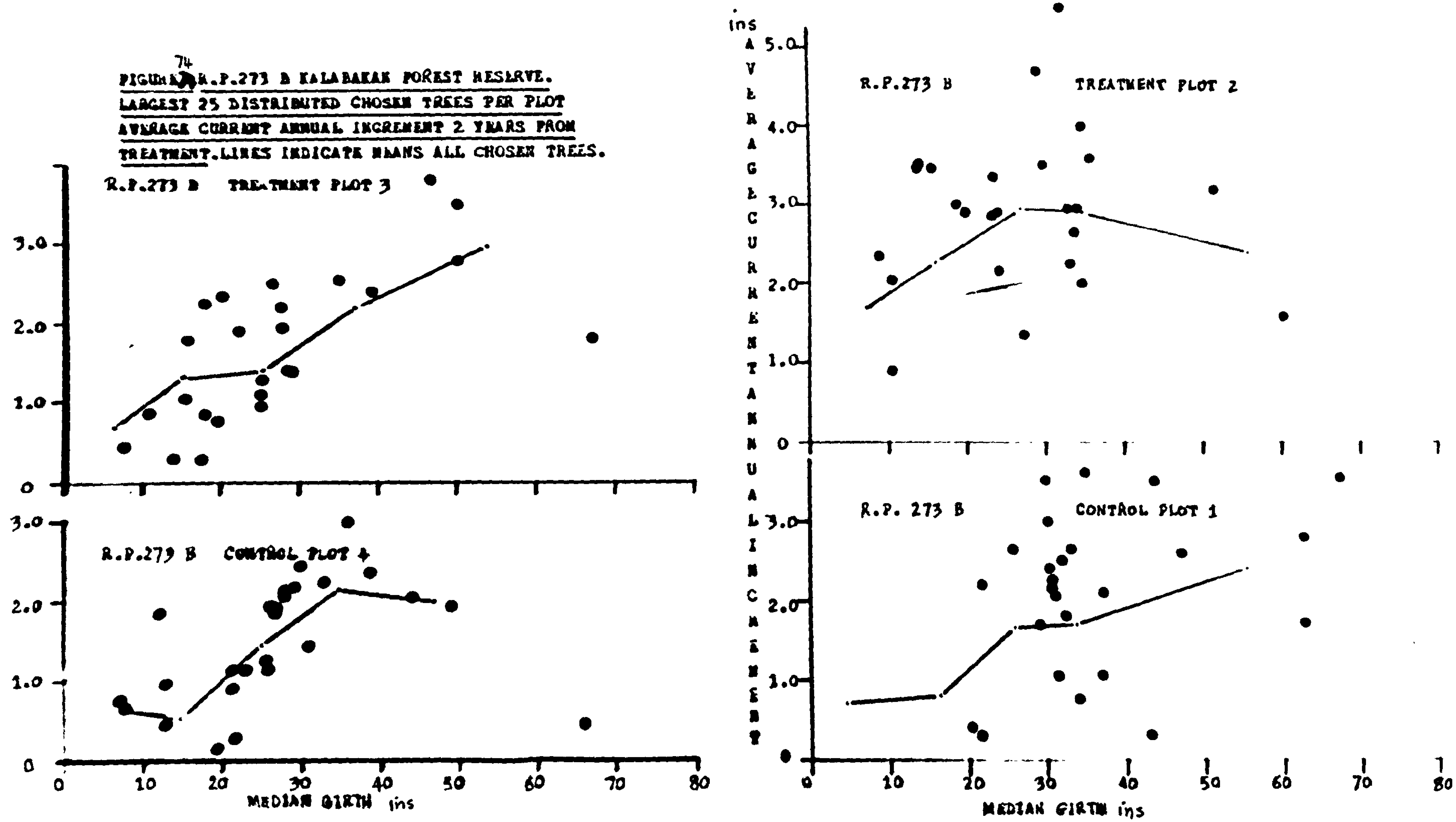


FIGURE 73

FIGURE 74

FIGURE 74 R.P.273 B KALABAKAN FOREST RESERVE.
LARGEST 25 DISTRIBUTED CHOSEN TREES PER PLOT
AVERAGE CURRENT ANNUAL INCREMENT 2 YEARS FROM
TREATMENT. LINES INDICATE MEANS ALL CHOSEN TREES.



Each replicate is discussed separately below, with emphasis on the results of greatest importance. The implications of treatment gains will be discussed in Chapter 10.

Silabukan Replicate C.

This was in Type A forest felled in 1954 with delayed post felling girdling done in 1957. As overall average girth of crop trees was low compared with the other replicates it may be assumed that the presence of ungirdled material for three years following felling had a depressant effect on early growth. The following compares average crop performance up to the time of treatment:

Replicate	A	B	C	
Years from F	11.2	12.7	15.0	
B.a./acre	86	106	57	(square ft)
Average girths (ins)				
All chosen trees	20.3	17.8	16.1	
20/acre (as Table 50)	20.5	20.9	17.1	

Replicate C had lowest total basal area, lowest average girths and in addition slightly fewer numbers of chosen trees. Distribution was such that fewer numbers contributed to the best 50 increments (20 per acre). Control plots had larger mean girth at the start (Table 50) suggesting that delayed first treatment may have accentuated patchy distribution.

The stand was characterised by abundance of regeneration of *Parashorea malaanonan*, this species accounting for 85 per cent of all trees selected at the start. The only other species of importance was *Shorea leprosula* with 12 per cent; small numbers of *S.parvifolia*, *S.leptoclados* and *Hopea sangal* were recorded. Size class representation of the 339 individuals available for comparative girth measurement at the time of treatment in June 1969 and one year later is shown at

Appendix 12 Table 1. There was considerable variation between plots; of the 19 individuals of *P.malaanonan* over 40 ins girth 9 were in plot 1, the remainder divided about equally. These form a distinct population possibly representing individuals that grew rapidly from seedlings at the time of felling, or were present then as pole sized trees. Plots 1, 3 and 4 had more chosen trees over 15 ins girth than plot 2, which was deficient in well grown regeneration from 15-29.9 ins; this size class was particularly well represented in plot 4:

Nos in sizes:	< 15	15-29.9	30+(ins)
P1	50	26	15
P2	49	4	4
P3	64	24	6
P4	41	51	5

This uneven distribution of trees was largely responsible for the poor result of heavy liberation in plot 2; not only was dipterocarp growth poor but swampy conditions in the east of the plot (Figure 70), accentuated by tractor compaction, resulted in uneven growth of invasive species. This is reflected in basal area which was as follows, per plot (square feet):

Years from F	P1	P2	P3	P4
14.8	168	99	141	158
14.8 (after T)	168	27	83	158
16.1	178	27	98	160

Representation of additional dipterocarps over 12 ins girth was good with 113 stems in plot 1, including 4 large relicts of *P.malaanonan* (only one other natural forest relict here was a *Diospyros* sp at 5 ft). In plot 3 there were 111 additional dipterocarps of which 36 died as a result of treatment (including 2 relicts of *P.malaanonan* and 1 *S.leprosula* girdled; and 1 *P.malaanonan* and 1 *Hopea sangal* ungirdled). Plot 4 had 304 additional dipterocarps of which 10 died between measurements; plot 2 had only 12. The principal nomadic species was *Macaranga hypoleuca*, whose distribution in plot 1 is illustrated in Figure 69, together with the additional dipterocarps. Figure 72 illustrates comparative stocking of *P.malaanonan* and *S.leprosula* in plot 4.

Throughout the area *P.malaanonan* was generally the most abundant but *S.leprosula* was often more vigorous and better represented in larger sizes. In plot 1 fifteen stems of *S.leprosula* and *S.parvifolia* had an average C.A.I. of 1.20 ins compared with 1.27 for all trees, whereas 14 such trees of slightly higher average girth had an average C.A.I. of 2.34 in plot 4, compared with the average for all stems of 1.46.

The average C.A.I's for surviving chosen trees in the year following treatment were:

Table 51 Average C.A.I. (1 year) R.P.273 C

Girth Class(ins)	<10	10-19.9	20-29.9	30-39.9	40+
Treatment		(increment in ins)			
Control	0.81(39)	1.28(95)	2.05(37)	1.65(4)	1.58(13)
T2	1.17(36)	1.20(14)	2.73(3)	4.20(1)	0.76(3)
T3	1.23(30)	1.68(50)	2.39(8)	2.25(2)	2.55(4)
	(numbers contributing in brackets)				

No significance can be attached to the value for T2 in larger size classes due to the small number of trees involved. The difference between control and T3 increments is of significance and shows a clear gain in increment for T3 at all sizes. A comparison of the distribution of increments in four increment classes for control and T3 plots is given at Appendix 9 Table 2. Chi square analysis of numbers of increments in four classes of increment, all sizes combined, for control and T3 gave $\varepsilon\ \chi^2 = 11.18$, at 3 degrees of freedom: this is significant at 2 per cent. Similar analysis showed difference in increments between control and T2 to be insignificant; T3 was almost as significantly different from T2 ($\epsilon\ \chi^2 = 11.04$) as from control.

The effect of treatment was more pronounced on the smaller classes (i.e. trees less than 30 ins girth at the start). A comparison of crown scores for tree position and shape at the start showed broad similarity of mean values for plots 3 and 4. Treatment 3 gave higher increment on trees with lower average scores for position and shape:

Mean values for:	Plot 3		Plot 4	
Category of Chosen trees	P	S	P	S
All	2.1	2.6	2.3	2.8
25 best C.A.I.	2.5	3.0	3.3	3.3
C.A.I. 2.5ins+	2.8	3.3	3.5	3.9
C.A.I. 3.0ins+	3.3	3.3	3.8	3.8

(P = position; S = shape)

However little significance is attached to this: large increments were often found on trees with small crowns.

Kalabakan Replicate B

This replicate in Type C forest was felled over in 1956 and received post felling girdling treatment within a year of logging. The species content of regeneration here was much more variable than in replicate C, though *Shorea parvifolia* was the most abundant chosen tree species in each plot with at least 30 per cent, and 42 per cent overall. *S.leprosula* and *S.smithiana* accounted for 18 and 10 per cent respectively and the following, present in each plot, accounted for fewer trees: *S.ovalis*, *S.leptoclados*, *P.tomentella* and *Dr.lanceolata*; small numbers of some 12 other species were selected as chosen trees. The group Rubroshorea comprised over 80 per cent of all regeneration in the replicate as a whole. Size class distribution of chosen trees at the start is given in Appendix 12, Table 2. The area was fully stocked at the start, i.e. a tree of the regeneration list was present in each half chain square. Despite the more mixed species composition than replicate C size class distribution of chosen trees at the start was comparable, though plot 1 had fewer smaller trees and more larger than the other plots. The following numbers survived the 2 years following treatment:

Nos in sizes	<15	15-29.9	30+(ins)
P1	23	47	17
P2	43	27	9
P3	50	29	9
P4	46	39	8

Basal area per plot (square feet) was as follows:

Years from F	P1	P2	P3	P4
12.7	252	222	347	240
12.7 after T	252	31	292	240
14.7	252	46	286	267

In addition to the chosen trees there was good additional representation of other dipterocarp stems. As with replicate C the principal invasive species was *Macaranga hypoleuca* and there were a number of relict dipterocarps present. In plot 2 twenty one of the 100 chosen trees at the start had fallen down or been badly damaged, largely as a result of treatment, compared with 12 in plot 3, and an average, representing normal mortality, of 10 in the control plots. Sufficient new trees were available to allow overall stocking to remain complete after 2 years. Average C.A.I's for surviving chosen trees over the two years following treatment were:

the start and in the best response plot, in this case T2, treatment allowed trees of smaller average crowns to grow with enhanced increment. Increment was generally higher on trees in better positions with respect to light but in plot 2 the trees with fastest increment had slightly poorer crown shapes. Crown scores were higher in control and T3 for the same increment (Appendix 13, Table 3).

Average height of the stand as defined by chosen trees gradually increased over the period of measurement, but due to breakages in T2 its height increase was comparatively small (Appendix 13, Table 4). A comparison of mean girth increments by species suggested that *S.smithiana* in smaller sizes, grew faster than either *S.leprosula* or *S.parvifolia* in the untreated plots; too few measurements were available to compare the effect of treatments on species apart from the two most common. These are shown in Table 53:

Table 53 Comparative Increments R.P.273B

Girth Class(ins)	<10	10-19.9	20-29.9	30-39.9	40+
	(increment in ins)				
Treatment	*Shorea parvifolia*				
Control	0.69(5)	0.70(20)	1.68(37)	1.97(8)	3.05(2)
T2	2.44(5)	3.17(8)	3.10(10)	3.05(6)	-
T3	1.10(9)	1.30(20)	1.60(10)	2.40(4)	3.35(3)
	Shorea leprosula				
Control	1.36(3)	0.83(12)	1.55(16)	2.02(4)	1.95(1)
T2	1.95(4)	1.90(4)	3.45(1)	2.00(1)	-
T3	0.45(9)	0.85(3)	1.12(5)	1.50(1)	-

These figures suggest similar growth in control plots but that *Shorea parvifolia* showed greater response to treatment. Generally it must be assumed that both species respond in a similar way.

Volume tables based on regenerating stands of limited applicability have been prepared for R.P.95 (Fox

1967b) and R.P.87 (Fox 1972). In the absence of an all embracing table, or set of tables, management volumes based on Howroyd and Alabazo (1961) have been prepared for use here (Appendix 14 contains details). Treatment 2 consistently gave higher management volume increments than control or T3; T3 gave no better values than control.

Figure 74 illustrates the 25 largest trees with their increments by plots. The mean line represents median girth and average C.A.I. for all surviving chosen trees averaged by girth classes. For plots 1 and 4, 17 and 15 respectively of these 25 trees are also the best increments; for plot 3 only 12 of the largest trees fall in the 25 best increments, and for plot 2 sixteen.

Segaliud-Lokan Replicate A

This area, in Type B forest, was felled in 1957 and girdled in the same year. Species represented as chosen trees were fewer in number than in replicate B but the more frequent species were of the same order of abundance. The stand was characterised by abundance of *Shorea leptoclados* and *Parashorea tomentella*; these two accounting for 39 and 22 per cent of chosen trees at the start. *P.tomentella* was of the same order of consistency throughout, but *S.leptoclados* was twice as frequent in plot 2 as in plot 1. Other species also showed a tendency to aggregation, e.g. *S.leprosula* 17 per cent overall, but 28 per cent in plot 4; *Dr.lanceolata* 10 per cent overall, 24 in plot 1; *Dipterocarpus caudiferus* and *S.smithiana* were each 10 per cent in plot 3, with 6 and 4 per cent overall, respectively. Other species present in small numbers were *S.parvifolia*, *S.agami* and *P.malaanonan*. The area was not quite fully stocked at the start with 386 chosen trees of possible 400. Size class distribution of chosen trees at the start is given in Appendix 12, Table 3.

Size class distribution between plots was comparable, with the following numbers consistently present at the start and two years later:

Nos in sizes	<15	15-29.9	30+(ins girth)
P1	26	40	5
P2	15	55	9
P3	29	35	13
P4	28	53	10

Basal areas of the four plots were as follows (sq. ft):

Years from F	P1	P2	P3	P4
11.2	209	165	249	238
11.2 after T	209	79	152	238
13.2	198	88	162	235

As with replicate B there was good additional representation of dipterocarps over 12 inches girth, and the principal secondary species was again *Macaranga hypolueca*. On average there were 2 relict dipterocarps per acre (5 per ha) over 6ft girth, the main species being *Dr.lanceolata* and *D.caudiferus*. Mortality was of the same order as in the other replicates: control plots lost an average of 4, plot 2 lost 19 and plot 3 lost 6 chosen trees.

Average C.A.I's for surviving, consistently measured chosen trees over the 2 year period following treatment were as follows:

Girth Class(ins)	<10	10-19.9	20-29.9	30-39.9	40+
Control plots	0.49(25)	1.12(72)	1.73(50)	1.48(6)	1.67(9)
T2	1.97(11)	2.39(26)	2.05(33)	1.55(4)	1.07(5)
T3	1.30(12)	1.35(33)	2.18(19)	1.35(4)	2.00(9)

(numbers contributing in brackets)

This suggests that treatment 3 as applied in this replicate (note basal area reduced to substantially below that of control plots) was superior with respect to increment gain compared with replicate B. This is borne out by χ^2 analysis of increments in 4 increment level classes, as with the other replicates:

Comparison	$\epsilon\chi^2$	Significance (3 degrees of freedom)
Control and T2	42	at 0.1 per cent
T2 and T3	14.4	at 1 per cent
Control and T3	12.4	at 1 per cent

The effect of treatment, was much less (if at all) on larger trees (see Appendix 9, Table 3). As with replicate B increased growth occurred in all plots in the second year from treatment and this slightly reduced the effect of treatment in plot 3, compared with control though differences were still large. (Appendix 13, Table 2). Increments by crown scores showed the same general trend of faster growth on trees with higher scores. There was little variation due to treatment however *pace* replicate B.

A comparison of increment for the three most abundant species in control plots confirmed general observations (and the trend exemplified by original size class distribution cf Appendix 12, Table 3) that, at least for smaller trees, *S. leptoclados* grew faster than *S. leprosula* which was also faster than *Parashorea tomentella*. The latter species showed significant gains due to treatment in smaller size classes (Table 54).

Table 54 Comparative Increments R.P.273A

Girth Class(ins)	<10	10-19.9	20-29.9	30-39.9	40+
	(increment in ins)				
Treatment	*Shorea leptoclados*				
Control	0.98(3)	1.17(32)	1.72(22)	1.40(2)	-
T2	2.25(3)	2.56(15)	2.05(25)	2.55(1)	-
T3	1.05(2)	1.55(13)	2.08(13)	0.30(1)	3.65(1)
	Parashorea tomentella				
Control	0.47(5)	0.91(13)	1.41(5)	2.70(1)	1.72(8)
T2	2.03(6)	2.05(7)	1.90(2)	1.50(1)	1.08(4)
T3	1.45(1)	1.48(10)	2.67(2)	1.30(2)	1.17(4)
	Shorea leprosula				
Control	0.40(3)	1.27(21)	1.80(16)	-	-
T2	-	3.02(2)	1.77(4)	-	-
T3	2.85(2)	1.15(7)	2.77(2)	-	0.70(2)

FIGURE 75

FIGURE 75 RAINFALL AND AVERAGE INCREMENTS OF VERNIER TREES R.P.273A

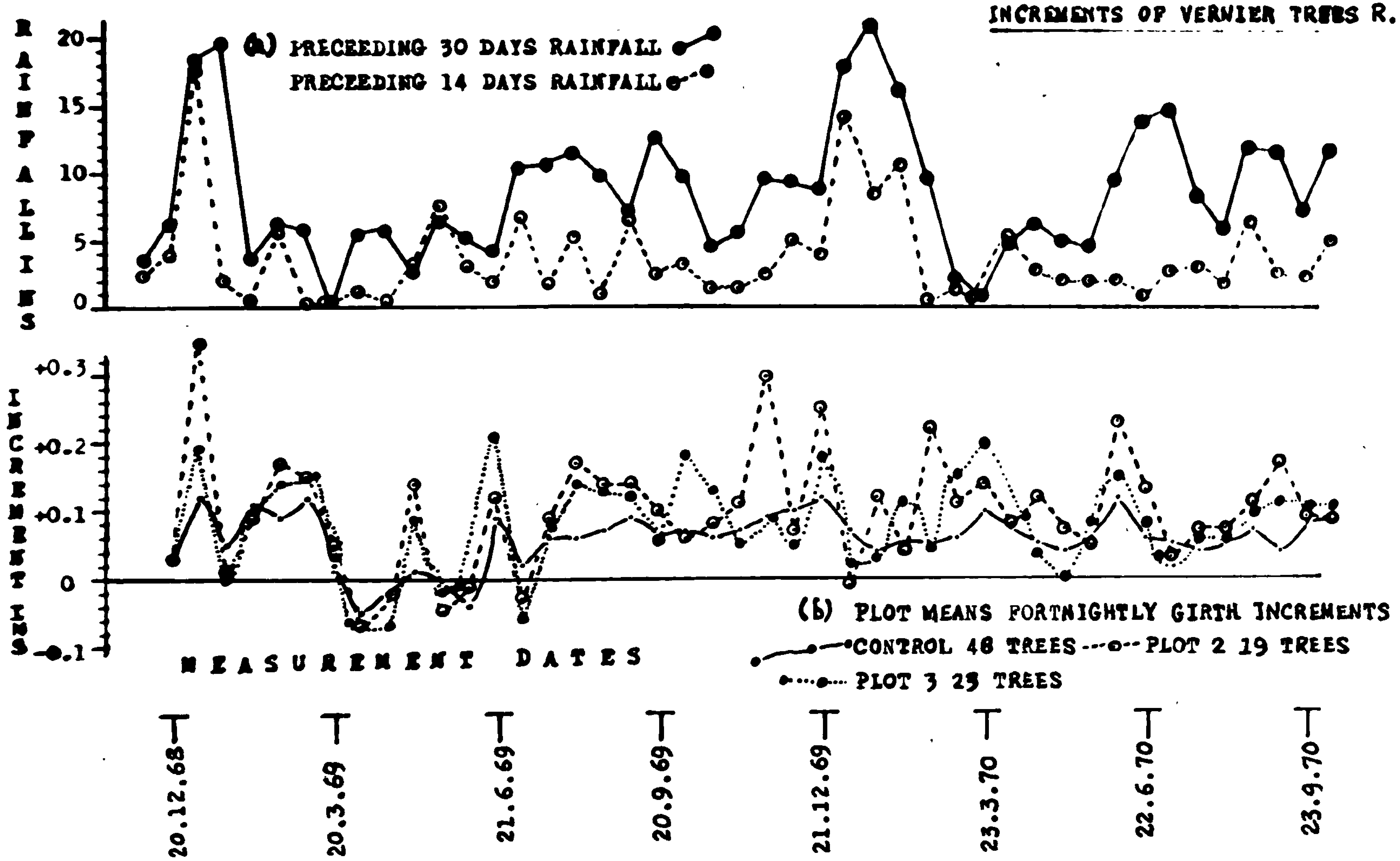


FIGURE 76

FIGURE 76 AVERAGE MONTHLY INCREMENTS OF VERNIER TREES AND MONTHLY RAINFALL AT PLOT SITES

Averaged fortnightly measurement of control plot trees in replicate A (Figure 75) showed shrinkage following the period of very low rainfall in early 1969. There was a tendency for swelling to occur in rhythm with periods of heavier rainfall with pattern more closely correlated to the preceeding 30 days fall, though no clear relation is shown. Fluctuations of bole size in treatment plots was much greater, with plot 2 showing shrinkage at four different times; the last in January 1970 when heavy rainfall probably affected growth by waterlogging. Individual tree fluctuation was greater for trees in all plots, though plot 2 trees showed most individual changes. Two years after treatment the rate of change in plot 3 had approximated that of control and fluctuated more in harmony with control than earlier.

Monthly change of vernier trees and the preceeding monthly rainfall is illustrated for all replicates in Figure 76. This compression of data exaggerates fluctuation in replicate A, and it is presumed the tendency is general. Similar response to low rainfall is seen in a lag in swelling, especially in control plots, for Kalabakan in April and October 1970, and for September 1970 at Silabukan. There was a tendency for greater change to be associated with monthly rainfall in excess of 15 inches (380 mm) at Segaliud-Lokan and in excess of 10 ins (255 mm) at the other locations.

Other Experiments

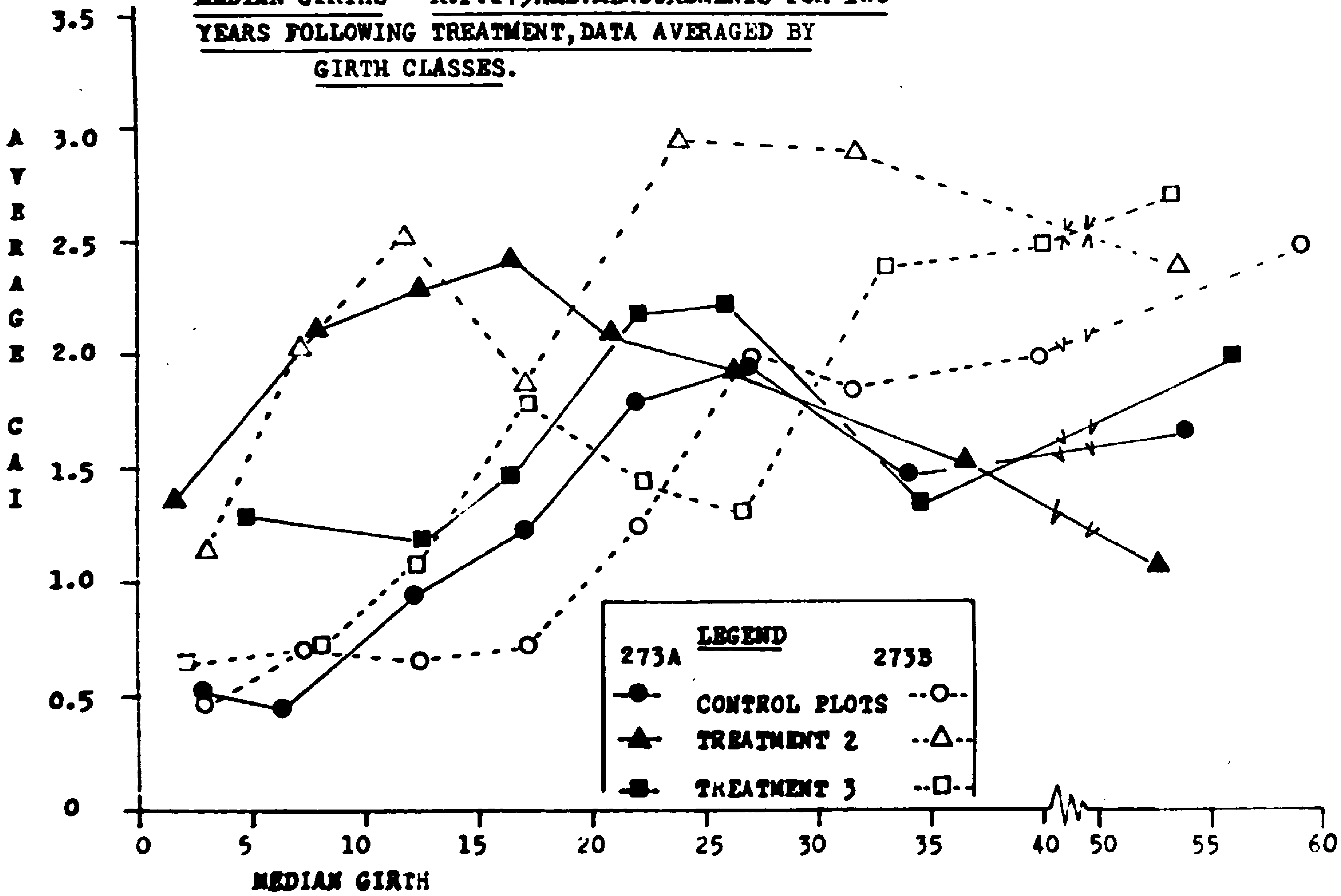
Similarly designed plots laid down in younger forest at Segaliud-Lokan (R.P.336, felled 1963) and Kalabakan (R.P.356, felled 1962), Forest Reserves to test intervention in smaller sized regeneration may provide evidence to modify conclusions reached to date. Two untreated controls in each replicate of R.P.273 are available to test other methods of treatment.

The Third Silvicultural Treatment

The foregoing account has demonstrated that silvicultural intervention in stands 10-15 years from felling can result in increased growth of the desirable regeneration components of such stands. Figure 77 emphasises the results of liberation in R.P.273 A and B. More girth classes are used in this presentation than in Figure 73, 74 (see also Tables 53, 54 for species) and the effect of treatment on increasing growth rates in smaller size classes is clearly shown. However the experiments undertaken to date suggest that simple treatments confining elimination to broad categories of growth, cannot be utilised. As the stands vary considerably in local abundance of invasive species and dipterocarps (cf Figures 68, and 69-72 for exceptionally varied areas) silvicultural treatment must be localised to take account of patches of good growth and to avoid perpetuating (or creating) climber tangles.

Blanket treatments may be more easily understood but their effects may be as disastrous as indiscriminate poisoning of all stems after felling in areas unstocked by dipterocarp seedlings. Localised treatments may tend to result in patchy representation of good stands of regeneration and exaggeration of what would occur, albeit more slowly, with no treatment. As the major growth stimulus is to smaller size stems it is considered that the third silvicultural treatment should result in an evening up of the stands; the larger sized trees, already in dominant or codominant positions *vis-avis* the invasive

FIGURE 77 AVERAGE CURRENT ANNUAL INCREMENT AND MEDIAN GIRTHS - R.P.273A&B.MEASUREMENTS FOR TWO YEARS FOLLOWING TREATMENT, DATA AVERAGED BY GIRTH CLASSES.



and understorey species, may be joined by additional recruits from the smaller categories.

As the stands coalesce after a release operation it may be expected that growth increases will slacken off as competition sets in again (cf Figures 75, 76). There may be possibilities for further silvicultural treatment in older stands (to remove remaining relict trees formerly retained for seed etc.), but such treatments should, desirably, influence larger stems. Thinning experiments in older stands have not been shown to affect the rate of growth of larger stems thus far (Fox 1972). It is possible that viable uses for the nomad species may arise which will render areas covered with invasive species of some value, or allow their selective removal by cutting rather than poison girdling. A trial of limited applicability, to cut out *Macaranga* species from a 15 year stand at Kalabakan F.R., to provide rafting poles is one illustration.

General rules adopted in applying the third silvicultural treatment at Segaliud-Lokan (Figure 67, compartment 23 and adjoining areas) and at Silabukan (Figure 68, area sampled by LS$\frac{1}{2}$) Forest Reserves were as follows:

> Cut climbers, bamboo and rottan except in dense tangles or where tree canopy lacking. In areas of dense secondary species girdle one or two stems where suppressed dipterocarp seedlings are present. Girdle lightly to favour dipterocarp pole sized stems suffering impedance from secondary, large understorey, or relict trees of defective or non commercial status. Do not eliminate all secondary species where falling will cause damage to dipterocarp stems. No treatment to be undertaken (except climber cutting) in the vicinity of large sound dipterocarps with crowns in dominant or emergent positions. Girdle relicts where adequate stocking is present.

These rules are selective in nature and require adequate field supervision by intelligent trained staff; treatment must be a skillful compromise between the extremes of so severe as to cause loss and so light as to be scarcely worth doing. The linear sampling half chain survey (or examination of representative yield plot data) is generally an essential prelude to treatment. Examination of the results of this, coupled with an ocular inspection by the district forest officer, should allow a decision to be made as to whether an area needs treatment and to allow the formulation of rules for treatment of the nature given above.

CHAPTER 9

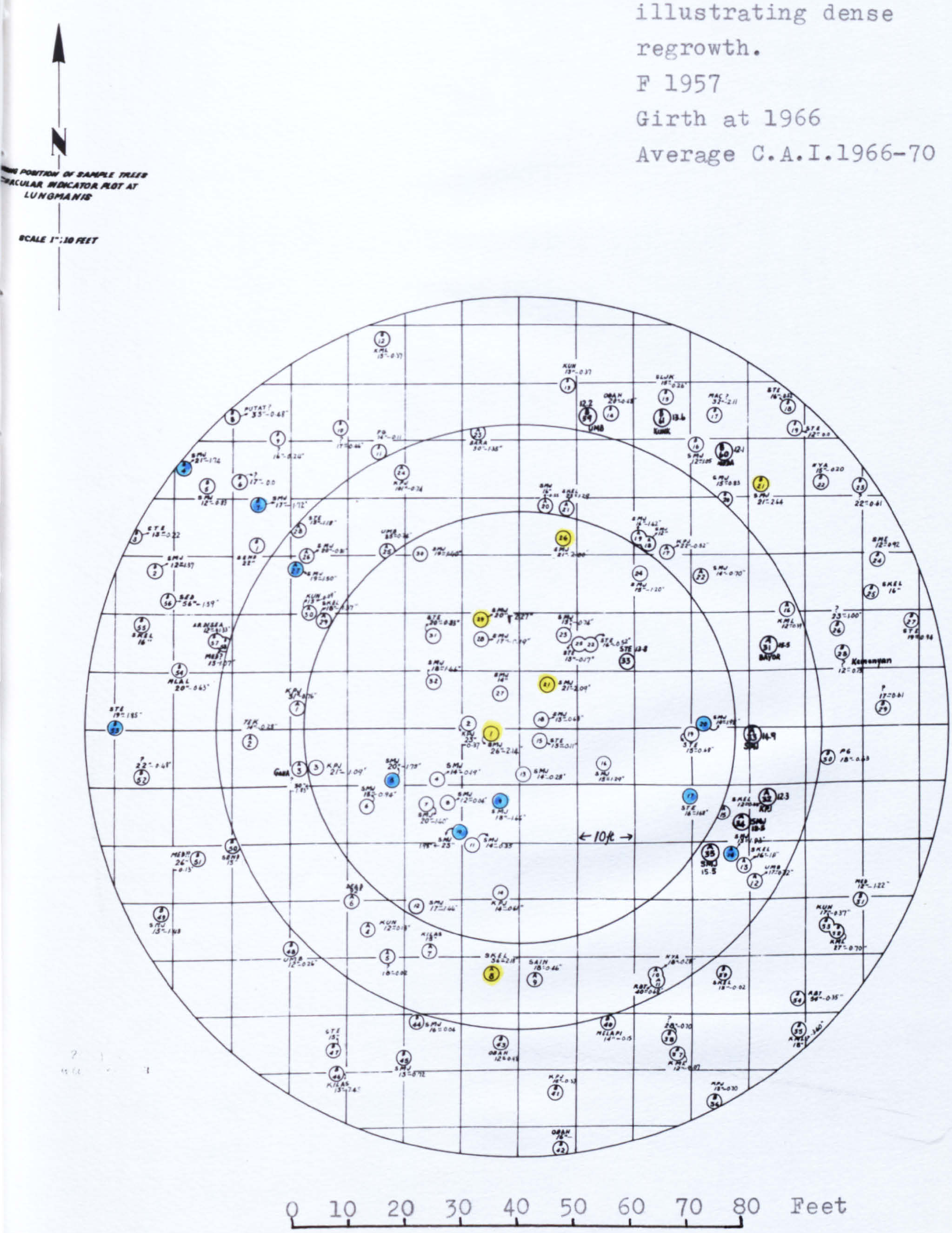
MEASUREMENT OF GROWTH AND STOCKING BY YIELD PLOTS

The techniques of assessment using linear sampling referred to earlier give useful records of the status of stands at a given time,particularly with respect to stocking. The principle of sustained yield requires growth over time and to obtain this is was necessary to establish permanent, re-measurable sample areas. Plots established prior to 1966 in regeneration areas were mainly sited in areas of good growth (e.g. R.P.'s 38, 87, 88, 89) with only one plot (R.P.45) placed in an area probably typical of average regeneration of known age from felling. The system adopted was that of yield plots following the general principles of dynamic sampling outlined by Dawkins (1958). I have described the yield plot technique in detail elsewhere (Fox 1970a) and wish to draw attention here to several general points. As the program is of recent origin it is considered prematu~~t~~re to present all plot sets, the examples given are a representative sample with the aim of illustrating some of the results to date.

Growth on an Area Basis

In the natural forest individuals differ in growth rates, and in freshly logged areas individual seedlings often grow faster than others. An example of variation in growth rates at 9-13 years from felling is given in Figure 78 with a dense central stand of Rubroshorea species, mainly *Shorea leptoclados*, of Type B forest in Segaliud-Lokan F.R. Girth measurements of all stems over 12 ins in 1966 (9 years from felling)

FIGURE 78 Growth and stocking of natural regeneration illustrating dense regrowth.
F 1957
Girth at 1966
Average C.A.I.1966-70



● Average C.A.I. 2.00ins girth,or over
● Average C.A.I. 1.50-1.99ins girth

are shown together with average current annual increments in girth over the period 1966-70. Concentric circles of 0.1, 0.2, and 0.4 acres (0.04, 0.08 and 0.16 ha) contained highest density of dipterocarp stems in the central area, where the trees were also growing faster:

No./acre	Dipterocarps		Increments (ins C.A.I.)	
Sample area(acres)	1966	1970	1.50+	2.00+
0.1	320	330	90	40
0.2	250	275	60	25
0.4	188	205	40	15

This example illustrates variation in stocking and growth (the central area was subjectively selected from a large area of forest as containing an example of excellent stocking) and the necessity of considering large samples (see also Figure 60). In order to overcome local variations the yeild plots are fairly large (2.5 acres, 1 ha) and randomised. One tree is selected for detailed measurement from each half chain square (10mx10m) and growth measurements are averaged (Figure 82).

Species Composition of Regeneration

The varied nature of regeneration stands has been discussed earlier and an example of 10 year regeneration in the vicinity of the above example, covering an area of 1.5 acres (0.6 ha) has been given in Figure 64. In that example three categories of species namely regeneration species, understorey species and seral species were illustrated. These were also the categories used in R.P.273. The acceptability rating of regeneration species ('Assessment of Regeneration Following Felling' page 257) is based on expected frequencies of the commercially acceptable species. As older regeneration contains components likely to persist, unless removed, of different growth rates and utilisation standards may change, a system of classification was devised to combine attributes of silviculture, abundance, marketability and ecological status in the selection of trees for measurement in yield plots.

Nine groups of species are used:

Group 100	*Parashorea* and Rubroshorea species (White and Red Seraya)
Group 200	*Dryobalanops* and *Dipterocarpus* (Kapur and Keruing)
Group 300	*Shorea* sections Richetia and Anthoshorea; *Anisoptera* and *Hopea* species.
Group 400	*Shorea* section Shorea (Selangan Batu), *Cotylelobium* and *Intsia palembanica*.
Group 500	*Eusideroxylon zwageri*
Group 600	*Heritiera, Sindora, Mangifera* etc.
Group 700	*Koompassia excelsa, Canarium* species, *Sympetalandra borneensis* etc.
Group 800	*Diospyros* and *Eugenia* species, *Paranephelium nitidum* etc.
Group 900	*Anthocephalus, Macaranga, Geunsia, Trema* etc.

In this classification group 100 represents the common, fast growing, commercially acceptable lightweight species; group 200 species are generally slower growers of heavier wood; group 300 are the less common dipterocarp species; and group 400 includes species with harder timbers. Group 500 is used for species of special use, or of limited occurrence, with only *Eusideroxylon* thus far assigned. Group 600 are species which reach timber size, yield useful timber, but are found in small quantities and are not always cut at present.

A tree must belong to one of these six groups to qualify as a chosen tree (or crop tree) for inclusion in regeneration stocking. In practice most are from groups 100, 200. Trees of group 700 are those capable of reaching large size but which are not cut at present. Group 800 embraces the understorey species (sometimes referred to as "weeds") rarely reaching timber size, while group 900 consists of the seral species which come in after felling.

Stocking Using Yield Plots

Two types of yield plot have been established. In Mark 1 plots all stems over 12 ins girth at each measurement are recorded and in Mark 11 plots only chosen trees (the crop trees) are recorded. Appendix 15 summarises sampling errors for the five parameters of: total basal area, total stems, stocking (of chosen trees), stocking over 12 ins girth, and mean girth of crop trees. These are for the first measurement of 8 sets of Mark 1 plots which, apart from Garinono F 1928 (see below), randomly sample large areas of logged over forest at about 10 years from felling. Standard error as a percentage of the mean for stocking has been under 10 per cent for all series, including those embracing more than one felling period. Efficiency in sampling of the other parameters given has also been generally good with standard errors less than 15 per cent of the mean.

The system based on the half chain square (10 m x 10m) as the unit of stocking means that the population being measured in detail is confined to the well distributed, largest regeneration stems to a maximum of 40 per acre (100 per plot, 100 per ha). Complete stocking at this level should provide adequate stems to last the rotation when perhaps half the number would be more than adequate. Desirable stocking will be discussed in Chapter 10. As for linear sampling assessments stocking exceeding a given size class at a particular point in time can be obtained from the yield plots. Growth rates for various levels of stocking and size class representation will become available after a number of yield plot re-measurements are completed. Predictions of future growth from stocking based on linear sampling surveys may then be possible. In some cases yield plot analysis reveals circumstantial evidence concerning the role of post-felling girdling, and it is anticipated that crop treatment effects can be followed in Y.P's (yield plots) as for the analysis of R.P.273 given in Chapter 8.

Results to Date from Yield Plots

Some of the more important results obtained from analysis of Y.P.'s measured to mid 1971 are presented in this section. Several of the Mark 1 sets established 1966-68 have been measured twice using a time interval of sufficient length to allow useful girth increment calculations to be made. From these estimates of the time necessary for the larger crop trees to reach six feet girth are given. Full details of the sets of plots referred to are given as Appendices: Appendix 16 contains stand tables of chosen trees by size classes; Appendix 17 gives mean girths of the most abundant chosen tree species, excluding those over four feet girth; and Appendix 18 summarises the average current annual increment of girth by species and size classes for sets of plots. In the latter separate averages are given for the largest two (leading dominants) per chain square (20mx20m) equivalent to a per acre stocking of 20 (50 per plot, 50 per ha).

Type A Forest

Three sets of Y.P.'s fall in forests of this type, two sets in Silabukan F.R. and one in Kalumpang F.R.

(a) Silabukan F.R. Felled 1954-57 Mark 1.

This series sampled areas which received post felling girdling in 1957. A complete summary of first measurement data has been given elsewhere (A.R.R.B. 1970, in press). Four felling periods are sampled (not randomly, as the set samples the area girdled) as follows: Y.P. 10 in F 1954, Y.P.'s 1,4,5,8 and 9 in F 1955, Y.P.'s 6 and 7 in F 1956, and Y.P.'s 2 and 3 in F 1957. The location of Y.P.'s 6, 7 and 8 is illustrated in Figure 68, and the LS½ sample (Appendix 11) covers the F 1955 area in the vicinity of Y.P. 8 R.P.45 (Figure 60) was also felled in 1955 and girdled in 1957.

Summaries of two measurements, 1968 and 1971, are given in the Appendix, viz.: Appendix 16 Table 1 stand tables of chosen trees by size classes, Appendix 17 Table 1 mean girths of most abundant chosen tree species, Appendix 18 Table 1 average current annual girth increments by species and size classes.

Parashorea malaanonan was the most abundant chosen tree species (61 per cent overall) and was present in all plots, most abundant in seven. *Shorea leprosula* was next in importance (22 per cent overall), present in all plots except Y.P.4, and most abundant in Y.P.'s 3 and 6. Four other species accounted for 2 per cent or more of chosen trees. *Dryobalanops lanceolata* was present in four, most abundant in Y.P.4; *S.parvifolia* was present in six plots; *Dipterocarpus caudiferus* was present in two, mainly in Y.P.4; and similarly, *S.leptoclados* was mainly in Y.P.2 *Eusideroxylon zwageri* was very scarce in this area.

Comparison of results by time of felling suggests that those plots girdled later have grown less well. Poorest results to date are shown by Y.P.10 (see Appendices) which had lowest values for stocking, overall mean girth and current annual increment:

History	F1957	F1956	F1955	F1954
Plots	2,3	6,7	1,4,5,8,9	10
Average C.A.I.(ins)	1.45	0.99	0.94	0.53
Average girth 1968(ins)	17.3	17.0	14.5	6.1
Average girth 1971(ins)	20.5	18.9	16.4	7.2

This circumstancial evidence re-enforces earlier statements concerning the desirability of early post felling girdling treatment and suggests that treatment delayed more than two years can seriously set back growth rates of regeneration (cf R.P.273 C, especially plot 2).

Differences in growth rates between species, with the Rubroshorea species consistently faster than *P.malaanonan* and *Dr.lanceolata* in size classes over 18 ins girth, affected plot performance. Thus in the F1957 pair Y.P.2 with 26 Rubroshorea and 18 *Dr.lanceolata* contributing to increment had average C.A.I. of 1.13 ins compared with 1.78 for Y.P.3 with 57 Rubroshorea (48 *S.leprosula*) and no *Dr.lanceolata*. Similarly for the F1956 pair Y.P.6 had average C.A.I. of 1.10 with 51 *S.leprosula* and 37 *P.malaanonan* compared with 0.89 ins for Y.P.7 with 67 *P.malaanonan* and 23 *S.leprosula* Plots 3 and 6 also had highest overall mean girth of chosen trees. Of the five Y.P.'s felled in 1955, Y.P.8 had highest average C.A.I. at 1.21 ins coinciding with highest representation of Rubroshorea stems and Y.P.4 the lowest, at 0.77. In this plot 25 *Dr.lanceolata* 15 *D.caudiferus* and only 1 Rubroshorea contributed to increment.

In Y.P.'s 2,3 the invasive species *Macaranga hypoleuca* averaged 14 per plot greater than 24 ins girth at first measurement compared with an average of 34 per plot for the set felled two years earlier.

Growth rates in R.P.45 for the period 1966-1971 are summarised in Appendix 18, Table 2 for comparison. Overall mean C.A.I.'s by species are similar to those for the ten yield plots combined, though there is some difference between size classes. As data spanning a longer time scale is available for R.P.45, it is incorporated here. The assessed area was 4.8 acres (1.9 ha) and measurements are available from 2.9 years from felling to 15.5 years, for the best 40 distributed trees per acre, i.e. the same population as measured in the Y.P.'s. The species composition of the measured trees has fluctuated as the best trees at each measurement were selected. *S.leprosula* grew faster than *P.malaanonan* as the following summary shows:

Table 55. Numbers of Trees by Sizes R.P.45

(a) 1958 F+2.9 years

Girth(ins)	<3	3<6	6<9	9<12	Total	Per Cent
P.malaanonan	10	28	16	2	56	35
S.leprosula	1	13	18	-	32	20
Other dipterocarps	13	28	27	3	71	45

(b) 1971 F+15.5 years

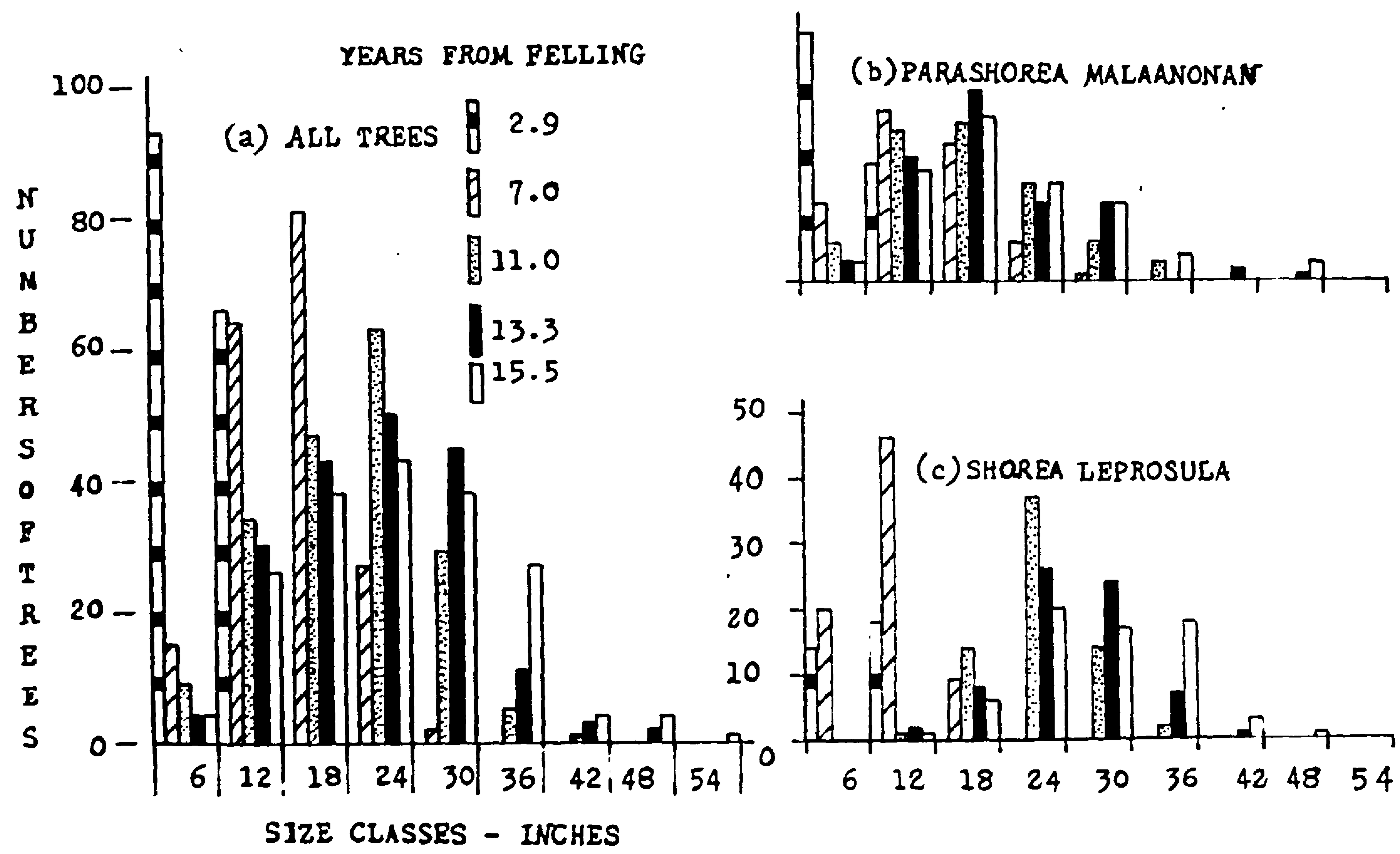
Girth(ins)	<12	12<18	18<24	24<30	30<36	36+	Per Cent
P.malaanonan	20	25	15	12	4	3	43
S.leprosula	1	6	20	17	18	4	36
Other dipterocarps	9	7	8	9	5	2	21

Progression of measured trees through size classes is illustrated in Figure 79. Mean girths (in ins) at various times from felling were as follows:

Years from F	2.9	5	6	7.8	8.9	11	13.3	15.5
Mean girth(ins)								
40/acre	5.3	9.8	11.7	14.4	16.0	17.8	20.0	21.8
25/acre	6.8	12.4	14.4	17.6	19.5	21.0	23.5	25.8

This suggests that current increment rates have tended to decline, on average, but as Appendix 18, Table 2

FIGURE 79 R.P.45 SILABUKAN F.R. DISTRIBUTION OF MEASURED TREES BY SIZE CLASSES - BEST 40/ACRE



shows the larger trees are still growing fairly rapidly Many of the larger stems grew more rapidly between 1966 and 1971 than in the period 1962-66, and the lower growth rates are on trees which may be expected to be gradually lost from the stand due to competition. Changes of chosen trees were much more frequent in the early stages of growth: 50 per cent were changed at 3 to 7 years from felling, 28 per cent at 7-11 years and only 3 per cent thereafter. Between 6 and 9 years the proportion of the stand basal area contributed by dipterocarps rose from 19 to 24 per cent of the total.

Returning to the Y.P.'s overall stocking of dipterocarps in classes 100-300 (and also of all measured stems over 12 ins) was highest within the felling date sets in the three plots with best C.A.I. of chosen trees i.e. Y.P.'s 3, 6 and 8. Average per acre stocking for all plots at the two measurements was

Table 56 Average Per Acre Stocking
10 Y.P.'s Silabukan F.R.F. 1954-57

Category	Time from F(years)	12.5	15.2 (averages)
Total Stocking	12ins+	210.9	204.1
	30ins+	19.8	26.7
Groups 100-300	12ins+	67.3	66.7
	30ins+	8.3	9.2
Chosen Trees only	12ins+	25.9	26.6
	30ins+	6.4	7.4

That is some 32 per cent of all measured trees were of species in groups 100-300 at first measurement, and this changed slightly to just under 33 per cent at the second measurement. Similarly the numbers of chosen trees over 12ins constituted 12.2 per cent of the stands at first measurement and 13 per cent at the second.

Forty four of the chosen trees (24 of *P.malaanonan*) exceeded six feet girth, equivalent to 1.8 per acre, and these may not last the rotation. The largest 20 chosen trees per acre (50 per plot) exceeded 12 ins girth at 15.2 years from felling (Appendix 16) and if current growth rates are maintained (Appendix 18) the following times will be taken to pass through size classes:

Size class(ins)	12<18	18<24	24<30	30<36	36<48	48<60	60<72
Time (years)	8.6	5.4	3.8	3.2	6.6	7.5	6.3

a total of 41.4 years. This gives an estimated rotation from felling to over six feet girth of 57 years as an average for the area as a whole. If individual times of felling are taken then the following considerations apply:

F1954 Y.P.10 had only 7.6 per acre over 12 ins at 16.7 years, giving a rotation for them of 58 years. If 20 per acre required then growth from the six inch class requires a rotation of 66 years.
F1956 Y.P.'s 6 and 7 averaged 32.2 per acre over 12 ins at 14.7 years, and 24 per acre were available over 18 ins; these latter would require a rotation of 50.5 years.
F1957 Y.P.'s 2 and 3 had an average of 27.4 per acre over 12 ins at 13.6 years, and 21.4 were available over 18 ins which would require a rotation of 49.4 years.

Similarly R.P.45 at 15.5 years had the largest 20 per acre in excess of 18 ins girth and if current rates are maintained (Appendix 18, Table 2) the following times will be taken to pass through size classes:

Size class(ins)	18<24	24<36	36<48
Time (years)	6.6	8.9	4.7

and thereafter as above, for the yield plots, giving a total of 34 years. This gives an estimated rotation from felling to over six feet girth of 49.5 years.

Thus in the better stocked areas rotations of about 50 years are adequate for the largest 20 per acre to exceed 6 feet girth, but, without further intervention of a silviculture nature, the more poorly stocked areas (c.f. much of the LS½ area of Figure 68, Appendix 11) require much longer periods.

(b) Silabukan F.R. Felled 1961 Mark 11

A series of five plots was laid out in 1970 to sample the area felled in 1961. The location of Y.P.'s 3, 4 and 5 are shown in Figure 80. All received post felling girdling treatment within a year of felling. Stand tables of chosen trees by size classes are given in Appendix 16, Table 2.

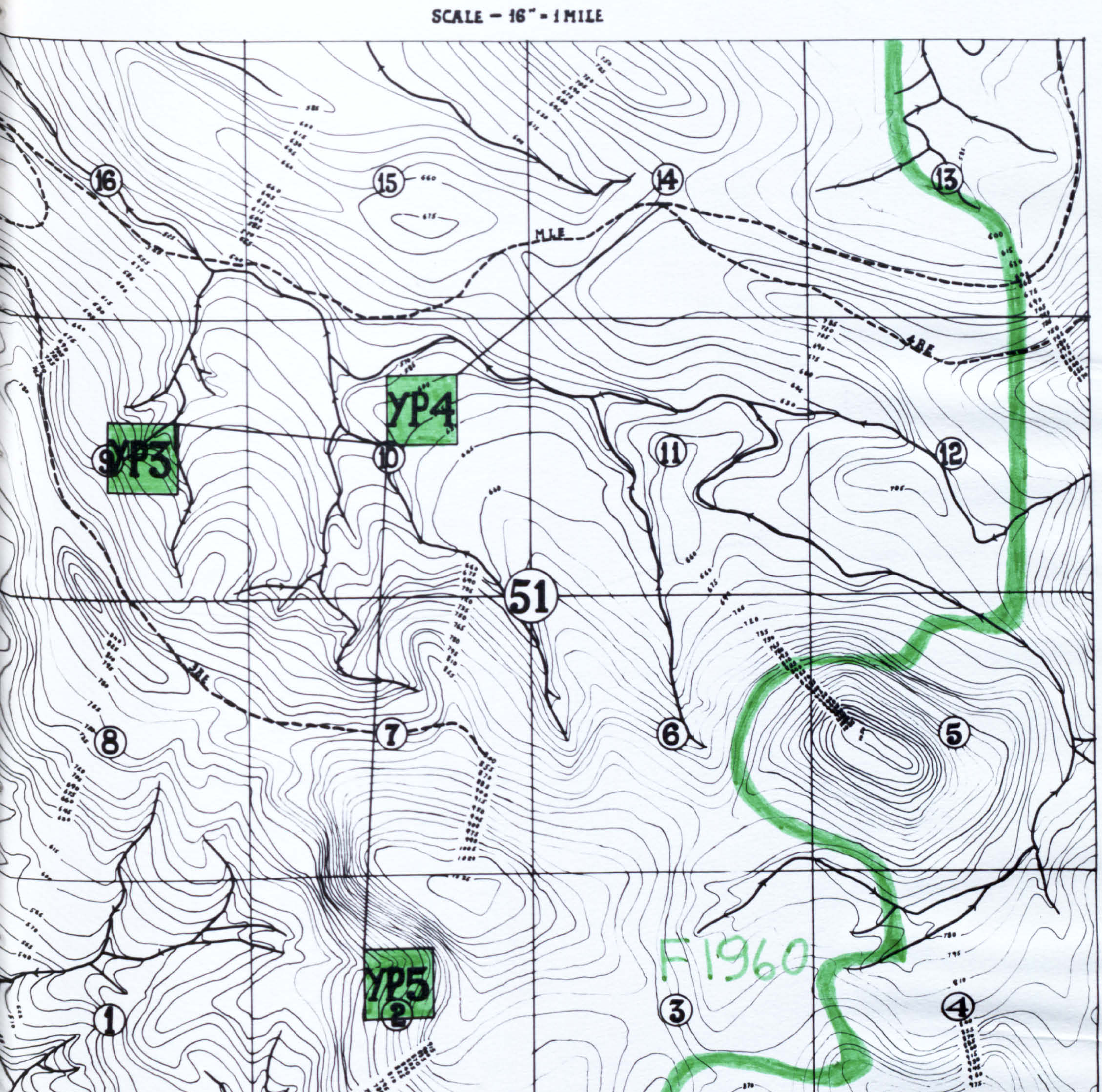


FIGURE 80 Location of Yield Plots in F 1960 area, Silabukan F.R.

Parashorea malaanonan was the most abundant species accounting for 55 per cent of chosen trees, and was present in all plots; every chosen tree in Y.P.5 was of this species but only three stems were recorded in Y.P.1. In the latter *Shorea leptoclados* was particularly abundant (cf Y.P.2 F 1957 above), accounting for over half the chosen trees. Though not recorded in other plots, its representation in Y.P.1 gave it 11 per cent of overall stocking for the set. S.~~*parvifolia*~~ leprosula was present in Y.P.'s 1-4 with 25 per cent overall stocking. *S.parvifolia* also present in Y.P.'s 1-4 and accounting for 7 per cent overall was the only other species of abundance.

At 9.2 years from felling the overall mean girths of chosen trees were 11.8, 11.3, 10.9, 6.8 and 7.8, for Y.P.'s 1-5 respectively, and 9.7 overall. This is about the size reached by R.P.45 at five years. The Rubroshorea species, as in the other samples, had grown considerably faster than *P.malaanonan*:

	Total	Nos 12ins+	Per cent 12ins+
P.malaanonan	237	32	13.5
S.leprosula	108	70	65
S.parvifolia	31	14	45
S.leptoclados	49	26	53

The largest 20 chosen trees per acre exceeded 6 inches girth at 9.2 years from felling and if the growth rates of the preceeding set of plots apply then the estimated rotation to reach six feet girth is of the order of 59 years.

(c) Kalumpang F.R. Felled 1957-59 Mark 1

A set of 10 plots sampled areas felled over during 1957-1959; some areas were girdled late, others did not receive post felling girdling. A summary of performance with respect to history is given below. Summaries of measurements made in 1967 and 1970 are given in the Appendix.

Parashorea malaanonan was the most abundant chosen tree species (35 per cent, overall) present in all plots, most abundant in three and second in a further five plots. *Shorea leprosula* and *S.parvifolia* , with 25 and 22 per cent of chosen trees respectively, were also present in all plots, the former most abundant in 3, second in another, while the latter was most abundant in two plots and second in a further four. Three other species accounted for 2 per cent or more: *S.leptoclados* 6 per cent, present in four plots, most abundant in Y.P.10; *Eusideroxylon zwageri* (locally abundant in this area) was selected as the chosen tree only in Y.P.2. where it was the most abundnat species with *Dipterocarpus applanatus* (cf R.P.18); *S.pauciflora* present in 8 plots accounted for a little over three per cent overall. A number of other species were also selected but *Dryobalanops lanceolata* was generally absent.

Further circumstantial evidence suggesting the desirability of early girdling treatment is provided by this set:

History	F1957 G1960	F1957 no G	F1958 G1960	F1959 G1959	F1959 no G
Plots	1,2	9,10	3,4	5,6	7,8
Av.C.A.I.(ins)	0.71	0.78	1.12	1.28	0.80
Av.girth 1967(ins)	8.1	11.3	12.5	13.5	8.4
" " 1970 "	10.3	12.9	15.4	17.2	9.7

Best increment and largest average size of chosen trees occurred in plots treated in the same year as the area was felled (Y.P.'s 5,6). A major factor contributing to differences in C.A.I. was the preponderance of small sized chosen trees in some plots e.g. Y.P.1 43 less than 12 inches girth at 1970, Y.P.2 64 less than 12 ins (including a lot of slow growing *Eusideroxylon*) with average C.A.I.'s of 0.89 and 0.50 respectively. In pairs of plots with the same history higher numbers of Rubroshorea largely account for one plot having higher average C.A.I. than the other.

Poor growth in ungirdled areas is probably explained by the depressant effect of residual medium sized trees. There were an average of 26.6 trees per acre of 3 feet girth and greater of groups 700, 800 in the ungirdled plots compared with 6.6 in those girdled. Corresponding basal areas for these were 48 and 11 square feet per acre respectively out of total plot basal areas per acre of:

Time from F	8.7	11.9
Ungirdled	86	95 (trees 3ft+63)
Girdled	49	64 (" " +30)

Seral species of group 900 grew faster in girdled areas; at the second measurement there were 3.7 per acre over 3 ft compared with 1.0 per acre in the ungirdled area.

Average per acre stocking for all plots at the two measurements was:

Table 57. Average Per Acre Stocking 10 Y.P.'s Kalumpang F.R.F. 1957-59

Category	Time from F(years)	8.7	11.9 (Average)
Total stocking	12ins+	175.4	177.8
	30ins+	27.6	33.1
Groups 100-300	12ins+	27.1	31.3
	30ins+	3.6	4.5
Chosen Trees only	12ins+	15.2	18.0
	30ins+	2.5	3.6

The proportion of total stocking accounted for by dipterocarps was much less in this set than in the Silabukan Mark 1 plots though the proportion of chosen trees over 12 ins was similar.

Only twelve (11 of *P.malaanonan*) chosen trees exceeded six feet girth in this set. Taking the set as a whole the largest 20 chosen trees per acre (50 per plot) exceeded 6ins girth at 11.9 years from felling (Appendix 16, Table 3), while 18 were over 12 ins, and if current growth rates (Appendix 18, Table 3) are maintained the following times will be taken to pass through size classes:

Size class(ins)	6<12	12<24	24<36	36<48	48<60	60<72	Total
Time(years)	11.3	10.1	6.5	6.9	7.1	9.4	51.3

This gives an estimated rotation from felling to over six feet girth of 63 years, or for the 18 over 12 ins of 52 years. If individual felling times are considered the following apply.

F1957 Y.P.'s 1, 2, 9, 10 had an average of 15.2 over 12 ins at 12.8 years; these would require a rotation of 53 years to reach 6 ft.
F1958 Y.P.'s 3 and 4 twenty stems were available at first measurement, 8.8 years, over 12 ins, and these would require a rotation of 49 years.
F1959 Y.P.'s 5, 6, 7, 8 17.2 per acre over 12 ins at 10.9 years would require a total rotation of 51 years to reach 6 ft.

Rotations here are suggested as being slightly longer than at Silabukan, but if stocking standards are lowered (i.e. less than 20 per acre) similar time periods could be used.

Type B Forest

Two sets of ten plots each in Segaliud-Lokan F.R. (Figure 67) are discussed in detail, and several other sets from different reserves will be described more briefly.

(a) Segaliud-Lokan F.R. Felled 1957 Mark 1

This set (together with the next) were the first yield plots established and the density of sampling, at 3 per cent, is higher than for most other sets of plots. The area sampled was felled in 1957 and girdled shortly after felling. Summaries of measurements made in 1966, 1968 and 1971 are given in the Appendix.

Parashorea tomentella was the most abundant chosen tree species at the first measurement with 30 per cent of overall stocking. This and the other species typical of Type B forest viz *S.leptoclados* (23 per cent overall stocking), *S.leprosula* (14), *Dryobalanops lanceolata* (11), and *Dipterocarpus caudiferus* (9 per cent) were present in all plots. *P.tomentella* was most abundant in Y.P.'s 2, 6, 7, 8, 9; *S.leptoclados* in Y.P.'s 1, 3, 4, 5; and *S.leprosula* in Y.P.10. *S.parvifolia* was the only other species accounting for more than two per cent of chosen trees, this species was present in 7 plots, though a number of other species were represented by small numbers, including *E.zwageri*.

Table 58 shows the gradually increasing role of the regeneration components of the stand:

Table 58. Average Per Acre Stocking 10 Y.P.'s Segaliud-Lokan F.R. F1957.

Category	Time from F (years)	9.3	10.9	13.7
Total stocking	12ins+	245.0	251.0	227.8
	30ins+	25.0	35.0	42.9
Groups 100-300	12ins+	60.3	76.0	82.3
	30ins+	7.0	7.2	10.4
Chosen Trees only	12ins+	24.0	26.5	28.0
	30ins+	3.9	4.3	6.4

Trees in groups 100-300 as a proportion of the stand, rose from 25 per cent at 9.3 years to 30 at 10.9 and to 36 per cent at 13.7 years from felling. At the 1971 measurement chosen trees over 6 ft in girth averaged 0.8 per acre.

The largest 20 chosen trees per acre (50 per plot) exceeded 18 inches girth at 13.7 years from felling (Appendix 16, Table 4) and if current growth rates (Appendix 18, Table 4) are maintained the following times will be taken to pass through size classes:

Size class(ins)	18<24	24<30	30<36	36<48	48<60	60<72	Total
Time (years)	4.8	3.9	3.1	9.5	7.2	9.7	38,2

This gives an estimated rotation from felling to over 6 ft girth of 52 years, and for the 12.7 trees over 24 ins at 13.7 years the rotation time would be 47 years.

(b) Segaliud-Lokan F.R. Felled 1959 Mark 1.

The area was girdled shortly after felling in 1959. Summaries of measurements at 1966, 1968 and 1971 showing stand tables of chosen trees by size classes, mean girths and current annual increments (for 1968-1971) are given in the Appendix.

Species distribution and abundance were similar to the previous set. *P. tomentella* was the most abundant chosen tree species overall (20 per cent), and the most important species in Y.P.'s 1, 3 and 4. This was closely followed by *Shorea leptoclados* with 19 per cent, first in Y.P.'s 5 and 8 with the other abundant species: *S. leprosula* 16 per cent, first in Y.P.'s 6, 7 and 9; *Dr. lanceolata* 14 per cent, most abundant in Y.P.2; and *D. caudiferus* 14 per cent, most abundant in Y.P.10. These five species were present in all plots. Others over 2 per cent were *S. parvifolia* 5 per cent, present in 9 plots; *P. malaanonan* 3 per cent, present in 8 plots; and *S. waltonii* 3 per cent, present in 7 plots.

The following average stocking values may be compared with Table 58:

Table 59 Average Per Acre Stocking 10 Y.P.'s Segaliud-Lokan F.R.F 1959

Category	Time from F (years)	7.4	8.9	11.9
Total stocking	12ins+	181.1	221.8	206.5
	30ins+	18.7	27.6	32.6
Groups 100-300	12ins+	46.7	54.9	56.6
	30ins+	5.7	5.5	7.0
Chosen Trees only	12ins+	20.3	21.6	23.3
	30ins+	3.9	4.3	5.2

Dipterocarps were slightly less in total numbers over 12 ins girth than for the 1957 plots, but formed a similar proportion of the stand at 25-30 per cent. Chosen trees at 11.9 years from felling were 11 per cent, similar to the 1957 plots at 10.9 years from felling. Chosen trees over six feet girth averaged 0.9 per acre at the 1971 measurement.

The largest 20 chosen trees per acre exceeded 12 ins girth at 11.9 years from felling (16.1 exceeded 18 ins) and also at 7.4 years (Appendix 16, Table 5). If the younger state is considered and current growth rates are maintained (Appendix 18, Table 5) the following times will be taken to pass through size classes:

Size class(ins)	12<18	18<24	24<36	36<48	48<60	60<72	Total
Time (years)	7.1	5.1	8.1	9.0	10.0	10.5	49.8

This gives an estimated rotation from felling to over six feet girth of 57 years, slightly longer than for the 1957 set where trees over 4 ft grew rather faster; as fewer increments on these trees were available than for the 1957 set growth rates may be greater and if the 1957 set increments are used for sizes over 4 ft the rotation is reduced to 54 years. The 16.1 trees per acre over 18 ins at 11.9 years require a rotation of 55 years or, if a similar reduction is made for larger sizes, only 51 years.

As the two sets differ only in time of felling they are discussed together below.

Segaliud-Lokan F.R. F 1957-1959 ((a) and (b) combined)

Growth through size classes has been similar despite slight differences in average C.A.I. between the sets. An almost linear relation between size and increment occurred for six inch girth classes to 30 ins girth at which size increment was greatest; growth rates in the 3-4 ft classes may be expected to increase as the bulk of the fast growing regeneration ex-seedlings pass through those classes (pace R.P.45, Appendix 18, Table 2). *Shorea leptoclados* was generally the fastest growing species only exceeded by *S.parvifolia* in the 1959 set where a few large increments swelled the mean for that species. The other Rubroshorea species *S.leprosula* and *S.waltonii* also grew faster than *P.tomentella* , which performed better than *Dryobalanops lanceolata* and *Dipterocarpus caudiferus*.

Average stocking per plot for all chosen trees over the period 1966-1971, representing the 7 to 14 years from felling, was as follows:

Table 60 Average Stocking Per Plot (Ha) Segaliud-Lokan Y.P.'s Numbers of Chosen Trees Over Minimum Girths of:

Set	Time from F (years)	Overall (Max.100)	12ins+	18ins+	24ins+	30ins+
1959	7.4	91	51	24	13	10
1959	8.9	90	54	31	17	11
1957	9.3	96	60	29	14	10
1957	10.9	95	66	41	19	11
1959	11.9	88	58	40	24	13
1957	12.0	89	67	46	24	12
1957	13.0	90	69	51	29	14
1957	13.7	88	70	53	32	16

Stocking by sizes are illustrated in Figure 81 where LS½ results from the same area (cf Figures 65, 66) show progression through size classes. The two leading dominants per chain square (20 m x 20 m) to a possible total of 50 per plot (20 per acre) occurred in size classes as follows:

Table 61 Average Stocking Per Plot (Ha) Segaliud-Lokan Y.P.'s Leading Dominants over Minimum Girths of:

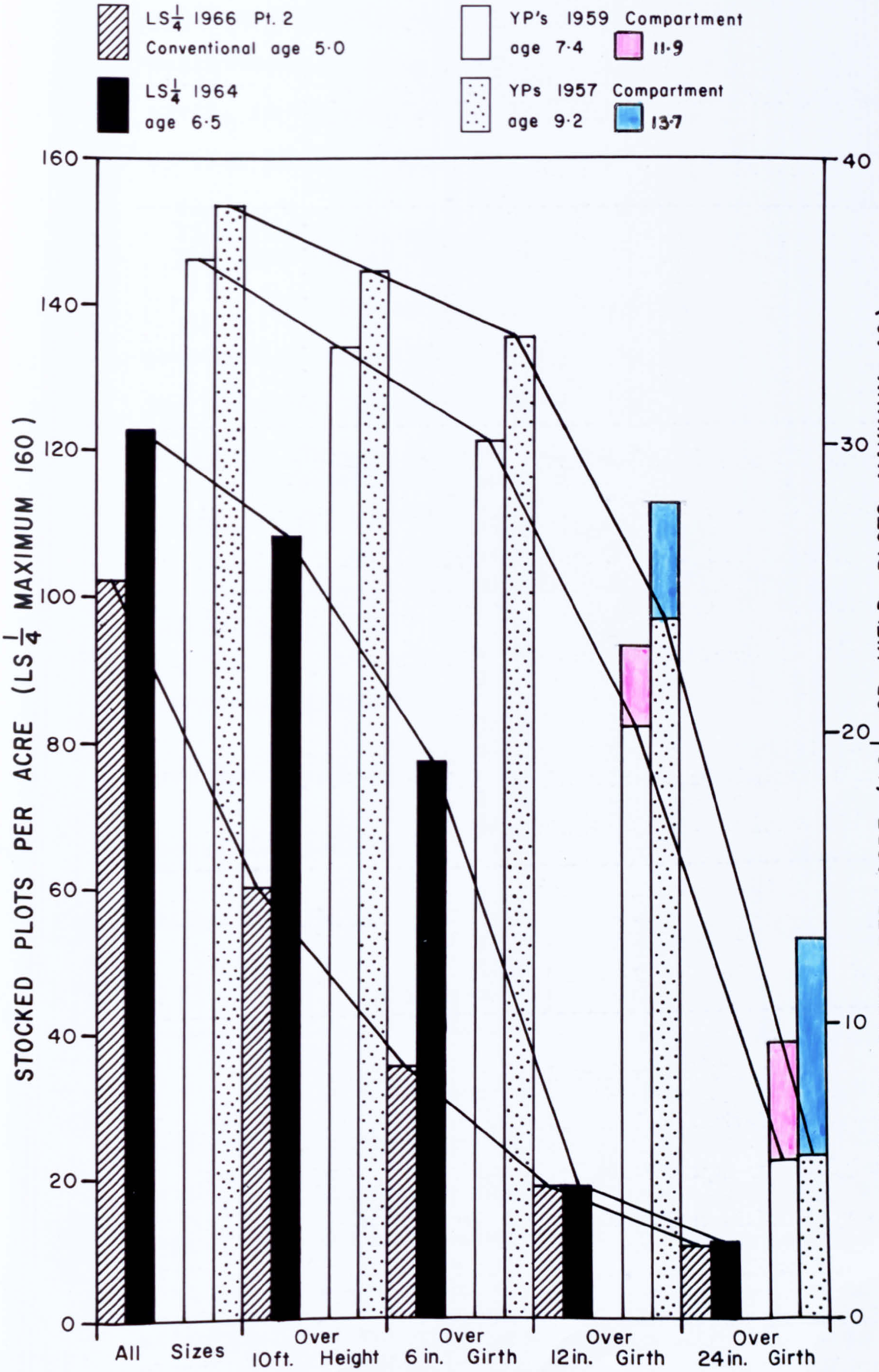
Set	Time from F (years)	12ins+	18ins+	24ins+	30ins+	36ins+
1959	11.9	41	32	22	13	9
1957	12.0	45	37	23	12	9
1957	13.0	46	39	26	14	9
1957	13.7	46	41	29	16	10

Both Tables 60 and 61 refer to the well distributed marked trees, but, as indicated in Tables 58 and 59, gross stocking of dipterocarps was higher. Mortality and changes of tree selection which may arise through differential growth rates, are both well provided for. Gross stocking of all trees presently classifiable as timbers exceeded 100 per ha (40/acre) over 18 ins girth and 50 per ha (20/acre) at 12 years

FIGURE 81

STOCKING BY SIZES

SEGALIUD-LOKAN FOREST RESERVE



Forest Department, Sabah. 1971.

from felling; about double the numbers of chosen trees. In addition to movement through measured size classes smaller dipterocarps are continuously being recruited into measurement as they reach the minimum size of 12ins girth, in contrast with decline in numbers of invasive species (group 900) viz:

Set	1959	1959	1957	1957	1959	1957
Time from F(Years)	7.4	8.9	9.3	10.9	11.9	13.7
Per cent numbers 900	25	23	37	33	16	27

An illustration of the pattern of growth is provided by considering changes in numbers of five of the commonest species in Y.P.5, 1957 set:

Table 62 Changes in Plot Values. 5 Species Y.P.5 Segaliud-Lokan F 1957

Species	Time From F (years)	Total Stems Over: 12 (ins girth)	24	30	Basal area (sq. ft.)
Geunsia pentandra	9.3	129	61	23	43
	10.9	99	66	28	40
	13.7	12	10	8	9
Macaranga hypoleuca	9.3	101	37	19	31
	10.9	99	58	27	39
	13.7	68	49	37	42
Parashorea tomentella	9.3	35	3	3	6
	10.9	48	3	3	8
	13.7	50	5	3	11
Shorea leptoclados	9.3	72	3	2	11
	10.9	84	12	2	18
	13.7	86	29	8	24
Shorea leprosula	9.3	27	2	-	4
	10.9	28	2	1	5
	13.7	31	5	2	8

(All values per plot, divide by 2.5 for per acre)

Of the five species the three dipterocarps are continuously increasing in numbers and in basal area as established trees move through the size classes; the larger increase of *S.leptoclados* in the sizes over two feet reflects trends in the whole area, similar to the effects of differential growth between *S.leprosula* and *P.malaanonan* in Type A forests (e.g. Figure 79). *Geunsia pentandra* is a short lived nomadic species which tends to die off when about 2-3 ft girth at some ten years from felling. The other invasive species, *Macaranga hypoleuca,* though unable to increase in numbers, persists much longer and survivors reach sizes of 4-6ft girth.

Overall mean plot basal area changed from 132 (53 /acre) square feet at 7.4 years to 179 (72/acre) at 11.9 years for the 1959 set and from 161 (64/acre) square feet at 9.3 years to 208 (83/acre) at 13.7 years for the 1957 set.

(c) Kretam F.R. Felled 1952-54 Mark 1.

Five plots established in late 1966 in this area were remeasured in 1970. Summary tables of stocking, mean girths and average C.A.I. are given in Appendix 16, Table 6; Appendix 17, Table 5 and Appendix 18, Table 6, respectively.

This set illustrates the difficulty of deriving useful growth functions from areas felled prior to the introduction of mechanical logging and where post felling silvicultural treatment had been neglected. The area sampled is mainly lowlying land with abundance of *Eusideroxylon zwageri* and the low growth rate of this species suggests slower overall growth of chosen trees. At the first measurement *Eusideroxylon* accounted for 29 per cent of chosen trees, practically all of those selected in Y.P.1 and it was also the most abundant species in Y.P.6, and second in Y.P.2. It was recorded in all plots. *Dryobalanops lanceolata* was the most abundant species in Y.P.'s 3 and 5, though absent in Y.P.'s 1 and 2 the species accounted for 18 per cent overall. *Dipterocarpus caudiferus* and *Shorea leptoclados* with the same plot distribution as *Dr. lanceolata* accounted for 10 and 6 per cent respectively. *Parashorea tomentella* with 8 per cent was absent only in Y.P.2; other abundant species were *S.parvifolia* 5 per cent, *S.acuminatissima* 4 per cent and *S.symingtonii* 3 per cent.

The plots are believed to have had the following origins:

History	Handlogged 1952 G1952	F1953 no G	F1954 no G
Av.C.A.I.(ins)	0.37	0.52	0.57
Av.girth 1966(ins)	7.7	9.3	11.6
" " 1970(ins)	8.4	10.5	13.5
Plots	1,2	5,6	3

and average per acre stockings for all plots at the two measurements were:

Table 63. Average Per Acre Stocking 5 Y.P.'s Kretam F.R. F 1952-54.

Category	Time from F(years)	13.6	17.1 (Average)
Total stocking	12ins+	201.1	170.6
	30ins+	38.0	36.9
Groups 100-300	12ins+	25.4	21.2
	30ins+	7.3	6.9
Chosen Trees only	12ins+	12.2	13.0
	30ins+	5.3	5.4

Total dipterocarp representation in the area is poor but it is considered that if *Eusideroxylon* had been ignored in selection of chosen trees higher representation of groups 100-300 could have improved the average C.A.T. (cf Figure 42). Management of areas dominated by *Eusideroxylon* cannot ignore the species, though it may be possible for dipterocarps to grow through its shade; the high representation of *Dr.lanceolata* and *D.caudiferus* suggest that these slower growing, more shade tolerant species will form much of the second crop.

The largest 20 chosen trees per acre exceeded 6ins girth at an average time from felling of 17.1 years (Appendix 16) and if current growth rates are maintained (Appendix 18) the following times will be taken to pass through size classes:

Size class(ins)	6<12	12<18	18<24	24<36	36<48	48<60	60<72
Time (years)	16.2	9.1	5.8	14.2	13.0	10.5	7.3

a total of 76.1 years. This gives an estimated rotation from felling to over 6ft girth of 93 years. The apparent rotation can be reduced if the total stocking of classes 100-300 over 12ins is considered or the 13 chosen trees per acre over 12ins are taken.

The rotation would then be 78 years. It is possible that silvicultural treatment being undertaken in the area may greatly improve the growth status of the potential crop trees but the combination of species suggest longer rotations, even with treatments, than other Y.P. sets.

(d) Tenegang F.R. Felled 1957 Mark 11.

A set of 8 plots sampled areas felled over in 1957 which were girdled shortly after felling. In this area *Parashorea tomentella* accounted for 28 per cent of chosen trees, and *P.malaanonan* a further 12 per cent. Of the Rubroshorea species *Shorea parvifolia* was most widespread, this and the preceeding two species being present in all plots. *S.parvifolia* accounted for 15 per cent overall, slightly less than *S.leptoclados* (16 per cent) which was more patchily distributed: though most abundant in two plots, and second in another two, it was recorded in only five plots.

At 12.1 years from felling this set had an average of 14.3 chosen trees per acre over 12ins girth, and 21.6 over 6ins. If the same growth rates as for Segaliud-Lokan 1957 apply then the former would require 58 years and the latter 68 years from felling to reach 6 ft girth.

(e) Tenegang F.R. Felled 1961-63 Mark 11.

Fifteen plots sampled these areas where species distributions were broadly similar to the previous set, but *S.leptoclados* (2 per cent). *S.parvifolia* (4 per cent) were much less abundant and *Dipterocarpus caudiferus* (11 per cent) and *Dryobalanops lanceolata* (7 per cent) were of greater importance. Only one measurement has been undertaken for both Tenegang sets and it would be premature to give greater detail. However of the areas felled 1961-63 size class representation in the Y.P.'s felled and girdled in 1963 was better than for earlier areas or where no girdling had been done. At 7.0 years from felling there was an average of 18.6 stems per acre over 12ins girth in the area felled and girdled in 1963.

(f) Garinono F.R. Felled 1928 Mark 1.

Five yield plots were placed in the vicinity of spar pole sites in the area worked by high lead logging in 1928 (see Figure 58) to specifically sample heavily disturbed sites. Plot positions were selected by reference to the original logging map, traces of logging in the form of rusty wire rope, and abundance of *Anthocephalus chinensis*. Average C.A.I. for 1968-1969 is given in Appendix 18, Table 7 and a summary of species and size class representation at 41 years from felling, of chosen trees, is given in Appendix 16, Table 7. This area received no silvicultural treatment.

Parashorea tomentella and *Dipterocarpus caudiferus* were the most abundant chosen tree species but Rubroshorea species were particularly abundant in larger sizes. It is probable that elements of three populations contribute to stocking of chosen trees. Firstly some larger stems, especially of *P.tomentella*, *Dr.lanceolata*, and *D.caudiferus*, were probably present as at least intermediate sized trees at the time of logging; secondly the bulk of Rubroshorea species and *P.tomentella* from 3 to 6ft girth and over probably grew from seedlings; and lastly the majority of chosen trees under one foot girth probably represent recruitment at various times since logging. Distribution of *S.leptoclados* stems in size classes is particularly interesting with a concentration in the 4 and 5 ft classes but extending through to 8 ft girth, a range of sizes which would have required average annual girth increments of from 1.5 to 2.4 inches. This range of growth is by no means improbable. Similarly a dearth of stems between the 3 and 5 ft girth classes of *Dr. lanceolata* and *D. caudiferus*, coupled with abundant small representation, suggests subsequent seedling recruitment from the few large trees of these species.

Stand parameters, for comparison with other yield plot sets, at 41 years from felling were:

Stems per acre	12ins+	30ins+
Total stocking	174	54
Trees in Groups 100-300	28.6	9.3
Chosen Trees only	18.8	6.2

In all five plots *Anthocephalus chinensis* formed a high proportion of the basal area, 21 per cent overall, with most stems over 4 ft girth and its longevity as an invasive species beyond 40 years will be of interest. *Glochidion conoratum* and *Pterocymbium elongatum* were also abundant as smaller trees, and the latter especially appears to have survived due to its ability to persist in climber infested areas referred to earlier. *Macaranga* species, *Geunsia pentandra* and other short lived seral species were largely absent. Invaders and understorey species combined accounted for 47 per cent of total basal area (which averaged 110 square feet per acre) and 56 per cent of stems. Appendix 19 summarises an LS$\frac{1}{2}$ survey in the same general area which further confirms these general trends of seral species representation.

Increments for this set of yield plots cover a shorter period than those given for other sets and may later prove abnormally high or low. They give the following times as necessary for trees to pass through the size classes:

Size class(ins)	12<24	24<36	36<48	48<60	60<72	Total
Time (years)	16.6	11.3	7.7	8.7	11	55.3

This would suggest that a further 55 years must elapse before the 18.8 chosen trees per acre exceeding 12ins girth at 41 years from felling (Appendix 16) will exceed 6ft girth. This suggests an effective rotation of 96 years. The estimate may be reduced if distribution is ignored and numbers reduced, e.g. in groups 100-300 12.5 stems per acre exceeded 24ins girth, and 17.8 exceeded 18ins girth at 41 years. These would require estimated rotations of 80 and 87 years respectively to reach 6ft girth and over. Differential growth between species could further reduce these estimates.

(g) Sapagaya F.R. Felled 1934-35 Mark 11

Two plots placed in this area of uncertain history were measured in 1970. Almost certainly some form of silvicultural treatment was done but details are not available.

At 35 years from felling there were 17.8 chosen trees per acre of three feet girth and greater and 14.8 over 4ft. If these trees grow at the rates of the Garinono set then rotations from felling to over six feet girth of 62 and 55 years, respectively, are necessary.

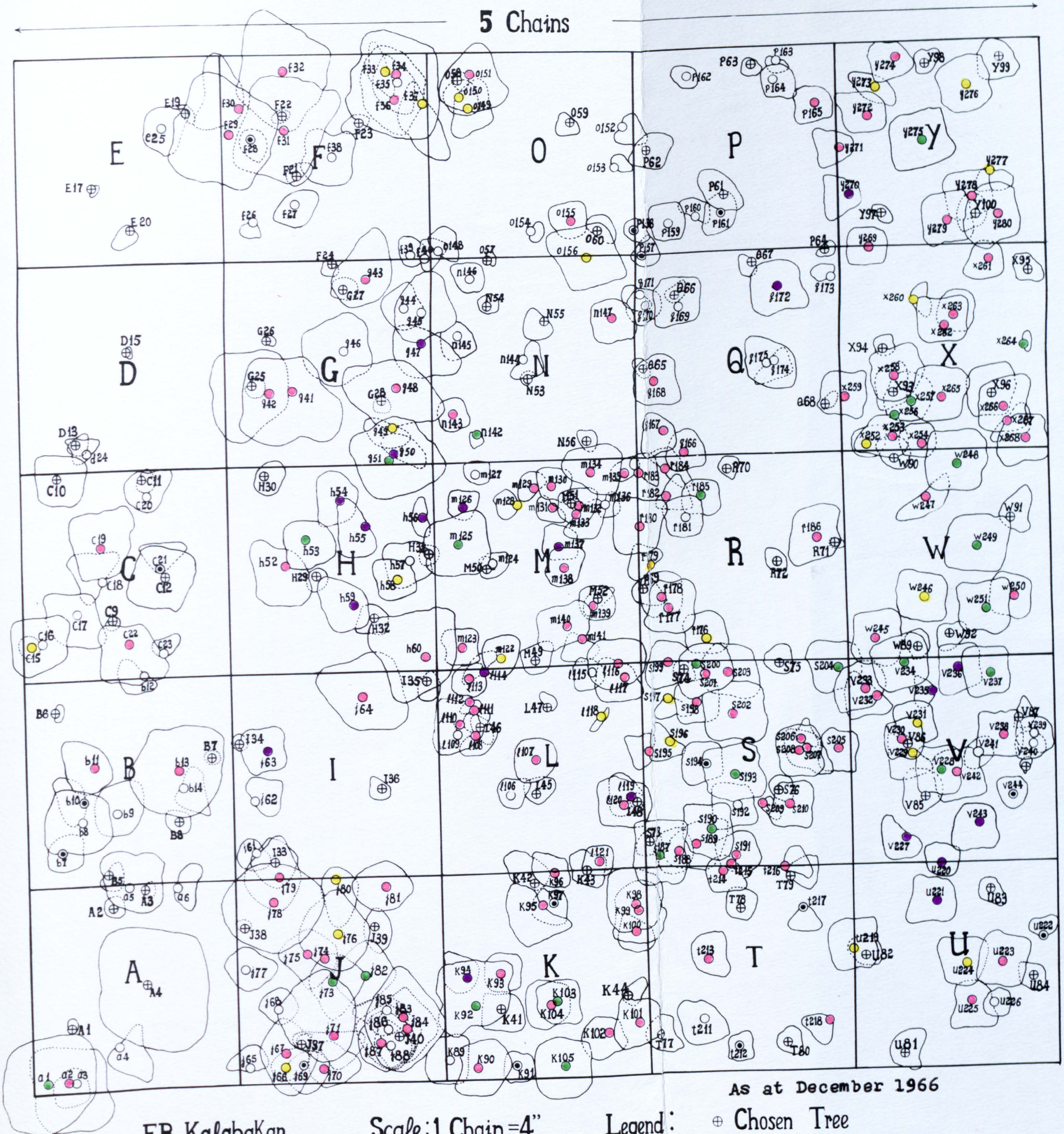
Type C Forest

A number of sets of yield plots have been established in Kalabakan F.R.; two sets of Mark 1 and two of Mark 11 will be discussed here.

(a) Kalabakan F.R. Felled 1953 Mark 1.

Five plots in the vicinity of the camp at Kalabakan sample the area felled in 1953. Part was girdled in 1957 (Y.P.'s 1, 4) and part in 1958 (Y.P.'s 2,3,5). Figure 82 illustrates stocking of Y.P.3 at first measurement in 1967. Summaries of three measurements, 1967, 1968 and 1970 are given in the Appendix.

A large number of species were included as chosen trees in this set, the most abundant overall being *Shorea parvifolia* with 28 per cent. This species was present in all plots and was the most abundant species in Y.P.'s 3 and 4. *Parashorea tomentella* accounted for



As at December 1966

F.R. Kalabakan
Coupe 1953
YP No.3

Scale: 1 Chain = 4"

- Anthocephalus chinensis
- Macaranga hypoleuca
- Macaranga gigantifolia
- Geunsia pentandra

Legend:
- ⊕ Chosen Tree
- ⊙ Commercial Species
- ○ Weed Tree

20 per cent, but was mainly present in smaller sizes; this species was most abundant in Y.P.'s 1 and 5. Among the Rubroshorea group *Shorea leprosula*, *S.leptoclados* and *S.smithiana* were well represented with 7.7 and 3 per cent respectively. These were absent in Y.P. 1; *S.leptoclados* was also absent in Y.P.4 and *S.leprosula* was the most abundant species in Y.P.3. Other species accounting for more than two per cent were *Dryobalanops lanceolata* (10 per cent) especially abundant as a large tree in Y.P.4 and *Eusideroxylon zwageri* (5 per cent).

Possibly as a result of delayed girdling, or exceptionally severe logging (logs from the area were dragged to the Kalabakan River prior to the construction of the main road) overall growth to plot establishment was poor and stocking was patchy. Y.P.1 was particularly poorly stocked and had few additional dipterocarps to back up chosen trees. Only in Y.P.4 was there an abundance of good regeneration, especially of vigorous *S.parvifolia* which accounted for much of the stocking of groups 100-300 over 30 ins in Table 64.

Table 64 Average Per Acre Stocking 5 Y.P.'s Kalabakan F.R. F1953.

Category	Time from F (years)	13.5	14.7	17.4
Total stocking	12ins+	198.2	185.7	144.2
	30ins+	38.5	45.7	47.2
Groups 100-300	12ins+	33.0	31.9	29.9
	30ins+	5.1	6.5	8.3
Chosen Trees only	12ins+	17.2	17.5	18.9
	30ins+	4.2	5.5	6.0

Despite an apparent decline in total dipterocarp representation, possibly reflecting lack of recruitment, the proportion increased from 16 per cent at 13.5 years to over 20 per cent at 17.4. Decline in total numbers and an increase in those over 30ins girth reflects the trend of growth of *Macaranga* species, *Anthocephalus chinensis* and *Geunsia pentandra* (Figure 82) as discussed above for Type B plots.

The largest 18.9 trees per acre (47 per plot) exceeded 12ins girth at 17.4 years from felling and if current growth rates are maintained the following times will be taken to pass through size classes:

Size class(ins)	12<18	18<24	24<36	36<48	48<60	60<72	Total
Time (years)	8.6	5.6	10.3	13.0	8.5	10.7	56.7

This gives an estimated rotation from felling to over six feet girth of 74 years. The rotation applying to Y.P.4, atypically highly stocked, on the same basis (i.e. average rates for all five plots) would be only 60 years as 18.4 stems over 24 ins girth were present at 17.4 years (Appendix 16, Table 8). The most poorly stocked plot, Y.P.1 with 17.6 chosen trees per acre over 6ins, would require 85 years. This period would be necessary if final stocking of 20 per acre over the area as a whole is to be obtained.

(b) Kalabakan F.R. Felled 1955-1956 Mark 1.

A set of 7 plots sampled the area felled 1955-56; all plots fell in areas which received delayed post felling girdling. The following summarises stocking and history:

Felled	1955	1955	1956
Girdled	1958	1959	1959
Plots	4,5	2,3	1,6,7
Time from felling(years)	12.1	12.1	11.1
Av.girth,chosen trees	12.9	11.6	13.0
Chosen trees/acre 12ins+	16.2	16.4	18.6

Further details of stand table distribution of chosen trees and mean girths, are given in the Appendix. Complete tables pertaining to this set have been given elsewhere (Fox 1970a).

This area contained a high proportion of *Eusideroxylon zwageri* and also of the two common *Parashorea* species. *Eusideroxylon* accounted for 26 per cent of chosen trees overall and was the most important species in Y.P.'s 3 and 7, but absent in Y.P.5.

Parashorea malaanonan was of the same overall abundance, present in all plots and first in Y.P.'s 1, 2, and 6. *Shorea parvifolia* (first in Y.P.'s 4, 5), *S. leprosula* and *P. tomentella* were also present in all plots and accounted for 16, 12 and 10 per cent of chosen trees respectively. *S. leptoclados* was conspicuous by its absence and *Dryobalanops lanceolata* was scarce.

Stand parameters of overall stocking, for comparison with other sets, at an average time from felling of 11.7 years were:

Stems per acre	12ins+	30ins+
Total stocking	220.6	33.8
Trees in Groups 100-300	21.3	3.4
Chosen Trees only	16.7	6.3

The apparent anomally of more chosen trees over 30 ins than groups 100-300 is explained by abundance of *Eusideroxylon* (group 500). The overall stocking of *Eusideroxylon* over 30ins girth (often taken as the exploitable limit for this species) was 6.6 stems per acre.

Growth rates in this set are likely to be slow and the area has similar characteristics to the Kretam example described from Type B above.

Both Kalabakan examples described so far may be expected to show considerable response to a liberation treatment (cf R.P.273 B above).

(c) Kalabakan F.R. Felled 1959 Mark 11.

Ten plots sampled the area felled and girdled in 1959. Stocking by size classes and mean girths of the most abundant species are given in the Appendix for the first measurement made in 1970 at 10.9 years from felling.

Shorea parvifolia was the most abundant chosen tree species with 23 per cent overall, present in all plots, and first in numbers in Y.P.'s 2, 4, 6, 7, 9 and 10. *S. leptoclados* (11 per cent) was present in 8 plots and first in Y.P.'s 1and 3; *Dryobalanops lanceolata* was equally abundant but present only in 9 plots and first in Y.P.5. *S.macrophylla* was the most abundant species in Y.P.8 but was absent elsewhere. Other abundant species were *S.leprosula* (10 plots, 10 per cent), *P.tomentella* (10 plots, 9 per cent), *S.oleosa* (9 plots, 7 per cent) and *S.almon* (6 plots, 5 per cent). A number of other species, including *Eusideroxylon* were recorded in small numbers as chosen trees.

At 10.9 years from felling there were an average of 16.9 chosen trees over 12ins girth. The proportionally higher representation of Rubroshorea species and low numbers of *Eusideroxylon* compared with the two previous sets suggest that growth rates in this area will be faster.

(d) Kalabakan F.R. Felled 1961 Mark 11.

Five plots sampled the area felled in 1961 and girdled in 1962. Stocking by size classes and mean girths of chosen trees are given in Appendix 16, Table 11 and Appendix 17, Table 9 respectively for the first measurement made in 1970 at 9.1 years from felling.

Of the common species only *Dryobalanops lanceolata* (13 per cent) was recorded in all five plots and was first in Y.P.2 *Shorea leprosula* was most abundant overall and was the most abundant species in Y.P.4; this species accounted for 18 per cent of stocking. *S.parvifolia* was next with 17 per cent and was most abundant in Y.P.'s 1 and 3. *S.leptoclados* was present in only 3 plots but was first in Y.P.5. and accounted for 8 per cent overall. Other common species were *S.almon* (4 plots, 9 per cent), and *S.oleosa* (2 plots, 6 per cent). A large number of other species, including *Eusideroxylon zwageri*, were also included as chosen trees.

At 9.1 years from felling there was an average of 13.4 chosen trees per acre over 12ins girth.

The 1959 and 1961 sets were more generally akin to the area felled in 1956, described above under R.P.273 B, than to the two sets of Mark 1 yield plots described. Control plot trees in R.P.273 B showed the following average C.A.I.'s and times to pass through size classes;

Size class(ins)	6<12	12<18	18<24	24<36	36<48	48<60	60<72
C.A.I.(ins)	0.70	0.66	1.09	1.89	1.97	(2.18)	2.68
Time(years)	8.6	9.1	5.5	6.4	6.1	5.5	4.5

The entry for the four foot class is based on the average of the trees in the three and five feet classes. This suggests that for the R.P.273 B area of F 1956, which had an average per acre stocking of 20 stems over 15ins girth at 12.7 years from F (Appendix 12, Table 2), a rotation of 45 years from felling would be necessary to reach 6ft girth.

Similarly for the F1959 yield plots the 16.9 trees over 12ins at 10.9 years would require a rotation of 48 years and the 13.4 chosen trees in the same category for the F1961 set would require a rotation of 46 years. The periods would be 57 and 55 years respectively if 20 chosen trees per acre are taken, and shorter still if the 3rd silvicultural treatment is undertaken.

Development of Yield Plot Technique

As the above analysis has shown the main results to date are limited to stocking, species, size class representation and girth increment. These preliminary results suggest that conservative rotations of under 60 years can be adopted for well stocked areas; rotations may in fact be considerably less due to differential species growth and faster growth rates on larger trees. Times of passage given with respect to the smaller size classes are overestimates in all cases as the largest stems of the class are the ones likely to grow faster, whereas the increment summaries include individuals making little or no growth (which are unlikely to survive), and stems of all sizes within the class.

It is necessary to relate volume to girth in order to obtain yield estimates. A program to establish volume relations of components present in the yield plots using the Barr and Stroud dendrometer is in hand. Continuous re-assessment of the existing plot sets is needed to chart the progress of the stands. Further plots in areas coming into the population over 10 years from felling will have to be established to take account of changes in logging and inevitable species differences due to the large areas involved.

Correlation of aerial photographic characteristics with yield plot stocking and growth should lead to more precise estimates of areas of regenerating forest with characteristics in common. As suggested earlier it should be possible, eventually, to relate stocking, as determined by LS$\frac{1}{2}$ survey to potential growth. Comparative study of performance of the Mark 1 and Mark 11 series should enable less detailed field sampling of subsequent areas.

CHAPTER 10

DESIRABLE MANAGEMENT OBJECTIVES

In recent years the dipterocarp forests have been worked on a system of felling over large, adjacent coupes down to a general girth limit of six feet. Insufficient dipterocarp trees are left undamaged after logging to form a second crop but abundant seedling regeneration is usually present. Management of the forests in terms of the sustained yield principle entails seeking to obtain maximum output: harvesting of pre-existing natural forest is the first stage in the management process and has greatest effect on the regenerative potential. I have earlier demonstrated the effects of methods which seek to ensure that logging of natural forest maximises this potential (Chapter 6).

When the natural forest has been logged it enters a phase of regeneration towards its pre-existing state, the manifestation of which varies from place to place within the stand depending on the variable effects of logging and other factors. Once regeneration is in motion the dynamic nature of dipterocarp growth should allow cutting of a second crop to occur at an earlier stage in the process of development. At subsequent cuts the presence of numbers of intermediate sized dipterocarp stems may allow a sufficient nucleus for regrowth from these.

Second growth stands refined by poison girdling should carry more stems below the exploitable limits. Differential growth rates lead to the development of a bulge in girth class representation. For example R.P.

38 had the bulge in the 6 ft girth class at 40 years (Table 66), and similar bulges in growth were shown in R.P.45 (Figure 79) and many of the yield plot sets (e.g. Appendix 16, Tables 3, 6, 7, 9). In larger, older, samples the bulge is masked by species differences (e.g. Garinono Appendix 16, Table 7 and Appendix 20).

Intervention in the regenerative process after felling should aim at increasing growth rates (and yields) of the trees which will constitute the following crop so that the period between harvests is a minimum. Rates of growth in the regenerating stands dictate the time necessary for sufficient quantities of exploitable material to accumulate. The number of stems contributing to second crops will vary according to the levels of stocking available and the desirable rotation will be one which is sufficient to enable a satisfactory yield to be taken from the second growth stands.

In this chapter desirable management objectives are discussed in terms of possible "normal" stocking of regeneration. This is linked to rotations and gains in growth due to intervention with a brief account of costs involved. This presentation is made with a view to selection by the Sabah Forest Department of a sound set of management criteria.

Desirable Stocking of Regeneration

Stocking levels for regenerated forest may be examined from two realistic standpoints. The density possible in the natural forest may be repeated and crown diameter limitations may be considered using the stocking of older regenerated plots as a yardstick.

Density in the Natural Forest

Comparison of stand tables of representative natural forest stocking (Appendix 1 and 2; and Appendix 5, Table 2) suggests that for the dipterocarp forests as a whole the range of numbers over 5 ft girth is 12-18 per acre (30-45 per ha) and 9-14 (22-35) over 6 ft. Stocking of individual booking plots in the Segaliud-Lokan and Kuamut enumerations (Appendix 5, Tables 10 and 11) over two thirds of the sample was 5-19 stems per acre (12.5-47 per ha) over 5 ft and a quarter of the plots carried 20 or more per acre (50 per ha) over this size. Adequate stocking of smaller stems in regenerating forest to achieve this level would be 40 per acre (100 per ha). Obviously the sizes of trees in second growth areas will be less than in natural forest, unless extremely long rotations are employed, and higher numbers in the lower exploitable sizes (e.g. compare Table 20 and Appendix 20, Table 1) will compensate for lack of very large trees in average conditions.

Basal area level may well be a limiting factor and the desirable aim must be to concentrate a high proportion of the basal area in the dipterocarps, plus other acceptable regeneration species where necessary. The most complete data available for the parameter of basal area is for R.P.228. Individual hectares within this large area ranged in basal area (5ft+) from 87.5 to 246.7 sq.ft. (35-98.8 per acre) with the following distribution:

Basal areas Per ha	/ acre	No. of Plots	Basal areas Per ha	/ acre	No. of Plots
<100	<40	3	162.5<175	65<70	4
100<112.5	40<45	1	175<187.5	70<75	4
112.5<125	45<50	3	187.5<200	75<80	5
125<137.5	50<55	4	200<212.5	80<85	5
137.5<150	55<60	6	212.5<225	85<90	2
150<162.5	60<65	10	225+	90+	3

That is, at this level of sample, 80 per cent lay between 50 and 90 sq ft per acre (125-225 per ha) and two thirds 50 and 80 (125-200).

Mean basal area was 65.7 sq. ft per acre (164.3 per ha) and in R.P.295, a 10 acre (4 ha) sub-sample, basal area was 125.9 sq. ft. per acre (315 per ha) for all stems over 12 ins girth, with 75.7 per acre (189 per ha) over 5 ft. Other values for these populations were

	Basal area 1ft+	Basal area 5ft+	Source
Per acre	123.9	73.6	Fox 1967 a
Per ha	310	184	"
Per acre	127	60	Nicholson 1962a
Per ha	.317	150	"

Basal area may be higher in Types A, E and F (Chapter 4) and also locally within Types B and C on ridges (e.g. Figure 36). However the available data suggests that 50-80 sq. ft. per acre (125-200 per ha) may be aimed at for the larger trees, with an additional 50 sq.ft. (125) available for undergrowth beneath the emergent or main canopy, some of which, providing crown size is not limiting, could consist of additional dipterocarp contribution to stocking.

Crown Diameter Limitations

Attention has been drawn by Dawkins (1963) to the use of the crown (CD)/bole (BD) diameter ratio in predicting basal area density.

The equation

$$\text{Unit area x canopy density} \div \left(\frac{CD}{BD}\right)^2$$
$$= \text{Basal area density}$$

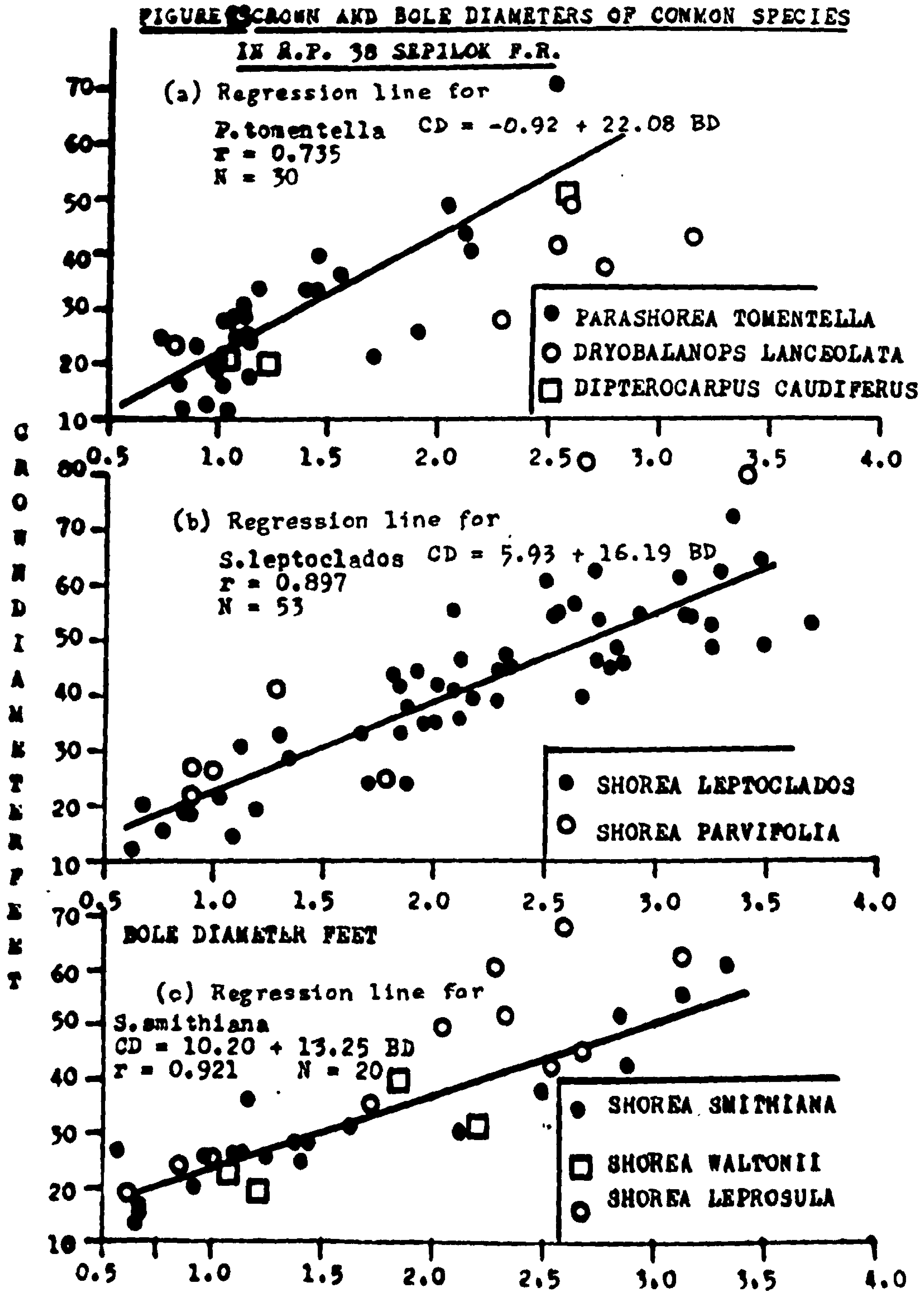
can be used to predict possible stocking levels from measurements of crown and bole diameters where canopy density is 0.9069 for circular touching crowns; 0.7854 for stems at square spacing; and 0.50 specifies a 50 per cent canopy. For consideration of stocking to be aimed for the range of crown/bole ratio in the vicinity of final stocking is of interest. The natural forest pattern of scattered emergents (Burgess 1961) with low numbers of completely exposed crowns (Fox 1967 a) can be considered an extreme as more trees of smaller size could theoretically stand together. Francis (1966) has given an account of crown/bole ratio determination in connection with volume estimation, mainly in natural stands. Species differences, e.g. *Dryobalanops* and *Dipterocarpus* tending to have smaller crowns for given bole sizes, have been long recognised (Howroyd 1954) and any postulated stocking will be weighted, to some extent, by species composition. Dawkins's examples were for single species in plantations and for individuals from open situations. Calculations based on his (Dawkins 1963) data for *Shorea parvifolia* and *S.leprosula* from Malaya suggest that about 20 per acre (50 per ha) with 50-60 sq ft of basal area, can be carried at 6 ft girth or 11 to 12 at 8 ft girth with basal area of 55 to 65 sq ft. Of the two species *S.parvifolia* had slightly smaller crowns, and accounted for the higher stocking levels.

Measurement of crowns and boles during 1970 in R.P.38, in Sepilok F.R. (Figure 83) gave satisfactory linear regressions of crown on bole diameters:

a) Trees < 1.5ft diam	CD= 4.71 +18.22 BD,	r=0.607,	N=60
b) Trees > 1.5ft diam	CD= 7.35 +15.90 BD,	r=0.665,	N=74
c) *P.tomentella*	CD=-0.92 +22.08 BD,	r=0.735,	N=30
d) *S.leptoclados*	CD= 5.93 +16.19 BD,	r=0.897,	N=53
e) *S.smithiana*	CD=10.20 +13.25 BD,	r=0.921,	N=20
f) All measured trees	CD= 6.87 +16.10 BD,	r=0.861,	N=134

Estimates of possible basal area density and equivalent numbers per acre from these regressions are summarised in Table 65. Values predicted from (b) and (f) are

FIGURE [illegible] CROWN AND BOLE DIAMETERS OF COMMON SPECIES IN R.P. 38 SEPILOK F.R.



similar, and closest to (d) amongst the individual species, reflecting the predominance of *Shorea leptoclados*.

Table 65 Possible Stocking from CD/BD R.P.38

	a) Square spacing			b) 50 per cent canopy		
Bole size (ft. girth)	6.5	7.5	8.5	6.5	7.5	8.5
(i) Basal areas (sq.ft. per acre)						
Regression						
c) *P. tomentella*	73	73	72	47	46	46
d) *S. leptoclados*	95	98	102	60	62	65
e) *S. smithiana*	103	112	118	66	71	75
f) All	91	94	98	58	60	62
(ii) Equivalent nos. per acre						
c) *P. tomentella*	22	16	13	14	10	8
d) *S. leptoclados*	28	22	18	18	14	11
e) *S. smithiana*	30	25	21	19	16	13
f) All	27	21	17	17	13	11

Techniques of assessment referred to earlier are all based on theoretical square spacing and if it is assumed that natural regeneration stands will vary from 50 per cent canopy to square spacing then consideration of the crown diameter ratio suggests final (all species) crop spacings between 11 and 27 trees per acre (27-67 per ha) as possible. The relation between numbers of trees at different sizes and basal area per acre is as follows:

Basal area per acre	60	70	80	90
Girth (feet)	Numbers of stems/acre			
5	30	35	40	45
5.5	25	29	33	37
6	*21*	24	28	31
6.5	18	*21*	24	27
7	15	18	*21*	23
7.5	13	16	18	*20*
8	12	14	16	18
8.5	10	12	14	16

On the basis of available evidence final "normal" stocking of 20 stems per acre (50 per ha) is within any limitations imposed by crown size, providing distribution is regular. That is somewhere between 50 per cent canopy and square spacing.

Older Regenerated Areas

Studies in the Garinono area and plots in Sepilok F.R. provide the only examples of older regeneration which have received attention.

(a) Sepilok F.R.

The plots discussed here are of uncertain origin but some ten years of measurement are available (Fox 1972). Three small plots of *Shorea leprosula* (R.P.'s 87, 88 and 89) presumably arose from seedling regeneration following temporary war time cultivation. Comparison with early growth of Segaliud-Lokan yield plots and R.P.45 suggests that these stands originated about 1942 (Figure 84). R.P.38 is an adjacent area of 5.9 acres (2.4 ha) carrying larger trees, mainly *Shorea leptoclados*, whose largest 25 stems per acre averaged 5 feet girth in 1957 and 5.5 feet in 1961. Average C.A.I. for 3-4 year periods during 1957-69, with corresponding times of passage were:

Girth class (ft)	1	2	3	4	5	6	7	8+
Average C.A.I.	1.3	1.4	1.5	1.4	1.2	1.2	1.3	1.5
No. of increments	63	86	36	21	41	50	33	60
Years in class	9.2	8.8	8.0	8.6	9.9	10.3	9.2	7.9

As the yield plot analyses show (Chapter 9) time to reach one foot is of great importance in determining rotation length. For larger sizes an average of ten years for one foot of girth increase is an overestimate if R.P.38 is typical (cf Table 23). Extrapolation of the trends illustrated in Figure 84 suggests a time of origin for R.P.38 as about 1917.

The following growth pattern, based on plots illustrated in Figure 84, is postulated as being typical for areas of well stocked regeneration:

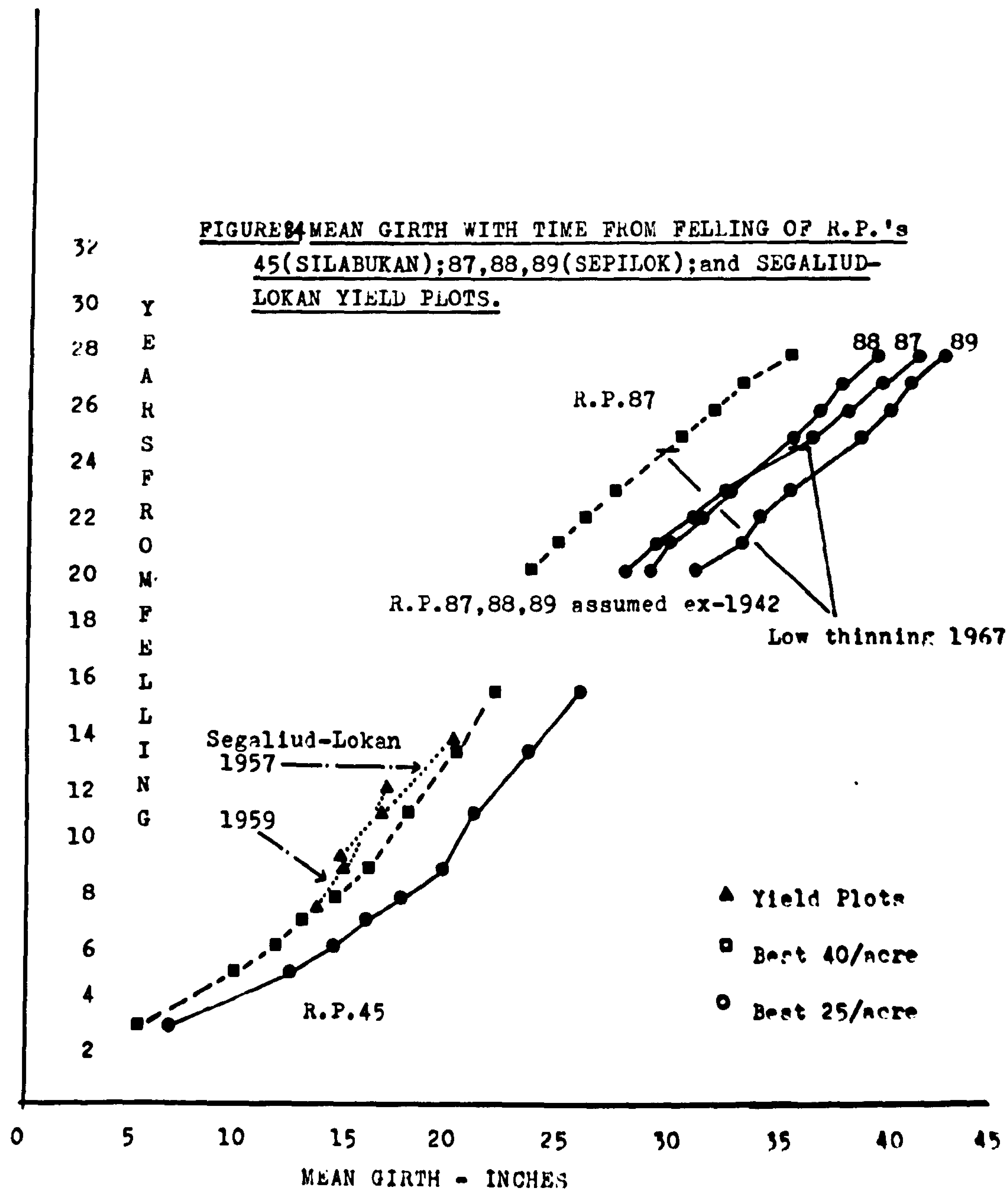


FIGURE 84 MEAN GIRTH WITH TIME FROM FELLING OF R.P.'s 45(SILABUKAN);87,88,89(SEPILOK);and SEGALIUD-LOKAN YIELD PLOTS.
YEARS FROM FELLING
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5
10
15
20
25
30
35
40
45
MEAN GIRTH - INCHES
R.P.87
88
87
89
R.P.87,88,89 assumed ex-1942
Low thinning 1967
Segaliud-Lokan
1957
1959
R.P.45
Yield Plots
Best 40/acre
Best 25/acre

Years from F	5	15	25	35	45
Category	mean girths (ins)				
40 per acre	10	20	30	41	55
25 per acre	12.5	25	35	52	70
20 per acre	17.5	29	43	63	79
15 per acre	21	32	52	73	87

This pattern may be termed the "normal" for areas which are silviculturally treated. It represents considerable spread of the larger trees through size classes as a result of differential species growth and patchy stocking.

More uniform growth occurred in R.P.'s 4 (mainly *Shorea argentifolia*) and 16 (mainly *S.leprosula*); smaller areas with higher density. Total stocking of larger trees, all dipterocarps, at estimated times from felling for all these older areas was as follows:

Table 66 Stocking of Dipterocarps, Sepilok Plots

Plot (area)	Time From F	Size class (ft) 2	3	4	5	6	7+	Total 4+
		(numbers per acre)						
R.P.38 (5.9ac)	40	7.5	3.0	4.7	3.4	4.6	4.5	17.2
	43@	11.2	3.7	4.2	3.9	3.9	6.8	18.8
	53	9.1	6.1	1.7	2.4	3.4	8.1	15.6
R.P.4 (1.0ac)	42	8	3	6	12	8	3	29
	45	6	4	7	10	9	5	31
	50	6	6	5	9	14	5	33
R.P.16 (0.6ac)	28	25.4	33.9	6.8	-	-	-	6.8
	37	20.3	13.5	22.0	11.9	-	-	33.9
R.P.87 (1.0ac)	28	36	17	4	-	-	-	4

@ Thinned after this measurement

All these plots were selected to encompass limited areas of good regeneration (though stocking in R.P.38 has been comparatively patchy) and all have received silvicultural intervention. In addition the three smaller plots have considerable edge effect, swelling their numbers, and are decidedly better stocked than adjacent unsampled areas. The growth and stocking patterns given here probably represent best performance of second growth stands.

(b) The Garinono Area

The area illustrated in Figure 58 has received a great deal of attention. In addition to the five yield plots in Garinono F.R., discussed earlier, an extensive LS½ survey (R.P.258) made in 1967 and 1970 covering 18 acres of sample line south and east of Garinono F.R.; a 50 acre (20 ha) felling study (R.P. 315), discussed in detail elsewhere (Fox 1971): and R.P. 210/1, a 10 acre plot (4 ha) described in Meijer (1970), all provide data on the status of regeneration 40 years after felling. The whole area, apart from the two forest reserves shown on Figure 58 was logged for a second time in 1969.

Complete stocking data for the 1970 LS½ survey is given in Appendix 19, for all stems over 12ins girth (and some chosen trees in smaller sizes). Part of the area had been logged for a second time by the date of this measurement. The following (Table 67) summarises total dipterocarp stocking of the Garinono samples, all at about 40 years after first felling:

Table 67 Stocking of Dipterocarps Garinono Plots

Plot	Area (acres)	Size class (ft) 2	3	4	5	6	7+	Total 4+
		(numbers per acre)						
R.P.210/1	10	@	@	1.7	3.0	1.6	5.4	11.7
R.P.315	50	@	@	2.3	1.8	1.5	4.0	9.6
R.P.258	18(1967)	5.2	2.5	2.5	1.2	1.1	2.7	7.5
R.P.258	18(1970)	4.2	2.5	2.1	1.6	0.8	1.2	5.7

@ This class not measured.

The yield plots averaged 9.3 stems/acre for all trees in groups 100-300 over 30ins girth suggesting their comparability with the LS½ sample as representative of areas of poorer growth. Much of the LS½ sample followed the original railway extraction line; part showed traces of wartime disturbance (a stockade built of *Eusideroxylon zwageri* posts and rusty Japanese army helmets were found) and in addition part of the area was cultivated for rice during the 1928 operation.

Actual yield from R.P.315 was 809 hoppus cu.ft. per acre of which the volume over 8 ft girth was 615 cu ft. Not all the exploitable volume was removed however, and the following compares total estimated standing volumes for this area and R.P.38:

Plot	Time from F (years)	Volumes per acre (hoppus cu.ft.) Total	6ft+	8ft+
R.P.38	40	2500(62.5)	1650(41.2)	746(18.6)
	53	3230(60.5)	2510(47)	1680(31.5)
R.P.315	40	?	1385(35)	774(19.3)

M.A.I. volume in brackets

Insufficient data is available to suggest possibilities for maximising volume yields at about rotation age, but clearly the average annual increment into exploitable sizes is high as stands move into the range of exploitability. The Garinono measurements suggest that second cut volumes per tree may be lower than those for the natural forest. Figure 85 illustrates the mean of Howroyd and Alabazo's (1961) tables as "Conservators Circular No. 3/62" together with the mean for R.P.315 and individual regressions (Fox 1971).

Dense stocking (e.g. Figure 78) leads to best growth (cf- Landon 1955) and this is reflected in Tables 66 and 67. The areas sampled in the latter all had much greater representation of non-dipterocarps, both long lived seral species, large trees of little commercial value and understorey species. This suggests that competition has resulted in considerable mortality

R. P. 315

Regression lines of 6 species and a miscellaneous group from Garinono felling area

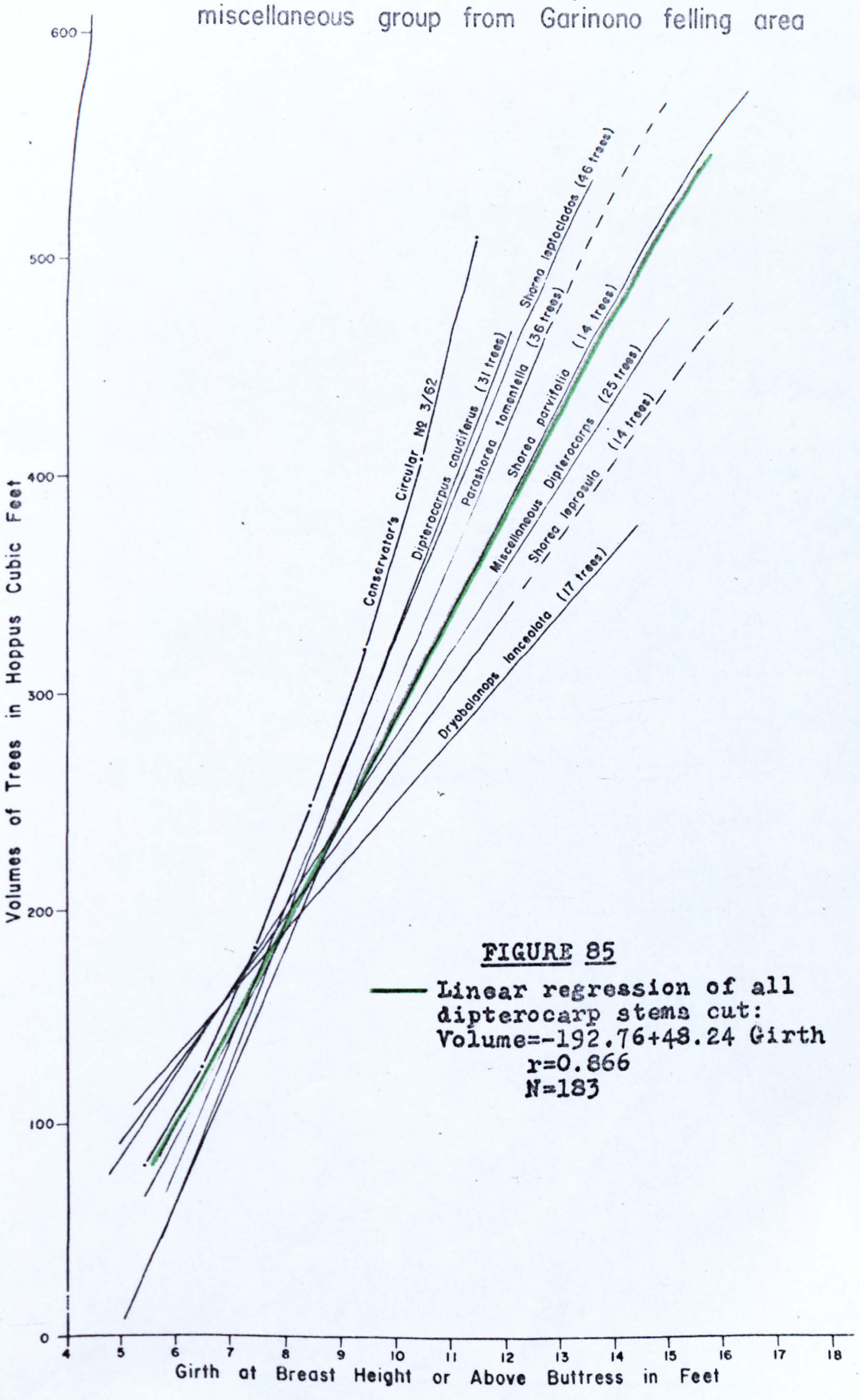


FIGURE 85

of smaller dipterocarps, compared with active recruitment, despite some suppression, in the Sepilok plots. The Garinono area probably represents lower limits of possible regeneration which could have been improved considerably by silvicultural treatment.

Gains Due to Silvicultural Treatment

At this stage it is not possible to give any satisfactory suggestions with regard to a treatment at 20-30 years from felling. Thinning allows increased increment on smaller stems and may stimulate growth of seedlings into small poles replacing the natural understorey (Fox 1972). Depending on the nature of stocking at 20-30 years from felling further refinement or liberation may be needed. For the first three silvicultural treatments (as set out in Chapter 6) improvements have been demonstrated.

First Silvicultural Treatment

Climber cutting and tree marking carried out prior to felling may affect subsequent stocking and rotation length. Substantial benefit to stocking on an area basis results from holding down the proportion of an area damaged by machinery. Providing such damage is under 20 per cent and no large landings are involved it would seem that regeneration levels similar to those of the 1957, 1959 areas in Segaliud-Lokan F.R. (Figure 81) should be achieved. Additional damage will reduce yield in proportion to the area damaged. When LSM after logging gives values in excess of 200 stocked milliacre plots per acre (cf Table 38, and Appendix 8) it is suggested that an adequate area basis for successful seedling regeneration exists, providing these are well distributed.

Survival of advance growth will contribute to second cut volumes in a substantial manner. Some four undamaged stems per acre (and double this number with survival value, Table 32) over one foot girth may be expected. Of these 60 per cent will be over two feet girth and will move through size classes (Table 22, Figure 43 (b)) as follows:

Size class(ft)	2	3	4	5	Total
Time (years)	9.9	9.8	12.9	10.4	43

More than half the survivors are likely to grow at 1 inch C.A.I. girth or better (Appendix 9, Table 1) and the 1+ stems per acre over 4 ft girth likely to survive felling should exceed 8 ft at 48 years. Prior to this they will provide a guarantee of further seedling presence at the second cut. It should not be necessary to leave relict trees longer than 5-10 years from felling, and if selective girdling is done damage following disintegration is unlikely to be severe (experience in R.P.87).

Positive favouring of Rubroshorea for retention at the first silvicultural treatment is desirable because of faster growth rates, lower susceptibility to *Ceriopalus wallaceii*, and the general desirability of promoting presence of these species for the first rotation from felling.

Possible gains due to reduction of tractor damage may be calculated using the following assumptions:

1) Twenty per cent, or less, damage allows 20 per acre final stocking.
2) Each additional five per cent machinery damage reduces final stocking in proportion to area.
3) Crown diameter, basal area and growth limitations allow "normal" regeneration of 20 per acre to reach 6.5 ft girth at 50 years; and 16 per cent to reach 7.5 ft girth at 60 years.
4) Volume = -192.76 + 48.24 girth (i.e.Figure 85).

These assumptions suggest the following "normal" yields per acre:

	Per cent damage at F				
	20	25	30	35	40
Final stocking at 50 years:					
Numbers	20	18.8	17.5	16.3	15
Volumes	2400	2250	2100	1950	1800
Final stocking at 60 years:					
Numbers	16	15	14	13	12
Volumes	2700	2540	2370	2200	2030

Similarly gains per acre for each stem of 4 ft+ at the time of felling will be of the order of 220 cu ft at 50 years and 270 at 60 years.

Second Silvicultural Treatment

Gains due to removal of residual non commercial stems following felling have been substantial in the past (cf Tables 45, 46) and may possibly be less due to heavier recent logging, though results to date do not show this (e.g. Table 47). Generally girdling following felling results in increased numbers of stems over 6ins girth by up to 50 per cent more, at five years from felling, and more than double the number with dominant or codominant status. It must be emphasised most strongly that rapid early growth is most important in obtaining short rotations.

Circumstantial evidence with respect to growth in yield plots (Chapter 9) suggests that rotations have been lengthened in areas girdled late. For example rotations to 6 ft are calculated as being 15 years longer if girdling was delayed 3 years or more in Silabukan and Kalabakan F.R.'s, and average growth is set back during the first 10-20 years following felling when no girdling was done (e.g. Kretam, F.R.). Subsequent intervention in such stands may enhance growth, but rotations will remain somewhat longer than areas which have grown normally.

Third Silvicultural Treatment

Climber cutting at five years increased increment rates by 20 per cent on the best 40 stems per acre over the four years following treatment (Table 48). Slightly lower differences occurred in growth of the largest 25 per acre, and these gains are insufficient to significantly shorten the rotation. Combined with liberation treatment, involving the removal of competing trees, an intervention including climber cutting is seen as desirable at 10-15 years. Such intervention in well stocked vigorous stands has been shown to have most effect on potential crop trees in size classes under 3 feet girth (Chapter 8). Gains due to liberation are most evident therefore when the largest 20 per acre extend downwards into the smaller size classes.

Estimates of rotation for replicates of RP 273 based on the following assumptions:

1) Time to pass through size classes based on C.A.I. averages for individual treatment plots over the period following treatment, for trees under 3 feet girth.

2) Calculations for larger sizes based on yield plot C.A.I. averages from the same forest.

give the following rotations (from time of felling) for the largest 20 per acre to exceed 6 ft girth:

	Control	T2	T3
Segaliud Lokan	52	48	50
Kalabakan	46	37	42
Silabukan	52	53(1)	48

(Note (1) this is based on time for trees from the 6ins class to reach 6ft, whereas control and T3 for Silabukan are from the 10ins class; it would have taken a rotation of 56 years for control from the 6ins class).

It remains to be seen how long the differences brought about by treatment will endure, but the experiment is sufficient to justify the need of harnessing the potential of enhanced growth. Release of future crop trees is considered particularly desirable in areas where seral species form a high density or where dipterocarps have grown poorly. In the former treatment may be seen as hastening the process of succession.

Heavy liberation in such areas can probably safely remove more than 50 per cent of the basal area, where the dipterocarps are strong and well grown. The evidence suggests that heavy liberation can be accompanied by substantial gain in increment on the 40 stems per acre, e.g.

Replicate		Percentage Basal area left	C.A.I. increase
R.P.273	A T2	48	52
	A T3	61	26
	B T2	14	70
	C T3	59	38
compared with	B T3	84	5

Where the dipterocarps have grown poorly (e.g. R.P.273 C T2) treatment must be less severe. Climber cutting is generally beneficial and where a canopy exists rules of a similar nature to those given at the end of Chapter 8 can be employed, aiming at the liberation of 40 well distributed final crop trees per acre.

Available evidence suggests that the third silvicultural treatment can lead to potentially shorter rotations. The reduction in rotation is likely to be four years or more in vigorous stands but may be more in poorly developed areas.

Treatment Costs

The money costs of silvicultural treatment can provide useful comparisons of yield with respect to inputs but are limited because of changing values and rising wages. The use of man days per unit area is considered more useful, especially for labour intensive tasks where technological change is unlikely to substantially alter physical performance rates. Average costs of silvicultural treatments in terms of may days per acre, with suggested targets are:

1 (a) Climber cutting 0.85, target 0.70
(b) Tree marking 0.42, target 0.40
2 Girdling 1.00, target 0.75
3 Liberation:heavy 1.60 target 1.50
light 1.00
4 Possible liberation/refinement at 20-30 years target 2.0

Man days of input can be equated with yield through royalty value at a given time. For example 10 man days of effort spent on silviculture at the time of felling which results in an increased yield at 40 years of 100 cu.ft per acre would be 70 man days compounded at 5 per cent interest. If the value of the additional volume exceeds the cost of paying 70 men for a day the input may be said to have been worthwhile. This method equates mans efforts with timber values. It may be noted that in 1971 the average daily pay was about $7, roughly equivalent to the royalty payable on 14 cu.ft. of timber. Compounded costs of man days of input for various rotations are summarised in Table 68. An arbitrary rate of 5 per cent interest is used. A complete assessment of costs is outside the scope of the present work, but this general presentation serves to focus attention on the need to attempt equation of input with additional volume production.

Table 68 Compounded Costs of Effort Incurred in Silvicultural Operations (Man days per acre, interest 5 per cent).

Operation	Year from F	Cost (man days/ acre)	Rotation Length (Years) 45	50	55	60	70	80
			Compounded Costs					
1(a) climber cutting	F-1	0.7						
(b) Tree marking	F-1	0.4	9.9	12.6	16	20.6	33.4	54.5
2 Girdling	F+1	0.75	6.8	8.6	11	14	22.8	37.2
3 Liberation	F+10	1.5	8.3	10.5	13.5	17.3	28.1	45.6
or	F+15		6.5	8.3	10.5	13.5	21.9	35.7
4 Possible 4th	F+20	2.0	6.8	8.6	11.0	14	23	37.4
Treatment	F+30		4.2	5.4	6.8	8.6	14	23

Using the 1971 equivalence the implication of Table 68 is that the third silvicultural treatment, for example, applied at 15 years from felling in an area which will produce a normal yield at 50 years should increase yield by 8.3 x 14 = 116.2 cu ft per acre. A lower increase or no change in rotation could suggest that the treatment should be reconsidered.

Yield estimates from the yield plots will shortly provide a mass of information on the progress of the different areas. The analysis of probable yields and costs which it has been possible to include herein is severely restricted by the lack of physical production data. However it is considered that the double criteria of need for treatment, (that is does a particular stand appear to need a treatment), and of likely response outlined above should be adopted for all forests likely to remain in management.

Suggested Management Objectives

Natural regeneration in the dipterocarp forests is not difficult. The seedlings to be found on the ground in natural forest, and under regeneration of advancing age, respond with rapid growth to the stimulus of canopy opening. Over a period of time seral species, which may locally dominate regenerating forests, tend to die out and succession towards the natural forest occurs. The objects of silviculture may be expressed as attempts to improve on the natural condition by increasing the representation of dipterocarps and by shortening the time period for the accumulation of large trees. The sizes of trees to be grown in managed forests will be smaller than the range found in natural stands. Considerations of growth rates suggest that sizes in the range of 6 to 9 feet can be grown on rotations of 60 years and that stocking levels of 20 trees per acre should be aimed for.

Progress of individual stands can be assessed against the standards for "normal" regeneration outlined in this chapter, and by comparison with yield plot production tables as these become available. Silvicultural intervention should start prior to the first felling when perhaps the most important of all management objectives should be to minimise tractor damage. The suggested allowable maximum is 20 per cent and companies operating concessions and other licence agreements should be enjoined to assist Forest Department Officials in holding damage at levels below this minimum.

Wherever members of the section Rubroshorea exist these should be favoured during silvicultural intervention. Of particular interest are the three commonest, fast growing, species *Shorea leptoclados*, *S.leprosula* and *S.parvifolia*. Locally such species may form small concentrations of large trees accentuating the patchy distribution of natural forest stocking. Silvicultural treatment should aim at achieving complete stocking however and some differenc in sizes may lead to revised ideas at the time of the second cut *apropos* for example the possibility of polycyclic felling, at least on a group or patch basis.

CHAPTER 11

GENERAL CONCLUSIONS

In this final chapter I attempt to relate the findings of the dissertation to the objectives. The realisation of my objectives is influenced by methods used, selection and interpretation of the results and a degree of inevitable personal bias.

In the preceeding chapter I have brought together a set of desirable management objectives. These are based on the facts of physical production and assume the desirability of growing second crops of dipterocarps to sizes in excess of six feet girth. I believe that these objectives, using the criteria of "normal" standards, can form the basis of a rational silvicultural program. Such a program can, with perhaps a little additional work related to the incorporation of reasonable assumptions acceptable to Government, be put into practice now by the Sabah Forest Department. These reasonable assumptions must include policy considerations, staff availability and selection of areas. These matters are now outside my own terms of reference.

The objectives are clearly based on the premise that market demand for dipterocarps in sizes over six feet girth will continue. If some radical change in market preference were to arise then the objectives would need reconsideration. For example if *Anthocephalus chinensis* in sizes of 3-5 feet girth suddenly became a highly desirable commodity the silvicultural treatments necessary to grow crops of this nature would be quite different. Present indications are that *Anthocephalus* can be grown readily by bulldozing lowlying areas and then leaving them alone for a few years. Similarly if *Eusideroxylon, Intsia* and the heavier wooded species of Dipterocarpaceae again became fashionable then longer rotations and much less severe canopy opening would probably be entailed.

My main concern has been to firstly classify the forests of Sabah and secondly to assess the regeneration of dipterocarp forests after felling in terms of present biological and market realities. In drawing together the principal conclusions I shall discuss the five topics of classification, regeneration, silvicultural practices, limitations of the present study and areas where further work is needed. Under the latter I shall attempt to distinguish between fundamental problems of more academic interest and those of more immediate practical value to forest management.

Classification

The classification scheme based on ecological criteria presented in Part 2 forms the basis for the rest of this work (page 41). My consideration of regeneration has necessarily excluded those forests other than the dipterocarp forests, though both peat swamps and mangroves are of commercial interest. Study of the regeneration of these forms of vegetation is desirable and is being undertaken to some extent. A substantial program of "Virgin Jungle Reserve" allocation is also in progress to set aside representative areas of the various vegetation types for general scientific study.

Within the dipterocarp forests I have distinguished seven main Types (Chapter 4). Of these Types A, B, C and E(page 28) account for the bulk of the data presented in Part 3. These Types largely cover the areas of natural forest in Forest Reserves already felled and likely to be worked over in the next 10-20 years. Limited felling in Reserves of Types, D, F and G has restricted consideration of regeneration with respect to Types in general.

Typing emphasises the abundant species; the large number of species present in the forests forms an impediment to rational management and the main concern throughout has been to simplify the species considerations. Particular attention has been paid to the dipterocarps as few other species are ever as abundant in large size or have timber of such general utility. The main natural groupings within the family Dipterocarpaceae have been shown to be of considerable importance with respect to regeneration patterns and growth.

Over wide areas where conditions change gradually the most abundant species tend to be regular (and the less abundant more contagious) in their natural distribution. Many of the species considered tend to occur in groves at the smaller scale; gregariousness is more common in species with heavy or wingless fruit. Species abundant in some areas are notably locally distributed in other areas and changes in representation are more pronounced with more severe local changes in site. Available evidence suggests that local topographical conditions (and swampiness) have considerable influence on species distribution (e.g. Tables 12, 15 and 16).

The principal silvicultural implication of the Types is related to relative abundance of the Rubroshorea species (particularly *Shorea leptoclados*) of fast growth and the presence of substantial quantities of the slow growing *Eusideroxylon zwageri* in some areas. Indeed the latter is of such importance that it may be necessary to consider subdivision so that different management objectives apply to areas where *E.zwageri* is abundant. In areas where the Rubroshorea species are more abundant overall growth rates are likely to be higher and shorter rotations may be postulated. A longer period of measurement is necessary to determine whether regeneration growth rates differ between the Types. It is fairly clear that Type G (cf R.P.17, Chapter 5), because of its species assemblage, has lower growth rates than those of Types A, B and C, and this may well be due to soil factors.

The possibility of a connection between growth rates and rainfall in respect to the main Types exists. I have been unable to show this but there is a response to rainfall in all areas (Chapter 8). There is considerable evidence that Type A has more frequent flowering, and some evidence of higher seedling numbers, than the other Types. Within the Types the more common species exhibit more frequent flowering and the species abundant in the natural forest are generally of most importance in regeneration.

There is a suggestion that mortality may be higher in the Types where faster growth occurs, and that mortality is related to abundance at all stages. I have discounted age for importance with respect to regeneration. Climbers (and climbing bamboo) appear to be more important in Type B forests and the incidence of defect due to *Ceriopalus wallacei* may be higher in the *Parashorea* forests. Erosion problems may be assumed to be of less importance in Type B forests generally, though blocked drainage of lowlying areas is probably more prevalent and the gently undulating areas appear to encourage excessive tractor path development.

LSM surveys after logging generally confirm that the most abundant species of the natural forest occur after logging as seedling regeneration. The incidence of *Dryobalanops beccarii* in northern parts of Type B suggests that this species (as with *Dr.keithii* in Type C) merits local attention. Similarly the species forming the potential crop components in Yield Plots largely reflect the Types. No evidence of differences in seral components was found; site preferences generally appear more important. *Macaranga* species are numerically important for at least 15 years from felling and possibly *Anthocephalus chinensis* thereafter. The three long living seral species *Octomeles sumatrana, Duabanga moluccana* and *Anthocephalus* are found in all areas, but particularly on moist sites.

The main determinants of regeneration growth appear to be the silvicultural history of given stands coupled with relative abundance of the Rubroshorea species. These largely account for differences in preliminary rotation calculations given in Chapter 9. The "preferred commercial species" (Page 257) namely *Parashorea tomentella, P.malaanonan, Shorea leptoclados, S.leprosula, S.parvifolia, S.smithiana* and *Dryobalanops lanceolata* are represented in most regeneration assessments and may be taken as representative of the forests as a whole. The complete assessment list of 37 species is a general guide and can be refined to give separate lists for individual areas.

For yield assessment I have classed all trees into 9 groups (Chapter 9). Apart from areas with abundant *Eusideroxylon* dipterocarps of Groups 100-300 generally account for 20 per cent or more of the total stand over 12 ins girth at some 10 years from felling. The system is flexible and allows inclusion of non dipterocarps as chosen trees. These broad groups will form the basis of silvicultural management overall, though I believe that further study of the Types may bring out more positive differences of a silvicultural nature than I have been able to demonstrate.

Regeneration

The evidence presented suggests that excellent regeneration would follow complete defoliation and removal of timber and climbers from above, just after a heavy fruit fall. This is not possible, and attempts at improving regeneration prospects must start from consideration of gap regeneration in natural forest. Opening initiates a succession towards the emergent stand and the variable effects of logging create a patchwork of conditions superimposed on the initial diversity.

Periodic gregarious flowering, with some annually, allows generally adequate stocking of dipterocarp seedlings in the natural forest. The milliacre convention of stocking generally gives 6-800 stocked plots per acre. The more abundant species as large trees have highest seedling populations, but there are patterns of distribution dependant on fruit characters. Of the common species four groups may be distinguished:

(a) Well to regularly distributed

Long wings
Shorea almon(Ru)
S.macroptera(Ru)
S.smithiana(Ru)
S.valtonii(Ru)
Parashorea species

(b) Locally well distributed

Small wings
S.acuminatissima(Ri)
S.argentifolia(Ru)
S.gibbosa (Ri)
S.leprosula (Ru)
S.parvifolia(Ru)
S.leptoclados(Ru)

(c) More clumped

Heavier fruit
Dryobalanops species
Dipterocarpus caudiferus
D.grandiflorus
S.beccariana (Ru)
S.macrophylla(Ru)
S.mecistopteryx(Ru)

(d) Gregarious

No wings
S.multiflora (Ri)
S.oleosa (Ru)
S.seminis(SB)
Vatica oblongifolia

There are substantial losses of seed, germination is rapid and a high rate of attrition occurs in the first 9 months after germination. Surviving seedlings grow slowly, though different patterns are shown. Individuals can probably persist for 20 years or more, yet overall average seedling height is more or less constant.

There is generally an adequate number of well distributed seedlings forming a potential for regeneration. The main problem is loss of seedlings during felling and I have placed particular emphasis on attempts at minimising this. Some 50-75 per cent of stocked milliacre plots prior to logging become unstocked due to falling and extraction damage. The greater proportion is due to tractor damage; some 20-30 per cent of present felling areas are rendered bare of dipterocarp seedlings. Low lying areas tend to have greater machinery disturbance and regeneration is completely lost in the vicinity of spar tree sites and landings.

However there are generally some 200 milliacre plots per acre remaining stocked after logging and this figure is taken as forming a desirable basis for regrowth. The lower limit acceptable for "normal" treatment is 100 stocked plots. Assessment shows that species of importance in the natural forest form the bulk of the surviving seedling regeneration. There is no present case for considering artificial regeneration except on landings where no dipterocarps remain. These areas pose difficult problems with respect to techniques and species. Of the dipterocarps *Dr. lanceolata* is the hardiest and survives well, but its growth rate is not as good as that of the Rubroshorea species. The factors of cost and scale will probably mitigate against restocking with dipterocarps.

Logging allows light into the forest and dipterocarp seedlings commence rapid growth. A second entry to remove timber in two lots is unwise. Growth rates differ between individuals, but average heights double from under one foot to over 2 feet in the first year. At two years from felling dipterocarp seedlings may exceed 10 feet in height and "normal" growth (page 321) gives the following sizes thereafter:

F+5 years	Best	40/acre	10ins girth:
	Best	20/acre	17ins girth:
F+15 years	Best	40/acre	20ins girth;
	Best	20/acre	29ins girth.

An influx of seral species occurs in the opened forest and a variety of species representing short and longer lived forms commence rapid growth, often exceeding the dipterocarps. Considerable losses of both groups occur in the first few years due to competition. Certain climbers also become abundant. The residual stand of undergirth dipterocarps, defective or useless trees, and undergrowth species suffers considerable damage from felling. However the surviving dipterocarps increase their growth rates and may form a valuable addition to the second cut as well as providing subsequent seedling regeneration. Losses of advance growth are greatest in the smaller girth classes and there is some indication that Rubroshorea species are more prone to falling damage.

Different growth rates result in a range of sizes as the stands age. Dipterocarps surviving tend to form a bulge in the size class representation and the Rubroshorea poles grow faster through the size classes. Several seral species are persistent and may overtop desirable regeneration; similarly the thickening up of the climbers causes damage. The Yield Plot approach to stand assessment seeks to overcome local variation in growth and stocking.

The assumptions given in Chapter 1 may be qualified as follows:

(1) Seedling regeneration can be relied on, but is threatened by machinery. Advance growth retention serves to guarantee adequate seedling stocking and may also enhance volume and seeding at the second cut.

(2) More or less clear felling at one time should be further encouraged; subsequent entry may upset succession.

(3) Heavy mechanical equipment can be used but poses a distinct threat to satisfactory regeneration if it involves excessive soil disturbance. The question of choice of equipment needs investigation.

(4) Blanket girdling after felling can be wasteful, and in some cases detrimental. The use of more sophisticated, but still simple, options dictated by varying conditions should be cheaper as well as more selective in producing gains. Similarly with later intervention.

I have been unable to show any difference in stocking or growth between different topographical sites or soils.

Silvicultural Practices

Complications of time scale and age from felling of the various examples used, coupled with differing silvicultural history account for substantial differences in growth and stocking between stands. Earlier felled areas presumably were generally less severely logged, and in many areas a number of large trees are present. However my main consideration has been with the present day fellings and on the basis of certain assumptions I have outlined a concept of "normal" growth expectations and desirable objectives. The suggestion is that 20 trees per acre larger than 6 feet girth can be grown in 60 years (Chapter 10).

My consideration of silviculture has been influenced by a desire to employ as few treatments as possible and to restrict the time of treatment within a framework which attempts coincidence of highest response and ease of application. Silviculture is seen as an aid in hastening the succession from gap conditions to large trees which occurs naturally on a theoretically longer time scale. The greatest influence on the time taken for trees to reach large size is the period spent in sizes less than one foot girth. Fortunately trees of the smaller size classes appear to give considerable response to intervention. The first silvicultural treatment seeks to reinforce the certainty of obtaining a desirable basis for regeneration by reduction of seedling mortality and positive retention of advance growth.

The simple three part silvicultural sequence proposed for normal conditions is

1. F-2 to F-1 Climber cutting, tree marking.
2. F+3-6 months Girdling.
3. F+10-15 years Liberation, Refinement.

Logging is seen as the major influence on the succeeding crop and since losses occur then, the first treatment aims at reducing losses. Experiments suggest that more advance growth survives where more is marked; an even distribution would be desirable. As the Rubroshorea undergirth trees are more likely to be damaged in felling, special efforts are needed to ?preserve them. Company cooperation in attempting to comply with tree marking suggestions (i.e. to avoid damaging marked trees) is essential and a reduction of tractor path intensity to less than 20 per cent is impossible without such help. As the majority of undergirth trees are damaged in logging any retention of sound trees is useful.

Girdling with arsenic after felling, of useless trees to refine the stand further, is most easily done just after felling has ceased. Circumstantial evidence confirms experimental results. The combination of the varied effects of felling, natural differences and girdling results in patchy development. The option system proposed builds on the patchiness; attempts at uniformity of the second stand are rejected as unattainable but full stocking is to be aimed at.

As the regrowth thickens up climbers increase in severity and cause damage to dipterocarp poles. If girdling after felling is omitted then treatment at five years to remove useless trees and bring forward some of the aspects of the third normal treatment could be employed. Selective removal is advocated again because of the varied nature of development. In some places nomads dominate the stand and rapidly reach basal areas of 50 square feet per acre or more. The growth of *Anthocephalus chinensis* is particularly rapid and girths of 2 feet in 3 years are often achieved. After some 7 years from felling growth of this species slows as severe competition sets in. Mixed regrowth of nomads and dipterocarps continue steady growth, e.g. basal areas increased from 53 sq.ft. at 7 years to 83 sq.ft. at 14 years in Segaliud-Lokan Y.P.'s. In such areas short lived nomads die out, others persist and dipterocarps gradually increase in importance.

Intervention at some 10-15 years after felling allows substantial growth to occur on selectively liberated dipterocarps. In dense seral growth ingrowth of seedlings (e.g. *Shorea parvifolia*, and *Dryobalanops lanceolata*) may have occurred since felling. This may also respond to release. Removal of some seral species trees at this time hastens the succession. However the treatment must attempt to achieve a balance, the succession may be set back if dipterocarp poles are knocked down by falling debris, or damaged by additional climber influx; similarly if small seedlings are rapdily overtopped by seral species recruits they may remain dormant for a further period. At this stage climber tangles are likely to be intensified if treatment is done where no canopy has developed.

Of the three treatments the first is least necessary, and the third probably has greatest effect on the rotation. The pattern of "normal" growth postulates 6 ft girth at some 45 years from felling (page 321) and this could be reduced with an effective liberation treatment at 10-15 years. Patchy growth and varied species representation suggest that 60 years be taken as the desirable management objective (page 330). Special consideration needs to be paid to the areas where *Eusideroxylon zwageri* is abundant as longer periods may be necessary for attainment of an exploitable second crop. The aggressive nature of some of the Rubroshorea species may allow these to grow through *E.zwageri.*

Sampling of regeneration progress. coincidental with the periods of anticipated response and ease of application of treatment, is again, minimal:

F+0-2 months LSM
F+5,10 or 15 YP
F+10-15 LS½

Both linear samples are diagnostic, and the yield plots are also open to diagnostic interpretation. In some unstudied areas it may be necessary to sample the pre-felling seedling populations. At 10 years from felling it should be possible to say a certain area is regenerated or not, on the basis of numbers per acre exceeding a given size. This does not necessarily imply a detailed breakdown into simple management units. All field work is likely to be on an extensive basis and silvicultural treatments using selective options are ideally suited to this.

When the dipterocarps have reached large size there is no justification for conventional thinning as no response in increased growth is likely. Further intervention in the regenerating stands after the third silvicultural treatment is likely to be more of a refinement, possibly *apropos* subsequent seedling regeneration, or repetition of the third treatment.

Differential growth superimposed on a patchy stocking is likely to mean that patches within individual large areas will reach a state of readiness for second felling sooner than others. Under these circumstances polycyclic logging on a group basis may be advantageous. However there are considerable administrative difficulties involved.

Limitations of the Present Study

Lack of knowledge is the main limitation of this presentation. Despite greatly increased access in recent years and a number of exploratory trips, vast areas of the interior forests remain largely unknown. This applies to both dipterocarp forests and to other types of vegetation, in particular the fresh water swamps, perhaps the most difficult of penetration.

On the regeneration side the additional qualification of time scale is of importance. All growth studies entail long term observation and the progress of individual areas is of great significance. I have necessarily been obliged to partition the rotation into discrete units of time and synthesise conclusions from limited time studies. The principal limitation of this approach is that felling has been intensified over time. As felling is the most significant intervention it may be inferred that both the succession process and the attainment of satisfactorily regenerated stands will differ according to felling intensity.

The silvicultural system has been said to be similar to the Malayan Uniform System (Chapter 7). A more apt description could be the "Sabah Succession System". This would be defined as

> A uniform felling of natural forest emergents and large trees of the main canopy followed by intervention in the process of succession to accelerate the attainment of large size by essentially the same species as those removed. This results in patchy

> regrowth and presumed increased representation of large individuals of the group Rubroshorea and of the genus *Parashorea*. The system depends mainly on seedling regeneration but advance growth is also retained where possible. Silvicultural techniques of a selective nature seek to reduce losses at felling and to increase subsequent growth rates.

There is no evidence for the notion that second growth stands will carry substantially higher volumes than the natural stands and the desirable management objectives postulated (Chapter 10) are in terms of average growth. Substantial areas of 'abnormal' forest (cf Malaya, Wyatt-Smith 1963), following earlier lighter fellings or where silvicultural intervention has been variable (Chapter 9) form a considerable impediment to the early attainment of sustained yield with control on an area basis. Lower felling limits and acceptance of the seral species *Anthocephalus chinensis*, *Octomeles sumatrana* and *Duabanga moluccana* as commercially acceptable timbers could lead to shorter rotations than those indicated in this study.

Variability of stocking and growth throughout the time scale of regeneration complicates the demonstration of conventional statistical significance in experimental work. A more detailed approach using more measurement parameters and smaller samples (perhaps down to comparable single trees) of greater numbers may have produced more definitive results than many of those given. This will have to be considered in future comparative tests. Some evidence of seasonality in bole growth necessitates averaging of measurements and long time intervals. I have rejected a number of comparative studies on these grounds and where short term observations have been given I have accorded less weight to them.

Further Work

A definitive account of the vegetation awaits complete exploration of Sabah and clearly the conclusions I have drawn relating to regeneration can be periodically reviewed as stands age. Continued assessment of many existing R.P.'s forms an essential basis for progress. More information is needed with respect to, for example, survival of advance growth, prospects for regenerating bare areas, long term effects of silvicultural intervention, and ecology of climbers and bamboos. These and other aspects of continuing research are incorporated in the 1970-75 Research Program (A.R.R.B. 1969 pages 51-56).

Comparative regeneration and growth studies need initiation in circumstances where departures from "normal" conditions are anticipated. This is particularly so should the continued labour shortage lead to further mechanisation when the implications of change may be of great importance. Similarly with consideration of areas of 'abnormal' growth and high stocking of *Eusideroxylon zwageri*.

The first priority for forest management is, I believe, yield projection on an area basis. The yield plot program needs extension to incorporate volume increment and to relate aerial assessment of the large areas sampled to growth patterns discerned. Any regrouping of Forest Reserves as a result of the 1972 Forest Inventory Report will involve a critical re-appraisal of the samples necessary to provide sufficient information for formulating cutting programs in those areas where sustained yield is accepted as desirable. The present practice of treating the entire productive estate of

Forest Reserves as one unit for sustained yield management should be reconsidered. Both productivity and rotations are likely to differ within the total estate and considerable advantages of long term stability would accrue from the organisation of regional units from which periodic cuts could be allocated. Policy considerations in relation to the export trade are paramount and should receive adequate attention.

The question of machinery damage with respect to regeneration prospects needs urgent attention. It will be necessary to test my suppositions relating to tolerable levels of tractor damage in terms of both regeneration and the economical considerations of logging. Can logging personnel exert a positive effect on regeneration prospects? Continued testing of the properties of the nomadic species and those of local abundance in the natural forest (e.g. *Dillenia borneensis* Chapter 5) is needed.

Problems of a more fundamental nature have been touched on throughout. Some of the more important are:

1) Utilisation. What is the significance of degrade due to logging? Can defect factors be included in second yield forecasts? What uses can be devised for timber damaged by *Ceriopalus wallacei*? What is the relation between external evidence of this insect to internal damage? Can the light wooded seral species be used for industrial cellulose?

2) Types. Are there real differences in seedling survival between Types? Similarly with growth. Regeneration lists need compilation for different areas.

3) Production. Can the fast growing dipterocarps grow through *Eusideroxylon zwageri* where this species is dense? What are the effects of heavy liberation in areas of no previous treatment? Are differing production rates likely on different topographical sites? Is an understorey of value? If so can this consist of dipterocarps?

4) General silvicultural problems. How best can drainage patterns be restored? What plantation species make satisfactory growth on bared soil? Can any method of seed storage for dipterocarps be devised? Can seedlings survive under crown debris? How long do seedlings survive in the natural forest? Does seedling age affect subsequent growth? Does climber cutting prior to felling, by giving more light, affect numbers of seedlings surviving until felling? What 'normal' mortality rates occur with the different seral species?

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